U.S. Department of Transportation
Federal Highway Administration

2018–19 ANNUAL REPORT

ACCELERATED IMPLEMENTATION AND DEPLOYMENT OF PAVEMENT TECHNOLOGIES

Cover Image: ©Leonid Andronov/Shutterstock.
Image: ©Valentin Valkov/Shutterstock.

Turning Best Practices into Everyday Practices

The mission of the Federal Highway Administration (FHWA) is to improve connectivity, mobility, and accessibility on the Nation's highways. We strive for roads that are safe, smooth, and free of significant delays, and that provide a great traveling experience for motorists and other users.

The Accelerated Implementation and Deployment of Pavement Technologies program advances the latest and best practices and technologies for constructing and maintaining high-quality, long-lasting pavements. This program is vital to support FHWA's mission.

As we reflect on our progress this year, we want to highlight various technology transfer and outreach efforts. These activities deliver critical insights, experience, and practices to the pavement community through meaningful and cost-effective strategies, ranging from preparation and delivery of training courses and workshops, demonstrations, and videos to development of guidance documents.

This year, several technologies and outreach efforts are being implemented in new program areas. These implementations are having significant impacts on highway practices. For example:

- **Design:** Updates to FHWA's pavement design policy and a new pavement design catalog provide pavement engineers with tools to inform the decisionmaking process and to ensure use of appropriate design features and criteria to minimize the risk of poor performance.
- **Construction:** An FHWA report and technical support encourage more highway agencies to implement precast concrete pavement (PCP) technology. Highway agencies, contractors, and precast concrete suppliers have worked together in 28 States to demonstrate PCP projects.
- **Sustainability:** A four-part series of documents provides information for asphalt mix producers and contractors on how to implement sustainability concepts.
- **Data Management:** Regional peer exchanges on pavement data management enable States to share experiences and learn from each other about how agencies are increasingly using technologies to achieve uniform and accurate data collection.
- **Training:** A revamped National Highway Institute course helps inspectors understand best practices for asphalt paving construction and incorporates new improvements and advancements in construction technologies, material testing, and monitoring procedures.

In addition, work continues to promote pavement safety and performance while minimizing maintenance activities and overall lifecycle costs.

We continue to enable our stakeholders to effectively manage their pavement assets and improve the condition of the highway system through our strong partnership with highway agencies, industry, academia, the consulting community, and more. I am pleased to share these highlights from our ongoing activities, and I look forward to sharing more successes as we continue to develop and deploy innovations on the Nation's roadways together.

Sincerely,

Hari Kalla

Hari Kalla
FHWA Associate Administrator for Infrastructure

Image: ©Valentin Valkov/Shutterstock.

About the Program

Congress established the Accelerated Implementation and Deployment of Pavement Technologies (AID-PT) program in 2012 under the Moving Ahead for Progress in the 21st Century Act (MAP-21) (Pub. L. 112-141). The program's purpose is to document, demonstrate, and deploy innovative pavement technologies—including their applications, performance, and benefits.

In 2015, Congress continued the program in the Fixing America's Surface Transportation (FAST) Act (Pub. L. 114-94), with funding available through fiscal year 2020. Through strategic partnerships with highway agencies and others across the pavement community, FHWA is leveraging Federal investments to maximize the impact of the program, effectively amplifying the benefits to the traveling public.

The AID-PT program focuses on promoting, implementing, and deploying proven technologies and demonstrated practices. Specifically, the program encourages highway agencies to adopt and implement new technologies that have been shown to save money, enhance safety, improve performance and quality, increase efficiency, reduce delay, and enhance road user satisfaction. This annual report documents FHWA's approach to achieve the six overarching goals Congress set for the program (see page 1). The FAST Act Section 6003 requires "a report on the cost and benefits from deployment of new technology and innovations that substantially and directly resulted from the program." The report may include the analysis of Federal, State, and local cost savings; improvements in project delivery time; reduced fatalities; and reduction of the impacts of congestion.

"Long-life strategies can be built into the pavement design," says Dulce Rufino Feldman, senior transportation engineer, California Department of Transportation. "By applying long-life strategies, the lifecycle costs are reduced and both highway agencies and users benefit in terms of fewer lane closures and less exposure for highway workers."

Because of the broad scope of the Federal-aid program and the wide spectrum of Federal, State, and local stakeholders involved, it is difficult to quantify the overarching impact of the program and the costs and benefits directly attributable to it. Therefore, this report highlights case studies that discuss the anticipated long-term improvements in cost savings, project delivery time, congestion relief, enhanced safety, and pavement performance because of the program.

The case studies in the following pages offer a snapshot of the exciting work that FHWA and its partners are doing to accelerate implementation and deployment of cutting-edge pavement technologies and practices.

FHWA is engaged in a variety of efforts to improve training materials and deliver guidance to help highway agencies design and construct both asphalt and concrete pavements more effectively. These efforts range from focused technology transfer activities featuring webinars and on-demand YouTube videos to practical guide documents on various asphalt and concrete pavement technologies. In addition, they range from stakeholder-based initiatives to promote the overall sustainability of pavement systems to field demonstration and construction projects supported by the agency's mobile technology centers.

The AID-PT program is an outstanding example of FHWA operating under a shared vision with its teaming partners to implement and deploy critically needed products and technologies. With strong stakeholder support, the program is providing benefits ranging from shorter project delivery times and less congestion to cost savings and fewer roadway fatalities.

Summary of How Recent FHWA Deployment Efforts Support the Goals of the AID-PT Program

AID-PT Goals [Title 23, United States Code, Section 503(c)(3)]	Selected FHWA Deployment Efforts: Concrete Clips Video Series	Pavement Design Policy Outreach	Pavement Management Peer Exchanges	Pavement Design Catalog	Continuous Friction Measurement	Precast Concrete Pavement	Long-Life Pavement Strategies	Guide to Sustainable Pavements	Constructing and Inspecting Asphalt Paving Projects	Mobile Technology Centers
1. The deployment of new, cost-effective designs, materials, recycled materials, and practices to extend the pavement life and performance and to improve user satisfaction.		●		●	●	●	●	●	●	●
2. The reduction of initial costs and lifecycle costs of pavements, including the costs of new construction, replacement, maintenance, and rehabilitation.	●		●	●	●	●	●	●	●	●
3. The deployment of accelerated construction techniques to increase safety and reduce construction time and traffic disruption and congestion.	●					●	●	●	●	
4. The deployment of engineering design criteria and specifications for new and efficient practices, products, and materials for use in highway pavements.	●	●		●		●	●	●	●	●
5. The deployment of new nondestructive and real-time pavement evaluation technologies and construction techniques.	●				●	●			●	●
6. Effective technology transfer and information dissemination to accelerate implementation of new technologies and to improve life, performance, cost-effectiveness, safety, and user satisfaction.	●	●	●	●	●	●	●	●	●	●
See page	2	5	8	12	15	20	25	29	33	36

At a demonstration project in Colorado in 2018, a drone hovers overhead as the crew prepares to capture aerial footage to use in a Concrete Clips video titled Real-Time Smoothness. *Source: Tom Yu, FHWA.*

Now Streaming: Concrete Clips

FHWA leverages the YouTube platform to share innovative and successful pavement practices through an online video series.

FHWA is using YouTube to share news and information related to the agency's work. FHWA established its YouTube presence in 2011. Since then, the agency's YouTube channel has offered a steady stream of videos spotlighting content on highway research and programs.

One of FHWA's recent contributions to the platform is a series of videos covering established practices and new technologies related to concrete pavements and materials. The agency's "Concrete Clips" target personnel at State highway agencies and other engineers with quick, easily digestible insights and best practices.

Using Technology to Share Technology

Each 10- to 15-minute video provides a high-level overview of a given topic, with videos falling under four broad categories—materials, design, construction, and technology transfer and deployment.

In some cases, videos cover multiple aspects of a particular topic. For example, under the construction category, viewers can learn how to measure pavement smoothness in real time, install smoothness-measuring devices on concrete pavers, and use the pavement Profile Viewing and Analysis (ProVAL) software to analyze the profile data collected by these devices.

Lights, Camera, Action

Much of the content for each video comes from site visits to paving projects and associated facilities, where the FHWA video crew captures still photographs and video footage relevant to the topic. In some cases, the crew works with FHWA's Mobile Concrete Technology Center to leverage access to specific job sites and technology demonstrations. For example, the crew filmed demonstration projects in Colorado in 2018 and South Carolina in 2019 and incorporated the footage obtained from those projects into videos on real-time smoothness, workability, and durability, among others.

CONCRETE CLIPS VIDEOS UNDER DEVELOPMENT AND CURRENTLY POSTED

Category	Concrete Clip Title	Video Content
Materials	Cement Manufacturing*	Steps in manufacturing portland cement
	Blended Cements*	Types and characteristics of blended cements
	Supplementary Cementitious Materials*	Types and benefits of supplementary cementitious materials in concrete mixtures
	Aggregates for Concrete Paving Mixtures*	Key aggregate characteristics and recommended aggregate specifications and test methods
	Ensuring Durability of Concrete Paving Mixtures	Mechanisms of materials-related distress in concrete pavements and recommendations for improving concrete durability
	Admixtures	Types and benefits of chemical admixtures used in concrete paving mixtures
Design	Mechanistic-Empirical Pavement Design	Mechanistic-empirical pavement design concepts and analysis procedures for concrete pavements
	Performance-Engineered Mixtures	Overview and application of the new AASHTO PP 84 specification for performance-engineered mixtures
Construction	Internal Curing*	Curing of concrete pavement from the inside out using prewetted lightweight aggregate
	Real-Time Smoothness Overview*	Monitoring and ensuring the smoothness of concrete pavement during paving via real-time smoothness equipment
	Real-Time Smoothness Sensor Installation*	Installation of alternative real-time smoothness systems on a concrete paver
	Real-Time Smoothness Data Analysis	Uploading and analyzing real-time data on pavement profile and smoothness with the ProVAL software
	Workability	Optimizing concrete mixtures via the Tarantula Curve and use of the Box Test and V-Kelly test for assessing concrete workability
	Curing	Types of liquid membrane-forming curing compounds for curing concrete pavements
	Maturity Testing	Monitoring the early strength gain of concrete pavement using a variety of maturity testing methods
	Concrete Durability Test Methods	Durability-related test methods and equipment for constituent materials and project-specific concrete mixes
Technology Transfer and Deployment	Mobile Concrete Technology Center	Services and concrete pavement technology transfer offered by FHWA's Mobile Concrete Technology Center

**Videos currently posted on FHWA's YouTube channel. Source: Table compiled by APTech using information provided by FHWA.*

Real-time smoothness systems like the one shown here installed on the back of a concrete paver are the topic of one of the videos in the Concrete Clips series. *Photo: ©Gary Fick, Transtec Group, Inc.*

The production crew collects video footage of workers preparing samples for Super Air Meter testing. *Photo: ©Jagan Gudimettla, ATI, Inc.*

"The photos and videos obtained during the site visits will help FHWA promote new and underused concrete technologies, including the Performance-Engineered Mixture initiative," says Mike Praul, senior concrete engineer with the Mobile Concrete Technology Center. "They will provide valuable awareness and support for the [center's] key program efforts of technology demonstrations, implementation, and training workshops for States and industry."

Another key component of the video content is on-camera interviews with subject matter experts, including construction personnel, technicians, supervisors, managers, and industry and academic leaders.

"Including the insights and perspectives of concrete professionals at all levels makes the videos more engaging, while providing an added level of assurance about the quality of the information conveyed," says Shreenath Rao, project manager at Applied Research Associates, Inc., the contractor producing the videos.

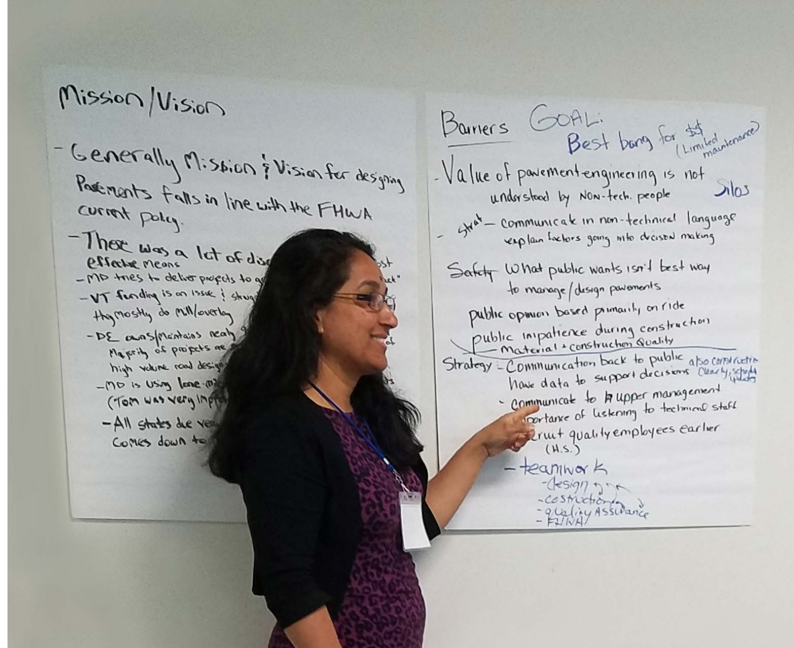
The first two Concrete Clips videos, **Internal Curing** and **Blended Cements**, have garnered more than 3,500 and 1,300 views to date, respectively.

Video Schedule

Seven of the 17 planned videos have been completed and posted on FHWA's YouTube channel. The first two to be uploaded, Internal Curing and Blended Cements, already have garnered more than 3,500 and 1,300 views to date, respectively.

Work continues on development and production of the remaining videos, which are scheduled for release by early 2020. As each new video becomes available, FHWA will announce its release to the agency's division offices and various industry organizations.

To access the Concrete Clips, go to www.youtube.com/playlist?list=PL5_sm9g9d4T1ND5YlNt0OuL6g2T_NbGdR.



Sejal Barot, director of the Office of Materials Technology at the Maryland State Highway Administration (SHA), presents at the peer exchange meeting in Baltimore, MD, in May 2019. *Photo: ©Sejal Barot, Maryland SHA.*

Reaching Out About Policy

Regional peer exchange meetings bring States together to discuss FHWA's pavement design considerations and technical guidance.

