ACCELERATED IMPLEMENTATION AND DEPLOYMENT OF PAVEMENT TECHNOLOGIES

ANNUAL REPORT

U.S. Department of Transportation
Federal Highway Administration

TURNING BEST PRACTICES INTO EVERYDAY PRACTICES

Today's highway users expect to travel on roads that are safe and smooth and cause the least possible delay. And they expect a high-quality traveling experience at the lowest possible cost.

One way the Federal Highway Administration (FHWA) is meeting the needs of the traveling public is through the Accelerated Implementation and Deployment of Pavement Technologies (AID-PT) program. At its core, the program advances the latest and best practices and technologies for constructing and maintaining high-quality, long-lasting pavements.

Technology transfer and outreach are central to the program, which delivers critical insights, experience, and practices to the pavement community through meaningful and cost-effective strategies, including:

- Direct technical assistance
- Site reviews and project-specific consultations
- Field studies and demonstrations
- Scanning tours
- Workshops and webinars
- Development and distribution of resource materials

By partnering with highway agencies, industry, academia, the consulting community, and others, we're enabling stakeholders to manage the Nation's pavement assets more effectively, improve the condition of the roadway network, and make effective use of recycled materials and industrial byproducts in pavements.

I'm honored to share these highlights from our ongoing activities, and I look forward to further successes as together we continue to develop and deploy innovation on the Nation's roadways.

Sincerely,

Thomas D. Everett

Thomas D. Everett
FHWA Associate Administrator for Infrastructure

About the Program

Congress established the AID-PT program in 2012 under the Moving Ahead for Progress in the 21st Century Act (MAP-21). 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, with funding available through fiscal year 2020. Through strategic partnerships with highway agencies and others across the paving 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, increase efficiency, and reduce delay.

Source: American Concrete Pavement Association.

AID-PT PROGRAM BY THE NUMBERS

11,400+ pavement professionals trained

100+ publications and articles distributed

25 highway agencies provided with technical assistance

This annual report represents FHWA's approach to demonstrating how the agency is achieving the six overarching goals Congress set for the program (see page 3).

The FAST Act calls for "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 minimized impacts of congestion.

Due to the broad scope of the Federal-aid program and 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 due to 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.

Specifically, FHWA is engaged in a variety of efforts to improve paving materials and deliver guidance to help highway agencies design and construct both asphalt and concrete pavements more effectively. Examples of ongoing initiatives include the following:

- Increasing the use of reclaimed asphalt pavement, recycled asphalt shingles, and ground tire rubber in new pavements. Recycling these materials saves an estimated $2.1 billion annually. Plus, these efforts support an overarching focus on sustainability and reduce the impact of pavements on the environment.
- Improving construction processes for asphalt pavements, such as identifying more effective compaction practices and constructing more robust longitudinal joints, both of which lead to longer lasting pavements at little to no additional cost.
- Advancing a comprehensive program for concrete pavements featuring innovative field testing procedures to enhance highway agencies' quality assurance programs. At the same time, FHWA is supporting development of a performance-based specification with a focus on long-term durability.
- Training highway agencies on the technological advancements associated with the *Mechanistic-Empirical Pavement Design Guide*, leading to tangible cost savings.

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.

Source: National Asphalt Pavement Association.

"It has been very encouraging to see the AID-PT program…rapidly advance new pavement technologies that are critical to keeping our transportation system in as good a condition as possible with available funding."

— Jim Duit, Duit Construction Company

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							
	Quality Assurance Workshops	Sustainability	Pavement Mechanistic-Empirical Design	Longitudinal Joint Practices	Ground Tire Rubber Use	RAP-RAS Use	Performance Engineered Mixes	Enhanced Density
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.	●	●	●	●	●	●	●	●
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Taking Quality Assurance on the Road

FHWA is delivering innovative techniques and training to highway agencies and their contractors.

A road is only as good as the quality of the materials used to build it. That's why FHWA has a comprehensive program to assist highway agencies in enhancing their quality assurance (QA) programs. Through sampling, testing, and inspections, QA procedures ensure that the materials and workmanship in Federal-aid highway projects conform to specifications.

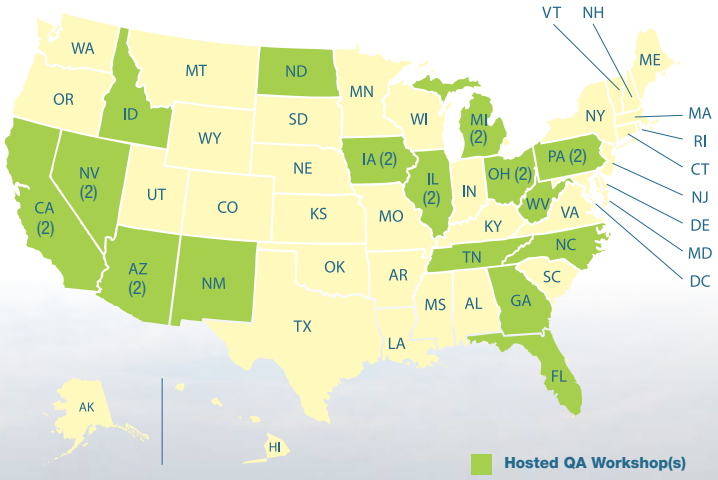
A key feature of FHWA's program is a series of workshops focused on QA practices for concrete pavements. The workshops outline the benefits of effective QA programs and highlight best practices that highway agencies and contractors can use to improve the durability and longevity of their pavements.

The 2-day events draw about 30 participants, with about half representing highway agencies and the remainder from contractors, suppliers, and consultants. Eight modules cover topics including materials, design, and construction considerations; testing and acceptance of material properties; and putting QA concepts into practice. To date, FHWA has conducted 24 workshops in 16 States, bringing innovative QA practices to bear on projects across the country.

BENEFITS OF QA WORKSHOPS

- Demonstrate effective practices and QA procedures for agencies and contractors.
- Document QA results on projects and identify areas for improving specifications.
- Encourage dialogue between highway agency personnel and industry partners.
- Demonstrate and promote the adoption of new and innovative testing technologies.

State Hosts of Quality Assurance Workshops



To support FHWA's quality assurance workshops, the Mobile Concrete Trailer delivers state-of-the-art testing equipment to project sites for hands-on demonstrations.

From the Field to the Workshop

FHWA tailors each workshop to an agency's specific needs, using the agency's materials, specifications, and project-specific test data to generate customized results. Because the workshops focus on the practical aspects of the QA process, one module uses data from a real-world project. FHWA technicians collect data from an active paving site 4 to 6 months earlier and summarize the results in a report shared with the agency during the workshop.

FHWA's Mobile Concrete Trailer assists with the analysis. The trailer is outfitted with state-of-the-practice equipment, including tests for compressive and flexural strength, elastic modulus and Poisson's ratio, temperature, slump, air content, and unit weight measurements. It also can conduct nondestructive and in situ tests, including dowel bar alignment, pull-out strength, and impact echo testing. In addition, the trailer performs specialized durability-related testing, such as air void analysis and rapid chloride permeability tests.

"It was great to work with the Mobile Concrete Trailer technicians these last 2 weeks in South Dakota. The data they collected from three concrete paving projects will be valuable as the we evaluate how the new tests could be implemented."

