Accelerating Infrastructure Innovations

FOCUS

June 2012

INSIDE

Ultra-High Performance Concrete Connections for Bridges: Superior Strength and Durability

As transportation agencies look for innovative solutions to facilitate the rapid construction of highway bridges, they are turning to ultra-high performance concrete (UHPC) for superior strength and durability.

"UHPC has advanced the state of the art for construction of prefabricated bridge elements and systems," said Ben Graybeal of the Federal Highway Administration (FHWA). A new Tech Note released by FHWA, *Construction of Field-Cast Ultra-High Performance Concrete Connections* (Pub. No. FHWA-HRT-12-038), highlights how UHPC enables significant simplifications in the design of the field-cast connections that link prefabricated bridge components. New UHPC connection details eliminate the conflict points between the reinforcing bars and other discrete connectors, allowing for easy field assembly.

As of early 2012, field-cast UHPC connections between prefabricated bridge components have been used in 18 bridges in the United States and Canada. These bridges use a range of details to connect different precast concrete modular bridge components, including adjacent box beams, full-depth precast deck panels, and deck-bulb-tee girders. Examples include the Route 31 Bridge over the Canandaigua Outlet in Lyons, New York, and the U.S. Route 6 Bridge over Keg Creek in Pottawattamie County, Iowa. Both bridges use field-cast UHPC in longitudinal connections for pre-decked superstructure elements.

UHPC is an advanced cementitious composite material first developed in the 1990s and commercially available in the United States since 2000. It is typically acquired from a supplier in three separate components: a pre-bagged cementitious powder, steel fiber reinforcement, and chemical admixtures. Water is then added at the construction site, and the UHPC is mixed and placed into the formwork using standard construction equipment.

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U.S. Department of Transportation

Federal Highway Administration

Ultra-High Performance Concrete Connections,

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Above: Field-cast ultra-high performance concrete (UHPC) connections were used to construct the Route 31 Bridge in Lyons, NY.

Right: A portable concrete pan mixer is used to prepare UHPC for placement during construction of field-cast connections.

Compared to more conventional concrete materials, UHPC exhibits superior properties such as exceptional durability, high compressive strength, usable tensile strength, and long-term stability. It generally contains high cementitious material contents, low water-to-cementitious material ratios, compressive strengths above 21.7 ksi (150 MPa), and sustained tensile strength resulting from internal fiber reinforcement.

Buy America provisions are relevant to the steel fiber reinforcement used in UHPC. States planning to use UHPC in projects should work with their FHWA division office early in the design process to determine the availability of a domestic manufacturer, and if necessary, submit a Buy America waiver request for FHWA's consideration.

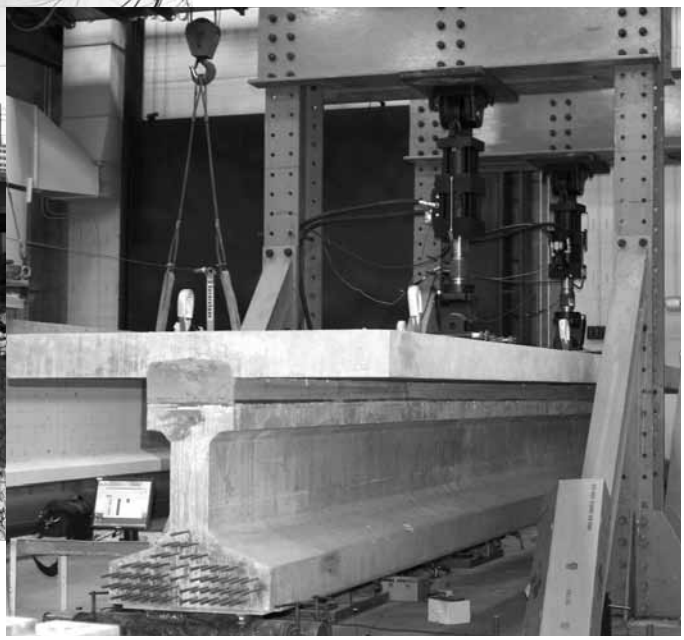
The Tech Note takes readers through the steps involved in constructing field-cast UHPC connections, including design, prefabricated component preparation, formwork, mixing and placing, initial and final curing, surface profiling, and material testing. The design of the field-cast connections, for example, is critical to the overall performance of the structural system. Designers must consider both service and ultimate limit states, as well as the practicality of construction and the long-term durability of the deployed system.

> "UHPC has advanced the state of the art for construction of prefabricated bridge elements and systems."