Design decisions have implications on safety, durability, and costs of pavement, and thereby impact highway investments across the Nation. The past few decades have witnessed a paradigm shift in pavement design methodologies and standards, including a transition from empirical to mechanistic-empirical procedures to predict pavement performance over its design period. Changes in pavement design procedures—as well as material and construction technologies—necessitate a proactive policymaking approach to promote best practices for design processes. These changes also have increased focus on overall network performance, maintenance, lifecycle thinking, and environmental concerns.

A holistic pavement design process should consider a wide gamut of factors, such as design principles, location or site-specific factors, constructability, maintenance and preservation, lifecycle approach, traffic patterns and variations, environmental impacts, performance, and quality. Pavement designers also must exercise engineering judgment in scenarios where limited guidance is available.

FHWA's existing pavement design considerations do not specify the decisions that States should make. Instead, FHWA provides technical guidance for States to design pavements that are best suited to their local conditions and environment.

Based on stakeholder feedback, FHWA realized a need to evaluate its existing pavement design considerations and update related technical guidance. Consequently, it has undertaken an initiative to better understand from State departments of transportation (DOTs) and industry stakeholders the challenges and best practices pertaining to pavement design.

Existing Pavement Design Considerations and Guidance

FHWA's pavement design considerations are defined by Title 23 Code of Federal Regulations (CFR) part 626, which establishes the requirement that "pavements shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost-effective manner."

Pavement design is the "project level activity where detailed engineering and economic considerations are given to alternative combinations of subbase, base, and surface materials [that] will provide adequate load carrying capacity."

— Source: 23 CFR part 626.

To support States' pavement design procedures, FHWA published *Pavement Design Considerations* (formerly the *Federal-aid Policy Guide Non-Regulatory Supplement NS 23 CFR Part 626*).

The supplement details the pavement design factors that States should consider, such as traffic, safety, foundation, shoulder structure, engineering economic analysis, and rehabilitation pavement design. When engineering and economic analysis does not indicate a clear choice between different pavement designs, FHWA's *Technical Advisory T 5040.39A Use of Alternate Bidding for Pavement Type Selection* provides guidance to State and local highway agencies on use of alternate bidding procedures to make the pavement type selection on Federal-aid projects on the National Highway System.

The Need for Updates

FHWA last updated its pavement design considerations and technical guidance 2 decades ago. Lately, States and industry stakeholders have expressed concerns related to a few definitions in the current policy. For example, what type of analyses are States expected to perform to determine if a pavement is designed in a "cost-effective manner"? Concerns also focus on incorporating considerations for other issues, such as sustainability and resiliency of pavements and impacts of emerging technologies (for example, connected and automated vehicles).

To address concerns and further support State DOTs and industry stakeholders, FHWA initiated a series of outreach efforts to gather information on best practices and barriers related to designing pavements.

"Recognizing that it has been over 20 years since the FHWA pavement design policy's technical guidance has been updated, FHWA would like to further understand from State agency and industry stakeholders the best practices and barriers related to designing pavements," says Heather Dylla, sustainability program manager at FHWA. "FHWA plans to use this feedback to help identify future policy improvements, program needs, and initiatives."

Outreach to Industry Stakeholders

FHWA gathered initial feedback on the existing pavement design technical guidance through surveying its division offices, and then held a listening session with industry stakeholders. The listening session topics included likes and dislikes, issues, and challenges with the current policy and technical guidance, as well as ways to address the challenges and concerns, missing and outdated information, and additional feedback for FHWA to consider related to pavement design issues.

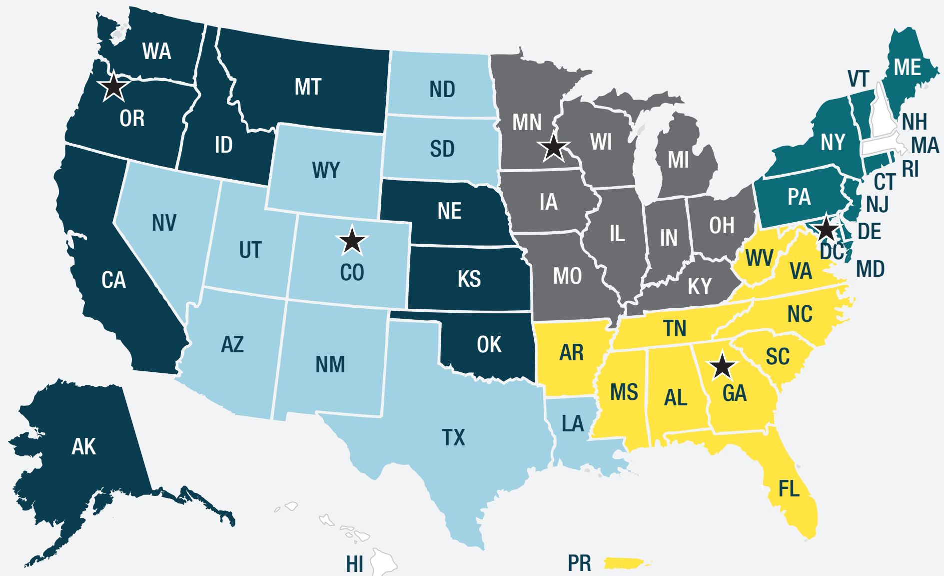
Industry participants represented:

- Advanced Concrete Pavement Consultancy LLC
- American Association of State Highway and Transportation Officials
- American Concrete Pavement Association
- American Council of Engineering Companies
- Interlocking Concrete Pavement Institute®
- National Asphalt Pavement Association
- National Ready Mixed Concrete Association
- National Stone, Sand and Gravel Association

Listening session participants generally appreciated the simplicity and flexibility of the existing design considerations. However, the participants recommended regular reviews because the pavement design process is changing to incorporate new technologies and performance demands.

"The concrete pavement industry appreciates the opportunity to provide stakeholder input on FHWA's pavement design policy and guidance. FHWA serves a critically important role in the Federal-aid program and must continue to take a firm stand and posture in favor of transparency, good governance, and stewardship," says Leif G. Wathne, executive vice president, American Concrete Pavement Association, who participated in the listening session. "The taxpaying public is investing significant resources into our National Highway System, and strengthening current policies and guidance in favor of safe, cost-effective, durable, and resilient pavements is the only way to ensure that taxpayers receive the greatest long-term benefit for their highway dollar."

Audrey Copeland, president and chief executive officer, National Asphalt Pavement Association, had similar feedback after the listening session. "FHWA's current policy and accompanying guidance strikes a balance that facilitates sound pavement type decisions that are cost effective without unnecessary burdens on State highway agencies and departments of transportation. The industry participants in the listening session generally agreed on this," says Copeland. "Further, FHWA's recycled materials policy and the guidance that engineering evaluation should include



PEER EXCHANGE REGIONS AND LOCATIONS

★ Atlanta, GA ★ Baltimore, MD ★ Denver, CO ★ Portland, OR ★ Minneapolis, MN

REPRESENTATIVE PARTICIPATION

BOTH DIVISION OFFICE AND DOT

Alaska	Kentucky	New York
Arizona	Louisiana	North Dakota
Arkansas	Maine	Ohio
California	Maryland	Oklahoma
Colorado	Michigan	Oregon
Delaware	Minnesota	Pennsylvania
District of Columbia	Mississippi	Puerto Rico
Florida	Missouri	Rhode Island
Georgia	Montana	South Carolina
Illinois	Nebraska	South Dakota
Indiana	Nevada	Tennessee
Iowa	New Jersey	Washington
Kansas	New Mexico	West Virginia

EITHER DIVISION OFFICE OR DOT

Alabama	Texas	Virginia
Connecticut	Utah	Wisconsin
Idaho	Vermont	Wyoming
North Carolina		

NO DIVISION OFFICE OR DOT

Hawaii	Massachusetts	New Hampshire

Pavement Design Policy Peer Exchange Participants. *Source: FHWA.*

reused and recycled materials and processes has resulted in savings of more than $2 billion per year. With the overall policy being sound and contributing to cost savings, there is still room for improvement. We look forward to continuing to assist FHWA in the review of the policy toward a cost-effective, high-performing highway network."

Regional Peer Exchange Meetings

FHWA hosted peer exchange meetings to discuss and document best practices and obstacles to designing cost-effective pavements. Representatives from State DOTs and FHWA division offices were invited to attend the five regional peer exchange meetings scheduled between March and July 2019 in Atlanta, GA; Baltimore, MD; Denver, CO; Portland, OR; and Minneapolis, MN.

In general, the peer exchange topics focused on merits and demerits and challenges and concerns regarding existing pavement design considerations and technical guidance.

The 2-day-long peer exchange meetings involved discussions about the State DOTs' missions related to pavement designs, strategies, and barriers to implementing the FHWA pavement design policy, and updates needed to the policy. Participants discussed how their agencies' pavement design policies address pavement design considerations such as:

- pavement structure
- maintenance and rehabilitation
- foundations
- pavement materials
- drainage
- shoulder
- surface texture and safety
- project location
- traffic
- climate and environmental considerations
- contracting and project delivery methods
- construction schedule
- costs and benefits
- other design factors

The Impact of Outreach

Stakeholder outreach efforts have provided FHWA with valuable insights regarding how its pavement design policy aligns to State DOT missions and informs their decisionmaking process for pavement design. FHWA intends to use the information gathered from stakeholder engagement efforts to improve existing initiatives and programs through development of regulatory, guidance, and research needs documents.

For more information, contact Heather Dylla at 202–366–0120 or heather.dylla@dot.gov, or visit www.fhwa.dot.gov/pavement/cfr06261.cfm.

Managing Pavement Data Quality

Peer exchanges enable States to share experiences and learn from each other about pavement data quality management while working to meet Federal regulations.

Ensuring data quality will help States address Federal requirements for national performance measures. Here, the Montana Department of Transportation prepares to collect pavement surface distress measurements (such as rutting, cracking, and faulting). *Source: FHWA.*

Federal and State governments spend significant resources on managing highway pavements to ensure system safety, mobility, durability, and reliability. To make informed investment decisions and support performance-based management of highway pavements, transportation agencies rely on quality data.

Many States follow data quality practices and determine data quality based on accuracy, precision, and resolution. However, most States do not have a formalized and standardized process to address issues with the quality of pavement-related data.[1] Without quality assurance procedures, data collection may be inaccurate and inconsistent, impacting a State's ability to make and provide justification for the best-informed transportation investment decisions.

"Data have an increasingly important role in transportation today," says Thomas Van, pavement preservation program manager, FHWA's Office of Preconstruction, Construction, and Pavements. "It is particularly challenging to collect pavement condition data in the quantity and quality needed to support decisions that involve millions of dollars every year."

The Moving Ahead for Progress in the 21st Century (MAP-21) Act and Fixing America's Surface Transportation (FAST) Act identified national goals for the Federal-Aid Highway Program and directed the U.S. Department of Transportation to establish national performance measures, including for assessing the condition of pavements.[2] The laws also require USDOT to identify data elements necessary to support these measures.[3] State DOTs must use the national performance measures to assess their pavement condition and establish targets in support of the national goals.[4]

The national pavement performance measures are calculated from pavement condition metrics. These metrics include the International Roughness Index (IRI), rutting (for asphalt concrete pavements) or faulting (for jointed concrete pavements), and cracking percent, as well as three inventory data elements (through lanes, surface type, and structure type) that are submitted to FHWA's Highway Performance Monitoring System (HPMS) by States.[5] The performance measures are based on condition ratings of good, fair, or poor calculated for each pavement section.[6] Additionally, the regulations require that States develop Data Quality Management Programs that implement formal collection and assessment standards and processes that ensure States meet an acceptable level of data quality.[7]

Data-Driven Decisionmaking

Pavement data play an important role in evaluating performance metrics and performing asset management and planning activities. Contractors and agency personnel use various types of equipment to collect pavement data and demonstrate that the equipment successfully

PAVEMENT TPM REGULATIONS: PERFORMANCE MEASURES[8]

Performance Target		Interstate Condition (Lane-miles)	Non-Interstate NHS Condition (Lane-miles)
Two-year	% Good	% Good
	% Poor	% Poor
Four-year	% Good	% Good
	% Poor	% Poor

Under transportation performance management (TPM) regulations, States must set performance targets for condition of highway pavements on the Interstate System and non-interstate National Highway System (NHS).[9] *Source: FHWA.*

meets the established minimum requirements for accuracy, precision, and resolution of data set forth by the State's DOT. Agencies are increasingly using emerging and automated technologies to achieve uniform and accurate data collection across the pavement network.

Pavement-related data collected by State DOTs includes distress data that feeds into databases such as the national HPMS and agencies' pavement management systems. To assemble and manage quality pavement data, it is imperative for agencies to use high-quality data collection techniques with adequate coverage, secured data storage and management strategies, and robust statistical techniques and performance models for data integration and analysis. Using quality data collected following established standards and procedures to inform decisionmaking ensures process consistency and helps States appropriately allocate funding for transportation infrastructure needs.

Ensuring Data Quality

The purpose of managing data quality is to validate the accuracy, precision, and resolution of the data. A data quality management program defines the acceptable level of data quality and describes the processes that will ensure the data quality standards. Quality management processes and procedures include calibrating and certifying the data collection equipment, certifying data collection personnel, assessing and verifying that data meet defined quality standards, reviewing the assembled data for outliers and missing information, and implementing corrective procedures to address data anomalies and errors.

Pavement and Bridge Condition Performance Measures Rule

FHWA's National Highway Performance Program established the Pavement and Bridge Condition Performance Measures rule in 23 CFR part 490. The rule identifies performance measures for State DOTs and metropolitan planning organizations to assess the condition of highway pavements on the Interstate System and non-interstate National Highway System and maintain highway pavement assets in a state of good repair.[10] The rule also establishes the data elements necessary to collect and maintain standardized data to carry out a performance-based approach to pavement management and requires States to develop and follow a Pavement Data Quality Management Program to collect and process data used to evaluate pavement performance.[11,12]

PAVEMENT CONDITION THRESHOLDS[13]

	Good	Fair	Poor
IRI (inches/mile)	<95	95-170	>170
Rutting (inches)	<0.20	0.20-0.40	>0.40
Faulting (inches)	<0.10	0.10-0.15	>0.15
Cracking (%)	<5	5-20 (asphalt) 5-15 (JCP) 5-10 (CRCP)	>20 (asphalt) >15 (JCP) >10 (CRCP)
PSR	PSR ≥ 4.0	2.0 ≤ PSR ≤ 4.0	PSR ≤ 2.0

States rate the condition of pavement sections as good, fair, or poor for metrics including the International Roughness Index (IRI), rutting, faulting, cracking, and present serviceability rating (PSR). *Source: FHWA.*

Pavement Data Regulations

Development requirements for data quality management programs, excerpted from 23 CFR § 490.319:

* * *

(c) Each State DOT shall develop and utilize a Data Quality Management Program, approved by FHWA that addresses the quality of all data collected, regardless of the method of acquisition, to report the pavement condition metrics, discussed in § 490.311, and data elements discussed in § 490.309(c).