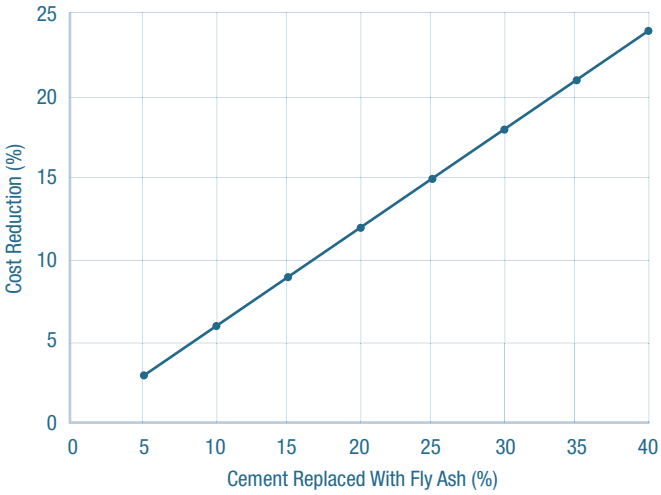
— Darin Hodges, Concrete Engineer, South Dakota DOT

Trends in Concrete Strength

Collecting QA data on concrete pavements from across the country provides a unique opportunity for FHWA to identify national trends. For example, technicians reviewed data on the compressive strength of concrete pavements from 17 projects in 13 States and discovered that 28-day strength requirements are being met in 7 days and exceeded by an average of 60 percent.

These findings reveal that agencies are consistently using concrete mixtures with high cement contents. The reasons for this may include specifications, mix designs, and production. And, more often than not, highway agencies want the higher strength early in the project so the road can open to traffic sooner. However, the findings clearly indicate that contractors are achieving the design strength in 7 days, suggesting that high cement contents may not be warranted. Further, the disadvantages of using higher cement contents—including increased shrinkage, costs, and environmental impacts—raise concerns. As a result, many agencies now are taking another look at their mix designs and specifications.

Potential Cost Savings From Replacing Portland Cement With Fly Ash



Note: Savings are per ton of cementitious materials used and assume 1:1 replacement. Unit cost of cement is assumed to be $100 per ton, while fly ash is $40 per ton.

Replacing cement with fly ash, a byproduct of coal-fired power plants, helps agencies save money and make their pavements more sustainable. Producing a ton of cement releases about a ton of carbon dioxide, so using less cement in concrete mixtures not only reduces costs but also lowers greenhouse gas emissions.

Ready to Deploy

Could your QA methods or specifications benefit from refinement? FHWA's Mobile Concrete Trailer is ready to visit your next project.

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

A technician from the Mobile Concrete Trailer is preparing a fresh concrete sample for air void testing at a project site. *Source: APTech.*

Towards Sustainable Pavements

FHWA is supporting highway agencies as they work to meet environmental, social, and economic needs with their pavement structures.

How do paving materials affect the sustainability of a roadway? How can highway agencies adopt more sustainable designs and construction practices? What does sustainability mean within the highway and pavement environment? These are some of the questions that FHWA's Sustainable Pavements Program is on its way to answering.

The program defines a "sustainable" pavement as one that:

1. Achieves the engineering goals for which it was constructed.
2. Preserves and, ideally, restores surrounding ecosystems.
3. Uses financial, human, and environmental resources economically.
4. Meets basic human needs, such as health, safety, equity, employment, comfort, and happiness.

Further, sustainable pavements are context sensitive. That means they're designed to fit the location and climate, use locally available materials when possible, and meet the agency's design and performance goals.

With the help of a technical working group, FHWA's Sustainable Pavements Program is putting knowledge into action. Here's a look at some of the program's latest accomplishments.

Rallying the Troops

At the heart of the program is the Sustainable Pavements Technical Working Group. With 20 members representing Federal, State, and local transportation agencies, as well as industry and academia partners, and more than 280 "friends," the working group provides overall guidance for the program and helps raise awareness of sustainability issues among pavement professionals.

Warm-mix asphalt, which was used when paving this stretch of scenic roadway in Yellowstone National Park, is an innovation that improves the sustainability of pavements by requiring about 20 percent less energy to produce.

The group meets twice a year to share information through technical presentations, reviews of project documents, breakout sessions, and roundtable discussions. Recent meetings have covered topics including life-cycle assessments, product category rules, and pavement-vehicle interaction.

According to Leif Wathne, executive vice president of the American Concrete Pavement Association and a member of the working group, "the Sustainable Pavements Program has been exceedingly fruitful in bringing together stakeholders and engaging in meaningful dialogue on all issues related to pavement sustainability."

Defining the Playing Field

To provide best practices and hands-on guidance, FHWA has produced a variety of reference materials and training opportunities:

- A series of 25 technical articles.
- A framework document for assessing the life cycle of pavement structures.
- A compilation of technical resources.
- Five technical briefs on sustainability topics.
- A series of webinars focusing on all phases of the pavement life cycle.

The program's hallmark deliverable is *Towards Sustainable Pavement Systems: A Reference Document* (FHWA-HIF-15-002). Published in 2015, the document provides an overview of key concepts and advice on how to make paving practices more sustainable, such as:

- Consider the entire life cycle, from mining the materials and trucking them to the site through the design, construction, use phases, and end of the pavement's life.
- Recognize that there is no "one size fits all" approach to pavement sustainability.
- Embrace tradeoffs between economic, environmental, and societal factors.
- Aspire to improve sustainability from project to project over the long term.

Jim Pappas, assistant director of pavement management at the Delaware Department of Transportation, says his agency has begun integrating sustainability concepts into its operations. "Highway agencies can use the *Reference Document* as a guide to holistically approach the life cycle of their infrastructure and achieve the desired environmental, engineering, and economic benefits."

Together, these references constitute a growing library of resources available on FHWA's Web site to assist pavement practitioners in adopting more sustainable practices.

Two-lift concrete paving, as shown here, uses a higher percentage of recycled or marginal aggregate in a thicker bottom layer, while reserving more durable material for the thinner surface layer, thereby improving the sustainability of the pavement without compromising performance. Source: APTech.

The Proof Is in the Pudding

Adopting more sustainable practices yields a variety of benefits, not just for the environment but also for agencies' bottom lines. For example, in the reconstruction of the Jane Addams Memorial Tollway (I–90), the Illinois Tollway documented the reuse of nearly 1.2 million tons of recycled materials, including aggregate and both asphalt and concrete pavements, from the project site. Recycling and reusing materials reduces the demand for virgin materials and the related transport and energy costs.

Reusing materials also yields significant cost savings. At the national level, FHWA estimates that highway agencies saved more than $2.8 billion during the 2014 construction season by incorporating reclaimed asphalt pavement and recycled asphalt shingles into paving products. Further, the American Road & Transportation Builders Association estimates that the use of fly ash—a byproduct of coal-burning power plants—in concrete paving mixtures saved $2.3 billion over a 5-year period.

These savings are just the tip of the iceberg. In October 2015 FHWA authorized continuing the Sustainable Pavements Program for another 5 years. Plans include additional guidance on best practices to help highway agencies incorporate the latest sustainability considerations into their daily activities.

Heather Dylla, director of sustainability for the National Asphalt Pavement Association (NAPA) and a member of the working group, says the program "will continue to provide a platform where industry, government, and other stakeholders can meet with a shared purpose to discuss and develop real-world solutions for a more sustainable future."

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

The Next Generation of Pavement Design Is Here Today

Highway agencies across the country are embracing state-of-the-art software that promises improved pavements for lower costs.

INDOT was the first agency to use AASHTO's Pavement ME Design procedure, employing it here in the design of the interchange of I–465 and I–70 near Indianapolis. *Source: Tommy Nantung, INDOT.*

In the world of pavements, a revolution is underway. For decades, pavements were designed according to a unique combination of empirical relationships to fit a given project. Today, the ability to account for these relationships and their potential to yield durable, long-lasting pavements has improved dramatically thanks to one groundbreaking publication: the *Mechanistic-Empirical Pavement Design Guide* (MEPDG).

