Accelerating Infrastructure Innovations

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INSIDE

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U.S. Department of Transportation

Federal Highway Administration

A New Era for Continuously Reinforced Concrete Pavement

A new era for concrete roadways has arrived with the use of continuously reinforced concrete pavement (CRCP) in projects across the country.

"CRCP has the potential to provide a long-term, zero-maintenance service life under heavy traffic loadings and challenging environmental conditions, provided proper design and quality construction practices are utilized," said Sam Tyson of the Federal Highway Administration (FHWA).

CRCP differs from other concrete pavements in that it has no constructed transverse contraction or expansion joints except at bridges or pavement ends. It is reinforced with continuous steel bars throughout the length of the pavement, resulting in closely spaced transverse cracks in the concrete. Rather than the usual transverse joints, these cracks accommodate volume changes in the concrete. CRCP can extend, joint free, for many miles with minimal maintenance required.

Illinois began experimenting with CRCP technology in 1947 and now has the second largest inventory of CRCP in the United States, behind Texas. California built its first experimental CRCP on U.S. 40 in 1949, followed by a second CRCP section on the roadway in 1971. The last 10 years have brought renewed interest in using the technology, leading the California Department of Transportation to adopt CRCP in its specifications and highway design manual.

CRCP use began in Texas in 1951 and continues to increase as the Texas Department of Transportation expands its roadway network and replaces jointed pavements taken out of service. Highway agencies in North Dakota, Oklahoma, Oregon, South Dakota, and Virginia have also used CRCP since the 1960s or 1970s. Their experiences have been significant in developing today's best practices for CRCP.


ACPT

TechBrief

Continuously Reinforced Concrete Pavement Performance and Best Practices

More information about CRCP design is available in FHWA's Tech Brief on *Continuously Reinforced Concrete Pavement Performance and Best Practices.*

In 2008 FHWA entered into a 5-year Cooperative Agreement with the Concrete Reinforcing Steel Institute (CRSI) to advance the use of CRCP in the United States. Work accomplished under this agreement has resulted in updated guidance for designing and constructing CRCP.

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A typical paving operation for CRCP. The pavement is reinforced with continuous steel bars and has minimal maintenance requirements.

CRCP design includes determining the proper combination of slab thickness, concrete mixture constituents and properties, and steel reinforcement content and location; providing for sufficient slab edge support; strengthening or treating existing soils; and using bases that don't erode but provide the friction that will lead to desirable transverse cracking patterns.

"While most of these features are common to all good pavement designs, reinforcement and edge support are particularly critical to CRCP," said Greg Halsted of CRSI. To learn more about CRCP design, download FHWA's Tech Brief on *Continuously Reinforced Concrete Pavement Performance and Best Practices* (Pub. No. FHWA-HIF-12-039) at www.fhwa.dot.gov/pavement/pub_details.cfm?id=848.

Best practices for constructing well-performing CRCP and CRCP overlays include:

- Providing an adequate amount of longitudinal reinforcement.
- Controlling the depth of steel placement.
- Ensuring well-drained and stable support (for roads with heavy truck traffic, an asphalt base or a cement-treated base with an asphalt concrete interlayer is recommended).
- Building a 4-m-wide (13-ft) outside lane.
- Using the appropriate slab thickness for the long-term traffic design.

During construction, it is important to focus on steel bar placement and concrete consolidation and curing. Along with the actual concrete strength, these elements will have the most significant impact on the transverse crack formation and the CRCP's long-term performance. Research and performance studies have shown that crack spacing between 0.9 and 1.8 m (3 and 6 ft) and crack widths less than 0.5 mm (0.02 in) generally result in successful CRCP performance.

A new FHWA Technical Summary and Tech Brief introduce highway pavement engineers to use of the Pavement ME Design™ software for designing CRCP. Available from the American Association of State Highway and Transportation Officials' (AASHTO) AASHTOWare® line of products, Pavement ME Design is the accompanying software to the *Mechanistic-Empirical Pavement Design Guide* adopted by AASHTO in 2008. The improved design procedure resolves CRCP performance problems that had been observed in the past, including those relating to material durability, base erosion, steel placement and content, and construction methods.

