TR NEWS
May–June 2022
NUMBER 339

Pavement Preservation, Maintenance, and Rehabilitation

PLUS

Pavement Preservation in Raleigh, North Carolina

Transforming Pavement Preservation

The Preserved Road Ahead

NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

NATIONAL ACADEMIES *Sciences Engineering Medicine*

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. John L. Anderson is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the National Academies of Sciences, Engineering, and Medicine to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.nationalacademies.org**.

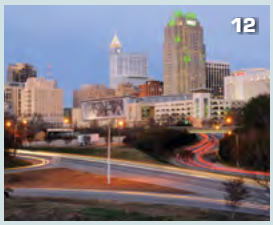
The **Transportation Research Board** is one of seven major programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to provide leadership in transportation improvements and innovation through trusted, timely, impartial, and evidence-based information exchange, research, and advice regarding all modes of transportation. The Board's varied activities annually engage about 8,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state departments of transportation, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

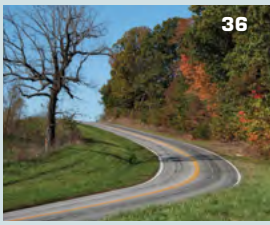
Learn more about the Transportation Research Board at **www.TRB.org.**

TRB

TR NEWS

Number 339 / May–June 2022





COVER Laying an environmentally responsible path, Illinois Department of Transportation crews apply micro surfacing along US-50 during the summer of 2021. Research revealed that micro surfacing produces about 0.4 pound per square yard of greenhouse gases, an environmentally friendly treatment compared with heavier asphalt treatments. However, a cleaner environment is just one of the reasons for such roadway preservation operations. Preservation and maintenance practices result in reduced life-cycle costs and better system performance. (John Senger, Illinois DOT)

Coming Next Issue

The July–August 2022 issue of *TR News* features a roster of articles on the theme of new construction technologies. Some of the subjects authors explore include the implementation of cyberphysical systems in the highway construction industry, human-augmented technology interaction that improves construction quality control and task monitoring, and unmanned aerial systems.


Ohio DOT

Making last-minute checks, Ohio Department of Transportation (DOT) flight operations manager David Gallagher prepares to inspect nearby Veterans' Glass City Skyway Bridge in Toledo. Drones can reach tight spots and capture data with far more ease, speed, accuracy, and safety than traditional hands-on inspections.

ALSO IN THIS ISSUE

TRB COVID-19 Resources

Agencies and organizations can use TRB publications and online resources for useful and timely information to help address issues related to the COVID-19 pandemic. To read about TRB's current research and activities, and for a list of relevant publications, visit www.nationalacademies.org/trb/blog/transportation-in-the-face-of-communicable-disease.

The *TR News* Editorial Board thanks Nelson Gibson, TRB, for his work assembling and developing this issue.

TR NEWS
features articles on innovative and timely research and development activities in all modes of transportation. Brief news items of interest to the transportation community are also included, along with profiles of transportation professionals, meeting announcements, summaries of new publications, and news of Transportation Research Board activities.

***TR News* is produced by the Transportation Research Board**

Publications Staff
Natalie Barnes, Director of Publications
Heather DiAngelis, Associate Director of Publications
Cassandra Franklin-Barbajosa, Senior Editor
Jennifer G. Correro, Assistant Editor

TR News (ISSN 0738-6826) is issued bimonthly by the Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001. Internet address: www.TRB.org.

Editorial Correspondence: By mail to the Publications Office, Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001, by telephone 202-334-2278, by fax 202-334-3495, or by e-mail cfranklin-barbajosa@nas.edu.

Subscriptions: North America: 1 year $75; single issue $19. Overseas: 1 year $100; single issue $19 plus shipping. Inquiries or communications concerning new subscriptions, subscription problems, or single-copy sales should be addressed to the Business Office at the following address, or by phone 202-334-3216, fax 202-334-2519. Periodicals postage paid at Washington, D.C.

Postmaster: Send changes of address to *TR News,* Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001.

Pavement Preservation, Maintenance, and Rehabilitation

Courtesy of ACPA/IGGA

ANDREW BRAHAM, DINGXIN CHENG, KURT SMITH, LESLIE MYERS, AND DAVID PESHKIN

Braham is an associate professor of civil engineering at the University of Arkansas, Fayetteville; Cheng is a professor of civil engineering at California State University, Chico; Smith is a program director at Applied Pavement Technology, Urbana, Illinois; Myers is a senior asphalt pavement engineer at FHWA, Washington, D.C.; and Peshkin is vice president of Applied Pavement Technology, Urbana, Illinois.

Above: Road workers seal the traverse and longitudinal joints of a rural concrete highway, a project that helps prevent water and incompressible materials—such as sand, rock, and grit—from entering the joints and contributing to distress. Timing is everything for such maintenance practices. Waiting for more wear and damage can mean costly rehabilitation or repair. But staying on top of the task is easier on transportation agency budgets.

A traditional approach by those tasked with managing road networks is to fix the roads in worst condition first, often referred to as the "worst-first" strategy. However, this approach is not sustainable, as it allows pavement conditions to deteriorate to the point that they require either reconstruction (complete removal and replacement) or a major rehabilitation. These are among the most expensive of all pavement fixes. The repercussions of the worst-first approach are a pavement network in increasingly poor condition and an agency budget unable to keep up with the rehabilitation demands of the network. This places the efficiency and safety of the network at risk, as it may no longer satisfactorily meet the needs of the traveling public. The result is a need to move in the direction of preservation and more innovative maintenance and rehabilitation treatments to improve the quality of our roads.

According to FHWA, preservation is "work that is planned and performed to improve or sustain the condition of the transportation facility in a state of good repair. Preservation activities generally do not add capacity or structural value but do restore the overall condition of the transportation facility" (*1*).

There are several key words and phrases in this definition, including "planned," "state of good repair," and "do not add structural value." Simply put, the word "preservation" describes the treatments and strategies used to keep good roads in good condition. Pavement preservation takes the time to preserve a road proactively and helps to prevent catastrophic—and costly—failures in the future.

Think of preservation as simply taking care of the surface of a pavement. Flexible pavements (built with asphalt materials) and rigid pavements (built with concrete materials) have their own set of preservation treatments. Typically, these low-cost, low-invasive procedures can effectively preserve pavements when applied to the right pavement at the right time (see Tables 1 and 2, Page 4). Some

treatments—such as micro surfacing and diamond grinding—do more than just treat the pavement surface; they also can improve the ride experience by reducing roughness or enhancing the texture for tires to grip the roadway. This can reduce skid potential and improve safety. However, these treatments do not add structural value, but they address any issues related to the surface of the pavement. These treatments are most effective when they are planned rather than reactive.

Ideally, in order to obtain longer lasting roads at a reduced cost, these preservation treatments should be used on pavements in good condition so they do not deteriorate further and so that they help reduce the potential development of structural damage.

However, as all road owners know, many pavements that have structural damage are in need of more than just a maintenance or preservation treatment. These pavements are in need of rehabilitation to restore structural capacity to the roadway. While reconstructing a pavement is the most comprehensive form of rehabilitation, there are several rehabilitation treatments available for both flexible and rigid pavement, including mill and fill, cold in-place recycling, and slab replacement (Tables 3 and 4).

This theme issue explores many facets of pavement preservation, maintenance, and rehabilitation. First, two local agencies share their experiences using maintenance and rehabilitation. Next, case examples of implementing pavement preservation, leveraging maintenance treatments, and showcasing rehabilitation treatments are highlighted. These articles are followed by a comprehensive look at successful implementation of pavement preservation, maintenance, and rehabilitation programs to strategically reduce costs and emissions.

TABLE 1 Flexible Pavement Preservation Treatments

Flexible Pavement
Fog seal, rejuvenating fog seal
Crack seal
Chip seal
Scrub seal
Slurry seal
Micro surfacing
Cape seal
Ultrathin bonded overlay
Thin overlays (<1.5 inches)
Mill and fill (<1.5 inches)

TABLE 2 Rigid Pavement Preservation Treatments

Rigid Pavement
Seal and reseal joints and cracks
Retrofitted edge drains
Diamond grinding
Thin overlay (flexible or rigid overlays)
Dowel bar retrofit
Cross-stitching and slot-stitching

TABLE 3 Flexible Pavement Rehabilitation Treatments

Flexible Pavement
Overlays (>1.5 inches)
Mill and fill (>1.5 inches)
Hot in-place recycling
Cold in-place recycling
Full-depth reclamation

TABLE 4 Rigid Pavement Rehabilitation Treatments

Rigid Pavement
Slab undersealing/stabilization
Thick overlays (flexible or rigid overlays)
Partial-depth repair
Full-depth repair
Slab replacement

Andrew Braham, University of Arkansas, Fayetteville

A heated asphalt emulsion is sprayed on a fully cleaned and crack-sealed surface. Topped off with fine aggregates, the resulting chip seal reinforces the structurally sound existing road southeast of Madison, Wisconsin.

Colorado DOT

A Colorado Department of Transportation (DOT) road crew rolls out the heavy equipment to resurface U.S. 287 near Lamar. This preservation work can decrease emissions.

Scattered throughout these articles are short takes on using pavement preservation resources in the classroom, important standards, and state research reports. Finally, two experts in the field provide their perspectives on where we go from here, followed by a short piece on electric vehicles. These are all just the tip of the iceberg, and we hope that this issue allows you to explore the use of pavement preservation, maintenance, and rehabilitation in your community.

REFERENCE

1. Waidelich, W. Guidance on Highway Preservation and Maintenance, Memorandum. FHWA, U.S. Department of Transportation, 2016.

Several groups are actively working in pavement preservation, maintenance, and rehabilitation.

Related TRB Standing Committees

- Pavement Preservation,
- Pavement Maintenance,
- Design and Rehabilitation of Concrete Pavements, and
- Design and Rehabilitation of Asphalt Pavements.

Related AASHTO Groups

- Committee on Materials and Pavements,
- Committee on Maintenance, and
- Transportation System Preservation Technical Services Program: Pavement Preservation.

Related FHWA Resources

- Every Day Counts,
- Pavement Preservation Research Roadmap,[1] and
- Pavement Preservation Technical Feedback Group.

Learn more about FHWA's pavement preservation checklist series, training efforts, and publications at https://www.fhwa.dot.gov/preservation.

[1] Download the Pavement Preservation Research Roadmap at https://rosap.ntl.bts.gov/view/dot/60355.

Asphalt Materials, Inc.

Thinking Local

Pavement Management Practices for County Agencies

DAN SWIERTZ, NATE JENKINS, AND SCOTT ASSENMACHER

Swiertz is an engineer at Asphalt Materials, Inc., Portage, Wisconsin; Jenkins is a sales representative at Asphalt Materials, Inc., Indianapolis, Indiana; and Assenmacher is a sales representative at Asphalt Materials, Inc., Oregon, Ohio.

Above: Full-depth reclamation—an in-place recycling method that uses existing pavement section material as the base for the new roadway wearing surface when reconstructing existing flexible pavements—can be a cost-effective alternative to traditional mill-and-fill operations on rural roads. The use of such methods in two Indiana and Michigan counties can prove successful for other local transportation agencies, despite restrictive road rehab budgets.