Prior to completing the UHPC connections between prefabricated components, the components must be fabricated, transported, and assembled on the bridge. Critical steps include the preparation of the bonding surfaces where the precast component meets the field-cast UHPC. While UHPC can bond exceptionally well to conventional concrete, the bond strength is highly dependent on the surface of the precast concrete. As with other cementitious grouts, UHPC is not likely to form a strong bond with smooth, dry, precast concrete. An enhanced bond can be obtained by using concrete that has an exposed aggregate surface finish.

The formwork required to contain UHPC when it is placed into a connection requires tighter control than the formwork commonly used in field-cast concrete applications, as UHPC exhibits higher pressure than conventional concrete and can easily leak between formwork that is not appropriately sealed.

Guidance is also provided on mixing and placing the concrete. UHPC is sensitive to mixing deviations, so the supplier's specifications for mix proportions and timings must be followed. Mixing UHPC requires significant energy in order to disperse the liquids uniformly within the powder matrix. Both portable concrete pan mixers and conventional concrete ready-mix trucks have been used on projects to mix UHPC. The volume of UHPC that can be mixed is approximately half that of conventional concrete that could be



Above: The Route 23 Bridge in Oneonta, NY, was built using precast concrete deck panels and field-cast UHPC connections.

Right: UHPC composite connection test specimens are subjected to cyclic loading.

processed in the same mixer. Typically, either motorized or nonmotorized wheelbarrows have been used to place UHPC into field-cast connections, with connection spaces being filled consecutively. UHPC should always be placed into connection spaces so that successive placements are poured into concrete that was recently cast and remains fluid.

Although UHPC tends to exhibit long dwell times before it begins to set, once setting begins, strength gain occurs rapidly. The initial setting behavior is dependent on the temperature of the UHPC. Although cooler temperatures are beneficial for mixing and placing UHPC, warmer temperatures are better for the rapid setting of the concrete. This setting can be accelerated by supplying supplemental heat to the UHPC and surrounding prefabricated elements. Heat can be supplied externally (e.g., ground heating mats) or internally (e.g., resistance heating wires), but forced air heat should not be applied to exposed UHPC surfaces.

The Tech Note also highlights material testing for UHPC. While established testing procedures for conventional concrete are generally applicable to UHPC, procedures may need to be modified in some instances to appropriately capture the behavior of the UHPC. Modified procedures for flow testing and compression testing, for example, are discussed.

To download the Tech Note, visit www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/12038/index.cfm.

Further information on a specific type of UHPC connection can be found in FHWA's new Tech Brief, *Ultra-High Performance Concrete Composite Connections for Precast Concrete Bridge Decks* (Pub. No. FHWA-HRT-12-042). The Tech Brief describes a study FHWA conducted on the performance of field-cast UHPC composite connections between precast modular bridge decks and supporting girders. This evaluation is part of Transportation Pooled Fund Study TPF-5(217), which is being done in partnership with the New York State Department of Transportation.

Two full-scale test specimens were built for the study. One used conventional concrete with standard composite connection details, while the other used UHPC and novel connection details. Each specimen simulated both a steel girder connection and concrete girder connection to precast concrete deck panels. The specimens were subjected to both cyclic loads and static loading. The UHPC connections withstood loads greater than those required by the American Association of State Highway and Transportation Officials *Load and Resistance Factor Design Bridge Design Specifications* and surpassed the performance of the conventional test specimen.

Also featured in the Tech Brief are recommendations for using the UHPC composite connection detail. These recommendations are conceptual guidance, rather than formal design specifications. To download the Tech Brief, visit www.fhwa.dot.gov/publications/research/infrastructure/structures/hpc/12042/. The full report on the FHWA study is available through the National Technical Information Service at www.ntis.gov (search for NTIS Accession No. PB2012-107569).

For more information on UHPC, contact Ben Graybeal at FHWA, 202-493-3122 (email: benjamin.graybeal@dot.gov). ✻

Sharing Best Practices and Project Solutions Through the Construction Peer Network

The Construction Peer Network's first peer exchange was held March 6–7, 2012, in Warwick, RI.

Transportation agencies and contractors are sharing construction best practices and proven solutions to project challenges through the new Construction Peer Network (CPN).

The CPN is a collaboration among the American Association of State Highway and Transportation Officials (AASHTO), American Road and Transportation Builders Association (ARTBA), Associated General Contractors of America (AGC), and Federal Highway Administration (FHWA). Using regional peer exchanges and new products such as the Program Information Tool (PI Tool), the network is bringing practitioners together to discuss more effective construction practices and learn from each other's experiences. The CPN will benefit both State agencies and contractors by:

- Providing options to State transportation agencies for maximizing limited resources.
- Widely deploying proven practices and innovations across the Nation.
- Promoting ways to use construction funding more effectively, resulting in a positive impact on quality, cost, time, and other important project delivery metrics.
- Developing or enhancing each participant's regional network of peers.

