PRACTICES FOR MAINTAINING AND RESURFACING EXISTING COMPOSITE PAVEMENTS

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16. Abstract

In recognition of the prevalence of asphalt concrete (AC) overlays as a rehabilitation solution for existing portland cement concrete (PCC) pavements, this project looked at State Departments of Transportation (DOTs) practices for the evaluation, design, construction, maintenance, and rehabilitation of AC/PCC composite pavements. This was primarily accomplished through a 2-day, multi-agency peer exchange, meetings with selected State DOTs, and the preparation of case studies highlighting practices that have been used by State DOTs in managing their composite pavement systems. It was found that many State DOTs have experienced improved performance as the result of ongoing research studies and initiatives. Much of that improved performance is the result of the State DOTS taking a “systems” approach to considering and addressing the potential for reflective cracking issues throughout the entire composite pavement design and construction process, including:

- Evaluation of existing pavement.
- Selection of appropriate overlay materials.
- Development of appropriate overlay thickness.
- Effective preparation of existing pavement and placement of overlay.
- Timely application of effective future maintenance and rehabilitation treatments.

This report documents the various activities that were performed under the project, provides key takeaways from the State DOT outreach meetings, and presents practices being used by the State DOTs in managing their AC/PCC pavements.

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AC	Asphalt Concrete
ADA	Americans with Disabilities Act
ADT	Average Daily Traffic
BRIC	Binder Rich Intermediate Course
CAM	Crack Attenuating Mixture
CCI	Critical Condition Index
CLC	Contract Leveling Course
CRCP	Continuously Reinforced Concrete Pavement
DCP	Dynamic Cone Penetrometer
DOT	Depart of Transportation
FHWA	Federal Highway Administration
FWD	Falling Weight Deflectometer
FI	Flexibility Index
GPR	Ground Penetrating Radar
HPTO	High Performance Thin Overlay
HiMA	Highly Modified Asphalt
I-FIT	Illinois Flexibility Index Test
IRI	International Roughness Index
JPCP	Jointed Plain Concrete Pavement
JRCP	Jointed Reinforced Concrete Pavement
MRD	Materials-Related Distress
MTD	Material Transfer Device
MPPP	Midwest Pavement Preservation Partnership
NMAS	Nominal Maximum Aggregate Size
NTEA	Nontracking Emulsified Asphalt
PMS	Pavement Management System
PCC	Portland Cement Concrete
RWD	Rolling Weight Deflectometer
SDI	Surface Distress Index
SMA	Stone Matrix Asphalt
THMACO	Thin Hot Mix Asphalt Concrete Overlay
TSD	Traffic Speed Deflectometer
TRB	Transportation Research Board
UBAWS	Ultra-thin bonded asphalt wearing surface
UTBWC	Ultra-thin bonded wearing course
WMATA	Washington Metropolitan Area Transit Authority

CHAPTER 1. INTRODUCTION

Background on Composite Pavements

Composite pavement systems are multi-layered pavement structures that are constructed using materials of different composition. The most prevalent composite pavement type is an asphalt concrete (AC) overlay on an existing portland cement concrete (PCC) pavement, a strategy that is commonly used to address structural and functional deficiencies of the underlying pavement. AC/PCC composite pavements comprise a significant portion of roadway mileage in the U.S., representing over 91,000 centerline miles, including 9,500 centerline miles on the Interstate network alone (FHWA 2020). Figure 1 illustrates a typical cross section of an AC/PCC composite pavement.

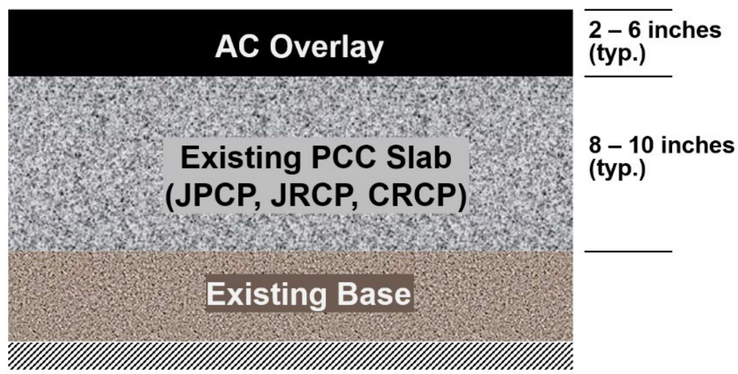


Figure 1. Typical AC/PCC composite pavement.

The rehabilitation of an existing PCC pavement through the placement of an AC overlay offers a number of benefits:

- Rapid construction and opening to traffic, leading to reduced travel disruption.
- Increased structural (load-carrying) capacity of the pavement system.
- Functional improvements (smoothness, friction, noise).
- Low initial cost.
- Ease of future maintenance.
- Easily renewable through placement of additional overlays.
- Limited increase in grades and elevations.
- Reduction in water/salt ingress into the underlying PCC layer.
- Insulation of the PCC layer and reductions in the temperature gradient through the slab, resulting in reductions in slab curling.
- Utilization of the PCC pavement in place (i.e., no demolition, hauling, or landfilling).

It is not uncommon for additional asphalt overlays to be used in the future rehabilitation of an existing AC/PCC composite pavement, either through the complete removal of the existing asphalt layer down to the PCC slab and the placement of the new overlay or through the partial removal or patching of the existing asphalt layer and the placement of the new overlay. These "second-generation" overlays are often used because of their ease of construction, rapid opening to traffic, and the need to maintain existing grades, elevations, and curb reveals.

AC overlays of existing PCC pavements may be constructed using a variety of bituminous materials, including:

- Dense-graded mixtures.
- Open-graded friction courses.
- Polymer-modified mixtures.
- Asphalt-rubber mixtures.
- Stone matrix asphalt (SMA).

The selection of the specific material for the overlay depends on a number of factors, including traffic levels, environmental conditions, the needs of the particular project, and State DOT practices.

The existing PCC may be one of three different pavement types:

- Jointed plain concrete pavements (JPCP), which contain no distributed steel in the central portions of the slab, may or may not include dowel bars at the transverse joints, and are characterized by short panel lengths (typically 15 ft).
- Jointed reinforced concrete pavements (JRCP), which contain light reinforcing steel in the central portions of the slab (about 0.1 percent of the cross-sectional area), dowel bars at the transverse joints, and are characterized by longer panel lengths (typically 40 to 80 ft).
- Continuously reinforced concrete pavements (CRCP), which contain heavy longitudinal steel reinforcement (typically 0.6 to 0.7 percent of the cross-sectional area) and no regularly spaced transverse joints.

Many State DOTs (particularly in the Midwest) constructed JRCP designs on their major routes in the 1940s through the 1970s (Smith and Hall 2001). The longer joint spacings associated with those designs often limited the performance of the AC overlay due to larger joint movements and the development of mid-panel cracks. Conversely, AC overlays of CRCP designs (which have no regularly spaced transverse joints) have generally exhibited good performance (Flintsch, Diefenderfer, and Nunez 2008).

AC/PCC Performance

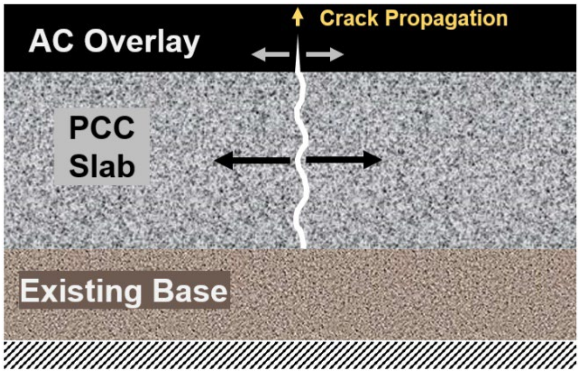
The performance of AC overlays on existing PCC pavements varies considerably. Variables include the thickness of the AC overlay, the condition of the underlying pavement (particularly the load transfer at the transverse joints and their integrity), traffic levels, environmental conditions, the underlying PCC joint spacing, the type and properties of the overlay material, and the type and amount of preoverlay repairs (Bennert 2010). In the peer exchange meetings (see Chapter 3), most State DOTs were reporting performance lives of about 10 to 15 years for first-generation overlays, with shorter performance lives for second- and third-generation overlays (on the order of 6 to 14 years).

The major distress affecting the performance of AC/PCC composite pavements is reflective cracking (see figure 2). Reflective cracks occur in the AC overlay above cracks and joints in the underlying concrete pavement, and once they appear they serve as an entry point for infiltration of water, salts, and debris that can affect the integrity of the asphalt overlay and continue the degradation of the underlying pavement layers. Furthermore, as the cracks continue to deteriorate and break down under traffic and environmental loadings, they contribute to increased surface roughness and in severe cases may also pose a safety issue.

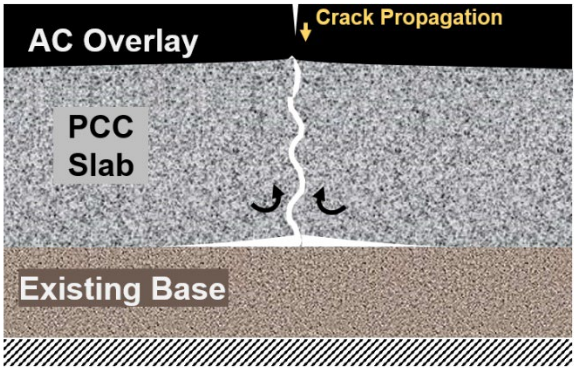
Figure 2. Reflective cracking on AC/PCC pavement.

As shown in figure 3, reflective cracks develop as the result of various horizontal and vertical forces acting on the underlying slab in response to:

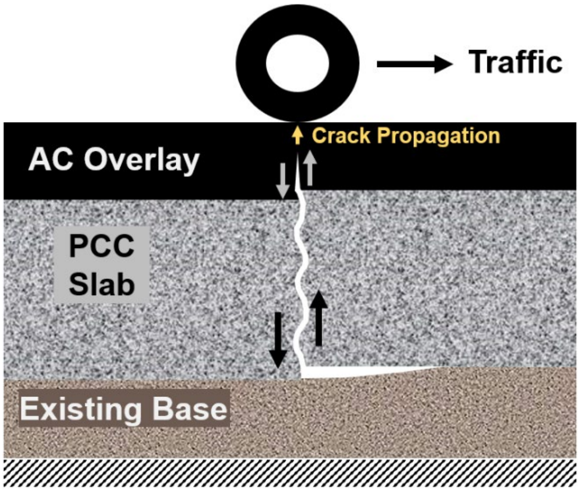
- Temperature changes (expansion/contraction).
- Thermal gradients (curling).
- Traffic loading (deflections).



a) Horizontal movements due to temperature changes.



b) Curling of PCC slab due to thermal gradient.



c) Excessive deflections (traffic + poor load transfer and support)

Figure 3. Mechanisms contributing to reflective cracking.