Information about pavement preservation has never been more accessible than it is today. Online resources offer a library of videos, calculators, and printable media to guide the decision-making process. Yet, it can be difficult to apply these concepts sustainably at a local level, where budgets, public expectations, and contractor availability can be singular to the municipality. This article highlights tools and concepts that two unique county agencies are using to achieve demonstrable and replicable success in applying preservation and recycling concepts.

Neighboring the Indianapolis, Indiana, metropolitan area, Hancock County has a population of about 80,000 residents. The county highway department is responsible for maintaining approximately 670 centerline miles of road, including through some 90 local neighborhoods. County engineer Gary Pool notes that meeting the public's expectations on a limited budget can be challenging, as the public does not always understand roadway types in terms of preservation and maintenance budgets. Comparatively, Southeast Michigan's Monroe County has nearly double the population and centerline miles relative to Hancock County, but the area experiences similar budget constraints.

Even with these challenges, both counties continue to improve their networks. The Michigan Transportation Asset Management Council rated 41.7 percent of Monroe County–maintained roads in "good–fair" condition during the 2013–2014 rating cycle, increasing to 79.5 percent for the 2018–2019 rating cycle—an improvement of about 10 percent annually (Figure 1). Using the Pavement Surface Evaluation and Rating (PASER) system, less than 10 percent of Hancock County–maintained roads are currently in "poor" condition. These ratings are a marked improvement over national averages. For example, the 2021 ASCE Report Card for America's Infrastructure reports that 43 percent of public roadways are in "poor" or "mediocre" condition (*1*). These counties share two important similarities

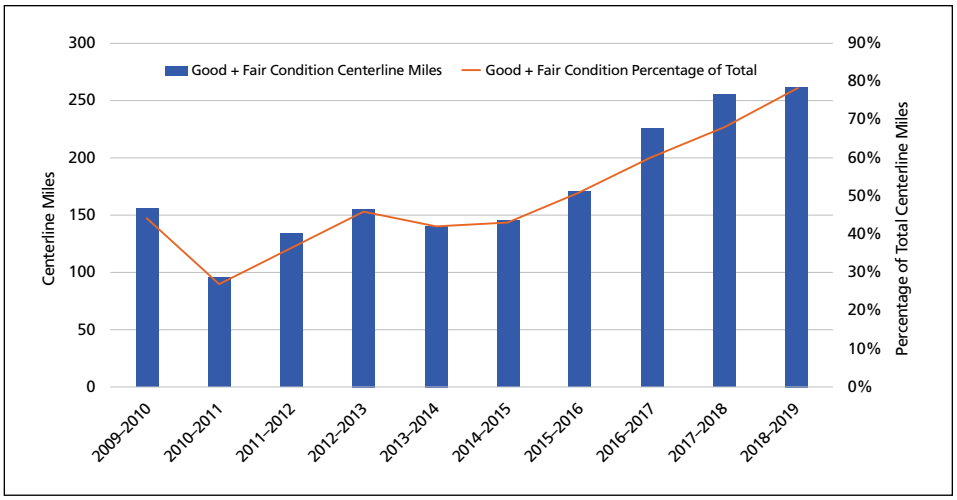


FIGURE 1 **Michigan Transportation Asset Management Council rating of Monroe County–managed roads, based on the original data.**

that drive pavement management success: robust data collection and willingness to try new and innovative processes.

"We have a great relationship with our material suppliers and contractors as trusted advisors to help in selecting good project candidates," Monroe County Superintendent Dave Leach explains. "The early investigation of a sound, engineered solution with these resources really helps." The clear priority in the county is to preserve assets first and to avoid disinvestment in infrastructure. "Focusing available funds toward preservation early in a pavement's life at a much lower cost in lieu of waiting until the fix gets too expensive puts us in a good spot," Leach adds. Monroe County relies on annual PASER scores and RoadSoft computer software to house and track data, and it has adopted a five-year transportation asset-management plan for preservation.

Pool agrees that it is necessary to *see* problems to be successful in fixing them. Hancock County uses an in-house Excel database to track PASER scores systematically and couples these data to remaining service life for each road. For each year a pavement section deteriorates with no maintenance, the remaining service life of that section is reduced by one year. Preventive surface treatments add years to the remaining service life, a concept presented by Galehouse and Sorenson (*2*). Remaining service life allows the county to place a higher discount rate on roads in poor condition, since pavement deterioration is not linear. Table 1 is an example of how Hancock County applies this system. Using remaining service life, Pool quantitatively assesses how the county's practices are improving the roadway network over time. Hancock County tracks the PASER score for each road and strives to lower the standard deviation of the PASER score among roads within the county. Pool believes that a practical way to audit the success of a rating system is the annual cost of pavement patching. Hancock County spent nearly $500,000 on patching in 2013 alone, whereas this number dipped below $50,000 in 2021. Less expenditure on reactive maintenance results in more dollars available for preventive treatments.

TABLE 1 **Hancock County Remaining Service Life Application**

PASER Score	RSL (Years)	RSL Annual Loss (Years)
10	16	1
9	14	1
8	12	1
7	10	1.05
6	8	1.10
5	6	1.25
4	3	1.50
3	1	1.75
2	0	2
1	0	2

Note: RSL = remaining service life.

Commitment to data collection is only one piece of the pavement management puzzle. Both counties view network maintenance as a collaborative approach. Monroe County highway engineer Matthew Snell and project engineer Michael Smith agree that when leadership is willing to try different things—such as combination treatments—it helps stretch taxpayer dollars. Having a board that gives their county team the latitude to try innovative maintenance procedures and expand their toolbox has played a large part in the successful improvement of their overall road network. Pool concurs that suppliers, contractors, and the public are all partners with a vested interest in the products, processes, and outcomes; all parties must form a cooperative relationship for sustained success. Pool also is a believer in gaining the confidence of the public, and the county's goal is to provide a treatment to every road at least every seven to eight years. Treatments as simple as fog seals—spraying a thin asphalt emulsion over an existing asphalt surface—or as involved as scrub seals—applying a polymer-modified asphalt emulsion to an asphalt road surface, scrubbing it into cracks and voids with a broom, and covering it with aggregate—can make a significant difference in pavement management. This works toward Pool's first goal in maintenance: preventing water penetration.

Hancock County demonstrated this commitment to cooperative project selection on a recent polymer-modified cape seal project in Greenfield. Public perception and feedback indicated a standard chip seal—a thin film of asphalt sprayed onto the road surface and covered with aggregate chips—would unlikely be well received for this section of road. Nevertheless, the condition of the roadway suggested that a more advanced treatment was necessary, but budgetary constraints ruled out repaving. Using a remaining service life analysis, the county settled on a cape seal—a conventional chip seal covered with a micro

Asphalt Materials, Inc.

Combining two or more preservation treatments, such as fog sealing and scrub sealing, often can be used to increase performance of the treatment without adding significant project costs. Such preservation treatment processes also allow agencies to address a wider range of pavement conditions.

surfacing or slurry seal—with an anticipated life of 10 years. The county engineering team believed the chip seal would seal the underlying pavement from moisture while providing a stress-absorbing layer for the micro surfacing. The micro surfacing itself would provide a uniform, smooth appearance (which the public wanted), as well as its own performance benefits. Although this was the first cape seal constructed in Hancock County, the county has since added this treatment to their "toolbox" and the volume of cape seals is increasing annually. Hancock County already had a strong polymer-modified chip seal program, so the incentive to use such a process was obvious. Including all stakeholders was an important step to adding this new and valuable tool for the county.

Network management does not end with preservation and maintenance. Countless miles of roads at the end of their service life exist throughout local networks. The reality with many of these roads is that the funding simply does not exist to reconstruct them. Reclamation and recycling processes can help offset some reconstruction costs by utilizing in situ materials while providing a proven and high-performing solution. In 2018, Monroe County identified a 12.5-mile primary road corridor that needed replacement through four townships. Engineers considered traditional mill and fill and cold in-place recycling. However, by utilizing existing materials in an asphalt emulsion–stabilized full-depth reclamation process, the county estimated that it could gain an 8 percent increase in structural value at an increase of $10,000 per mile to conduct the process relative to cold in-place recycling for this corridor. Since this route is a major connector, especially for trucks entering Michigan, structural capacity was heavily weighted in the decision-making process. Additionally, full-depth reclamation allowed correction to grading, superelevation, and shouldering; all while conserving materials. Online tools available through RoadResource.org provided Monroe County an easy comparison of this project's options (Figure 2).

Monroe County engineers estimate the service life of a full-depth reclamation at 18 years, but they believe that—with proper preservation of their investment—

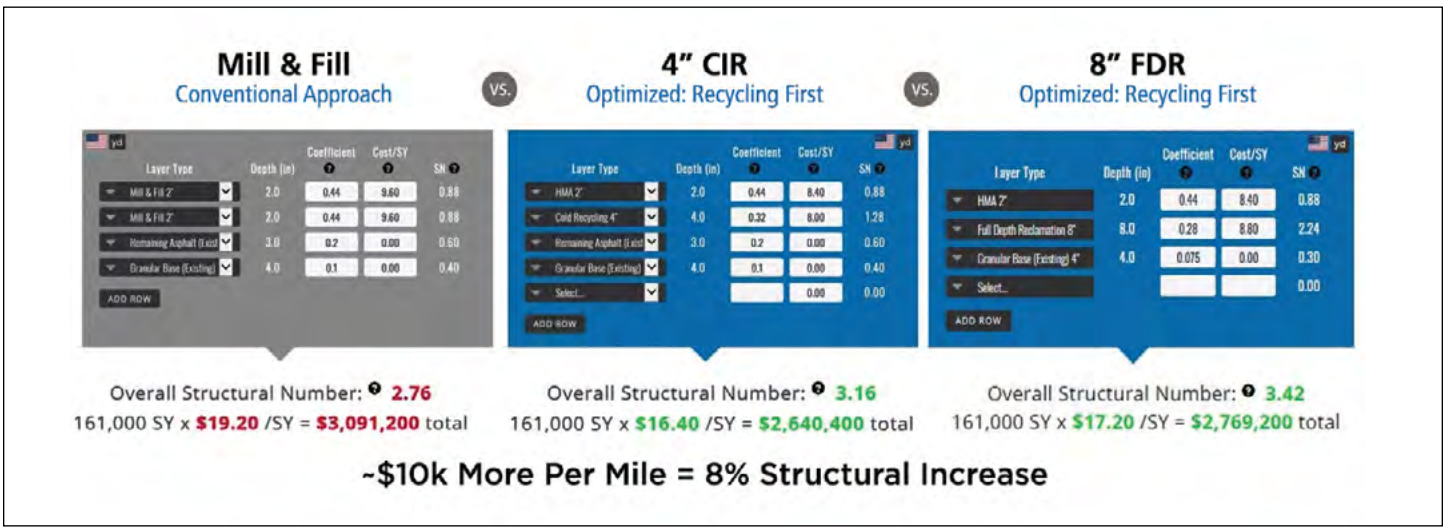


FIGURE 2 Using online resources to compare treatment options helped prioritize structural capacity for the Monroe County Road Commission.

they will not need to rehabilitate this road significantly for 40 to 50 years. The county worked with material suppliers, contractors, and even local legislators to make this project a reality, again demonstrating an all-in approach to management. Since 2007, Monroe County has treated 54 miles of road with full-depth reclamation. "Employing the mix-of-fixes approach, including rehabilitation and reconstruction using recycling techniques, allows us to assign the right fix to the right road at the right time," Snell remarks, "and provides a cost-effective and environmentally responsible way for us to maintain our network in the most effective way possible."

