Repair and retrofit of bridges using UHPC

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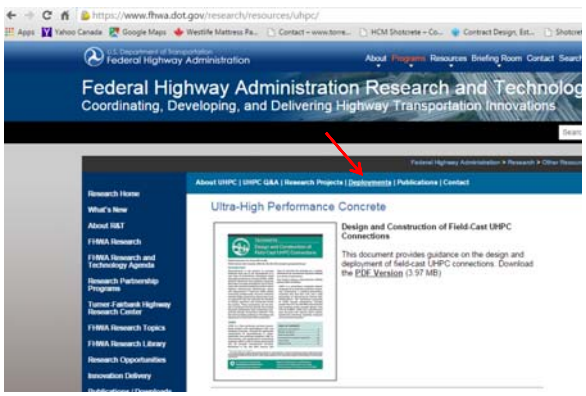
UHPC in North America

UHPC has been used on bridges projects for over 10 years in NA. Precast deck panels connected with field cast UHPC joints has been the most popular application. Approximately 200 projects completed in more than 25 states and provinces to date.

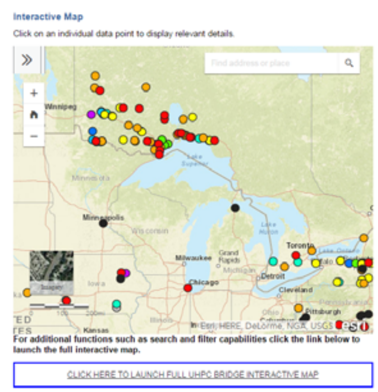
UHPC has also been used for:

- Structural overlays
- Headers and link slabs to replace traditional expansion joints
- Jackets for columns/piers
- Pier cap to column connections
- UHPC precast elements to widen and strengthen existing bridges

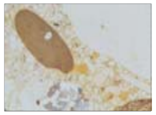
UHPC projects in North America



UHPC projects in North America



UHPC matrix



30 MPa (4 ksi) normal

70 MPa (10 ksi) high performance

150 MPa (22 ksi) UHPC

UHPC vs Normal Concrete

	Characteristics	Normal Concrete	Ratio	UHPC
Mechanical	Compression - MPa (psi)	20 – 40 (3,000 - 6,000)	6 x	140 – 160 (20,000 – 23,000)
	Flexure – MPa (psi)			30 (4,000)
	Elastic Tensile Strength – MPa (psi)			8 (1,200)
	Water / Cement ratio	0.40 - 0.70	< 2	< 0.25
Durability	Chloride ions diffusion (coulombs)	> 2000	20 x	< 100
	Freeze / thaw cycles scalling (g/m^2)	> 1000	100 x	< 10
	Abrasion (kg/m^2)	1	100 x	0.01

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Steel fibers

Fibers = Ductility

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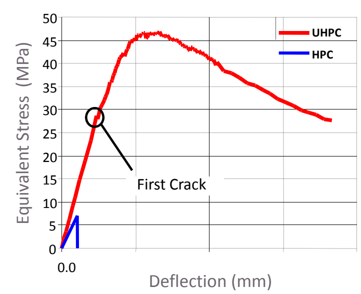
UHPC in Flexure

Fibers = Stain hardening (1st crack at 4,000 psi)



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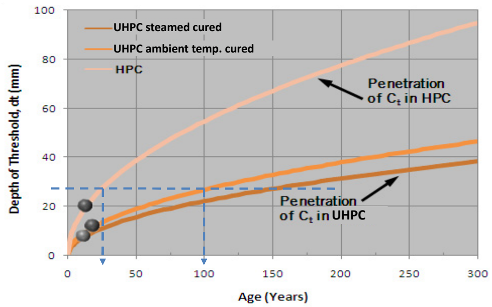
Chlorides penetration test

US Army Corps test site in Maine



Design Guides - FHWA

FHWA has published over 40 reports, TechNotes and Guidelines

Design Standard – SIA 2052 - 2016

Swiss Society of Engineers and Architects


sia

Béton fibré ultra-performant (BFUP) –
Matériaux, dimensionnement et exécution

2052

Design Standard - NF P 18-470 - 2016

AFNOR (Association française de normalisation)


French standard

Design Guidelines US/Canada

Committee work in progress

- In December of 2015, the Canadian Standards Association (CSA) formed a new “Working Group on UHPC” under A23.1, Chapter 8, with the mandate to develop a new annex on UHPC materials (CSA A23.1, 2014). Target 2019 edition of the next CSA A23.1-19.
- American Concrete Institute (ACI)
  239 - Ultra-High Performance Concrete
  239-A Emerging Technology Report
  239-B Report on UHPC
  239-C Structural Design on UHPC
  239-D Materials & Methods of Construction with UHPC

Batching equipment

A size for every job

On site batching is the preferred option for most projects.
We have a fleet of portable mixers which can be rented by contractors.