Reflective cracks may propagate to the pavement surface at a rate of about 1 inch per year; so, on a 3-inch AC overlay cracks would be expected to appear on the surface after about 3 years. Still, many of the other factors previously described can affect the propagation rate.

Mitigation of Reflective Cracking

A number of treatments have been used to mitigate the effects of reflective cracking on AC/PCC pavement structures, including:

- Treatments that delay the onset of reflective cracking, such as the use of strain-tolerant asphaltic interlayers, geotextile interlayers/fabrics, preoverlay treatments (full-depth patching, slab stabilization), or thicker AC overlays.
- Treatments that attenuate the source of cracking, such as the use of fractured slab techniques consisting of three different approaches:
  - Crack and seat, which is used on JPCP to reduce the effective slab size.
  - Break and seat, which is used on JRCP to reduce the effective slab size and to debond the steel from the concrete.
  - Rubblization, which is used on all PCC types to reduce the concrete to much smaller fragments, with the size of the broken pieces ranging from a few inches on the surface of the slab to about 6 to 12 inches at the bottom of the slab.
- Treatments that control the resultant cracking, such as through the sawing and sealing of joints in the AC surface above the joints in the underlying PCC.

The approaches' effectiveness varies. It can be difficult to sort out the impacts of the various treatments given the large number of pavement condition, traffic loading, and environmental factors that affect performance. Furthermore, it can be difficult to interpret results for effectiveness and performance across various studies. Overall, however, an effective solution to the reflective cracking problem is needed for AC/PCC composite pavements. The solution should evaluate and characterize the underlying PCC, address key deficiencies, make use of quality (and strain-tolerant) overlay materials, and employ effective construction and installation practices.

Project Objective

This project builds on previous work done by the Strategic Highway Research Program 2 (Rao et al. 2014) and by FHWA (Smith et al. 2019) on new composite pavements (i.e., where both the AC overlay and underlying PCC are built at the same time). This project focuses solely on the management of existing AC/PCC pavements, where highly variable performance is often experienced. The study documents practices used by State DOTs in the evaluation, design, construction, maintenance, and rehabilitation of their AC/PCC composite pavements.

Overview of Report

This report consists of five chapters, including this introductory chapter. Brief descriptions of the chapters are provided below:

- **Chapter 2. Summary of Project Activities.** This chapter provides a brief summary of the State DOT outreach activities that were performed under the project, which included a 2-day, multi-agency peer exchange, meetings with selected State DOTs, and the delivery of technical presentations.
- **Chapter 3. Key Takeaways from State Departments of Transportation (DOT) Composite Pavement Practices.** This chapter summarizes the key takeaways and lessons learned from State DOTs in the management of their AC/PCC pavements, including information on evaluation, materials and mix design, construction, maintenance and rehabilitation, and performance.
- **Chapter 4. Composite Pavement Case Studies.** This chapter presents four brief case studies.
- **Chapter 5. Conclusions.** This chapter provides a brief recap and describes some of the current gaps and research needs.

CHAPTER 2. SUMMARY OF PROJECT ACTIVITIES

Introduction

This chapter provides a summary of the various activities performed to collect and communicate the successful practices used by State DOTs in the management of their composite pavements. Chapter 3 then documents those practices by major topic area.

Literature Review

The project team performed a literature search on the design, construction, maintenance, and performance of AC/PCC composite pavements. The literature search focused on work performed in the last 10 years, drawing primarily from national (e.g., FHWA, Transportation Research Board [TRB]), State DOT, and pavement industry sources. The literature search considered all aspects and components of AC/PCC composite pavements (including first and subsequent generation overlays) but the majority of the identified documents focused on approaches to address or mitigate reflective cracking.

Peer Exchange

The FHWA conducted a national virtual peer exchange on May 11-12, 2021. The peer exchange featured a mix of technical presentations, State reports, and breakout sessions. It also provided a forum for States DOTs to share their general experiences with composite pavements and to discuss critical topics such as evaluation, preoverlay repairs, reflective cracking control, and current gaps and research needs. The peer exchange attracted more than 40 attendees with representation from State DOTs, FHWA, academia, and industry. Figure 4 indicates the States represented in the peer exchange.

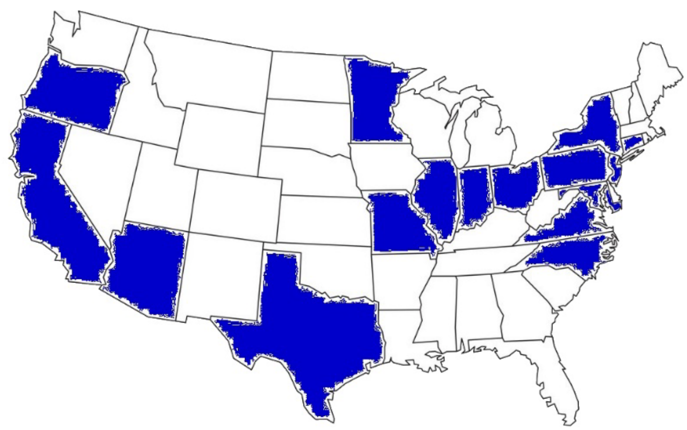


Figure 4. States represented in peer exchange.

The first part of the peer exchange focused on the design and construction of AC/PCC composite pavements, anchored by an overview presentation and featuring a summary of the experiences of several State DOTs. This was followed by a breakout session in which participants were divided into groups and shared their practices related to AC overlay design and construction.

The second day of the meeting included a technical session on evaluating and maintaining composite pavements. A lead presentation on pavement evaluation procedures then transitioned to specific State DOT experiences in composite pavement maintenance. In a second breakout session of four groups, participants discussed current practices and future needs related to AC/PCC maintenance and rehabilitation.

The meeting concluded with a third breakout session in which participants discussed current gaps and research needs for AC/PCC composite pavements.

As part of the peer exchange, the general characteristics of the participating State DOTs on several key aspects of composite pavements were documented, and these are presented in figures 5 through 10.

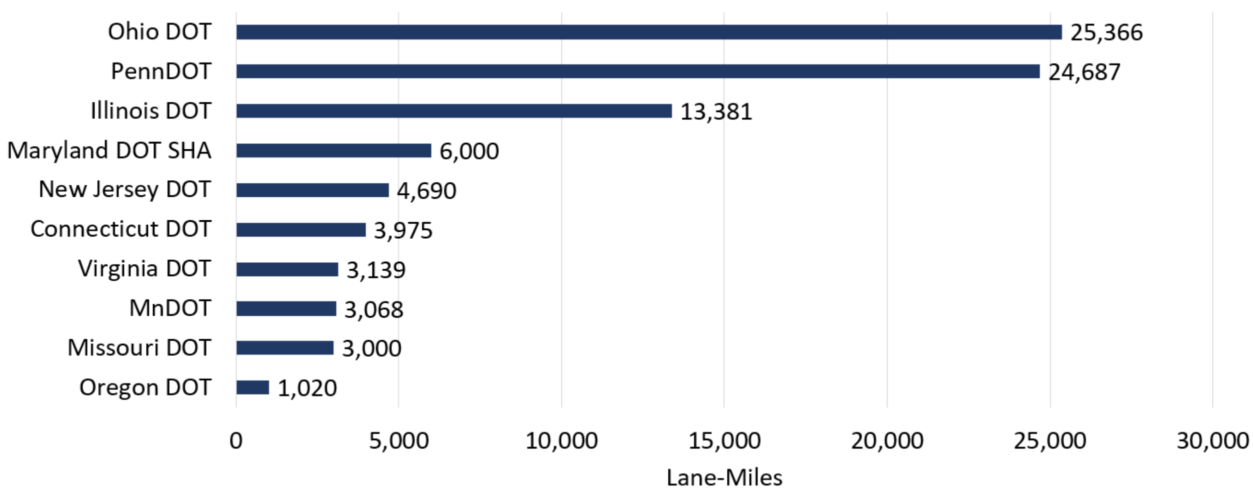


Figure 5. Composite pavement mileage for selected State DOTs.

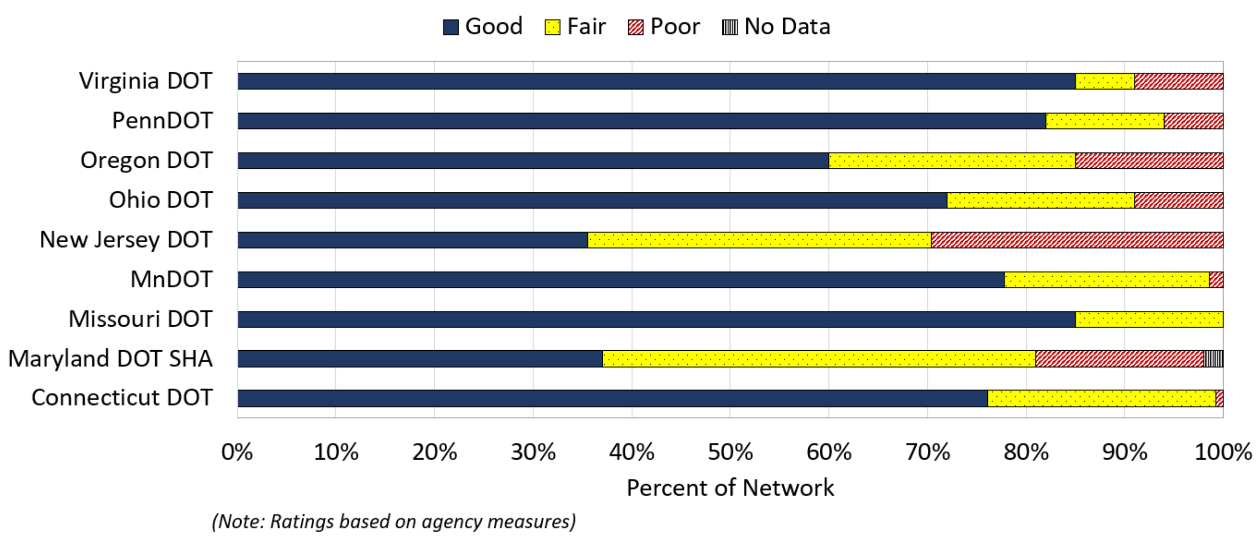


Figure 6. Composite pavement conditions for selected State DOTs.

