Infrastructure Needs, Applications, and Pathways to Adoption

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ARPA-E Extremely Durable Cementitious Materials Workshop
April 10-11, 2018 – Dallas, TX
Clearly there is a **NEED**

Clearly there are many **APPLICATIONS**

To address this challenge, we must use **APPROPRIATE MATERIALS** as part of **APPROPRIATE SYSTEMS** that are tailored to the anticipated **environmental stressors** and the anticipated **service lives**.
Clearly there is a **NEED**

Clearly there are many **APPLICATIONS**

To address this challenge, we must focus on both new construction and on rehabilitation of existing constructed facilities.
Clearly there is a NEED
Clearly there are many APPLICATIONS

Novel “concretes” can be part of the solution...

...but only if they offer a clear advantage while being adoptable into existing practices.
UHPC from FHWA’s Perspective

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What is Ultra-High Performance Concrete?
What is Ultra-High Performance Concrete?

Fiber Reinforcement

Supplementary Cementitious Materials

Superplasticizers

Particle Packing Theory

Nist.gov

American Coal Ash Association
What is Ultra-High Performance Concrete?

• FHWA
  - UHPC is a cementitious composite material composed of an optimized gradation of granular constituents, a water-to-cementitious materials ratio less than 0.25, and a high percentage of discontinuous internal fiber reinforcement. The mechanical properties of UHPC include compressive strength greater than 21.7 ksi (150 MPa) and sustained post-cracking tensile strength greater than 0.72 ksi (5 MPa).
What is Ultra-High Performance Concrete?

Highly durable, strain-hardening concrete
What is Ultra-High Performance Concrete?

Micro-Reinforced Concrete
What is Ultra-High Performance Concrete?

Exceptionally Resilient Cementitious Composite
### Example Composition of a UHPC

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Amount (lb/yd³)</th>
<th>Amount (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland Cement</td>
<td>1331</td>
<td>790</td>
</tr>
<tr>
<td>Silica Fume</td>
<td>334</td>
<td>198</td>
</tr>
<tr>
<td>Fly Ash (Class F)</td>
<td>324</td>
<td>192</td>
</tr>
<tr>
<td>Fine Basalt</td>
<td>1923</td>
<td>1141</td>
</tr>
<tr>
<td>Steel Fibers</td>
<td>199</td>
<td>118</td>
</tr>
<tr>
<td>Superplasticizer</td>
<td>47</td>
<td>28</td>
</tr>
<tr>
<td>Water</td>
<td>246</td>
<td>146</td>
</tr>
</tbody>
</table>

* Wille and Boisvert-Cotulio report titled “Development of Non-Proprietary UHPC for Use in the Highway Bridge Sector” (FHWA NTIS-PB2013-100587)
Availability of UHPC-Class Materials

Example Proprietary Versions

Non-Proprietary Versions

FHWA-HRT-13-100: Dr. Kay Willie at UCONN
UHPC Deployments Across US and Canada

Source: https://www.fhwa.dot.gov/research/resources/uhpc/bridges.cfm
UHPC Properties: Some Ballpark Values

- Fresh “Slump” – Self Consolidating
- Compressive Strength – 18 to 35 ksi
- Modulus of Elasticity – 6000 to 8000 ksi
- Sustained Tensile Capacity – 0.9 to 1.5 ksi
- Interface Bond – Can surpass substrate tensile strength
- Permeability – 100x less than conventional concrete
- Freeze/Thaw Resistance – RDM > 95%
- Rebar Bond – 8d_b embedment can deliver yield
UHPC: A Timeline of Progress

- UHPC had recently become available in US
- FHWA recognized the potential in UHPC
- Pretensioned bridge girders?
UHPC: A Timeline of Progress

- FHWA characterizing UHPC properties
- Community of practice started to grow
UHPC: A Timeline of Progress

- FHWA investigating structural optimization
- Iowa DOT constructed I-girder bridge
- Initial use of UHPC connections in Ontario
UHPC: A Timeline of Progress

• FHWA recognizes synergy with connections
  ...The KILLER App...

• Connections research:
  – Construction advantages
  – Structural advantages
  – Durability advantages
UHPC: A Timeline of Progress

- 25 bridges using UHPC are in service
- New York, Iowa, Ontario are leaders
- Broader community becoming interested
- ACI 239 formed
UHPC: A Timeline of Progress

• 100 bridges in service
• FHWA published connection design and construction guidance
• Grassroots effort for Symposium initiated
UHPC: A Timeline of Progress

- 200+ bridges in service across 25 States
- AASHTO expressed interest in bridge design and construction guidance
- UHPC being used for:
  - Connections
  - Deck rehabilitation
  - Girder repair
  - Girders, deck, piles
Clearly there is a **NEED**

Clearly there are many **APPLICATIONS**

**Pathways to Adoption...**
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