

Infrastructure Needs, Applications, and Pathways to Adoption



Ben Graybeal, Ph.D., P.E.

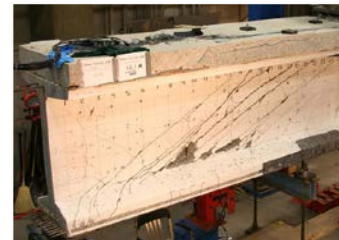
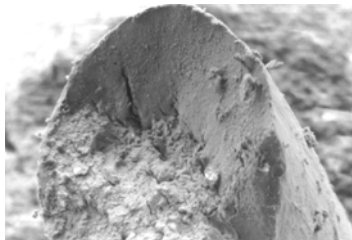
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ARPA-E Extremely Durable Cementitious Materials Workshop

April 10-11, 2018 – Dallas, TX



U.S. Department of Transportation
Federal Highway Administration











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



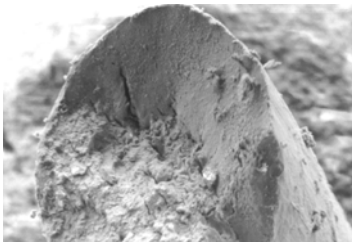
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What is Ultra-High Performance Concrete?

What is Ultra-High Performance Concrete?

Fiber Reinforcement



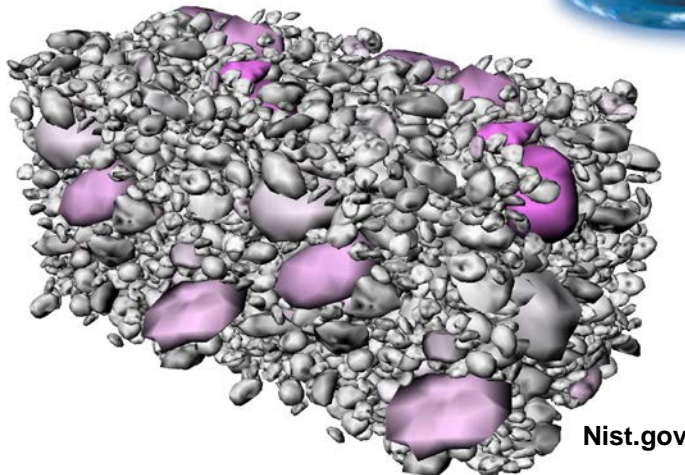
Superplasticizers



Supplementary Cementitious Materials



Particle Packing Theory



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

| Constituent | Amount (lb/yd ³) | Amount (kg/m ³) |
|-------------------|------------------------------|-----------------------------|
| Portland Cement | 1331 | 790 |
| Silica Fume | 334 | 198 |
| Fly Ash (Class F) | 324 | 192 |
| Fine Basalt | 1923 | 1141 |
| Steel Fibers | 199 | 118 |
| Superplasticizer | 47 | 28 |
| Water | 246 | 146 |

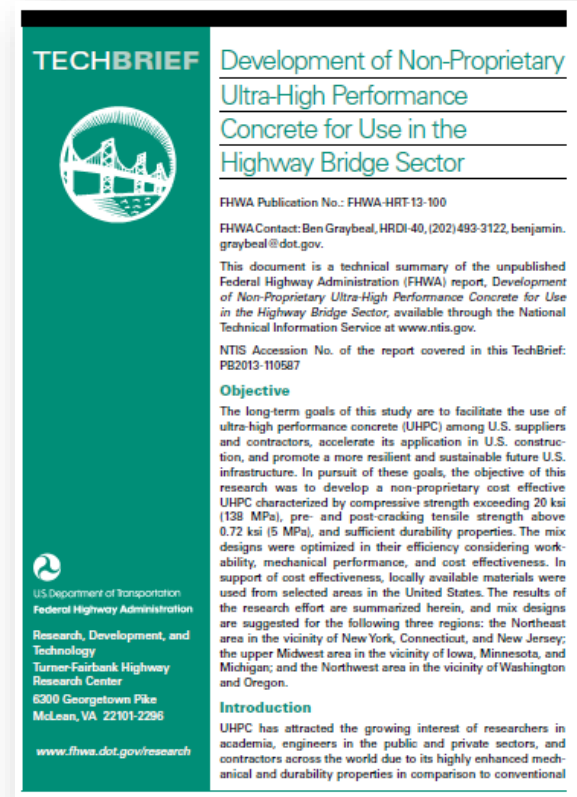
* Wille and Boisvert-Cotulio report titled “Development of Non-Proprietary UHPC for Use in the Highway Bridge Sector” (FHWA NTIS-PB2013-100587)