Local municipalities face many unique challenges in maintaining and improving their pavement network. But, as these two project examples illustrate, sustained success can be achieved. Although Hancock and Monroe counties differ in many ways, five common themes appear when reviewing their management practices:

- **Good pavement management starts with knowing your network**. Use data collection and management tools that work for individual needs. There is no one size that fits all.
- **Audit your system**. Pavement network data can be audited indirectly by patching budgets or directly by third-party agencies and councils. Auditing data systems improves outcomes and allows municipalities to make better decisions.
- **Establish buy-in from all parties**. Material suppliers, contractors, and the public all have a vested interest in the success of a road management program, so all should be included in the decision-making process.
- **Use available resources**. This can include web-based resources, local consultants, and fellow municipalities.
- **Be flexible**. An out-of-the-box approach is sometimes necessary. Leveraging existing experience is important but continuing to evolve, and finding ways to improve is what creates true sustainability.

REFERENCES

1. ASCE. 2021 Report Card for America's Infrastructure. https://infrastructurereportcard.org.
2. Galehouse, L., and J. Sorenson. A Quick Check of Your Highway Network Health. FHWA-IF-07-006. FHWA, U.S. Department of Transportation; and the National Center for Pavement Preservation. 2007.

Acknowledgments

The authors thank David Leach, Gary Pool, Michael Smith, and Matthew Snell for their interviews, article structure input, and article content review.

VOLUNTEER VOICES

"If I could go back in time, I would bring the knowledge of justice, equity, diversity, and inclusion to our transportation planning practices to avoid detrimental planning and building of infrastructure in communities across the country. For example, in Denver, Colorado, two majority Hispanic neighborhoods—Globeville and Elyria Swansea—were built out with industrial operations that provided jobs but also produced negative environmental impacts on air quality, water, and soil. The construction of Interstates 70 and 25 in the 1960s restricted physical access to the neighborhoods and contributed to air quality and health issues. At the time, little consideration was given to the health problems associated with such development. Now, as we learn more about social justice and healthy community planning, it is imperative that we correct past mistakes.

—NATALIE STIFFLER
Deputy Director of Transportation and Mobility
City of Boulder, Colorado

Mike Emery, University of Arkansas, Fayetteville

Pavement Maintenance and Rehabilitation

Teaching the Next Generation

ANDREW BRAHAM

The author is an associate professor of civil engineering at the University of Arkansas, Fayetteville.

Above: Students take in the details as the author teaches Sustainability in Civil Engineering, the senior-level technical elective course he developed at the University of Arkansas, Fayetteville.

Inspired by a 2018 presentation by Lindsay Matush, founder and CEO of Vario Consulting, at the Asphalt Emulsion Manufacturers Association/International Slurry Surfacing Association/Asphalt Recycling and Reclaiming Association Annual Meeting, I developed a semester-long, senior-level course project based on RoadResource.org. Students love interactive resources, and this website provided a wealth of information to explore the concepts behind pavement preservation.

Four assignments related to the project are included during the semester, and—in all—they are 20 percent of the course grade. The class is split into groups of three, and each group is assigned one maintenance treatment and one rehabilitation treatment out of the 18 treatments included on the website. At least one group covers all 18 treatments, but some of the more common treatments—such as chip seals and cold in-place recycling—are assigned to more than one group. Throughout the project, I emphasize that no one treatment should ever be used on an entire network, but performing the academic exercise is useful in order to see the power of each treatment. Once the groups are established, each assignment leverages one of the four interactive calculators on RoadResource.org to compare the treatments so that students get a feel for the difference between maintenance and rehabilitation. These calculators display equivalent annualized costs, life-cycle costs, remaining service life, and the cost–benefit value of each treatment. In addition, a group of students explores a mill-and-fill and a complete removing-and-replacing operation, two common treatments that state agencies use.

For the classroom project, actual Arkansas Department of Transportation (DOT) data are leveraged. Students use the roughly 16,300-mile network of freeways, multilane highways, and two-lane highways, as well as Arkansas DOT's traffic and budget numbers. Since the class is divided into groups, all of the RoadResource.org treatments are explored and, after each assignment, a summary of the class's findings is shown. Each group uses Arkansas DOT's complete maintenance and rehabilitation budget on each of its treatments over a 50-year analysis period, applying the nationwide default costs and life extensions

Andrew Braham, University of Arkansas, Fayetteville

In rural New York State, about a half-mile stretch of the United States' 2.9 million miles of paved road undergoes a preservation treatment. The structurally sound existing road (*at left*) has been fully cleaned and crack sealed. On the right, freshly placed slurry seal fills in small cracks and surface imperfections.

found on RoadResource.org. For example, the third assignment looks at the remaining service life calculator, which provides the number of lane-mile years gained or lost for each treatment. Lane-miles are a great unit to help illustrate how individual projects can affect a network. For example, if one lane-mile of road has no work done on it, the network loses one lane-mile. However, if one-lane mile of road has a fog seal that is anticipated to last three years, the network gains two lane-miles. Figure 1 shows the results from the fall 2020 class.

After the class completes the third assignment, students look at both graphs in Figure 1 and can immediately see two things: First, since they each looked at one maintenance and one rehabilitation treatment, they have a sense of how much more effective pavement maintenance is versus pavement rehabilitation. Because the budget is fixed, lower cost treatments can be applied more frequently than the more expensive treatments. Second, even though they only looked at two treatments, they not only have a sense of the behavior of their treatments but also of the other treatments.

During the last week of the course, pavement preservation, pavement maintenance, and pavement rehabilitation become the focus of classroom discussion in the last two lectures. For these lectures, the "flipped classroom" idea—in which students learn the basics of a concept before entering the classroom so that actual classroom time is spent looking deeper into the concept—is introduced. Since the students already know about pavement preservation, pavement maintenance, and pavement rehabilitation from the semester-long project, they can explore the benefits of each treatment more quickly and learn how using the treatments as a collection can leverage the highest benefits for an agency.

To explore the use of this project in your classroom, contact Andrew Braham at afbraham@uark.edu.

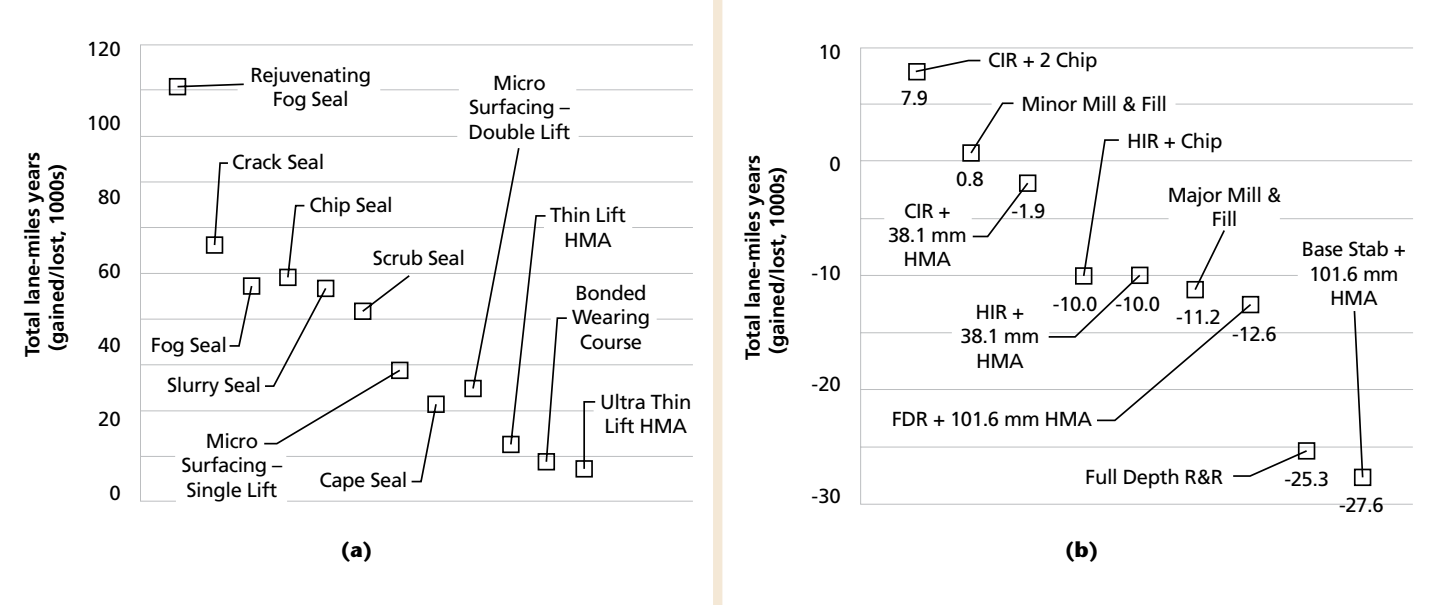


FIGURE 1 Total lane-mile years of (*a*) maintenance and (*b*) rehabilitation treatments over a 50-year analysis period (HMA = hot-mix asphalt; CIR = cold in-place recycling; HIR = hot in-place recycling; R&R = removing and replacing).

Implementing Pavement Preservation

A Case Example in Raleigh, North Carolina

North Carolina DOT, Flickr

CHRIS MCGEE, TRACY PILSON, AND CAROLINE DICKEY

McGee is city manager for Havelock, North Carolina. Pilson is a pavement management engineer, and Dickey is an asset management engineer with Mott MacDonald in Raleigh, North Carolina.

Above: Raleigh, North Carolina, shimmers at dusk near McDowell Street (NC-50/US-401). The skyline is not the only asset shown here—the roadway is an asset, as well. A poorly maintained road network would detract from the appeal of the city.

Raleigh, the capital of North Carolina, has a 2020 Census population of 467,665 people and is the second most populous city in North Carolina.[1] Census projections for 2022 list Raleigh as the 40th most populous city in the country. It often appears on annual lists of the fastest growing cities in America.

The City of Raleigh Transportation Department maintains a network of approximately 1,120 centerline miles of roadway. Typical average daily traffic on individual streets ranges from 200 to 40,000 vehicles per day, depending on street classification. The city's predominant pavement surface type is asphalt, and it has an estimated total replacement cost of more than $700 million.

[1] For more information, see https://www.census.gov/quickfacts/raleighcitynorthcarolina.

Transitioning to New Tools, Metrics, and Methods

In the past, Raleigh determined the condition of roads using a visual rating methodology developed 40 years ago by North Carolina State University's Institute for Transportation and Research Education. Additionally, the city's maintenance program was limited to a one-inch to two-inch mill and overlay resurfacing program and patching activities (full-depth patching and mill patching). Project selection was determined using a worst-first approach—meaning that the roads in the worst condition were fixed first.

In 2018, Raleigh undertook an effort to implement a comprehensive program that would better manage the roadway network. The goal was to maximize improvement of the city's roads with the limited funding available. As part of this effort, Raleigh hired an engineering, management, and development consultant to implement a pavement management system. In addition,

Raleigh developed a comprehensive plan to transition from visual to automated data collection of pavement distresses. The plan also included a shift to crack density as one of the primary pavement metrics to determine treatment decisions. At the same time, Raleigh wanted to expand its treatment toolbox to include more maintenance and pavement preservation alternatives to maximize limited available funding. The treatments recommended by the project team included chip seal, fog seal, crack pour, rejuvenators, localized patching, and thin lift overlays.