(1) In a Data Quality Management Program, State DOTs shall include, at a minimum, methods and processes for:

- (i) Data collection equipment calibration and certification;
- (ii) Certification process for persons performing manual data collection;
- (iii) Data quality control measures to be conducted before data collection begins and periodically during the data collection program;
- (iv) Data sampling, review and checking processes; and
- (v) Error resolution procedures and data acceptance criteria.

* * *

Challenged by data-related standards and requirements, many States have developed innovative solutions to ensure pavement data quality. For States facing new or continuing obstacles related to data quality, the opportunity to learn from other States that have been successful in finding solutions could be invaluable. To provide States with an opportunity to share experiences and further learn about pavement data-related topics, issues, and best practices, FHWA initiated a series of peer exchange meetings on pavement data quality.

Peer Exchanges

During the past few years, FHWA hosted many peer exchanges focused on topics related to pavement management, recognizing the value of providing a forum for States to share experiences and learn from other agencies. Responding to evolving pavement needs, FHWA convened recent peer exchanges addressing pavement data quality and new regulations for pavement data. The peer exchanges enable State DOTs to share best practices and obstacles they encountered in collecting pavement data, ensuring quality, and implementing MAP-21 and FAST Act regulations.

PAVEMENT MEASURES CALCULATION[14]

	Pavement Type			
	Asphalt and Jointed Concrete	Continuous Concrete		
Overall Section Condition Rating	3 metric ratings (IRI, cracking, and rutting/faulting)	2 metric ratings (IRI and cracking)		Measures
Good	All three metrics rated “Good”	Both metrics rated “Good”	→	percentage of lane-miles in “Good” condition
Poor	≥ 2 metrics rated “Poor”	Both metrics rated “Poor”	→	percentage of lane-miles in “Poor” condition
Fair	All other combinations	All other combinations		

To determine whether States have met their performance targets, highway agencies calculate the percentage of lane-miles in good and poor condition based on combinations of individual metric ratings. *Source: FHWA.*

The exchanges center around presentations by States on pavement condition and management data, emerging data collection and management tools and technologies, data aggregation and integration, data quality assurance, data quality management programs, data standards and governance, pavement management processes, and performance measures. The participating States have 45 minutes to present on data-related obstacles and resolution processes, followed by a 15-minute question-and-answer session. These peer exchanges have typically been attended by six State DOTs, whose representatives have included personnel involved with data collection, data assembly, data analysis, and decisionmaking.

So far, FHWA has hosted two 1.5-day regional-level peer exchanges focused on pavement data and management, in November and December of 2018. The first, in Colorado, was attended by representatives from Colorado, Montana, Oklahoma, Oregon, South Dakota, and Wyoming. The second, in Indiana, was attended by Indiana, Michigan, North Dakota, Ohio, Pennsylvania, and Virginia. FHWA plans to conduct more peer exchanges on pavement data and management in 2019.

Looking Ahead

The technology and practices to improve data quality continue to evolve. These advancements will help States implement Federal regulations as well as develop pavement data and management practices for improved decisionmaking capabilities. States have already demonstrated their commitment to and proficiency in finding solutions that will lead to ensuring data quality. Data-centric peer exchanges could continue to provide the forum for States to discuss how to approach pavement data needs.

“There is a lot of expertise in data collection and data management in State DOTs,” says Van. “Sharing that know-how among peers continues to be one of our most valuable programs.”

For more information, contact Thomas Van at thomas.van@dot.gov or 202–366–1341, or visit www.fhwa.dot.gov/pavement/mana.cfm.

[1] *Guidelines for Development and Approval of State Data Quality Management Programs*. Federal Highway Administration, Washington, DC. 2018.

[2] 23 USC 150(c)(1)
[3] 23 USC 150(c)(3)(A)(iv)
[4] 23 USC 150(d)(1)
[5] 23 CFR 490.309(a)
[6] 23 CFR 490.313(b)
[7] 23 CFR 490.319(c)
[8] 23 CFR 490.307(a)
[9] 23 CFR 490.105(e)(4)
[10] 23 CFR 490.307(a)
[11] 23 CFR 490.309(a)
[12] 23 CFR 490.319(c)
[13] 23 CFR 490.313(b)
[14] 23 CFR 490.313(c)

A construction crew is using a slipform paver to spread, consolidate, and screed concrete. FHWA recently published a *Pavement Design Best Practices Catalog* with recommendations related to pavement structures for both asphalt concrete and jointed plain concrete pavements. *Photo: ©Shreenath Rao, Applied Research Associates, Inc.*

Pavement Design Best Practices Catalog

FHWA's new reference presents guidelines and recommendations that address a variety of real-world conditions.

Effective pavement designs are essential to constructing smooth and safe roads that offer long service lives and require minimal repair and rehabilitation over time. Pavement designers consider a variety of factors, including traffic loads and distribution, climate, material alternatives, and subgrade and soil properties. They also face decisions regarding design features, material properties and durability, layer thicknesses, surface and subsurface drainage, subsurface condition mitigation, construction quality, preservation strategies, and other criteria that affect a pavement's performance.

To help pavement designers improve the quality and long-term durability of their designs, FHWA developed a catalog of best practice guidelines for varying criteria and conditions. The new *Pavement Design Best Practices Catalog* serves as a reference for considering the reasonability of designs for both asphalt concrete (AC) and jointed plain concrete pavements (JPCP) constructed in the continental United States.[15]

Need for a Pavement Design Catalog

Efforts to develop the catalog began in 2016. Over the past few years, FHWA officials recognized a need for guidance summarizing best practices that can complement design analysis strategies, which do not account for degradation of the condition of the pavement structure over time. Although analysis tools such as the American Association of State Highway and Transportation Officials' (AASHTO) mechanistic-empirical design software, AASHTOWare® Pavement ME Design, help ensure that designs are structurally adequate, the results are valid only if the design assumptions remain true throughout the design period of the pavement. Unless designers adopt appropriate measures, the properties assumed in the design analysis might no longer be true, and the pavement materials might degrade prematurely.[16]

Experts Weigh In

FHWA convened an expert task group to provide the research team with guidance on the most relevant topics to include in the catalog. Invited experts represented the State departments of transportation in California, Mississippi, Missouri, Utah, and Wisconsin, as well as the National Asphalt Paving Association and the American Concrete Pavement Association. Topics covered during the in-person gathering ranged from the design of JPCP and AC pavements to base and subbase designs, foundations and subgrades, and considerations related to materials and construction.

Scope and Contents

Completed in summer 2019, the *Pavement Design Best Practices Catalog* provides best practice recommendations on pavement structures for new JPCP and AC pavements only. It uses the pavement mechanistic-empirical design methodology as the basis for the structural design and can help guide the design process prior to analysis of the structural design. The best practices, which are not legally binding, are based on agency design practices, prior research efforts, insights from test sections in the Long-Term Pavement Performance (LTPP) Program, and other studies that highlight potential risks and distresses due to climate, traffic, materials, and subgrade conditions.

Featured topics include the following:

- Design considerations such as site conditions (traffic distribution, climate, and subgrade foundation), and pavement structure and material properties (AC, portland cement concrete, bases, subbases, shoulder).
- Subsurface pavement drainage and special considerations to minimize moisture-related pavement damage.
- Special subsurface conditions, such as frost susceptibility, expansive or swelling soils, and erodibility.
- Recommendations to reduce early development of distresses over a pavement's design period, including nonstructural distresses due to design, material, or construction defects.

Topics Discussed by the Expert Task Group

- **Pavement performance.**
- **Failures and repairs.**
- **Drainage.**
- **Design methodology gaps.**
- **Pavement construction quality.**
- **Subgrades, bases, and subbases.**
- **Material selection.**
- **Design alternatives.**

"The main purpose of the design catalog is to provide the pavement engineers with a tool that could be used to conduct design checks and to determine that appropriate design features are used for the design condition to minimize the risk of poor performance."

— Tom Yu, Program Manager,
Pavement Design, FHWA

Here, a crew uses a paving machine to place and finish an asphalt concrete surface layer. Pavement designers can use FHWA's catalog to facilitate planning, budgeting, and design checks for new pavements. *Photo: ©Shreenath Rao, Applied Research Associates, Inc.*

- Recommendations on structural design features for AC and JPCP projects.
- Guidelines on earthwork considerations, soil constructability, and variations along a project and climatic situations that might apply to a project's geographic location and region.
- Pavement features that can be adapted to fit an agency's cross-sectional designs, thickness design procedures, material specifications, mix designs, and other standards.

The guidelines capture the necessary decisions related to pavement design, help verify design strategies, and serve as a check to avoid unrealistic designs. The catalog is not, however, intended to be a project-level design tool. Rather, designers can use it to facilitate planning, budgeting, and design checks.

Using the Catalog

The catalog designs are based on nationally calibrated models and default inputs in the AASHTOWare® Pavement ME Design software. If an agency's local calibration coefficients or default inputs vary significantly from nationally calibrated ones, designers will need to revise the pavement layer thicknesses to reflect local conditions and experience.

"We see the catalog being used as a training guide for less experienced pavement engineers and as a reference guide for experienced engineers," says Jason Simmons, statewide pavement engineer, Utah Department of Transportation.

The *Pavement Design Best Practices Catalog* can assist highway agencies in checking the reasonableness of their pavement designs through highlighting features that could improve pavement life and reduce the risk of early failure. Other benefits of using the guide include ensuring ride quality and, thereby, enhancing safety over a pavement's design period.

For more information, visit www.fhwa.dot.gov/pavement/pavedesign.cfm.

[15,16] Applied Research Associates, Inc., *Pavement Design Best Practices Catalog*. Federal Highway Administration, Washington, DC. 2019 (In Print).

This aggregate spreader is using automated application to increase pavement friction on this road. *Source: FHWA.*

Improving Safety Through Continuous Friction Measurement

Data from higher resolution testing can better direct improvements to areas with elevated friction-related crash risk.

Some characteristics of a pavement's surface affect how vehicles interact with the roadway. A pavement's surface texture, for example, is a key determinant of friction, which impacts safety considerations such as driving control, braking, and steering. Monitoring pavement friction values and improving them when they fall below a certain threshold, especially at horizontal curves, intersections, and ramps, can prevent many roadway departure-related crashes and improve roadway safety. FHWA's efforts to reduce fatal and severe injuries have achieved significant crash reduction with the installation of high friction surface treatments (HFST) nationwide.

Traffic safety depends on multiple types of factors: human factors (such as driver and/or passenger behavior), vehicle factors (such as design and condition), and the roadway environment (including roadway geometry, roadside design, traffic control features, and pavement surface characteristics). Pavement surface characteristics include friction, texture, roughness, cross slope, and hydroplaning potential. These characteristics are defined by the pavement surface course and include both physical attributes, such as stand-alone pavement surface properties—for example, texture and porosity—and dynamic attributes such as friction and rolling resistance that result from vehicular movement over the pavement surface.

Highway engineers can influence some of these roadway environment factors and minimize friction-related vehicle crashes by designing, constructing, and maintaining new pavement surfaces to provide adequate and durable friction properties. In addition, engineers can identify and correct sections of roadways that have elevated friction-related crash rates such as horizontal curves, intersection approaches, and congested and merging/weaving areas of freeways. Highway engineers can prioritize resource use to reduce friction-related vehicle crashes in a cost-effective manner.

“Improving pavement friction is one of the FHWA Office of Safety’s Proven Safety Countermeasures. Continuous friction measurement will assist in the advancement of the application of a systemic approach using the pavement friction data collected. It will also enhance site selection and installation limits for HFST construction.”

— Joseph Cheung, P.E., Senior Safety Engineer, Office of Safety, Safety Design Team, FHWA

Friction and Texture Effects Safety

Pavement surface characteristics can contribute to highway crashes. This is partially because of low sensitivity or awareness of drivers toward pavement friction and texture during wet pavement conditions.

Pavement friction is the force that resists the relative motion between a vehicle tire and pavement surface. Friction is key for roadway safety because tires need friction to avoid sliding across the pavement surface and to stop and safely navigate curves. Pavement friction is influenced by the microtexture and macrotexture of the pavement surface. Microtexture is a fine-scale texture (wavelengths of 1 µm to 0.5 mm) on the surface of the coarse aggregate in asphalt or the sand in cement concrete that interacts directly with tire rubber on a molecular scale. Macrotexture is large-scale texture (wavelengths of 0.5 mm to 50 mm), typically formed by the shape and size of the aggregate particles in the asphalt pavement surface or by supplemental treatments such as tining and grooving on concrete pavement surface.

Pavement macrotexture is important to produce friction and to channel water away from beneath the tire, helping to avoid hydroplaning (wherein the tire floats on a film of water above the roadway surface). Both microtexture and macrotexture help provide wet pavement friction at low- and high-speed conditions, but the role of macrotexture becomes more critical as travel speeds increase. Adequate texture depth can improve pavement friction test results at high speeds and reduce crash rates on high-speed facilities.

Sufficient pavement friction and texture can positively contribute to vehicle crash reduction by meeting the friction demand of the road users,

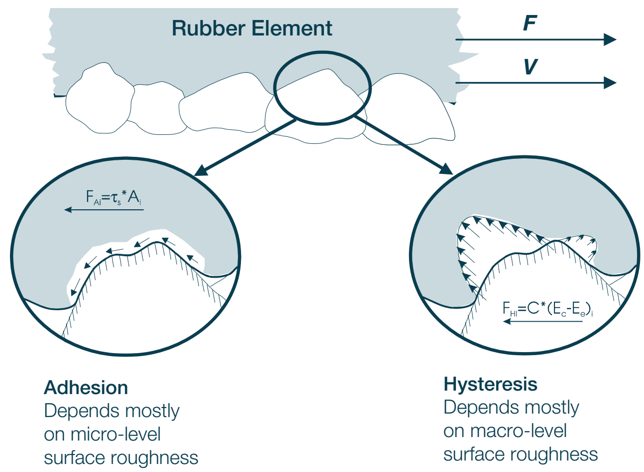


Diagram of frictional impact of macro- and microtexture. F = tangential friction force and V = vehicle speed in miles per hour. The equations for both adhesion and hysteresis are shown, and friction is the sum of the adhesion and hysteresis frictional forces. *Adapted from ©National Cooperative Highway Research Program.*

which can reduce roadway departures. Roadway departures result in 53 percent of traffic fatalities across the United States.[17] Research indicates that some wet-pavement crashes can be prevented or minimized by improving pavement friction and texture.[18] These improvements could also lead to reductions in dry pavement crashes.