Created by the American Association of State Highway and Transportation Officials (AASHTO), the guide and its associated software, AASHTOWare Pavement ME Design, represent a quantum leap forward. The software enables engineers to incorporate a variety of inputs—from materials to climate data to traffic loading—and predict precisely how the resulting pavement will perform over time.

Although it represents a dramatic departure from its predecessor, the MEPDG procedure and the software's analytical capabilities already have won over many in the pavement design community. To assist highway agencies and their industry partners in making the transition, FHWA provides training and workshops to help them understand and put the new approach into practice.

Indiana Jumps Onboard

One of the earliest to receive the training was the Indiana Department of Transportation (INDOT). Even while the procedure was under development, INDOT's engineers realized that the MEPDG would provide greater analytical capabilities, yielding significant advantages. Most notably, it enables them to evaluate a pavement design as a system rather than a collection of individual components. Further, it facilitates a thorough evaluation of tradeoffs in the costs and benefits of using different materials, layer thicknesses, and design features.

"The mechanistic-empirical design approach has been very effective for us because we now know how the pavement is going to perform," says Tommy Nantung, research manager for pavement, materials, and construction at INDOT. "We can target specific distresses and design so they are kept to a minimum percentage."

Benefits and Lessons Learned

As an early adopter, INDOT identified many benefits associated with implementing the MEPDG. The most significant is the cost savings. At FHWA's request, INDOT developed dual designs using both the traditional approach, based on AASHTO's 1993 *Guide for Design of Pavement Structures*, and the MEPDG procedure. What they found was that the MEPDG procedure reduced pavement thickness between 0.5 and 1.5 inches, resulting in lower construction costs.

Even more important is the MEPDG's ability to predict how a pavement will perform and avoid premature distresses. For example, in looking at failure modes for its designs, INDOT engineers can predict maintenance costs and work to minimize them by addressing the predicted distresses.

Plus, Nantung says, INDOT's design engineers now have a greater understanding of how pavements perform, so they can better calculate the costs of ownership and make data-driven decisions.

Paving the Way Forward

To provide a forum for sharing information, FHWA hosted five regional peer exchanges in 2014 and 2015. Those meetings drew participants representing 32 State highway agencies, 2 Canadian provincial highway agencies, 6 universities, the concrete and asphalt pavement industries, and consultants.

The States shared their experiences on a wide range of topics, including key design inputs, recommended threshold and hierarchical levels, ongoing calibration efforts, and implementation challenges. Each meeting ended with a discussion of key takeaways and lessons learned, which are summarized in the *FHWA AASHTO MEPDG Regional Peer Exchange Meetings: Final Technical Report* (FHWA-HIF-15-021). Among the takeaways were that models need to be recalibrated as additional data are obtained, and training is necessary for successful implementation.

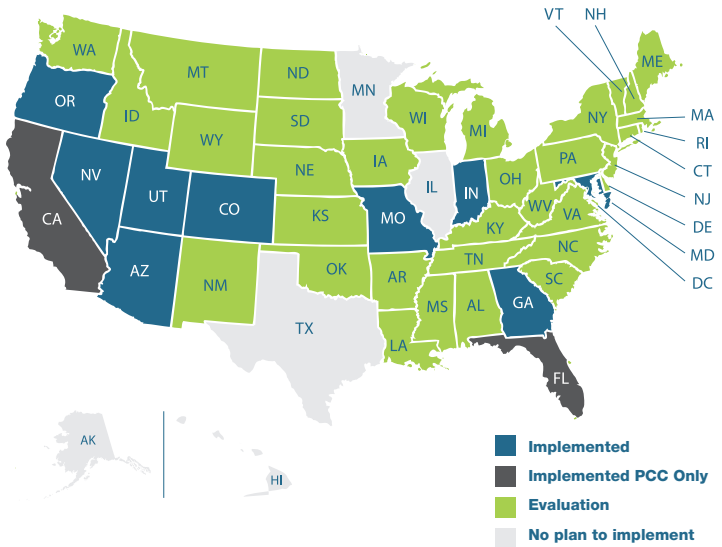
"The peer exchanges were very open, and people freely shared their successes and failures," says Judith Corley-Lay, State pavement engineer at the North Carolina Department of Transportation. "The feedback from the meetings helped us and will undoubtedly help other agencies as they move through the implementation process."

As a follow-up to the successful peer exchanges, FHWA is assembling a national users group that will meet annually beginning in late 2016. Workshops on hot-button issues or software applications may be included in the annual meeting, as well.

"These types of outreach activities are instrumental in facilitating a more rapid adoption of the MEPDG," says Christopher Wagner, P.E., manager of FHWA's Pavement and Materials Technical Service Team, "as agencies take this giant step forward in evolving their design practices and producing more cost-effective pavements for the traveling public."

For more information, contact Gina Ahlstrom at 202–366–4612 or gina.ahlstrom@dot.gov.

Summary of MEPDG Implementation Status (2016)



Source: FHWA.

Meeting in the Middle

FHWA and industry are partnering to promote best practices for constructing durable longitudinal joints.

A crew is repairing a longitudinal joint in Pennsylvania using a mill and fill patching process along the full length of the pavement. *Source: PennDOT.*

Every year highway agencies lay down thousands of miles of asphalt pavements. How well these pavements perform is determined in large part by the quality and uniformity of their longitudinal joints, or the seams between adjacent lanes. Failure to apply best practices during construction can lead to weakness at these joints, and an otherwise sound pavement can become a maintenance nightmare.

Considering that the United States spends billions annually on pavements, it's a small wonder highway agencies are focused on ensuring that longitudinal joints withstand the demands of exposure to traffic and weather. That's why FHWA is teaming with industry experts to make sure agencies and contractors understand and employ the latest techniques for constructing longitudinal joints.

Defining the Problem

Asphalt pavements depend on adequate compaction to provide good long-term performance. When you place a new layer of asphalt next to a previously laid layer—known as paving against a cold joint—problems can arise if the contractor doesn't follow proper construction procedures. For example, if the paver doesn't place enough new material against the joint, the roller won't be able to achieve the desired density along the seam. Air and moisture can infiltrate the voids, causing joint separation and raveling. These distresses lead to accelerated aging and deterioration, which are costly to repair.

Identifying Best Practices

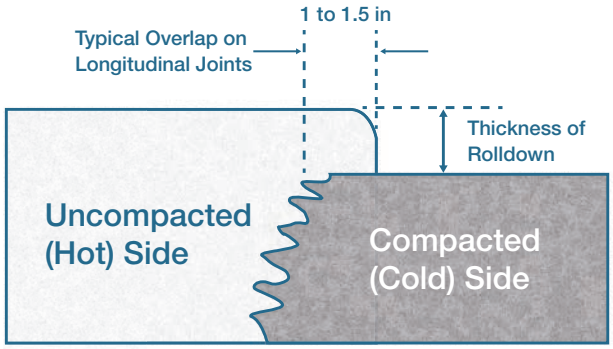
Seeking methods to minimize premature deterioration, FHWA and the Asphalt Institute partnered to produce the report *Best Practices for Constructing and Specifying HMA [Hot-Mix Asphalt] Longitudinal Joints*. The report presents 18 paving and compaction procedures that help maximize long-term performance. Many are straightforward, such as tacking the face of the joint and overlapping the paver by about 1 inch onto the cold mat in the adjacent lane. Together, these procedures can result in joints that perform as well as the rest of the pavement.