A New Approach

Raleigh was one of the first local government entities to implement the use of the crack density pavement metric in their data collection. Crack density is a relatively new distress collection methodology that measures the total crack length per unit area. As part of their transition to automated data collection and the implementation of the crack density methodology, the city developed a comprehensive data quality management plan and a data dictionary. To ensure that potential vendors understood what Raleigh expected as a final product, the data dictionary and data quality management plan were included in the city's request for proposals package that would result in awarding the work to an automated data collection vendor. Some of the specifications that the vendor needed to meet included the following:

- Management sections had to be divided into two-meter (6.5-foot) segments;
- Each segment had five transverse zones per lane (two wheelpath zones, two zones outside the wheelpaths, and the center zone);
- Crack density data were collected separately for each zone per two-meter segment;
- Five control sections were used for calibration and testing before and during the data collection period; and
- Initial calibration for crack density included a comprehensive quality assurance program to ensure that good quality data were collected.

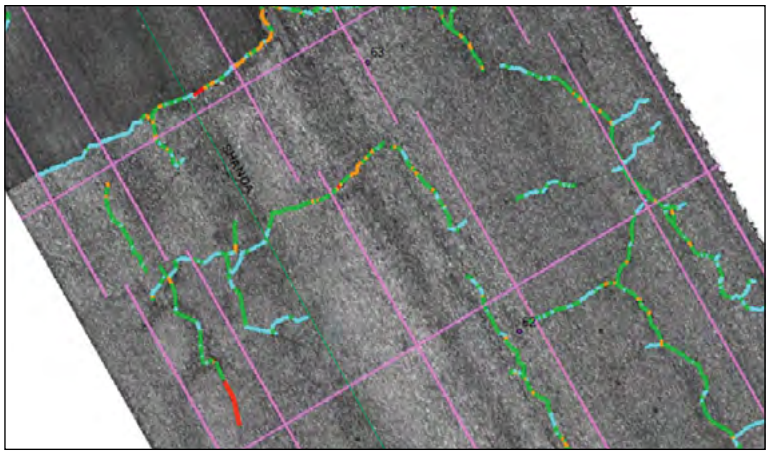


FIGURE 1 The crack density distress collection methodology measures total crack length per unit area using laser images produced by an automated data collection van.

The implementation of crack density as the key metric for treatment decisions and transitioning to automated data collection eliminated subjectivity from the pavement evaluation process. Subsequently, the crack density data collection methodology has been expanded and formalized in ASTM E3303–21, Standard Practice for Generating Pavement Surface Cracking Indices from Digital Images, which was informed by the Raleigh project. The city's crack density measurements have proven to be 90 percent accurate and 90 percent repeatable over the data collection cycle.

Pavement Preservation Benefits

Raleigh's transportation leaders recognized that a worst-first approach to maintenance is the least economical approach—while spending funds on the worst roadways, the part of the network that is in good condition is allowed to deteriorate until it is in fair or poor condition. Raleigh's transportation leaders strongly believed that preventive maintenance and pavement preservation were the basis of a superior philosophy.

Raleigh's highly configurable pavement management system combines novel and sophisticated data collection methods to provide optimized use of treatment alternatives in the annual paving program. As a result, the city has implemented a treatment plan that relies heavily on pavement preservation. The key to a successful pavement preservation program is to select streets that are the right candidates for preservation. One challenge: Because of a city ordinance, streets without curbs and gutters do not qualify for the pavement preservation program. Approximately 10 percent of Raleigh's streets fall into this category and require additional consideration of treatment decisions.

Tracy Pilson, Mott MacDonald

In Raleigh, this automated data collection van gathers and records cracking data with the aid of a laser system.

Tracy Pilson, Mott MacDonald

Marking the endpoints of the calibration sections for the automated data collection survey is a necessary part of the process. The calibration sections in Raleigh were selected to represent different types of cracking and the extent of cracking.

The project team configured the pavement management system to examine different funding scenarios and treatment alternatives, providing Raleigh with optimized work plans to help preserve the condition of the network. The city's expanded comprehensive pavement management program maximizes the impact of the annual budget to the overall system condition. The pavement management program now consists of multiple approaches, including low-cost and economical preventive maintenance and preservation treatments, moderate expenditures on mill and overlay, and a reconstruction component for streets falling below specific thresholds.

To free up more funds for their preservation program, the city plans to pursue a bond for full-depth reclamation and reconstruction projects. These types of projects take up most available resources if funded from annual maintenance budgets and result in very few lane-miles of treated roads. Once those streets are returned to good condition, the pavement preservation plan will keep them in good condition longer.

Raleigh is realizing many positive impacts and benefits from their pavement preservation program. The economic nature of preservation treatments provides an improved level of service for the same budget levels. The improved aesthetics and ride quality of well-maintained streets provide satisfaction to the traveling public. Some positive environmental benefits may be realized from improved travel times on better-maintained roads and fewer road closures due to major rehabilitation projects. In addition, the city implemented a pilot project to use a titanium dioxide additive in their pavement rejuvenation process to reduce nitrous oxide and carbon monoxide from auto emissions and improve solar reflectivity. The project won a Cleantech Impact Award for Transportation from the Research Triangle Cleantech Cluster, a North Carolina industry initiative of business, government, academic, and nonprofit leaders.

Stretching Resources to Pave the Future

Of the many challenges facing municipal government departments managing roadway networks, a shortage of resources is the most obvious. Even with Raleigh's implementation of a comprehensive pavement management strategy, current levels of funding continue to yield a decline in the overall health of the system.

However, the use of the pavement management system, current best practice automated data collection, and a comprehensive pavement preservation program have significantly reduced the rate of decline of the pavement network. Prior to implementation of this comprehensive strategy, the network was losing 2.0 to 2.5 points per year in pavement condition on a scale of 1.0 to 100. According to the predictions from the pavement management system, this rate has experienced a significant reduction to 1.5 points per year. Most importantly, a one-point change in overall network condition represents $8 million to $9 million in the value of this asset. An important feature of the new program and its associated predictive modeling is the ability to show the savings over the previous strategy, as well as the need for additional funding.

Pavement preservation in Raleigh provides a blueprint for other municipalities looking for ways to maintain their roads in good condition while stretching funding. Applying low-cost preservation treatments to roads in good condition helps slow the deterioration of roadways and minimizes the loss of value that occurs when an increasing percentage of a pavement network falls into poor condition.

Raleigh's transportation leaders strongly believed that preventive maintenance and pavement preservation were the basis of a superior philosophy.

Maintenance and Longevity of Longitudinal Joints

John Senger, Illinois DOT

LARRY GALEHOUSE AND LARRY SCOFIELD

Galehouse is the founder of the National Center for Pavement Preservation at Michigan State University in Okemos, Michigan; and Scofield is director of Pavement Innovation at the American Concrete Pavement Association and director of Engineering and Research at the International Grooving and Grinding Association in Mesa, Arizona.

Above: Since completing a successful micro surfacing project, the Minnesota Department of Transportation has used the treatment—a mixture of water, asphalt emulsion, aggregate, and chemical additives applied to an existing composite pavement surface—to maintain and preserve longitudinal joints along other roadways. Years of project evaluations have led to better ways of slowing deterioration of U.S. roads, like this centerline and fog line joint maintenance project on Interstate 77 in Jackson County, West Virginia.

Many highway agencies have discovered that significant safety issues often occur when longitudinal pavement joints deteriorate. This deterioration can appear in both asphalt and concrete pavements and is typically visible at longitudinal lane joints and shoulder joints (Figure 1).

Joint deterioration in asphalt pavements is a consequence of improper bonding of a new mix to the adjacent pavement surface or the result of lower densities at the joint due to poor compaction during paving. The lower density results in higher air-void levels at the joint, leaving it permeable and susceptible to the intrusion of water that accelerates deterioration. In time,

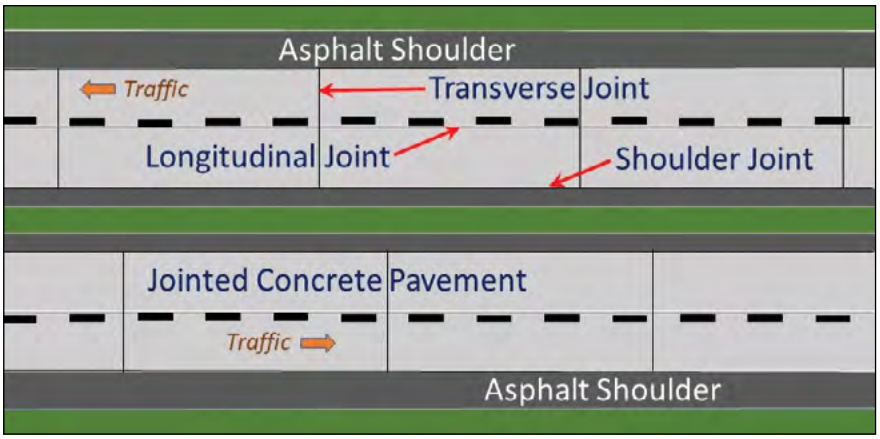


FIGURE 1 Typical pavement joint configuration.

the joint tends to ravel under traffic and material is then lost.

Generally, infiltration of surface water into the pavement structure at traverse and longitudinal joints is the cause of concrete pavement deterioration. Filling joints with an engineered sealant will eliminate the intrusion of water and reduce the potential of future pavement degradation.

When the longitudinal joint deterioration is unattended, a potential hazard can develop. Loose pavement material from the joint will eventually find its way onto the travel lanes, leading to possible vehicle damage from flying debris and injury risks to motorcyclists. Severely deteriorated joints present an even greater risk for motorcycles and small vehicles when changing lanes. Their narrow tires drop into the open joint, causing a momentary loss of control and greater potential for a serious accident. Therefore, it is important not only to maintain longitudinal joints but also to design longitudinal joints to have a long service life.

Background on Longitudinal Joint Maintenance

Every highway agency has a mission to save lives, prevent injuries, and reduce economic costs due to accidents. When the Minnesota Department of Transportation (DOT) faced serious deterioration of longitudinal joints on a major highway, maintenance forces needed to find a quick and cost-effective solution. In the past, they tried different patching methods without success. These approaches were expensive, left a poor driving surface, and deteriorated rapidly under heavy traffic.

Interstate 494 is an urban freeway in Minneapolis that consists of three to four lanes in each direction, with average daily traffic between 140,000 to 150,000 vehicles. The extremely high average daily traffic limited Minnesota DOT from performing most repair options, since they would endanger maintenance personnel. Longitudinal joint deterioration was evident throughout both directions of the 5.3-mile section, with some areas exhibiting joints that had opened as much as three inches wide and four inches deep.

Minnesota DOT

Before repair, the ride was rough—and potentially dangerous—along a stretch of Interstate 35 in Minnesota, where, in some spots, cracks along longitudinal joints were inches deep and several inches wide.

The freeway is like many urban composite pavements seen today: an older concrete pavement covered with numerous hot-mix asphalt overlays. The most recent overlay was a 1.5-inch-thick Superpave® mix using a PG (performance grade) 64-28 binder.

