

Performance of Cost-Effective Non-proprietary UHPC in Thin Bonded Bridge Overlays

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OUTLINE

- ☐ Background of thin bonded UHPC overlay
- ☐ Construction specifications for UHPC overlay
- ☐ Material properties of non-proprietary UHPC

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Chillon Viaducts, Switzerland, 2015

Ductal®



(Brühwiler 2015)



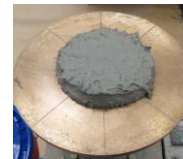
- Structure affected by ASR
- Structural overlay repair **thickness = 1.75 in. (45 mm)**
- Hydro demolition for surface preparation
- **Maximum slope: 7% (5°)**

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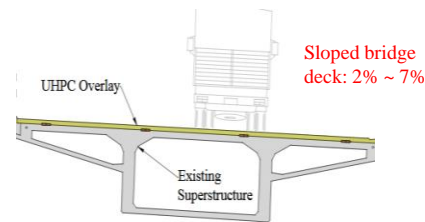
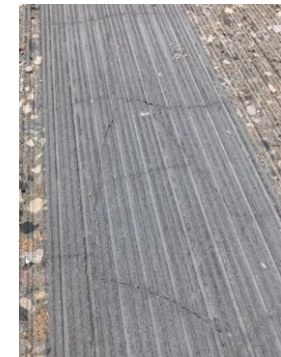
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Challenge of UHPC overlay

High thixotropic UHPC



Early-age shrinkage cracking if fiber distribution is impaired



Otego Creek New York, 2019

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Inclined plane test



Mixtures were at rest after UHPC preparation



Thixotropic UHPC can be used for bridge deck overlay with slope of 7% (5°):

- 5 min: 45°
- 10 min: 90°



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Mud Creek Bridge, Iowa, 2016



Grooved substrate surface with roughness of 1/12-1/8 inch (2-3 mm)
Overlay thickness: 1.5 in. (38 mm)
 $V_f = 3.25\%$



Grooved surface



Wire mesh in the negative moment region

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Branch Callioon Creek Bridge, New York, 2019



Hydro-demolition substrate surface
(Aggregate exposed surface)
Overlay thickness: 1.5 in. (38 mm)
 $V_f = 3.25\%$



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Surface preparation of bridge deck

Surface preparation procedure:

- remove distressed concrete and any contaminant from substrate surface
- roughen the surface: [hydrodemolition](#) and [scarification](#)
- prewet substrate surface to an SSD condition immediately prior to placing UHPC



Hydrodemolition (UHPC overlay on Branch Callioon Creek Bridge deck, New York, 2019)

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Scarification (UHPC overlay on Mud Creek Bridge deck, Iowa, 2017)

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Mixing procedure

- binder and sand are added and mixed for 2 min at 1 rps (low speed);
- 90% of mixing water and superplasticizer are added and mixed for 2 min at 6 rps (med speed);
- remaining water, superplasticizer, and other chemical admixtures are added and mixed for 4 min at 6 rps;
- fibers are **gradually added over 2 min**, then material is mixed for 2 min at 10 rps.

Portable high shear pan mixer



Pre-mix binder and sand



Figure Resource: UHPC overlay on Branch Callioon Creek Bridge deck, New York, 2019

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Mixing control

- High shear mixer is recommended
- Maximum volume of UHPC: 1/3 - 2/3 of volume capacity of mixer
- Some of water can be replaced by crushed ice to secure UHPC lower than 86°F (30°C).
- Content of water and/or superplasticizer can be slightly adjusted to secure adequate fluidity



Figure Resource: UHPC overlay on Branch Callioon Creek Bridge deck, New York, 2019

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Placing, finishing, and curing

After mixing, UHPC should be transported, placed, and covered **as quickly as possible**

- delivered using motorized buggies from a field mixer nearby
- spread into place using hand tool, such as rakes
- finished using vibrating truss screed
- overlay surface is coated with a wax-based curing compound and covered with plastic sheeting (7-d moist curing is recommended)



Figure Resource: UHPC overlay on Mud Creek Bridge deck, Iowa, 2017

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Surface profiling of UHPC overlay

- Surface of UHPC overlay is grinding and grooving for rideability.
- Grinding and grooving can start when compressive strength of UHPC reaches 14,000 psi (97 MPa) for ease of profiling.