FHWA estimates **savings of $1.3 billion per year** as a result of applying best practices in longitudinal joint design and construction.

"FHWA's pavement technology assistance steered us toward a percent within limits approach that has proven very successful. The higher densities will reduce maintenance costs and improve long-term performance at the most vulnerable area of the asphalt pavement."

— Garth D. Bridenbaugh, P.E., PennDOT

The best practice for a conventional butt joint calls for partially overlapping the adjacent lane (cold side) with hot mix as part of the paving operation to ensure that there is adequate material to compact.



Source: National Highway Institute

The report also identifies 14 recommendations for agencies to consider in terms of mix design, project planning, and alternative construction techniques and materials. Examples include selecting a maximum aggregate size that is compatible with the thickness of the asphalt layer, paving and rolling in echelon, and using warm-mix asphalt, which increases the material's workability for a longer compaction time.

A Success Story: Pennsylvania

One State that is enthusiastically embracing best practices is Pennsylvania. In 2009, the Pennsylvania Department of Transportation (PennDOT) adopted a new specification for joint density that uses a statistical method known as percent within limits (PWL) to monitor density at the joint. Using PWL, PennDOT can specify quality levels for a job and determine the value at which the contractor will receive 100 percent of the payment, as well as the value at which the contractor must remove and replace a pavement or not get paid. Two years later, PennDOT began using bonuses for exceeding these specifications and penalties for failing to meet them.

As a result, between 2007 and 2013, PennDOT's average joint densities increased from 87.8 to 91.4 percent. Based on these results, the department estimated an increase in percent service life from 64 percent in 2007 to 96 percent in 2013.

"This is a good example of the DOT, FHWA, and industry working together," says Gary Hoffman, director of technical services at the Pennsylvania Asphalt Pavement Association. "A reasonable, step-wise implementation and monitoring plan was developed that resulted in marked improvements."

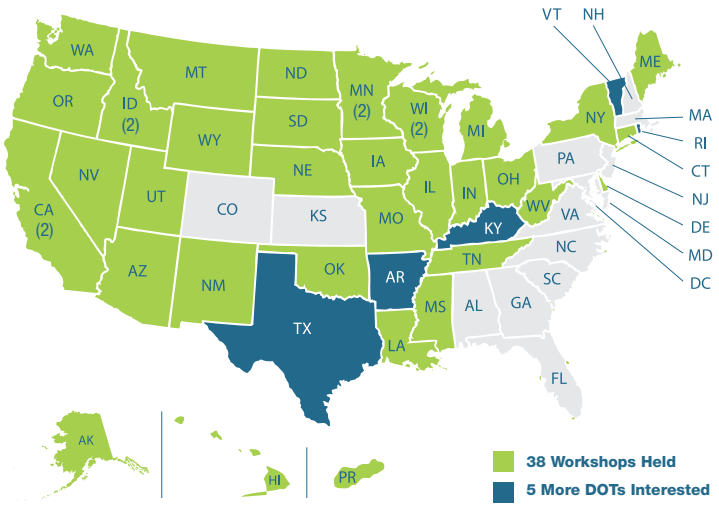
Hosting Workshops

FHWA and the Asphalt Institute also developed a 4-hour workshop to educate highway agencies and contractors on how to avoid premature deterioration in longitudinal joints. The goals include raising awareness of the problem, enhancing agency specifications, and improving contractor practices.

The West Virginia Department of Transportation hosted the first in a series of nationwide workshops. The feedback from agency and industry personnel was overwhelmingly positive. Attendees reported a greater understanding of the factors that affect pavement performance and increased awareness of new construction techniques that improve both density and joint performance.

To date the workshop has been conducted 43 times, reaching agency personnel and contractors in 36 States. FHWA estimates that these events have drawn more than 3,600 attendees.

States That Hosted the Longitudinal Joints Workshop



Source: FHWA/Asphalt Institute

For more information, contact John Bukowski at 202–366–1287 or john.bukowski@dot.gov.

Using Ground Tire Rubber in Asphalt Pavements

Agencies around the country are discovering the benefits of this environmentally responsible paving solution.

Waste tire piles like this one could dwindle as use of recycled rubber in pavement mixtures continues to grow in the United States. Source: © shutterstock.com, JCVStock.

This is a story about where the rubber meets the road. Literally. Every year the United States generates nearly 300 million scrap tires. Rather than consuming acres of landfill space, highway agencies are repurposing old tires, or ground tire rubber (GTR), as a feedstock in asphalt pavements.

"Rubber-modified asphalt is an important market for scrap tires because of the benefits the material brings to pavement construction, performance, and life," says John Sheerin, director of end of life tire programs at the Rubber Manufacturers Association. "Rubber-modified asphalt can have a lower life-cycle cost and a lower install cost in the right applications."

A Slow Start

Highway agencies have been using rubber from discarded tires in asphalt pavements since the 1960s. But until recently, only a few States have used GTR routinely in their pavements. Making scrap tires suitable for use in pavements requires processing to remove the steel and fiber and then grind the remaining rubber into small pieces.

Although GTR's performance is generally good, the cost has been higher compared to conventional practices due to the specialized equipment needed to blend the rubber into the asphalt binder at high temperatures. However, the cost of asphalt binders fluctuates with the price of crude oil and polymer additives. In contrast, recycled car and truck tires tend to hold a relatively stable market price.

Using GTR in pavement presents other challenges related to mix design and processing. For example, there have been issues with compaction and raveling of mixes in cold climates. Also, highway agencies need to use slightly higher binder contents in the rubber-modified mixtures because of their open-graded nature. These challenges underscore the need for quality control tests to ensure satisfactory performance.

Local, State, and Federal regulations have helped increase the availability of recycled tire rubber, driving a renewed interest in the material—always with the goal of providing a long-life, cost-competitive, environmentally responsible pavement system.

What Are the Benefits?

Using rubber-modified asphalt offers many benefits:

- *Improved field performance*. When constructed properly, rubberized asphalt exhibits increased resistance to rutting, fatigue cracking, and reflective cracking.

Highway agencies divert nearly **4.2 million scrap tires** away from landfills for paving projects every year.

- *Improved safety.* When used in open-graded friction surfaces, GTR helps this semi-porous surface in reducing splash and spray during wet weather, improving visibility for motorists.
- *Less noise.* When used in an open-graded mix design, rubberized asphalt helps reduce traffic noise.
- *Increased cost-effectiveness*. Although rubberized asphalt costs approximately 20 to 25 percent more than conventional mixtures, when designed and constructed properly, it lasts longer and costs less to maintain.
- *Less environmental impact.* Diverting tires from landfills results in less solid waste.

A handful of rubber powder produced from ground up tires. Source: Lehigh Technologies, Inc.

Expanding Usage Nationwide

Currently, about a third of the States are using GTR for pavement applications. Highway agencies in Arizona, California, Florida, and Texas are leading the way by allowing for the use of this technology in their construction standards and specifications.

"We will soon be placing asphalt modified with GTR on three test projects for evaluation," says Brian Egan, director of materials and tests at the Tennessee Department of Transportation.

To increase the use of GTR for pavement applications, FHWA plays key roles in several ongoing deployment activities. These include the following:

- Working with NAPA to create a guide on best practices.
- Cosponsoring, with the Rubber Manufacturers Association, a workshop at the 2016 Rubber Modified Asphalt Conference in Ann Arbor, MI.
- Sponsoring the Binder Expert Task Group, which meets twice a year for technical presentations and discussions on testing practices and standards.
- Using its Mobile Asphalt Testing Trailer for activities—such as material characterization, replication of mix designs, and production testing—at project sites involving rubberized asphalt.
- Working with highway agencies and suppliers to implement best practices in design, production, and construction.