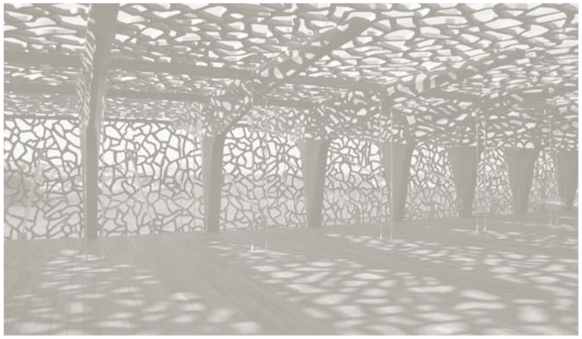
0.15 m^3 batches - 0.6 m^3 / hour
(0.2 yd^3) (0.8 yd^3)

0.5 m^3 batches - 2 m^3 / hour
(0.65 yd^3) (2.6 yd^3)

1.0 m^3 batches - 4 m^3 / hour
(1.3 yd^3) (5.2 yd^3)

4.5 m^3 per truck
(6 yd^3)

Applications



Joint fill / Closure Pours / Haunches

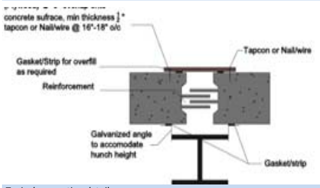
UHPC has been used to joint precast elements together and also used to secure the deck to the supporting beams by filling the haunches and shear keys pockets.

DOT’s elaborate their own specifications and designs.

Main issue: UHPC joints are now the stronger elements and not affected by live loads, freeze-thaw or deicing salts.

Solution: UHPC joints allows for faster construction because no need to form decks on site and wait for deck curing. Also, ideal for remote areas where the contractor is not dependant on the availability of ready mix.

Installation of precast panels



Typical connection detail

Pulaski Skyway, NJ 2014/17

5.5 km (3.5 miles) - 4 lanes

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Pulaski Skyway, NJ

Traffic maintained on 2 lanes during construction

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Nipigon Bridge, east of Thunder Bay

Grouting precast deck panels with UHPC

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Peoria Street Bridge, Chicago, IL

Bridge 56 precast panels – 3 span bridge -- 83 m (270 ft) x 17 m (56 ft)

Typical 200 mm (8 in) wide UHPC joints

UHPC casting completed

Surface before applying the overlay

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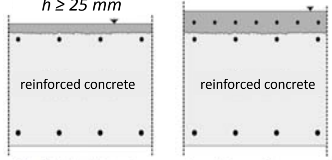
Photos by David Liu

UHPC overlay

Application of dense layer of strain-hardening UHPC with 25 to 60 mm (1 in to 2.5 in) thickness applied on the superstructure in zones of severe environmental and mechanical loads.

UHPC *h ≥ 25 mm* | **Reinforced UHPC** *h ≥ 35 to 60 mm*

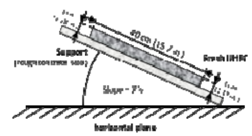


protection | **protection + strengthening**

UUPC overlay formulation

Self leveling mix to thixotropic mix



UHPC overlay – large project

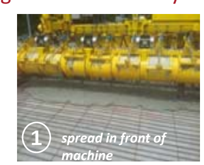
Batching 60 to 75 m^3 (75 to 100 yd^3) capacity per day

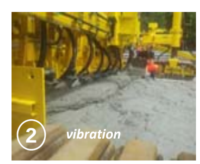
Motorized buggies to bring material in front of the paver

Portable batching plant; one silo for sand, one silo for the premix, 2 high shear mixers 1 m^3 (1.5 yd^3) batches

UHPC overlay

Placing – industrialized system





Chillon Viaducts, Switzerland 2014-15

45 mm (1.75 in) cast-in-place overlay with rebar reinforcement
Thixotropic mix used to cast on 7% slope

2 parallel structures
each 12 m (40 ft) wide 2 km (1.2 mile) long
51,000 m^2 (61,000 yd^2) total deck area
Original segmental box system built 1969

Main issue: ASR (alkali silica reaction) and lost of concrete performance

Solution: Thin structural UHPC overlay provides waterproofing to halt ASR progression and increase substantially the strength of the deck

