ABC-UTC Non-Proprietary UHPC Workshop

Summary of UHPC Work Across the Country and Discussion

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Outline

- Non-proprietary UHPC work outside of ABC-UTC
- Lessons learned
- Time of discussion

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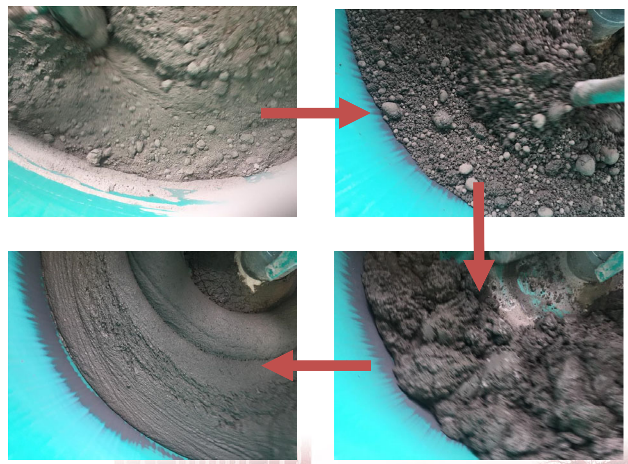
Final ABC-UTC Mix Design

Constituent	Mix Proportion
Type I Cement	0.6
Silica Fume	0.1
Slag Cement	0.3
Masonry Sand (1:1 agg/cm)	1.0
w/cm	0.2
Steel Fibers	2% by Volume
HRWR	18 oz/cwt



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Arizona

Mobasher, B., Arora, A., Aguayo, M., Kianmofrad, F., Yao, Y., and Neithalath, N. (2019) "Developing Ultra-High-Performance Concrete Mix Designs for Arizona Bridge Element Connections, FHWA-AZ-19-745, Arizona Department of Transportation, Phoenix, AZ.

- Materials available in Arizona
- Multiple mix designs
- Particle packing, cement chemistry, rheology
- Up to 3% steel fibers
- Compressive strengths in excess of 22 ksi
- $417/yd^3 to $989/yd^3 depending on mix design

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Michigan

El-Tawil, S., Alkaysi, M., Naaman, A. E., Hansen, W., and Liu, Z. (2016) "Development, Characterization and Applications of a Non Proprietary Ultra High Performance Concrete for Highway Bridges, RC-1637, Michigan Department of Transportation, Lansing, MI.

El-Tawil, S., Tai, Y.S., Meng, B., Hansen, W., and Liu, Z. (2018) "Commercial Production of Non-Proprietary Ultra-High Performance Concrete, RC-1670, Michigan Department of Transportation, Lansing, MI.

El-Tawil, S., Tai, Yuh-Shiou, and Belcher II, J. A. (2018) "Field Application of Nonproprietary Ultra-High-Performance Concrete, *Concrete International*, January 2018.

Michigan

El-Tawil, S., Tai, Y. S., and Belcher II, J. A. (2018) "Field Application of Nonproprietary Ultra-High-Performance Concrete, *Concrete International*, January 2018.

- 21.5 ksi at 28-days
- Michigan based contractor performing bridge repair
- Pan mixer
- Type I portland cement, slag cement, silica fume, HRWR, two silica sands, steel fibers

El-Tawil, S., Tai, Y. S., Belcher, J. A., and Rogers, D. (2020) "Open-Recipe Ultra-High Performance Concrete, *Concrete International*, June 2020.

- Estimate $567/yd^3 to $856/yd^3 for material

Montana

Berry, M., Snidarich, R., and Wood, C. (2017) "Development of Non-Proprietary Ultra-High Performance Concrete", FHWA/MT-17-010/8237-001, Montana DOT, Helena, MT.

- Easy-to-obtain Montana materials
  - Type I/II portland cement
  - Class F fly ash
  - Fine masonry sand
  - Silica fume
  - HRWR

Montana

Berry, M., Snidarich, R., and Wood, C. (2017) "Development of Non-Proprietary Ultra-High Performance Concrete", FHWA/MT-17-010/8237-001, Montana DOT, Helena, MT.

- 8-11 in. flow and 20 ksi compressive strength
- Compressive strength, tensile strength, elastic modulus, and shrinkage with good results
- Multiple durability tests with good results
- Conventional mortar mixer
- Variability was a problem
- \$300/yd^3 to \$350/yd^3 without fibers

Arkansas

Alsalman, A., Dang, C. N., and Hale, W. M. (2017) "Development of ultra-high performance concrete with locally available materials", *Construction and Building Materials*, 133: 135-145.

- 22.5 ksi compressive strength at 90 days
- Portland cement, silica fume, and fly ash

Nebraska

Mendonca, F., El-Khier, M. A., Morcous, G., and Hu, J. (2020) "Feasibility Study of Development of Ultra-High Performance Concrete (UHPC) for Highway Bridge Applications in Nebraska", SPR-P1(18)M072, Nebraska DOT, Lincoln, NE.

- Three mix designs with Type I/II portland cement, silica fume and slag cement
- 8-10+ in. flow and 17 - 20 ksi compressive strength depending on specific mix design
- Demonstrated full-scale connection casting
- High shear pan mixer
- Estimated cost of $682/yd^3

PCI

e.Construct (2020) "Implementation of Ultra-High-Performance Concrete in Long-Span Precast Pretensioned Elements for Concrete Buildings and Bridges", Phase I Report, Precast/Prestressed Concrete Institute, Chicago, IL.

- Five mix designs developed with precasters
- 8-10+ in. flow and 16 - 24 ksi compressive strength depending on specific mix design
- Demonstrated full-scale mixing and casting
- High shear pan and horizontal shaft mixers

Lessons Learned

- Trial batches are necessary even if using the same mix design and materials in different locations
- Existing mixes can be adapted, but admixture dosages often must be adjusted
  - Achieve adequate flowability
  - Ensure fiber suspension
- Different mixers exhibit different performance
  - Effective mixing capacity must be understood
  - Mixing time variations and subsequent effects on fresh properties

Lessons Learned

- VMA can be used to stabilize fibers in the mix design
- Proper fine aggregate moisture control is an important consideration
- Adequate cylinder grinding/end preparation is critical for consistent testing results
- Direct tension testing is difficult, but can be done with repeatable results using a modified testing apparatus
- Bond strength of non-proprietary UHPC is sufficient to develop reinforcing steel using available recommendations

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Thank you!

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