"FHWA has fostered significant advancements in the science and use of rubber in asphalt materials," says Robert B. McGennis, P.E., technical manager for asphalt at The HollyFrontier Companies. "The technical brief *The Use of Recycled Tire Rubber to Modify Asphalt Binder and Mixtures* is a seminal document providing a state-of-the-art overview of the array of systems and processes available for using recycled tire rubber in asphalt pavements."

The joint report NAPA and FHWA will complete later this year will help improve current practices and expand the use of old tires in new paving applications.

For more information, visit www.fhwa.dot.gov/pavement/pubs/hif14015.pdf.

FHWA's Mobile Asphalt Testing Trailer, shown here at a plant in Lake City, FL, recently visited projects in Florida and Arizona to evaluate the performance of GTR. The mobile testing trailer also supported the American Association of State Highway and Transportation Officials and ASTM International in revising the standards for evaluating binders incorporating GTR.

Going Green with Recycled Materials

Reusing old pavements and roofing shingles in asphalt pavements reduces life-cycle costs and enhances the sustainability of new pavements.

A milling machine is removing layers of asphalt pavement to generate recycled asphalt pavement, or RAP, as part of a rehabilitation project. *Source: Astec Industries.*

Across the United States, use of recycled materials in asphalt pavements is on the rise. And for good reason. Not only is it better for the environment, but it's also good for the bottom line. According to the latest annual survey by NAPA, using reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS) in paving projects saved taxpayers nearly $2.8 billion in 2014 alone.

At the same time, the use of RAP saved 20 million barrels of virgin asphalt binder, while RAS use conserved an additional 2.2 million barrels. The amount of recycled materials used annually in asphalt pavements continues to grow, as engineers come to better understand the performance attributes of mixtures containing higher percentages of RAP and RAS.

With support from NAPA and other partners, FHWA is leading the way through the sharing of best practices and educating stakeholders about the value of using reclaimed materials in pavements.

What Are RAP and RAS?

RAP is most often produced through the process of cold milling, which involves using heavy machinery equipped with a large carbide steel-tipped milling head to grind and remove a layer of distressed asphalt pavement from the roadway. Typically, RAP consists of rock and asphalt cement that was processed into asphalt mixtures and placed years earlier. The first significant use of RAP was during the oil embargo of the 1970s, when petroleum products became scarce and more expensive. Highway agencies found a number of uses for RAP, but the most cost-effective was as a replacement for virgin aggregates and asphalt in asphalt pavements.

This handful of processed shingles, or RAS, is ready for inclusion in an asphalt mixture. *Source: Astec Industries.*

Although asphalt cement typically makes up only 5 to 6 percent of the RAP material by weight, economically, it makes up 50 percent of the material's value. Specifications typically allow up to 15 percent RAP in mixtures without a change to the base specified binder. Including higher percentages requires either softening the binder (for mixtures with between 15 and 30 percent RAP) or verifying the performance grade of the composite binder (for mixtures with more than 30 percent RAP). As more and more projects use RAP, experience has shown that it is a fitting substitute for virgin materials and, in some cases, improves the performance of asphalt pavements.

Another recycled product that provides asphalt cement for use in HMA is residential asphalt roofing shingles. These shingles consist of approximately 25 percent asphalt cement, in addition to felt, fiberglass, and fillers. The primary source of RAS is from roof tear-offs, but shingle manufacturers also have waste material that can be recovered. More recently, efforts are underway to remove housing shingles from the landfill waste stream and create a secondary market. FHWA and the HMA industry now are evaluating whether those materials could be incorporated cost effectively to produce asphalt pavements.

In 2014, highway agencies used more than **71.9 million tons of RAP** and nearly **2 million tons of RAS** in the United States, saving taxpayers more than **$2.8 billion**. *Source: NAPA.*

Expanding What We Know

As highway agencies look to do more with less, the push to incorporate recycled materials is growing. But how will these mixtures perform? Are the resulting pavements durable over time and after being subjected to traffic and exposure to various weather conditions? To answer these and other questions, FHWA has sponsored significant efforts to evaluate the performance of RAP and RAS, build engineering familiarity with the products, and increase the body of knowledge.

Best practices. In partnership with NAPA and the National Center for Asphalt Technology (NCAT) at Auburn University, FHWA supported developing the publication *Best Practices for RAP and RAS Management*. The document reflects latest advice and successful strategies for using these materials cost effectively in highway projects. For example, it highlights a number of improved construction methods such as high-frequency screens and crushers that enable production of a range of sizes of RAP products suitable for many types of projects.

In partnership with FHWA, NCAT also investigated methods of characterizing binders made from RAS for use in asphalt mixtures. The study highlighted methods for successfully dealing with the much stiffer properties in RAS binders and minimizing the likelihood of fatigue and low-temperature cracking in in-service pavements.

Recycling manual and testing/design specifications. In cooperation with the Asphalt Recycling & Reclamation Association, FHWA sponsored a 2015 revision and publication of the *Basic Asphalt Recycling Manual*. FHWA engineers also partnered with agencies and the American

Using advanced testing equipment inside the Mobile Asphalt Trailer, FHWA technicians can provide valuable feedback to agencies on the performance of their mixtures containing increased percentages of recycled materials. *Source: Matthew Corrigan, FHWA.*

Association of State Highway and Transportation Officials to revise mix design protocols and the related standards and specification for incorporating RAP and RAS materials into pavements.

Testing with the Mobile Asphalt Trailer. FHWA used its Mobile Asphalt Trailer to conduct predictive performance testing on mixtures containing high levels of RAP, RAS, and ground tire rubber in several States.

Scan tour in Japan. To understand best practices in other countries, in late 2014 representatives from NAPA, highway agencies, and contractors visited Japan to observe mixtures being placed with a much higher recycled content—on average, twice the typical percentage used in the United States. According to NAPA and FHWA's follow-up report, *High RAP Asphalt Pavements Japan Practice — Lessons Learned*, the scan tour readily illustrated the potential for asphalt mixtures with higher RAP content—greater than 25 percent—that maintain equivalent or better quality and performance.

In their report on Japanese practices, the delegates recommend increasing the percentage of RAP incorporated into asphalt mixtures in the United States. *Source: NAPA.*

Lowering Life-Cycle Costs

By recycling and reclaiming materials and minimizing the need for virgin aggregate and asphalt binder, the practice of using RAP and RAS can help highway agencies build pavements at a significantly reduced cost. Efforts to increase the proportions of RAP and RAS in mixtures and verify the performance characteristics, including long-term durability, point to a continued promising future for RAP and RAS in paving applications.

Through ongoing technology enhancements and deployment activities, FHWA and its partners are making it easier for practitioners to expand their use of recycled asphalt products, reduce the demand for virgin resources, and reap the economic benefits of more sustainable pavements.

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

"The information and experiences shared by the FHWA staff have been invaluable as we consider modifications to current limits on recycled materials for asphalt."

— Brian Egan, Director of Materials and Tests
Tennessee Department of Transportation

Using high-frequency screens and crushers to process RAP, crews can produce a variety of product sizes, which facilitates use in a wide range of applications. *Source: NCAT.*

Engineering Mixtures for Better Performance

With a renewed focus on long-term durability, FHWA and its industry partners propose a new specification for concrete paving materials.

A new materials specification is expected to improve the durability and longevity of the Nation's concrete pavements. Source: APTech.