Hosted by the Rhode Island Department of Transportation, the first peer exchange was held March 6–7, 2012, in Warwick, Rhode Island. A select group of construction leaders representing State agencies, contractors, consulting firms, AASHTO, AGC, ARTBA, and FHWA participated in the session.

Participants submitted information on construction best practices using the electronic PI Tool prior to the exchange. Discussion topics for the exchange were chosen based on the information gathered with the PI Tool.

Several States presented best practices, which initiated further discussion on topics such as innovative practices and tools for inspection, project staffing levels, allowing innovations by the contractor, innovative construction methods, and performance measurement.

"The first peer exchange was a success," said David Unkefer of the FHWA Resource Center. "Participants were able to share what works for them and to learn from the advancements of others, so that proven processes and technologies can be disseminated across the country, enhancing highway infrastructure performance and safety."

Several States discussed approaches to using performance measures in construction. For example, New York and Rhode Island conduct formal evaluations to assess the cause for change orders, allowing the agencies to determine how well a project performed. Maryland, Massachusetts, Pennsylvania, and New York share performance measures transparently with the general public.

Practices shared for keeping projects moving include timely approval of change orders. Connecticut, the District of Columbia, and New Jersey, for example, have streamlined the change order approval process by authorizing mid-level approvals by the project engineer, resident engineer, and construction engineer. Vermont has also streamlined its approval process by using electronic signatures. Many participants indicated they are using prefabrication for appropriate structures and decks to accelerate projects, including in Connecticut, Delaware, Maine, Maryland, and New Jersey.

The Pennsylvania Department of Transportation, meanwhile, has improved project delivery by asking contractors to evaluate a project's design after construction is completed. Also discussed was the use of risk assessment to systematically evaluate the need for review testing and frequency. The New Hampshire Department of Transportation, for example, conducted a risk assessment of its testing processes to optimize the use of its limited testing resources.

The next peer exchange will be held July 10–11, 2012, in Detroit, Michigan. Tentative future dates include November 2012 in Salt Lake City, Utah; March 2013 in Orlando, Florida; and July 2013 in Boise, Idaho.

For more information on the CPN, contact Chris Schneider at FHWA, 202-493-0551 (email: christopher.schneider@dot.gov), or David Unkefer at the FHWA Resource Center, 404-562-3669 (email: david.unkefer@dot.gov). To download a copy of the CPN User Guide, PI Tool, and a summary report from the Rhode Island peer exchange, visit http://construction.transportation.org/Pages/ConstructionPeerNetworking.aspx. *

FHWA Introduces New Asset Management Web Site

Take a fresh look at transportation asset management with the Federal Highway Administration's (FHWA) new and improved Asset Management Web site (www.fhwa.dot.gov/asset).

Asset management provides a framework to improve performance on a long-term basis. It also enables transportation agencies to preserve their assets, minimize their whole-life costs, and operate in a financially sustainable manner.

The new site features the information you need to make asset management a reality for your organization, with sections on everything from publications and training to resources and useful contacts. Also highlighted are current FHWA asset management projects.

Visit FHWA's new and improved Asset Management Web site at www.fhwa.dot.gov/asset.

Publication categories include general asset management, bridges, pavements, safety, operations, management systems, and case studies. Among the newly added publications are *Bridge Management Practices in Idaho, Michigan, and Virginia* (Pub. No. FHWA-IF-12-029) and *Executive Brief: Advancing a Transportation Asset Management Approach* (Pub. No. FHWA-IF-12-034).

Training options include a list of courses and workshops offered by FHWA and the FHWA National Highway Institute (NHI), including Transportation Asset Management (NHI Course No. 131106), Economic Analysis for Highway Decision Makers Workshop, Pavement Management Systems: Characteristics of an Effective Program (NHI Course No. 131116), and Fundamentals of Life-Cycle Cost Analysis. Also listed are upcoming conferences and other events.

Visitors to the Resources section can find guidance documents, recordings and presentations from asset management Webinars, videos, details on software programs, information on Transportation Asset Management Plans, and a list of frequently asked questions. Links to other useful information include Web sites for the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Asset Management, Transportation Research Board Asset Management Committee, and State transportation agencies.