The Technical Summary, *Continuously Reinforced Concrete Pavement: Design Using the AASHTOWare Pavement ME Design Procedure* (Pub. No. FHWA-HIF-13-025), describes the primary data inputs needed to use the Pavement ME Design software for CRCP design. Sample design problems are included that demonstrate the success of the new software in designing both CRCP and CRCP overlays for different climatic zones. For a copy of the Technical Summary, visit www.fhwa.dot.gov/pavement/pub_details.cfm?id=887. For an overview of the topic, download the Tech Brief (Pub. No. FHWA-HIF-13-027) at www.fhwa.dot.gov/pavement/pub_details.cfm?id=871.

Agencies can consult another FHWA Tech Brief, *Continuously Reinforced Concrete Pavement: Improved Transition Designs* (Pub. No. FHWA-HIF-13-026), to find guidance on transition designs for CRCP, including contraction, construction, and isolation joints. These designs accommodate a transition between a CRCP and any other type of pavement or structure. To download the Tech Brief, visit www.

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Construction Peer Network: Collaborating to Improve Highway Construction Practices

From construction best practices to project innovations, transportation agencies and contractors across the country have learned from each other's experiences and gained solutions to common challenges by participating in the Construction Peer Network (CPN).

A collaboration among the American Association of State Highway and Transportation Officials, American Road and Transportation Builders Association, Associated General Contractors of America, and Federal Highway Administration (FHWA), the CPN sponsored five regional peer exchange sessions in 2012 and 2013. Practitioners representing a total of 53 transportation agencies, including 48 State agencies; contractors; consulting firms; and the sponsoring organizations participated in the exchanges. The sessions' goals included:

- Foster communication and innovation among the highway construction community.
- Identify best construction processes and practices.
- Widely share, and encourage implementation of, successful processes and practices.
- Identify opportunities for continuous program improvement.

The Construction Peer Network held its final regional peer exchange July 9–10, 2013, in Boise, ID.

Five regional peer exchanges sponsored by the Construction Peer Network helped to identify best highway construction practices nationwide.

"With a small investment of time, construction leaders were able to take away proven practices to advance their programs, while strengthening relationships as a catalyst for future collaboration," said David Unkefer of the FHWA Resource Center.

Prior to each exchange, participants submitted information on construction best practices using an electronic Program Information (PI) Tool. Discussion topics for the exchanges were chosen based on the information gathered with the PI Tool. "Session agendas tailored to regionally important topics enhanced the potential that participants would gain implementable ideas," said Chris Schneider of FHWA.

For each topic, lead States were identified and asked to present their successful practices at the exchange. At the first peer exchange held in Warwick, Rhode Island, in March 2012, representatives from New York and Rhode Island discussed approaches to using performance measures in construction. Both States conduct formal evaluations to assess the cause for change orders, allowing them to determine how well a project has performed. These presentations initiated further discussion by exchange participants on other regional practices. Maryland, Massachusetts, Pennsylvania, and New York, for example, share performance measures transparently with the general public.

At the Southeast Peer Exchange, held March 6–7, 2013, in Orlando, Florida, participants from States such as Louisiana and North Carolina discussed the use of handheld tablets to electronically document field inspections as part of the new "digital job site." North Carolina is also using radio frequency identification devices for approved project materials. This technology provides better inventory control for the contractor and minimizes the risk that materials that have not been

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Ultra-High Performance Concrete: The State-of-the-Art

Is ultra-high performance concrete (UHPC) part of your highway infrastructure's future?

A new report released by the Federal Highway Administration (FHWA) summarizes UHPC research, development, and deployment efforts around the world. "Compiling this information allows State and local transportation agencies, researchers, and others to deepen their understanding of UHPC and the opportunities it offers to accelerate bridge construction," said Ben Graybeal of FHWA.

Ultra-High Performance Concrete: A State-of-the-Art Report for the Bridge Community (Pub. No. FHWA-HRT-13-060) includes details on materials and production, mechanical properties, and structural design and testing. Also highlighted are results from durability testing.

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 completes the mixture. The UHPC is then placed into the formwork using standard construction equipment.

FHWA began investigating UHPC for highway infrastructure use in 2001 and has worked with State transportation departments to deploy the technology since 2002. Bridge applications have included using UHPC for precast, prestressed girders; precast waffle panels for bridge decks; and as a field-cast material joining precast concrete deck panels and girders and the flanges of adjacent girders.

More than 90 UHPC bridges have been completed worldwide.

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. These advanced properties have been used to develop new structural forms that facilitate accelerated bridge construction. While UHPC has higher initial costs than conventional concrete, UHPC bridges are expected to have a longer service life and require less maintenance than conventional structures.