Pavement Friction Management Programs

FHWA, through *Technical Advisory 5040.38 Pavement Friction Management*, encourages States to develop pavement friction management programs (PFMPs) that include network-level friction testing. The role of a PFMP or policy is to provide a framework for highway engineers to use to monitor the condition of their roadway networks and to make informed decisions regarding treating or resurfacing the roadway based on the evidence of the data produced through roadway monitoring. These programs or policies are important because they consider factors of driving behavior and roadway characteristics to identify areas where the demand for higher friction levels is greater.

PFMPs require maintaining adequate levels of friction on all roadway sections based on the friction demand needed for different types of roadway segments. Friction demand is the level of friction needed to perform braking, steering, and acceleration maneuvers. In general, horizontal curves, intersection approaches, and congested and merging/weaving areas of roadways have a higher friction demand than tangent segments of the same roadway.

A confounding element related to friction demand and the available pavement surface friction is highlighted in the 1967 National Cooperative Highway Research Program Report 37.[19] The report states that "because the intensity of the polishing process increases markedly with tread element slip, all other factors being equal, the lowest friction levels are found on high-speed roads, curves, and approaches to intersections; in short, in locations at which high friction values are needed most." This is because of the higher tire stresses induced on the pavement, which increase the polishing process.

Highway engineers can set different friction threshold values or investigatory levels based on friction demand categories. When friction thresholds are not met, a detailed project-level pavement evaluation should be done to verify if it warrants a raise in the friction level to reduce the crash risk.

Critical aspects of a PFMP include the equipment used to collect friction data, the processes needed to analyze and interpret friction data along with the crash data and the geometric parameters that influence the vehicle response in each section, and the comparison of the cost-effectiveness of possible treatments. Furthermore, the PFMP should be an integral part of a network-level systemic approach that involves widely implemented improvements based on high-risk roadway features.

Deploying Continuous Friction Measurement Equipment

FHWA's Acceptance Testing and Demonstration of the Continuous Friction Measurement Equipment project aims to help reduce annual fatalities by implementing proactive PFMPs that include investigatory thresholds for pavement friction and macrotexture.

The objectives of the project were to:

- Assist four States in developing PFMPs by considering pavement friction, texture, and crash rates.
- Develop and demonstrate methods for establishing investigatory levels of friction and macrotexture for different friction demand categories, including:
  - » Subdividing the highway networks into groups according to friction needs (demand categories);
  - » Collecting the necessary friction, texture, crash, traffic, and other data; and
  - » Analyzing the data to set investigatory threshold levels for pavement friction and texture.
- Demonstrate proven continuous friction and macrotexture measurement equipment.

FHWA partnered with four States: Florida, Indiana, Texas, and Washington. FHWA selected the States based on their opportunity to benefit from a PFMP because of a high number of crashes or crash rate, the geographic representativeness and diversity in practices, and availability of a friction database. The four States have established friction testing programs. In addition, it was important that the State departments of transportation collaborate with FHWA and conduct locked-wheel skid testing alongside the continuous friction measurement.

Current friction measurement in the United States is a sample-based discrete measurement test, using locked-wheel skid trailers (LWSTs). The LWST test is a high-quality friction test procedure for the 60 feet of pavement tested at a testing speed of 40 miles per hour. The LWST test can be a challenge at critical locations such as curves, intersections, and ramps. The conventional testing approach of one or two tests per mile (that is, one or two percent of the pavement surface) does not accurately capture friction variations at a high degree of granularity.

Continuous friction measurement is the standard for Australia, New Zealand, and most European countries that conduct network-level friction testing. Continuous friction measurement equipment uses a rubber tire to continuously measure friction and characterize microtexture. It also uses a high-speed vehicle-mounted laser device for macrotexture measurement across every foot of pavement.

Contracted by FHWA, a team of researchers conducted field testing and data collection in 2015 and 2016 to demonstrate continuous friction measurement equipment. The results of the demonstration studies indicate that measuring friction continuously, especially when complemented by macrotexture, roadway geometric data, traffic, and crash data, provides a more effective method to identify the most critical sections. Thus, States can focus on safety improvement efforts at higher risk locations, which are most commonly intersections and curves.

Analysis of the friction data collected showed that the typical LWST friction testing frequency of one or two tests per mile is insufficient to identify the most critical sections for potential friction enhancement. The demonstration also indicated that providing an appropriate level of macrotexture is critical for high-speed roadway segments.

Systemic Approach to Safety Friction Data Analysis

The researchers demonstrated an analysis approach to identify high crash risk areas using safety performance functions (SPFs) and Empirical Bayes (EB) rate estimation from observed crashes. Researchers developed SPFs incorporating friction and other relevant parameters using the negative binomial model to predict the number of

A locked-wheel skid trailer, such as this one owned by the South Carolina Department of Transportation, is currently the most commonly used equipment for friction measurement in the United States. *Source: FHWA.*

Continuous friction measurement equipment, as shown here, provides a much higher spatial coverage and reduces the chances of missing localized areas with friction deficiencies. *Source: FHWA.*

crashes in the 3-year study period for each 0.1-mile long roadway segment. The EB method was used to produce an estimate of the number of crashes in each segment and the possible crash reduction because of various surface treatments (hot-mix asphalt overlays for asphalt pavements, conventional diamond grinding for portland cement concrete, and high friction surfaces on critical locations with both types of pavements). The researchers assessed the overall potential savings of various treatments using potential crash reductions estimated using the final SPF and the EB method and average treatment costs.

The results showed potential crash reductions of up to 25 percent in the network investigated in one of the States because of friction-improving treatments in the highest expected crash count sections. The results indicated a high return on investment. However, the crash analysis sections investigated were selected because they have expected high crash counts; the percentage will likely be lower if the approach is applied statewide.

The relationship between SPF and crashes is presented using the following equation:

$$P = L \times e^{\beta_0 + \ln(AADT)\beta_1 + X_{1+i}\beta_{1+j}}$$

P = Number of crashes on segment L
AADT = Annual average daily traffic/traffic volume
X_i = Friction, texture, curvature, cross-slope, grade, etc.

Benefits of Continuous Friction Measurement

While LWST testing frequency conventionally tests one or two percent of the pavement surface, with approximately one or two tests per mile, continuous friction measurement tests 100 percent of the pavement surface. This data-driven approach showing the difference in testing resolution, or the amount of data collected for a roadway segment, creates significant differences in the potential to inform safety improvements to roadways with friction.

FHWA has conducted quantitative and qualitative assessment of the advantages of using continuous friction measurements versus the traditional LWST sampling approach. The continuous devices provide a much higher spatial coverage and reduce the chances of missing localized areas with lower friction. FHWA's assessments demonstrated the importance of having a higher resolution with examples that showed how the current LWST testing/sampling approach can miss critical locations, especially in locations where there is high demand for friction and more polishing of the pavement (lower available friction) resulting from braking and turning maneuvers.

Looking Ahead

FHWA and the partner States were limited to investigating a small fraction of each State's roadway network. To develop robust friction investigatory thresholds or safety performance metrics, States will have to expand their continuous friction measurement equipment analysis across a wider roadway network.

Washington State has agreed to conduct a comprehensive study to further investigate continuous friction measurement equipment and assess its adaptability.

"Based on Washington [State Department of Transportation's] participation in the FHWA project, Washington has programmed a research project to start in 2019 to further explore the potential benefits of continuous friction measurement," says Kim Willoughby, P.E., State pavement management engineer, Washington State DOT Construction Division, Materials Laboratory. "The research will analyze pavement friction and safety performance using random parameter modeling."

As more States use continuous friction measurement equipment, recognition will grow about the benefits of implementing high-resolution friction testing to identify road sections that may reduce crash risk with a friction improvement treatment.

For more information, visit https://safety.fhwa.dot.gov/roadway_dept/pavement_friction.

[17,18] Smith, K.L., Larson, R.L., Flintsch, G. and de León Izeppi, E., *Development and Demonstration of Pavement Friction Management Programs: Theoretical Relationship of Vehicle-Tire-Pavement Interactive and Skid Crashes*. Contract Number: DTFH61-09-R-00035. Federal Highway Administration, Washington, DC. 2011.

[19] Kummer, H. W., and Meyer, W. E., *Tentative Skid Resistance Requirements for Main Rural Highways*, National Cooperative Highway Research Program Report No. 37, Highway Research Board. 1967.

In Connecticut, PCP panels with leveling bolts engaged replaced a rutted asphalt bus pad. *Source: FHWA.*

States Cast Their Votes for Precast Concrete Pavement

Highway agencies adopt precast technology for projects in high traffic areas to increase pavement performance while shortening construction work-windows.

Repair and rehabilitation of aging highway pavement infrastructure is a challenge for highway agencies across the Nation. Many of the highway pavements in need of rehabilitation are heavily trafficked and require extended lane closures for construction activities, which worsen traffic congestion and affect project delivery. Accelerating pavement repairs helps to minimize the traffic impacts while ensuring consistent and high-quality pavement performance.

One accelerated pavement construction and repair technique involves using precast concrete pavement (PCP) systems. PCP systems use slabs of precast concrete pavement that are fabricated or assembled in a controlled environment, often remotely, and then transported to and installed at a project site.

Over the past decade, many highway agencies have increased adoption of PCP systems for rapid repairs and rehabilitation on critical roadways. The traditional cast-in-place (CIP) construction technique requires placing, setting, and curing concrete slabs onsite prior to opening the pavements to traffic. PCP panels are fabricated offsite, which provides greater control over the final quality of the pavement. Furthermore, unlike CIP concrete pavements that necessitate extended road closures of more than a week, highway agencies can install PCP panels quickly—in a matter of hours—and open the roads to vehicles immediately.

"PCP is often selected by highway agencies for rapid renewal of pavements in locations where traffic volumes are high and long-life pavement performance is required," says Sam Tyson, concrete pavement engineer, FHWA. "Typical lane closures for PCP projects are from 9:00 p.m. until 6:00 a.m. the following morning with lanes fully restored to traffic after implementation."

PCP enables transportation agencies and contractors to restrict construction on critical roadways to off-peak times, reducing worker and driver exposure to work zone hazards.

FHWA Support

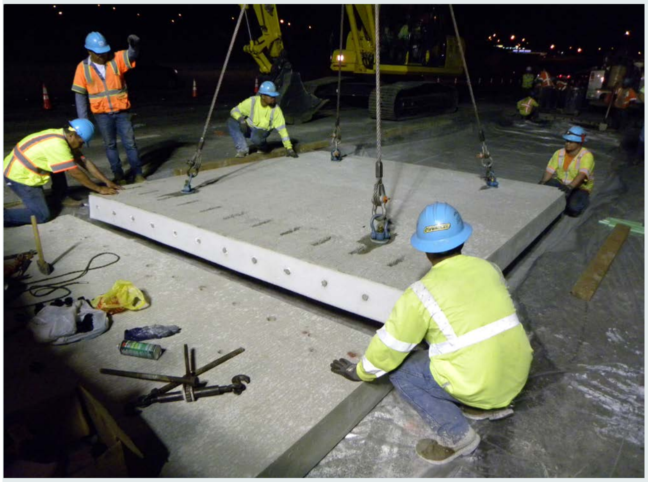
FHWA has developed extensive guidance for the use of PCP technology through the Second Strategic Highway Research Program (SHRP 2). PCP has gained wide acceptance for rapid repair and rehabilitation of concrete pavements, reconstruction of ramps and heavily trafficked asphalt intersections, and numerous other applications. Through its various PCP initiatives, FHWA:

- Provides technical support to highway agencies to mitigate perceived risks related to PCP adoption.
- Enhances awareness and dispels misunderstandings of potential users.
- Trains highway agencies' design, materials, and construction personnel.
- Educates the contractor community, including concrete precasters and concrete paving contractors.
- Promotes technology transfer within academia to advance knowledge and understanding of potential uses.

Applications and Design

Highway agencies are using PCP technology for intermittent repairs, such as full-depth joint repairs or full panel replacement, and for continuous applications, such as longer and wider area rehabilitation. Precast concrete works well at various types of sites, such as intersections, ramps, underpasses, and bus pads. Predominant examples of PCP technologies include jointed reinforced or pretensioned PCP panels installed either separately or continuously, and posttensioned PCP panels with fewer joints (wherein thinner concrete panels are installed and posttensioned in a continuous manner).

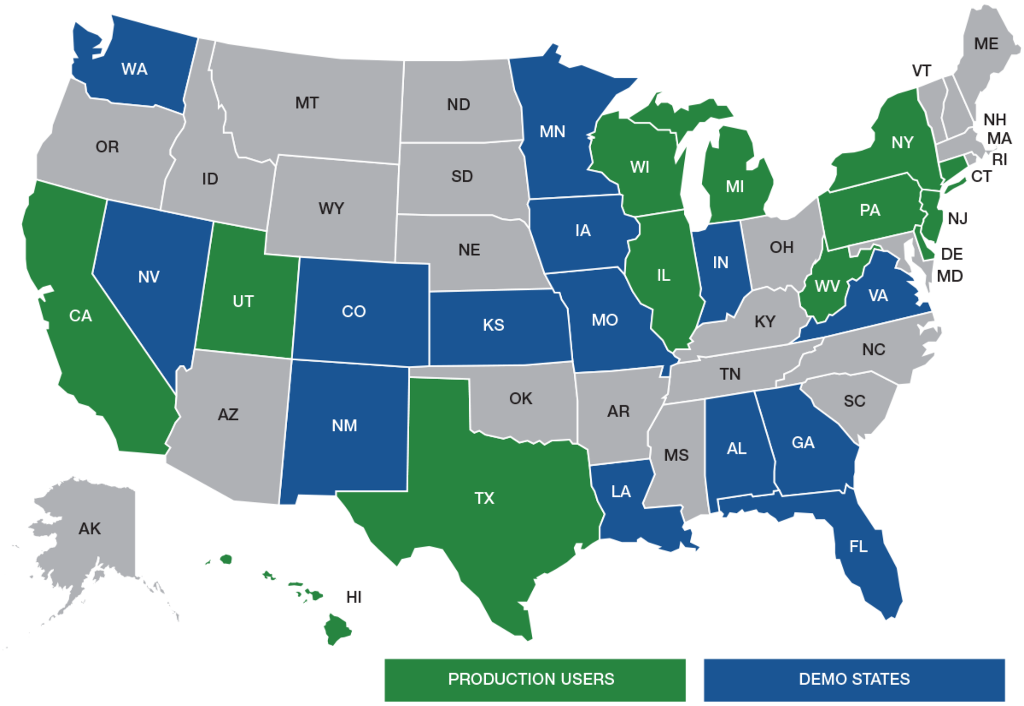
Highway agencies use generic and proprietary panel designs for both intermittent repair and continuous applications of PCP. Engineers base panel designs on load transfer provision at transverse joints using slots or other features. For PCP systems, load transfer is provided by installing dowel bars in slots or ducts fabricated along one transverse side of a panel, either through bottom slots (a patented detail) or a variety of top slot details.