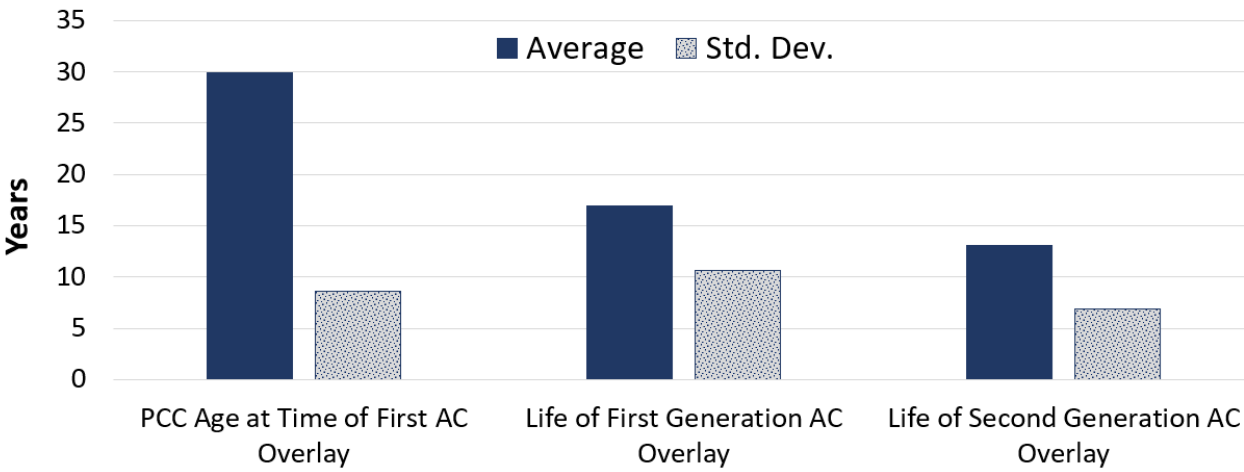


Figure 7. Average reported performance lives.

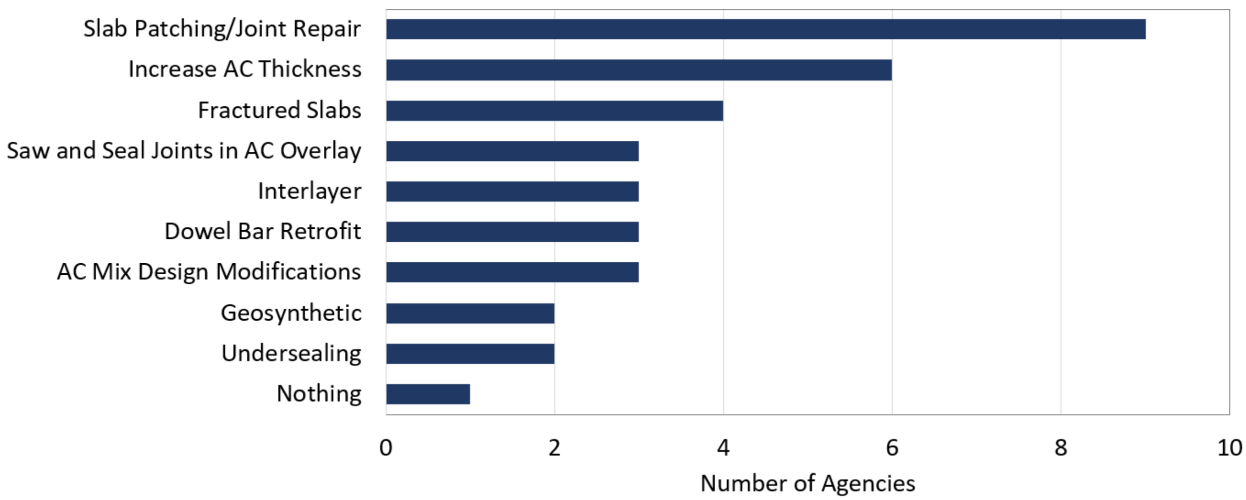


Figure 8. Use of techniques to reduce reflective cracking.

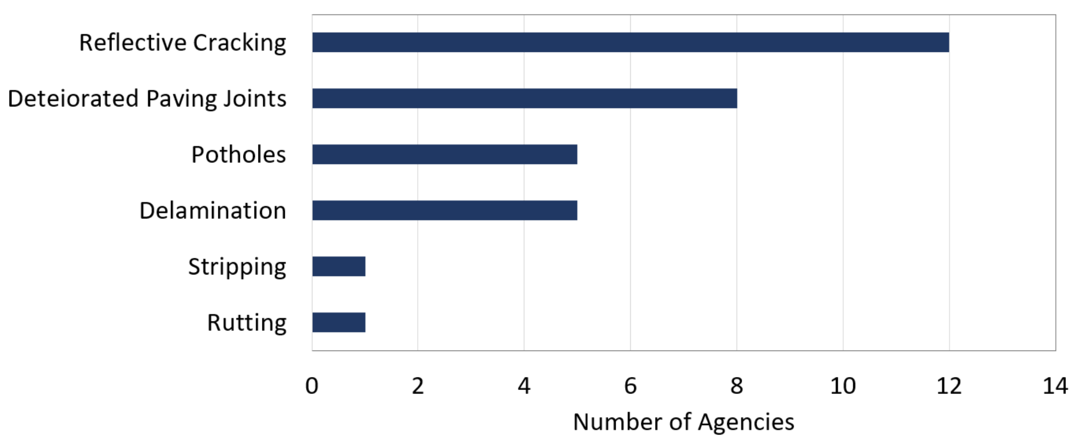


Figure 9. Challenges in maintaining composite pavements.

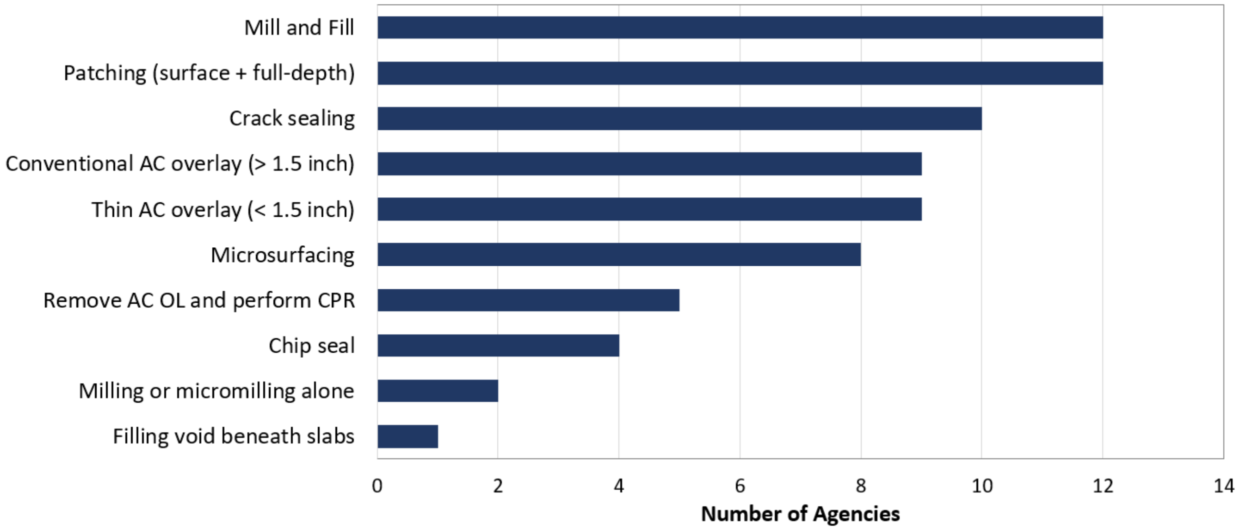


Figure 10. Common maintenance and rehabilitation activities performed on existing composite pavements.

State DOT Meetings/Visits

A series of follow-up visits were scheduled with selected State DOTs to document some of their practices. Table 1 lists the States DOTs that participated in the follow-up meetings, which covered the following key topics:

- General experience.
- AC overlay materials.
- PCC evaluation and repair.
- Reflective cracking control.
- Performance of AC/PCC.
- Preservation and maintenance of AC/PCC.
- Innovations and research.
- Case studies.
- Research needs.

Participants also shared their material and construction specifications, policies, procedural manuals, guide documents, and relevant research reports.

Table 1. Summary of State DOT meetings.

Date	State DOT	Format/Location
September 1-2, 2021	New Jersey DOT (NJDOT)	Virtual
September 16-17, 2021	Illinois DOT (IDOT)	Springfield, Illinois
September 21, 2021	Indiana DOT (INDOT)	Indianapolis, Indiana
November 3-4, 2021	Virginia DOT (VDOT)	Virtual
December 2-3, 2021	Missouri DOT (MoDOT)	Virtual
March 22-23, 2022	Pennsylvania DOT (PennDOT)	Virtual

Field visits to nearby composite pavement projects were conducted as part of the two in-person meetings held in September 2021. These visits provided the opportunity to review first-hand the performance of several AC/PCC projects at the following locations:

- Various composite pavements in the vicinity of Springfield, Illinois (see figure 11).
- Recently completed composite pavement on I-65 northwest of downtown Indianapolis (see figure 12).

Figure 11. US 54 in Lake Fork, Illinois.

Figure 12. I-65 northwest of Indianapolis.

With input from the State DOTs, four case studies were developed to illustrate State DOT practices with AC/PCC composite pavements:

- Route 1/Route 9, Newark and Elizabeth, New Jersey.
- I-55, Lincoln, Illinois.
- I-65, Indianapolis, Indiana.
- I-66, Fairfax, Virginia.

The case studies appear in chapter 4.

Outreach Events

The FHWA supported the delivery of several technical outreach activities to help disseminate the key findings from the peer exchange and State DOT meetings, including:

- Presentation at the Midwest Pavement Preservation Partnership (MPPP) Annual Meeting in St. Louis, Missouri on September 15, 2022. This presentation focused on the maintenance and resurfacing activities associated with composite pavements and reached an audience of more than 60 participants.
- Hosting of a 1.25-hour webinar on October 20, 2022. This webinar targeted State DOTs (including pavement designers, material technologists, construction engineers, and maintenance practitioners); local roadway agencies; contractors; consultants; and academia and attracted over 200 attendees. The webinar included all stages of composite pavement management, including design, materials, preoverlay repair, construction, and maintenance and rehabilitation.

CHAPTER 3. KEY TAKEAWAYS FROM STATE DOT COMPOSITE PAVEMENT PRACTICES

Introduction

This chapter presents the significant findings, key takeaways, and lessons learned from the literature search, peer exchange meeting, and the follow-up meetings. The information is organized into the four broad topics shown in figure 13.

Figure 13. Key topic areas for composite pavements.

The majority of the information presented herein is based on the experience of the State DOTs that participated in the peer exchange. While much of the overall experience centers around high-volume, Interstate-type facilities, a number of State DOTs manage composite pavements on lower volume highways. Some of those lower volume roadways include original concrete pavements dating as far back to the 1930s and 1940s that presented design and construction challenges due to:

- Longer joint spacings, which lead to greater joint widths/openings.
- Narrow, 10- to 11-ft wide lanes that had to be widened to 12 ft before overlaying.
- Grade/elevation restrictions and the presence of curb/gutter elements, both of which limited the available rehabilitation options.