Updates on current FHWA asset management projects are posted on the site. These initiatives include establishing the Transportation Asset Management Expert Task Group as a forum to discuss changes in the way highway agencies are managing assets and identify strategies to advance asset management (see May 2012 *Focus*). Also in development are plans for FHWA and the AASHTO Subcommittee on Asset Management to conduct Webinars on asset management topics beginning in summer 2012, with more details to be posted as they become available.

FHWA is also preparing the first of five planned reports on risk-based transportation asset management. Expected to be released in fall 2012, the first report will provide an overview of risk management as applied to managing physical assets. Additional FHWA initiatives include enhancing the Pavement Health Track Analysis Tool, which agencies can use to determine the health of a road network in terms of remaining service life.

To use the many asset management tools and resources available, visit www.fhwa.dot.gov/asset. For more information on asset management, contact Steve Gaj at FHWA, 202-366-1336 (email: stephen.gaj@dot.gov). *

FHWA Offers Online Training on Chip Seal Best Practices

Find the guidance you need to make chip seals part of your pavement preservation program with a free online course from the Federal Highway Administration (FHWA).

The 3-hour Chip Seal Best Practices course (Course No. FHWA-NHI-131132) is an on-demand training that can be scheduled at your convenience. Developed by the Transportation Curriculum Coordination Council (TCCC), the course is offered through FHWA's National Highway Institute (NHI).

Six modules cover introductory information, designing chip seal mixes, selecting the proper materials for the chip seal mix, using the right equipment, following proper construction practices, and incorporating performance measures. Topics also include common chip seal distresses.

The course will benefit entry-level construction inspectors, maintenance employees, and contractor personnel, as

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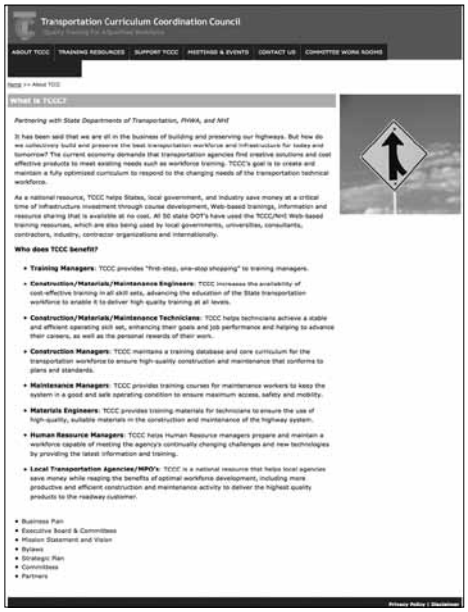

To learn more about the Chip Seal course and other training opportunities, visit www.tccc.gov.

Infrastructure Innovation Webinars

These free Webinars provide a quick introduction to the latest infrastructure innovations and technologies.

Resilient Bridge Design
June 21, 2012, 2:30–4 p.m. (eastern daylight time)

The Webinar is based on a new Federal Highway Administration (FHWA) publication, *Framework for Improving Resilience of Bridge Design*. This publication draws on lessons from past bridge failures to improve the resilience of bridge designs by using the "fault-tree analysis" methodology to identify potential events that could lead to a bridge failure. Designs that prevent such failures are then discussed. Examples of a fault-tree analysis for both concrete and steel bridges will be featured during the session. The Webinar is hosted by the National Highway Institute (NHI), in conjunction with the FHWA Highways for LIFE program.

To register, visit www.nhi.fhwa.dot.gov/resources/webconference/web_conf_learner_reg.aspx?webconfid=24526. For more information, contact Julie Zirlin at FHWA, 202-366-9105 (email: julie.zirlin@dot.gov).

Rigidified Fiber-Reinforced Polymer (FRP) Tubular Arches and Hybrid Composite Beams
July 19, 2012, 2:30–4 p.m. (eastern daylight time)

The Webinar will discuss two market-ready FRP composite technologies for bridges that could yield significant economic benefits. Rigidified FRP tubular arches (RFTA) are well suited to a variety of sites, including environmentally sensitive areas and locations where it is difficult or damaging to bring in heavy equipment and machinery. Using RFTAs can also result in low life-cycle and maintenance costs.

Hybrid composite beams (HCB) can weigh considerably less than conventional bridge components and can be erected using smaller, lighter pieces of construction equipment. Combining the enhanced properties of concrete, steel, and FRP composites, HCBs also show promise for providing a long service life with corrosion resistance.

Webinar presentations will include testing verification of structural properties, short-and long-term benefits of using the two technologies, implementation challenges, and case histories.