Approach to Longitudinal Joint Maintenance

The Minnesota DOT Metro District worked closely with Tom Wood and Paul Nolan of the Minnesota DOT Office of Materials to consider several possible solutions to the joint deterioration on I-494. In identifying solutions, the group was constrained by available funding and the need to minimize traffic disruptions. They discussed milling the joint one foot wide and four inches deep, tacking the milled area, and filling the joint with hot-mix asphalt. Contractor estimates varied from $4.83 to $9.66 per linear foot, which exceeded the planned budget. They then decided to try micro surfacing technology to fill the joints and leave a smooth durable surface. A St. Joseph, Minnesota, company was awarded the project contract.

Together, they devised a plan to apply micro surfacing over two longitudinal lane joints and a shoulder joint, with each application totaling more than 28,000 feet in length. The entire project in both directions totaled nearly 167,000 linear feet of needed repair. The quantity of micro surfacing to fill the joints was estimated at 2.5 pounds per linear foot. The micro surfacing used International Slurry Surfacing Association Type II gradation, containing granite from a St. Cloud quarry. The haul distance to the job site was more than 80 miles, which increased the trucking delivery cost.

The project mix design called for 13 percent Ralumac micro surfacing emulsion and 1 percent portland cement.

Field Implementation of Longitudinal Joint Maintenance

Due to high traffic volume, the contractor's daily work window was restricted to six hours, which began at 11 p.m. and ended at 5 a.m. In addition, the Metro District stipulated that no more than two lanes could be closed at any time.

The contractor fabricated a rut-filling spreader box to accommodate the narrow placement width of two feet. The spreader box was fitted with flexible seals on the sides to control the mixture application and a rear adjustable strike-off plate that allowed the operator to feather the mixture to align with the existing pavement cross-section. Crews removed loose debris from the longitudinal joints by using compressed air before the micro surfacing operation began.

The entire project was finished in six nights, and Minnesota DOT received many positive comments about the smooth ride. Maintenance crews installed new permanent pavement markings one week after completing joint filling. Public comments regarding the increased visibility of new white markings over the black micro surfacing also were positive.

Minnesota DOT

Creative engineering came into play when contractors fabricated a spreader box to distribute the micro surfacing mixture on Interstate 494.

Minnesota DOT

Repaired and ready for white paint, the fog line joint (*at left*) marks the boundary between the shoulder and the legally driveable road surface. Open to traffic after less than a week of undergoing maintenance, the finished section of Interstate 494 offered motorists a much smoother ride.

Conclusions on Longitudinal Joint Maintenance

The final yield of micro surfacing was 3.6 pounds per linear foot, surpassing the original estimate of 2.5 pounds per linear foot. The final project cost of micro surfacing was $.50 per linear foot.

The use of micro surfacing to fill the deteriorated joints proved to be a cost-effective, durable treatment that is performing well under high traffic volumes. After three years, the micro surfacing was performing well with only a few small cracks appearing where transverse joints intersected with longitudinal joints. Due to the successful outcome of the I-494 project, Minnesota DOT maintenance forces are continuing to use micro surfacing in other locations to repair deteriorated longitudinal joints.

As discussed before, just as it is important to maintain longitudinal joints in asphalt pavement, it is important to design them to last a long time. The following case examples explore how to establish concrete pavement joint sealant longevity.

Minnesota DOT

Interstate 94 near St. Cloud is one of several Minnesota roadways benefiting from micro surfacing as a practical—and affordable—solution for deteriorating longitudinal joints.

Background on Joint Sealant Longevity

The processes for sealing and resealing concrete pavements are the same, except the latter requires removal of the existing sealants. As such, performance of either type of sealant installation can be evaluated in the same manner. The following case examples in Arizona, Washington State, and Illinois demonstrate the benefits of

establishing field-test sections in selected locations to define sealant performance.

Sealant test sections are relatively easy and inexpensive to install on construction projects or with maintenance forces. The most difficult aspect is documenting the necessary performance factors and maintaining the data and evaluations over a long time. Placement of sealant test sections in selected areas that represent different climate, traffic, and aggregate conditions can significantly benefit the selection of material types and joint design. The case examples also illustrate this concept.

Arizona LTPP SPS-2 20-Year Sealant Evaluation

The SHRP Long-Term Pavement Performance (LTPP) program Strategic Pavement Study 2 (SPS-2) experiment, *Strategic Study of Structural Factors of Jointed Plain Concrete Pavements*, consisted of constructing 12 test sections in each of 14 selected states in a designed experiment between 1992 and 2000. The FHWA LTPP has continued to evaluate these test sections to this day. It is the largest and longest monitored concrete pavement research ever conducted.

The takeaway from the Arizona SPS-2 experiment is that silicone joint sealant had exceptional performance and lasted more than 20 years with no maintenance. At the other SPS-2 locations, the silicone sealant was not as effective and did not have as significant a life span. This suggests that the best information for a particular location may not be the range of results found on the overall SPS-2 experiment (or the average life), but rather determined in specific areas where the same aggregate, mix designs, construction procedures, and so on are used (*1*).

Larry Scofield, IGGA/ACPA

Standing up to the test of time—and daily use, the silicon joint sealant applied during the Arizona SPS-2 experiment has lasted more than 20 years without maintenance.

Fairchild Air Force Base, Washington, 21-Year Sealant Evaluation

In 1989, the U.S. Army's Construction Productivity Advancement Research Program constructed a joint sealant experiment at Fairchild Air Force Base in Washington State. It was evaluated for 10 years.

Many years after the final report, researchers conducted another evaluation and reported the results at the 2013 Transportation Research Board Annual Meeting (*2*). Two important findings resulted from this 21-year evaluation: First, joints flush-filled with hot-pour sealants (i.e., filled until flush with the pavement surface) had about twice the service life as the recessed installations with the same sealant. Second, one of the sections exhibited moisture bubbles in the hot pour during installation. This occurs if moisture is present when installing the hot-pour sealant; the water vaporizes and rises to the surface, resulting in small cavities or bubbles in the surface. Typically, this condition is a construction problem, but it is difficult to avoid in high-humidity environments. However, after 21 years in service the hot pour with bubbles was still performing well.

Larry Scofield, IGGA/ACPA

During the hot-pour sealant installation at Washington's Fairchild Air Force Base, moisture bubbles formed in the mix. Still, after 21 years, the sealant performed well.

Illinois SR-59 Joint Sealant Experiment

In 2009, a new concrete pavement roadway was constructed on SR-59 in Cook County. Nine test sections were constructed to evaluate the impact of transverse joint sealant width and material type on sealant performance. Silicone and hot-pour materials were installed in both a narrow (0.2-inch) and standard (0.375-inch) width joint configuration. To achieve this, contraction joints are sawed into concrete pavement to control the location of shrinkage cracking. Often, these joints are widened to allow installation of joint sealants. The pavement structural section consisted of a dowelled 9.75-inch-thick jointed plain concrete pavement on a 12-inch-thick aggregate base with 15-foot joint spacing. Researchers then conducted three evaluations of the test sections.

The first evaluation in 2010 established the range of transverse joint widths, creating a baseline for comparing future sealant and pavement performance to joint width and movement (*3*). Most specifications require a single joint width, but many factors affect the final opening width. Often, every third to fifth joint opens significantly wider and exhibits more problematic sealant performance.

The second evaluation—conducted in 2013—was a visual determination of sealant performance and baseline pavement performance (*4*). Researchers removed sealant samples to determine the installed sealant shape factors that are width-to-depth ratio. For example, if the sealant thickness in the joint is twice as large as the width of the joint, it has a shape factor of 0.5. Conversely, if the sealant thickness is half as large as the width of the joint, then the shape factor is 2. Researchers compared joint opening widths to those obtained in 2010 and noted that joint opening widths increased between May 2010 and September 2013 from approximately .04 inch to .09 inch. Temperatures ranged from 75°F to 90°F in the 2010 test and from 53°F to 75°F in the 2013 test.

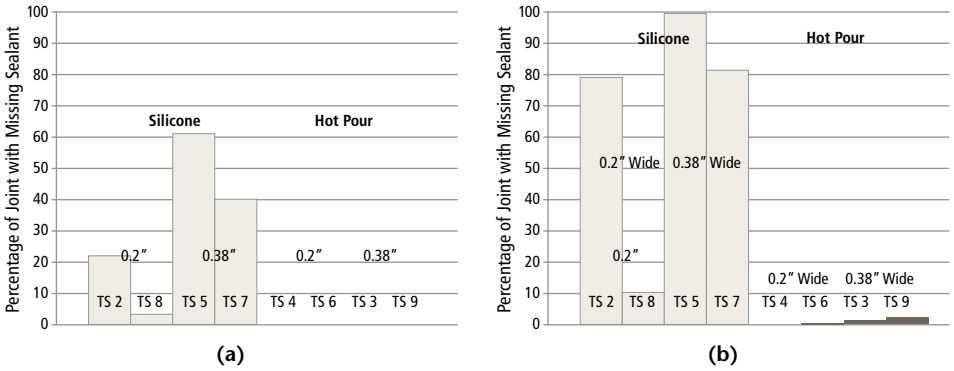


FIGURE 2 **Percentage of joint sealant missing from transverse joint with (*a*) 2013 and (*b*) 2021 data (TS = test section).**

The third evaluation took place in 2021 and was a visual assessment of the percentage of missing sealant (i.e., sealant loss) (*5*). Although not a research-level evaluation, some interesting findings regarding shape factor were discovered.

Figure 2 presents the results from the 2013 and 2021 visual assessments of missing sealant. The 2013 results indicate that material type was already a factor in performance. That is, hot-pour sealant was outperforming silicone sealant after just four years in service. The silicone sections indicated the effect of joint width, specifically that the narrow joint width was outperforming the wider joint width. The value of having replicate test sections also was evident, as Test Section 2 and Test Section 8 were performing differently but should have had similar performance.

The 2021 test results continue to support the 2013 test conclusions: Hot-pour sealants significantly outperformed silicone sealants. Narrow width joints outperformed wider width joints, and Test Section 2 and Test Section 8 exhibited even larger performance disparities.

Sealant shape factor had a dominant impact on sealant performance at this location but opposite that of conventional wisdom where sealants placed with shape factors of less than 1 should not perform.

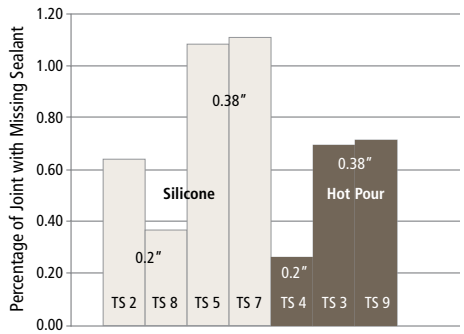


FIGURE 3 **Shape factor of test section sealant installations.**

However, as indicated in Figure 3, the narrow sealant installations had the worst shape factor by far, yet the best performance. This is true for hot pour, as well as silicone installations.

One explanation for this is the possible impact of vertical forces on the sealant surface. For silicone sealants, a flush-filled condition will fail quickly in the wheelpaths due to contact with tires. This is why silicone sealant should be installed in a recessed condition. In situations that involve snow, ice, or high rainfall, vertical forces also may be transferred to the sealant surface through snow and ice or hydrostatic pressures beneath the tire. If this assumption is true, there may be an optimum shape factor for these conditions, and it may favor narrow joints—the opposite of conventional wisdom on shape factor.