UHPC cheaper alternative


Concrete paver developped by WALO


Work staged over 2 years with traffic maintained on one of the structures

Chillon Viaducts


Hydro demolition


On site portable batching plant – 2 mixers


Material brought to the concrete machine with motorized buggies


Concrete paver with customized dispensing system at the front

Iowa DOT, Buchanan Country, 2016

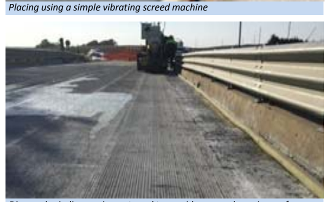
38 mm (1.5 in) cast-in-place overlay
Thixotropic mix used to cast on 5% slope

30 m (100 ft) long, 3-span deck
8.5 m (28 ft) wide
260 m^2 (310 yd^2) total deck area

Main issue: Pilot project to evaluate the constructability and performance of a UHPC overlay

Solution: Current low lump concrete overlays are not performing optimally. A more durable UHPC product would provide added durability. This pilot project done in conjunction with Iowa DOT, Buchanan County, FHWA, local contractors and Lafarge will be monitored for long term durability.


Placing using a simple vibrating screed machine


Diamond grinding equipment used to provide grooved running surface

Cudrex Viaduct, Switzerland, 2016

30 mm (1.25 in) waterproofing overlay
45 mm (1.75 in) used on curbs and sidewalk for deicing protection

Built in 1968
440 m (1,450 ft) long
9.5 m (31 ft) wide deck
24,000 cars/trucks per day
230 m^3 (300 yd^3) of UHPC

Main issue: Waterproofing at end of its life, supporting structure in good shape

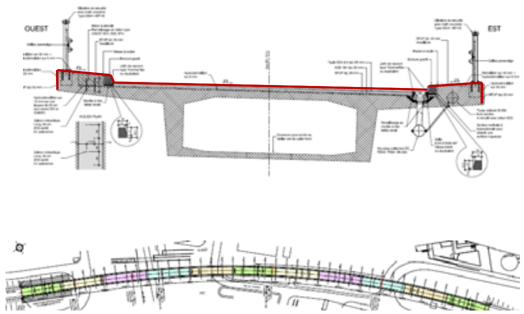
Solution: Thin structural UHPC overlay provides waterproofing. Option with minimal traffic interruption.

UHPC cost comparable but more durable than other options.


Work performed at night on weekends with traffic back on Mondays


UHPC overlay prior to installation of asphalt layer

Cudrex Viaduct, Switzerland, 2016



443 m (1,450 ft) x 9.5 m (31 ft) wide deck

Kanderal Bridge, Switzerland, 2017

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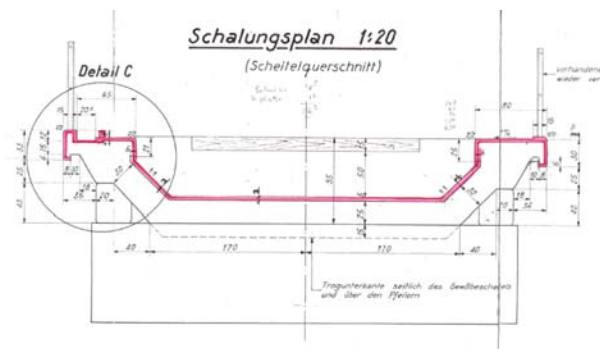
Kanderal Bridge, Switzerland, 2017



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Mission Bridge, Abbotsford, BC, 2014

230 mm (9 in) thick UHPC jacket used on a height of 3.5 m (11.5 ft) along with additional dowels and a rebar cage to confine the area.

Main issue: Final stage to complete the retrofit of the bridge. One pier on the south shore required additional work because of pour soil conditions.

Solution: Using a UHPC jacket allowed for a thin layer that does not obstruct the view or significantly alter the original appearance.

UHPC cheaper than using soil consolidation techniques.

Pier prior to final retrofit

Completed project

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Mission Bridge, Abbotsford, BC, 2014

Loading and batching in ready-mix truck at Lafarge plant

Delivery to the site (total of 4 trips)

Hoisting and casting from the top of the formwork

Completed project

CN Rail Bridge, Montreal, Quebec, 2013

115 mm (4.5 in) thick UHPC jacket cast around an existing pier which is 600 mm (2 ft) thick x 3.5 m (11.5 ft) in height.

Main issue: Deteriorated surface due to rebar corrosion and chloride spray because of the very narrow lanes.

Solution: Owner wanted to minimize maintenance and required a material with very low porosity and that could last at least twice as long compared to normal concrete.

UHPC jacket - Ramp to Pont Victoria under the CN Rail track

Damaged pier prior to repair

CN Rail Bridge, Montreal, Quebec

Formwork

Casting – traffic maintained on adjacent lane

Completed repair

Grafstal Bridge, Switzerland, 2016

Grafstal Bridge, Switzerland, 2016

Hooper Road Bridge, Union, NY, 2014

UHPC used to connect new precast pier cap elements to existing columns. Part of a 21-day structure replacement.