Registration information will be available approximately 2 weeks before the Webinar at www.fhwa.dot.gov/hfl/commtool.cfm. The Webinar is hosted by NHI, in conjunction with the FHWA Highways for LIFE program. For more information, contact Julie Zirlin at FHWA, 202-366-9105 (email: julie.zirlin@dot.gov). ✻

Highway Technology Calendar

The following events provide opportunities to learn more about products and technologies for accelerating infrastructure innovations.

Forty-Ninth Annual Petersen Asphalt Research Conference
July 9–11, 2012, Laramie, WY

Organized by the Western Research Institute (WRI), the conference will present current research aimed at understanding and improving asphalt performance. Topics covered range from fundamental compositional research to applied field engineering. Attendees are invited to participate in an open mic discussion.

Contact: Steve Salmans at WRI, 307-721-2306 (email: ssalmans@uwyo.edu), or Jack Youtcheff at the Federal Highway Administration (FHWA), 202-493-3090 (email: jack.youtcheff@dot.gov). Information is also available at www.petersenasphaltconference.org.

2012 Pavement Performance Prediction Symposium
July 12, 2012, Laramie, WY

Presented by WRI in cooperation with FHWA's Turner-Fairbank Highway Research Center, the symposium will take an indepth look at a single asphalt-related topic.

Contact: Steve Salmans at WRI, 307-721-2306 (email: ssalmans@uwyo.edu), or Jack Youtcheff at FHWA, 202-493-3090 (email: jack.youtcheff@dot.gov). More information on the selected topic will be available at www.petersenasphaltconference.org.

National Pavement Preservation Conference
August 27–30, 2012, Nashville, TN

The conference will feature best practices in pavement preservation and information on new materials, equipment, and technologies. Participants can also observe demonstration projects showcasing preservation techniques for both asphalt and concrete pavements used across the country. Conference sponsors include the American Association of State Highway and Transportation Officials (AASHTO), FHWA, Foundation for Pavement Preservation, National Center for Pavement Preservation, and the National Association of County Engineers.

Contact: To learn more, visit www.nationalpavement2012.org.

2012 National Hydraulic Engineering Conference
August 28–31, 2012, Nashville, TN

The theme of the 2012 conference is "Flow Near, Under, and Over Roads: Optimizing Highway Hydraulics." Presentations will highlight solutions to hydraulics challenges highway agencies face, including scour, stream stability, water quality, climate change, and modeling. Featured topics include coastal engineering, stormwater quality, erosion and sediment control, flooding case studies, bridge and culvert hydraulics, and changes in watersheds. The conference is sponsored by FHWA, AASHTO, the Tennessee Department of Transportation, Transportation Research Board, and the U.S. Army Corps of Engineers Cold Regions Research Laboratory.

Contact: Cynthia Nurmi at FHWA, 404-562-3908 (email: cynthia.nurmi@dot.gov), or visit www.fhwa.dot.gov/engineering/hydraulics/conferences/120412.cfm.

International Conference on Long-Life Concrete Pavements
September 18–21, 2012, Seattle, WA

Organized by FHWA, in partnership with the National Concrete Pavement Technology Center, the conference will address concrete pavement design, construction, and materials technologies that result in long-life, sustainable concrete pavement. A mini-symposium on concrete paving durability will be held on the final day of the conference.

Contact: Shiraz Tayabji at Fugro Consultants, Inc., 410-302-0831 (email: stayabji@aol.com), or Sam Tyson at FHWA, 202-366-1326 (email: sam.tyson@dot.gov). Conference information is also available at www.fhwa.dot.gov/pavement/concrete/2012conf.cfm. ✻

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Its primary mission is twofold: (1) to serve the providers of highway infrastructure with innovations and support to improve the quality, safety, and service of our roads and bridges; and (2) to help promote and market programs and projects of the various offices of FHWA's Office of Infrastructure.

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Chip Seal Best Practices,

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well as provide refresher training for more experienced staff.

Launched in 2000, the TCCC is a partnership that includes representatives from FHWA, NHI, regional State training and certification groups, several American Association of State Highway and Transportation Officials subcommittees, and industry associations. More than 70 online training courses developed by the TCCC are available from NHI. All TCCC courses are reviewed every 2 years and updated if needed. If there is a change in a specification or method used in a course, that course is updated as soon as possible.

For more information on the course content, contact Jason Harrington at FHWA, 202-366-1576 (email: jason.harrington@dot.gov). To take the Chip Seal Best Practices course, visit www.nhi.fhwa.dot.gov. Details on other online TCCC training opportunities can be found at www.nhi.fhwa.dot.gov/training/course_search.aspx (click on "View All Available Web-Based Training Courses"). For more information on the TCCC, visit www.tccc.gov. *