Pavement Evaluation

In the realm of composite pavements, pavement evaluations may be performed on either an existing PCC pavement or an existing AC/PCC pavement. In either case, the shared objective is to determine the appropriate maintenance or rehabilitation needs. The primary methods used for pavement evaluation include condition surveys, roughness testing, deflection testing, and coring.

- Condition data. Network-level condition data (such as faulting, cracking, and roughness on PCC pavements and cracking, rutting, and roughness on AC/PCC pavements) from the State DOT's pavement management system (PMS) generally serve as the first source of information and often trigger the project for rehabilitation. At that point, more detailed condition surveys may be performed to confirm the types and quantities of distress; these in turn are used to help determine the suitability of an overlay and the amount of patching or other preoverlay repair work that may be required. Information from the condition surveys also helps identify the need for additional field testing.
- Roughness. Roughness is collected by State DOTs on their primary network at regular intervals and is available within their PMS. Excessive roughness is a common driver for the rehabilitation of both existing PCC and existing AC/PCC pavements.
- Deflection testing. Deflection testing, often using a falling weight deflectometer (FWD), is performed by several State DOTs. This testing may be done on a project-by-project

basis as specified or on larger, more significant projects. The results of the FWD testing can provide information on subsurface support conditions, joint load transfer, and inputs for use in structural overlay design. Some concerns were expressed about interpreting FWD results on AC/PCC pavements. Structural deficiencies of the PCC pavement are not a common issue.

- Coring. Coring is a common pavement evaluation method, particularly if there are concerns about the integrity of the in-place materials (such as D-cracking or alkali-silica reactivity on PCC pavements and stripping or delamination on AC pavements); furthermore, coring can be helpful if there are questions regarding the type, thickness, and condition of the underlying support layers. On existing AC/PCC, cores can be examined to help provide an indication of appropriate milling depths.
- Other procedures that are seeing some use by State DOTs include:
  - Ground penetrating radar (GPR), primarily for layer thicknesses but also occasionally for identifying the presence of underlying voids. GPR is calibrated against field cores taken from the specific project.
  - Rolling weight deflectometers (RWD) and traffic speed deflectometers (TSD) are being investigated by a few State DOTs to provide continuous readings on structural support conditions.
  - Dynamic cone penetrometer (DCP) testing is occasionally used by a few State DOTs to investigate (or quantify) subsurface support conditions.
  - Friction testing may be done in areas with a history of crashes in wet-weather conditions.

One potential issue in developing treatment (particularly rehabilitation) recommendations is the lapse between the time that the condition data are collected and the time that the project is constructed; in many cases, this can be 2 years or longer. As a result, this often necessitates the conduct of a follow-up pavement survey to ensure that the conditions have not significantly changed since the time of the initial survey.

Design and Materials

Design of AC Overlays

The determination of AC overlay thickness for existing PCC pavements varies by the State DOT. Many State DOTs do not "design" the overlays in the conventional sense but consult design tables or standard overlay protocols for the traffic and condition levels of the existing pavement. On major rehabilitation projects, several State DOTs make use of the AASHTO 1993 overlay design procedure while a few use the AASHTO Pavement ME procedure (but only for rubblization projects). The use of either procedure is not a Federal requirement.

The determination of AC overlay thickness for existing AC/PCC pavements is driven by many factors, including:

- The condition of the existing AC overlay (including any signs of stripping or degradation).
- The depth and location of the AC overlay lift lines (which are avoided if surface milling is employed).

- Any elevation, profile, or grade constraints (e.g., intersections, curb reveal, bridges).
- The State DOT's minimum overlay thickness policy.

Formal structural thickness designs for the unique project conditions may be performed for extensive projects or on higher class facilities.

Some typical overlay thickness practices are summarized below:

- Common AC overlay thicknesses: 2 to 5 inches.
- Minimum thickness of about 3.5 inches is used on bare PCC.
- Improved performance reported for thicker overlays (those greater than 4.5 inches).
- 1 additional inch of overlay thickness provides about 1 year of additional life.

Surface and Interlayer Mixtures for AC Overlays

Many State DOTs use their conventional dense-graded mixtures for AC overlays of existing PCC pavements. However, as many of the pavements are exposed to significant traffic levels, some State DOTs (such as New Jersey, Virginia, and Illinois) are specifying more durable surface mixtures. Furthermore, a number of State DOTs are adopting or incorporating modified interlayer mixtures that are more "strain-tolerant" and therefore more capable of withstanding the extreme movements of the underlying PCC. These interlayer mixtures help mitigate the development of reflective cracking and contribute to improved performance. A few examples of asphalt interlayer materials that are being used with reported good performance include:

- Crack-attenuating mixtures (CAM) were developed by the Texas DOT to help reduce reflective cracking. Texas DOT has used a fine-graded mixture (typically PG76-22 and polymer modified) with a minimum binder content of 7 percent as an interlayer between the existing pavement and the asphalt surface layer (FHWA 2022). It is placed in thin, 0.5- to 1-inch lifts.
- The binder-rich intermediate course (BRIC) is a 4.75 mm nominal maximum aggregate size (NMAS) polymer-modified mixture (commonly PG70-28) with 7 percent asphalt; it is placed over the existing PCC (and beneath an asphalt surface course) to help mitigate reflective cracking (NJDOT 2019). This material is used by the New Jersey DOT and was based on the CAM material developed by TxDOT; it is typically placed in about 1-inch lifts.
- A binder-rich sand mix (4.75 mm NMAS) is used by the Illinois DOT to help mitigate reflective cracking.

In combination with these interlayer materials, some State DOTs have been using different surface mixtures to help improve the performance of their AC/PCC pavements. One material in particular that is seeing more use is SMA, which is a gap-graded mixture offering increased stone-on-stone contact and greater resistance to rutting and fatigue cracking (Smith et al. 2019). Several State DOTS observed that these mixtures perform better than conventional dense-graded mixtures, particularly in conjunction with a high-binder intermediate course. The New Jersey DOT commonly uses a 2-inch SMA over a 1-inch BRIC.

Other examples of modified surface mixtures include high-performance thin overlays (HPTO), highly modified asphalt (HiMA) mixtures, fiber-modified asphalt, ground tire rubber modified asphalt, and ultra-thin bonded wearing course (UTBWC).

Overlay Preparation and Construction

Preoverlay Repairs

Repairs to the existing pavement prior to the placement of the AC overlay are critical to the future performance of the overlay. The type and amount of preoverlay repairs depend on the type of distress exhibited by the existing pavement, the current structural adequacy, subsurface support and drainage conditions, future traffic loadings, grade and elevation constraints, and overall costs. A summary of some of the common preoverlay repair activities performed on existing PCC or existing AC/PCC pavements are listed in table 2.

Table 2. Common preoverlay repair treatments.

Repair Activity	Applicable Conditions (PCC or AC Surface)	Comments
Full-Depth Repair/ Slab Replacement	Deteriorated Joints Cracked/Shattered Slabs Reflective Cracking	Replace materials in kind; full-depth concrete repairs most commonly used (many State DOTs do not allow the use of full-depth asphalt repairs)
Partial-Depth Repair/Patching	Joint Spalling Potholes Raveling/Delamination	Concrete, asphaltic, and flexible repair materials all used
Joint/Crack Sealing	Joints/Cracks	Performed by a few State DOTs prior to AC overlay
Load Transfer Restoration	Joints/Cracks with Poor Load Transfer	Generally applied on bare PCC pavements
Slab Stabilization	Joints/Cracks with Poor Support	Polyurethane materials commonly used
Retrofitted Edgedrains	Pavements with Poor Drainage	Limited use, but more often on fractured slab projects or on pavement widening
Surface Leveling	Rutting Surface Irregularities	Includes the leveling of ruts on PCC caused by studded tires. For AC surfaces, these are often more effectively addressed with milling.
Diamond Grinding or Micromilling (existing PCC)	Roughness	Contributes to a smoother ride of the AC overlay and contributes to overlay bond
Milling (existing AC/PCC)	Cracking Rutting Surface Deterioration Elevation/Grades	Typically used on all existing AC/PCC projects

Milling of an existing AC/PCC pavement can be a quick and effective way of removing deteriorated surface materials and preparing the pavement to receive a subsequent overlay. "Mill and fill" projects are used to maintain the AC/PCC pavements and may include the removal of a few inches of asphalt with in-kind replacement or may include removal of all material down to the underlying PCC. Milling also affords State DOTs the opportunity to maintain grades, elevations, and curb reveal. Typical milling practices reported by the State DOTs participating in the peer exchange include:

- Avoid leaving 0.5 inch or less of AC above a lift line (determined from an examination of cores).
- Avoid leaving 1 inch or less of AC above the PCC.
- Be sure to clean up scabs (areas of incomplete material removal) prior to overlay placement as these can otherwise affect compaction, smoothness, and overlay performance.
- Limit the amount of edge drop-off (normally no more than about 2 inches) between adjacent paving lanes.
- In some cases, limit the amount of time that the milled surface is exposed to traffic.

Many State DOTs have adopted micromilling, which uses additional teeth on the milling drum affixed in a tighter pattern that allows more precise removal and produces a smoother pavement texture than conventional milling.

Reflective Cracking Control Measures

As described in Chapter 1, a number of approaches and treatments are used to help mitigate the effects of reflective cracking on AC/PCC performance. Common approaches reported by the State DOTs participating in the peer exchange include:

- Asphalt interlayers, such as BRIC and CAM, are strain tolerant and help minimize reflective cracks and are seeing more widespread use. A few State DOTs have also used chip seals and UTBWC as interlayers.
- Fractured slab techniques are used by State DOTs on more deteriorated concrete pavements, but they require a thicker asphalt overlay and are more applicable in rural areas.
- Paving fabrics may retard reflective cracking but do not stop it. They should not be used on faulted or rocking slabs and appear to be more effective on longitudinal joints and in moderate climates where there is less slab movement. In consideration of future rehabilitation, these should be millable and recyclable.
- Sawing and sealing of joints in the AC overlay is a technique used by several State DOTs, but a number have moved away from it because of issues in getting the joints sawcut accurately. When used, State DOTs will cut the joints to a depth of one-third of the AC overlay thickness.
- Thicker AC overlays can delay the onset of reflective cracking but could significantly increase the cost of the project.

Several State DOTs employ a "systems" approach to mitigate reflective cracking, one that considers important aspects of the entire overlay process. This approach addresses the condition and characteristics of the PCC, uses strain-tolerant interlayers and durable surface courses, develops adequate AC overlay thicknesses, uses appropriate reflective cracking control measures, specifies effective placement practices, and prescribes timely and effective maintenance.