A construction crew lowers a PCP panel onto a prepared base as part of reconstruction of Interstate H–1 west of Honolulu, HI. *Source: FHWA.*

Benefits of PCP Technology

- **Short installation time:** Off-peak nighttime lane closures can accommodate installation.
- **Reduced construction-related road closures:** Minimized impact on traffic and reduced exposure of workers and drivers to work zone hazards.
- **Better-quality concrete:** No issues related to the quality of fresh concrete delivered to the project site, CIP paving equipment operation, or uniform placement of concrete.
- **Improved concrete curing conditions:** Curing occurs under controlled conditions at the precast concrete plant.
- **Minimal weather restrictions on placement:** Extended construction season because panels can be placed in cooler weather or during light rainfall.
- **Elimination of construction-related early-age failures:** No issues related to late or shallow sawing.



State Highway Agencies Implementing PCP. *Source: FHWA.*

An important design consideration is the bedding layer (or interlayer) that ensures uniform contact between the flat bottom of a panel and the graded/finished base. The grade-placed option enables placement of the PCP panels directly on grade, while the grout-supported option allows for the panels to be set over a thin layer of bedding grout using leveling lifts.

Panel reinforcement and production rates are also important factors that can impact PCP implementation. Engineers typically use a double mat of reinforcement for jointed PCP panels to mitigate any cracks that may develop during lifting or transporting of panels and to extend panel service life. Panel production rates depend on length of panels and type of repair activity. Using longer PCP panels can achieve greater production rates. A typical PCP panel production rate is about 15 to 20 panels per nighttime lane closure for intermittent repairs, and about 40 to 50 panels per night (or about 600 to 800 feet of installed length) for continuous applications.[20]

Highway agencies can use PCP technology for corridor-wide pavement reconstruction, or on smaller roadway segments for construction phasing flexibility. PCP panels can be reinforced from the top and bottom in both the longitudinal and transverse directions, pretensioned in the longitudinal direction and reinforced top and bottom in the transverse direction, or pretensioned in both the longitudinal and transverse directions. Agencies can place PCP panels on a reworked existing base or a newly installed base and achieve adequate and uniform base support conditions using either grade-placed or grout-supported options.

Maintaining Traffic on Critical Roadways

Maintenance of traffic and long-life pavement performance are the principal needs that lead to the use of precast concrete for pavement applications. Precast concrete in full-depth repairs is expected to last for 20 or more years, depending on the condition of the adjoining pavement. Precast concrete intersections, ramps, and other continuous applications are expected to provide 40 or more years of maintenance-free service, except for periodic grinding to restore desired surface characteristics.

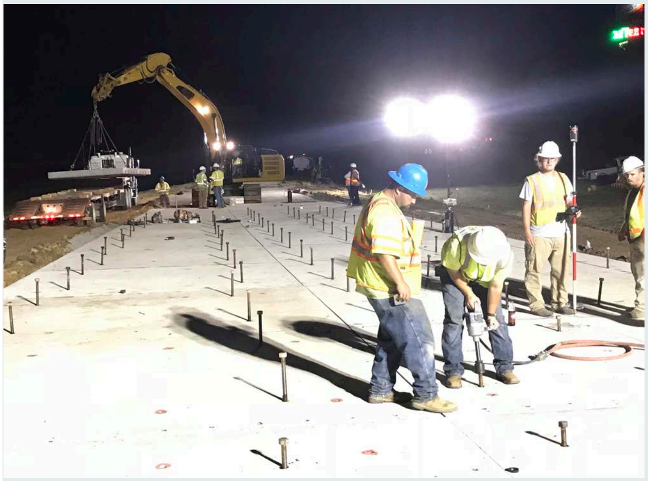
Because PCP adoption is a relatively recent development in pavement technology, no projects currently exist where PCP has been in place for more than 20 years. However, based on the use and condition of current installations, the life expectancy of PCP is anticipated to be significantly greater than traditional CIP concrete pavement. In contrast, asphalt and rapid-hardening concrete can provide short-term service but will require several replacements during the same timeframe as the expected life of PCP panels.

Guidance Development and Technical Assistance

SHRP 2 initiatives resulted in guidelines and tools for agencies to use in the selection, design, construction, installation, and maintenance of PCP systems, with guide specifications to spread awareness about potential concerns and cautions. FHWA developed a guide specification and checklists for fabrication and installation of precast concrete panels.

In addition, SHRP 2 also investigated 16 PCP projects at locations with wide-ranging climate patterns (from Michigan to Texas) and assessed the use of the PCP systems (on ramps, toll plazas, at-grade roadways, and airports). Field surveys included short, intermittent repairs, as well as longer, continuous applications. The research found that modular pavement technology is still evolving, but that over the 10 to 20 years it has been used, well-designed and well-constructed PCP systems can provide high-quality, long-term service. The research confirmed that PCP systems are often a good choice for rapid repair and rehabilitation of existing pavements.

FHWA recently published the report *Precast Concrete Pavement Technology Implementation Final Report* (FHWA-HIF-19-013), which provides an overview of PCP technology and explains FHWA's goal to provide technical support to highway agencies that receive grants through SHRP 2 for PCP implementation, as well as to other highway agencies interested in using PCP technology. The final report provides links to case



Construction workers install PCP panels and maintain grade control using leveling bolts as part of an access ramp replacement project along I–20 west of Shreveport, LA. *Source: FHWA.*

PCP Guidance Documents

- ***Precast Concrete Pavement Technology Implementation Final Report*, FHWA-HIF-19-013 www.fhwa.dot.gov/pavement/concrete/pubs/hif19013.pdf**
- ***Precast Concrete Pavement Technology Resources*, FHWA-HIF-19-012 www.fhwa.dot.gov/pavement/concrete/pubs/hif19012.pdf**
- ***Guide Specification for Jointed Precast Concrete Pavement*, FHWA-HIF-19-017 www.fhwa.dot.gov/pavement/concrete/pubs/hif19017.pdf**
- ***Jointed Precast Concrete Pavement Panel Fabrication and Installation Checklists*, FHWA-HIF-19-016 www.fhwa.dot.gov/pavement/pubs/hif19016.pdf**
- ***Precast Concrete Pavement Bedding Support Systems*, FHWA-HIF-16-009 www.fhwa.dot.gov/pavement/concrete/pubs/hif16009.pdf**
- ***Load Transfer Systems for Jointed Precast Concrete Pavement*, FHWA-HIF-16-008 www.fhwa.dot.gov/pavement/concrete/pubs/hif16008.pdf**

study reports for SHRP 2 projects, technical briefs, a guide specification, checklists for fabrication and construction activities, and other resources.

Growing Adoption Across States

FHWA will complete a 5-year project supporting implementation of PCP technology in 2019. As a part of this project, an expert task group (ETG), including representatives from FHWA and State highway agencies, industry associations, academia, precasters, contractors, and suppliers, among others, was constituted to oversee and facilitate development of PCP guidelines. The ETG met five times throughout the project period of performance to allow for oversight and to provide useful information concerning implementation of PCP technology.

Highway agencies, contractors, and precast-concrete suppliers have worked together in 28 States to demonstrate PCP projects. Highway agencies in 13 of those States are production users of PCP and have adopted PCP as an alternate pavement strategy for certain types of projects. The California Department of Transportation has constructed more than 20 PCP projects, and other production users have constructed 5 to 10 PCP projects. Project sizes ranged from 200 panels for the replacement of intersections and ramps to 7,000 panels for the reconstruction of continuous sections of pavement. Several States, including Alabama, Connecticut, Florida, Hawaii, Kansas, Louisiana, Texas, and Wisconsin, received funding from the SHRP 2 Implementation Assistance Program to offset a portion of the cost of PCP construction.[21]

Industry Preparedness

The technology for precasting is available and ready for use in all areas of the United States with heavily trafficked roadways. Precasters are prepared and knowledgeable about the production of PCP panels, and almost any potential project site in the United States is within a reasonable distance from a precaster (fewer than 250 miles). Lead times associated with PCP panel production depend on time to cure panels as part of their production, delivery time, the overall pace of the project, and the number of panels placed per application. Contractors and precasters typically coordinate to ensure smooth precast operations, and to account for additional lead times that could result from shortcomings between the number of panels produced and the number of panels placed during each application.

Getting What You Pay For

PCP has a higher initial cost compared to conventional CIP concrete; however, the performance life and traffic delay times vary significantly between the two techniques. Highway agencies also should consider factors such as the lifecycle cost of each material, maintenance costs, user delay costs, and the value of the safety associated with each installation technique. A fair comparison will include all anticipated costs incurred over a given period, usually selected to be at least equivalent to the expected life of the longer life alternative, plus at least one rehabilitation activity. As stated previously, service life expectation of PCP is at least 20 years for intermittent repairs and 40 years for continuous applications, without significant corrective treatments. This can ultimately lead to significant cost savings over an extended period on a given roadway with PCP installations.

"Urban roadways will continue to become more congested and the expectations of freight continue to demand efficient trucking," says FHWA's Tyson. "PCP provides an alternative type of pavement for certain applications to minimize traffic disruptions and maintain a high level of performance over a significant period."

For more information, visit www.fhwa.dot.gov/goshrp2/Solutions/Renewal/R05/Precast_Concrete_Pavement.

[20,21] Tayabji, S., *Precast Concrete Pavement Technology Implementation*. Report No. FHWA-HIF-19-013. Federal Highway Administration, Washington, DC. 2019.

FHWA efforts help State highway agencies build concrete pavement roads that last longer. *Photo: ©APTech.*

Prevention Is Better than Cure

A revamped approach to preserve concrete pavements focuses on addressing the underlying causes of deficiencies in both the design and use stages.

The philosophy behind pavement preservation emphasizes the importance of applying the right treatment to the right pavement at the right time. The goal is to maintain the functionality of the pavement (that is, its smoothness, friction, quietness) in a cost-effective manner.

Unfortunately, many preservation treatments are stop-gap measures used only to address visible signs of deterioration. In this application, the treatments address the symptoms of the problem, but they may not directly address the underlying causes of the distress, which could require more significant rehabilitation, or even reconstruction.

Defining Concrete Pavement Preservation

Preserving the existing concrete pavement structure to extend its service life for as long as possible by arresting, greatly diminishing, or avoiding the pavement deterioration process.

An ongoing FHWA study is developing guidance on concrete pavement preservation and reconsidering the term to go beyond the traditional concept. The idea is that three fundamental approaches can help to preserve concrete pavement:

1. Designing and constructing pavements that remain structurally adequate and relatively distress-free throughout their service lives (that is, using long-life concrete pavement).
2. Using asphalt or concrete overlays as preservation treatments to maintain the functional performance of the pavement.
3. Maintaining the serviceability of the pavement using concrete pavement restoration (CPR) treatments.

Many resources exist on *how* to apply concrete pavement preservation treatments. However, under this study, FHWA is focusing on *what* to do and *when* to do it.

“Long-life strategies can be built into the pavement design,” says Dulce Rufino Feldman, senior transportation engineer, California Department of Transportation. “With the advent of pavement mechanistic-empirical design, a pavement can be designed to achieve the desired performance parameters at the end of the design life without the need for intervention. By applying long-life strategies, the lifecycle costs are reduced, and both highway agencies and users benefit in terms of fewer lane closures and less exposure for highway workers.”

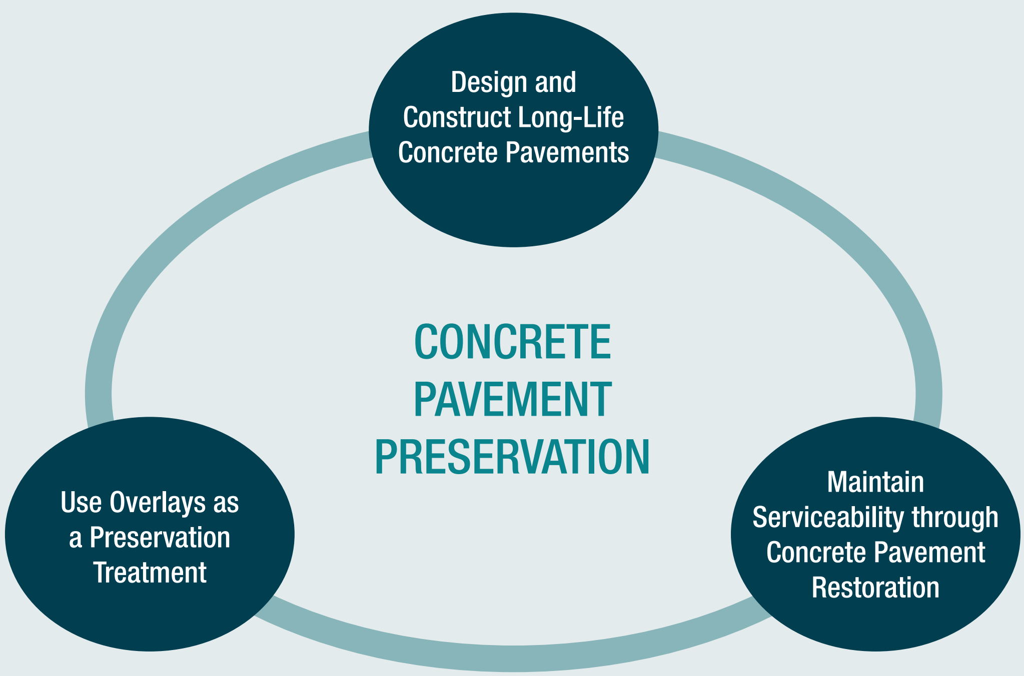
Preservation Begins with Initial Design

The most significant shift in philosophy is the basis that preservation begins with the initial design of the concrete pavement structure. The objective is two-fold: (1) to design and construct long-life concrete pavements that are structurally adequate and largely distress-free over their service lives, and (2) to apply preservation strategies that maintain pavement functionality without compromising the structural capacity of the underlying pavement structure. In other words, design the pavement to perform instead of designing the pavement for a certain level of distress.