Today's concrete pavements take a beating from the ever-growing traffic loads on the Nation's roadways and extreme weather events, the coldest of which require heavier applications of deicers. These factors can affect a pavement's performance or even lead to premature failure, particularly if the concrete's durability characteristics, such as its air void system or permeability, aren't up to par.

Although concrete pavements are inherently long-lasting and durable structures, their performance hinges on use of effective mixtures designed for the prevailing traffic loads and environmental conditions. To ensure that tomorrow's concrete pavements stand up to modern demands, FHWA is working with highway agencies and industry partners to provide technical guidance that agencies can use to develop a new specification for concrete mixtures.

Development of new guidelines identifying critical engineering properties, associated test procedures, and threshold values will help meet long-term durability and sustainability goals.

Behind the Scenes

Two key factors are driving this initiative. First, both the Moving Ahead for Progress in the 21st Century Act (MAP-21) and the Fixing America's Surface Transportation (FAST) Act called for renewed focus on asset performance. Plus, public agencies and the construction industry recognize that optimizing mixture designs improves durability—and ultimately results in more sustainable pavements.

To support implementation, FHWA convened a task group consisting of experts in concrete pavements and materials from highway agencies, industry, and academia. The expert group outlined the key factors for achieving good concrete mixture performance.

Going Back to Basics

"At the heart of the specification is making sure that we are measuring the right things," says Peter Taylor, director of the National Concrete Pavement Technology Center. "We found that beyond concrete strength, most of the critical factors that we need for performance are durability related, and typically not captured in existing specifications."

An expert task group of stakeholders selected broad categories of properties for the basis of the new guidelines: strength, cracking tendency, workability, and durability. The specification provides flexibility in implementation by including both prescriptive and performance options for highway agencies to choose from as they transition to a performance approach. The prescriptive approach

A Framework for Developing and Implementing the Specification

QA program implemented using *Concrete Pavement QA Toolkit*

Performance Specification
- Expert task group and champion agencies promote specification in pilot projects

Guidance on Specification
- FHWA provides guidance on performance specification through outreach initiatives

Guidance on Test Methods
- FHWA provides guidance through:
  - Educational videos
  - One-page briefs
  - Mobile Concrete Trailer

State Acceptance
- Technical manual with guidance on:
  - Test methods
  - Test frequency
  - Test implementation
  - Mobile Concrete Trailer

Contractor Quality Control
- Quality control plan template

Shown here is the vision for the new specification, moving from development through a series of dissemination and outreach initiatives, and ultimately to adoption. FHWA's Concrete Pavement QA Toolkit will provide critical support for the technology transfer component of the effort. *Source: FHWA.*

provides specific guidance on target values and test methods for certain material properties, while the performance approach specifies target performance levels for each key material property identified. The specification also features a tiered approach, so highway agencies can impose tighter controls as the level of risk increases.

One of the highlights of the specification is the incorporation of new test methods and procedures developed in collaboration with industry and academic partners. The tests under consideration include the Super Air Meter, the box test, the vibrating Kelly ball test, calorimetry, and formation factor.

Innovative tests represented in the new specification for concrete pavements. *Source: National Concrete Pavement Technology Center.*

Champions and Pilot Testing

To move the specification forward, FHWA identified nine highway agencies to serve as champions in pilot testing. The Indiana, Iowa, Michigan, Minnesota, Nebraska, South Dakota, and Wisconsin Departments of Transportation are participating, as well as the Illinois Tollway and the Manitoba highway agency in Canada. In 2015 and 2016, a number of these agencies received equipment to perform the new test methods proposed in the specification to see how field friendly they are. Initial testing also helped ensure the validity and reasonableness of some of the pass–fail limits. Using the results of that field testing, along with feedback from the champion agencies, FHWA further refined the specification.

Once a provisional specification is adopted by the American Association of State Highway and Transportation Officials (AASHTO), the champion agencies and other interested States will start using the specification on actual construction projects as a shadow specification, essentially running it in parallel with their current specifications to gather information and learn how they can fully adopt the specification. FHWA and its partners will assist in the process by conducting workshops and other outreach events, as well as through the development of videos, technical briefs, and guidance documents. FHWA's Mobile Concrete Trailer is available to assist States on their paving projects.

Prescriptive and Performance Approaches for Achieving Concrete Properties

Property	Prescriptive Approach	Performance Approach
Adequate Strength	• Cementitious type and content • Water-to-cementitious-materials ratio	• Flexural strength testing • Compressive strength testing
Cracking Risk	• Paste (cement + water) content • Shrinkage reducing admixture	• Unrestrained shrinkage testing • Restrained shrinkage testing
Freeze-Thaw Durability	• Total air content in system • Air void system parameters • Water-to-cementitious materials ratio • Super Air Meter test results	• Freeze-thaw testing performed using either ASTM C666 or C672
Resistance to Chemical Deicers	• Supplementary cementitious material type and content • Water-to-cementitious materials ratio	• Low-temperature differential scanning calorimetry
Durable Aggregate	• Prequalified sources that meet requirements of AASHTO PP65, Iowa Pore Index test, or ASTM C666	• Job mixture that meets requirements of AASHTO PP65, Iowa Pore Index test, or ASTM C666
Impermeability	• Supplementary cementitious material type and content • Water-to-cementitious-materials ratio	• Resistivity testing • Formation factor
Workability	• Assessing the Box test and vibrating Kelly ball test—performed during mixture design and construction	

Source: National Concrete Pavement Technology Center.

"Implementation of this specification will be an ongoing process," says Tom Cackler, project manager for the National Concrete Pavement Technology Center. "It will require a significant outreach and dissemination program to help agencies work toward its adoption."

Timeline for Deployment

In November 2016, AASHTO will ballot the provisional specification. A separate commentary document will accompany it to provide agencies, contractors, and material producers more detailed information on applying and implementing the specification.

The ultimate vision is this: By implementing a modern-day concrete specification, highway agencies can look forward to faster and better quality assurance tests, optimized mixtures that lead to cost savings, and longer lasting concrete pavements, while allowing industry to innovate.

For more information, contact Gina Ahlstrom at 202–366–4612 or gina.ahlstrom@dot.gov.

Improving Durability Through Density

A 10-State demonstration project aims to see if increased in-place compaction leads to longer life for asphalt pavements.

Crews in Florida are constructing experimental sections as part of a demonstration project to evaluate the performance of asphalt pavements with increased compaction density. *Source: NCAT.*

Consisting of more than 9.6 million lane miles, the U.S. highway network is one of the country's largest assets. But keeping the system in good working order comes at a high cost. In the *2013 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance* report, FHWA estimates that the average annual investment needed to maintain the condition and performance of the Nation's roads and bridges between 2010 and 2030 is $86.3 billion.

What if there were a way to design and construct pavements that could improve performance by 5 to 25 percent? The result could be an annual savings of up to $8.75 billion. That's the potential FHWA sees in increasing the compaction density of asphalt pavements.

The Appeal of Compaction

Over the years, advancements in techniques and technology have increased pavement performance and reduced costs. Now, engineers know that combining controlled compaction with higher in-place pavement density can have a dramatic effect on the performance of asphalt pavements.

Studies have shown that increasing the density and reducing the air void content of asphalt pavements results in increased resistance to load-related cracking and, ultimately, a longer pavement life. For example, one study found that an increase in compactive effort that results in a 1-percent decrease in air void content can result in a 10- to 30-percent increase in pavement life. Assuming a 20-percent life increase on asphalt pavement with a 20-year design life, the estimated cost savings associated with deferring rehabilitation for 4 years is 14 percent of the rehabilitation cost. For a 1-mile segment of four-lane asphalt pavement, that's a savings of $83,000 in terms of present value.