UHPC bridge projects in the United States, Canada, Europe, Asia, and Australia are highlighted in the report. More than 90 UHPC bridges have been completed worldwide. The first highway structure in the United States to use UHPC was the Mars Hill bridge in Wapello County, Iowa, in 2006. This simple single-span bridge used precast, prestressed concrete girders topped with a cast-in-place concrete bridge deck. Subsequent UHPC projects in Wapello County have included construction of the Little Cedar Creek bridge in 2011. This structure features a precast bridge deck system, known as a waffle slab, that uses the mechanical and durability properties of UHPC to create a resilient, lightweight deck.

Bridges built in Iowa, Montana, New York, and Oregon, meanwhile, have used field-cast UHPC connections between prefabricated bridge components. The bridges, including 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, use a range of details to connect different precast concrete modular bridge components, including adjacent

The Jakway Park bridge in Buchanan County, IA, features UHPC girders.

Field-cast UHPC connections were used to construct the Route 23 bridge in Oneonta, NY.

box beams, full-depth precast deck panels, and deck-bulb-tee girders. These new UHPC connection details eliminate the conflict points between the reinforcing bars and discrete connectors, allowing for easy field assembly.

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. "There are strong indications that a proven class of steel fibers will be domestically produced and available by the end of 2013," said Graybeal.

While highlighting UHPC projects to date, the report also examines the future direction of the technology and current challenges to achieving wide-scale implementation in the United States. These include the need for more demonstration projects, cost-benefit studies, and a new design and production document based on the American Association of State Highway and Transportation Officials' (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications and the AASHTO LRFD Bridge Construction Specifications. As the report notes, "A guide specification for construction with UHPC will help owners implement the technology."

To download a copy of *Ultra-High Performance Concrete: A State-of-the-Art Report for the Bridge Community*, visit www.fhwa.dot.gov/publications/research/infrastructure/structures/hpc/13060. For more information on UHPC, visit www.fhwa.dot.gov/research/resources/uhpc.cfm, or contact Ben Graybeal at FHWA, 202-493-3122 (email: benjamin.graybeal@dot.gov). ✻

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tested and approved will be used in the project.

Florida, Georgia, and North Carolina were also among the States that discussed their success in holding closeout conferences with contractors and other stakeholders to evaluate projects after completion.

> "It was extremely valuable to be able to talk to our peers about regional Northwest issues."

The final regional peer exchange was held July 9–10, 2013, in Boise, Idaho. Hosted by the Idaho Transportation Department, the event also drew participants from Alaska, Montana, Nebraska, North Dakota, Oregon, South Dakota, Washington, and Wyoming. The five discussion topics chosen were using innovative methods to resolve contract claims and disputes, establishing project staffing qualifications, assessing inspection levels of effort with risk-based processes, utilizing contractors' quality control most effectively, and implementing the digital job site.

Best practices shared included North Dakota's development of a form for highway contractors to submit immediately after any occurrence for which a contractor anticipates filing a claim. With this notice of intent, both the contractor and the North Dakota Department of Transportation staff can keep more detailed records on related work and daily progress on all activities related to the potential claim.

Idaho and Oregon also shared their strategies for improving staff training by mentoring new inspectors. In Oregon, experienced inspectors provide training and visit project sites at critical times to assist less experienced staff. Idaho sends more experienced inspectors to multiple project sites to help ensure quality and workmanship.

"It was extremely valuable to be able to talk to our peers about regional Northwest issues," said Boise peer exchange participant Jeff Carpenter, Director of the Construction Division at the Washington State Department of Transportation. "The question and answer sessions were also very useful, as well as the presentation on using handheld devices in the field."

Ken Keel, Construction Staff Engineer at the Wyoming Department of Transportation, also participated in the Boise peer exchange. "It went very well. I have been on the phone since then several times with other peers, exchanging ideas," said Keel.

FHWA is consolidating results from all five peer exchanges into a national summary. Due out in November 2013, the summary will focus on nationwide trends, best practices, and potential future research directions. Reports from the regional peer exchanges and additional information on the CPN are available at http://construction.transportation.org (click on "Construction Peer Network"). For more information, 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). ✻

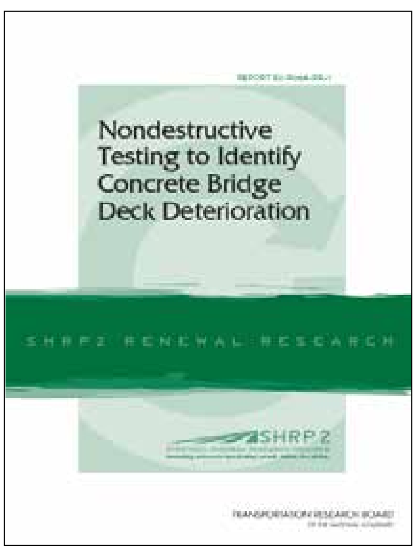
SHRP2 Research Reports Available Online

Are you looking for a research report from the second Strategic Highway Research Program (SHRP2)?