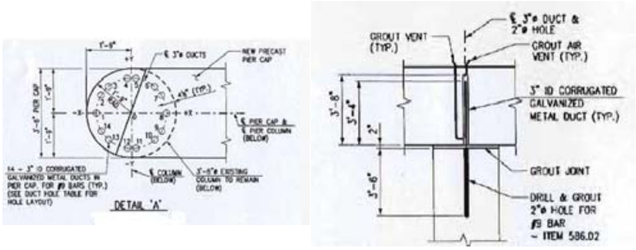
Main issue: Original detail called for ducts and drilling of a total of 84 holes in the existing columns and grouting of each individual holes. Difficult to implement on site and potential for many delays and issues.

Solution: UHPC connection; initiated by the Contractor who was looking for an alternative solution. Saved 2 days on the schedule. Very short development length of 280 mm (11 in) required for the joint because using UHPC.

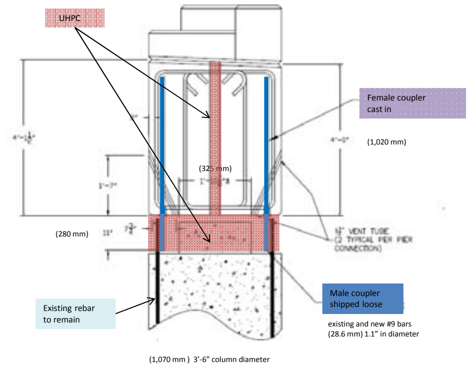
New precast pier cap set on existing columns

Completed connections

Hooper Road Bridge, Union, NY, 2014



Hooper Road Bridge, Union, NY, 2014



Hooper Road Bridge, Union, NY, 2014

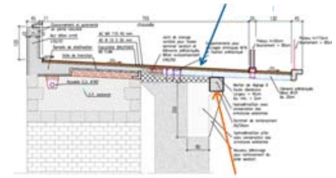
Pont de la Tine, Switzerland, 2011

Precast 200 mm (8 in) thick UHPC slabs added to extend the bridge by 1.5 m (5 ft).

cantilevered slabs are anchored to the existing structure with mechanical anchors.

Main issue: Narrow structure needed to be retrofitted to accommodate larger vehicles and provide a proper protected sidewalk

Solution: taking advantage of the flexural capacity and durability. Underside is exposed to elements. Low cost option in this case.



Details of the bridge widening

Precast UHPC slab ready to be anchored

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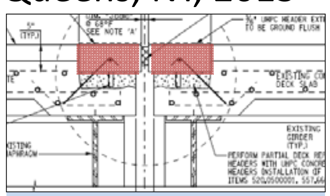
Francis Lewis Blvd., Queens, NY, 2015

Removed existing steel angles and associated deteriorated concrete. Add new rebar and use 125 mm (5 in) x 300 mm (12 in) wide UHPC headers

Main issue: Steel angle and rebar corrosion damage concrete, affect supporting beams and require maintenance.

Solution: Remove the original problem in header joint, the steel angle and rebar that can corrode. By using UHPC, the corners/edges of the slabs will no longer be affected by chlorides and water penetration.



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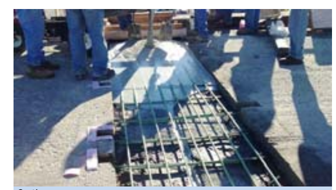
Link Slabs, Binghamton NY, 2014

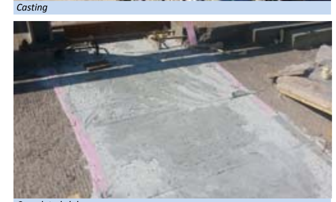
Eliminating joints on bridge decks extends the life of the structure

Main issue: Expansion joints deteriorate over time and water/chloride penetrate and damage the slabs edges and the supporting girders.

Solution: By providing a continuous link on top of the piers (approx. 100 mm thick), water/chlorides can not longer deteriorate the structure. The UHPC slab can flex and the strain-hardening provided by the steel fibers limit the width of micro cracks while maintaining the integrity of the link slab.



Casting



Completed slab

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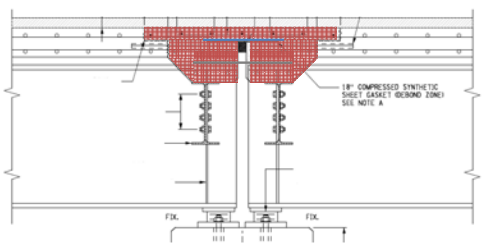
Link Slabs details, NY, 2016



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