Placement of AC Overlays

Conventional paving practices apply to the placement of the AC overlay on the existing pavement (PCC or AC/PCC), with the following key considerations noted:

- Sweeping and cleaning of the pavement surface.
- Proper and sufficient application of the tack coat to the pavement surface to promote bond. Many State DOTs increase the tack rate, and several are also using a non-tracking tack. At least one State DOT uses a spray paver for thin AC overlay projects on PCC, which provides a good bond with the PCC.
- Placement of overlay in multiple lifts (with tack between lifts) to help achieve compaction and ensure good bonding.
- As with conventional AC paving, proper longitudinal paving joint practices are important to ensure compaction and prevent the joint from raveling and deteriorating. Some State DOTs are using void reducing asphalt membranes (VRAM) to achieve higher densities and prevent moisture infiltration, some have implemented incentive specifications for longitudinal joint density, and others employ innovative joint configurations (e.g., notched wedge).

Pavement Maintenance, Rehabilitation, and Performance

Maintenance and Rehabilitation AC/PCC Pavements

Pavement roughness and overall pavement condition (often including transverse reflective cracking) are common triggers used when determining the need for maintenance and rehabilitation of AC/PCC pavements. Other factors that may trigger a need for maintenance and rehabilitation include increased patching or rehabilitation requirements, deterioration of the AC longitudinal paving joints, and edgedrain failures. A State DOT's pavement management system normally triggers the candidate projects and then the districts will often weigh in on priorities. An example trigger chart used by the New Jersey DOT is shown in table 3.

The actual trigger value used to initiate a maintenance or rehabilitation activity will often vary by roadway facility type or functional classification, with higher trigger values used for lower volume roadways that can tolerate greater levels of deterioration. In some cases, State DOTs may consider reconstruction of the existing AC/PCC pavement when dealing with factors such as:

- Increased traffic volumes.
- Outdated geometrics.
- Increased frequency of rehabilitation.
- The presence of significant cracking, poor load transfer, poor support or drainage conditions, and severe materials-related distress (MRD) in the underlying PCC.

Table 3. Condition index criteria used by New Jersey DOT (NJDOT 2020a).

Status	**Condition Index Criteria** (IRI=International Roughness Index, in/mi; SDI=Surface Distress Index, 0-5 scale)	**Engineering Significance**
Deficient (poor)	IRI > 170 *AND/OR* SDI ≤ 2.4 (Deficient classification results from either deficient roughness alone or surface distress alone or both).	**These roads are due for treatment.** Drivers on these roads will notice that they are driving on a rough surface and may be barely tolerable for high-speed traffic. These pavements may have deteriorated to such an extent that they affect the speed of free flow traffic and may cause damage to vehicles. There will be signs of significant deterioration, including potholes and deep cracks. Deficient pavements will generally be most costly to rehabilitate.
Fair	All combinations of IRI and SDI between those above and below listed range. IRI > 95 and IRI < 170 and/or SDI > 2.4 and < 3.5	**These roads exhibit minimally acceptable smoothness that is noticeably inferior to those of new paving.** These pavements may show some signs of deterioration such as rutting and cracking or patching. Most importantly, roads in this category are in jeopardy and should immediately be programmed for a cost-effective treatment that will restore them to a good condition and avoid costly rehabilitation in the near future.
Good	IRI < 95 AND SDI ≥ 3.5 (Both IRI and SDI must be good to rate this classification).	**These roads exhibit good ride quality with little or no sign of deterioration.** A proactive preventive maintenance strategy is necessary to keep roads in this category as long as possible.

When projects are triggered for maintenance or rehabilitation, a range of potential treatments are used by State DOTs depending on the overall condition levels. These treatments are similar to what are normally used on conventional AC pavements, such as:

- Crack sealing.
  - Increased use of mastics.
  - Often on regular cycle (3 to 5 years).
- Fog seals and rejuvenating seals.
- Patching.
  - Full- or partial-depth.
  - AC or PCC.
- Slurry seals and microsurfacing.
- Chip seals
  - On low-volume routes, typically less than 5,000 ADT.
  - Crack sealing may be performed 1 year prior.
- Cape seals (usually on routes less than 10,000 ADT).

- UTBWC.
- Thin overlays.
- Milling and AC overlay.
  - Some limited use of synthetic fibers, polymer-modified asphalt, and ground tire-rubber mixes in the AC overlay.
  - Partial surface milling or complete milling down to PCC (depending on AC overlay thickness and depth of deterioration).
  - "Buried treasure" concept: where underlying PCC is structurally sound, some State DOTs are removing the AC overlay and restoring the underlying PCC as the riding surface (often through full-depth repairs and diamond grinding).
- Cold, in-place recycling.
- Rubblization (in the case of severe deterioration in the PCC).

The maintenance/preservation treatments listed above may be applied at fixed time intervals set by the State DOT, typically between about 2 and 8 years after the AC overlay placement. Many State DOTs have developed tables providing information on the use of preservation and rehabilitation treatments by functional class or pavement conditions (see examples in table 4 and table 5).

Table 4. Missouri DOT treatment selection guide (MoDOT 2022).

Route Type Based on ADT	Roadway in Good Condition (Goal – Keep in Good Condition)	Roadway in Poor Condition (Goal – Bring to Good Condition)	Roadway in Poor Condition (Goal – Keep Safe and Passable)
Interstate	UBAWS 1 ¾" AC Overlay	Alt. Bid Rehab/Constr. 1 ¾" – 3 ¾" AC Overlay	N/A
Major Routes	Microsurface UBAWS 1 ¾" AC Overlay Chip Seal only if ADT < 2,500	Alt. Bid Rehab/Constr. 1 ¾" – 3 ¾" AC Overlay 1" CLC	N/A
Regionally Significant Minor Routes	Microsurface UBAWS ≤ 1 ¾" AC Overlay Chip Seal	1" – 2 ¾" AC Overlay 1" CLC	N/A
Minor Routes > 400 ADT	Chip Seal Fog Seal	1" CLC Cold-Mix Overlay Hot/Cold Mix Partial Overlay	Cold-Mix Overlay Hot/Cold Mix Partial Overlay
Low Volume Routes < 400 ADT	Chip Seal Fog Seal	Cold-Mix Overlay Hot/Cold Mix Partial Overlay	Cold-Mix Overlay Hot/Cold Mix Partial Overlay

Table 5. Minnesota DOT treatment selection guide (MnDOT 2019).

Pavement Conditions	Severity Level	Crack Filling	Crack Sealing	Micro-surfacing	Chip Seal	Thin HMA Overlay	UTBWC	Rut Filling	Micro Milling	Fog Seal	Mastic
Transverse Cracking	Low	R	R	R	R	F	F	NR	R	F	NR
	Medium	R	R	F	F	NR	NR	NR	F	NR	R
	High	F	F	NR	NR	NR	NR	NR	F	NR	R
Longitudinal Cracking	Low	R	R	F	F	F	F	NR	R	F	NR
	Medium	R	F	F	F	F	F	NR	F	NR	F
	High	NR	NR	NR	NR	NR	NR	NR	NR	NR	F
Longitudinal Joint Cracking	Low	F	F	F	F	F	F	NR	F	NR	NR
	Medium	NR	NR	F	NR	NR	NR	NR	NR	NR	NR
	High	NR	NR	F	NR	NR	NR	NR	NR	NR	NR
Multiple Cracking	Low	R	R	R	R	F	F	NR	R	F	NR
	Medium	R	R	NR	F	NR	NR	NR	F	NR	F
	High	F	F	NR	NR	NR	NR	NR	NR	NR	NR
Alligator Cracking	Low	F	F	F	F	F	F	NR	NR	NR	NR
	Medium	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	High	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Rutting	Low	NR	NR	R	F	F	F	R	R	NR	NR
	Medium	NR	NR	R	F	F	F	R	F	NR	NR
	High	NR	NR	F	NR	NR	NR	F	NR	NR	NR
Raveling and Weathering	Low	NR	NR	R	R	F	F	NR	R	R	NR
	Medium	NR	NR	R	R	F	F	NR	F	F	NR
	High	NR	NR	F	F	NR	NR	NR	NR	NR	NR
Patching	Low	F	F	F	F	F	F	NR	F	NR	R
	Medium	NR	NR	NR	NR	NR	NR	NR	NR	NR	F
	High	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
RQI	3.0 – 4.0	R	R	R	R	R	R	NR	R	F	F
	2.0 – 2.9	F	F	F	NR	R	R	NR	R	NR	F
	1.0 – 1.9	NR	NR	NR	NR	NR	NR	NR	F	NR	F
ADT	<2,500	R	R	R	R	R	F	R	R	NR	R
	2,500–10,000	R	R	R	R	R	R	R	R	NR	R
	> 10,000	R	R	F	F	R	R	R	R	NR	F
Friction	Poor	NR	NR	R	R	R	R	NR	R	NR	NR

- Microsurfacing, Thin HMA Overlay, and UTBWC require ADA compliance as part of the project.
- Longitudinal joint cracking medium and high severity is feasible for Microsurfacing when using a special application box to apply directly to the longitudinal joint.
- For more information on severity levels, see the MnDOT Pavement Distress Identification Manual

Legend

R	Recommended
F	Feasible
NR	Not Recommended

Performance of AC/PCC Pavements

State DOTs participating in the peer exchange generally report acceptable performance from their first-generation AC overlays of PCC pavements but indicate that subsequent overlays do not perform as well. On average, first-generation overlays provide 10 to 15 years of service whereas subsequent overlays provide 6 to 14 years of service. The typical age of the PCC at the time of the first AC overlay is around 30 years.

A number of factors can affect AC overlay performance, including:

- Existing pavement distress and support conditions.
- Environmental conditions.
  - AC overlays generally work better in moderate climates where the underlying PCC sees less movement.
- Type of concrete pavement.
  - Jointed concrete pavements are more problematic.
  - Generally better performance on CRCP.
- Amount of preoverlay repair.
- Type and characteristics of overlay materials.
- Development of reflective cracking and subsequent deterioration.

As previously indicated, reflective cracking is the major performance issue for AC/PCC pavements. Reflective cracking can appear as soon as 1 or 2 years after overlay construction, but more commonly develops after about 4 years, depending on the pavement condition, AC properties, and AC thickness. Other distress conditions that can affect the performance of the AC overlay are deteriorated paving joints, delamination, and stripping of underlying AC layers.

Summary of Key Takeaways

Table 6 summarizes the general experience of State DOTs participating in the peer exchange across various aspects of AC/PCC pavements. Based on that information, the following are some of the overarching takeaways:

- A “systems” approach to AC/PCC pavements helps to address the issue of reflective cracking since the performance of the AC overlay may be limited by poor practices in any part of the system. This means that all components impacting the performance of composite pavements should be considered, including:
  - Existing pavement condition and distresses.
  - Amount and type of preoverlay repairs.
  - Characteristics and properties of the overlay materials (with many State DOTs favoring strain-tolerant interlayers and durable surface courses).
  - AC overlay thickness (for the traffic loadings and design conditions).
  - Reflective crack control measures.
  - Quality of construction/workmanship.
  - Type and timing of future maintenance of the AC overlay.