Nearly 90 reports are now available as free downloads at www.trb.org/SHRP2/researchreports, organized by focus area and topic. New reports are being added each month. Printed copies of selected reports are available for purchase through the Transportation Research Board online bookstore, while e-books of selected reports will also be available to purchase from Google, iTunes, and Amazon. Currently, eight reports are available from Google, four from iTunes, and one from Amazon. These include *Preservation Approaches for High-Traffic-Volume Roadways* (Google) and *Strategies for Improving the Project Agreement Process Between Highway Agencies and Railroads* (Google and iTunes).

Research projects conducted under SHRP2 have focused on improving highway safety, renewal, reliability, and capacity. The renewal program is developing tools and resources for speeding project delivery, minimizing disruption, and producing long-lived facilities. Reports available in the renewal area include *Design Guide for Bridges for Service Life, Nondestructive Testing to Identify Concrete Bridge Deck Deterioration, Composite Pavement Systems,* and *Precast Concrete Pavement Technology.*

To learn more about the new tools and technologies that are now being released as SHRP2 Solutions products, visit the GoSHRP2 Web site at www.fhwa.dot.gov/goSHRP2. ✻



Nearly 90 SHRP2 reports are available at www.trb.org/SHRP2/researchreports.

Infrastructure Innovation Webinars

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

Towing and Recovery Service Partnerships
September 17, 2013, 2:30–4 p.m.
eastern daylight time (EDT)

Presented by the Federal Highway Administration's (FHWA) Highways for LIFE program, the Webinar will discuss Towing and Recovery Service Partnerships (TRSP). These initiatives allow public and private partners to work together to expedite the clearance of traffic incidents where large trucks are involved. Already at work in several States, the partnerships effectively reduce the length of time and the severity of incident-related traffic congestion. TRSPs can be customized to fit the needs, laws, and practices of each region or agency. More information about TRSPs is available at http://tig.transportation.org/Pages/TowingandRecoveryServicePartnership.aspx.

To register for the Webinar, visit www.nhi.fhwa.dot.gov/resources/webconference/web_conf_learner_reg.aspx?webconfid=25395.

Asset Management Book Club
September 25, 2013, 2–3:30 p.m. EDT—Bringing It All Together and Moving Forward (Appendix D of *Transportation Asset Management Guide*)

In 2011 the American Association of State Highway and Transportation Officials (AASHTO) published the *Transportation Asset Management Guide: A Focus on Implementation,* which encourages transportation agencies to use asset management principles. Sponsored by FHWA and AASHTO, this Webinar will review the content of the guide and share experiences from practitioners.

To register, visit www.fhwa.dot.gov/asset/bookclub.cfm. For additional information, contact Nastaran Saadatmand at FHWA, 202-366-1337 (email: nastaran.saadatmand@dot.gov). ✻

Highway Technology Calendar

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

Sixth Rubber Modified Asphalt Conference
October 15–17, 2013, Tempe, AZ

Advances in research, design, specifications, and materials and construction practices will be spotlighted at the conference. Participants will include State, local, and Federal government staff; contractors; suppliers; consultants; and members of academia. International participants will have the opportunity to discuss technology advancements worldwide. Sponsors include the Federal Highway Administration (FHWA).

Contact: Lee Gallivan at FHWA, 317-226-7493 (email: victor.gallivan@dot.gov); Michael Blumenthal at the Scrap Tire Research and Education Foundation, 202-682-4805 (email: michael@stref.org); or Patte Hahn at the National Center for Pavement Preservation, 517-432-8220 (email: phahn@rma.org). To register, visit http://stref.org/events/rubber_modified_asphalt_conference/index.cfm.

Sixth Asphalt Shingle Recycling Forum
November 7–8, 2013, Denver, CO

The forum will highlight practical applications for shingles in pavements, modifications to American Association of State Highway and Transportation Officials (AASHTO) standards, and ongoing research efforts to advance the technology. Sessions will be of interest to State, local, and Federal government staff; contractors; suppliers; consultants; and members of academia. Sponsors include FHWA.