Most in-service concrete pavements were not designed as long-life structures. Therefore, they may require a different approach for preserving and extending the service lives through a combination of overlays and rehabilitation treatments. In some cases, complete removal and replacement of the existing pavement structure may be the most economical and environmentally sustainable solution from a lifecycle perspective.

Longer Service Life = More Sustainable Pavement

- **Reduces pavement lifecycle cost.**
- **Conserves natural resources.**
- **Reduces energy use.**
- **Improves safety.**
- **Decreases work-zone related traffic delays.**



Concrete pavement preservation includes three fundamental approaches: designing and constructing long-life concrete pavements, using asphalt or concrete overlays to preserve functionality, and maintaining serviceability through timely restorative treatments. *©APTech.*

Category #0. No apparent distress. Candidate for monitoring to identify initial and progression of distresses.

Category #1. No structural deterioration. Requires functional preservation.

Category #2. Improvements (e.g., structural overlays) have been performed to prevent/arrest structural deterioration.

Category #3. Continuous structural deterioration. Treatments applied to maintain serviceability until major rehab or reconstruction can be performed.

These concrete pavements fall into four different categories as potential candidates for long-term preservation.
Photos: ©APTech.

The ongoing FHWA study is focusing on identifying suitable preservation approaches for concrete pavements in varying levels of distress and deterioration.

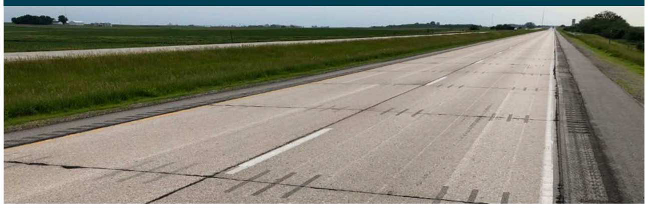
Learning from History

Project researchers are documenting the performance of 10 concrete pavement projects around the country that have successfully employed the approaches highlighted in the new preservation philosophy. The lessons learned from the case studies will bolster the development of new guidelines for concrete pavement preservation that focus on longer service periods and proactive application of maintenance, preservation, and rehabilitation treatments.

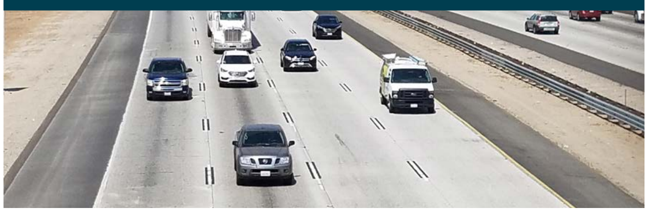
Strategy Selection Using Engineering Economic Analysis

In addition to developing a fresh set of guidelines for concrete pavement preservation, the study is also evaluating the potential application of the dollars per lane-mile per year metric to evaluate the effectiveness of pavement preservation strategies. The approach builds on a concept originally proposed by FHWA and the National Center for Pavement Preservation in 2007, which notes that maintaining a roadway network of X lane-miles for 1 year requires X lane-mile-years of service life purchased annually (through the application of maintenance, preservation, rehabilitation, and reconstruction activities) to maintain the network at the same level of service.

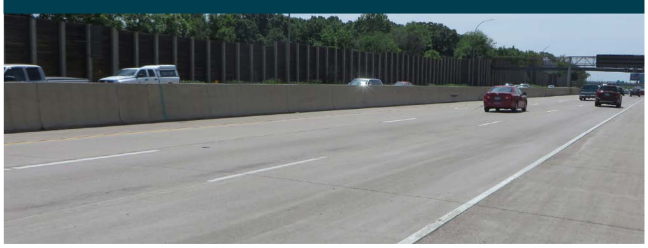
US–20, Blairsburg, IA
- Original construction: 1968
- Asphalt overlay: 2003
- CPR: 2013
- Still in service as of April 2019



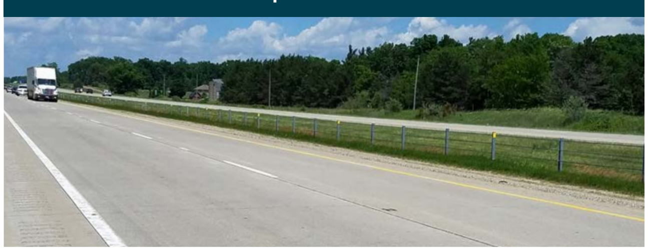
I–10, Ontario, CA
- Original construction: 1947
- CPRs: 1966–1967, 1976, 1982, 1991–1993, 1998–2001, 2006, 2012, 2015
- Still in service as of April 2019



I–35 W, Richfield, MN
- Original construction: 2000
- 60-year, long-life concrete pavement design
- First minor CPR planned: 2020



US–23, Brighton, MI
- Original construction: 1959
- Unbonded concrete overlay: 1999
- Still in service as of April 2019



Examples of concrete pavement projects that have exhibited long service lives through proper design and application of timely preservation treatments. *Photos: ©APTech.*

Researchers are comparing the dollars per lane-mile per year approach with the traditional lifecycle cost-analysis technique. The final project report will document the pros and cons of each approach, along with recommended application guidelines.

Interim Report and Beyond

FHWA published an interim report for the study that presents the revised definition for concrete pavement preservation, reviews the primary factors affecting performance, and includes a summary of the various concrete pavement preservation techniques. It also includes state-of-the-practice reviews on the approaches for concrete pavement evaluation and on traditional and emerging engineering economic analysis (EEA) techniques.

STRATEGIES FOR CONCRETE PAVEMENT PRESERVATION

Interim Report

FHWA-HIF-18-025

Prepared For:

Federal Highway Administration
Office of Preconstruction, Construction and Pavements
1200 New Jersey Avenue SE
Washington, DC 20590

U.S. Department of Transportation
Federal Highway Administration

February 2019

FHWA's interim report presents strategies for long-term preservation of concrete pavements and engineering economic analysis approaches for evaluating the effectiveness of different preservation techniques. *Source: FHWA.*

The project will also yield the following deliverables with an estimated delivery in early 2020:

- Project Report: A detailed report, building on the findings documented in the interim report.
- Guideline Document: A concise practical guideline document focused on selecting concrete pavement preservation strategies and EEA approaches targeted at pavement practitioners within State highway agencies.
- Case Study Reports: A summary of key design and construction aspects, as well as the lessons learned from 10 case studies.
- TechBrief: A summary of the project that provides brief, effective arguments on why agencies should use long-life preservation strategies for concrete pavements.

For more information, visit www.fhwa.dot.gov/pavement/pubs/hif18025.pdf.

Perpetual asphalt pavements are one example of improvements made in the sustainability of asphalt pavement systems. The section of pavement shown here is in excellent condition after 13 years of service. *Photo: ©APTech.*

Sustainable Asphalt Pavements: From Theory to Practice

A four-part technical series provides asphalt mix producers and contractors information they need to improve sustainability.

Sustainability considerations in highway transportation infrastructure continue to grow as agencies recognize the positive impacts that they can make in balancing environmental, economic, and social demands. Numerous resources are available on *why* to be more sustainable and *what* to do to be more sustainable. However, practical guidance on *how* to implement sustainability concepts for asphalt mix producers and contractors is still lacking.

To address this need, FHWA and the National Asphalt Pavement Association (NAPA), under a cooperative agreement, partnered on an outreach effort to provide practical solutions for the asphalt paving industry. The effort will produce a four-part series of documents, collectively called *Sustainable Asphalt Pavements: A Practical Guide*. Asphalt mix producers and contractors can implement the practical solutions shared in the guide to improve the sustainability of asphalt pavement systems. The overarching goals are to encourage asphalt mix producers and contractors to examine their processes and procedures and to identify opportunities for improving sustainability to better serve the highway community.

Going Above and Beyond

Portions of the four-part guide are still in development, but the introductory guide document emphasizes the importance of continuous improvement and evolution. The end goal is the achievement of a sustainable society where everyone within the society is happy, healthy, and living in a healthy environment.

Practical Sustainability

In practice, being more sustainable is:

- **Going above and beyond standard practice and required national regulatory minimums.**
- **Showing innovation in meeting standards and minimums in support of people and the environment.**

According to the first part of the guide, some of the key characteristics of sustainability are:

- **Sustainability is a high-level strategy.** Sustainability is the highest level goal of an organization or project. It is not an add-on feature that can be implemented at the last minute.
- **Sustainability elevates value of human and environmental health**. Sustainability essentially means "consider everything," including economic, environmental, and social factors.
- **Sustainability is context sensitive.** At the project level, sustainability priorities depend on the overall context. Sustainability means evaluating trade-offs and prioritizing according to the goals identified by the agency.
- **Sustainability implies continuous improvement.** Sustainability is always striving for improvement. The goal should not be to "do less bad" but instead to "do more good."
- **Sustainability evolves constantly.** What was once considered innovative or exceptional is likely to become standard practice. As the bar becomes higher, sustainable actions must continue to evolve to meet the goals of the organization.
- **Sustainability should create value.** For long-term viability, sustainability should create economic, environmental, and social value to both owners and customers.

To emphasize the last point, sustainability has demonstrated economic value while also meeting environmental and social demands. For example, a study published in 2012 from the Harvard Business School, *The Impact of Corporate Sustainability on Organizational Processes and Performance*, defines low sustainability firms as ones that tackle social and environmental issues by adhering to regulations and high sustainability firms as ones that go above and beyond the regulatory requirements. The study emphasizes that in the long term, high sustainability firms outperformed low sustainability firms in stock market and accounting measures. Similarly, in the highway construction arena, the Illinois Tollway has realized significant cost savings and environmental benefits while adopting more sustainable pavement practices, such as greater use of recycled materials, in both new and rehabilitation design.

What's in the Guide?

The guide series focuses on practical sustainability and consists of four individual documents:

- Part I: Sustainability Overview (completed). This document provides a practical description of sustainability along with several supporting arguments on why asphalt mix producers and contractors should incorporate sustainability into their business practices. Part I is available at www.asphaltpavement.org/PDFs/EngineeringPubs/SIP101-Sustainability-Overview.pdf.
- Part II: Sustainability Specifics (completed). This document presents a compendium of specific asphalt pavement sustainability best practices that asphalt mix producers and contractors can implement today. The practices fall into the following areas: corporate/organizational strategy, project delivery, mix design, materials production, construction activities, and pavement design. Part II is available at www.asphaltpavement.org/PDFs/EngineeringPubs/SIP102-Sustainability-Specifics.pdf.

SUSTAINABILITY CONSIDERATIONS AND MOTIVATIONS

Sustainability Considerations	Motivation: Project Requirement	Motivation: Business Opportunity	Motivation: Goodwill
ENERGY AND EMISSIONS **Sustainability Impacts: Neighbors & Stakeholders, Consumption, Climate, Budget, Worker Safety, Maintenance & Operations**			
Aggregate Moisture	●	●	
Plant Management	●	●	●
MATERIAL QUALITY **Sustainability Impacts: Consumption, Climate, Budget, Maintenance & Operations**			
Mix Design		●	
Quality Control		●	
Recycle/Reuse	●	●	
Specialty Mixes	●		
CONSTRUCTION QUALITY **Sustainability Impacts: Workers, Users, Consumption, Climate, Budget, Maintenance & Operations**			
Density	●	●	
Lift Thickness	●		
Longitudinal Joints	●		
Eliminate Segregation	●		
Smoothness	●	●	
Mat Temperature	●	●	
Warm Mix Asphalt	●	●	
Warranty	●		
CONSTRUCTION EQUIPMENT **Sustainability Impacts: Workers, Neighbors & Stakeholders, Pollution, Consumption, Climate, Budget**			
Tier 4 Engines	●	●	
Alternative Fuels	●	●	
Noise Reduction	●		
Automated Grade Control		●	
WORK ZONE HEALTH AND SAFETY **Sustainability Impacts: Workers, Users, Budget**			
Health and Safety Management Plan	●	●	
Job Hazard (Safety) Analysis		●	
Work Zone Intrusion Alert Systems	●	●	
Design for Construction Safety		●	
NEW PAVEMENT DESIGN **Sustainability Impacts: Users, Consumption, Climate, Budget, Maintenance & Operations**			
Perpetual Pavement	●	●	
Specialty Layers	●	●	
PAVEMENT REHABILITATION **Sustainability Impacts: Users, Consumption, Climate, Budget, Maintenance & Operations**			
Use SHRP 2 R23 Guidance	●	●	
Crack, Seat, and Overlay	●	●	
Rubblization	●	●	
Thin Overlays	●	●	

This table highlights a few key sustainability considerations documented in Part II: *Sustainability Specifics. Source: NAPA. Table compiled by APTech.*

- Part III: Procuring and Evaluating Sustainability (expected publication: third quarter 2019). Part III of the series describes how to incorporate sustainability in the procurement of public projects and how to evaluate and assess sustainability efforts using sustainability rating systems. Often, specifications may not allow for the implementation of sustainable practices, but pursuing a sustainability certification on a project can provide justification and leverage for modifying specifications.
- Part IV: How to Develop a Sustainability Program (expected publication: fourth quarter 2019). The final document in the series provides information on developing an effective sustainability program that incorporates the key components, including goals, best practices, implementation, and reporting.