Contractors know how to achieve higher densities through increased compaction. But the risks of over-compaction, bleeding, and even crushing the aggregate have limited the practice. However, recent improvements such as using warm-mix asphalt technology to provide better mixture workability, intelligent compaction, high-tech pavers, and quality control processes have made it possible to achieve higher in-place density and avoid those risks. And,

unlike other methods that might involve more costly materials or construction practices, increasing the compactive effort during construction doesn't have to add much to the cost.

A Demonstration Project Begins

In 2016, to demonstrate the long-term value of improving pavement performance through increased density, FHWA is providing guidance and onsite assistance with construction of experimental sections in 10 States. The goal is to demonstrate the feasibility of increasing minimum in-place density from 92 percent up to 94 percent of maximum theoretical density (no voids) to extend a pavement's life—and to establish the basis for States to increase their requirements for in-place density.

The highway agencies in Alaska, the District of Columbia, Florida, Indiana, Minnesota, Oklahoma, Pennsylvania, Washington, Wisconsin, and Virginia are partners in the study. As of July 2016, three States—Florida, Minnesota, and Pennsylvania—had constructed trial sections, while the remaining seven anticipate completing theirs by fall 2016. Each project includes control sections constructed using the agencies' current density specifications to provide a basis for direct performance comparisons.

The National Center for Asphalt Technology and the Asphalt Institute will provide training, assist with mix design, monitor construction, and help document the results.

Early Signs of Success

Although it may take several years to determine the true impact of increased densities on pavement performance, the fact that 10 agencies enthusiastically volunteered to participate is a good sign that States see the value in this study.

Robert Crandol, assistant State materials engineer at the Virginia Department of Transportation, says "comparing other States' requirements with Virginia's was eye-opening." Further, he agrees with one instructor's assessment that "our current density specs are weak and could stand an overhaul."

Based on the 2016 results, additional project demonstrations and technical assistance are planned for 2017.

For more information, contact Tim Aschenbrener at 720–963–3247 or timothy.aschenbrener@dot.gov.

A technician is collecting a core sample to confirm the in situ density and other key characteristics of the pavement.

Appendix

Other Pavement Technology Development and Deployment Activities Under MAP-21

The Technology and Innovation Deployment Program, launched under the Moving Ahead for Progress in the 21st Century Act (MAP-21), provides funds and other resources to offset the risk of innovation. Following are initiatives, projects, and solutions developed under the program.

Every Day Counts (EDC) Innovation Deployment Program

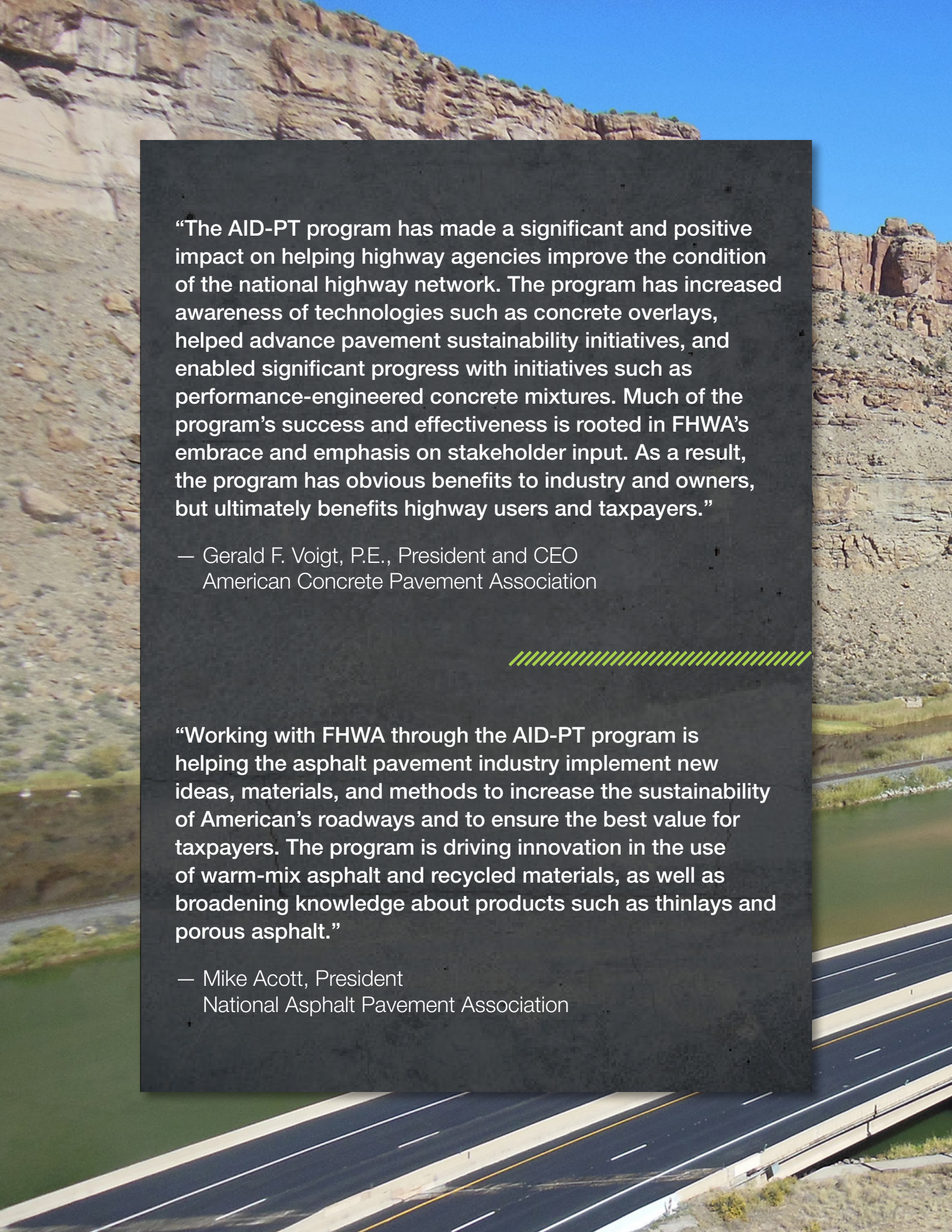
EDC Cycle	Innovation
EDC-2 (2013–2014)	Intelligent Compaction
EDC-2 (2013–2014)	High Friction Surface Treatments

Accelerated Innovation Deployment Grant Program

Agency	Project	Innovation
Kentucky Transportation Cabinet	Paving	Intelligent Compaction
Michigan Department of Transportation and the Dickinson County Road Commission	Pine Mountain Road/Westwood Avenue Pavement Rehabilitation	Hot In-Place Recycling and Warm-Mix Asphalt
Minnesota Department of Transportation	Paving	Intelligent Compaction and Infrared Imaging
Missouri Department of Transportation	High Friction Surface Treatment Projects in Missouri	High Friction Surface Treatments
Missouri Department of Transportation	Paving	Intelligent Compaction and Infrared Imaging
New Hampshire Department of Transportation	I–93 Pavement Preservation	Asphalt Rubber Bonded Wearing Course
Oklahoma Department of Transportation	Improving Safety at Multiple Locations in Oklahoma City	High Friction Surface Treatments
Rhode Island Department of Transportation	Improvements to Rhode Island Route 102	Warm-Mix Asphalt and Intelligent Compaction
South Dakota Department of Transportation	Increasing Safety on South Dakota's State Highway System	High Friction Surface Treatments