Contact: Lee Gallivan at FHWA, 317-226-7493 (email: victor.gallivan@dot.gov), or William Turley at the Construction and Demolition Recycling Association, 630-585-7530 (email: turley@cdrecycling.org). Registration information is available at www.shinglerecycling.org/content/home.

Transportation Research Board (TRB) 93rd Annual Meeting
January 12–16, 2014, Washington, DC

Transportation professionals from around the world will gather to share perspectives on current developments in transportation research, policy, and practice. The conference will feature more than 4,000 presentations in nearly 750 sessions and workshops. The spotlight theme for 2014 is "Celebrating Our Legacy, Anticipating Our Future."

Contact: For information, visit the TRB Web site at www.trb.org (click on "Annual Meeting"). Questions about the meeting can be emailed to trbmeetings@nas.edu.

2014 Design-Build in Transportation Conference
March 19–21, 2014, San Jose, CA

Join transportation leaders in discussing lessons learned in the use of the design-build project delivery method for transportation projects. Topics will include choosing the right delivery method, contracting approaches, tools and techniques that enhance collaboration, innovative financing solutions, risk allocation, and performance contracting. All modes of transportation will be featured.

Contact: Jerry Yakowenko at FHWA, 202-366-1562 (email: gerald.yakowenko@dot.gov), or visit www.dbtranspo.com.

Tenth National Conference on Transportation Asset Management
April 28–30, 2014, Miami, FL

The conference is designed for transportation agencies and metropolitan planning organizations in all stages of asset management implementation. Themes will include establishment and monitoring of asset management plans, performance measures for asset management, tools and technology to assist decisionmaking, and adaptation to extreme weather events and climate change, including using risk assessment and vulnerability analysis. Strategies for overcoming barriers to asset management implementation will also be discussed. Organized by TRB, the conference is also supported by FHWA and AASHTO.

Contact: Steve Gaj at FHWA, 202-366-1336 (email: stephen.gaj@dot.gov), or visit www.trb.org/conferences/AssetManagement2014.aspx. *

FOCUS

Focus (ISSN 1060-6637), which is published monthly by the U.S. Department of Transportation's Federal Highway Administration (FHWA), covers the implementation of innovative technologies in all areas of infrastructure.

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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fhwa.dot.gov/pavement/pub_details.cfm?id=884.

Transportation agencies can also find guidance on rehabilitation strategies to extend the service life of an existing CRCP. Restoration techniques include full-depth repairs, partial-depth repairs, diamond grinding and grooving, joint resealing, slab stabilization and jacking, and cross stitching. Resurfacing options, meanwhile, include both bonded and unbonded concrete overlays and hot-mix asphalt overlays.

"When considering rehabilitation strategies, it must be understood that CRCP is designed to crack in the transverse direction. Such cracks are designed and expected to remain tight, and are not considered distress," said Halsted. For more information, see *Continuously Reinforced Concrete Pavement: Extending Service Life of Existing Pavements* (Pub. No. FHWA-HIF-13-024) at www.fhwa.dot.gov/pavement/concrete/pubs/hif13024.pdf.

Also available is *Jointed Full-Depth Repair of Continuously Reinforced Concrete Pavements* (Pub. No. FHWA-HIF-12-007), which describes a CRCP restoration technique that uses precast concrete panels. To obtain a copy, visit www.fhwa.dot.gov/pavement/pub_details.cfm?id=736.

FHWA and CRSI's collaboration to improve guidance for CRCP design and construction has included holding workshops in California, Georgia, Louisiana, Maryland, Oklahoma, Oregon, and Virginia, with peer-to-peer assistance also provided on request. FHWA is considering a future technology transfer initiative that would emphasize peer-to-peer assistance for project assessment, specification development, and implementation of best practice guidance for design and construction.

"While CRCP constructed in the 1960s and 1970s experienced variable performance, many miles of those pavements continue to provide satisfactory service today. CRCPs constructed since then, with improved guidance that is now the standard, promise to provide even longer maintenance-free service lives," said Tyson.

For more information on CRCP, contact Sam Tyson at FHWA, 202-366-1326 (email: sam.tyson@dot.gov), or Greg Halsted at CRSI, 360-920-5119 (email: ghalsted@crsi.org). ✻