Table 6. Summary of typical State DOT experiences related to AC/PCC pavements.*

Element	Typical Experiences or Practices
Pavement Evaluation	• Condition surveys, roughness, coring, and FWD are common evaluation methods; a few State DOTs are using or investigating rolling or traffic speed deflectometers. Some State DOTs use GPR for thicknesses. • In-person surveys are needed to help identify repair locations and quantities. • Structural deficiencies of the PCC pavement are generally not an issue.
Design of AC Overlays	• Design tables or standard overlay thickness protocols are often used. • Formal overlay design procedures may be used on major rehabilitation projects. • Typical range of AC overlay thicknesses: 2 to 5 inches. – Minimum thickness of about 3.5 inches on bare PCC. – Improved performance reported for thicker overlays (> 4.5 inches). – 1 additional inch of overlay thickness gives about 1 extra year of service.
Materials for AC Overlays	• Conventional dense-graded materials are used for many AC overlays. • A few State DOTs use modified mixtures with high binder interlayers (Binder Rich Intermediate Course, Crack Attenuating Mixture, binder-rich sand mix) to help mitigate reflective cracking and improve performance. • Several State DOTs use or are investigating SMA surface overlays, which tend to perform better than dense-graded mixes. • Other modified mixtures being used include HPTO, HiMA, fiber-modified asphalt, GTR-modified, and UTBWC.
Preoverlay Repairs	• Common preoverlay repairs: full-depth repair, partial-depth repair, load transfer restoration. Some State DOTs do not allow full-depth asphalt repairs. • Less common treatments: slab stabilization, joint/crack sealing, diamond grinding, retrofitted edge drains. Diamond grinding or micromilling existing PCC pavement prior to overlay helps provide a smoother ride.
Milling (existing AC/PCC)	• Typically used on all existing AC/PCC projects and effective to maintain grades/elevations. • Typical milling practices: – Avoid leaving 0.5 inch of AC above lift line. – Avoid leaving 1 inch or less of AC above PCC. – Clean up scabs (areas of incomplete material removal) as these could affect overlay performance. – Many State DOTs limit the amount of drop-off between adjacent paving lanes (normally about 2 inches).
Reflective Crack Control Procedures	• Use of strain-tolerant asphalt interlayer (e.g., BRIC, CAM) helps minimize reflective cracking. • Fractured slab techniques are used by State DOTs on more deteriorated concrete pavements (but will require thicker AC overlay). • Paving fabrics may retard reflective cracking and appear to be more effective on longitudinal joints and in milder climates (where there is less movement). • Sawing and sealing of joints in AC overlays is used by some State DOTs, but several have discontinued the practice. • Some State DOTs employ a “systems” approach that collectively addresses the existing pavement condition, encourages the use of appropriate materials for the asphalt overlay, develops adequate AC overlay thicknesses, uses appropriate reflective cracking control measures, specifies effective construction and placement practices, and prescribes timely and effective maintenance of the AC overlay.

Table 6. Summary of typical State DOT experiences related to AC/PCC pavements (continued).*

Element	Typical Experiences or Practices
Placement of AC Overlays	• Adequate cleaning of surface and proper/sufficient application of tack coat. • Placement of AC overlay in multiple lifts to help achieve compaction and bonding. • Proper longitudinal paving joint practices.
Maintenance and Rehabilitation of AC/PCC Pavements—Triggers	• Roughness and overall pavement condition (often including transverse reflective cracking) are common triggers for the maintenance or rehabilitation of AC/PCC pavements. These triggers can vary by facility type or functional class. – Other factors that may trigger a need for maintenance or rehabilitation include increased patching or rehabilitation requirements, deterioration of the AC longitudinal paving joints, and edgedrain failures. – Factors that may trigger the need for reconstruction include increased traffic volumes; outdated geometrics; increased frequency of rehabilitation; and the presence of significant cracking and poor support conditions; and severe MRD in the underlying PCC. • The time period between data collection and treatment placement can be an issue (may be 2 years or more).
Maintenance and Rehabilitation of AC/PCC Pavements—Common Treatments	• Patching of existing AC/PCC can be done either full depth or partial depth, and with either concrete or asphalt. • Same typical preservation treatments as used on conventional pavements: crack sealing, fog seals, rejuvenating seals, slurry seals, microsurfacing, chip seals (on low-volume routes), cape seals, UTBWC, thin overlays, cold, in-place recycling. • Crack sealing is often performed on a regular cycle (3 to 5 years) and with an increased use of mastics on wider cracks. • Partial or complete milling of existing AC performed for many overlay treatments. • Where underlying PCC is structurally sound, some State DOTs are removing the AC overlay and restoring the underlying PCC to serve as the riding surface.
Performance of AC/PCC Pavements	• Typical performance range: – First-generation overlays: 10 to 15 years. – Subsequent overlays: 6 to 14 years. • Typical age of PCC at time of first AC overlay is about 30 years. • Reflective cracking is the major performance issue. – Can appear as soon as 1 or 2 years, but more commonly about 4 years. – Other critical distresses that affect performance include deteriorated paving joints, delamination, and stripping of underlying AC layers.

* Typical experiences or practices column includes broad summaries of experiences and practices across all State DOTs participating in the peer exchange.

- While there were variations in the performance of AC/PCC pavements, generally longer service lives were realized for the following conditions:
  - Comprehensive pavement evaluation to assess conditions and determine needs.
  - Use of strain-tolerant AC interlayers.
  - Effective preoverlay repair.
  - Stable underlying materials and foundations.
  - First-generation AC overlay.
  - Thicker AC overlays.
  - Underlying CRCP.
  - Milder climates.

CHAPTER 4. COMPOSITE PAVEMENT CASE STUDIES

Introduction

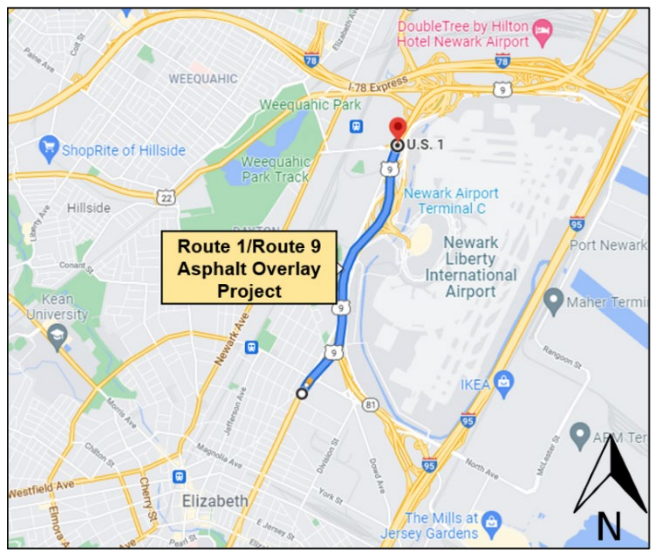
As a result of the visits and meetings with the State DOTs, four case studies were developed. These case studies track the design and construction of the new AC/PCC composite pavement, from the evaluation of the original existing pavement to the design and construction of the AC overlay. Where available, recent performance data are also provided. Case studies were prepared for:

- Route 1/Route 9, Newark and Elizabeth, New Jersey.
- I-55, Lincoln, Illinois.
- I-65, Indianapolis, Indiana.
- I-66, Fairfax, Virginia.

Brief summaries of each of these projects are provided in the following sections.

Route 1/Route 9, Newark and Elizabeth, New Jersey

This project, rehabilitated in 2011, is located on Route 1/Route 9 in the cities of Newark and Elizabeth, between milepost 45.5 and 47.6 in both directions (see figure 14). It serves as a primary access road to Newark Liberty International Airport.



Map data © 2023 Google (The map overlays added as a result of this research project include the North symbol and the route project label.)

Figure 14. Location of Route 1/Route 9 project in Newark and Elizabeth, New Jersey.

What Was the Problem?

This 2-mile stretch of a 2- to 3-lane (local) and 2- to 3-lane (express) urban principal arterial freeway/expressway pavement was exhibiting severe reflective cracking, delamination, and roughness. In 2008, the SDI was 0.67 and the overall project average IRI measurement was 165 inches/mi. The SDI, which ranges from 0 to 5, is a composite index made up of over 15 distresses and severities (NJDOT 2020b). It is the primary trigger used by the New Jersey DOT to select pavement treatments, and is categorized as follows:

- Good: ≥ 3.5 to ≤ 5.0.
- Fair: > 3.0 to < 3.5.
- Mediocre: > 2.5 to ≤ 3.0.
- Deficient: ≥ 0 to ≤ 2.5.

The existing pavement in 2008 consisted of a 3- to 4-inch AC overlay on an underlying 10-inch JRCP. The JRCP was constructed circa 1930 to 1950 on top of a quarry-processed stone base and subbase and featured 56-ft transverse joint spacings (all expansion joints).

What Was Done?

Beginning in 2008, the NJDOT initiated a series of activities to address the shortcomings of the pavement:

- Pavement evaluation (performed in September 2008).
  - FWD testing indicated loss of support beneath PCC slabs.
  - Coring indicated some joint deterioration, but generally sound concrete.
  - Elevation constraints existed so the AC overlay thicknesses could not be increased.
- Rehabilitation design.
  - Mill off 3 to 3.5 inches of existing AC overlay.
  - Resurface with:
    - 1- to 1.5-inch BRIC (4.75 mm).
    - 2-inch SMA surface course (9.5 mm).
- Preoverlay repairs.
  - Full-depth concrete pavement repair.
  - Hot-mix asphalt pavement repair.
- Rehabilitation construction (summer 2011).
  - Existing AC was milled to a depth of 3 to 3.5 inches over the majority of the project.
  - The AC overlay (BRIC + SMA) was placed in two lifts.
- Targeted reflective crack control treatments.
  - BRIC.
- Expected overlay performance.
  - 10 years.

What Is the Current Performance?

An overview of the pavement condition in 2021 after about 10 years of service is shown in figure 15. Performance data from 2020 include:

- Current SDI: 3.4.
- Current roughness: 104 inches/mi.
- Observed distresses to date: Longitudinal construction joint deterioration, isolated low-severity fatigue cracking, and low-severity joint reflective cracking.

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a) NB MP 45.76

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b) SB MP 45.97

Figure 15. Overview of Route 1/Route 9 condition in 2021.

What Are the Key Takeaways from the Project?