Recommendations and Conclusions for Sealing Jointed Plain Concrete Pavement

Case examples have shown how construction of sealant test sections can and should be used to establish sealant performance and to select the sealant types and joint configurations for new installation and resealing strategies. Through evaluation of these cases, several important points were established:

- Long-life joint sealants are possible (Arizona SPS-2 and Fairchild Air Force Base).
- Test section construction is the most effective means of establishing project sealant performance (i.e., case examples).
- Although research-grade sealant test section construction and evaluation are recommended, researchers demonstrated that more-limited studies also can provide useful results (SR-59).
- The success of field sealant performance may not coincide with conventional wisdom (SR-59).

REFERENCES

1. Evans, L. Arizona SPS-2 PCC Joint Seal Performance. Technical Memorandum, Applied Research Associates, Seal/No Seal Group, 2013.
2. Lynch, L., J. G. Chehovits, D. G. Luders, and M. Belangie. Joint Resealing Project at Fairchild Air Force Base, Washington: Twenty-One-Year Field Performance. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2361, 2013, pp. 98–105. https://doi.org/10.3141/2361-12.
3. Scofield, L. *SR59 SB Roadway Joint Sealant Experiment: Sealant Effectiveness Study*. Seal/No Seal Group, June 2010.
4. Scofield, L. *Sealant Test Section Evaluation Report*. Seal/No Seal Group, 2013.
5. Scofield, L. *Sealant Test Section Evaluation Report*. Seal/No Seal Group, 2021.

Just as it is important to maintain longitudinal joints in asphalt pavement, it is important to design them to last a long time.

Pavement Rehabilitation

Case Examples from Missouri and Virginia

Courtesy of D. Allen Covey, Virginia DOT

TRENTON CLARK, TOMMY E. NANTUNG, KURT SMITH, AND RICHARD WILLIS

Clark is president of the Virginia Asphalt Association in Richmond; Nantung is a pavement, materials, and construction research manager at the Indiana Department of Transportation in West Lafayette; Smith is a program director at Applied Pavement Technology in Urbana, Illinois; and Willis is vice president for engineering, research, and technology at the National Asphalt Pavement Association in Lanham, Maryland.

Above: Roadwork is disruptive. How can transportation agencies keep roads—ranging from winding scenic routes to major highways or evacuation routes—in good condition? As pavement rehabilitation projects—like this one in Virginia—age well, what was once new thinking may offer options that are longer lasting.

In the last 20 years, refinements to pavement rehabilitation techniques have been introduced by the construction industry and transportation agencies to better address challenges—such as cost, timeliness, and durability—that those agencies face. Each pavement rehabilitation strategy, either by resurfacing, reuse, or materials specialization, will have advantages and disadvantages in terms of initial construction and overall life-cycle cost, construction timeline, complexity of construction, design life, and pretreatment requirements for the existing pavement. The roadway classification of the pavement is important in the selection of a rehabilitation strategy because interstate highways, which serve as an economic lifeline for cities, states, and the nation, will require pavements that are longer lasting and more robust.

Pavement rehabilitation strategies are specific to the existing pavement structures and project constraints. For example, the type of pavement—rigid or flexible—will dictate a range of options for consideration, as will subsequent surface treatments applied to those pavements over the years. The current pavement condition and available resources to address specific rehabilitation requirements need to be thoroughly explored, reviewed, and analyzed. By conducting a detailed analysis of pavement rehabilitation selection options (with proper scoring and weights), a transportation agency often may choose one or more specific surface treatment or pavement rehabilitation strategies that will meet its cost and performance expectations.

The pavement rehabilitation case examples that follow feature two unique pavement rehabilitation solutions that were selected based on the expectations of the pavement facilities owners.

Thin Unbonded Concrete Overlay over Existing Concrete Rehabilitation

Advancements in concrete pavement overlay design and construction practices have accelerated in the last 20 years.

There are two options for the placement of concrete overlays over existing concrete pavements: bonded or unbonded. The option selected depends on how the pavement is designed to accommodate future traffic loads. Bonded concrete overlays will increase the structural capacity of the existing pavement and eliminate the distresses of the existing pavement by bonding to the existing concrete pavement. Unbonded concrete overlay will restore the structural capacity of moderately and significantly deteriorated existing concrete pavement by adding the overlay without bonding to the existing concrete pavement using a separator layer. For constructability reasons, the popular option is unbonded concrete overlay, which can be used on existing concrete pavements in virtually any condition and is designed to accommodate any level of traffic loading—as long as it is structurally adequate and economical.

A major geometric design limitation to any type of thicker overlay placed on an existing surface is the degree to which the subsequent higher roadway level impacts bridge and sign clearances, guardrail heights, slope grading, and transitions back to original pavement elevation. State transportation agencies must be aware of this problematic design issue, which can impact the clearance of overpasses and the associated signage that alerts motorists to height restrictions, as well as the height of adjacent roadway guardrails. These issues must be resolved during project scoping to select the right rehabilitation option and minimize project cost.

NONWOVEN GEOTEXTILE INTERLAYER REDUCES THICKNESS

One innovative technique employed to resolve the issue of pavement elevation uses a nonwoven geotextile layer as a separator layer. This replaces the more commonly used asphalt interlayer between the new overlay and the existing concrete pavement. Originally implemented in Germany to reduce pavement-curling stress by adding a cushioning effect from the 0.2-inch (5-millimeter) geotextile, this technique also reduces the thickness of the interlayer and total overlay thickness.

The first project in the United States to implement a nonwoven geotextile in an unbonded concrete overlay was a section of Route D between Route 150 and Route 58, south of Kansas City, Missouri. The original pavement structure of this nearly three-mile roadway was built in 1986 and featured a two-lane, eight-inch jointed plain concrete pavement with 30-foot transverse joints containing one-inch-diameter dowel bars. The current traffic level on this route is 9,900 average daily vehicles, of which 7 percent are trucks. In 2008, the pavement was exhibiting severe durability cracks (known as D cracking) in both transverse and longitudinal joints.

The Missouri Department of Transportation (DOT) explored several rehabilitation

Missouri DOT

The condition of the pavement (*top left*) on Route D, south of Kansas City, Missouri, prior to placement of the unbonded concrete overlay reveals existing concrete joint deterioration. Proper preparation means the nonwoven geotextile interlayer (*top right*) has been laid down and secured at six-foot intervals. After this process is completed, it is sprayed with water before placement of the concrete overlay on the nonwoven geotextile interlayer. Ten years after placement of the geotextile interlayer and concrete overlay, the roadway (*above*) is still in good condition and this specific choice of rehabilitation treatment is on track to exceed its expected life.

options to structurally maintain the ability of the current roadway pavement to accommodate future traffic and to restore ride quality. Missouri DOT estimated that approximately 25 percent of the pavement surface area needed full-depth repair prior to pavement rehabilitation. After discussions between Missouri DOT and industry, an alternate solution employing a thin unbonded concrete overlay with a nonwoven geotextile interlayer was selected. The concrete overlay was five inches thick and featured the use of six-foot-by-six-foot panels without dowel bars or reinforcing steel.

The nonwoven geotextile interlayer provided the following three benefits:

- Prevented the concrete overlay from bonding to the existing concrete pavement, which could have resulted in reflective cracks;
- Channeled the infiltrating moisture through the interlayer to the shoulder edge; and
- Reduced the effects of bearing stresses and dynamic loads.

The geotextile was specified to have a mass per unit area between 13.3 and 16.2 ounces per square yard. It also needed to meet several requirements for thickness under load, tensile strength, maximum elongation, water permeability, weather, and alkali resistance.

EXPECTATIONS AND IMPLEMENTATION

Since this was an experimental test section with a new rehabilitation option, the expectation from Missouri DOT was to meet a service life of 15 years before requiring rehabilitation. The performance of the concrete overlay was reviewed periodically to document the progress of any deterioration.

Pre-overlay repair costs of the pavement joints were minimized by allowing the contractor to use a cementitious sand grout slurry to fill surface voids, without extensive preparation other than removal of loose patch material. The desired result was simply to have a smooth, stable surface with an overlay that would not lock into the existing pavement and restrict movement of the underlying slabs. High pre-overlay repair costs could have tipped the balance when choosing between a pavement rehabilitation option and new reconstruction.

After patching, the existing concrete surface was swept clean before geotextile interlayer placement. Where separate fabric rolls met, two geotextile sheets overlapped each other for eight inches. Extra care was made to avoid creating wrinkles. Securing the fabric was accomplished by fastening the material with nails and two-inch galvanized washers at a maximum spacing of six feet between nails. Construction traffic on the fastened fabric was limited to essential activities until the concrete overlay was placed. Prior to placing the concrete overlay, the fabric was dampened—but not saturated—to ensure that it would not absorb moisture from the concrete mix. Placement of the overlay followed conventional concrete overlay practice. Finally, the overlay was sawed into six-foot-by-six-foot panels.

DID THIS TREATMENT HOLD UP?

After 10 years in service, the experimental test section was reviewed in May 2018 by conducting a visual distress survey and measurement of the pavement roughness. Out of 9,828 panels, 192 had cracked or spalled. This is a failure rate of 1.95 percent in 10 years of service, which was categorically determined to be very low. Most of the failure was located within 600 feet of the northern transition to the existing intersection at Route 150. The pavement's international roughness index (IRI) was 88 inches per mile, which indicates that the overlay is still in excellent condition. For comparison, a condition of full payment in most state DOT specifications is an IRI of 70 inches per mile for new pavement smoothness and the maximum IRI before imposing any new pavement surface corrective action is 90 inches per mile. The IRI value of 88 inches per mile after 10 years of service is still far below the threshold value of 200 inches per mile that would trigger pavement rehabilitation for a state route–pavement classification. With such a low IRI value and very limited cracking after 10 years, Missouri DOT anticipates that this experimental pavement section will exceed its expected 15-year service life. Considering the extremely distressed state of the original pavement due to durability cracks, the nonwoven geotextile applied has proven to be an effective interlayer for this concrete overlay design.

Asphalt Overlay over Existing Concrete Rehabilitation

Since the 1990s, the Virginia DOT has wanted to increase the capacity of Interstate 64 between Richmond and the Hampton Roads region. This section of I-64 is a heavy tourist route heading eastbound toward Virginia's beaches. In the westbound direction, it is a hurricane evacuation route for the Tidewater region. Nearly 54 miles long from the I-295 interchange to milepost 253.6, the roadway was primarily constructed with continuously reinforced concrete pavement and jointed reinforced concrete pavement. By 2010, all but approximately 18 miles had been maintained with asphalt overlays to provide a functional driving surface. Unfortunately, funding was not available to add the lanes needed to increase capacity or to replace the aging pavement.

In 2013, Virginia's state government signed into law a bill that provided new statewide transportation funding and established regional transportation authorities. As a result, the Hampton Roads Transportation Accountability Commission (HRTAC) was established in the Tidewater area. The commission was given the authority to assess and collect taxes to improve the region's transportation system. One of their main projects was the widening of I-64 west of the city of Hampton toward Williamsburg (Figure 1).

The I-64 widening projects identified by HRTAC and Virginia DOT were divided into three segments. Segment 1 was a concrete pavement rehabilitation project with capacity expansion. Segments 2 and 3 were pavement reconstruction and capacity expansion projects. For all three segments, the roadway was expanded from two to three lanes in each direction.