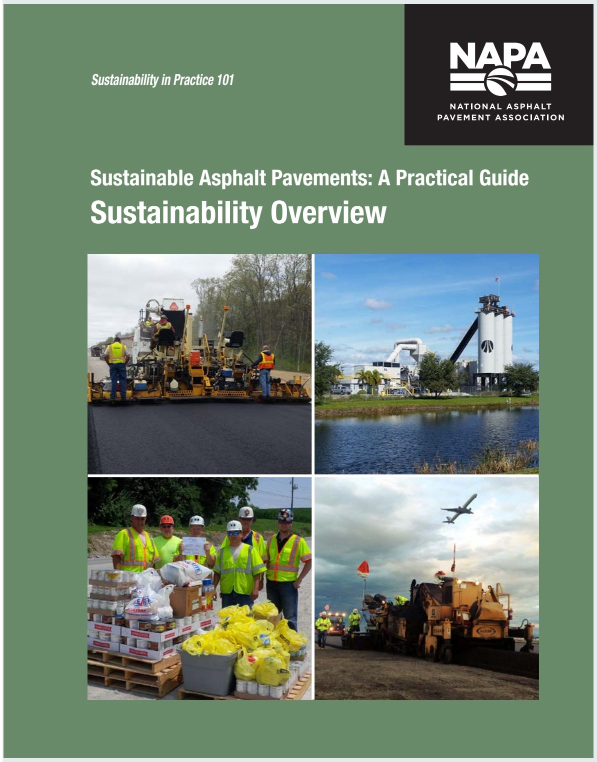
"Identifying and implementing sustainable practices has social, environmental, and economic benefits for asphalt mix producers, road owners, and communities," says Joseph Shacat, director of sustainable pavements, NAPA. "These documents help identify opportunities to incorporate sustainability into day-to-day activities and projects, as well as help to recognize and document sustainable practices already being used."

Webinars to Learn More

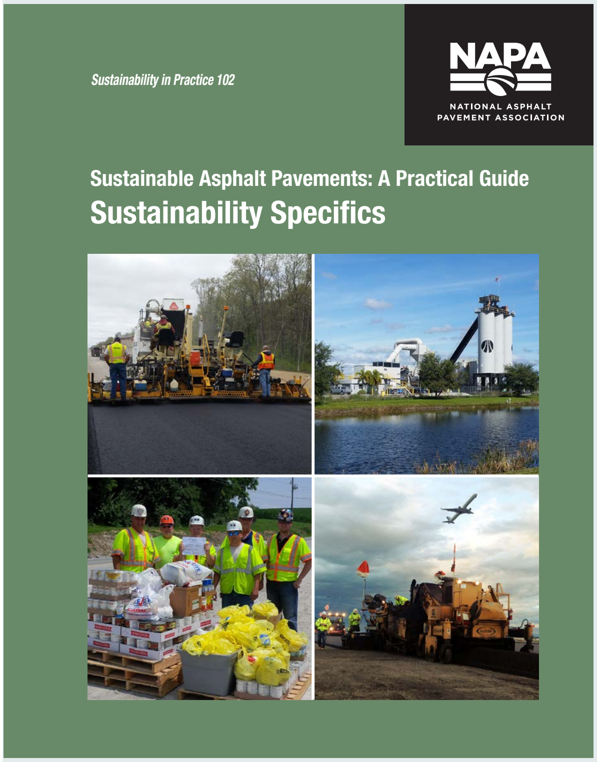
To help promote the document series, NAPA is hosting a webinar series that introduces each publication. The webinars provide asphalt mix producers and contractors with the information they need to practically implement sustainability concepts at various levels within their organizations.

NAPA conducted the first webinar in February 2019 and the second in May 2019. The webinars were well attended, with more than 40 attendees at each event. Future webinars will coincide with the publication of each document.

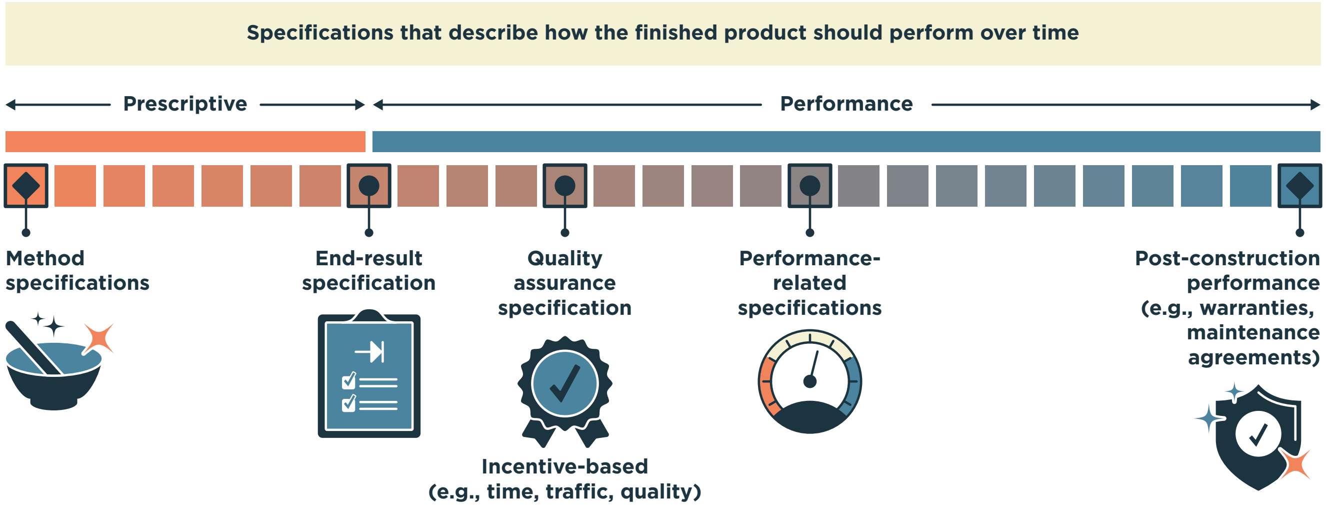
For more information, visit www.asphaltpavement.org.



The first volume of the four-part guide provides a practical description of sustainability along with several supporting arguments on why an organization should incorporate sustainability. *Photo: ©NAPA.*



The second volume of the guide is a catalog of sustainable practices. *Photo: ©NAPA.*



Asphalt specifications have evolved from prescriptive method-based to end-result and performance-related specifications, passing more responsibility for quality to the contractor. *Photo: ©APTech.*

Asphalt Construction Course Gets Infusion of Innovation

Revamped training from the National Highway Institute kicked off in Boise, Idaho in May 2019.

Asphalt paving is one of the most commonly contracted construction services delivered for transportation agencies. Because of that, asphalt paving projects are often a training ground for an agency's new inspectors, exposing them to the project inspection process through observing, running calculations, documenting, and performing acceptance tests normally assigned to entry-level inspectors.

Recognizing that inspectors need to understand best practices for asphalt paving, FHWA and the asphalt paving industry developed the National Highway Institute (NHI) course 131032, *Hot-Mix Asphalt Construction,* in the early 1990s. The course covered the asphalt production, delivery, laydown, and compaction process. Between 1994 and 2013, the course was delivered 220 times.

However, after more than 20 years and numerous changes in construction and inspection practices, course 131032 needed an update. FHWA recognized this need and recently created a new version, course 131139, *Constructing and Inspecting Asphalt Paving Projects*.

Time for Upgrades

At the time of its development, the original course was state of the practice and introduced innovative technology of the time. The course presented 1990s-era construction specifications, including the move away from prescriptive, method-based specifications to accepting asphalt mix based on material property consistency and test result outcomes. However, asphalt mix specifications have continued to evolve.

Asphalt mix specifications now often include incentive clauses for either reduced test result variability or exceeding required properties that lead to better performing pavements. In some cases, specifications require the contractor to provide a warranty for the pavement with reduced agency inspection and reduced governance for mixture construction properties. This greatly shifted the responsibility for quality to the contractor and required inspectors to document project activities and test results rather than to direct contractor actions.

Because of these shifts in specifications and the continued improvements in construction technologies, material testing, and monitoring procedures, the course became dated and inconsistent with current construction techniques.

New Technology Injected

In 2018, FHWA partnered with NHI to update the asphalt course content and to focus the new content on the role that inspectors play in achieving high-quality asphalt pavement construction. FHWA and NHI introduced new technology uses, such as thermal imaging for segregation identification and intelligent compaction to achieve optimum density, into the course.

In addition, the course now emphasizes how the communication between agency inspectors, the project manager, and the contractor's personnel contributes to achieving high-quality construction practices and to resolving potential performance concerns before they become problems. With project quality being a shared responsibility between the contractor and the agency inspection team, communications should be proactive and open.

The updated course provides agency and contractor checklists to clarify how each team member contributes to project quality and to inform less-experienced personnel about what actions to anticipate during each project phase. The checklists include tasks for inspectors to review project plans and contract documents, and tasks for the contractor to submit sequencing plans to meet geometrical layout requirements and to keep the paving production balanced. When agency and contractor personnel understand their responsibilities for project quality and how the construction processes impact overall project quality and pavement life, they can minimize project disputes.

New Technologies Added

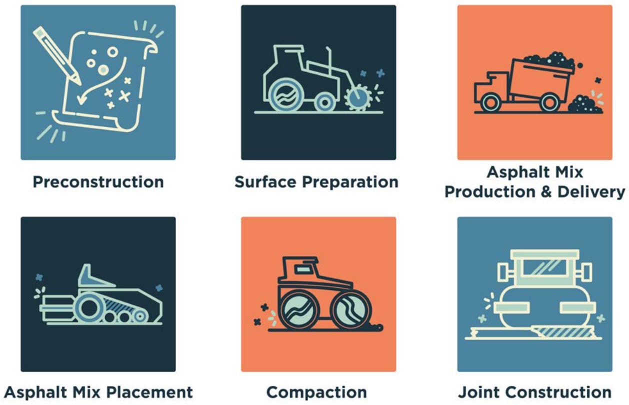
***Thermal imaging* is the use of infrared cameras mounted above the paver to scan the mixture after laydown and to identify where temperature differences across the mat are significant.**

An infrared camera, mounted above the paver screed, detects significant temperature differentials in the mat. *Photo: ©Tim Murphy.*

***Intelligent compaction (IC)* uses global positioning equipment mounted on rollers to provide real-time feedback to the roller operator tracking the number of passes across the pavement. IC also incorporates force measurement devices on the roller drums to measure the load resistance the pavement is providing during compaction. The operator can correlate compaction to the strength increase in the mixture as the roller makes more passes.**

Contractors and State agencies with acceptance decisions tied to their metrics have adopted both thermal imaging and IC as quality control techniques.

Intelligent compaction equipment provides real-time feedback to the roller operator measuring the number of roller passes on each section of mat. *Source: NHI.*



The new course is taught in six modules: preconstruction, surface preparation, asphalt mix production and delivery, asphalt mix placement, compaction, and joint construction. *Photo: ©APTech.*

The updated course has six modules:

- Preconstruction – pre-paving meeting agenda, project layout, specification review, and balanced paving plan.
- Surface preparation – pavement distress identification, tack placement, leveling, milling.
- Asphalt mix production and delivery – production, trucking, loading and unloading procedures, thermal imaging.
- Asphalt mix placement – paver components, grade control, forces acting on the screed.
- Compaction – roller types, roller pattern, time available for compaction, environmental effects, intelligent compaction.
- Joint construction – joint types, joint compaction, staggered layout, improving joint performance, safety edge.

Course participants learn asphalt construction practices and examine the effect of deviations from best practices on pavement performance. The course describes causes and remedies for asphalt mixture and thermal segregation throughout the lessons and provides current, real-world examples of ways to recognize construction defects. Technical content for the compaction and joint construction lesson draws on a recent FHWA initiative to increase asphalt density requirements to achieve longer lasting pavements.

Piloting the Updated Material

The updated course is an interactive, instructor-led classroom session with several workshop opportunities for participants to practice their new skills. After the new course content was refined and developed, the Idaho Transportation Department (ITD) volunteered to sponsor the pilot offering. John Bilderback, construction and materials engineer with ITD, invited inspectors and engineers of diverse experience levels from all the State's districts to the pilot.

"After attending the new NHI *Constructing and Inspecting Asphalt Paving Projects* course, ITD inspectors and engineers gained a stronger background to design and inspect asphalt resurfacing projects," says Bilderback. "ITD plans to introduce new asphalt construction specifications and the course provided a timely introduction to new content for our less-experienced engineers and inspectors."

As part of the pilot presentation, NHI solicited feedback from participants after each module. Feedback included comments such as:

- "(The course) has given me a larger view of my job."
- "This course will definitely help me in future paving projects."
- "Good information for me to use out in the field."

The participants concluded that the course's technical content, facilitated discussion, and workshops expanded their knowledge and understanding, which are required by today's agency inspectors.

Following the pilot course, NHI is in the process of finalizing the training materials and advertising the course. Agencies can schedule a session of the new course through the NHI website.

For more information or to host a session, visit www.nhi.fhwa.dot.gov/course-search?tab=0&cat=130000&sf=0&course_no=131139.

The MATC sits on a staging lot for a resurfacing project near a highway in New Mexico. *Source: FHWA.*

Taking Pavement Technologies into the Field

Deploying innovative practices and methods is a shared mission of FHWA's two mobile technology centers.

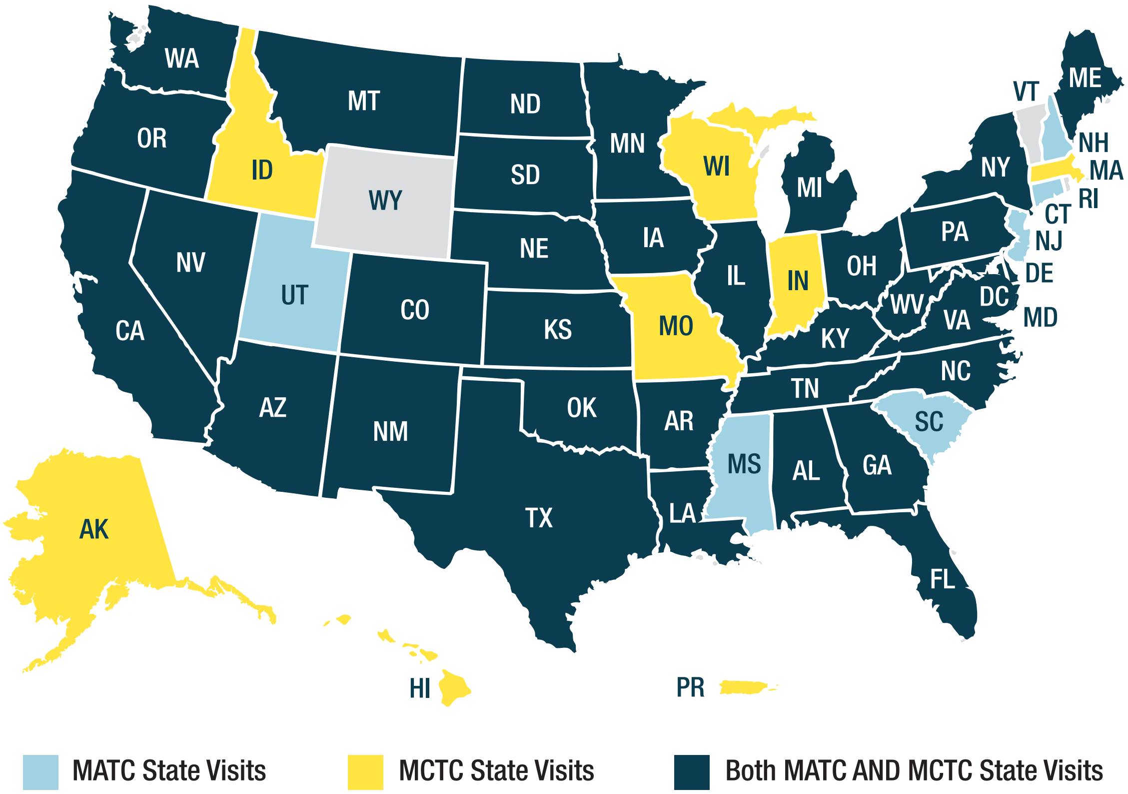
Within FHWA, two program areas provide mobile services to assist State departments of transportation in implementing new technologies capable of improving the performance of highway pavement materials: the Mobile Asphalt Technology Center (MATC) and the Mobile Concrete Technology Center (MCTC). FHWA, working in partnership with pavement industries and highway agencies, has engaged the MATC and the MCTC at the national level to showcase materials and construction best practices, champion emerging technologies, and expose stakeholders to more involved and evolving test methods. Both mobile technology centers have also worked to provide shadow evaluations of new specifications and test methods, a process in which agencies compare proposed procedures to existing practices.