NJDOT cited the following factors as contributing to the success of the project:

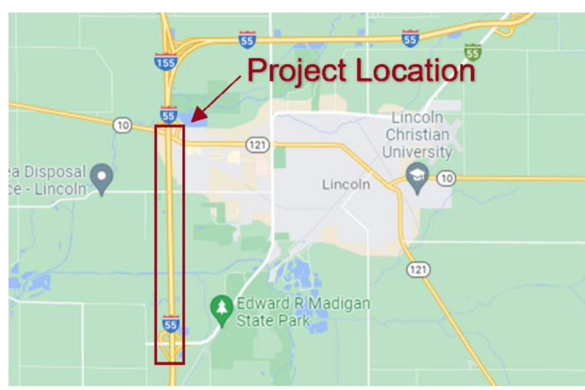
- The comprehensive pavement evaluation confirmed the structural integrity of the underlying pavement and identified specific joint issues that needed to be addressed before the placement of the overlay.
- Preoverlay repairs (consisting of full-depth concrete pavement repair and hot-mix asphalt pavement repair) helped to extend the pavement life.
- The use of a strain-tolerant intermediate course (BRIC) accommodated slab movements associated with long-jointed pavement constructed with expansion joints.
- The SMA surface provided resistance to rutting and cracking.

Interstate 55, Lincoln, Illinois

This project is located between mileposts 123 and 127 on I-55, a major north-south route between Chicago and St. Louis. Located west of Lincoln (see figure 16), the project was rehabilitated in 2020.

What Was the Problem?

This 4-mile stretch of a 6-lane rural interstate pavement was exhibiting severe longitudinal cracking, reflective durability cracking, longitudinal joint deterioration, and severe weathering. The existing AC surface deterioration had progressed to a point where emergency intermittent resurfacing had been



Map data © 2023 Google (The map overlays added as a result of this research project include the project location on I-55 West of Lincoln.)

Figure 16. Location of I-55 project near Lincoln, Illinois.

performed at multiple locations. The IDOT condition indicator was 4.8 (on a 1 to 9 scale), indicating a pavement in fair condition and in need of improvement in the short term (IDOT 2021). The average IRI for the project was 61 inches/mi (with the deterioration on the pavement located outside of the primary wheelpaths) and the rutting averaged 0.11 inches.

The pavement consisted of a nominal 6-inch total AC overlay on an underlying 9-inch CRCP. The first AC overlay had been placed in 1991 and a second AC overlay was placed in 2002. The underlying CRCP was constructed around 1975 and rests on a 4-inch stabilized subbase. Multiple pavement patching contracts had been performed to repair material durability distress in the existing CRCP pavement.

What Was Done?

A summary of the work done by IDOT to investigate the deficiencies of the pavement and to develop the needed solution is presented below.

- Pavement evaluation (performed in spring 2019).
  - Coring confirmed freeze-thaw related deterioration in the existing CRCP.
  - Laboratory testing indicated that the AC materials remaining in place from the 1991 overlay had inadequate stability (based on conditioned split tensile tests).
  - A detailed field evaluation indicated the most critical performance issue was surface distress related to the severe weathering, which required significant reactive maintenance activities.
  - With time and funding not conducive to pavement replacement, the evaluation indicated the existing AC overlay should be completely removed and the rehabilitation activities should avoid causing additional damage to the CRCP.
- Mix design.
  - SMA mixtures were selected for both the binder and the surface lift. These were 12.5 NMAS Superpave N80 mixtures designed at 4.0 percent air voids utilizing a SBS PG 76-28 liquid AC with a design asphalt binder replacement (ABR) of 8 percent. The design liquid asphalt content was 6.1 percent. The mixtures met the IDOT Hamburg Wheel criteria of 20,000 passes with only a 3 mm nominal rut depth. The design also had an unaged Flexibility Index (FI) value of 14 based on Illinois Flexibility Index Test (I-FIT) procedures.
  - The friction properties of the aggregates used in the SMA mix design made it acceptable for use in both the binder and surface lift.
- Structural design.
  - Available funding restricted the total SMA thickness to 4 inches. Reducing the overlay thickness from a nominal 6 inches to 4 inches magnifies the risk of accelerated deterioration of the underlying CRCP pavement under future traffic loading. However, the risk of CRCP deterioration was considered more acceptable than the risk of rutting from unstable materials that would have resulted from not removing all the existing AC.
  - The SMA was placed in two, 2-inch lifts (each 12.5 mm in NMAS).

- Preoverlay repairs.
  - Preoverlay repairs were not performed because the poor existing surface condition made it impossible to determine whether a surface distress was due to AC deterioration or due to deterioration in the underlying CRCP.
- Construction (placed in fall 2020).
  - Traffic management required a minimum of two lanes to be open in each direction, and no paving activities were allowed during daytime hours. Additionally, traffic was not allowed on any milled surface, and the maximum drop-off at the lane edge was limited to 2 inches.
  - The existing AC was milled down to the CRCP. Following milling, the exposed concrete surface was cleaned, and a non-tracking emulsified asphalt (NTEA) tack coat was applied at a residual asphalt rate of 0.05 lb/ft^2.
  - The SMA was placed in two lifts utilizing a Material Transfer Device (MTD). The traffic management restrictions required milling, cleaning, tack coat application, and the placement of both the binder and surface lift in one night in the center lane.
  - SMA compaction was accomplished with oscillatory rollers with no vertical impact component to limit any additional damage to the underlying CRCP. The SMA was placed with confined edges on both sides of each lane for every lift, which facilitated higher densities near the longitudinal joints.
  - Quality management utilized IDOT pay-for-performance specifications, which include IDOT's mixture and density verification testing and percent within limits quality evaluation methods.
  - I-FIT tests performed on field samples showed a field FI value up to 30.
  - Existing underdrain outlets were also cleaned to improve subsurface drainage performance.
- Expected overlay performance.
  - 10-15 years.

Figure 17 depicts portions of the overlay construction.

a) Typical CRCP condition under overlay.

b) Paving the center lane with MTD offset.

Figure 17. I-55 overlay construction.

What Is the Current Performance?

A summary of the current performance (based on 2021 data) is as follows:

- IDOT Condition Index: 8.6 (indicating a pavement in excellent condition).
- Roughness: 54 inches/mi.
- Rutting: 0.07 inches.
- Observed distress to date:
  - There are some locations where material durability issues in the underlying CRCP were identified after milling but could not be repaired prior to the overlay because of the traffic management requirements. These areas were marked and repaired after the overlay was placed. There are no new distresses in the SMA overlay.

Figure 18 provides an overview of the condition of the pavement in 2021.

Figure 18. Overview of I-55 pavement in 2021.

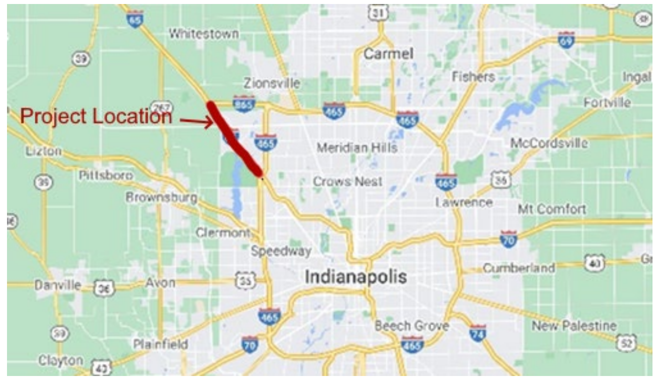
What Are the Key Takeaways from the Project?

IDOT attributes the following factors as important takeaways from this project:

- A comprehensive pavement evaluation was performed, and the resulting information utilized to evaluate the risks associated with different rehabilitation approaches.
- The SMA was placed using oscillatory rollers without a vertical component, which minimized further damage to the existing concrete pavement.
- The polymer-modified SMA is considered a more resilient cover for the existing PCC due to its higher asphalt content and higher flexibility index.
- The SMA surface provides greater resistance to rutting than conventional dense-graded mixes.

Interstate 65, Indianapolis, Indiana

This project is located on I-65 between I-465 and I-865, just northwest of Indianapolis (see figure 19). The highway carries a significant amount of truck traffic between Chicago and Indianapolis and was rehabilitated in 2019.



 (The map overlays added as a result of this research project include the project location on I-65 NW of Indianapolis.)

Figure 19. Location of I-65 project.

What Was the Problem?

A 5.85-mile stretch of this 4-lane composite pavement (AC/JRCP) urban interstate highway was exhibiting medium-severity transverse reflective cracking. The existing composite structure consisted of a 5.5-inch AC overlay placed on a 10-inch JRCP. The original JRCP was constructed in 1961 with doweled joints spaced at 40-ft intervals. A series of AC overlays (and mill and AC overlays) had been performed in 1988, 1993, 1995, 2005, and, most recently, in 2014. Typical conditions of the 2014 AC overlay pavement are shown in figure 20.

a) Above underlying full-depth repair.

b) Above underlying transverse joint.

Figure 20. Reflective cracking of 2014 AC overlay observed in 2019.

What Was Done?

The project was constructed in the summer of 2019, with the work in the northbound lanes performed in June and the work in the southbound lanes performed in July. Traffic was maintained using cross-overs. Evaluation, design, and construction activities included:

- Pavement evaluation
  - The original scope was patching, mill and fill, and a single-lift overlay based on coring and FWD data.
  - An automated distress survey performed in 2019 indicated the need for approximately 20 percent patching.
  - This resulted in a scope change to a full-AC thickness mill and two-lift overlay with an interlayer paving fabric and full-depth concrete patching at high-distressed areas.

- Structural design
  - 3.5-inch AC intermediate overlay (PG 76-22).
  - Interlayer paving fabric on heavy tack coat (0.2 gal/yd^2 PG 64-22 hot liquid asphalt cement).
    - ➢ Needle-punched, nonwoven product conforming to AASHTO M288.
    - ➢ Mass: 4.5 oz/yd.^{2}
    - ➢ Millable and recyclable.
  - 2-inch SMA surface course (PG 76-22) placed on interlayer paving fabric.
- Preoverlay repairs
  - The existing AC was milled down to the concrete.
  - Full-depth concrete repairs were performed at high-distressed areas.
- Construction
  - 3.5-inch AC intermediate overlay was placed.
  - Heavy tack coat was applied on top of intermediate layer.
  - Pavement fabric interlayer was placed on heavy tack coat.
  - 2-inch SMA surface was placed over the pavement fabric interlayer.
  - 1 mile control section without fabric.
- Targeted reflective crack control treatments.
  - Full-depth repairs.
  - Geosynthetic paving fabric interlayer.
- Expected overlay performance.
  - More than 10 years.

Figure 21 shows some of the construction activities from the 2019 rehabilitation.

a) Interlayer fabric installation.

b) Intermediate overlay.

Figure 21. Interlayer fabric installation and intermediate overlay.

What Is the Current Performance?