FIGURE 1 Map of the staged plan for I-64 peninsula widening. (Courtesy of Virginia DOT)

PROJECT DEFINITION AND IMPLEMENTATION

Segment 1 was located just east of Exit 247 to milepost 253.6 in the eastbound direction and milepost 254.3 in the westbound direction, where the roadway transitioned from a four-lane section to an eight-lane section in the city of Newport News. Initially, the mainline was constructed in 1965 as a nine-inch jointed reinforced concrete pavement slab on a three-inch to four-inch granular base over a cement-stabilized soil subbase. The shoulders were asphalt concrete ranging from two to five inches thick with a variable depth aggregate base layer. To maintain the structural and functional performance of the pavement, Virginia DOT previously conducted several patching and grinding operations—most recent projects were completed from 2006 to 2007. As part of these concrete pavement restoration projects, longitudinal underdrains were installed to improve drainage and reduce the potential for joint faulting (i.e., one slab being higher or lower than the adjacent slab). The installations also were intended to reduce corner void development and breaking that result from a loss of subbase support.

TABLE 1 Virginia DOT Rating Criteria

Rating	CCI	IRI (in/mi)
Excellent	≥90	<60
Good	70 to 89	60 to 99
Fair	60 to 69	100 to 139
Poor	50 to 59	140 to 199
Very Poor	<50	≥200

NOTE: CCI = critical condition index.

After seven to eight years of service, the existing pavement was again experiencing joint and slab failures. The ride quality had deteriorated to "fair" (Table 1) where the IRI averaged 117 in the eastbound direction and 110 in the westbound direction. This is above the maximum ride-quality threshold of 110 set in the 2006 to 2007 project designs. Virginia DOT hired a consultant to perform a pavement evaluation and make design recommendations through an on-call pavement evaluation contract. The overlay designs were based on 10-year traffic projections following the *1993 AASHTO Pavement Design Guide*. The roadway carried approximately 46,000 vehicles per day, including 5 percent to 6 percent heavy truck traffic. For the existing pavement, the consultant recommended extensive patching in each direction and two overlay options: a four- to five-inch bonded portland cement concrete overlay or three- to five-inch high-performance asphalt, such as a stone matrix asphalt (SMA) overlay. SMA with polymer-modified asphalt binder had become the standard asphalt material in Virginia to overlay repaired concrete pavement. This was based on 20 years of performance data. The stone structure resists rutting, and the binder minimizes the raveling of surface cracks that will form due to the underlying concrete. As for the new travel lanes in each direction, the pavement design consisted of 12 inches of asphalt concrete over an asphalt drainage layer, and cement-treated aggregate subbase to match the rehabilitated pavement thickness.

INCORPORATING HIGH-POLYMER MODIFIED ASPHALT BINDER

While the contract for Segment 1 of I-64 was being awarded, Virginia DOT evaluated the performance of high-polymer modified asphalt binder incorporated in various asphalt mixes used in pilot projects around the state as well as at National Center for Asphalt Technology (NCAT) test sections at Auburn University in Auburn, Alabama. Unlike standard polymer-modified binders used in Virginia, high-polymer binder had approximately three times more polymers (2 percent to 2.5 percent versus 6 percent to 7.5 percent). This increase in polymers strengthens the asphalt mix and makes it more durable so that the surface and intermediate layers can resist cracking caused by the movement of underlying concrete slabs. Although initially more expensive, one goal of the pilot projects was to estimate increased pavement performance life and potential reduction in life-cycle cost. Based on the initial results of these projects and the lessons learned at NCAT, Virginia DOT chose to

modify the Segment 1 contract to incorporate high polymer into the surface and intermediate asphalt layers. The final pavement overlay design incorporated a 0.75-inch thin-bonded asphalt concrete layer placed on the existing concrete. This layer was used to ensure excellent bonding between the new asphalt layers and the concrete base. The SMA used included a two-inch SMA-19.0 intermediate layer and a 1.5-inch SMA-12.5 surface layer that were laid on top of the thin-bonded layer.[1–2] The surface and intermediate asphalt layers on the new lanes used the high-polymer binder, as did the surface layers on the shoulders and ramps. A total of 60,000 tons of high-polymer modified asphalt mixes, along with the standard Virginia DOT polymer-modified Superpave® mixes, were used on Segment 1.

Along with high polymer, a challenge for this project was scheduling the paving with other project activities. In each direction, the new lane and shoulders had to be constructed to allow for traffic shifts to maintain two travel lanes. The existing pavement was then patched and crack sealed before placing the thin-bonded asphalt concrete layer. A major bridge was replaced, and sound walls were installed. This led to many short paving pulls that were often less than 2,500 feet. Short pulls produce more transverse joints that have a negative effect on ride quality. This made it challenging to obtain an acceptable ride on the final surface. Like many major projects in Virginia, final project acceptance was tied to a ride specification based on the IRI.

Missouri DOT

The initial stages of concrete pavement repair and roadway widening (*top left*) are underway on I-64, west of the city of Hampton Roads toward Williamsburg on the Virginia Peninsula. The construction of temporary shoulders (*top right*) allowed traffic to shift during rehabilitation of the existing lanes. Sound walls (*above*) have been installed and pavement rehabilitation is near completion.

DID THIS TREATMENT HOLD UP?

Segment 1 was completed in 2017. Although the long-term performance of the high-polymer asphalt materials will not be known for another decade, the initial performance has met expectations. The 2021 ratings gathered by Virginia DOT in the outside travel lane of the Segment 1 pavements showed an "excellent" critical condition index of 96 (a rating of 100 indicates no surface distress) and a "good" ride quality of 81 inches per mile per Virginia DOT's rating criteria. The use of ultrathin bonded asphalt overlays to promote load transmission from the asphalt concrete overlays to the underlying concrete has proven successful in preventing delamination and potholes. The use of high polymer has not eliminated all reflective cracking from the underlying jointed reinforced concrete pavement; however, the cracks are extremely tight and not raveled. The ride quality has decreased due to the movement of the underlying slabs, but this was expected. Overall, the innovations first tested on the NCAT Test Track, then on smaller-scale projects in Virginia, led to the bold decision to incorporate high polymer in a high-profile rehabilitation project.

[1] The largest aggregate in SMA-19.0 is 19.0 millimeters (0.75 inch).
[2] The largest aggregate in SMA-12.5 is 12.5 millimeters (0.5 inch).

Essential Specifications for Pavement Preservation, Maintenance, and Rehabilitation

ANDREW BRAHAM

The author is an associate professor of civil engineering at the University of Arkansas, Fayetteville.

Requiring and enforcing specifications to ensure high-quality material selection, design, and construction is essential for all facets of roadway asset investment, including pavement preservation, maintenance, and rehabilitation treatments. AASHTO's Transportation System Preservation Technical Services Program Emulsion Task Force has been developing standards for various flexible pavement treatments. This group has developed—or is in the process of developing—material standards, design standards, construction guidelines, and quality assurance guidelines for the following:

- Chip seal,
- Micro surfacing,
- Cold recycled mixtures,
- Slurry seal,
- Fog seal,
- Sand seal,
- Tack coat (for preservation treatments), and
- Scrub seals.

Examples of AASHTO's work in this area include materials provisional (MP) and practice provisional (PP) documents, such as *AASHTO MP 31: Materials for Cold Recycled Mixtures with Emulsified Asphalt* and *AASHTO PP 83: Standard Practice for Micro Surfacing Design*.[1] Construction and quality assurance guidelines will be incorporated into the AASHTO *Guide Specifications for Highway Construction* as they are approved (see Page 50). At this time, there are no official specifications developed for any rehabilitation treatments.

Andrew Braham, University of Arkansas, Fayetteville

There are eight heaters, four milling machines, a pick-up machine, and a paver in this hot in-place recycling train. This type of rehabilitation treatment can be used on roads with oxidation, uneven surface profile, top-down cracking, minor rutting, and raveling.

However, FHWA's *Basic Asphalt Recycling Manual*, known as *BARM*,[2] provides excellent guidance for the following treatments:

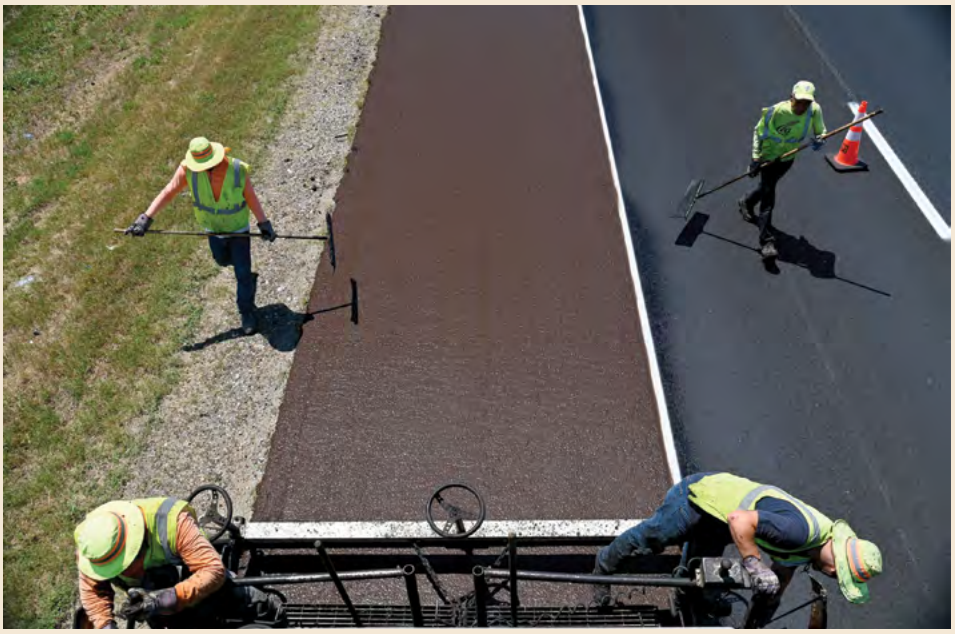
- Hot in-place recycling,
- Cold in-place recycling, and
- Full-depth reclamation.

[1] AASHTO standards can be found at http://www.aashtoresource.org/standards.

[2] Publications on asphalt recycling can be found at https://www.arra.org/store/viewproduct.aspx?id=9384006.

As with flexible rehabilitation treatments, rigid pavements do not have official specifications at this time. However, there is significant guidance in the second edition of FHWA's *Concrete Preservation Guide*, published in 2014. This guide provides recommendations for selecting, designing, and constructing the proper treatment. The document begins with guidance on how to evaluate a concrete pavement properly and then details the following treatments:

- Slab stabilization/jacking;
- Partial-depth repairs;
- Full-depth repairs, including precast concrete slab repairs;
- Edge drain retrofitting;
- Dowel bar retrofit, cross-stitching, and slot-stitching;
- Diamond grinding and grooving, including next-generation concrete surfaces;
- Joint resealing and crack sealing; and
- Concrete overlays.



Andrew Braham, University of Arkansas, Fayetteville

This bird's-eye view of a project about 30 miles east of Jonesboro on Arkansas Highway 18 shows a crew placing micro surfacing. Micro surfacing can be placed on roads that have experienced oxidation, raveling, a loss of friction, and—if properly designed—can be used to fill ruts.

Published in 2019, a more current document exploring concrete preservation is FHWA's *Strategies for Concrete Pavement Preservation*, which enhances much of the knowledge from the *Concrete Preservation Guide* but also focuses on designing concrete pavements for preservation.