Availability of UHPC-Class Materials

Example Proprietary Versions

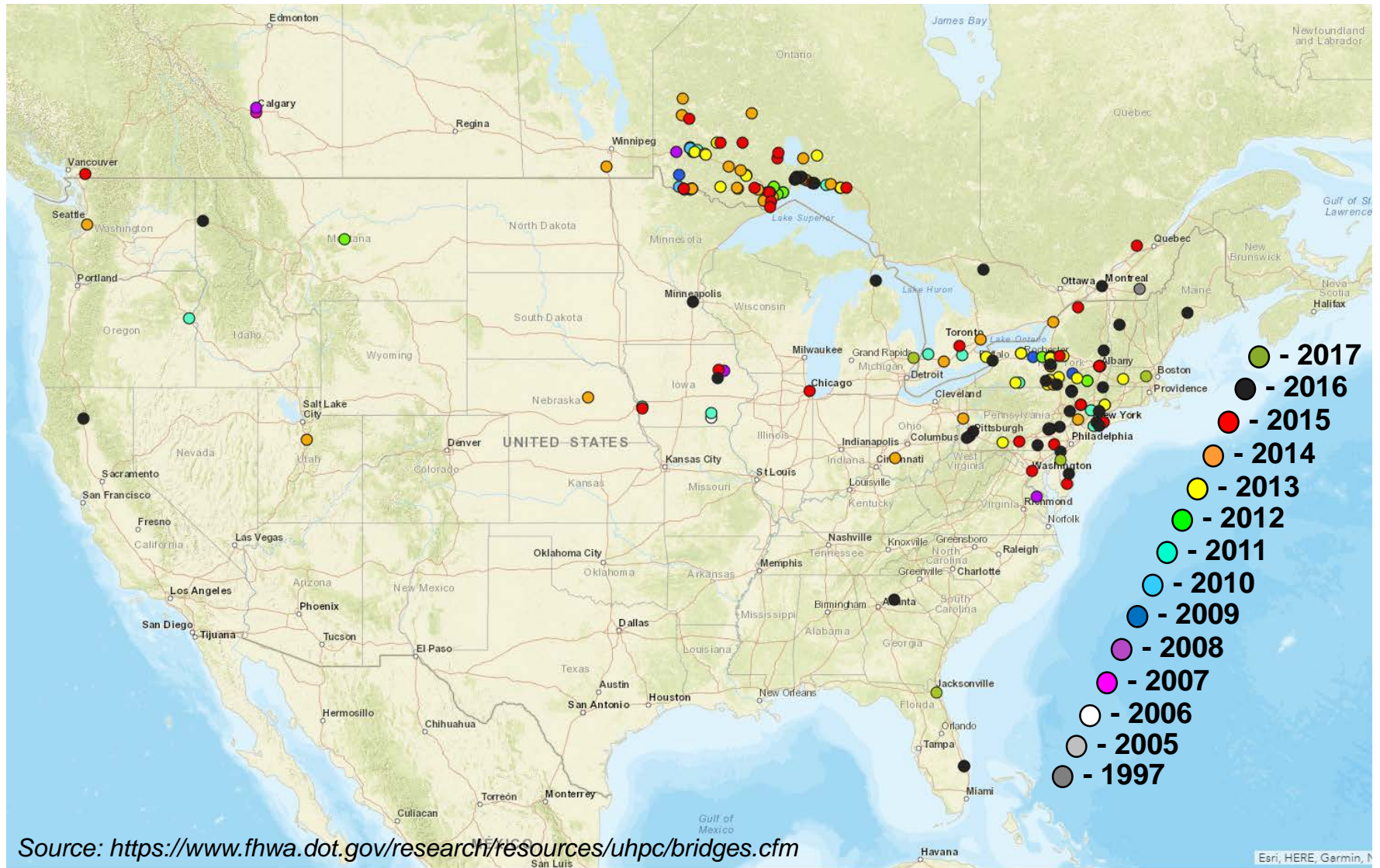


Non-Proprietary Versions



**FHWA-HRT-13-100:
Dr. Kay Willie at UCONN**

UHPC Deployments Across US and Canada



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?