To date, the pavement has been performing very well, according to INDOT (see figure 22). The only distress that has been observed in the 2 years of service is some sporadic minor joint reflective cracking.

a) March 2021 condition.

b) September 2021 condition.

Figure 22. Condition of I-65 project.

What Are the Key Takeaways from the Project?

INDOT cited the following items as key takeaways:

- Before the latest overlay, cycles of patching and overlays were providing increasingly shorter periods of performance due to recurrent reflective cracking issues.
- Significant expected patching quantities moved the project from a single-lift preventive maintenance project to a two-lift AC overlay.
- A geosynthetic paving fabric interlayer (millable and recyclable) was employed to evaluate its effect on retarding reflective cracking. The fabric was placed on a heavy tack coat on top of the intermediate layer. A 1-mile section without a fabric interlayer was included as a control.
- Preoverlay repairs were performed to restore support and reduce reflective cracking.
- The AC overlay is in good condition after 2 years of service.

Interstate 66, Fairfax, Virginia

This project is located on I-66 between I-495 and Route 50, just west of Washington, District of Columbia (see figure 23). The pavement was rehabilitated in 2012.

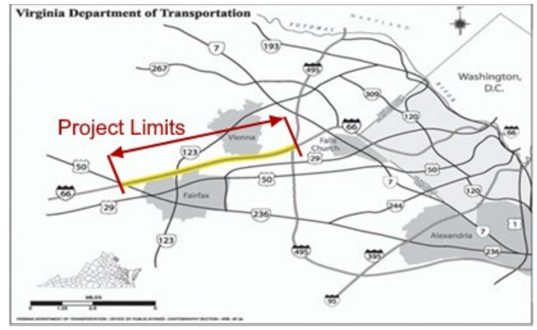


Figure 23. Location of I-66 project in Virginia.

What Was the Problem?

The existing jointed concrete pavement was exhibiting distresses at the transverse joints and spalling in the interior portions of isolated slabs. Approximately 20 percent of the total pavement area was in poor condition, and 15 percent of the transverse joints exhibited poor load transfer. In 2007, the average critical condition index (CCI) was determined to be 58, which corresponds to a rating of poor as indicated below (VDOT 2019):

- Excellent: CCI of 90 and above.
- Good: 70-89.
- Fair: 60-69.
- Poor: 50-59.
- Very Poor: 49 and below.

A number of challenges emerged for the rehabilitation of this project, including limited space for maintenance of traffic, limited time for dual-lane closures, limited overhead clearances of existing bridges, drainage issues, the presence of fixed concrete median barriers (including those adjacent to the Washington Metropolitan Area Transit Authority [WMATA] lines), and the need for lane shifts across longitudinal joints in the concrete.

The original pavement was constructed between 1960 and 1963 with 2 lanes (from Route 50 to east of Route 123) and 3 lanes (from east of Route 123 to I-495) in each direction. It consisted of a 9-inch JRCP with transverse joints spaced at 61.5-ft intervals. The underlying layers consisted of a 6-inch aggregate layer over a 6-inch soil-cement base. Between 1990 and 1993, the pavement structure was widened to 4 lanes in each direction, with the two new lane additions consisting of an 11-inch JPCP with transverse joints at 15-ft intervals. The new JPCP was constructed over a 4-inch stabilized open-graded drainage layer and a 6-inch cement-treated aggregate subbase. Typical distresses in the existing concrete pavement are shown in figure 24.

a) Deteriorated transverse joint.

b) Distress in isolated slabs.

Figure 24. Typical distresses from 2010 I-66 project.

What Was Done?

To address VDOT's roadway performance requirements while meeting the project constraints, a contract was awarded in December 2010 to rehabilitate this project with an AC overlay. The work was completed in the fall of 2012 and included the following activities:

- Preoverlay repairs
  - Full-depth concrete repairs were installed at badly deteriorated patches and joints.
  - Minor spalls were patched with asphalt or partial-depth concrete repairs.
  - All joints were sealed with a hot-poured elastomeric sealant.
  - A total of 55,572 yd^2 of full-depth and 4,697 yd^2 of partial-depth patching was performed.
- Structural design
  - Thin Hot Mix Asphalt Concrete Overlay (THMACO) stress absorbing membrane interface layer (0.625 inches thick) placed on top of existing concrete pavement. Tack was placed using a spray bar paver.
  - 2-inch SMA layer—SMA-12.5 (PG 76-22, polymer-modified) on top of THMACO.
  - 1.5-inch SMA-9.5 (PG 76-22, polymer-modified) placed over the 2-inch SMA as the surface course.
  - High-friction surface course (0.375 inches) placed on the 1.5-inch SMA in the rightmost auxiliary travel lane only (for demarcation purposes).
- Expected Overlay Performance
  - The rehabilitation was designed for 20 years but the pavement was removed in 2021 as part of a major VDOT reconstruction and transformation project performed on I-66.

Figure 25 shows some of the construction activities associated with the project from 2012.

a) Full-depth repairs.

b) SMA overlay placement.

Figure 25. Rehabilitation of I-66 in 2012.

How Did the Pavement Perform?

A summary of the short- and long-term performance of the project is provided below:

- Immediate post-construction (2012).
  - Average IRI (eastbound lanes).
    - 50, 49, and 46 inches/mile for lanes 1, 2 and 3, respectively.
  - Average IRI (westbound lanes).
    - 48, 48, 46, and 48 inches/mile for lanes 1, 2, 3 and 4, respectively.
- Prior to Removal (2021).
  - CCI: 81.
  - IRI: 69 inches/mile.
  - The pavement performed exceptionally well with only minor reflective cracking apparent in some locations.

Figure 26 shows photos of the I-66 project while in service.

a) Project with grass median.

b) Project with WMATA lines in median.

Figure 26. I-66 project in service (circa 2012).

What Are the Key Takeaways from the Project?

VDOT considered the following factors as important to the success of this project:

- Aggressive patching of the concrete pavement and sealing of all joints provided a solid base for the asphalt overlay.
- The THMACO interlayer tacked with a spray bar paver improved bond and helped minimize moisture damage.
- The two-lift SMA overlay provided good performance and was resistant to rutting. The use of a finer SMA on the surface helped minimize moisture intrusion.
- Safety was improved and the resulting pavement surface provided a smooth ride for road users.

Summary

This chapter presented four case studies from selected State DOTs that highlight pavement practices that can be used to improve performance of AC/PCC pavements. Some of these practices are related to the practices presented in Chapter 3.

CHAPTER 5. CONCLUSIONS

Summary

Composite pavements—AC overlays of existing PCC—represent a significant portion of the roadway mileage in the United States. These pavement structures are found on Interstates and freeways, primary and State highways, and arterials, collectors, and other local routes. The challenge of effectively managing these pavement structures exists for virtually all State and local highway agencies regardless of size, location, and budgets.

Historically, AC overlays have been a common rehabilitation solution for existing PCC pavement and offer a number of potential benefits:

- Rapid construction and opening to traffic, leading to reduced travel disruption.
- Increased structural (load-carrying) capacity of the pavement system.
- Functional improvements (smoothness, friction, noise).
- Low initial cost.
- Ease of future maintenance.
- Easily renewable through placement of additional overlays.
- Limited increase in grades and elevations.
- Reduction in water/salt ingress into the underlying PCC layer.
- Insulation of the PCC layer and reductions in the temperature gradient through the slab, resulting in reductions in slab curling.
- Utilization of the PCC pavement in place (i.e., no demolition, hauling, or landfilling).

Although widely used, the performance of these composite pavements across the board has been highly variable, largely due to the development of reflective cracking. As described in chapter 1, these cracks develop as the result of horizontal and vertical forces acting on the underlying PCC slab and have been a persistent and troublesome issue for composite pavements.

This project found that many State DOTs have improved the performance of their composite pavements as the result of ongoing research studies and initiatives. Much of that improvement is the result of considering and addressing the potential for reflective cracking issues throughout the entire composite pavement design and construction process, including:

- Evaluation of existing pavement, including distress surveys, PCC slab and joint performance and condition, and overlay cracking extent and condition.
- Selection of appropriate overlay system, including the use of strain-tolerant interlayers and durable surface mixtures.
- Selection or development of appropriate overlay thickness based on project design parameters and constraints.
- Effective preparation of existing pavement and placement of overlay, whether removing all the AC and addressing PCC slab issues or milling and maintaining remaining AC below the overlay.
- Timely application of effective future maintenance and rehabilitation treatments.

Specific details associated with each of these items are presented in previous chapters, all with an overarching goal of improving the performance of AC/PCC pavements.

Moving Forward

Although progress has been made in the last several years regarding the evaluation, design, construction, and performance of composite pavements, there remain a number of research and training needs to help further advance the state of the practice. These items are summarized in the following sections, and largely come from the 2021 peer exchange meeting (as described in chapter 2).

Gaps and Research Needs

The following are among some of the critical gaps and research needs regarding composite pavement systems identified by the State DOTs:

1. Level of testing and evaluation needed on existing pavements (FWD, coring, etc.).
2. Modeling of AC/PCC performance, specifically how do all the variables come into play (soils, foundation, drainage, traffic)?
3. Extending life of second-generation overlays.
4. Conditions that make an AC overlay a poor rehabilitation choice.
5. Mechanisms of reflective cracking.
6. Interpretation of FWD data of composite pavements.
7. Preoverlay repair:
   - How much to patch? Extensive patching may be needed but it can slow down the overlay operation.
   - What patching materials should be used?
   - How to do effective patching in urban areas with lots of utilities?
   - How to perform preoverlay repairs effectively under traffic and within limited repair windows?
   - How to address poor drainage conditions?
   - How to deal with poor underlying soils and foundational materials?
   - How to determine appropriate milling depths?
8. Dealing with profile restrictions and lane additions.
9. Evaluating the number of feasible overlay cycles.
10. Use of TSD for assessment of composite pavements.
11. Performance testing/evaluation of asphaltic materials for use in composite pavements.
12. Post-construction analyses or forensic investigations of AC/PCC pavements.

Technical Training and Outreach Opportunities

Some potential training and outreach opportunities that State DOTs can consider include:

1. Targeted training and knowledge transfer, particularly as it pertains to performance monitoring, specifications, and implementation. This was identified by the State DOTs as a larger, overarching issue as much institutional knowledge is being lost.
2. Training on pavement forensic analysis could help stakeholders and practitioners understand what did or did not work and why.
3. Training on pavement testing and inspection practices for materials and construction personnel on all aspects of composite pavement placement and construction.
4. Training on the development of effective and meaningful specifications.
5. Additional training on the effective maintenance and management of composite pavement systems.
   - Evaluation methods.
   - Maintenance/preservation treatments.
   - Application of life-cycle cost analysis to determine cost-effective solutions.
6. Development and sharing of case studies highlighting State DOT projects and practices.

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