Strategic Highway Research Program (SHRP2) Pavement Solutions

SHRP2 Solution	Description	State Involvement
Precast Concrete Pavement (R05)	Guidelines and model specifications to help agencies select projects that could benefit from precast concrete pavement systems, as well as design, fabricate, and install those systems.	Thirteen States and the District of Columbia
Techniques to Fingerprint Construction Materials (R06B)	Two portable spectroscopy technologies that can be used during construction to verify the chemical compounds or presence of certain additives or contaminants in some commonly used construction materials.	Three States
Technologies to Enhance Quality Control on Asphalt Pavements (R06C)	Two nondestructive technologies for measuring uniformity and potential defects in asphalt pavements during construction. Both technologies (infrared imaging and ground-penetrating radar) can be used to test up to 100 percent of the pavement area in real time, providing much more inspection coverage than most other quality control methods. See the American Association of State Highway and Transportation Officials' R06C product page for details.	Ten States
Advanced Methods to Identify Pavement Delamination (R06D)	Two nondestructive testing technologies for detecting subsurface discontinuities in asphalt pavement. The technologies include ground penetrating radar and impact echo combined with seismic analysis of surface waves.	Five States
Tools to Improve Portland Cement Concrete Pavement Smoothness During Construction (R06E)	Several innovative technologies that improve process control and allow for rapid adjustments to equipment and operations to correct surface irregularities on concrete pavements during construction, while the concrete is in a plastic state.	Nine States
New Composite Pavement Systems (R21)	This solution provides performance data and offers step-by-step guidance for several types of composite pavements using procedures consistent with the *Mechanistic-Empirical Pavement Design Guide.*	Four States
Pavement Renewal Solutions (R23)	An interactive, Web-based pavement design scoping tool that provides guidance for deciding where and under what conditions to use existing pavement as part of roadway renewal projects. See the AASHTO R23 product page for details.	Nine States
Guidelines for the Preservation of High-Traffic-Volume Roadways (R26)	Best practices and guidelines for applying pavement preservation techniques to extend the life of high-traffic-volume roadways. Materials include selection matrices to help match specific high-volume-traffic situations with the best available treatments. See the AASHTO R26 product page for details.	Sixteen States

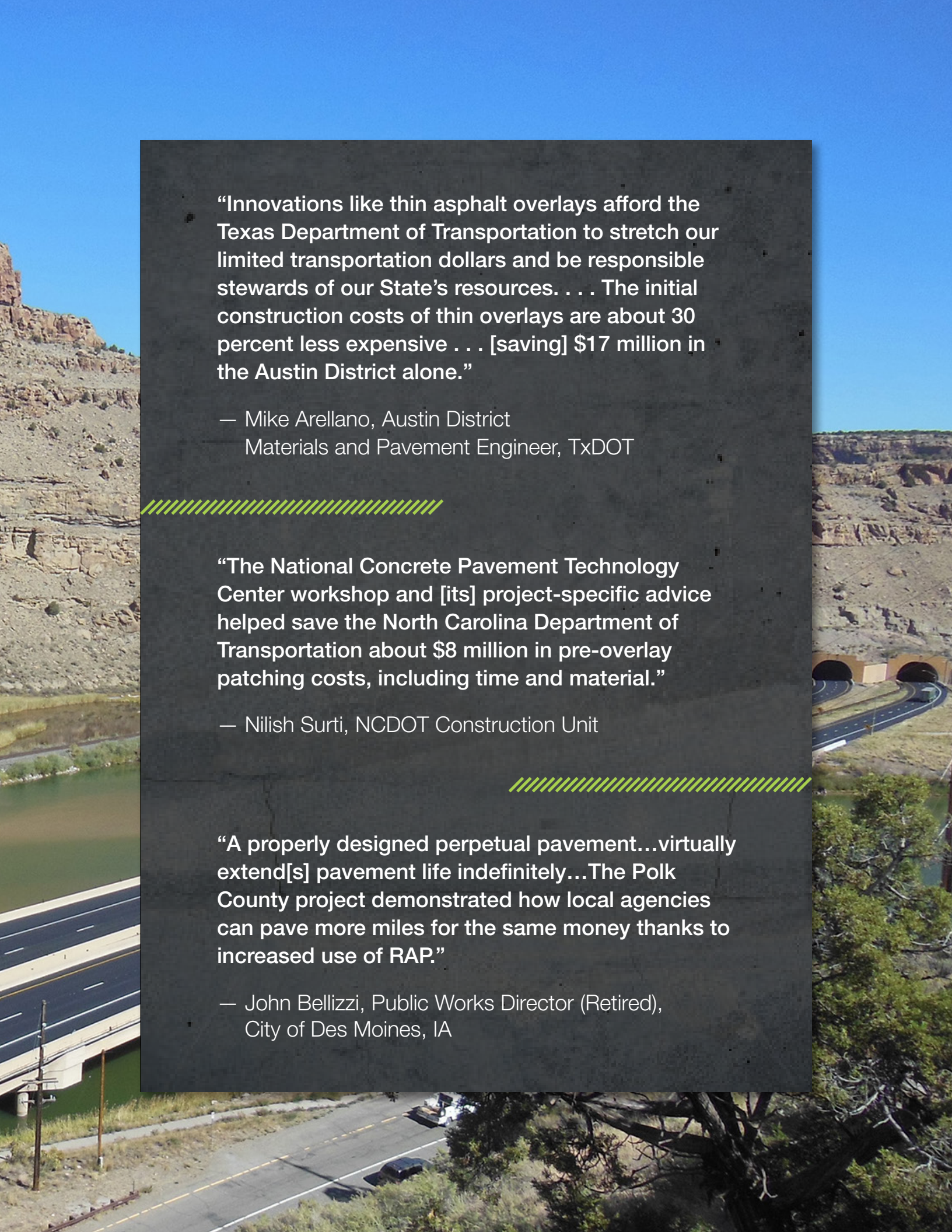


"The AID-PT program has made a significant and positive impact on helping highway agencies improve the condition of the national highway network. The program has increased awareness of technologies such as concrete overlays, helped advance pavement sustainability initiatives, and enabled significant progress with initiatives such as performance-engineered concrete mixtures. Much of the program's success and effectiveness is rooted in FHWA's embrace and emphasis on stakeholder input. As a result, the program has obvious benefits to industry and owners, but ultimately benefits highway users and taxpayers."

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

"Working with FHWA through the AID-PT program is helping the asphalt pavement industry implement new ideas, materials, and methods to increase the sustainability of American's roadways and to ensure the best value for taxpayers. The program is driving innovation in the use of warm-mix asphalt and recycled materials, as well as broadening knowledge about products such as thinlays and porous asphalt."

— Mike Acott, President
National Asphalt Pavement Association



“Innovations like thin asphalt overlays afford the Texas Department of Transportation to stretch our limited transportation dollars and be responsible stewards of our State’s resources. . . . The initial construction costs of thin overlays are about 30 percent less expensive . . . [saving] $17 million in the Austin District alone.”

— Mike Arellano, Austin District
Materials and Pavement Engineer, TxDOT

“The National Concrete Pavement Technology Center workshop and [its] project-specific advice helped save the North Carolina Department of Transportation about $8 million in pre-overlay patching costs, including time and material.”

— Nilish Surti, NCDOT Construction Unit

“A properly designed perpetual pavement…virtually extend[s] pavement life indefinitely…The Polk County project demonstrated how local agencies can pave more miles for the same money thanks to increased use of RAP.”

— John Bellizzi, Public Works Director (Retired),
City of Des Moines, IA

CONTACTS FOR MORE INFORMATION

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