There has been movement in the direction of developing and implementing specifications for pavement preservation, maintenance, and rehabilitation treatments, but there is still some way to go to cover all treatments in flexible and rigid pavements. Ideally, in the future, researchers, state departments of transportation, and the pavement industry will have material standards, design standards, construction guidelines, and quality assurance guidelines for all of the treatments.

VOLUNTEER VOICES

"Being an aviation person, I have always been fascinated by the concept of urban transportation integration. The plot gets thicker given the fact that every conceivable form of transportation is there—walking, equipment used by differently abled people, bicycling (two-, three-, four-wheelers), trains, buses, trams, underground, overground, inland waterways, not to speak of bulldozers and other types of equipment directly involved in enabling and maintaining transportation routes. Mind boggling, to say the least.

—BALA BALASUBRAMANIAN
Founder and CEO, Air Cargo Consultancy International Services
Bengaluru, Karnataka, India

TRANSFORMING PAVEMENT PRESERVATION

Tom Burnham, Minnesota DOT

TOM BURNHAM, JOHN SENGER, AND NATHAN KEBEDE

Burnham is a senior road research engineer with the Minnesota Department of Transportation in Maplewood; Senger is the engineer of pavement technology with the Illinois Department of Transportation in Springfield; and Kebede is the chief operating officer at ARRB Systems in Exton, Pennsylvania.

Above: The smooth rides on durable roadways that Minnesota drivers experience are often a result of research findings discovered at MnROAD, the pavement test track of the Minnesota Department of Transportation (DOT). Despite budget constraints, state transportation agencies are committed to safety, sustainability, and economics—just some of the motivators that drive their quest for new and better ways to preserve pavement.

Transportation agencies across the country know that pavement preservation plays a vital role in maintaining the nation's roadways and highways. Where applied correctly (right material, right pavement, right time), pavement preservation has been proven to extend the life of pavements and provide good returns on investment. Many agencies, however, have struggled to secure adequate funding, identify ideal project candidates, or implement appropriate treatments. Beyond questions about spending money on good looking pavements when so many others are in poor condition, poor project selection and inexperience with often innovative treatments have resulted in early failures that have made it challenging to convince policymakers to continue to invest in preservation activities. Ever constricted budgets—in combination with new federal and state regulations related to addressing environmental concerns—have directed many agencies to rethink how they approach pavement preservation. Whether it is new ways to distribute project funds, innovations in project selection, or new technologies speeding the collection of pavement management data, great strides are being made in this field.

New Paths Forward in Illinois

FUNDING COMES OF AGE

The Illinois Department of Transportation (DOT) officially started its pavement preservation program in FY 2005 with a mandate for each of its nine districts to install three preservation projects that—together—totaled $300,000. The district could choose from one of five treatments: micro surfacing; slurry seal; chip seal; cape seal; and half SMART, a thin (0.75-inch), hot-mix asphalt overlay topped with a chip seal and known as Surface Maintenance at the Right Time. The districts were not given additional funds to cover these projects; therefore, the funding had to come from already constrained budgets. Due to the districts' unfamiliarity with

these treatments and the short length of the projects, these early projects were considered stopgap treatments waiting for the next resurfacing. This meant selected sections were not ideal candidates, and these treatments were not given much room for success.

This situation—with a few minor program changes—continued for three more years before the funding was increased in FY 2015 to $7.5 million, money that was taken off the top of the department's overall program and set aside for pavement preservation. The $7.5 million was then equally divided among the districts to spend on pavement preservation. The original intent of this funding was to develop a committee that would assist the districts in selecting and approving preservation projects. It was not until FY 2018 that the official committee was formed, and the funding was then moved into a competition to select the best candidate projects—regardless of location. The districts saw this as a great way to gain much-needed additional funding for their districts and began taking the project selection process very seriously. The competition continued until FY 2019.

Passage of the Moving Ahead for Progress in the 21st Century Act (MAP-21) in 2012 required each state transportation agency to create a Transportation Asset Management Plan (TAMP) by June 2019. The creation of Illinois' TAMP changed the way in which Illinois DOT would select and fund its preservation treatments going forward. Development of Illinois DOT's TAMP also required the department to initiate more preservation to maintain their network better.

Pavement preservation treatments were always funded by state monies. However, the increase in use of preservation treatments demanded the expansion of the preservation definition (i.e., allowing additional treatment options), as well as requesting the use of federal funds for these treatments. The Illinois division of FHWA approved the use of federal funds on preservation treatments, but only if they were approved by the pavement preservation committee: a group of experts from the central office, the districts, and the FHWA Illinois division. This created the need for Illinois DOT to develop updated guidance for project selection.

John Senger, Illinois DOT

A yellow line marks the shoulder along a stretch of I-55/US-70 near Collinsville in Illinois. State DOT crews installed the ultrathin bonded wearing course in the summer of 2021. Although the hot-mix asphalt layer is only about 3/4-inch thick, it proves to be a durable surface that extends the life of the well-traveled roadway.

Armed with a new funding source, the department's central office required each district to spend 3 percent of its unrestricted funds on preservation projects (e.g., roads and bridges). Illinois DOT added SMART (1.5-inch hot-mix asphalt overlay with a chip seal wearing course), ultrathin bonded wearing course overlays, diamond grinding, diamond grooving, joint load transfer restoration, hot in-place recycling, joint sealing, and crack filling and sealing to their treatment options. An updated committee—comprised of central office and district representatives—was tasked with reviewing all proposed projects to ensure that treatments were being appropriately selected for the identified roadway sections.

Illinois DOT's central office now had the task of working with the districts to train the agency's personnel, select good projects, and educate the public on this new way of business. The department worked with FHWA, the National Center for Pavement Preservation, consulting engineering firms, and contractors and suppliers in the pavement preservation industry to provide training and updated guidance. The Bureau of Communications within Illinois DOT worked with expert staff and consultants to develop a new communication plan for preservation. The department utilized training from FHWA's Every Day Counts program, the International Slurry Systems Association, and the Midwest Pavement Preservation Partnership to train the agency's personnel on selection, design, and construction of these treatments.

In spring 2019, the Illinois General Assembly—along with support from local businesses, universities, and Illinois DOT—passed the Rebuild Illinois program, as well as a gas tax increase. This program helped grow all the programs within Illinois DOT, including the pavement preservation program. During the 2020 construction season, the department installed 1,220,400 square yards of micro surfacing, 828,600 square yards of cape seals, 1,060,700 square yards of ultrathin bonded wearing course, and 225,237 tons of SMART overlays. All of the preservation in 2020 totaled an awarded price of

$56,330,000. At the end of October 2021, Illinois DOT saw another record year for preservation, with $119,814,000 in awarded projects.

BENEFITS TO THE ENVIRONMENT

Not only is the increased use of pavement preservation projected to save Illinois DOT money in the long run, but these treatments also are better for the environment. Using data presented in *Energy Usage and Greenhouse Gas Emissions of Pavement Preservation Processes for Asphalt Concrete Pavements*, a hot-mix asphalt overlay three inches thick produces approximately 15.6 pounds per square yard of greenhouse gases (*1*). By comparison, micro surfacing produces about 0.4 pounds per square yard, cape seals produce 1.1 pounds per square yard, and a SMART overlay would create 9.0 pounds per square yard. Using these numbers to estimate the environmental impact of Illinois DOT's pavement preservation program, a reduction in environmental impact of 65 percent by producing 25.5 million pounds of greenhouse gases is projected, compared with a rehabilitation treatment using 73.8 million pounds. Assuming that Illinois DOT places the first preservation treatment at the appropriate time (while the pavement is still in good condition), historical performance has shown opportunities for a second preservation treatment to be placed, further delaying the need for a rehabilitation treatment and thus saving even more greenhouse gases from being produced.

Figure 1 shows the comparison of greenhouse gases created when using the same amount of square yards placed by Illinois DOT in 2020. The assumed rehabilitation was a three-inch hot-mix asphalt overlay, which is common practice in Illinois. The emulsion-based treatments greatly reduce the greenhouse gases created, and even the SMART overlay reduces the amount by nearly 50 percent.

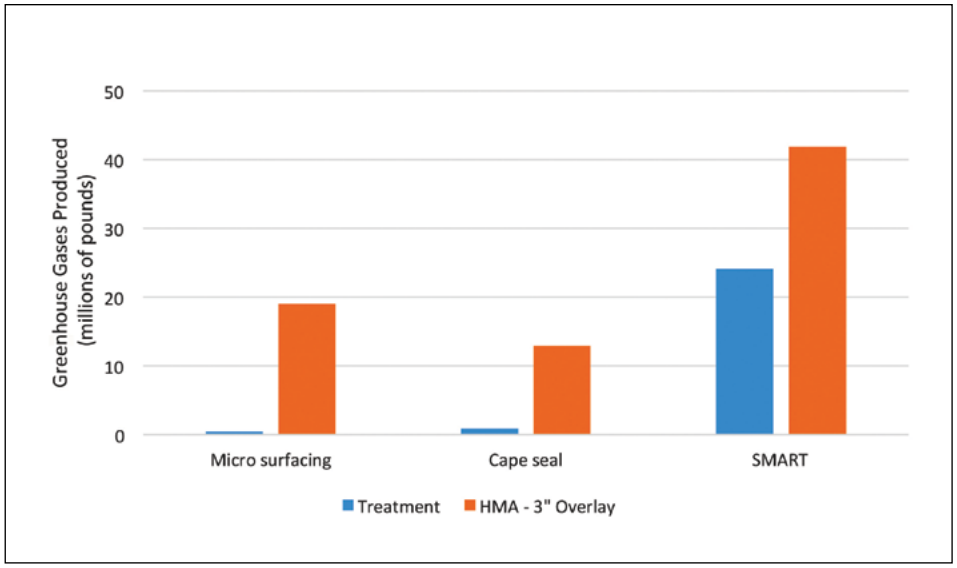


FIGURE 1 Impact of treatment selection on greenhouse gas emissions (HMA = hot-mix asphalt).

A New Recipe in Minnesota

BAKING A NEW PIE

A pastry chef often has to be cognizant of the cost of ingredients when creating a new dessert, as there is a limit to how much customers are willing to add to their final bill. Similarly, public road agencies need to live within their budgets when maintaining their networks. While the Minnesota DOT has a plethora of methods to maintain their roads, constrained budgets in the past decade have resulted in choosing to cover more miles with lower cost solutions than investing in longer term fixes. Without a mix of fixes, a pavement network will eventually decline to a point where lower cost repairs are no longer feasible. To address this situation, Minnesota DOT recently updated their method of selecting pavement rehabilitation and maintenance projects.

As a state agency, Minnesota DOT is responsible for maintaining the Interstate highway, U.S. highway, and state highway portions of the pavement system in Minnesota. It also provides financial aid and technical support to county, city, and local agencies. Minnesota's geographical location at the center of the continent results in pavements exposed to some of the most extreme weather conditions in the lower 48 states. Annual air temperatures range from –60°F to 100°F. Therefore, the condition of pavements is strongly impacted by environmental response and material durability. Minnesota DOT has always invested in and been a leader in seeking the latest in pavement technology, as demonstrated by their 30-year ownership and operation of the MnROAD pavement testing facility (*2*).

Tom Burnham, