Technology Transfer of Concrete Pavement Technologies

FINAL SUMMARY REPORT | DECEMBER 2018

Sustainability 1

Preservation and Overlays 2

Long-Life Pavements 3

Innovative Concrete Materials 4

Advancements in Placement 5

IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Pavement Technology Center
CP Tech Center

About the National CP Tech Center

The mission of the National Concrete Pavement Technology (CP Tech) Center at Iowa State University is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

Notice

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange under DTFH61-12-H-00010 Technology Transfer of Concrete Pavement Technologies. The U.S. Government assumes no liability for the use of the information.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this material only because they are considered essential to the objective of the material. They are included for informational purposes only and are not intended to reflect a preference, approval, or endorsement of any one product or entity.

Quality Assurance Statement

The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

Iowa State University Non-Discrimination Statement

Iowa State University does not discriminate on the basis of race, color, age, ethnicity, religion, national origin, pregnancy, sexual orientation, gender identity, genetic information, sex, marital status, disability, or status as a U.S. Veteran. Inquiries regarding non-discrimination policies may be directed to Office of Equal Opportunity, 3410 Beardshear Hall, 515 Morrill Road, Ames, Iowa 50011, Tel. 515 294-7612, Hotline: 515-294-1222, email eooffice@iastate.edu.

Front Cover Image Credits

Top: J-2 Contracting Co.

2nd: Washington County, Nebraska

3rd: National CP Tech Center 2013

4th and Bottom: National CP Tech Center 2008

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Technology Transfer of Concrete Pavement Technologies		5. Report Date December 2018
		6. Performing Organization Code:
7. Author(s) Peter Taylor, Dale Harrington, and Tom Cackler		8. Performing Organization Report No.
9. Performing Organization Name and Address National Concrete Pavement Technology Center Iowa State University 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664		10. Work Unit No.
		11. Contract or Grant No. DTFH61-12-H-00010
12. Sponsoring Agency Name and Address Office of Pavement Technology Federal Highway Administration 1200 New Jersey Avenue, SE Washington, DC 20590		13. Type of Report and Period Covered Final Summary Report: September 2013–December 2018
		14. Sponsoring Agency Code

15. Supplementary Notes

Visit cptechcenter.org for color pdfs of this and other publications from the National CP Tech Center.

16. Abstract

The goal of this project was to help bring the latest concrete pavement innovations, knowledge, and technologies to state highway agencies (SHAs) in support of the Accelerated Implementation and Deployment of Pavement Technologies (AID-PT) program goals. The purpose of the AID-PT program is to document, demonstrate, and deploy innovative pavement technologies, including their applications, performance, and benefits.

With the guidance of the Federal Highway Administration (FHWA), the National Concrete Pavement Technology (CP Tech) Center delivered products and technical support to SHAs so that they might be better equipped to manage their investments in concrete pavements. The objectives of this project were to advance the following:

- Sustainability aspects of concrete pavements and materials
- Preservation and maintenance techniques for concrete pavements
- Long-life concrete pavements
- Innovative concrete materials
- New technologies and advancements in concrete pavement placement

The National CP Tech Center provided nationwide open houses or showcases and workshops, presentations, and webinars in the five advancement areas to an average of 4,500 individuals representing associations, industry, academia, and SHAs each year. In addition to the technology transfer through these activities, the Center developed and delivered a number of resource webpages and a wide array of publications, which are also available online.

17. Key Words		18. Distribution Statement	
concrete overlays—concrete pavement maintenance—concrete pavement resources—concrete pavement training—concrete pavement webinars—concrete paving mixtures—expert task groups—pavement champion states—pavement technology assistance—performance engineered mixtures—recycled concrete aggregate		No restrictions.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 141	22. Price N/A

TECHNOLOGY TRANSFER OF CONCRETE PAVEMENT TECHNOLOGIES

Final Summary Report
December 2018

Principal Investigator
Peter Taylor, Director
National Concrete Pavement Technology Center, Iowa State University

Co-Principal Investigators
Dale Harrington, HCE Services
Tom Cackler, Woodland Consulting, Inc.

Summary Report Authors
Peter Taylor, Dale Harrington, and Tom Cackler

Sponsored by
Federal Highway Administration

A report from
National Concrete Pavement Technology Center
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-5798 / Fax: 515-294-0467
cptechcenter.org

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

The authors would like to thank the Federal Highway Administration (FHWA) for sponsoring this project under the Technology Transfer of Concrete Pavement Technologies cooperative agreement DTFH61-12-H-00010. The delivery of advanced products, knowledge, and technical support to state highway agencies (SHAs) was successful thanks to the contributions and involvement of the countless technical advisory committee and expert team members who participated in these efforts.

EXECUTIVE SUMMARY

The goal of this project was to help bring the latest concrete pavement innovations, knowledge, and technologies to state highway agencies (SHAs) in support of the Accelerated Implementation and Deployment of Pavement Technologies (AID-PT) program goals. The purpose of the AID-PT program is to document, demonstrate, and deploy innovative pavement technologies, including their applications, performance, and benefits.

With the guidance of the Federal Highway Administration (FHWA), the National Concrete Pavement Technology (CP Tech) Center delivered products and technical support to SHAs so that they might be better equipped to manage their investments in concrete pavements. The objectives of this project were to advance the following:

- Sustainability aspects of concrete pavements and materials
- Preservation and maintenance techniques for concrete pavements
- Long-life concrete pavements
- Innovative concrete materials
- New technologies and advancements in concrete pavement placement

The CP Tech Center provided nationwide technical assistance, including field reviews and site visits, as well as open houses or showcases and workshops, presentations, and webinars in the five advancement areas to an average of 4,500 individuals representing associations, industry, academia, and SHAs each year. In addition to the technology transfer and field application that resulted through these activities, the Center developed and delivered a number of resource webpages and an in-depth, wide array of publications, which are also available online.

Each of these topics is of critical importance to SHAs and other public owners of transportation infrastructure as they look for cost-effective solutions for managing pavement assets with limited financial resources.

The purpose of this final summary report is to recap the accomplishments and products developed, as well as summarize the national impact of the cooperative agreement work areas. Final task reports, which are included as appendices to this summary report, were also developed as follows:

Appendix A: Recycled Concrete Pavement Materials
Appendix B: Concrete Pavement Preservation
Appendix C: Concrete Overlay Field Application
Appendix D: Performance Engineered Mixtures
Appendix E: Long-Life Pavements, New Technologies, and Advancements in Placement Work Areas

In addition to this summary report, a standalone overview of the accomplishments for the cooperative agreement was developed.

PROJECT TEAM

Figure 1 shows organizational structure that was adopted for this cooperative agreement project team.

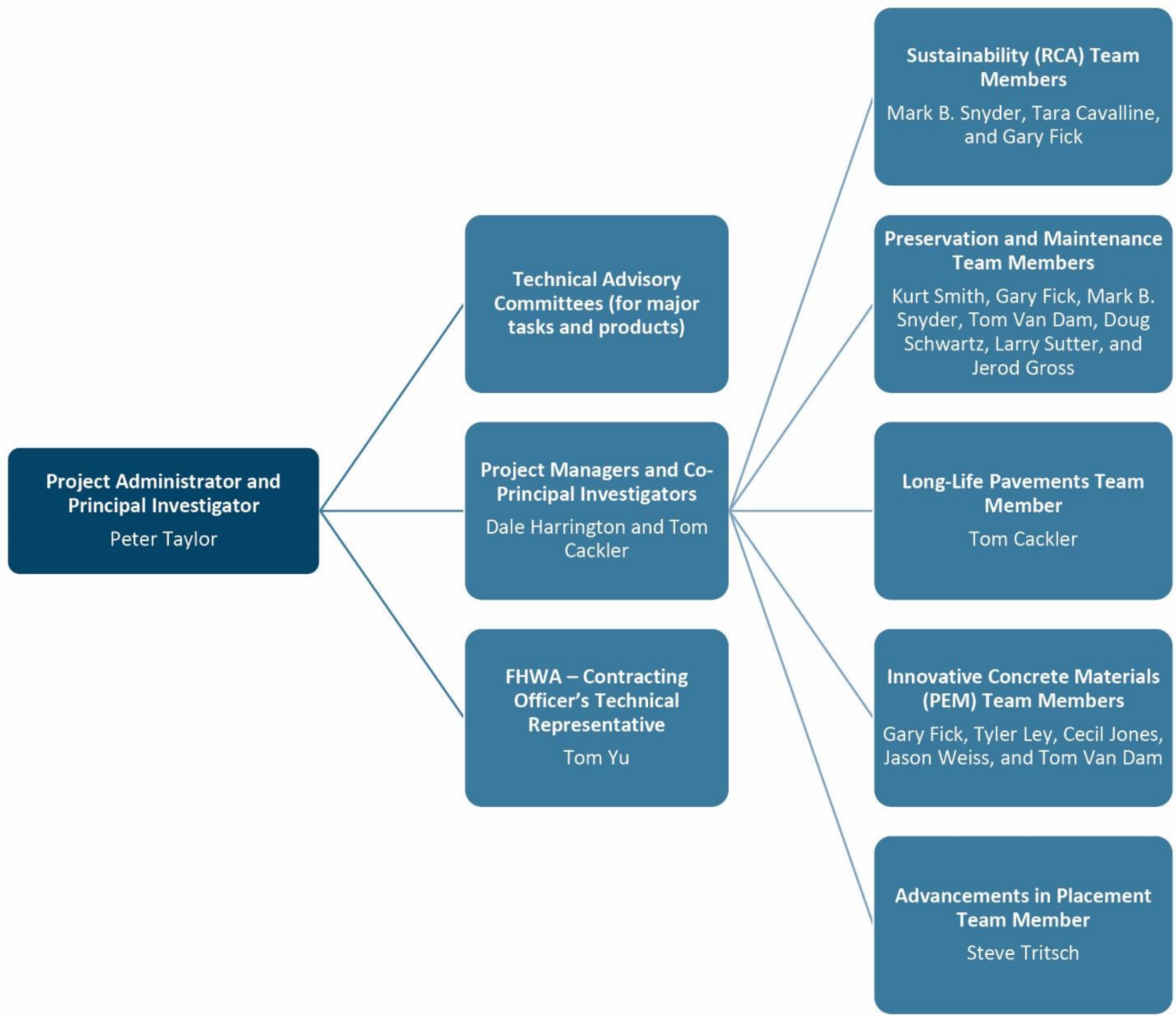


Figure 1. Cooperative agreement project team

Project Managers

Peter Taylor, Project Administrator and Principal Investigator, is the director of the National CP Tech Center. Taylor provided the overall leadership and vision for the project.

Dale Harrington, Project Manager and Co-Principal Investigator, is the principal engineer at Harrington Civil Engineering (HCE) Services and a former director of the National CP Tech

Center (2000–2003). Harrington's project responsibilities included scheduling, technical advisory committee (TAC) coordination, and task management.

Tom Cackler, Project Manager and Co-Principal Investigator is the principal engineer for Woodland Consulting, Inc. and a former director of the National CP Tech Center (2003–2015). Cackler's project responsibilities included scheduling, TAC coordination, and task management.

Tom Yu served as the FHWA contracting officer's technical representative (COTR).

ADVANCEMENT FOCUS AREAS

Sustainability of Concrete Pavements and Materials

The specific goals of this work area were to advance the use of recycled material, the use of industrial byproducts, and the use of blended cements in concrete pavements.

Guidance on Industrial Byproducts and Blended Cements

Technical guidance was developed on the use of *Supplementary Cementitious Materials and Blended Cements to Improve Sustainability of Concrete Pavements*. The November 2013 tech brief describes how supplementary cementitious materials (SCMs) and blended cements are used in paving concrete as one way to increase the overall sustainability of concrete mixtures.

Use of Recycled Concrete Aggregate

In cooperation with the National Concrete Consortium (NCC), an expert task group (ETG)/technical advisory committee (TAC) of champion states was formed in April 2015 to guide the development of technical products and address the technology assistance needs of SHAs on the use of RCA. The ETG represented SHAs, industry, and the FHWA. The location of the states and industry groups are shown in dark blue on the map in Figure 2.

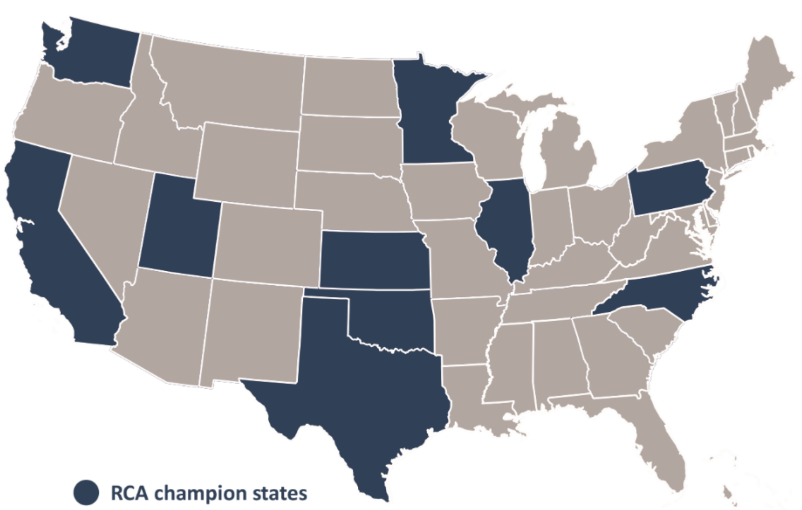


Figure 2. RCA champion states

Based on input from this group of experts, the following technical products were developed.

Recycling Concrete Pavement Materials: A Practitioner's Reference Guide

This guide is a comprehensive resource for practitioners on how to determine if using RCA is a good match for a project, which applications make the most sense, and how to specify and field inspect these pavements. This guide covers sustainability and economics; project selection; using RCA in pavement base products, concrete pavement, and unbound aggregate shoulders; and mitigation of environmental concerns.

Concrete Pavement Recycling Tech Briefs

As a complement to the Practitioner's Reference Guide, the following tech briefs were developed and distributed:

- *Concrete Pavement Recycling Series: Concrete Pavement Recycling and the Use of Recycled Concrete Aggregate (RCA) in Concrete Paving Mixtures*
- *CP Road Map: Concrete Pavement Recycling and the Use of Recycled Concrete Aggregate in Concrete Paving Mixtures*
- *Concrete Pavement Recycling Series: Quantifying the Sustainability Benefits of Concrete Pavement Recycling*
- *CP Road Map: Concrete Pavement Recycling—Project Selection and Scoping*
- *Concrete Pavement Recycling Series: Protecting Water Quality through Planning and Design Considerations*
- *Concrete Pavement Recycling Series: Protecting the Environment during Construction*
- *CP Road Map: Using Recycled Concrete Aggregate in Pavement Base Products*
- *Concrete Pavement Recycling Series: Using Recycled Concrete Aggregate (RCA) in Unbound Aggregate Shoulders*

Recycling Concrete Webinar Series

A webinar series was developed and presented to nearly 400 SHA and industry participants during 2016 and 2017. The webinars are available on the National CP Tech Center's website.

- Introduction to Concrete Pavement Recycling
- Construction Considerations
- Environmental Considerations
- Recycling Case Study Experiences

Survey on Current Utilization of RCA

In cooperation with the NCC and the American Concrete Pavement Association (ACPA) contractor members, a two-part benchmarking survey was conducted to identify current usage of RCA as well as understand potential barriers and opportunities to increased usage.

The results of the survey confirmed broad interest in increasing the applications of RCA on projects and the desire for better technical guidance on various project applications. The results of this survey were used to focus the technical products and direct SHA support activities on the areas of greatest interest.

Concrete Pavement Recycling Website

A resource webpage was developed to provide a technical library of material on concrete pavement recycling to support better understanding of how to use RCA. The Concrete Recycling Resources webpage includes links to the Practitioner's Guide, the eight tech briefs, all of the webinars, the usage survey results, and other technical resources.

Preservation and Overlays 2

Preservation and Maintenance

This work area provides guidance and technical assistance to SHAs on preservation and maintenance of concrete pavements.

Concrete Pavement Preservation Guide, Second Edition

One of the cornerstones of the National CP Tech Center's technology transfer efforts on preservation of concrete pavements is the *Concrete Pavement Preservation Guide, Second Edition*, published in September of 2014. The document provides guidance and information on the selection, design, and construction of cost-effective concrete pavement preservation treatments. It is based on a document prepared in 2008 but was revised and expanded to include updated information to assist highway agencies in effectively managing their concrete pavement network through the application of timely and effective preservation treatments. The preservation approach typically uses low-cost, minimally invasive techniques to improve the overall condition of the pavement.

Preservation Workshops

Understanding the latest technologies is integral to pavement preservation and rehabilitation. Therefore, a significant effort was undertaken by the National CP Tech Center to move information from the Preservation Guide into the hands of SHA professionals. To meet the requests for online and on-demand education, 10 online training modules were developed and launched as outreach resources for the Preservation Guide.

Twenty-nine one-day workshops on Portland cement concrete (PCC) pavement preservation and rehabilitation were held in 15 states (see Figure 3) with 1,200 participants.

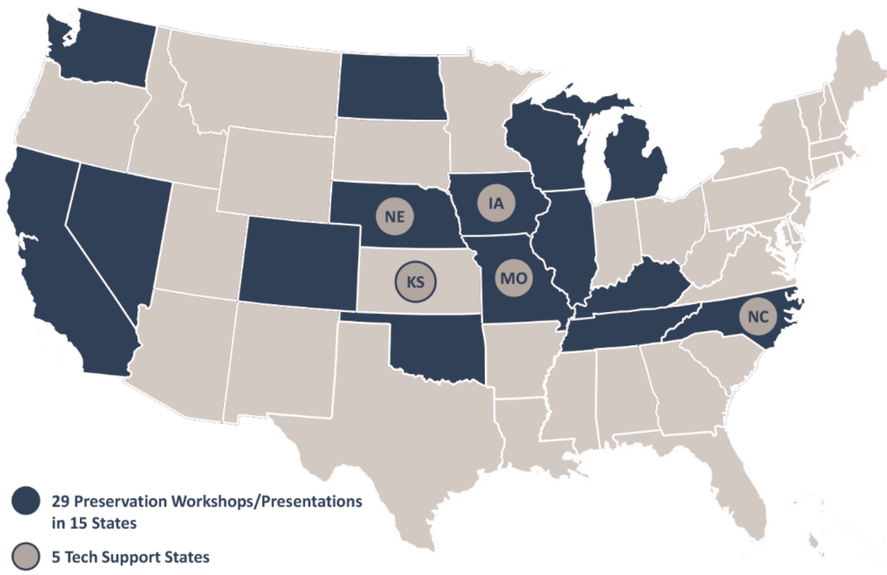


Figure 3. Preservation workshop and tech support locations

The reference documents, instructional material, and handouts presented in the workshops consider both optimizing performance and lowering the life-cycle cost of a concrete pavement. The following topics were covered:

- Introduction
- Preventive maintenance and pavement preservation concepts
- Concrete pavement evaluation
- Slab stabilization and slab jacking
- Partial-depth repairs
- Full-depth repairs
- Retrofitted edge drains
- Load transfer restoration
- Diamond grinding and grooving
- Joint/crack sealing
- Overlays
- Strategy selection

Five states received technical assistance for particular preservation techniques.

Pavement Preservation Webinars

As part of the technology transfer, the following six webinars on concrete pavement preservation were presented as part of the ACPA webinar program in 2015 and 2016:

- The Essentials: From Pavement Evaluation to Strategy Selection

- Partial- and Full-Depth Repair Methods
- Tips and Techniques for Specialized Repair and Construction Methods
- What You Need to Understand About Surface Treatments and Restoration Methods
- All About Joint Repairs and Sealing
- Maintaining and Preserving Concrete Pavement Overlays

Pavement Preservation Reference Website

The National CP Tech Center has provided a summary of web links for concrete pavement preservation. The Pavement Preservation webpage provides more than 80 individual links to national, state, consulting, and private online resources. The resources include technical reports, technical briefs, guides, websites, and videos on concrete pavement preservation

Guide for Concrete Pavement Distress Assessments and Solutions

Selecting a preservation technique requires the proper identification of the cause of the distress. The Concrete Pavement Distress Assessments and Solutions manual was developed to assist with this evaluation.

Historically, distresses in concrete pavements have been identified largely through visual surveys, with limited investigation of the underlying cause of the distress and often with limited knowledge of how to cost-effectively maintain a concrete pavement in good condition. This document incorporates proven and cost-effective solutions into a framework that assists the user in matching the appropriate solution for a given distress. The chapters of this manual focus on the following:

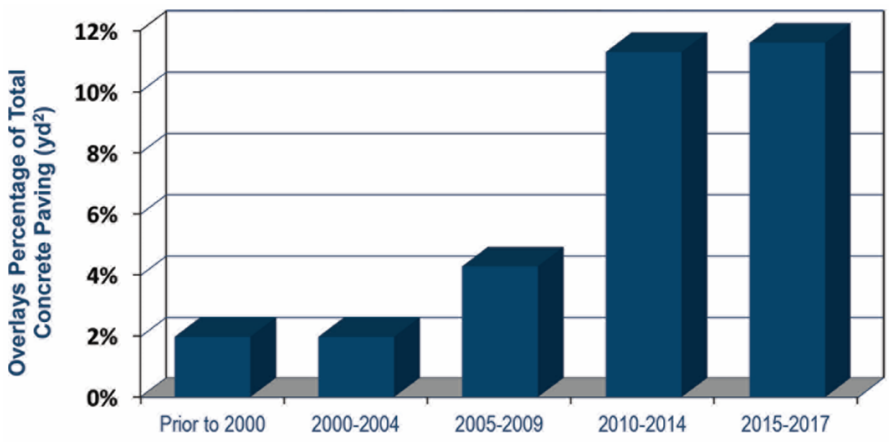
- What distress is present
- What caused it
- How to prevent its reoccurrence
- What repair options are available

A team of 15 experts from across the country served on the TAC, representing state departments of transportation (DOTs), concrete paving associations, and the FHWA. The National CP Tech Center has also provided webinars and tech briefs on pavement distress.

Concrete Overlay Technologies

Pavement preservation and rehabilitation have been growing in importance nationwide, leading to increased interest in concrete overlays. Concrete overlays are a cost-effective, low-maintenance preservation technique used to extend pavement life. Concrete overlays have been in existence for more than 100 years. Since 1901, thousands of miles of state primary and secondary roads have been successfully rehabilitated with concrete overlays.

In 2009 (after the release of the Second Edition of the *Guide to Concrete Overlays*), the use of concrete overlays jumped from 2 million square yards to 10 million square yards. From 2009 through 2016, an average of 7 million square yards per year were placed in the US. Figure 4 shows the growth as of November 2017 as a percentage of total concrete paving.



After Voigt November 2017 ACPA presentation, used with permission

Figure 4. Overlay placement as a percentage of total concrete paving over time

From September 2013 through September 2016, 11 different state DOTs that received the overlay training and support under this agreement constructed 15 projects, covering approximately 1,500 lane miles, representing more than $750 million in construction costs. With the transfer of technical information, concrete overlays have continued to grow in popularity and are a feasible and sustainable rehabilitation method.

Concrete Overlay Site Visits and Workshops

The National CP Tech Center provided technology transfer in fulfilling 35 site visit and/or technical assistance requests and by providing 32 in-depth workshops, reaching 29 states and more than 1,400 individuals, as part of the Concrete Overlay Field Application effort (see Figure 5).

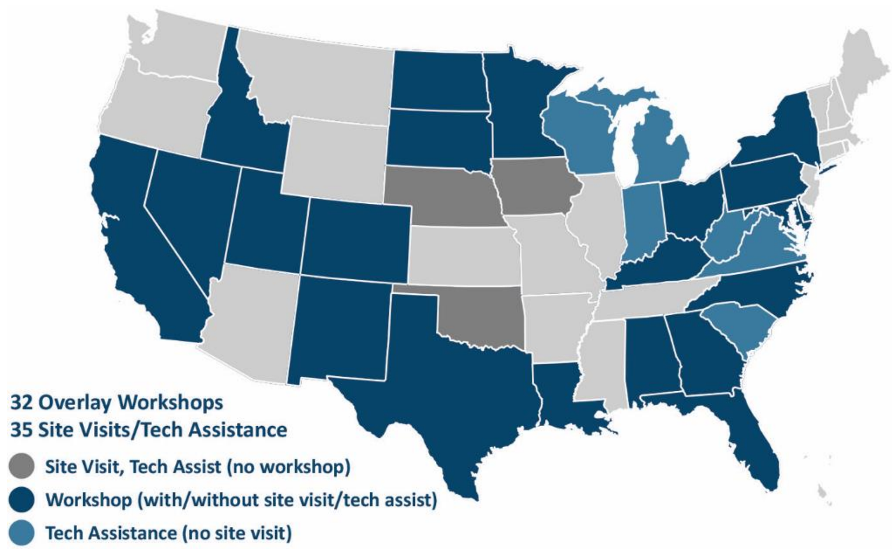


Figure 5. Overlays workshop, site visit, and tech assistance locations

Illustration: Color-coded map of the continental US showing the 20 states where overlay workshops were held (with or without site visits and/or technical assistance), Alabama, California, Colorado, Florida, Georgia, Idaho, Kentucky, Louisiana, Maryland, Minnesota, Nevada, New Mexico, New York, North Carolina, North Dakota, Ohio, Pennsylvania, South Dakota, Texas, and Utah, in dark blue, the 6 states that had technical assistance (but no site visit), Indiana, Michigan, South Carolina, Virginia, West Virginia, and Wisconsin, in medium blue, and the 3 states, Iowa, Nebraska, and Oklahoma, that had site visit technical assistance in light gray

Site visits included 1–2 hour presentations on concrete overlay topics, while the workshops included an overlay candidate evaluation, discussion on possible solutions, and a written report followed by a one-day workshop on concrete overlays. The technical presentations, developed for national audiences, included face-to-face presentations, web-based training, and webinars.

Performance History of Concrete Overlays

The purpose of this document was to demonstrate the applicability of concrete overlays as an asset management solution on a wide array of existing pavement types and roadway classifications. It includes a brief history of the construction of concrete overlays in the US and summarizes the details of 12 concrete overlay projects across the country. It concludes with a short list of additional resources.

Guide Specifications for Concrete Overlays

This document provides guidance for the development of project specifications that are tailored for concrete overlay projects. If the DOT's standard specifications are outdated or rarely used, modifications may be necessary to produce a high quality, long lasting, concrete overlay.

Guide for the Development of Concrete Overlay Construction Documents

This guide includes all the necessary tools for a pavement designer to develop a concrete overlay project. It includes standard construction details, specifications, costs, and design lessons learned. The standard construction drawings include new details on concrete overlay widening.

These details are a result of design lessons learned, with emphasis on improving performance—for example, under-slab drainage, tied shoulders, and locations of saw cuts. The standard details include guidance commentary and are provided to help the pavement designer efficiently assemble construction drawings. Guide specifications provide supplementary information and give the pavement designer the necessary process and product information for the development of an overlay project. Finally, a discussion on cost is provided based on actual concrete overlay projects from eight states.

Geotextile Interlayers

Geotextiles continue to rise in popularity and effectiveness as interlayers within unbonded concrete overlays. *Performance Assessment of Nonwoven Geotextile Materials Used as the Separation Layer for Unbonded Concrete Overlays of Existing Concrete Pavements in the US* covers the purpose, design, project experience, overall performance, construction lessons learned, cost savings, and nine case history summaries dating back to 2008. This comprehensive document, published in 2018, goes into greater depth on the performance, construction details, and ongoing optimization of nonwoven geotextile separation layers.

Long-Life Concrete Pavements

The work plan identified two activities of national importance for this focus area:

- Develop application guidance for two-lift paving construction
- Host a National Open House

In an effort to coordinate work with other national activities on long-life concrete pavements, the National CP Tech Center participated in a meeting to review the activities awarded under the Second Strategic Highway Research Program (SHRP2) R21: New Composite Pavement Systems project, which included the development of application guidance for two-lift concrete paving construction.

In cooperation with the Illinois State Toll Highway Authority (Illinois Tollway), a National Open House on Sustainable Concrete Pavement Practices was held August 20, 2013. More than 125 participants representing the FHWA, 23 SHAs, consultants, and industry attended the open house. The workshop featured sustainable practices being used by the Tollway, including two-lift concrete paving, use of RCA and fractionated reclaimed asphalt pavement (FRAP) in concrete pavement mixtures, and the application of life-cycle assessment and life-cycle cost analysis techniques.

Workshop participants were able to see pavement being placed using the recycled materials as well as participate in a technical program featuring Tollway and contractor experiences. They were also provided with two-lift paving specifications and construction details being used on actual projects.

Innovative Concrete Materials

The focus of this work area was to develop modern specifications for concrete paving mixtures that will be consistently durable in a given environment and have the performance life assumed during the design process. The key is being able to test and field-control parameters that relate to performance. Historically, concrete mixture designs focused extensively on strength, which is not a reliable measure of durability.

Performance Engineered Mixtures

Two executive level groups were formed:

- An oversight ETG was formed representing the ACPA, the National Ready Mixed Concrete Association (NRMCA), the Portland Cement Association (PCA), the NCC, the FHWA, and academia. The group met during the initiative and provided the strategic framework essential for specification development.

- At the April 2015 meeting of the NCC, a partnership was formed between the FHWA and DOT members to establish a performance engineered mixtures (PEM) champion states group to work with the National CP Tech Center on this goal. The champion state members, along with their industry partners, recognized the importance of developing the next generation concrete paving mixture specification. The members were very active in working with the development team by evaluating proposed new test methods, conducting shadow testing on active projects, and reviewing and providing comments on proposed specification language.

The results of this overall initiative culminated with the publication of American Association of State Highway and Transportation Officials (AASHTO) Standard Practice PP 84-17 for developing performance engineered concrete pavement mixtures. This specification represents an advancement from current specifications. The specification is developed around six critical mixture parameters:

- Transport properties
- Aggregate stability
- Strength
- Cold weather exposure
- Reduction of unwanted slab warping and cracking due to shrinkage
- Workability

A national transportation pooled fund study, TPF-5(368), Performance Engineered Concrete Paving Mixtures, was established to support the deployment of the specification into practice. The FHWA, 17 DOTS, and industry currently are involved with these efforts.

Advancements in Placement 5

New Technologies and Advancements in Placement

Workshop for Paving Inspectors

This training course was developed, with expertise from state agencies, industry, and the FHWA, to provide guidance and instruction to inspectors involved in the construction of PCC pavements. The important tasks involved in PCC paving are explained and proper procedures are described. The course is intended for those who have little to no experience in PCC paving field inspection.

The one-day training answers the following questions:

- Why is inspection necessary
- What is QA for PCC paving
- What is concrete
- What do you need to start a project
- What kinds of equipment are used
- What happens before you start paving
- What happens when you're finally paving
- What is the inspector's role
- What do you look for in urban paving
- What about all the other road building stuff
- What paperwork (including helpful forms)?

Three workshops were held in west and north central regions of the US, and a PDF of the presentation slides is available on the National CP Tech Center website. In addition, a set of field reference checklists were developed as a quick resource for field personnel. The checklists included the following:

- Paver Setup
- Daily Paving Summary
- Pavement Markings
- Subgrade Checks
- Depth Checks
- Paving Items
- Texture
- Air and Slump

TAC members and representatives from nine states were instrumental in reviewing the products.

SUMMARY OF TECHNOLOGY DEPLOYMENT ACTIVITIES AND TECHNICAL PRODUCTS DEVELOPED

Copies of the publications and materials developed for this project are available on the National CP Tech Center website (cptechcenter.org).

Workshops

- Preservation workshops/presentations held in 15 states with 1,200 participants
- Concrete Overlay workshops held in 20 states with 32 workshops and 1,400 participants
- Paving Inspector workshop held in 3 states

Webinars

Recycling

- Introduction to Concrete Pavement Recycling
- Construction Considerations in Concrete Pavement Recycling
- Environmental Considerations in Concrete Pavement Recycling
- Recycling Case Studies in Concrete Pavement Recycling

Preservation

- The Essentials: From Pavement Evaluation to Strategy Selection
- Partial- and Full-Depth Repair Materials
- Tips and Techniques for Specialized Repair and Construction Methods
- What You Need to Understand About Surface Treatments and Restoration Methods
- All About Joint Repairs and Sealing
- Maintaining and Preserving Concrete Pavement Overlays

Overlays

- Intro to Concrete Overlays
- Concrete Overlay Thickness Design
- Performance History of Concrete Overlays
- Materials for Concrete Overlays
- Concrete Overlay Design Details/Joints
- Maintenance of Traffic for Concrete Overlays
- Concrete Overlay Construction, Maintenance, and Rehabilitation

Project Site Visits/Technical Assistance

- Concrete overlay site visits and/or technical assistance for 35 requests

National Open House

- Two-Life Concrete Pavement – Illinois State Toll Highway Authority

Manuals

- *Recycling Concrete Pavement Materials: A Practitioner's Reference Guide*
- *Concrete Pavement Preservation Guide, Second Edition*
- *Guide to Full-Depth Reclamation with Cement* (with PCA)
- *Guide for Concrete Pavement Distress Assessments and Solutions: Identification, Causes, Prevention, and Repair*
- *Preservation and Rehabilitation of Urban Concrete Pavements Using Thin Concrete Overlays: Solutions for Joint Deterioration in Cold Weather States*
- *Guide to Concrete Overlays, Third Edition* (with ACPA)
- *Guide for the Development of Concrete Overlay Construction Documents*

Reports

- *Recycled Concrete Aggregate Usage in the US* (2016 Benchmarking Survey of SHAs and paving contractors, with ACPA)
- *Performance History of Concrete Overlays in the United States*
- *Performance Assessment of Nonwoven Geotextile Materials Used as Separation Layer for Unbonded Concrete Overlays of Existing Concrete Pavement Applications in the US*
- *MnDOT Thin Whitetopping Selection Procedures* (with MnDOT)

Tech Briefs

- *Supplementary Cementitious Material and Blended Cements to Improve Sustainability of Concrete Pavements*
- *Concrete Pavement Recycling Series: Concrete Pavement Recycling and the Use of Recycled Concrete Aggregate (RCA) in Concrete Paving Mixtures*
- *CP Road Map: Concrete Pavement Recycling and the Use of Recycled Concrete Aggregate in Concrete Paving Mixtures*
- *Concrete Pavement Recycling Series: Quantifying the Sustainability Benefits of Concrete Pavement Recycling*
- *CP Road Map: Concrete Pavement Recycling—Project Selection and Scoping*
- *Concrete Pavement Recycling Series: Protecting Water Quality through Planning and Design Considerations*

- *Concrete Pavement Recycling Series: Protecting the Environment during Construction*
- *CP Road Map: Using Recycled Concrete Aggregate in Pavement Base Products*
- *Concrete Pavement Recycling Series: Using Recycled Concrete Aggregate (RCA) in Unbound Aggregate Shoulders*
- *New Procedures Offer Guidance for Using Bonded Whitetopping on Asphalt Pavements* (Tech Summary with MnDOT)

Specifications

- *Guide Specifications for Concrete Overlays*
- *AASHTO PP 84-17: Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures*

Other Technical Assistance

Preservation

- Number of states that received technical assistance: 5

Overlays

- Number of states with site visits (where candidate overlay projects were field reviewed): 20
- Number of states that received technical assistance: 14
- Number of states that constructed, or plan to construct, overlays in the next two years: 13
- Number of overlay projects constructed, or will be constructed, in the next two years: 37

Web Resources Library

- Concrete Recycling
- Pavement Preservation
- Concrete Overlays
- Geotextiles
- Performance Engineered Mixtures

APPENDICES

Appendix A: Recycled Concrete Pavement Materials
Appendix B: Concrete Pavement Preservation
Appendix C: Concrete Overlay Field Application
Appendix D: Performance Engineered Mixtures
Appendix E: Long-Life Pavements, New Technologies, and Advancements in Placement Work Areas

Appendix A:

Recycled Concrete Pavement Materials

Final Task Report
December 2018

Principal Investigator
Peter Taylor, Director
National Concrete Pavement Technology Center, Iowa State University

Author
Tom Cackler, Woodland Consulting, Inc.

Manager
Tom Cackler, Woodland Consulting, Inc.

Team Leaders
Mark B. Snyder, Pavement Engineering and Research Consultants
Tara L. Cavalline, University of North Carolina at Charlotte
Gary Fick, Trinity Construction Management Services, Inc.
Dale Harrington, HCE Services

Sponsored by
Federal Highway Administration

A report from
National Concrete Pavement Technology Center
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-5798 / Fax: 515-294-0467
cptechcenter.org

TABLE OF CONTENTS

LIST OF FIGURES

RCA ACKNOWLEDGMENTS

The National Concrete Pavement Technology (CP Tech) Center would like to acknowledge the invaluable contribution of the Concrete Pavement Recycling Initiative expert task group (ETG)/champion states. This group was formed at the April 2015 meeting of the National Concrete Consortium (NCC), in Reno, Nevada. Ten states along with their industry counterparts, volunteered to lead this initiative on behalf of the NCC members (see Figure A-1).

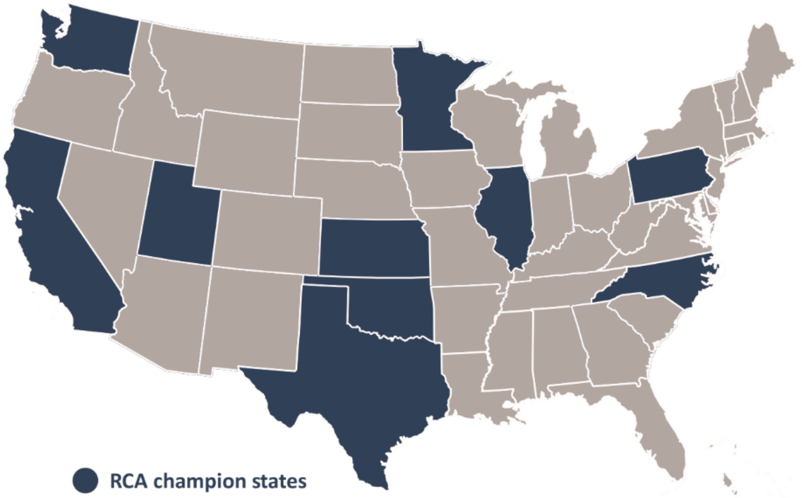


Figure A-1. RCA champion states

The ETG/champion state members are highly respected and qualified individuals with unparalleled experience in concrete pavement recycling. The following members served on the committee to identify needed products, review and provide input on the development of the deliverables, and participate in regular electronic meetings with the research team.

Agencies

- Ross Bentsen, Quigg Engineering, Inc. (representing Illinois State Toll Highway Authority/Illinois Tollway)
- Steve Gillen, Horner & Shifrin (formerly with Illinois Tollway)
- Brian Hunter, North Carolina DOT (NCDOT)
- Steve Koser, Pennsylvania DOT (PennDOT)
- Bryan Lee, Utah DOT (UDOT)
- Will Lindquist, Kansas DOT (KDOT)
- Maria Masten, Minnesota DOT (MnDOT)
- Rod Montney, KDOT
- Andy Naranjo, Texas DOT (TxDOT)
- Mehdi Parvini, California DOT (Caltrans)
- Greg Scheiber, KDOT

- Kenny Seward, Oklahoma DOT (ODOT)
- Jeff Uhlmeyer, Washington State DOT (WSDOT)

Associations

- Wayne Adaska, Portland Cement Association (PCA)
- John Becker, American Concrete Pavement Association (ACPA) – Pennsylvania Chapter
- Brent Burwell, ACPA – Oklahoma/Arkansas (OK/AR) Chapter
- Greg Dean, ACPA – Southeast Chapter/ Carolinas Concrete Paving Association
- Rich Jucha, ACPA – Pennsylvania Chapter
- Steve Kosmatka, PCA
- Todd LaTorella, ACPA – Missouri/Kansas (MO/KS) Chapter
- Colin Lobo, National Ready Mixed Concrete Association (NRMCA)
- Mitzi McIntyre, CTS Cement Manufacturing Corporation
- Jim Powell, ACPA – Northwest Chapter
- Jan Prusinski, Cement Council of Texas
- Charles Rea, California Construction and Industrial Materials Association
- Randy Riley, Formerly ACPA – Illinois Chapter
- Charles Stuart, Southwest Concrete Paving Association
- Tom Teitz, California Nevada Cement Association
- Leif Wathne, National ACPA

EXECUTIVE SUMMARY

On September 13, 2012, the Federal Highway Administration (FHWA) entered into a cooperative agreement with the National Concrete Pavement Technology (CP Tech) Center to address national priority needs to advance concrete pavement technologies. The agreement was titled Technology Transfer of Concrete Pavement Technologies. As part of this project, a focused effort to address technical and policy needs related to increasing the use of recycled concrete aggregate (RCA) was started in mid-2013.

The objectives of the recycled concrete pavement materials task were as follows:

- Understand current uses of RCA by state departments of transportation (DOTs)
- Identify technical and policy barriers that do not have a sound technical basis but restrict the use of RCA
- Identify and prioritize needed technical resources and training
- Develop a program of products and training to address the needs
- Provide technical support as needed to assist states with new applications

Through the recycled concrete pavement materials task, many lessons have been learned that have resulted in improved practices at various stages of project scoping, development, construction, and performance monitoring. Following are highlights of recommendations based on lessons learned:

- RCA should be considered an engineered material. Design requirements may be similar to those of applications with virgin material or may require some modification to meet the agencies' design objectives.
- Performance of RCA can be equal to or better than virgin materials when properly designed and constructed.
- Most projects can be good candidates for using RCA. It is important to consider the use of RCA during project scoping. On reconstruction projects, availability of the existing pavement for recycling needs to match staging requirements.
- Using RCA often results in time and cost savings on a project.
- In situ recycling can result in safer project traffic flow by taking haul trucks out of the traffic stream.
- Environmental concerns should not prevent the use of RCA. Mitigation measures are readily available to address potential impacts of properly engineered applications.
- Specification requirements should be reviewed to remove restrictions that do not have technical merit.
- Nearly all agencies and contractors have an interest in expanding the use of RCA materials.

BACKGROUND

Concrete pavements have been recycled successfully for reuse on highway projects for many years. One of the first uses of RCA in pavement construction was on US Route 66 in Illinois in the 1940s. There, concrete from a portion of the existing two-lane concrete road was crushed and stockpiled for use as aggregate in the second two lanes of the highway when it was expanded to four lanes after World War II.

As agencies look for more economical and environmentally sustainable practices for new paving applications as well as bases, shoulders, and other aggregate needs on projects, there has been renewed interest in using RCA. RCA can generate cost and time savings for a project as well as offer a more sustainable option than using virgin materials. According to a Construction Demolition and Recycling Association (CDRA) estimate in 2014, more than 140 million tons of RCA are produced annually.

Performance of various applications using RCA has generally been good, with some applications reporting equal or even improved performance. However, the FHWA recognized that additional technical guidance was needed to assist states with understanding how to select applications, develop specification requirements, ensure good construction practices, and mitigate any potential environmental concerns.

OBJECTIVES

Objectives of the recycled concrete pavement materials effort were as follows:

- Understand current uses of RCA by DOTs
- Identify technical and policy barriers that do not have a sound technical basis but restrict the use of RCA
- Identify and prioritize needed technical resources and training
- Develop products and training to address the needs
- Provide technical support as needed to assist states with new applications

TEAM MEMBERS

The organizational chart shown in Figure A-2 illustrates the management structure used by the National CP Tech Center for this task.

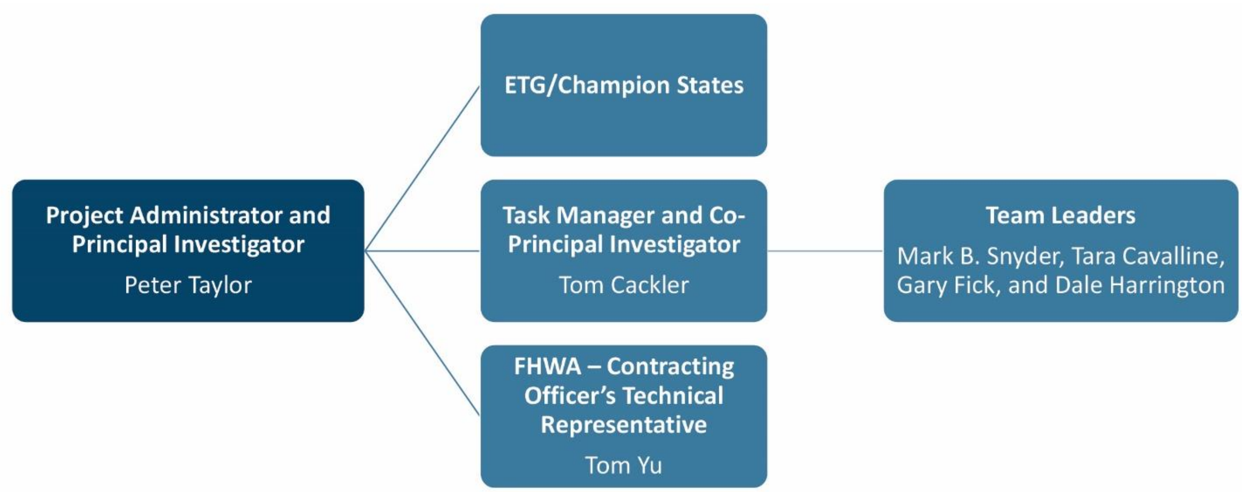


Figure A-2. RCA organizational chart

WORK PLAN

The research team developed a detailed plan of deliverables in consultation with the Concrete Pavement Recycling Initiative expert task group (ETG)/champion state members. The overall objective was to develop technical products and training that would be of the most value in addressing the needs of the DOTs. The proposed deliverables were presented and approved by the ETG/champion state members at their December 15, 2015 meeting. There were some minor adjustments over the life of the project in consultation with the ETG/champion state members.

MATERIALS DEVELOPED

Descriptions of the technical documents, training, and support resources that were developed follow.

Webinars

In consultation with the ETG/champion states, it was decided that web-based training would be the most cost-effective approach to reach a national audience. As a result, a four-part webinar series was developed to educate users on which applications can be considered for using RCA on projects, how to address potential concerns, and how the many projects that have been built across the US are performing.

It was also decided to offer each webinar at least three times, offering more opportunities for participants to interact. In addition to the regional webinars offered by the American Association of State Highway and Transportation Officials (AASHTO) regions, the introductory webinar was offered two additional times on a national basis.

Each of the webinars concluded with a question and answer session. Participants were encouraged to submit written questions by email, and the presenter(s) followed up with specific responses for each question.

Overall, nearly 500 individuals participated in the training. In addition, each of the webinars was recorded and this training, along with the other technical products, is accessible from the Concrete Recycling Resources menu on the National CP Tech Center's homepage at cptechcenter.org.

The following webinars were presented:

- Concrete Pavement Recycling
  - 2016: April 20, May 4 and 18, October 19, and November 16
- Environmental Considerations
  - 2017: March 15 and 29, and May 18
- Construction Considerations
  - 2017: April 5 and 19, and May 3
- Case Studies
  - 2017: May 24, June 21, and July 12

Recycling Concrete Pavement Materials: A Practitioner's Reference Guide

After reviewing the currently available technical resources with the ETG/champion states, it was determined that a priority deliverable would be the development of a practical, up-to-date manual on how to support RCA applications on projects. The primary author for this manual was Mark B. Snyder with contributing authors Tara Cavalline, Gary Fick, Peter Taylor, and Jerod Gross. This guide is available from the Concrete Recycling Resources menu on the National CP Tech Center's homepage at cptechcenter.org. These are the topics covered in the guide:

Chapter 1: Introduction to Concrete Pavement Recycling
Definition of Concrete Pavement Recycling
Brief Historical Perspective
Benefits of Recycling Concrete Pavements
Applications for RCA
Performance of Pavements Constructed using RCA
Chapter 2: Economics and Sustainability
Benefits Associated with Concrete Recycling
Assessment Tools and Techniques
Chapter 3: Project Selection and Scoping

Characterization of the Source Concrete and Use Selection
Production Options for RCA
Economic Considerations
Other Factors
Weighing Factors and Making Decisions
Chapter 4: Using RCA in Pavement Base Products
Unbound Aggregate Base Applications
Performance Considerations
Qualification Testing
Base Design and Construction Considerations
Concrete Pavement Design Considerations
Environmental Considerations
Example Projects
Bound (Stabilized) Base Applications
Chapter 5: Using RCA in Unbound Aggregate Shoulders
Qualification Requirements
RCA Shoulder Design Considerations
Assessing Potential Economic Benefits
Environmental Considerations
Chapter 6: Using RCA in Concrete Paving Mixtures
Constructability (Fresh Properties)
Pavement Design Considerations (Hardened Properties)
Developing Concrete Mix Designs Using RCA
Examples/Case Studies
Chapter 7: Mitigating Environmental Concerns
Legislative and Regulatory Considerations
Environmental Concerns Requiring Consideration
Planning Considerations and Design Techniques that Protect Water Quality
Construction Strategies and Controls to Mitigate Environmental Concerns
National Standard and Specification References

Concrete Pavement Recycling Tech Brief Series

To supplement the technical manual, *Recycling Concrete Pavement Materials: A Practitioner's Reference Guide*, a seven-part tech brief series was developed to focus on key aspects of the manual and make them readily available in a standalone format. To further ensure that the tech brief series was widely available, three issues from the series were also formatted as MAP briefs and sent out with the quarterly CP Roadmap e-newsletter.

Each of the tech briefs was authored by the subject matter expert who wrote the associated portion of the manual. The briefs are typically 8 to10 pages in length and address the following topics:

- *Concrete Pavement Recycling Series: Concrete Pavement Recycling and the Use of Recycled Concrete Aggregate (RCA) in Concrete Paving Mixtures*

- *CP Road Map: Concrete Pavement Recycling and the Use of Recycled Concrete Aggregate in Concrete Paving Mixtures*
- *Concrete Pavement Recycling Series: Quantifying the Sustainability Benefits of Concrete Pavement Recycling*
- *CP Road Map: Concrete Pavement Recycling—Project Selection and Scoping*
- *Concrete Pavement Recycling Series: Protecting Water Quality through Planning and Design Considerations*
- *Concrete Pavement Recycling Series: Protecting the Environment during Construction*
- *CP Road Map: Using Recycled Concrete Aggregate in Pavement Base Products*
- *Concrete Pavement Recycling Series: Using Recycled Concrete Aggregate (RCA) in Unbound Aggregate Shoulders*

Webpage with Technical Resources

An RCA technical reference library of products developed under this project as well as other key documents on RCA utilization were assembled and placed on the National CP Tech Center's website at cptechcenter.org. The following materials are available as downloads from the Concrete Recycling Resources webpage:

- *Recycling Concrete Pavement Materials: A Practitioner's Reference Guide*
- Training Materials
  - Links to recorded webinars discussed above
- Tech Briefs
  - Links to tech briefs discussed above
- Current Utilization and Guidance
  - Survey report
- Technical Resources
  - National resources from the American Concrete Pavement Association (ACPA), National CP Tech Center, Construction and Demolition Recycling Association (CDRA), FHWA, and Ready Mixed Concrete (RMC) Research and Education Foundation

Recycled Concrete Aggregate Usage in the US – Industry and DOT Survey

To gather insight on the current national practices of concrete pavement recycling, a benchmarking survey was conducted in 2016. The purposes of the survey were as follows:

- Document the current usage of concrete pavement recycling
- Understand the barriers preventing more use of recycled products
- Guide the development of technical products and educational materials that will promote greater consideration of using recycled concrete as a construction material

The survey was conducted by the National CP Tech Center in cooperation with the DOT members of the National Concrete Consortium (NCC), and the ACPA. The goal of this initial survey was to gather information both from DOTs and paving contractors to get a holistic perspective on current applications, the real and perceived barriers, and existing opportunities to increase the amount of recycling. Participation in the survey is summarized in Figures A-3 and A-4.

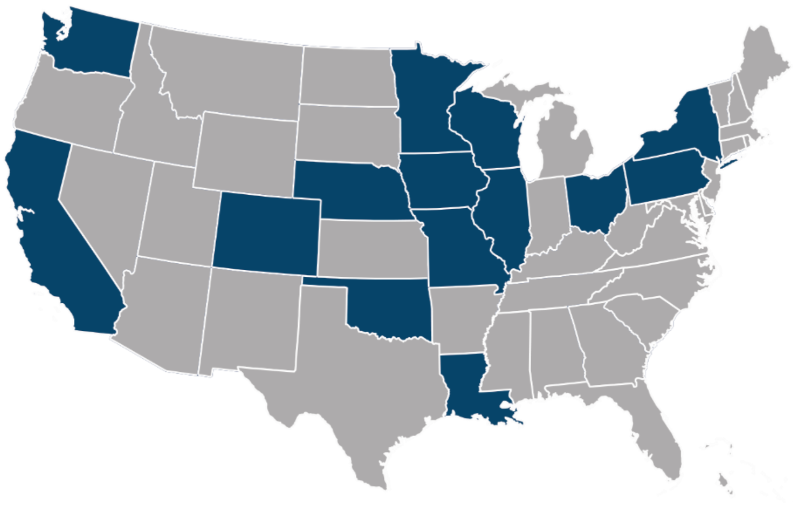


Figure A-3. Agencies: 14 DOTs plus the Illinois State Toll Highway Authority

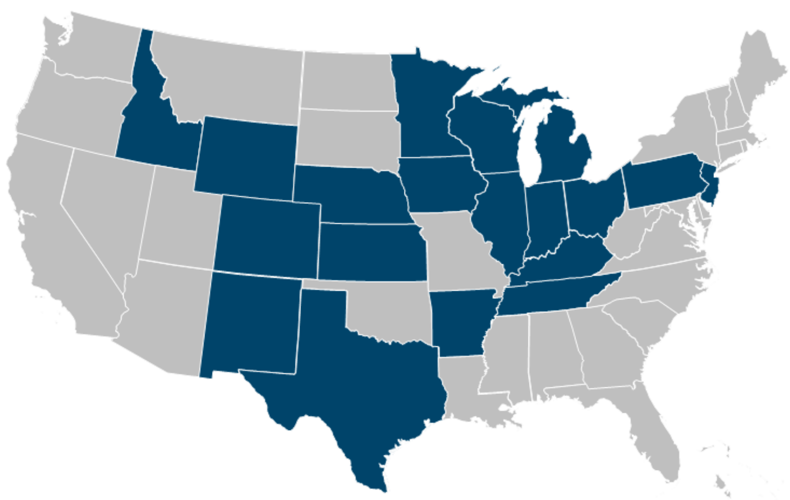


Figure A-4. Industry: 24 National contracting firms in 19 states

Key findings of the survey include the following:

- Agencies and contractors are interested in increasing the use of RCA
- Production and use of RCA is common on most projects involving concrete pavement removal
- There are opportunities to increase the total volume of RCA use

- The threshold for economical recycling appears to be relatively low (i.e., <5,000 yd^3), with some contractors committed to recycling 100% of concrete removals
- Unbound applications of RCA are the most common, with bases being the predominant use
- Agencies rely on state and federal regulatory agencies for guidance on environmental compliance
- Most agencies have less stringent technical requirements for RCA when it's obtained from the agencies' own infrastructure
- There appears to be a lack of knowledge and experience on how to utilize RCA as an engineered material in concrete mixtures
- Barriers that appear to constrain the use of RCA:
  - Restrictive specifications
  - Complex permitting regulations
  - Lack of knowledge on how to use RCA without compromising performance
  - Lack of knowledge on how to address potential environmental concerns related to RCA while in service

TECHNICAL SUPPORT TO DOTS

Support to DOTs and information sharing were also provided as part of this effort as follows:

- On-call technical support with specification development and review
- Sharing technical products through the NCC's e-news highlights and MAP Briefs
- Quarterly ETG/champion state TAC meetings where state best practices were part of the discussion
- RCA workshop incorporated into the International Conference on Concrete Pavement (ICCP) in San Antonio, Texas, August 28–September 1, 2016, with presentations including the following:
  - Cost Savings from Using RCA in Tollway Reconstruction
  - Colorado RCA Use
  - Beneficial Reuse of RCA in Granular and Concrete Pavements
  - Performance History of I-57 in Illinois
  - I-10 near Houston, Texas 100% RCA Back Into CRCP Section
  - Recycled ASR Distressed Concrete Pavement on Interstate 80 SE Wyoming
  - Performance History of Recycling D-Cracking Susceptible Concrete into US TH 59 in Minnesota

Appendix B:

Concrete Pavement Preservation

Final Task Report
December 2018

Principal Investigator
Peter Taylor, Director
National Concrete Pavement Technology Center, Iowa State University

Authors
Dale Harrington, HCE Services
Rabindra Pariyar, Snyder & Associates, Inc.
Melisse Leopold, Snyder & Associates, Inc.
Jerod Gross, Snyder & Associates, Inc.
Dan Frentress, Frentress Enterprises, LLC

Manager
Dale Harrington, HCE Services

Team Leaders
Kurt Smith, Applied Pavement Technology, Inc.
Mark B. Snyder, Pavement Engineering and Research Consultants
Jerod Gross, Snyder & Associates, Inc.

Sponsored by
Federal Highway Administration

A report from
National Concrete Pavement Technology Center
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-5798 / Fax: 515-294-0467
cptechcenter.org

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PAVEMENT PRESERVATION ACKNOWLEDGMENTS

The authors would like to thank the Federal Highway Administration (FHWA), the technical advisory committee, and the expert team members who were involved in the pavement preservation technology transfer efforts for this project.

EXECUTIVE SUMMARY

Concrete Pavement Preservation was a component of the Technology Transfer of Concrete Pavement Technologies cooperative agreement started in September of 2013 between the Federal Highway Administration (FHWA) and the National Concrete Pavement Technology (CP Tech) Center at Iowa State University.

The objective of this part of the project was to advance preservation and maintenance techniques for concrete pavements by continuing the development of a multi-state program addressing the need to preserve concrete pavements. Through the program, 16 state highway agencies (SHAs) received training on concrete preservation, demonstrations, and documentation of the concepts and benefits of concrete preservation techniques. Since 2013, the program has held workshops in 15 states, provided technical assistance to five states, and prepared 15 expert team reports or recommendations for specific projects (see Figure B-1).

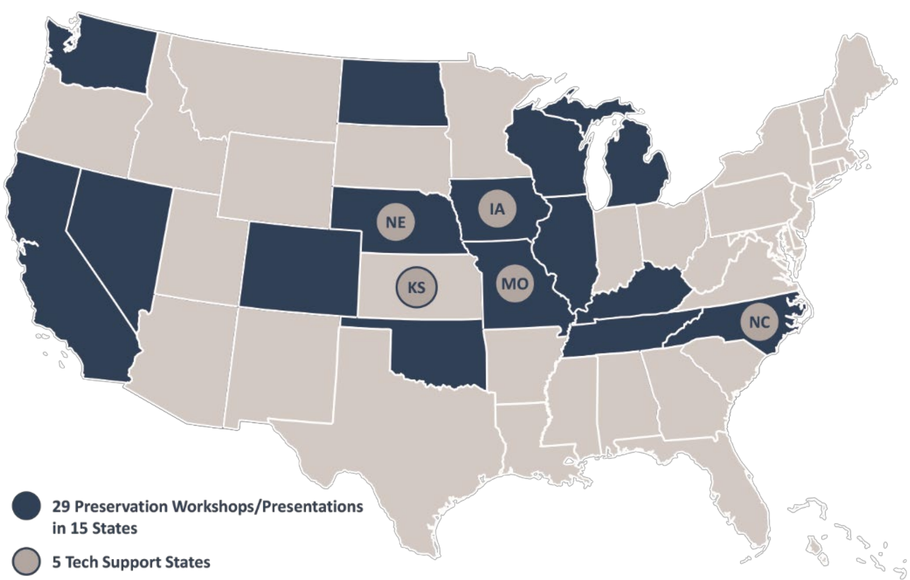


Figure B-1. States where concrete pavement preservation workshops and technical support were provided from 2013 through 2018

There were also two open house demonstration projects, both in Missouri. Technical support included recommendations on the following:

- Preventive maintenance and pavement preservation concepts
- Concrete paving evaluations
- Pavement distress and drainage surveys
- Slab stabilization and slab jacking
- Partial-depth repairs
- Retrofit edge drains, dowel bar retrofit, cross stitching, and slot stitching
- Diamond grinding and grooving

- Joint resealing and crack sealing
- Concrete overlays
- Strategic selection of preservation techniques

Training is summarized as follows:

- Number of states that held workshops: 15
- Number of site visits (where preservation projects were field reviewed): 4
- Number of states that received technical assistance: 5
- Number of individuals trained: 1,200

BACKGROUND

Pavement preservation is not a new concept and has been in practice at some level for more than 90 years. Although several detailed definitions exist for concrete pavement preservation, "keeping good roads in good condition" has emerged as a popular mantra for many highway agencies. Many factors make concrete pavement preservation treatments successful at extending the life of a pavement. A proactive approach greatly improves the following:

- Sustainability – Preservation improves the useful performance life of a concrete pavement, thereby lowering the cost and environmental impact over time
- Asset Management – From an agency standpoint, some of the most sought-after benefits of pavement preservation take the form of optimized utilization of techniques at the right time, leading to savings
- Maintenance of Traffic – Reduced downtime for roadway closures, reduced travel delays, shorter and fewer work zones, and decreased user costs all play a role in improving safety

Routine and corrective maintenance activities are reactive processes in which existing distresses are repaired or treated. Unfortunately, typical rehabilitation principles of agencies have been based on programming the "worst first," which results in pavement deterioration until the worst case rises to the top of the capital projects list. In contrast, pavement preservation is a proactive approach intended to preserve a pavement and extend its useful performance life at a higher level of service.

In 2007, the FHWA and industry recognized the less than optimal use of preservation principles in practice. In 2008, the FHWA and the National CP Tech Center entered into a cooperative agreement that included concrete pavement preservation to educate and provide technical assistance on concrete pavement treatments and techniques to state highway agencies (SHAs). During the five years of the agreement, the team conducted workshops, site visits, and web-based training for 18 states throughout the US.

At the end of this period, it was clear that many other states still needed the same training. As a result, a second five-year concrete pavement preservation effort was initiated in 2013. The same type of technical assistance was provided to 15 states, with numerous states adopting an improved preservation program.

OBJECTIVES

In an effort to clearly explain concrete pavement preservation techniques, the National CP Tech Center published the *Concrete Pavement Preservation Guide* in September 2008. Workshop materials were also developed and included slide presentations, web-based training modules, and an instructor manual. The guide was updated in September 2014.

The primary objective of pavement preservation technical assistance efforts has been the continuation and development of concrete pavement preservation construction assistance across the US. To accomplish this, SHAs were led through the scoping, evaluation, design, and construction phases of a concrete preservation project by a team of experts. These projects provided hands-on experience to the SHAs and contractors. These three technical deployment principles were used:

- The National CP Tech Center team of experts was tasked with providing unbiased technical assistance to SHAs from project conception through construction
- SHAs were provided with the tools to develop expertise internally and to conduct internal training
- SHAs were regularly provided with the latest technical developments and methods, and technical resources included web-based training and videos on preservation techniques, concepts, evaluations, treatments, timing, design features, and construction requirements

TECHNICAL RESOURCES DEVELOPED

In support of this effort, the National CP Tech Center published the following new or updated concrete preservation technical resources, all of which are available online:

- 2018 *Guide for Concrete Pavement Distress Assessments and Solutions: Identification, Causes, Prevention, and Repair*
- 2018 web-based training on PCC pavement preservation treatments
- 2016–2018 Concrete Pavement Preservation Webpage – Summary of web-links for concrete pavement preservation with more than 80 individual links to national, state, consulting, and private online resources, including reports, tech briefs, guides, websites, and videos
- 2017 *Guide to Full-Depth Reclamation with Cement* (with PCA)
- 2014 *Preservation and Rehabilitation of Urban Concrete Pavements Using Thin Concrete Overlays: Solutions for Joint Deterioration in Cold Weather States*
- 2014 *Concrete Pavement Preservation Guide, Second Edition*
- 2014 PCC Pavement Preservation web-based training modules (11 modules total)

TEAM MEMBERS

The organizational chart in Figure B-2 shows the National CP Tech Center's management structure for this task.

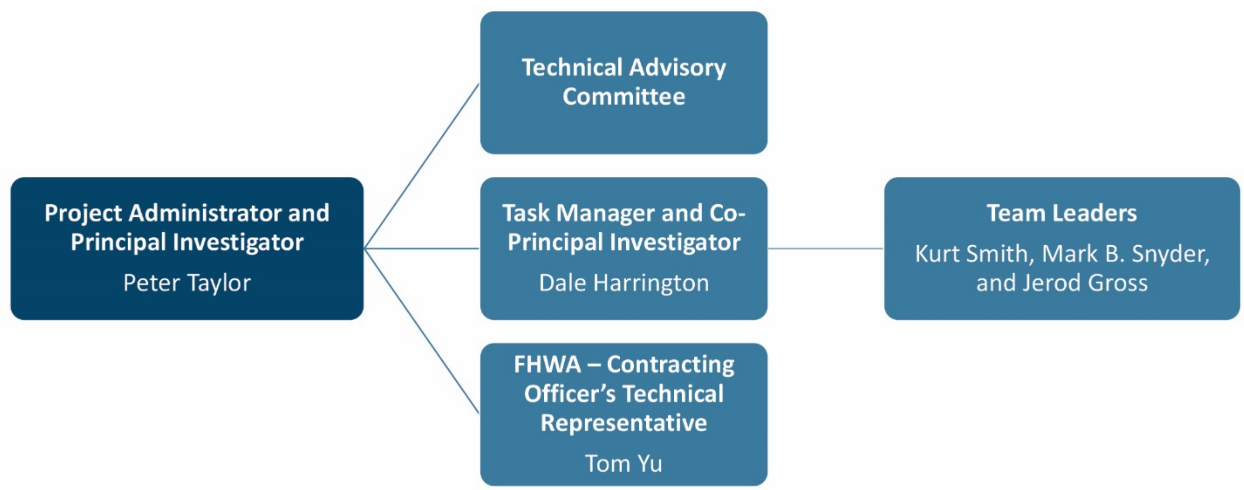


Figure B-2. Concrete pavement preservation organizational chart

The technical advisory committee (TAC) members were highly respected and qualified individuals with experience in concrete pavement preservation:

- Gina Ahlstrom, FHWA
- Bret Andreasen, Willamette Valley Company
- John Donahue, Missouri Department of Transportation (MoDOT)
- Larry Galehouse, National Center for Pavement Preservation
- Wouter Gulden, Retired Georgia DOT and ACPA-SE
- Craig Hennings, Southwest Concrete Pavement Association
- Robert Hogan, California DOT (Caltrans)
- Kevin Merryman, Iowa DOT
- Magdy Mikhail, Texas DOT (TxDOT)
- Vince Perez, CTS Cement Manufacturing Corp.
- John Roberts, International Grooving and Grinding Association (IGGA)
- Matt Ross, Penhall Company
- Larry Scofield, IGGA/American Concrete Pavement Association (ACPA)
- Gordon Smith, formerly Iowa Concrete Paving Association (ICPA) and currently National CP Tech Center
- Jim Tanner, Denton Concrete Services
- Francis Todey, Iowa DOT
- Thomas Van, FHWA
- Paul Wiegand, Iowa Statewide Urban Design and Specifications (SUDAS)
- Matt Zeller, Concrete Paving Association of Minnesota

WORK PLAN

SHAs and industry representatives were contacted to solicit. An effort was made to target states that either had no experience or limited experience with the design and construction of preservation techniques. Interested SHAs were encouraged to schedule a workshop and expert team visit to their states. Those that did not need a workshop but had detailed questions received site reviews or conference calls on specific issues. The typical steps for proceeding with the workshops were as follows:

- Initial contact with the SHA
- Follow-up with project objectives and proposed activities
- Distribution of a flyer to the SHA that could be distributed to potential participants
- Execution of a workshop to educate stakeholders about the principles of concrete pavement preservation
- Execution of an expert team site visit to review potential projects
- Preparation of a site visit report by the expert team, with detailed recommendations for the projects reviewed and listing of the next steps
- Provision of guidance from the expert team on design, bidding, and construction for those SHAs that chose to proceed with implementation of a preservation project
- Documentation of the entire preservation implementation process through a final project report

Twenty-nine concrete pavement preservation workshops/presentations were provided in 15 states, as shown in Table B-1 (and previously in Figure B-1): California, Colorado, Illinois, Iowa, Kentucky, Michigan, Missouri, Nebraska, Nevada, North Carolina, North Dakota, Oklahoma, Tennessee, Washington, and Wisconsin. Five states received technical support (included with site visits for four of the five): Iowa, Kansas, Missouri, Nebraska, and North Carolina.

Table B-1. Preservation technical assistance, training, and support provided

State	Support	Date(s)	Comments
California	4 Workshops	10/6, 10/8, 10/20, and 10/22/15	Met with Caltrans upper management 10/5/15; workshops in Sacramento, Fresno, Fontana, and San Diego
Colorado	Workshop	11/3/14	One-day workshop in Denver
Illinois	Workshop	10/20/15	Workshop in Springfield
Iowa	6 Workshops	3/1/15	Workshops in 6 districts
	Tech assistance	6/1/14	Assistance with delamination on 220th Street in Mahaska County
	Tech assistance	2/18/15	Meeting with City of Council Bluffs about joint maintenance
	Tech assistance	6/3/15	Reviewed pavement condition of 11 sections in District 2 (US 63, US 218, IA 58, and US 20) and provided recommendations for improvements
	Tech assistance	6/30/15	Conference call to review UBCOC cracks on IA 14 in Grundy and Butler Counties
	Tech assistance	6/8/16	Field reviews on 3 projects in District 3 (US 71 and US 175)
	Tech assistance	7/10/16	Assistance with corner cracking in Centerville
	Tech assistance	1/6/17	Assistance with FDR on George Flagg Parkway project in Des Moines
	Tech assistance	3/7/17	Field reviews on 3 projects in District 5 (IA 149, US 34, and IA 21)
Kansas	Tech assistance	10/31/16	Assistance on the downward curling at joints in Hays
Kentucky	Workshop	3/27–3/28/14	One-and-a-half-day workshop in Lexington
Michigan	2 Workshops	10/29–10/30/15	Workshops in Lansing and Detroit
Missouri	2 Workshops/ Open House	9/29–9/30/14	Workshops in St. Roberts and Jefferson City with a half-day site visit preservation demonstration
	Presentation	4/1/15	Pavement preservation manual update at Missouri University of Science and Technology
	Open House	4/18/17	Concrete PDR Open House in O’Fallon
	Presentation	5/2/18	Distress manual at Missouri University of Science and Technology
Nebraska	2 Workshop	11/4–11/5/15	One-day workshops in North Platte and Lincoln
	Tech assistance		Various phone/conference calls
Nevada	Workshop	4/14 and 11/8/16	Workshops in Carson City and Las Vegas
North Carolina	Workshop	2/20/17	One-day workshop in Winston–Salem
North Dakota	Workshop	12/15/15	Workshop in Bismarck
Oklahoma	Workshop	4/30/14	One-day workshop in Oklahoma City
Tennessee	Workshop	2/19/16	Workshop in Nashville
Washington	2 Workshops	3/29 and 3/31/16	One-day workshops in Everett and Moses Lake (preceded by field reviews for local information to include 3/27 and 3/30/16)
Wisconsin	Workshop	3/19/15	One-day workshop in Madison

WORKSHOPS (2013–2018)

The National CP Tech Center provided technology transfer in the form of in-depth workshops in 15 states reaching about 1,200 individuals. The workshops received ratings that averaged 1.4 out of 5 with 1 being the best score. The technical presentations were developed for national audiences and included face-to-face presentations, web-based training, and webinars.

Examples of Preservation Workshop Comments

What were the most worthwhile parts of this program?

California

- Very valuable
- Suggestions and insight on real world problems/issues
- Updated material on most recent standards
- Interactive between group and speakers
- This is very interesting subject for me. I learned a lot from this program.
- All is important to me
- Materials, handouts, all good. They're good reviews of the workshop and good reference.
- The speakers are very knowledgeable and fun to listen to
- The handouts are excellent
- A great consolidation class covering all methods used in pavement preservation
- Visual aids made it very easy to identify failing pavements
- The presentations went into adequate technical depth to be valuable as a designer
- Very directly relating to my current project
- Good topics – work related

Colorado

- Talking to instructors
- The various topics painted an excellent overview
- Very comprehensive; topics covered and material for each topic was substantial
- Preservation guide is a valuable hand-out, thank you

Illinois

- Knowledge of the instructors
- Great amount of information
- Format allowed for input/stories from both instructors and participants. Good order of program.
- Good overview of the many aspects of concrete pavement preservation

Kentucky

- As a designer it covered good design and survey issues. All were good.
- Learning of problems with concrete pavement and ways to best correct these problems. Speakers were both very good and knowledgeable.
- I'm new to pavement preservation/rehab so it was a good course for an overview and to get familiar with the process

Michigan

- All sections were very useful
- Topics addressed current topics and issues
- Great variety of topics. Very knowledgeable speakers.
- Great field experience and procedures cited
- Hearing from both national and state experts
- The knowledge of the presenters
- Lots of practical information

Missouri

- Very knowledgeable, real world examples, a lot of experience
- All topics very informative
- It was good to see how to do it right
- Good and useful information
- Knowledgeable instructors, PowerPoint slides, up-to-date pictures of what was talked about, hands on training

Nebraska

- This will be a great item in the toolbox
- Good training

Nevada

- Troubleshooting– great job at getting people involved w/their personal experience
- Instructors were enthusiastic
- Pictures presented an excellent visualization of the techniques
- Well put together and moved along well
- Lots of good information presented
- In-depth presentation of principles and details of subject

North Carolina

- The handouts and questions
- Very in depth descriptions and explanations
- Exposure to processes we don't usually use

North Dakota

- The topics that were covered by the instructors were very well covered and showed great knowledge of application in the field.
- Continue to go out and present

Oklahoma

- Good workshop
- Very in depth information
- Knowledgeable speakers that are enthusiastic about their areas
- The slides were very helpful and descriptive

Tennessee

- Any topic I had not personally seen in the real world was well covered so I feel informed
- Detailing which techniques were appropriate for real case scenarios. Instructors going into detail as to why things are done a particular way.
- The photos and examples of each presentation application were very useful. I thought the instructors did a great job explaining everything and giving TDOT new ideas.
- This is my first introduction to preservation and restoration of concrete. The whole course was good.

Washington

- All was very useful
- Knowledge of speakers
- Training was very good

Wisconsin

- Speakers' knowledge
- Information on performance factors to inspect for in procedures, small factors make a large impact on success
- New materials – polymers – methods, good ideas to consider for our repair program
- Like how it fit into one day, many topics with a lot of info

LESSONS LEARNED

Through this work, many lessons were learned that have resulted in improved practices at various stages of concrete preservation projects. Following are the highlights of recommendations based on lessons learned:

- Utilize coring, falling weight deflectometer, and other nondestructive tests, along with "as built" plans, to investigate existing pavement conditions and thicknesses to determine which type of preservation is appropriate.
- In freeze-thaw climates and/or areas with expansive soils, evaluate existing pavement in spring and summer to identify critical pavement distresses.
- During the early phases of design, consider all partial and full detour options and their impacts on construction.
- Choose the most appropriate treatment options to meet existing pavement conditions and anticipated future traffic loading.
- In non-arid climates, provide a positive drainage path for surface moisture to exit.
- Develop the construction sequence to meet closed-road or through-traffic conditions.
- Upon completion of a preservation treatment, give proper consideration to smoothness requirements, which may require some diamond grinding after preservation treatments are completed.
- Hold a public preconstruction meeting to communicate traffic control impacts and identify public concerns that should be addressed by the contractor and highway agency during construction.
- Clearly state the criteria for lane closures and allow for contractors' alternative suggestions to meet the criteria.
- Provide for alternative detour routes to be used in the case of unforeseen circumstances (crashes, wide loads, equipment breakdowns, etc.).
- Together with the contractor, develop a traffic control plan that allows sufficient space for construction operations and keeps the traveling public and pedestrians safe.
- Require contractor's development of a comprehensive construction plan to address construction and public impacts.
- When necessary, accelerate all construction processes to minimize public impact. Limit contract-stage work times to emphasize the need for accelerated work, if that is the goal of the contract.
- When a full-depth repair is placed in cooler weather, the concrete can set from the bottom up, delaying the sawing window. Temporarily covering the repair with plastic after paving helps the concrete to set properly, allowing for timely sawing.

CASE STUDIES

Of the five preservation tech support states (four of which had on-site field reviews), two states (Iowa and Missouri) are featured here with examples of the reports that were completed. These reports explain concrete pavement preservation techniques and concepts, evaluations, treatments, timing, design feature selection, and construction requirements.

The Iowa project was selected as it represented a good cross-section of preservation techniques. The Missouri project was selected because its preservation needs concentrated on a specific and extensive treatment (partial-depth repair). Also, the Missouri project featured actual field installation demonstrations with more than 350 individuals in attendance. Witnessing preservation treatment construction gave the SHAs guidance on the important considerations in completing successful preservation projects.

It should be noted that the majority of the 16 SHAs (with workshops or tech assistance) selected one or more preservation treatment to implement.

Iowa

A field review of several pavements was conducted on June 3, 2015. The purpose was to evaluate the condition of the pavements and discuss recommendations for future improvements. The following individuals were present:

Jared Bottjen – Iowa DOT District 2
Chris Brakke – Iowa DOT, Ames
Mark Callahan – Iowa DOT District 2
John Cunningham – ICPA (at the time)
Jerod Gross – Snyder & Associates, Inc.
Todd Hanson – Iowa DOT, Ames
Dale Harrington – Snyder & Associates, Inc., now HCE Services
Nick Humpal – Iowa DOT District 2
Keith Norris – Iowa DOT District 2
Jon Ranney – Iowa DOT District 2
Gordon Smith – ICPA, now National CP Tech Center
Barry Thede – Iowa DOT District 2

The following road segments were identified for review:

US 63 from US 20 to US 218
US 218 from US 63 to IA 58
IA 58 from US 20 to Hudson (Figure B-3)
US 20 from Grundy County Line to I-380

©2012 Google

Figure B-3. IA 58

Decision Matrix

After the pavements were reviewed, a decision matrix was developed to help determine priorities for the recommended improvements. The matrix listed the pavement sections, various strategies for improvement, risks if improvements delayed, unit costs, project costs per mile, and estimated project costs per pavement section. Unit costs were developed from similar preservation projects already completed.

Field Review

The routes were then divided into 11 pavement sections based on the pavement conditions. Section 11 was later divided into two sections: Section 11 from Hudson Road to Iowa 21 and Section 12 from Iowa 21 to US 218. The pavement sections are shown on the map in Figure B-4 (and additional information on Section 12 is not included in this task report).

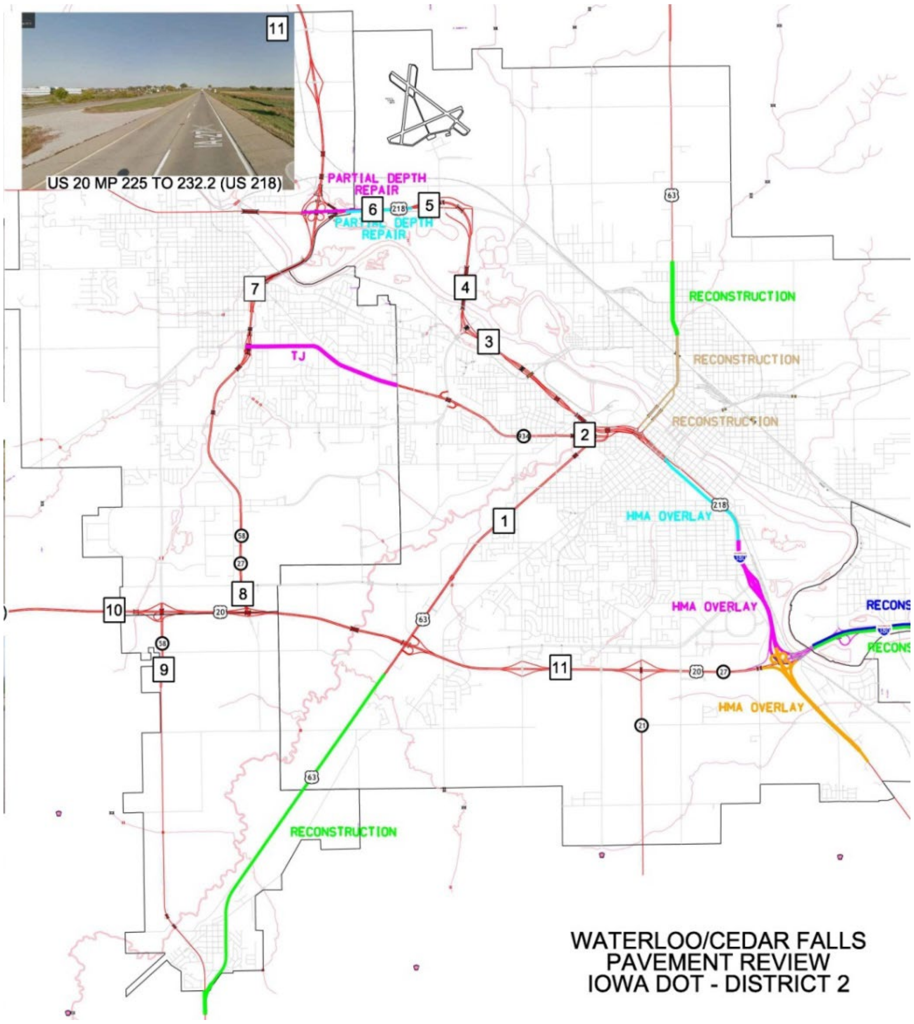


Figure B-4. Section map for Iowa field reviews

Section 1 – NB and SB US 63 from MP 160 to 162.5

Pavement History

- Existing composite section (HMA over PCC) (Figure B-5)
- 3.5 in. HMA in 2000 (1.5 in. and 2 in. lifts)
- 3 in. HMA in 1986 (1.5 in. lifts)
- 10 in. PCC on 6 in. GSB in 1969
- 2013 Traffic 5,300–6,000

©2012 Google

Figure B-5. US 63

Observations and Discussions

- Pavement has what appears to be quarter-point reflective joints.
- Microsurfacing was discussed as a rehabilitation option, but it is not a long-term treatment.
- This pavement is a cold-in-place candidate with 2.5 in. or more HMA surface, depending on truck traffic
- For a long-term solution, one option is a concrete overlay constructed under traffic (head to head).
- Intersection pavement has experienced heaving. The City of Waterloo plans to replace the intersection pavement at Ridgeway. The Iowa DOT needs to determine what is causing the heaving. It may be related to water.
- The objective is to provide a good traveling surface in 2–3 years that may last 15 years. If funding is limited and the public has to wait longer to do a concrete overlay, that is something to consider.

Recommended Strategies

- Cores should be taken near joints and quarter-points to verify the condition of underlying PCC pavement.
- Develop a cost estimate for cold-in-place HMA and an unbonded PCC overlay with 4 in.+ thickness. Both options will require paved shoulders, so these costs need to be included in an estimate. The design should be based on a 15-year design life. Truck traffic needs to be verified for thickness design.

Section 2 – US 63 (PCC Pavement from the End of HMA Overlay to US 218, including On-Ramps)

Pavement History

- 10 in. PCC pavement on 6 in. GRC in 1992 (Figure B-6)
- 2013 Traffic 6,200–7,100

©2012 Google

Figure B-6. US 63

Observations and Discussion

- PCC is showing early signs of joint deterioration.
- This would be a good candidate for backer rod removal and partial-depth patches. It is critical that we don't wait to rehabilitate this pavement or it could become a much more costly rehabilitation. Cores should be taken to verify there is not bottom up deterioration.
- The paved shoulder is not behaving similarly to the mainline roadway.

Recommended Strategy

This section should be rehabilitated with partial-depth patching. The following steps are recommended:

- Cores should be taken to verify depth of deterioration. The cores should be taken at areas where distress is worsening and at edge areas where deterioration is spreading outward.
- A distress count should be made to estimate cost and develop the project.
- The project should include removal of backer rod and joint sealing to slow the deterioration.

Section 3 – US 218 from MP 182 to 184.3

Pavement History

- 10 in. PCC pavement on 6 in. GRC in 1992 (Figure B-7)
- 2013 Traffic – Unknown

Figure B-7. US 218

Observations and Discussion

- PCC is showing more advanced stages of joint deterioration as compared to the area near the on ramps. Joints have received DURAPATCH treatment. Deterioration depth is approximately 4 in. based on visual observations during patching operations.
- Aggregate is mainly from the Franta quarry.
- Cores 19–24 were taken from MP 184 all the way to IA 58. Generally, the cores look good, except for the upper 1/3 of pavement at the joints, which would indicate that a partial-depth patch is a good option.
- Deterioration was observed in both WB and EB directions.

Recommended Strategy

This section should be rehabilitated with partial-depth patching. It is critical that this section be rehabilitated as soon as possible. If nothing is done soon, the pavement joints can no longer be repaired by partial-depth patching. Large full-depth repair of the pavement will be required and it may not be cost effective to complete. The deterioration has been observed over the last 10 years. The deterioration condition has not changed significantly but improvements need to be made to avoid more costly improvements in the future. The following steps are recommended:

- Cores should be taken to verify depth of deterioration. The cores should be taken at areas where distress is worsening and at edge areas where deterioration is spreading outward.
- A distress count should be made to estimate cost and develop the project.
- The project should also include removal of backer rod and resealing of joint cavity to slow the deterioration.

Section 4 – US 218 from MP 184.5 to MP 185.6

Pavement History

- 10 in. PCC pavement on 6 in. GRC in 1989 (Figure B-8)
- 2013 Traffic – 20,600

©2012 Google

Figure B-8. US 218

Observations and Discussion

- This north-south section is generally in good condition. There is some limited joint deterioration near MP 185.7.
- There is no change in maintenance or snow removal over the route. Maintenance is completed with plain salt and salt brine. Chloride is not used.
- There was general discussion on how backer rods can lead to deterioration.

Recommended Strategy

The following is recommended as a future need:

- Remove backer rod and reseal joint cavity

Section 5 – US 218 from MP 186.3 to MP 187

Pavement History

- 10 in. PCC pavement on 6 in. GRC in 1989 (Figure B-9)
- 2013 Traffic – 30,700

Figure B-9. US 218

Observations and Discussion

- This is the worst stretch of US 218 on the mainline highway, showing the most advanced stages of joint deterioration, which in some cases are approximately 12 in. wide. Deterioration may be too far advanced for partial-depth patching only. A cost estimate should be done to evaluate the feasibility of partial- and full-depth repair against full reconstruction.
- The ramp near MP 186.3 received partial- and full-depth repair in fall 2014 and is performing well.
- The Iowa DOT should take pavement cores to determine the depth of the deterioration. This should be done at the longitudinal and transverse joints and just outside the joint deterioration to determine the width of the deterioration.
- The estimate of percentages of partial-depth patching will change over time. Planning and programming can be done now, but a representative should come out before bidding and do an actual count. This section is small enough that a count can be made. The most costly solution is a full-depth repair project where deterioration is too great and a contractor needs to be paid for full-depth patching after removal.
- The WB direction is in worse condition than the EB direction.

Three options were discussed for this 0.7-mile section:

- Extensive full-depth repair and partial-depth repair with diamond grinding.
- Full reconstruction.
- Full 3R repair patch and HMA overlay. Mill out the deteriorated joints and fill partial-depth patches with HMA.

Recommended Strategies

- Cores should be taken to verify depth of deterioration.
- A distress count should be made to estimate cost for each of the three options.

Section 6 – US 218 from MP 187 to IA 58 (Recently Rehabilitated)

Pavement History

- 10 in. PCC pavement on 6 in. GRC in 1989 (Figure B-10)
- 2013 Traffic – 30,700

Figure B-10. US 218

Observation and Discussion

- MP 187 NB received partial-depth patching on nearly every joint.
- There was discussion on testing a sealant in an area of partial-depth patching. This area would be a good candidate. Type of sealant used needs to be verified by ICPA.
- This section did not receive diamond grinding but rides very well.
- Question for the district: What type of equipment was used to mill the partial-depth areas?

Recommended Strategies

- No recommendations are needed for this section.

Section 7 – IA 58/27 from MP 183.5 to 185

Pavement History

- 10 in. PCC pavement on 6 in. GRC in 1994 (Figure B-11)
- 2013 Traffic – 21,800

Figure B-11. IA 58

Observations and Discussion

- Transverse joints are showing early signs of deterioration in just a few areas located on the southbound lane south of East 18th Street.
- MP 184.4 south is showing early signs of joint deterioration on longitudinal joints. The deterioration is in the early stages.

Recommended Strategies

This section should be rehabilitated by removal of the backer rod and resealing of the joint cavity. In the case of small and isolated surface holes, consideration should be given to patching with rapid-set concrete similar to bridge patching.

The section from Mayors Bridge (pedestrian overpass) to Ridgeway Avenue is not being evaluated. It is planned for intersection improvements (Viking Road interchange reconstruction).

Section 8 – IA 58/27 South of Ridgeway Avenue and South of US 20

Pavement History

- 10 in. PCC pavement on 6 in. GRC in 1993 (Figure B-12)
- 2013 Traffic – 16,500

©2013 Google

Figure B-12. IA 58

Observations and Discussion

- This was constructed when US 20 was built and observations show that the pavement has been saturated. This section has been repaired with full-depth patches on transverse joints and some full panel replacement.

Recommended Strategies

- This section should be planned for reconstruction with a drainable base and subdrains if an outlet is available.

Section 9 – IA 58/27 South of US 20 to Hudson

Pavement History

- HMA composite section (Figure B-13)
- 9 in. PCC on 4 in. HMA
- 2013 Traffic – 3,790

Figure B-13. IA 58

Observations and Discussion

- Random cracks are routinely sealed.
- Truck traffic has increased from new co-op and industrial plants in Cedar Falls.
- The subdrain installed last fall from the end of the ramp to south (both sides) last year has helped. Drainage in shoulder has improved. Previously, shoulders were pumping.
- Pavement is showing signs of longitudinal joint deterioration. Subdrains should improve condition. Some displacement at centerline was observed.
- Curb intake on SB stretch was obstructed with trash.
- Northbound pavement near US 20 ramps has accelerated joint deterioration and has received patching on nearly every joint.
- PCC section is about 1.1 miles; HMA composite section is about 3 miles.

Recommended Strategies

This pavement should be evaluated for partial-depth patching. The following steps are recommended:

- Cores should be taken to verify depth of deterioration. The cores should be taken at both longitudinal joints and transverse joints.
- A distress count should be made to estimate cost and develop project.
- The project should also include backer rod removal and resealing of the joint cavity to slow the deterioration.
- For the HMA section, there are two possible options: unbonded PCC overlay and a traditional 3R cold-in-place HMA overlay.

Section 10 – US 20 from MP 223.3 to MP 224

Pavement History

- 9.5 in. PCC on 4 in. ECB in 1985 (Figure B-14)
- 2013 Traffic – 13,600 to 16,600

Figure B-14. US 20

Observations and Discussion

- Westbound US 20 from IA 58/27 to Hudson Road (IA 58 South) is in worse condition than westbound west of Hudson Road.
- District 2 maintenance goes west all the way to Dike.
- Backer rope is present in outer joint between travel lane and shoulder.

Recommended Strategies

The recommended rehabilitation includes partial-depth patching and joint resealing. This should be set up as a partial-depth patching project with joint resealing and removal of backer rod. Some full-depth repair may be necessary. The following steps are recommended.

- Cores should be taken to verify depth of deterioration. The cores should be taken at both longitudinal joints and transverse joints.
- Distress count should be made to estimate cost and develop project.
- The project should also include removal of backer rod and resealing of joint cavity to slow the deterioration.

Section 11 – US 20/IA 27 (EB) from Hudson Road to US 218, including IA 21 Ramps

Pavement History

- 9.5 in. PCC on 4 in. CTB in 1985 (Figure B-15)
- 2013 Traffic – 26,300 to 29,400

©2012 Google

Figure B-15. IA 27

Observations and Discussion

- This section of mainline pavement is in good condition.
- Some longitudinal DURAPATCH has been placed in limited areas.
- Safety for maintenance personnel is a concern due to the heaving of the shoulder.

- The backer rod along the shoulder pavement joint should be removed and the joint sealed.
- There is a section of shoulder pavement near IA 21 that should be removed due to safety concerns.
- District 2 will send information on areas east of I-380 (good and bad areas).

Recommended Strategies

Shoulder pavement should be considered for full replacement. The section of eastbound US 20 at MP 229.4 has a paved shoulder that has heaved above the mainline. The following steps are recommended:

- Check to see if subdrains are present in this area.
- If they are present, identify the outlets and clean the lines.
- Areas with excessive heaving should be corrected to facilitate surface drainage by full-depth replacement.

Missouri

Open House April 18, 2017

The City of O'Fallon, along with the sponsors listed below, held an open house with a classroom training session at the St. Peters, Missouri, City Hall (Figure B-16). Additionally, a field session was held to show the actual milling and removal operations along with concrete placement using concrete donated by American Ready Mix Companies.

Figure B-16. Classroom session at St. Peters, Missouri, City Hall

Here is a link to a video about the training session shown on the O'FallonTV channel: https://youtu.be/CViC-5BM2Cw.

Sponsors

- City of O’Fallon – Steve Bender, Tony Steele, Craig Salonies, Jay Herigodt
- City of O’Fallon street maintenance crews
- City of St. Peters
- National CP Tech Center (represented by Dale Harrington, Dan Frentress)
- FHWA
- ACPA, Missouri/Kansas Chapter – Todd Latorella, Ken Liescheidt
- Kienstra Ready Mix Company – Joe Garza
- MoDOT
- Keystone Engineering – Ches Latham
- American Milling Services – Dustin Lee
- Highway Materials, LLC – Jake Steinberg
- Concrete Council of St. Louis – Oliver (Skip) Dulle

Background

O’Fallon, Missouri, which is near St. Louis, Missouri, has an extensive concrete pavement system. Many of these streets were placed by developers and not fully inspected during construction. O’Fallon was the fastest growing city in the state at the time and one of the fastest growing cities in the country. This expansion stressed the inspection program that the city had in place, and these streets were accepted by the city council after construction was completed. Due to this construction system, it is likely that the coarse aggregate used in the construction could change a number of times along any length of the street depending on which developer constructed the street.

This open house event was part of an ongoing effort by the National CP Tech Center to assist O’Fallon officials in determining why their concrete pavements have suffered deterioration at an early age, and to propose a remedy. Similar problems have affected other cities located near O’Fallon.

In an August 2, 2016 report (P-933) completed by Concrete Research & Testing (CRT), LLC, it was explained that these concrete pavements are suspected of suffering from both alkali-carbonate reaction (ACR) and/or alkali-silica reaction (ASR) (Figure B-17). The result is a failed concrete showing a spider-like crack pattern starting at the joint area.

Figure B-17. Damage appearing as spider-like cracks around the joint area

O'Fallon, in conjunction with five other agencies, formed the Eastern Missouri Pavement Consortium (EMPC) to regulate and control concrete mixes uniformly across municipal boundaries. For placement of future concrete, the EMPC developed a procedure for aggregates to undergo a series of tests such as the ASTM 1260 16-day mortar bar expansion test.

After the problem was identified in the report by CRT, LLC, the National CP Tech Center hired Dan Frentress to help train the O'Fallon street division on how to place a concrete partial-depth patch. Frentress used the techniques outlined in the *Guide for Partial-Depth Repair of Concrete Pavements* published in 2012 by the National CP Tech Center.

Previous Patching

Normally, concrete partial-depth patching is not used in pavements suffering from ACR or ASR distress because the pavement may continue to deteriorate around the patch. The city of O'Fallon has had good success with 2-ft-wide asphalt patches placed the entire length of the joint (Figure B-18). However, the aesthetics of this solution were poorly received by residents.

Figure B-18. 24-in. wide asphalt patch

Partial-Depth Demonstration

The public asked the city to find a concrete patch that would work. It was decided to try a concrete partial-depth patch as a more cost-effective solution than a full slab replacement. The maintenance department of O'Fallon was willing to try a concrete partial-depth patch that could last longer than the asphalt patches and be more acceptable to the public. Concrete partial-depth patches can typically cost 33% of the cost of a full slab replacement.

O'Fallon hosted an open house for other agencies to watch the construction of the concrete partial-depth patches. There were 125 people in attendance from at least 15 different agencies.

As part of the construction demonstration, a milling head cut a notch 2 in. deep, centered on the distressed joint, leaving a 10 in. by 2 in. deep groove in the concrete pavement joint with a tapered side wall at an approximately 45-degree angle (Figure B-19).

Figure B-19. Milling head attached to skid steer for concrete removal

Since the Keystone mill only leaves a 10 in. wide top, multiple passes were needed to remove all of the asphalt material in the existing patch. A skid steer with a pick-up broom was used to clean up the rubble (see Figure B-20).

Figure B-20. Surface after milling and broom cleaning

Figure B-20 is a completed milled joint showing the tapered edge built by the Keystone head and the deteriorated concrete at the bottom of the joint. This deteriorated concrete was removed by hand with a small jackhammer using a 3-in. blade bit.

Sand blasting was used to clean the old concrete and prepare the new surface for a bond between the patch material and the existing concrete. Debris was confined by using hand-held burlap.

Due to the variable nature of the deteriorated concrete at the bottom of the joint, clean sand was used to fill the void at the bottom of the joint and ¼ in. insulation board was used to provide relief (Figure B-21).

Figure B-21. Installing compression relief board

After the concrete reached an opening strength of 1,800 psi (MoDOT specification), the insulation board was sawed out and replaced with joint sealant.

The other method demonstrated was grooving and sawing to create the compression relief. After concrete placement, the concrete finisher grooved a ¾-in. deep notch using a common sidewalk grooving tool. Grooving depth was set at ½ in. deeper than the bottom of the old joint.

A bonding grout of 1 part cement, 1 part sand, and 1 part water was placed in the opening in front of the concrete and worked into the edges of the patch.

The mixture used was comprised of 800 lbs of Type I cement and a 50/50 blend of 3/8 in. coarse aggregate and sand. The admixtures used were an air entrainer, a Type A water reducer, a retarder, and $CaCl_2$.

Curing compound was applied after the surface had been finished.

Lessons Learned

Because of the deteriorated concrete at the bottom of the joint, a lot of the holes were full depth. An early failure was due to a large hole at the intersection of the longitudinal and transverse joints (Figure B-22).

Figure B-22. Cracked PDR in intersection area

While this failure was unfortunate, it was not unexpected. Concrete partial-depth patching is a learned skill and involves doing all the steps correctly every time. Some failures may occur as a crew learns by practicing. This failure was also likely exacerbated by the depth of the damage in the existing pavement. The crew placed at least 200 linear ft of joint repair and, as of October 2017, this was the only failure.

Appendix C:

Concrete Overlay Field Application

Final Task Report
December 2018

Principal Investigator
Peter Taylor, Director
National Concrete Pavement Technology Center, Iowa State University

Authors
Dale Harrington, HCE Services
Rabindra Pariyar, Snyder & Associates, Inc.
Melisse Leopold, Snyder & Associates, Inc.
Gary Fick, Trinity Construction Management Services, Inc.

Manager
Dale Harrington, HCE Services

Team Leaders
Gary Fick, Trinity Construction Management Services, Inc.
Mark B. Snyder, Pavement Engineering and Research Consultants
Jerod Gross, Snyder & Associates, Inc.

Sponsored by
Federal Highway Administration

A report from
National Concrete Pavement Technology Center
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-5798 / Fax: 515-294-0467
cptechcenter.org

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CONCRETE OVERLAY ACKNOWLEDGMENTS

The authors would like to thank the Federal Highway Administration (FHWA), the technical advisory committee, and the expert team members who were involved in the concrete overlay technology transfer efforts for this project.

EXECUTIVE SUMMARY

Concrete Overlay Field Application was a component of the Technology Transfer of Concrete Pavement Technologies cooperative agreement started in September 2013 between the Federal Highway Administration (FHWA) and the National Concrete Pavement Technology (CP Tech) Center.

The objective was to continue the development of a national, multi-state concrete overlay construction program. Many state representatives participated out of a desire to learn about concrete overlays and to demonstrate and document the concepts and benefits of concrete overlays.

Between 2013 and 2018, 29 states were assisted with concrete overlay technology training. This training consisted of workshops, site visits, and technical assistance. Technical assistance included recommendations on design, specifications, and construction. Training is summarized as follows and in Figure C-1 and Table C-1.

- Number of states that held workshops: 32 in 20 states
- Number of states with site visits (where candidate overlay projects were field reviewed): 20
- Number of states that received technical assistance: 14
- Number of states that constructed, or plan to construct, overlays in the next two years: 13
- Number of overlay projects constructed, or will be constructed, in the next two years: 37
- Number of people trained: About 1,400

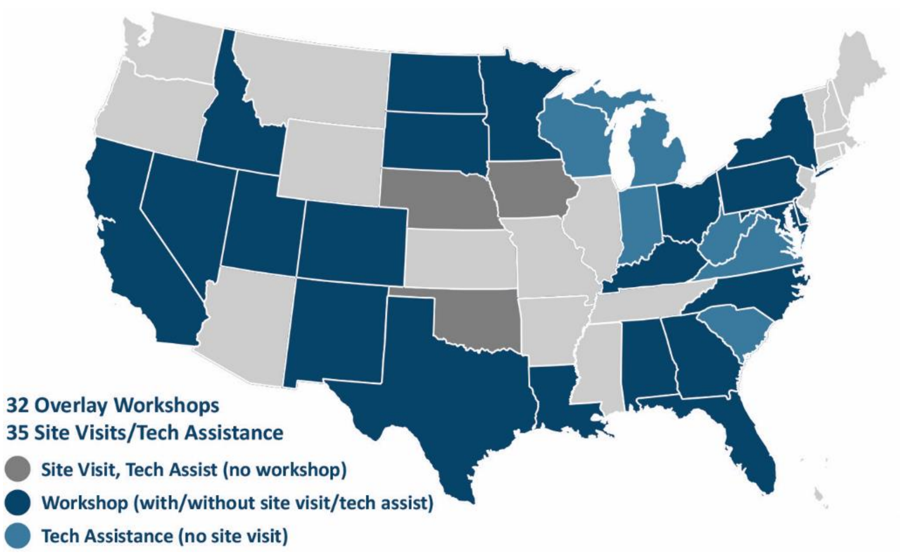


Figure C-1. Overlay workshops, site visits, and technical assistance provided to states

Table C-1. Summary of overlays workshops, site visits, and technical assistance provided to states

State	Workshop	Site Visit	Tech Assistance
Alabama	X	X	X
California	X	X	X
Colorado	X	X	
Florida	X		
Georgia	X	X	
Idaho	X	X	X
Indiana			X
Iowa		X	X
Kentucky	X	X	X
Louisiana	X	X	
Maryland	X		
Michigan			X
Minnesota	X	X	
Nebraska		X	X
Nevada	X	X	
New Mexico	X	X	
New York	X	X	
North Carolina	X	X	
North Dakota	X	X	
Ohio	X	X	
Oklahoma		X	X
Pennsylvania	X	X	
South Carolina			X
South Dakota	X	X	X
Texas	X		
Utah	X	X	
Virginia			X
West Virginia			X
Wisconsin			X

BACKGROUND

Concrete overlays can serve as cost-effective maintenance and rehabilitation solutions for nearly all combinations of existing pavement types and conditions. They have been used successfully in the US since 1913. Factors that make concrete overlays a viable choice for pavement resurfacing and rehabilitation include the following:

- Sustainability – Concrete overlays provide cost-effective, long-life solutions and are recyclable
- Asset Management – Existing pavements are fully utilized as a supporting layer
- Economics – Concrete overlay~~s~~ costs are very competitive with alternative pavement solutions on a volume basis
- Maintenance of Traffic – When necessary, concrete overlays can be constructed without closing the roadway to traffic

Despite this long history of performance, a number of state highway agencies (SHAs) had not embraced the use of concrete overlays as a standard practice until approximately ten years ago. A factor that has contributed to this limited adoption by SHAs is the perception that concrete overlays are expensive and difficult to construct.

In 2007, the FHWA and the concrete industry recognized the value that overlays could provide in increasing the life of pavements in the US. In 2008, the FHWA and the National CP Tech Center at Iowa State University entered into a cooperative agreement that included the establishment of the Concrete Overlay Field Application effort to educate and provide technical assistance on concrete overlays to SHAs. During the five years of the agreement, the team conducted workshops and site visits on potential projects in 24 states. At the end of this period nine states had built concrete overlays and there was the potential for many more to be constructed.

It was also learned that a single visit to a state may not be sufficient to address all their concerns. As a result, a second five-year Concrete Overlay Field Application effort began in 2013 under a new cooperative agreement.

As discussed below, technical assistance was provided to 29 states between 2013 and 2018, with 37 concrete overlay projects either constructed or planned to be constructed by 2020.

OBJECTIVES

The primary objective of the field application work was to continue to develop a concrete overlay construction program across the US. To accomplish this, SHAs were led through the concept, design, and construction phases of a concrete overlay by a team of experts. These projects provided hands-on experience to the SHAs and contractors, which could then be utilized on future concrete overlay projects.

This objective was addressed by adopting the following principles:

- The National CP Tech Center team of experts was tasked with providing unbiased technical assistance to SHAs from project conception through construction
- SHAs were provided with the tools to develop expertise internally and conduct internal training
- SHAs were regularly provided with the latest technical developments and construction methods including technical documents on design features and construction requirements, specifications, performance history, and sample design plans and construction documents

TEAM MEMBERS

The organizational chart shown in Figure C-2 illustrates the management approach used by the National CP Tech Center on this task.

Figure C-2. Overlays organizational chart

The FHWA representative from each state was asked to attend each site visit in their state.

The technical advisory committee (TAC) members were respected and qualified individuals with experience in the design and construction of concrete overlays:

- Gina Ahlstrom, FHWA
- Andy Bennett, Michigan Department of Transportation (MDOT)
- Brent Burwell, Oklahoma/Arkansas Chapter, ACPA
- Mike Byers, Indiana Chapter ACPA
- James Cable, Cable Concrete Consultation LC
- Tom Cackler, Woodland Consulting, Inc.
- Bill Cuerdon, American Concrete Pavement Association (ACPA), New York State Chapter (ACPA–NYS)

- John Cunningham, Aggregate & Ready Mix Association of Minnesota (formerly with Snyder & Associates, Inc.)
- Dan DeGraaf, Michigan Concrete Association
- Jim Duit, Duit Construction Co., Inc.
- Eric Ferrebee, ACPA
- Angela Folkestad, Colorado/Wyoming Chapter – ACPA
- Jim Grove, FHWA
- Todd Hanson, Iowa DOT
- Dan King, Iowa Concrete Paving Association
- Todd LaTorella, ACPA, Missouri/Kansas (MO/KS) Chapter
- Kevin Maillard, OHM Advisors
- Kevin McMullen, Wisconsin Concrete Pavement Association
- Kevin Merryman, Iowa DOT
- Greg Mulder, Iowa Concrete Paving Association and Iowa Ready Mixed Concrete Association
- Mark Pardi, Ohio Concrete Construction Association and ACPA, Ohio Chapter
- Jason Reaves, South Dakota Chapter, ACPA
- Randy Riley, Formerly Illinois Chapter, Inc. – ACPA
- Matt Ross, ACPA, MO/KS Chapter
- Ray Seipp, ACPA, Mid-Atlantic Chapter
- Gordon Smith, National CP Tech Center
- Chris Tull, CRT Concrete Consulting, LLC
- Sam Tyson, FHWA
- Jeff Uhlmeyer, Washington State DOT (WSDOT)
- Jerry Voigt, ACPA
- Leif Wathne, ACPA
- Jimie Wheeler, Illinois Chapter, Inc. – ACPA
- Paul Wiegand, Statewide Urban Design and Specifications Program (SUDAS)
- Tom Yu, FHWA
- Matt Zeller, Concrete Paving Association of Minnesota

WORK PLAN

After initiation of the contract, SHAs and industry representatives were contacted to solicit participation in the field application work. An effort was made to target states that either had limited or no experience with the design and construction of concrete overlays. Interested SHAs were encouraged to schedule a concrete overlay workshop and an expert team site visit to their state. The typical steps were as follows:

- Initial contact with the SHA
- Follow-up with project objectives and proposed activities
- Send the SHA a flyer that could be used to send to potential participants
- Conduct concrete overlay workshop to educate stakeholders about concrete overlays

- Conduct expert team site visit to review potential projects
- Prepare site visit report by the team, detailing recommendations for the projects reviewed, and listing the next steps to overlay implementation
- Provide guidance from the expert team throughout the design, bidding and construction phases of the project
- Prepare a final report documenting the entire implementation process

A total of 29 states were provided with workshops, site visits, or advice on projects. About 1,400 individuals were trained. Twenty states were visited by the expert teams and 32 concrete overlay workshops were held in 20 states, as shown earlier in Table C-1 and Figure C-1.

From September 2013 through September 2016, 11 different state DOTs that received the overlay training and support under this agreement constructed 15 projects, covering approximately 1,500 lane miles, representing more than $750 million in construction costs. The activities and outcomes of states that participated in the concrete overlay field application effort are summarized in Table C-2.

Table C-2. Overlays technical assistance, training, and support provided

State	Type of assistance	Dates	Expert Team Visit(s)	Proposed Overlay	Comments
Alabama	Workshop	11/21/13 2.5-day workshop with 0.5 day on overlays	11/20/13		
	SR 20 field review	3/4/14	3/28/14	UBCOA, 0.74 mi.	First phase built 2015
California	I-8 tech assistance	8/8/14		Unbonded CRCP, 2 segments, 22 mi.	Built 2017/2018
	Workshops	Sacramento 2/24, Fresno 2/26, Fontana 3/17, San Diego 3/19/15	2/23–2/26/15 and 3/17–3/19/15	I-80 BCOC SR 101 UBCOA SR 14 UBCOC SR 86 BCOA	
	Workshop on SR 113 and tech assistance	3/1/17	Woodland	BCOA	Let in 2018
	SR 247 tech assistance	1/5–2/23/18	San Bernardino	4.5 in. BCOA	Let 10/2018
Colorado	Workshops	5/10 and 5/15/16	5 sites in Denver metro area and I-70	UBCOA	
Florida	Workshop	11/10/15			
Georgia	Workshop and site visit	10/11/17	3 locations in Atlanta		
Idaho	Workshops and tech assistance	Pocatello 11/18, Boise 11/19, Coeur d'Alene 11/20/13	US 91 Chinden Blvd. US 95	BCOA and UBCOA	
	I-84 site visit	10/5/17	Glen Ferry	UBCOC	Let fall 2018
	I-84 site visit	10/5/17	Mountain Home	UBCOA	In concept stage
Indiana	I-65 tech assistance	11/13/14			
Iowa	Overlay tech assistance	6/3/15	Field review US 52, 218, and 20 and IA 58		
Kentucky	Workshop and field review	3/14–3/15/17	Frankfort KY Rt. 9002/Bluegrass Parkway	BCOA	Built 2 project sections
Louisiana	Workshop	8/15/17	Baton Rouge		
Maryland	Overlay presentation	3/17/15			

State	Type of assistance	Dates	Expert Team Visit(s)	Proposed Overlay	Comments
Michigan	I-80 tech assistance	10/31/14	3 miles	UBCOC	
Minnesota	Workshop	5/16/14	4 hr. workshop on bonded overlays of asphalt	4 in. BCOA	Built MN 24
	Workshop	10/27–10/28/15	Dodge County		
Nebraska	I-80 field review and tech assistance	5/8/15	Examination of composite section near Big Springs where asphalt overlay had been removed to expose the underlying JRCP	UBCOA	
Nevada	Workshops	11/18 and 11/20/14			
	Workshop and site visit	1/28/15	Site visit on possible overlays after workshop		
New Mexico	Workshop and field review	6/3–6/5/14	3 team members held field review of 3 regional sites	UBCOA and BCOA	Built NM 136
New York	Workshops	6/16 and 6/18/15	Site visits on 6/15 and 6/17/15		
North Carolina	Workshop	12/17/13	12/16/13	10 in. UBCOC	Built I-85
North Dakota	Workshop	11/18/15	11/17/15	BCOA/UBCOA	
Ohio	Workshop	3/30–3/31/15 10/22/13	Site visit; Michigan DOT team	Repair of overlay on I-70 and 6 in. bonded overlay on SR 151	Built SR 151
Oklahoma	Site visit and tech assistance	2/18/15	I-40 debonding had occurred particularly in areas of milled dowel bar retrofit	UBCOC	
Pennsylvania	Workshop and conference call	3/27 and 5/21/14	Summer 2014	BCOC, BCOA, UBCOC	Built SR 504; let SR 119 and I-81 in 2018
	Workshop	5/3/16			
South Carolina	Tech assistance	1/1/18	Correspondence about non-woven geotextiles		
South Dakota	Overlay/Preservation workshop, site visit, and tech assistance	2/10–2/11/15	2 team members	UBCOC and UBCOA	Built 15 overlays 2014–18
	Workshop	12/10/15			
Texas	Workshop	3/8/13	Williamson County		
Utah	Workshop and field review	8/19–8/21/13	Salt Lake City 6 sites	UBCOC and UBCOA	Built I-80, SR 201, I-215, I-15; I-80 near Parley’s Canyon for 2020

State	Type of assistance	Dates	Expert Team Visit(s)	Proposed Overlay	Comments
Virginia	Tech assistance	10/6/15	Discussion on bond breaker for UBCOC and patching requirements	7 in. UBCOC	
West Virginia	WV Rt. 30 tech assistance	8/12/15	Conference call to discuss what, if any, pre-overlay repairs needed prior to placement of bond breaker for UBCOC	UBCOC	Built 2016
Wisconsin	Tech assistance	June 2014	Upward curling on Dodge County CTG A Road	7 in. UBCOA	Built 7/2013

CONCRETE OVERLAY SITE VISITS AND WORKSHOPS (2013–2018)

One-day workshops were typical. The ratings for the workshops averaged 1.4 out of 5, with 1 being the best score. Technical presentations were developed for national audiences and included face-to-face presentations, web-based training, and webinars.

Site visits typically followed the workshops and included 4 to 7 hours of technical evaluations of potential overlay project candidates, with the state representatives in attendance. Following the site visits, an office review was held with verbal recommendations from the expert team to the state, followed by a written report with recommendations.

Examples of Concrete Overlay Workshops Comments

What were the most worthwhile parts of this program?

California

- Excellent explanation of the topics
- Enjoyed the whole day. Most worthwhile was learning about the subject since I had zero prior experience.
- Different strategies were discussed which was helpful. Also, did a good job of explaining the pros and cons of each strategy.
- All information was useful. Instructors/presenters were clear and answered all questions
- Good information of available alternatives and lessons learned
- Great field experience and descriptions that enhanced the discussions

Colorado

- Everything was worthwhile – excellent
- Overlays covered from multiple perspectives
- Overlay Guide is a fantastic resource
- Excellent presentation skills
- Thank you for a very interesting seminar
- Learning new methods, my last experience w/PCCO was 17 years ago

Florida

- The experience of the speakers, many good topics were discussed
- Learning about the various overlay options involving concrete
- Examples/case studies and theory behind performance

Idaho

- The experience and knowledge of the instructors
- All the information gained from this program
- Good balance of general concepts, as well as sufficient detail to promote the increased consideration of use of concrete overlays
- The vast knowledge of the speakers

Kentucky

- Easy environment to ask questions
- Have another workshop
- This was a very important workshop

Louisiana

- Pertains to job; another tool in toolbox
- Knowledge of the instructors; both were very experienced

Nevada

- There was a lot of new information
- Experience and knowledge of instructors
- The discussion of bonded concrete overlays, Nevada needs to justify their bond breaking theory

New Mexico

- Seeing the benefits of concrete overlays, very informative
- Addressing our concerns about using a new process – concrete overlays
- Access to state of the art answers on design and material and construction related issues
- Presentation and discussions were very informative

New York

- Having very little experience with pavement working terms, felt the instructors did great to constantly bring real life and current examples throughout each section. Great understanding and being able to connect ideas.
- Going over the many uses of the different types of overlays. Letting folks know that there are other “tools in the toolbox” other than milling and filling.
- Very interesting. This was my first exposure to this topic and the first two presentations were very informative.

- Consider all parts very worthwhile and beneficial for our work

North Carolina

- All very good
- There were some various items that were new to me or were explained in more detail that I have heard in the past; good pace
- Very good exposure to concrete overlays

North Dakota

- All information was beneficial
- The materials provided and the quality of the materials
- Great job!

Pennsylvania

- Lots of good information and examples
- Good overall knowledge of instructors
- Good overview of concrete overlays as a design option, using the existing roadway for structural strength on good base
- All good information

Texas

- Use of concrete as an overlay
- New knowledge for concrete being recyclable
- Good examples of concrete roads
- Advantages of concrete pavement
- Should repeat in two years
- All worthwhile

Utah

- The information was great.
- Great overview of overlays
- Real world applications

CONCRETE OVERLAY WEBINARS

The following webinars were hosted by the American Concrete Pavement Association (ACPA) and presented by Gary Fick, Mark B. Snyder, or Dale Harrington:

- Intro to Concrete Overlays
- Concrete Overlay Thickness Design
- Performance History of Concrete Overlays
- Materials for Concrete Overlays
- Concrete Overlay Design Details/Joints
- Maintenance of Traffic for Concrete Overlays
- Concrete Overlay Construction, Maintenance, and Rehabilitation

CONCRETE OVERLAY GUIDELINES DEVELOPED

Under this cooperative agreement, the National CP Tech Center published seven new or updated concrete overlay technical documents:

- 2014 *Guide to Concrete Overlays: Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements*, Third Edition
- 2014 *Performance History of Concrete Overlays in the United States*
- 2014 *Preservation and Rehabilitation of Urban Concrete Pavements Using Thin Concrete Overlays*
- 2014 Concrete Overlays (Chapter 11) in *Concrete Pavement Preservation Guide*, Second Edition
- 2016 *Guide Specifications for Concrete Overlays*
- 2018 *Guide for the Development of Concrete Overlay Construction Documents*
- 2018 five Concrete Overlay chapters in *Guide for Concrete Pavement Distress Assessments and Solutions*

LESSONS LEARNED

Through the concrete overlays field application efforts and research projects, many lessons were learned that have resulted in improved practices at various stages of concrete overlay projects. This section includes highlights of recommendations based on lessons learned for the following:

- Project Evaluation and Selection
- Concrete Overlay Design
- Plans and Specifications
- Sequence of Construction and Maintenance of Traffic
- Concrete Overlay Construction

Project Evaluation and Selection

- Utilize coring, falling weight deflectometers, and “as built” plans to investigate existing pavement layer conditions and thicknesses to determine which type of overlay is appropriate for a given roadway.
- If existing asphalt will be milled, take cores of asphalt to ensure that adequate (3–4-in.) asphalt depth will remain after milling as a design minimum and to allow trucks loaded with concrete to travel on it with minimal damage to the milled surface.
- In freeze-thaw climates and/or areas with expansive soils, evaluate existing pavements in spring and summer to identify critical pavement distresses that need to be accounted for in the overlay design.
- Identify all vertical constraints (including bridges, utilities, loop vehicle detectors, curbs, barriers, ramps, driveways, guardrails, and other structures) that may impact construction and develop a plan to mitigate the constraints.

Concrete Overlay Design

- Consider all partial and full detour options and their impacts on construction.
- Choose the most appropriate overlay type (bonded or unbonded) to meet existing pavement conditions and anticipated future traffic loading.
- For unbonded overlays over concrete in non-arid climates, provide a positive drainage path for surface moisture to exit the interlayer bond breaker (separation layer), to prevent interlayer erosion under heavy traffic loading.
- With designs for unbonded overlays over concrete, compare asphalt or geotextile interlayer (separation layer) costs, construction time, and performance.
- Determine transition lengths from the existing profile elevation to the top of the concrete overlay profile.
- Utilize both cubic yard and square yard payment items. Square yard covers placement, and cubic yard covers material, reducing both contractor risk and cost while accounting for concrete used to fill surface irregularities.

- Based on construction economics and expected overlay performance, with designs for unbonded overlays over concrete, correct irregularities in cross-slope and profile by varying the thickness of concrete, not the depth of the asphalt bond breaker (separator layer). Deeper transverse joint sawing may be necessary to achieve the typical thickness divided by three (T/3), but final overlay performance will be enhanced.

- With designs for bonded overlays over asphalt, exercise care when milling the asphalt to prevent leaving a thin asphalt lift, which can cause delamination.

- Consider the following two potential overlay quantity design options:

  1. For minimal preliminary work and cost:
     - Do no preliminary surveying other than measuring wheel rut depth and pavement cross-slope at 500-ft intervals.
     - Develop design profiles of centerline and pavement edges.
     - Estimate the quantity of concrete required to meet the profiles and provide minimum thickness at the centerline and edges of pavement.
     - Add a reasonable percentage to the concrete quantity to account for placement tolerance, construction losses, and surface/cross-section irregularities, and establish the "new theoretical" plan quantity. Some states use 15–20%, depending on the thickness of the overlay and the amount of pavement cross-slope correction desired. The thinner the overlay and the higher the cross-slope correction, the higher the percentage. Some states add a maximum overrun of 2–3% to the "new theoretical" plan quantity.

  2. For optimization of concrete quantities:
     - Conduct nine-shot cross-sections at 50-ft intervals to map the existing surface.
     - Develop a design centerline profile and cross-slope that optimizes pavement smoothness, maintains minimum overlay depth at the centerline, and optimizes concrete quantities.
     - Limit the contractor to an additional percentage of the quantity identified by the desired cross-section and design profile. Some states use 6–8%, depending on the thickness of the overlay.

- Evaluate the impacts of removing/replacing medians or existing curbs versus retaining them in terms of construction time, cost, and future performance.

- Provide adequate drainage in the support layer of concrete overlay widening.

- Pay attention to placement of tie bars in overlay widening.

- Ensure adequate thickness for concrete overlay widening.

- Place longitudinal sawcuts between the concrete overlay mainline and widening.

- Review the construction sequence and maintenance of traffic in conjunction with joint layout. In some cases, tied longitudinal construction joints can interfere with the maintenance of both public and contractor traffic.

- Develop the construction sequence to meet closed road or through traffic maintenance in conjunction with joint layout and design for turn lanes and shoulder concrete work.

- Develop staging plans that allow for the use of paving equipment between existing concrete railings and temporary safety-related barrier walls.

- Design transitions and bridge approach pavement sections to minimize hand placement and detailed jointing plans.

- Determine the type and amount of surface preparation required, based on agency ranking of the following goals:

    - Pavement smoothness
    - Concrete quantity
    - Matching existing surface features
    - Maintaining minimum cross-slopes
    - Removal of unstable existing pavement layers
    - Vertical clearance site conditions
    - Bond enhancement between existing and overlay pavement layers

Plans and Specifications

- Provide plan sets with necessary quantities, design details, plan/profile data (not sheets), and survey control information. One main item to note is that the concrete overlay construction drawings do not need to be a lengthy set of drawings. Construction drawing sets can be simplified by excluding excess pages of plan and profile information. The reproduction of profile sheets is tedious and need not be included in the drawing set. Because it is an overlay of the existing pavement, the profile should not be necessary as long as the existing plan and profile drawings are made available for reference. That said, the pavement design should include a review of the existing profile and cross-section information to determine the effects of raising the grade with an overlay. When raising the profile grade, special consideration should be given to vertical constraints. These vertical constraints may include the following:

    - Overhead clearance
    - Barriers and rails
    - Safety edge pavement treatment
    - Cross road drainage structures

- Cross slope and super-elevation
- Side roads and driveways

- Require the use of vibrator frequency monitor recorders on the paver.

- Utilize standard concrete mixes and maturity measurements to control opening of intersections and access points. Use accelerated concrete mixtures only when necessary.

- When existing surface milling is required, clearly define the purpose, vertical and cross-slope limits, and the required existing surface survey accuracy.

Sequence of Construction and Maintenance of Traffic

- Hold a public preconstruction meeting to communicate traffic control impacts and identify public concerns that should be addressed by the contractor and owner agency during construction.

- Minimize the number of gaps for intersections and driveways, to provide for uninterrupted paving.

- Consider paving plans that allow temporary access for adjacent property owners where possible and attempt to accommodate their daily needs.

- Clearly state the criteria for lane closures and allow for contractor alternative suggestions to meet the criteria.

- Provide for alternative detour routes to be used in the case of unforeseen circumstances (crashes, wide loads, equipment breakdowns, etc.).

- Develop a traffic control plan with the contractor that allows sufficient space for construction operations and keeps the traveling public and pedestrians safe.

- Anticipate and mitigate temporary drainage issues caused by milling operations.

- For construction of single-lane overlays with 24-hr pilot car operations on two-lane roadways, apply the following construction suggestions:

    - Allow multiple construction zones separated by 2 mi. between flagger stations. The 2-mi. work zone area requirement is the distance between flagger stations versus the outermost warning signs.
    - Consider using a 3.5-mi. paving work zone and allow the contractor to close local crossings in the work zone only when those in the adjacent zone are open.

- Allow the contractor to propose methods and materials to construct temporary access ramps (in use for less than one month).
- Encourage construction of bridge work, transition sections, subdrains, pavement patching, side ditch drainage work, and earthwork prior to staged surface preparation and paving operations.
- Delete centerline safety wedge construction where pilot car operations are used 24/7 through the work area.
- Allow for equipment work on shoulders and side ditches to proceed in the same area as a lane closure employed for other pre-paving work.
- Where bridge approaches and road intersections are immediately adjacent to each other, encourage use of extended temporary barrier rail lengths and three-leg traffic signal setups to reduce construction/traffic delays.

Concrete Overlay Construction

- Require the contractor to develop a comprehensive paving plan to address construction and public impacts.

- When necessary, accelerate all construction processes to minimize public impact. Limit contract stage work times to emphasize the need for accelerated work if that is the goal of the contract.

- Where load transfer is called for in wheel paths only, use separate partial dowel baskets for each wheel path and do NOT cut the basket shipping wires.

- When anchoring dowel baskets, consider the use of uniform thicknesses of separation layers, adequate numbers of anchors, and the relationship of anchor length and shot force to the separation layer depth and material, and minimize the head of concrete in front of the paver. Monitor dowels behind the paver for location, orientation, and depth.

- Utilize software such as HIPERPAV to anticipate paving or curing problems and mitigate their impacts on operations.

- Minimize the temperature differential between the existing pavement surface and the concrete overlay during placement and curing. This is especially critical during cool weather paving for the following reasons:

    - When a bonded concrete overlay is placed in cooler weather, the day/night temperature differential will cause movement in the existing pavement; the existing pavement will expand during the day and contract at night. To prevent cracking in the overlay, the overlay must reach saw strength before the underlying pavement’s nighttime contraction. Specifying a minimum overlay mix temperature of 65°F has proven to be helpful in mitigating this set-time issue.

- Also when a concrete overlay is placed in cooler weather, the concrete can set from the bottom up, delaying the sawing window. Temporarily covering the overlay with plastic after paving helps the concrete to set properly, allowing for timely sawing.

- For thin overlays, provide expansion joints in the overlay that match expansion joints in the existing pavement. The existing expansion joints must be located prior to the placement of the interlayer. Installation of expansion joints in the overlay can easily be accomplished after the overlay has been placed by making two, full-overlay-depth, saw cuts, 1 in. apart, at an overlay contraction joint located near an existing expansion joint, and then replacing the inch of concrete with expansion material.

- As part of the concrete overlay technical assistance efforts, a 17-mile project on I-85 in North Carolina was reviewed with the North Carolina DOT (NCDOT) pavement design engineer, Clark Morrison. Morrison estimated that the cost savings in full-depth repairs alone were at least $3.25 million.

CASE STUDIES

The 2014 *Guide to Concrete Overlays: Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements* (Third Edition) provides an evaluation and selection process, which was used for all site visits. From the 20 states that had concrete overlay field application site visits by expert team members, 13 individual, custom reports were prepared for participating SHAs during this effort. Numerous calls on specific questions were also fielded by the expert team.

Reports from two states are included here as case studies to illustrate the evaluation process conducted with SHA personnel to determine if their potential projects were good candidates for overlays. The evaluation of an existing pavement, its condition, its traffic loading, and the environment in which it exists, are important elements in meeting the desired design life of an overlay. The single greatest cause of failure for concrete overlays is the lack of proper evaluation of the existing roadway.

These states (Kentucky and Utah) were selected based on the types of overlays considered, the climatic conditions in which they exist, the variable evaluation conditions encountered, and whether or not the SHA constructed one or more of the review team's recommended overlay concepts.

Not every field site visit resulted in a recommendation by the expert team for a concrete overlay. However, witnessing the evaluation process gave SHAs guidance on the important considerations in evaluating candidates for concrete overlays. Both Kentucky and Utah did select concrete overlay projects, which were successfully constructed.

Kentucky

Workshop

An informational workshop led by Gary Fick and Mark B. Snyder was attended by about 40 engineers and practitioners on March 14, 2017 in Frankfort, Kentucky. The following topics were included in the workshop:

- Overview of concrete overlays
- Project evaluation and selection
- Overview of design and design details
- Construction overview and maintenance of traffic
- Case study scenarios
- Performance history of concrete overlays

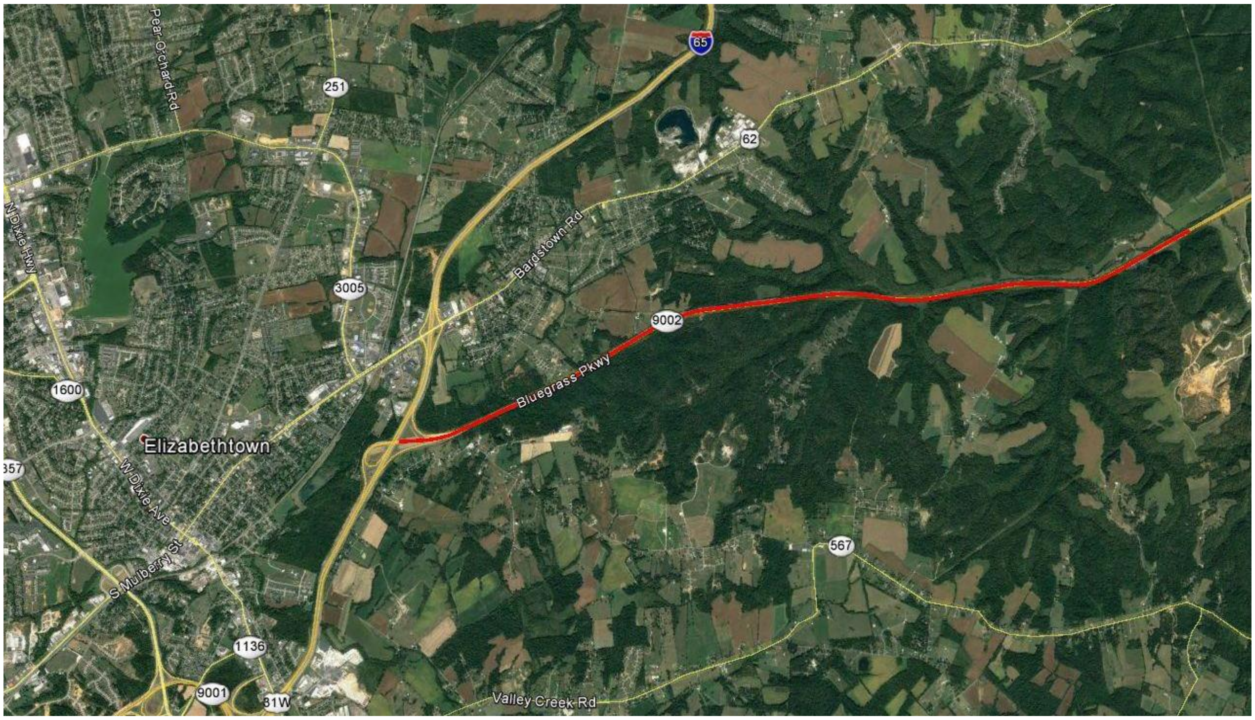
Attendee ratings for the workshop averaged 1.28, where 1=very good and 5=needs improvement.

Field Review

On March 15, 2017, a field review of two potential concrete overlay projects was conducted. Participants in the review included the following:

- Bob Criscillis, HMB Professional Engineers, Inc.
- Leo Frank, Kentucky Transportation Cabinet (KYTC)
- Adam Ross, KYTC
- Sunil Saha, KYTC
- Greg Smith, Kentucky Concrete Pavement Association
- Mark B. Snyder, Pavement Engineering and Research Consultants (PERC), LLC
- Gary Fick, Trinity Construction Management Services, Inc.

The purpose of the field review was to reinforce the concepts discussed in the workshop and to identify potential constraints that may affect design and construction of a concrete overlay on each section of this roadway. Both sections were part of KY Rt. 9002/Bluegrass Parkway MP 0.0 to 5.8 (see Figure C-3).



©Google

Figure C-3. KY Rt. 9002/Bluegrass Parkway MP 0.0 to 5.8 near Elizabethtown, Kentucky

This was a bonded concrete overlay on asphalt (BCOA) project that was identified by the KYTC and let in 2018. An image from the project review (when this was still considered a potential concrete overlay project) is included in Figure C-4.

Figure C-4. KY 9002 Looking west from approximately MP 0.6

Existing Conditions

KY Rt. 9002/Bluegrass Parkway is a 70-mi. rural divided highway connecting I-65 on the west to US 60 on the east near Versailles, Kentucky, which is just west of Lexington. Originally opened in 1965, KY 9002 is a full-depth, hot-mixed asphalt (HMA) pavement with 2016 annual average daily traffic (AADT) of about 13,600 vehicles, including about 20% trucks. The roadway section from MP 0.0 to 5.8 has been well maintained and overlaid multiple times throughout its life.

The original shoulder construction consisted of a dense-graded gravel base, with a 1¾ in. HMA base and seal coat surface. Based on the conditions observed during the March 15, 2017 field review, it was assumed that the shoulders have been overlaid along with the main lanes, with the exception of the 10 ft shoulder that was untouched during the 2007 mill-and-fill project from MP 0.0 to 4.8.

Recommendations

The section of KY 9002 reviewed and characterized in the report titled Structural Assessment of KY 9002, Martha Layne Collins Bluegrass Parkway, Hardin County, Kentucky, is a viable candidate for a concrete overlay (bonded or unbonded). There are two primary considerations that need to be addressed before a final design recommendation is made for the section from MP 0.0 to 4.8, and therefore MP 4.8 to 5.8, is addressed as a separate section of the project.

- The thickness of asphalt pavement in the shoulders from MP 0.0 to 4.8 should be determined by coring (1 core per mile from each shoulder). This thickness may have a bearing on whether milling is feasible and/or to what depth milling is feasible.

- The extent and severity of stripping noted in the cores already taken from the mainline should be investigated further. The presence and severity of stripping will influence the recommendation for depth of milling and whether a bonded or unbonded overlay is appropriate. Additional cores should be taken from MP 0.0 to 4.8 (1 core per ½ mi. from each lane, both EB and WB) to assess whether stripping is present and to what degree it has progressed. Some of these cores should be obtained at transverse crack locations.

The presence of the GlasGrid reflective crack isolators from MP 5.3 to 5.8 appears to have caused a delamination in the upper layer of HMA. Delamination was not observed in the one core obtained through the PaveTrac material from MP 4.8 to 5.3, but is a concern as well. Because of this, the upper 4 in. of HMA (or more, if necessary) should be removed by milling and/or other means prior to constructing a concrete overlay. Industry professionals should be consulted to see if milling through the PaveTrac and GlasGrid is feasible and/or what other means would be cost effective for removing the upper 4 in. of HMA and the reinforcing material.

The only area that appears to require any pre-overlay repair is at MP 4.8 in both directions where the typical section changes (approximate length of 100 ft). This pavement should be cored and evaluated to determine whether full-depth repairs are necessary or if the deterioration is only in the top layers. Scratch milling of any new HMA placed as a pre-overlay repair is recommended to enhance bonding.

Concrete Overlay of Existing KY 9002 MP 4.8 to 5.8

- Pre-overlay repairs should be limited to full- and/or partial-depth repairs in isolated areas of severe distress. Areas repaired with new HMA should be scarified by milling to enhance bonding.
- Based on preliminary data, the required thickness for a bonded concrete overlay is estimated to be in the range of 5 to 6 in.; the required thickness for an unbonded concrete overlay is estimated to be 7 in. or more. The final design must be performed by the KYTC, and the National CP Tech Center can assist in this process by reviewing design inputs.
- No joint steel is necessary for a BCOA design; fiber reinforcement (3 to 5 lb/yd3) may be considered as a design option for long-term prevention of opening of the longitudinal joints. Tie-bars would be recommended for an unbonded design.
- Transverse joints in the BCOA should be nominally spaced at 6 ft c/c.
- Longitudinal joints should be placed as noted in Figure C-5.

- Transverse and longitudinal joints should be cut to a depth of T/3 and a width of approximately ¼ in.
- Joints should be filled/sealed with a poured sealant (e.g., hot rubberized asphalt or self-leveling silicone).
- Pavement edges and safety slopes can be backfilled and re-graded using the asphalt millings.

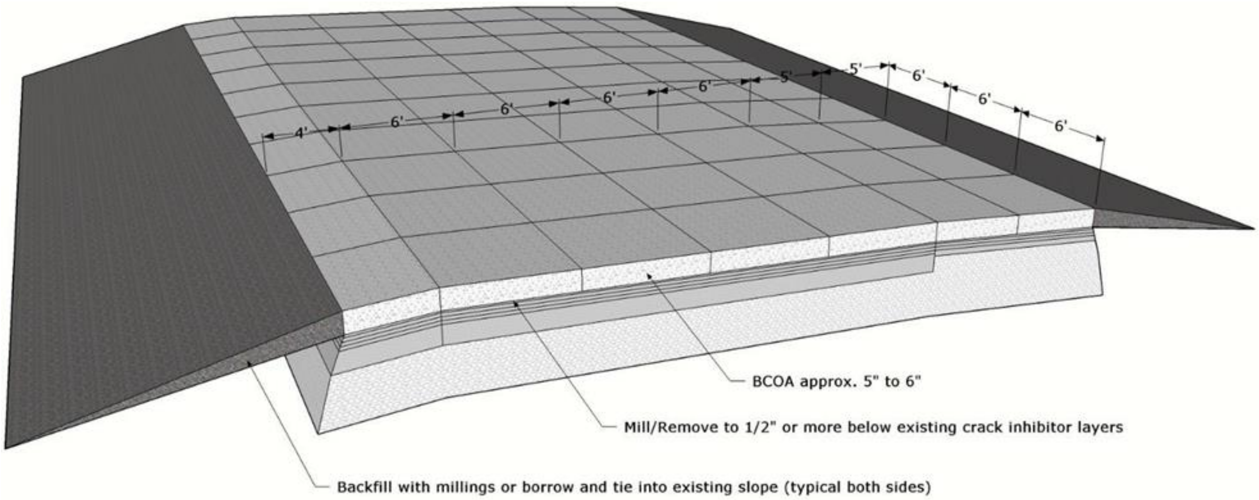


Figure C-5. Preliminary sketch of KY 9002 BCOA design from MP 4.8 to 5.8

Concrete Overlay of Existing KY 9002 MP 0.0 to 4.8

- Additional coring (1 core per lane every ½ mi.) should be performed to verify the thickness and condition of the asphalt.
- Additional coring (1 core per shoulder every 1 mi.) should be performed to verify the thickness and condition of the asphalt.
- The presence and severity of stripping will influence the recommendation for depth of milling and whether a bonded or unbonded overlay is appropriate.
- Pre-overlay repairs should be limited to full-depth and/or partial-depth repair in isolated areas of severe distress. Areas repaired with new HMA should be scarified by milling to enhance bonding.
- Based on preliminary data, the required thickness for a bonded concrete overlay is estimated to be in the range of 5 to 6 in.; the required thickness for an unbonded concrete overlay is estimated to be 7 in. or more. The final design must be performed by the KYTC, and the National CP Tech Center can assist in this process by reviewing design inputs.
- No joint steel is necessary for a BCOA design; tie-bars would be recommended for an unbonded design.
- Transverse joints in the BCOA should be spaced at 6 ft c/c.
- Design should be adjusted for the final design thickness.
- Saw cut joints to a depth of T/3 and a width of ±1/4 in.
- Joints should be filled/sealed with a hot-pour sealant.
- Pavement edges and safety slopes may be backfilled and re-graded using the asphalt millings.

Maintenance of traffic during construction is best handled by constructing crossovers at each end of the project and constructing each direction in separate phases. Strengthening of the existing 10 ft shoulder (e.g., using mill and inlay of HMA or concrete) may be necessary to maintain traffic during the first phase of concrete overlay construction.

Next Steps

Additional coring should be performed by the KYTC as noted to verify the condition of the HMA and range of existing HMA thickness in all lanes and shoulders throughout the project. After review of these cores, the National CP Tech Center will provide further recommendations on pavement design thickness, joint details, and traffic maintenance strategies. Also, identify and quantify all roadway features that may need to be adjusted and/or replaced by raising profile grade (guardrail, overhead signs, etc.). The National CP Tech Center is ready to support the KYTC throughout the plan, specification, and estimate (PS&E) process and can also provide technical support during the pre-construction and construction phases of the project. There is no cost for this technical support provided by the Center.

Utah

Workshop

An informational workshop was held on August 19, 2013, at the Utah DOT (UDOT) Region 2 Materials laboratory facility in Salt Lake City. The workshop was led by the expert team of Gary Fick, Doug Schwartz, and Gordon Smith with 15 UDOT engineers in attendance, as well as five engineering consultants and contractors.

The following topics were included in the workshop:

- Introduction – ½ hour
- Evaluation of Existing Pavement – ½ hour
- Concrete Overlay Types – 1 hour
- Experiences of Other DOTs – 1 hour
- Design and Construction of Concrete Overlays – ½ hour
- Recycling of Existing Concrete Pavements – ½ hour
- Discussion and FAQ – ¾ hour

The workshop received an average rating of 1.6, where 1=very good and 2=good. Site visits were conducted on August 20, 2013 to review six potential concrete overlay projects with UDOT personnel. On August 21, 2013, the expert team met with UDOT's project development director to discuss concrete overlays as a resurfacing and pavement preservation strategy.

Field Reviews

A tour of potential concrete overlay projects was conducted August 20, 2013. The roadways reviewed were chosen by UDOT personnel and are listed in Table C-3 with their locations shown in Figure C-6.

Table C-3. Potential concrete overlay projects reviewed

Map #	Project Description	Length (mi.)	AADT	AADTT	No. of Lanes
1	I-80 – Silver Creek Junction northeast to Wanship	≈6.7	13,720	6,037	4 plus auxiliaries
2	SR 201 – Urban divided arterial from 5600 West to the west	≈6.5	unreported	unreported	4 plus turn lanes
3	I-80 – Urban freeway from 1300 East, east to Parley's Canyon	≈2.5	83,475	23,373	6 plus auxiliaries
4	I-215 – Urban freeway from 3300 South, south to 4500 South	≈1.8	68,285	12,974	6 plus auxiliaries
5	I-215 – Urban freeway from 4700 South north to SR 201	≈4.0	102,580	3,077	6 plus auxiliaries
6	I-15 – From Lehi Main Street north to 12300 South	≈7.3	163,780	34,393	6 to 8 plus HOV and auxiliaries

Image Landsat © 2013 Google Image State of Utah

Figure C-6. Potential concrete overlay project locations

Excerpts on #1 and #6 are included as the remainder of this final task report appendix.

#1: I-80 – Silver Creek Junction, Northeast to Wanship (AADT = 13,720)

Existing Conditions

This section of I-80 is located east of Salt Lake City in mountainous terrain. The existing typical section constructed in 1998 consists of 7 to 12 in. of asphalt pavement on 4 to 6 in. of cement treated base (CTB) over variable subgrade materials (A-2 to A-7-5 [CBR of 1.5]). A mill and fill project was constructed in 2006 to restore the surface of the asphalt; an additional thin asphalt overlay was placed in 2010.

The existing asphalt pavement shows signs of distress (see Figure C-7).

Figure C-7. Rutting and fatigue cracking on I-80

UDOT reports that there are stripped layers of asphalt under the latest thin surface overlay, which was placed in 2010, and that there are known localized drainage issues, which need to be addressed. Rehabilitation of this roadway is currently scheduled for 2015.

Recommendations

Based on the conditions observed during the site visit, our team is concerned whether the existing pavement will survive until the programmed rehabilitation scheduled for 2015. We offer the following recommendations for UDOT's consideration.

- Perform a thorough pavement investigation including pavement coring. At a minimum, two cores per lane per mile should be obtained to evaluate layer thicknesses and existing pavement condition.

- Identify and correct the drainage issues as soon as possible as a means to extend the life of the existing pavement through 2015.

Considerations for designing and constructing a concrete overlay are as follows.

- An unbonded overlay is appropriate for this section of roadway; for design purposes, the existing pavement is treated as a high quality subbase.

- Design thickness should be determined by UDOT using AASHTOWare Pavement ME Design or the 1993 *AASHTO Guide for Design of Pavement Structures*.

- The condition of the existing pavement as determined from cores should heavily influence whether the concrete overlay is placed directly on top of the existing pavement, or if the asphalt pavement should be milled to remove the stripped layers before placing the concrete overlay. One concern with not removing the stripped asphalt is continued secondary consolidation of the stripped layer(s) that can lead to differential settlement and cracking of the concrete overlay. Aside from the structural considerations for milling down to a sound layer of asphalt, there is an additional benefit of reducing the change in profile grade, which mitigates the impact on adjustments for vertical constraints such as overpasses, side slopes, and drainage structures.

- For construction of the overlay, two-way traffic should be placed on one side (eastbound or westbound) of the route while the opposite side is constructed. This scenario accelerates construction as compared to constructing adjacent to live traffic and typically results in smoother pavements.

At UDOT's request, the National CP Tech Center's Overlay Implementation Team will assist UDOT in evaluating the pavement cores and offer our recommendation regarding the decision on whether to mill the existing pavement. If UDOT decides to proceed with an unbonded concrete overlay, our assistance is also available for pavement design, specification development, plan development and construction details.

#6: I-15 from Lehi Main Street, North to 12300 South (AADT = 163,780)

Existing Conditions

A summary of the existing pavement sections for this roadway is provided in Table C-4.

Table C-4. Summary of typical sections

Limits	Year Constructed	Pavement	Rehabs	Subbase	Subgrade
Lehi Main Street to County Line	1972	5 in. asphalt (2004) 9 in. JPCP (crack and seat)	Bonded wearing course (200X)	4 in. 4 in. CTB Granular	A-4 under variable embankment
Widening	unknown	5 in. asphalt		25 in. Granular	
County Line to 12300 South	1969	9 in. JPCP	2006 – Patch and grind 2011 – Patch and grind	4 in. CTB 4 in. Granular	A-4 under variable embankment
Widening	2004	8½ in. to 10 in. asphalt	1 in. mill and 1 in. OGSC	9 in. to 13½ in. Granular ½ in.	

The pavement appears to be in good condition (see Figure C-8).

Figure C-8. I-15 Looking north

Recommendations

It is our understanding that this project will be a design-build project with the pavement section(s) defined by UDOT. This project is a candidate for an unbonded overlay. One unique aspect of this project as compared to Projects #3, #4 and #5 is the asphalt widening. Thus, our recommendations are slightly different than for the projects previously discussed (but not included in the excerpts here).

A comprehensive analysis of costs (construction and road user), time, and maintenance of traffic (MOT) issues for all pavement alternatives should be performed by UDOT. If UDOT proceeds with an unbonded overlay, our recommendations are as follows:

- Design thickness should be determined by UDOT using AASHTOWare Pavement ME Design or the 1993 *AASHTO Guide for Design of Pavement Structures*.

- Support conditions assumed in the thickness design should be for the asphalt widening sections; the corresponding unbonded concrete overlay thickness should be used for the entire project.

- The separation layer should be a drainable asphalt layer placed across the full width of the concrete pavement and asphalt widening area. It should be either daylighted to the foreslope or tied into an underdrain system.

Conclusions

All six of the projects reviewed by the expert team were deemed to be candidates for unbonded concrete overlays. At UDOT’s request, our team is available to assist on one of these projects. If reconstruction is chosen over a concrete overlay, we recommend that the existing pavement be recycled and utilized on the project.

Appendix D:

Performance Engineered Mixtures

Final Task Report
December 2018

Principal Investigator
Peter Taylor, Director
National Concrete Pavement Technology Center, Iowa State University

Author
Peter Taylor, National Concrete Pavement Technology Center

Managers
Peter Taylor, National Concrete Pavement Technology Center
Tom Cackler, Woodland Consulting, Inc.

Team Leaders
Cecil Jones, Diversified Engineering Services, Inc.
Tyler Ley, Oklahoma State University
Tom Van Dam, NCE
Jason Weiss, Oregon State University

Sponsored by
Federal Highway Administration

A report from
National Concrete Pavement Technology Center
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-5798 / Fax: 515-294-0467
cptechcenter.org

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PERFORMANCE ENGINEERED MIXTURES ACKNOWLEDGMENTS

The National Concrete Pavement Technology (CP Tech) Center would like to acknowledge the invaluable contribution of the Performance Engineered Mixtures (PEM) champion states. This group was formed at the April 2015 meeting of the National Concrete Consortium (NCC), in Reno, Nevada. Representatives from eight state departments of transportation (DOTs), plus the Illinois State Toll Highway Authority (Illinois Tollway) and Manitoba, Canada, volunteered, along with their construction industry counterparts, to lead this initiative on behalf of the NCC members (see Figure D-1).

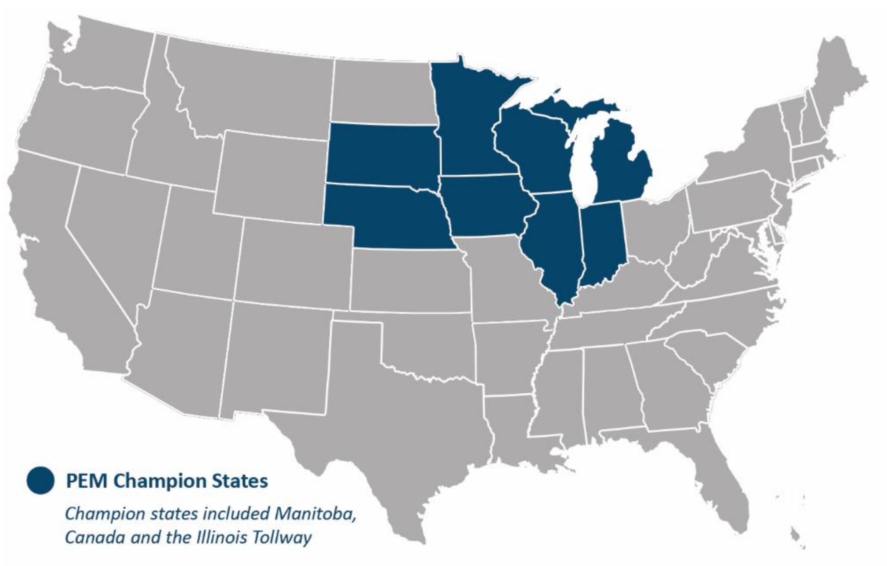


Figure D-1. PEM champion state locations

The PEM expert task group (ETG)/champion state members are highly respected and qualified individuals with considerable experience in both concrete paving and concrete mixtures. The following members served on the committee to identify needed training products, review and give input on the development of the test methods and specifications, and participate in regular electronic meetings with the research team.

Agencies

- Alauddin Ahammed, Manitoba, Canada
- Dan Gancarz, Illinois Tollway
- Steve Gillen, Horner & Shifrin (formerly with Illinois Tollway)
- Lieska Halsey, Nebraska DOT (NDOT)
- Todd Hanson, Iowa DOT
- Chad Hayes, Wisconsin DOT (WisDOT)
- Wally Heyen, NDOT
- Darin Hodges, South Dakota DOT (SDDOT)

- Maria Masten, Minnesota DOT (MnDOT)
- Archie Miller, Manitoba, Canada
- Michael Nelson, Indiana DOT (InDOT)
- Jim Parry, WisDOT
- Jason Smith, SDDOT
- Tim Stallard, Michigan DOT (MDOT)
- John Staton, MDOT
- Tony Zander, InDOT

Associations

- Mike Byers, Indiana Chapter, American Concrete Pavement Association (ACPA)
- Bill Cook, Nebraska Concrete Paving Association (NCPA)
- Dan DeGraaf, Michigan Concrete Association (MCA)
- Larry Engbrecht, South Dakota Chapter, ACPA (formerly)
- Kevin McMullen, Wisconsin Concrete Pavement Association (WCPA)
- Gordon Smith, formerly Iowa Concrete Paving Association (ICPA) (now with National CP Tech Center)
- Sherry Sullivan, Cement Association of Canada (CAC)
- Matt Zeller, Concrete Paving Association of Minnesota (CPAM)

Also essential to the PEM program was the development of the overall framework, which included the detailed plan for PEM implementation. A programmatic ETG met initially to develop the framework and met periodically throughout the life of the project to monitor progress of the implementation effort being led by the ETG/champion states. These programmatic ETG members drew upon their extensive, in-depth understanding of what needed to be addressed to ensure concrete pavement durability and the interrelationship of key concrete mixture engineering properties to develop the basic structure of the PEM program. Their contributions were critical to success of the initiative.

Programmatic Oversight ETG

- Gina Ahlstrom, Federal Highway Administration (FHWA)
- Mark Felag, Rhode Island Department of Environmental Management (DEM) (formerly with Rhode Island DOT)
- Doug Hooton, University of Toronto
- Ken Hover, Cornell University
- Cecil Jones, Diversified Engineering Services, Inc.
- Steve Kosmatka, Portland Cement Association (PCA)
- Tyler Ley, Oklahoma State University
- Colin Lobo, National Ready Mixed Concrete Association (NRMCA)
- Maria Masten, MnDOT
- Michael Praul, FHWA

- John Staton, MDOT
- Peter Taylor, National CP Tech Center
- Mike Tholen, American Concrete Institute (ACI)
- Paul Tikalsky, Oklahoma State University
- Tom Van Dam, NCE
- Suneel Vanikar, FHWA (retired)
- Jerry Voigt, ACPA
- Jason Weiss, Oregon State University
- Tom Yu, FHWA

EXECUTIVE SUMMARY

On September 13, 2012, the Federal Highway Administration (FHWA) entered into a cooperative agreement with the National Concrete Pavement Technology (CP Tech) Center to address priority national needs to advance concrete pavement technologies. Included in this project was a focused effort to address the technical and policy needs related to modernizing specification requirements for concrete paving mixtures.

The FHWA recognized that concrete paving specifications have not kept pace with advancements in concrete science and innovations in testing technologies. The guiding vision and keys for a successful Performance Engineered Mixtures (PEM) program were as follows:

- **Vision:**
  Concrete mixtures that are *engineered* to meet or exceed the design requirement, and are predictably durable, with increased sustainability

- **Keys:**
  - Design and field control of mixtures around engineering properties related to performance
  - Development of practical specifications
  - Incorporating this knowledge into an implementation system (Design, Materials, Construction, Maintenance)
  - Use of performance monitoring to validate and refine the approaches adopted

The FHWA's goal was to issue a provisional American Association of State Highway and Transportation Officials (AASHTO) specification in 2017. In April 2017, AASHTO published PP 84-17, Developing Performance Engineered Concrete Pavement Mixtures. Annual revisions were anticipated to refine the specification requirements to reflect lessons learned during implementation and the field performance of pavements built using PEM requirements.

BACKGROUND

Concrete for pavements has historically been specified and field controlled around acceptance criteria (slump, air content, strength) that do not relate well to durability. Paving concrete specifications need to be built upon engineering properties that directly relate to good field performance. With the recent advancements in research knowledge on failure mechanisms, and the parallel development of better testing method, this is possible.

A review of many current and new specifications found that they are still largely based on strength, slump, and air, which exhibit limited correlation with the mechanisms of pavement failure that is currently observed. The need for changes in the way concrete is specified, especially concrete for paving mixtures, is becoming increasingly apparent as mixtures become more complex with a growing range of chemical admixtures and supplementary cementitious materials (SCMs). Traffic loadings continue to increase, more aggressive winter maintenance practices are implemented, and demand increases to build systems more quickly, more cost effectively, and with increased longevity.

The FHWA, through their cooperative agreement with the National CP Tech Center, has been working with the 30 National Concrete Consortium (NCC) member-state departments of transportation (DOTs) to identify the specification approach and key testing technologies needed for paving concrete to have increased durability, including in the presence of wet freeze-thaw and winter deicing materials.

New testing technologies have been developed, but the next critical activities that were accomplished through the PEM program are deployment of the new testing technologies, development of practical specifications and quality assurance/quality control (QA/QC) recommendations, and correlation of specification limits with durable field performance. It was envisioned that the developmental efforts achieved through this program would lead the way for successful implementation efforts which are now underway through the FHWA Transportation Pooled Fund TPF-5(368), Performance Engineered Concrete Paving Mixtures.

Key milestones to date include the following:

- In 2014, the FHWA formed a programmatic oversight ETG to engage leaders in the field to help shape the practical focus for PEM. This ETG developed the basic framework through which the PEM specification and testing requirements were developed.
- In April 2015, at the NCC's semiannual meeting, a PEM ETG/champion states group was formed to work with the PEM research team on this project to evaluate new testing technologies, provide practical input on the use of these tests for mixture qualification and acceptance, and evaluate specification requirements (see previous Figure D-1).
- In April 2017, AASHTO published PP 84-17, Developing Performance Engineered Concrete Paving Mixtures. This standard of practice allows agencies to select from a menu of options for implementing a prescriptive or performance approach for each of the important mixture parameters addressed by the specification.
- On October 1, 2017, TPF-5(368), Performance Engineered Concrete Paving Mixtures, was started to focus on PEM implementation activities with pilot projects and performance monitoring being key objectives. This transportation pooled fund project picks up the developmental work accomplished under this cooperative agreement and supports DOTs with technical assistance for implementing PEM requirements.

OBJECTIVES

The objectives of the PEM effort under this project were as follows:

- Develop a practical specification framework that is built upon testing engineering properties of concrete mixtures that relate to performance
- Evaluate recently developed testing methods and determine their suitability for use in mixture qualification and acceptance requirements

- Work with the AASHTO Subcommittee on Materials to develop and publish a standard of practice in 2017
- Position DOTs through this program to be ready to move forward with implementation of PEM requirements under future programs by gaining hands-on experience with tests and education on the engineering properties that are important for pavements to perform in their local environment

TEAM MEMBERS

The organizational chart shown in Figure D-2 illustrates the management approach used by the National CP Tech Center on this task.

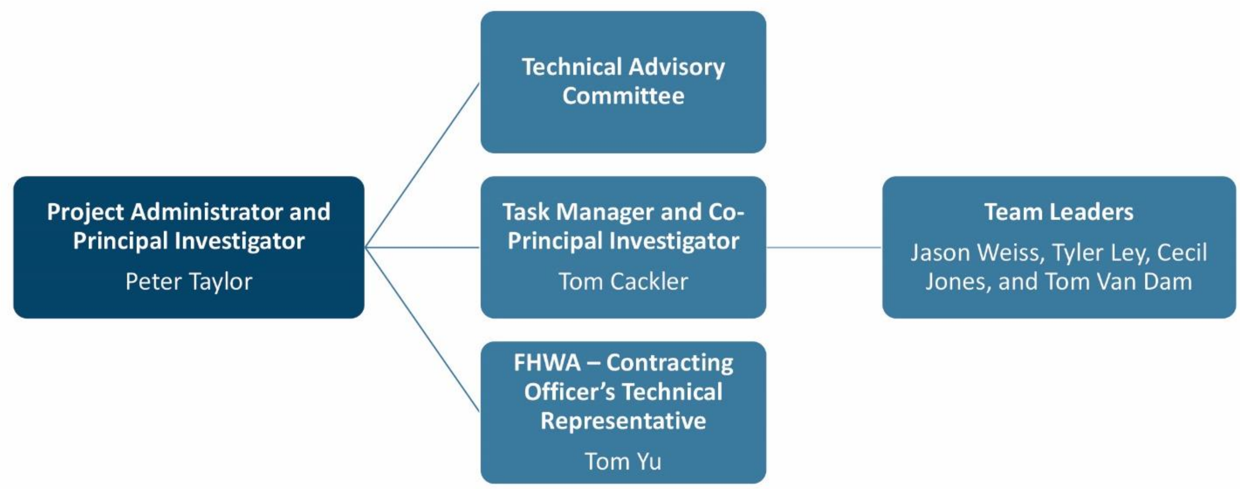


Figure D-2. Innovative materials organizational chart

WORK PLAN

The research team worked closely with the PEM ETG/champion states to evaluate new testing technologies and develop a PEM framework. The framework addresses both mixture qualification, field QC/QA, and acceptance criteria. Extensive effort went into training field personnel on the new tests, ensuring the DOTs had the needed equipment, and obtaining feedback on how the new tests worked in the field.

MATERIALS DEVELOPED

The following technical documents, training, and support have been developed since 2013 under the Technology Transfer of Concrete Pavement Technologies project:

- Specification framework
- Guide specification
- Work with DOTs to field evaluate new tests

- Technical support to DOTs

Development of Specification Framework

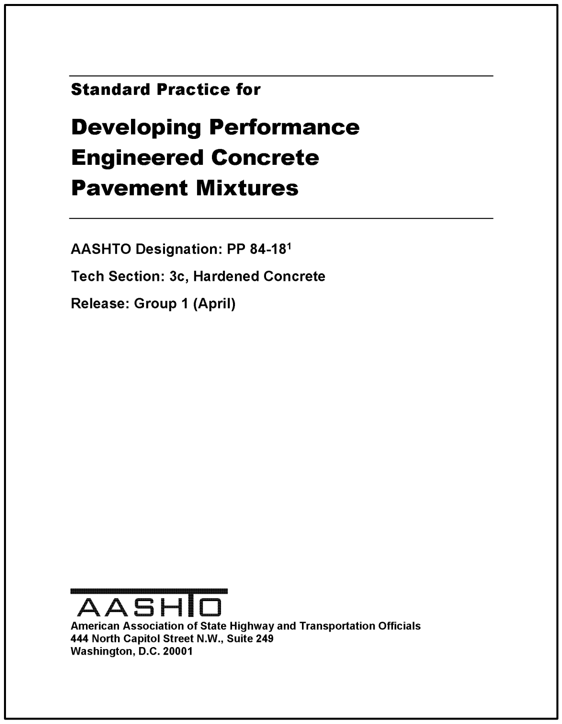
The oversight PEM ETG focused on developing the overall framework for the engineering requirements that consistently produce durable concrete paving mixtures. Identification of critical properties included work on answering the following questions: What do we measure now? What other properties are important? How can they be measured? When should they be used? This work resulted in the matrix, shown in Table D-1, that was used to develop the framework for the PEM specification.

Table D-1. Framework for ensuring durable paving concrete

Concrete Element Pavement/Overlay Design Inputs	**Mixture Design (engineering)**	**Mixture Verification**	**Acceptance**
Design tool: *Mechanistic-Empirical Pavement Design Guide* (MEPDG) • Strength • Coefficient of thermal expansion (CTE) • Climatic • Loading • Design life • Sustainability • Features	Fresh Properties • F/T/ • Permeability • Abrasion • Load transfer • Material-related distress (MRD) requirements	To ensure mixture delivered is okay	Based on specified limits

Development of AASHTO Standard Practice for PEM

The research team developed a draft specification in AASHTO format and provided it to the subcommittee on materials for balloting in 2017. The result of the balloting was unanimous approval with no negative votes. The standard was published in April 2017 as PP 84-17 and updated in 2018 (Figure D-3).



Standard Practice for

Developing Performance Engineered Concrete Pavement Mixtures

AASHTO Designation: PP 84-18[1]

Tech Section: 3c, Hardened Concrete

Release: Group 1 (April)

AASHTO

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Figure D-3. AASHTO PP 84-18 cover

The intent is to provide AASHTO recommendations on an annual basis with refinements that reflect the lessons learned during the implementation process.

An overview of the AASHTO specification and testing requirements for mixture qualification and acceptance that was developed partially under this cooperative agreement is summarized in Table D-2.

Table D-2. Summary of AASHTO PP 84-17 specification

AASHTO PP 84-18 test summary						Where is the test used?		
Mixture parameter	Traditional acceptance criteria	Property	AASHTO Specification reference	Specified test	Selection details	Mixture qualification	Acceptance	Special notes
Aggregate stability	√	D-cracking	6.7.1	AASHTO T 161, ASTM C666		√	—	
		Alkali aggregate reactivity	6.7.2	AASHTO R 80		√	—	
Transport properties		Water to cementitious materials (w/cm) ratio	6.6.1.1	_	Choose only one	√	√	The required maximum water to cementitious ratio is selected based on freeze–thaw conditions
		Formation factor	6.6.1.2	Table 1		√	√	Based on freeze–thaw conditions; other criteria could be selected
		Ionic penetration, F factor	6.6.2.1	Appendix X2		√	√	Determined using guidance provided in Appendix X2
Durability of hydrated cement paste for freeze-thaw durability		Water to cementitious materials (w/cm) ratio	6.5.1.1	—	Choose either 6.5.1.1 or 6.5.2.1	√	√	
	√	Fresh air content	6.5.1.2	AASHTO T 152, T 196, TP 118	Choose only one	√	√	
		Fresh air content/SAM	6.5.1.3	AASHTO T 152, T 196, TP 118		√	√	
		Time of critical saturation	6.5.2.1	ASTM C1585		√	—	Variation controlled with mixture proportion observation or F-factor and porosity measures
		Deicing salt damage	6.5.3.1	35% SCMs	Choose only one	√	√	Are calcium or magnesium chloride used
		Deicing salt damage	6.5.3.2	AASHTO M 224		√	√	Are calcium or magnesium chloride used; use specified sealers
		Calcium oxychloride limit	6.5.4.1	AASHTO T 365-17		√	—	Are calcium or magnesium chloride used

AASHTO PP 84-18 test summary						Where is the test used?		
Mixture parameter	Traditional acceptance criteria	Property	AASHTO Specification reference	Specified test	Selection details	Mixture qualification	Acceptance	Special notes
Reducing unwanted slab warping and cracking due to shrinkage		Volume of paste (25%)	6.4.1.1	—	Choose only one	√	—	
		Unrestrained volume change	6.4.1.2	ASTM C157		√	—	Curing conditions
		Unrestrained volume change	6.4.2.1	ASTM C157		√	—	
		Restrained shrinkage	6.4.2.2	AASHTO T 334		√	—	
		Restrained shrinkage	6.4.2.3	AASHTO TP 363-17 (Dual Ring)		√	—	
		Probability of cracking	6.4.2.4	Appendix X1		√		Variation controlled with mixture proportion observation or F-factor and porosity measures.
		Quality control check	Commentary			—	√	
Concrete strength	√	Flexural strength	6.3.1	AASHTO T 97	Choose either or both	√	√	
		Compressive strength	6.3.2	AASHTO T 22		√	√	
Workability	Slump	Box test	6.8.1	Appendix X3	Choose one		—	
		Modified VKelly test	6.8.2	AASHTO TP 129			—	

DOT Assistance with Field Evaluation of New Test Methods

Champion state representatives worked with the research team to conduct field tests using new test methods and provided feedback to the research team on the results and suggestions for improvement. In addition, champion states provided concrete samples for determining oxychloride expansion potential and calculation of the formation factor (F-factor). The new tests that were evaluated include the following:

- Vibrating Kelly Ball (VKelly)
- Super air meter (SAM)
- Box test
- Maturity method
- Oxychloride expansion (via low-temperature differential scanning calorimeter [LT-DSC])
- Formation factor (via surface resistivity)

Technical Support to DOTs

Technical support to DOTs included the following:

- Quarterly technical advisory committee (TAC) meetings
- PEM website with reference material on new testing methods
- Technical instructions on new test methods
- Training on running new tests
- Field support and assistance with new tests
- Tech Briefs
    - July 2017: *CP Road Map: Developing a Quality Assurance Program for Implementing Performance Engineered Mixtures for Concrete Pavements*
    - April 2017: *CP Road Map: Performance Engineered Mixtures (PEM) for Concrete Pavements*

Appendix E:

Long-Life Pavements, New Technologies, and Advancements in Placement Work Areas

Final Task Report
December 2018

Principal Investigator
Peter Taylor, Director
National Concrete Pavement Technology Center, Iowa State University

Author
Peter Taylor, National Concrete Pavement Technology Center

Team Leaders
Tom Cackler, Woodland Consulting, Inc.
Steve Tritsch, National Concrete Pavement Technology Center

Sponsored by
Federal Highway Administration

A report from
National Concrete Pavement Technology Center
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-5798 / Fax: 515-294-0467
cptechcenter.org

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LONG-LIFE PAVEMENTS ACKNOWLEDGMENTS

The authors would like to thank the Federal Highway Administration (FHWA), the technical advisory committee, and the expert team members who were involved in long-life pavements and advancements in placement work areas technology transfer efforts for this project.

INTRODUCTION

Work under the Long-Life Pavements, New Technologies, and Advancements in Placement focus areas was addressed in three tasks:

- National Open House on Two-Lift Concrete Pavement
- Demonstration of Technologies for Concrete Pavement Quality Monitoring
- Inspector Training

NATIONAL OPEN HOUSE ON TWO-LIFT CONCRETE PAVEMENT

A national open house was held in Chicago August 20–21, 2013 to demonstrate sustainable concrete paving practices being incorporated into the Illinois State Toll Highway Authority's (Illinois Tollway's) 15-year, $12 billion *Move Illinois* program.

The event comprised a day of presentations by Tollway personnel and researchers, consultants, and contractors who addressed their approaches to increasing sustainability in their systems through the following:

- Careful selection of materials, including fractionated reclaimed asphalt pavement (FRAP), reclaimed asphalt pavement (RAP), and ternary mix designs
- Design details
- Use of a two-lift construction system
- Life-cycle analyses

The first day included an opportunity to visit the Federal Highway Administration (FHWA) Mobile Concrete Laboratory.

The second day featured a bus tour to observe a bridge deck and section of highway under construction (see Figure E-1), including the batch plant.

Figure E-1. Section of highway under construction during Illinois Tollway Open House

The open house was attended by 125 people representing a cross section of FHWA and state department of transportation (DOT) staff, consultants, academic professionals, and materials suppliers.

Overall reviews gave the event a rating of 1.3 on a scale of 5, where 1 is very good. Contractors and agencies appreciated the opportunity to discuss the challenges of implementing innovative systems into a working contract.

DEMONSTRATION OF TECHNOLOGIES FOR CONCRETE PAVEMENT QUALITY MONITORING

Concrete is a complex material, and it is one of the few structural systems that is strongly influenced by site activities. At present, relatively little is done to monitor the quality and variability of the mixture as it is delivered, or in its final state. Implementation of technologies such as those demonstrated during this field demonstration will go a long way toward improving uniformity and potential durability of concrete pavements at the time of construction, thus likely increasing longevity of the system.

State DOT representatives and others had expressed interest in the tools and devices that can be used to monitor the concrete at a construction site.

A field demonstration to showcase the available technologies that can be used to improve quality monitoring of concrete pavements as they are constructed was held as part of the Spring 2013 National Concrete Consortium (NCC/NC_2) meeting in Philadelphia April 3, 2013. This field trip, which was hosted by the Pennsylvania DOT (PennDOT) was used as an opportunity to demonstrate the technologies listed in Table E-1.

Table E-1. Devices demonstrated

Device	**Measurement**
Air void analyzer (AVA)	Air void system
Coefficient of thermal expansion (CTE)	Design input for Darwin ME
Corrosion sensors	Chloride penetration
Field calorimeter	Monitor hydration
Ground penetrating radar (GPR)	Detect flaws in the slab
HIPERPAV III	Cracking risk assessment
Impulse response	Detect flaws in the slab
MIRA ultrasonic pulse echo	Detect objects or flaws in the slab
MIT Scan 2	Dowel location
MIT Scan T2	Slab thickness
P-wave	Setting time
Super air meter (SAM)	Air void system
Surface resistivity	Assess potential durability
Tensile bond	For bonded overlays

Peter Taylor from the National Concrete Pavement Technology (CP Tech) Center and Jim Grove from the FHWA organized the event, with assistance from Tom Cackler (formerly National CP Tech Center and currently Woodland Consulting, Inc.), and Gary Fick (Trinity Construction Management Services, Inc.), in the field, as well as George Dunheimer (PennDOT), at the DOT offices. Approximately 75 attendees were transported to the mobile laboratory/pavement and to the DOT offices where they were encouraged to walk around and observe the demonstrations (see Figure E-2).

Figure E-2. Device demonstration observations

General feedback from attendees was that it was an afternoon well spent learning about new technologies. Several people stated that they would be following up to implement at least one of these technologies at their construction sites.

INSPECTOR TRAINING

Personnel

Team members for this task included the following:

- Peter Taylor, National CP Tech Center
- Tony Babcock, formerly National CP Tech Center
- Steve Tritsch, National CP Tech Center
- Gary Fick, Trinity Construction Management Services, Inc.

The technical advisory committee (TAC) included the following members:

- Gina Ahlstrom, FHWA
- Dan DeGraaf, Michigan Concrete Association
- Jim Grove, FHWA
- Clint Hoops, Idaho Transportation Department (ITD)
- Kevin Merryman, Iowa DOT
- Brett Trautman, Missouri DOT (MoDOT)
- Kenny Seward, Oklahoma DOT (ODOT)
- Matt Zeller, Concrete Paving Association of Minnesota

Introduction

Transportation agencies at all levels are experiencing a transition in workforce and workload activities. Retirements and the presence of fewer full-time employees are reducing the experienced inspector talent pool in many agencies across the country. Programming has changed from building pavements on new alignment to funding more maintenance activities. The trend is to rely more on consultant inspection because agencies have a difficult time finding experienced people, budget restrictions have reduced their personnel, or their staff members have been re-assigned.

Ask any technician, inspector, or practitioner in the pavement industry what goes into concrete and what it takes to make quality concrete, and you will probably get fairly consistent answers: Concrete is made of cement (or cementitious materials), aggregate, water, and air. Making quality concrete is dependent upon air content, the water-to-cement ratio, and the quality of the input materials.

If you ask that same group of people what goes into building a quality concrete pavement, you will probably receive a wide variety of responses, such as good concrete, proper finishing, a drainable base, or use of proper equipment. Some might actually even say proper curing methods. These responses are correct, but none of them alone will ensure a quality concrete pavement. One answer you will probably not hear, but which encompasses all of the answers you will hear, is proper inspection.

Proper inspection is not the most important component of a quality concrete pavement, nor is it a guarantee for long-term performance. However, it is one of the final checkpoints during the construction process before a concrete pavement enters into service. The principles of good inspection aren't just for streets and highways—they can be applied to airfield pavements, parking areas, drainage channels, trails, and even sidewalks and driveways.

The responsibility of the inspectors is not to supervise or direct the activities of the contractor. It is, however, their responsibility to ensure that the contractor's activities conform to the requirements of the owner agency.

Quality

Quality can be simply defined as conformance to requirements. An inspector, armed with plans, specifications, and standards, is tasked with ensuring that a contractor's work conforms to the agency requirements. The mission of the inspector can be summarized by a statement from Philip Crosby, a quality management expert, "The customer deserves to receive exactly what we have promised to produce."

In a perfect world, the result of effective quality systems would always be a long-lasting pavement and all pavements would be built exactly to contract requirements. Unfortunately, we do not live in a perfect world. People make mistakes, things get overlooked, random failures occur, and as much as we would like to deny it, shortcuts do get taken.

In the past, the inspector was the sole point of acceptance on a project. As contractors have embraced the concepts and benefits of quality control, the role of the inspector has changed. Inspectors now are responsible for monitoring and verifying contractor quality control (QC) efforts, rather than being the QC for the contractor.

Workshop Format

The workshop was composed of a series of modules to give the participants a broad background of information that a new inspector needs to adequately perform their job duties:

- Why are we here
- How do we achieve quality for PCC paving
- Got a project…Now what
- What is concrete
- What kinds of equipment are used
- What happens before you start paving
- What happens when you're finally paving–daily items
- What is the inspector's role
- What about all of the other road building stuff
- What do you look for in urban paving
- What paperwork is necessary
- Checklist
- Troubleshooting

Consideration was given to carefully explaining processes and terminology throughout the course of the workshop. Each module was further divided into specific topics. For example, the following topics were under "What is the inspector's role?"

- Traffic Control
- Dust Control
- Safety
- Equipment
- Grade Control
- Concrete Delivery
- Concrete Placement
- Concrete Testing
- Pavement Testing
- Vibration
- Steel Placement
- Finishing

- Texture
- Curing
- Smoothness
- Haul Roads
- Documentation
- Housekeeping
- Non-Compliance Notices

This list was not intended to be exhaustive, but it does demonstrate the wide variety of activities about which an inspector must, at the very minimum, have fundamental knowledge. In addition to this list, an inspector must also be conscious of other construction activities and the impacts on or interactions with the concrete pavement by those activities. Items such as shoulders, subdrains, pavement markings, drainage structures, and roadway access points can have an impact on concrete pavements before, during, or after construction.

Workshop Presentation

Pilot versions of the workshop were presented on three occasions

- Idaho DOT
- By webinar with the City of Yorkton, Saskatchewan
- Manitoba (Canada) Ministry of Infrastructure

Checklists

Part of the resources provided to attendees was a series of checklists to assist field inspectors with their daily work. The checklists included the following:

- Paver Setup
- Daily Paving Summary
- Pavement Markings
- Subgrade Checks
- Depth Checks
- Paving Items
- Texture
- Air and Slump

TAC members and representatives from nine states were instrumental in reviewing the products.

National Concrete Pavement
Technology Center

Tech Center

2711 South Loop Drive, Suite 4700 | Ames, IA 50010-8664 | Phone: 515-294-5798 | cptechcenter.org