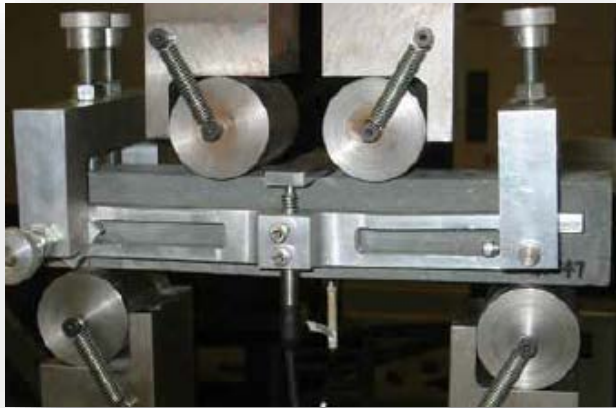


2001

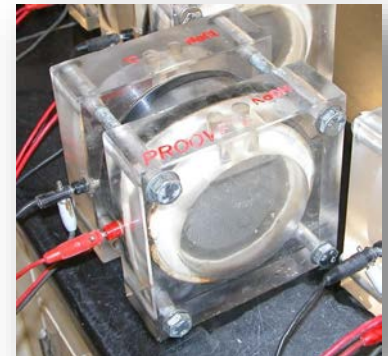


UHPC: A Timeline of Progress

- FHWA characterizing UHPC properties
- Community of practice started to grow



2003

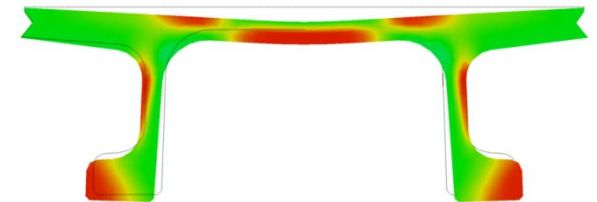


UHPC: A Timeline of Progress

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



2006



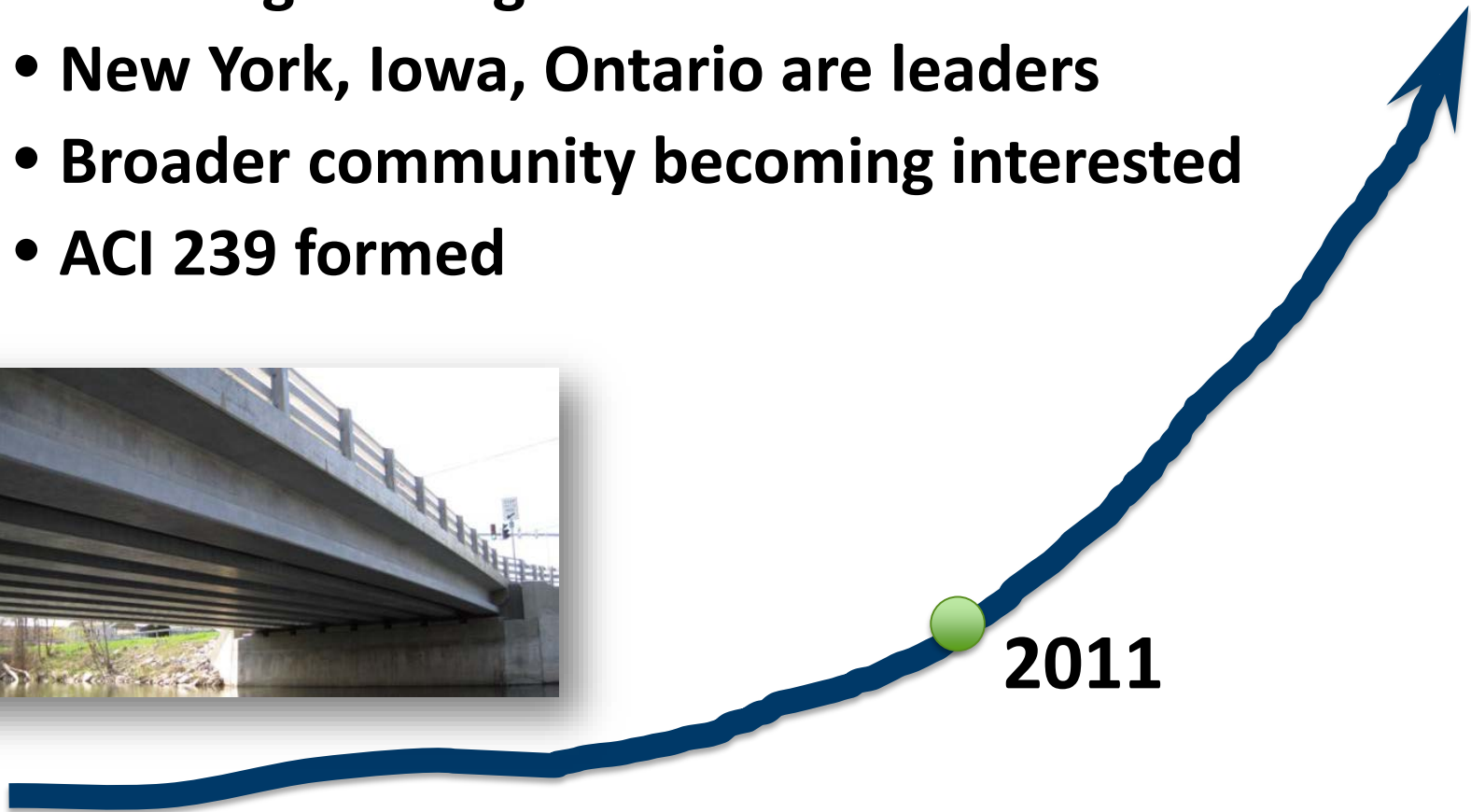
UHPC: A Timeline of Progress

- 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



2014

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

2017



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Clearly there are many **APPLICATIONS**

Pathways to Adoption...

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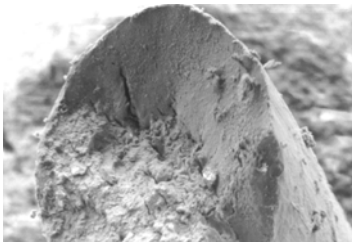


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