FHWA program leaders recently rebranded the MATC and MCTC from their former designations as the Mobile Asphalt Testing Trailer and the Mobile Concrete Trailer to better reflect the value and impact of the centers for stakeholders. The rebrand captures the broader effort to equip agencies and contractors with the knowledge needed to deploy new testing methods, protocols, and technologies in more aspects of a pavement's life.

A Record of Success

Both technology centers have a long track record of providing valuable support to State DOTs and industry partners. Since 2007, 41 States and the District of Columbia have had a visit from the MATC. Forty-one States, plus the District of Columbia and Puerto Rico, have hosted the MCTC between 2007 and 2017.

The MATC has plans to promote flexible pavement technology, with a specific focus on the asphalt materials technologies that influence the construction phase. A major effort in recent years was evaluating how to better predict pavement performance based on new tests.



States visited by the mobile technology centers since 2007. *Source: FHWA.*

The MATC spent several years deploying and evaluating the Asphalt Mixture Performance Tester (AMPT) because the American Association of State Highway and Transportation Officials is including it as an option for developing performance-related specifications.

In 2018, the DOTs in West Virginia and New York State hosted shadow evaluations of projects in conjunction with a 3-day workshop on performance-related specifications. In the workshops, the highway professionals took an indepth look at how they can characterize the as-built material using the new and traditional test results.

The focus for the MATC will broaden to include additional pavement technologies and to share practices that support the pavement quality and performance continuum, not only for asphalt materials but also for pavement construction. These practices advocate long-life pavement designs achieved through durable asphalt mixtures and high-quality construction.

For example, the MATC is pursuing deployment of promising technologies capable of measuring pavement materials' uniformity continuously and in real time. These technologies can aid in assuring construction quality. Examples include the paver-mounted thermal profiler, which measures thermal segregation behind the paver, and the ground penetrating radar dielectric profiling system, which measures dielectric values that can be correlated to density of the asphalt mixture after final compaction. The MATC will also assist agencies and industry by demonstrating various index-based cracking test procedures that support Performance-Engineered Mixture efforts.

For concrete technology, the MCTC has focused on promoting proven concrete paving practices and demonstrating available technology that is underutilized across the industry. Recently, much of the prevailing initiative has been validating inputs for *AASHTOWare® Pavement ME Design*.

The MCTC is set up on a concrete production facility. A concrete batch tower and mixing plant are visible behind the trailer. *Source: FHWA.*

The MCTC's redirected focus will be to demonstrate new technologies (such as the Super Air Meter, the Box Test, V-Kelly Test, and concrete surface resistivity testing) side by side with more traditional concrete practices using project-specific materials on active construction projects. The MCTC will continue to support the Performance-Engineered Mixture initiative and highlight good concrete practices, such as the use of the maturity meter to monitor strength development.

Continuing the Journey

Moving forward, the technology centers will continue to assist agencies in evaluating new equipment and test methods, and will provide more emphasis on addressing the agencies' specific needs. This outreach provides agencies with the chance to "kick the tires and look under the hood" before they adopt a new test method or specification. Both the MATC and MCTC are targeting specification shadow projects in addition to five or six State-hosted site visits per year and showcasing technologies in conjunction with regional industry conferences. Such events have been well-received by representatives from the paving and consulting industries, State agencies, and academia.

"This was a great experience for our company," says Craig Hughes, vice president for operations, Cedar Valley Corp., LLC, and participant in a shadow visit in Iowa. "Our concrete paving crews that actually *build* the pavement got to see how important quality is on a national level. That is a strong message for the folks building the work."

"Because MATC staff collaborate with asphalt professionals from across the country and are involved in testing diverse materials, they are able to validate innovative strategies being implemented in Florida's asphalt paving program," says Howie Moseley, State bituminous materials engineer, Florida Department of Transportation (FDOT). Moseley says he appreciates the broad perspective of the MATC staff in reviewing FDOT material testing results.

In addition, because of the significant investment associated with new technologies, the mobile centers have adopted an equipment loan program. The program enables State DOTs and contractors to gain hands-on experience with new equipment and technologies. By working with the mobile technology centers, State DOTs are more likely to consider adopting practices that advance the pavement performance continuum, which may include elements of Performance-Engineered Mixture, performance-engineered pavements, and even performance-related specifications. The mobile technology centers play a key role in ensuring State DOTs and contractors are more equipped to evaluate and implement new technologies with a reasonable expectation of success.

For more information on the MATC, contact Leslie McCarthy, Ph.D., PE, at leslie.mccarthy@dot.gov or visit www.fhwa.dot.gov/pavement/asphalt/trailer. For more information on the MCTC, contact Michael Praul, PE, at michael.praul@dot.gov or visit www.fhwa.dot.gov/pavement/concrete/trailer.

Appendix

Related Pavement Technology Development and Deployment Activities Supporting the AID-PT Program

The Center for Accelerating Innovation (CAI) leads five programs to support the accelerated deployment of transformative technologies into practice.

Every Day Counts Innovation Deployment Program

The Every Day Counts (EDC) Program (FAST Act §1444) is a State-based model that identifies and rapidly deploys proven, yet underutilized innovations to shorten project delivery, enhance roadway safety, reduce traffic congestion, and improve environmental sustainability. Proven innovations promoted through EDC facilitate greater efficiency at the State and local levels, saving time, money, and resources that can be used to deliver more projects.

The EDC program supported four pavement-related innovations during the first four rounds of the program from 2011 through 2018.

Intelligent Compaction	www.fhwa.dot.gov/innovation/everydaycounts/edc-2/compaction.cfm
Pavement Preservation (When, Where, and How)	www.fhwa.dot.gov/innovation/everydaycounts/edc_4/pavement.cfm
Safety Edge^{SM}	www.fhwa.dot.gov/innovation/everydaycounts/edc-1/safetyedge.cfm
Warm Mix Asphalt	www.fhwa.dot.gov/innovation/everydaycounts/edc-1/wma.cfm

FHWA selects EDC innovations through a robust process of stakeholder engagement. FHWA will conduct outreach to seek innovations for the next round of the program in fall 2019. The AID-PT program directly supports pavement-related innovations advanced under EDC.

State Transportation Innovation Councils

Key components to the success of innovation deployment programs such as EDC are the State-based approach and the State Transportation Innovation Council (STIC) concept. A STIC brings together public and private transportation stakeholders to evaluate innovations and spearhead their deployment in each State. The STIC Incentive program provides resources to help STICs foster a culture of innovation and make innovations standard practice in their States. Through the program, funding up to $100,000 per State per Federal fiscal year is made available to support or offset the costs of standardizing innovative practices in a State transportation agency or other public sector STIC stakeholder.

The STIC Incentive program provides resources to each STIC to advance innovation. Projects are selected at the individual STIC level and advanced through the Federal-aid Division Office and Federal Lands Highway Division for approval. The AID-PT program directly supports pavement-related incentive projects advanced under this program. The CAI maintains a list of all STIC Incentive projects.

Summary of Pavement-Related STIC Incentive Activities (June 2018 to May 2019)

State	Project
Oklahoma	Demonstrate the use of and develop special provisions/plan notes for rubberized asphalt concrete using recycled finely ground tire rubber.
Michigan	Develop a local agency pavement warranty training program.

Accelerated Innovation Deployment Grant Program

The Accelerated Innovation Deployment AID Demonstration program provides funding as an incentive to accelerate the use of innovation in highway transportation projects. FHWA expects approximately $10 million to be made available for AID Demonstration grants in each of fiscal years 2016 through 2020 from amounts authorized within the Technology and Innovation Deployment Program under the Fixing America's Surface Transportation (FAST) Act.

The AID Demonstration grants program operates under a rolling solicitation. Eligible agencies can submit applications through the Notice of Funding Opportunity published on September 1, 2016. The AID-PT program directly supports pavement-related AID Demonstration grants. The CAI maintains a list of all AID Demonstration grants.

Summary of Pavement-Related AID Demonstration Grant Activities (June 2018 to May 2019)

State	Project
Iowa	Validated intelligent compaction (VIC), e-Construction compaction reporting, and Automated Plate Load Testing (APLT)

Accelerating Market Readiness

The Accelerating Market Readiness (AMR) program is intended to spur the advancement of emerging and transformative innovations in the transportation industry: those that significantly advance conventional practice, address knowledge and technology gaps, significantly advance the state of the art, or constitute a sea change in the development and delivery of transportation projects and programs.

The AMR program is structured with an internal and an external component. The internal component sources topics from FHWA program offices and the Turner-Fairbank Highway Research Center. The CAI manages the internal component with the support of the FHWA Chief Innovation Officer and associate administrators for the review and selection of projects. The external component sources topics through a broad agency announcement (BAA) with the support of a technical evaluation panel for the review and selection of projects. FHWA issued the BAA in February 2019 and anticipates announcing awards in fall 2019.

Increased Federal-Share for Project-Level Innovation

Increased Federal-share for Project-level Innovation, a provision of Section 120(c)(3) of title 23, United States Code, provides the option of an increased Federal share for projects using innovative project delivery methods. Established by the Moving Ahead for Progress in the 21st Century Act (MAP-21) and amended by the FAST Act, this provision builds on the EDC initiative. The increased Federal share for innovative techniques incentivizes use of innovation to help deliver projects more efficiently and to rapidly deploy proven solutions that make a difference. This program is approved at the Federal-aid division office level.

"Profound changes are happening all around us and at an ever-increasing pace! Driving these changes are population increases and shifts, consumer trends, and the increased use of technology in almost every facet of life. These and other factors are transforming the roles of highways *and* the people responsible for their design, construction, and rehabilitation. By 2040, the American Concrete Pavement Association anticipates most highways will no longer serve solely the functions of transportation, and instead will increasingly play a role in communication among systems, vehicles, and people; multimodal transportation; energy storage and power generation; and autonomous and connected vehicle technologies. The Accelerated Implementation and Deployment of Pavement Technologies (AID-PT) program is the ideal mechanism to keep pace with these and other emerging trends and technologies.

The benefits of AID-PT investments can be seen in technology advancements such as performance-engineered concrete mixtures, a program striving to ensure that agencies can specify—and contractors can deliver—durable pavements every time. Practical technology transfer in the form of concrete pavement overlay implementation, FHWA's Mobile Concrete Technology Center and equipment/instrument loan programs, technical and tech transfer documents, and lifecycle cost analysis guidance are excellent examples of the way AID-PT benefits stakeholders by yielding higher quality and longer lasting pavements for roadways and highways. AID-PT will enable FHWA and all stakeholders to continue along an exciting, efficient, and productive path of capturing all the changes that lie ahead for the Nation's highways and roadways."

— Gerald F. Voigt, P.E., President & CEO
American Concrete Pavement Association

"We live in an age where drones fly overhead and vehicles are learning to maneuver through traffic by themselves. The way we move people and goods is changing rapidly, and so are the needs of our infrastructure. As advances in technology continue to expand the boundaries of the world we know and work in, it's imperative that we continue to implement innovations that ensure the health, drivability, and sustainability of our Nation's highways.

The AID-PT program allows the Federal Highway Administration to get the latest research products, as well as tried-and-true knowledge, in front of State and local agencies, which can then put these resources into action to increase pavement performance. In November 2018, AID-PT provided resources to encourage engineers from not only the United States, but also from around the world, to reconsider stone-matrix asphalt, an underutilized technology that provides a high-quality riding surface with a 50-year track record of performance.

Support from this program has allowed the asphalt industry to quantify the use of sustainable materials and technologies like reclaimed asphalt pavement and warm mix asphalt. Information points at the partnership between industry and agencies to responsibly rebuild our country's infrastructure.

This program also helped educate consulting engineers on how to design heavy-duty pavements for airports, highways, and port facilities through a webinar series and new publication. Through AID-PT, FHWA has encouraged the use of long-life pavements including furthering methodologies for design and construction. Through all of these efforts, FHWA has promoted its goal of implementing sustainable pavements and AID-PT has fostered sustainability education focused on the industry.

This program makes things happen. It is the boots on the ground that provides industry and agencies actionable takeaways to make a difference—not just in building the infrastructure of today, but in building infrastructure that will last for generations."

— Audrey Copeland, President & CEO
National Asphalt Pavement Association

Image: ©Valentin Valkov/Shutterstock.

U.S. Department of Transportation
Federal Highway Administration

Office of Preconstruction, Construction, and Pavements

Brian Fouch
Director
202–366–5915
brian.fouch@dot.gov

Pavement Design and Performance Team

LaToya Johnson
Team Leader
202–366–0479
latoya.johnson@dot.gov

Pavement Materials Team

Gina Ahlstrom
Team Leader
202–366–4612
gina.ahlstrom@dot.gov

Contacts for More Information

Federal Highway Administration
Office of Preconstruction,
Construction, and Pavements
www.fhwa.dot.gov/pavement

FHWA-HIF-18-058

Image: ©Rachel Duchesne/Shutterstock.