Figure Resource: UHPC overlay on Mud Creek Bridge deck, Iowa, 2017

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Iowa Hwy UHPC bridge deck overlay, Iowa, 2020



Video Source: <https://www.youtube.com/watch?v=nAwcxwCeefw>

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Mixture proportion of UHPC mixture

	LWS17- 3.25%	LWS17&SRA1- 3.25%
Portland cement	1080 lb/yd ³ (640 kg/m ³)	
Class C fly ash	675 lb/yd ³ (400 kg/m ³)	
Silica fume	70 lb/yd ³ (40 kg/m ³)	
River sand	860 lb/yd ³ (510 kg/m ³)	
Fine sand	505 lb/yd ³ (300 kg/m ³)	
Lightweight sand	195 lb/yd ³ (115 kg/m ³)	
Steel fibers (3.25% by volume)	430 lb/yd ³ (255 kg/m ³)	
Superplasticizer (Plastol 6400)	1.7 gal/yd ³ (8.3 L/m ³)	
Thixotropic admixture (EUCON ABS)	1.07 gal/yd ³ (5.3 L/m ³)	
Shrinkage-reducing admixture (EUCON SRA Floor)	N/A	2.2 gal/yd ³ (10.7 L/m ³)
Air detrain admixture (EUCON Air Out)	1.2 gal/yd ³ (6 L/m ³)	

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LWS property:

1. Type: Expanded Shale
2. Company: Northeast Solite
3. Plant Location: Shepardsville KY
4. Particle diameter: 0-0.187 in. (0-4.75 mm)
5. Water adsorption at 24 h: 17.5%-19%

	Ductal®-3.25%
Density (ASTM C138)	145-155 lb/ft ³ (2,320-2,485 kg/m ³)
Air content (ASTM C138)	< 2.5%
Temperature after mixing	< 86 °F (30 °C)
Initial mini-slump flow before jolting (ASTM C230)	6.5-8 in.(165-205 mm)
Initial mini-slump flow after jolting (ASTM C230)	8-9.5 in.(165-205 mm)
Static yield stress at 5 min after 25 cycles of jolting	> 0.1 psi (700 Pa)
Increase rate of static yield stress from 5 to 30 min after end of mixing determined using portable vane	0.01 psi/min (70 Pa/min)

Range of hardened properties of UHPC

Test methods/Description	Typical Range
1-d compressive strength (ASTM C109)	> 7,700 psi (53 MPa)
7-d compressive strength (ASTM C109)	> 17,400 psi (120 MPa)
28-d compressive strength (ASTM C109)	> 18,700 psi (130 MPa)
7-d flexural strength (ASTM C1609)	> 2,500 psi (17 MPa)
7-d flexural toughness (ASTM C1609)	> 310 lb·in. (35 J)
28-d flexural strength (ASTM C1609)	> 2,900 psi (20 MPa)
28-d flexural toughness (ASTM C1609)	> 350 lb·in. (> 40 J)
Autogenous shrinkage at 28 d for UHPC	< 450 $\mu\epsilon$
Shrinkage at 56 d (ASTM C157)	< 500 $\mu\epsilon$
Restrained shrinkage at 35 d (ASTM C1581)	No cracking

Fresh property

Mixtures were mixed at low speed of 0.5 rps between tests

0 min



15 min



30 min



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Slump cone:
upper dia. = 3 in.
lower dia. = 4 in.
H = 2 in.

Fresh property

Mixtures were mixed at low speed of 0.5 rps between tests

No jolting: 7 in. (180 mm)
25 jolting: 8 in. (200 mm)

4 in. (100 mm)
5.5 in. (140 mm)

4 in. (100mm)
4.5 in. (115 mm)

Mini-slump flow after 25 jolting

0 min



15 min



30 min



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Slump cone:
upper dia. = 3 in.
lower dia. = 4 in.
H = 2 in.

Fresh property

Mixtures were mixed at low speed of 0.5 rps between tests

Mini-slump flow after 25 jolting

30 min



4 in. (100mm)
4.5 in. (115 mm)

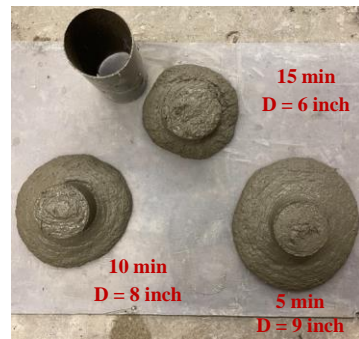
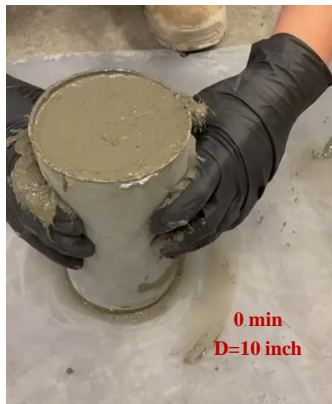
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Undisturbed spread slump

Mixtures were at rest after UHPC preparation



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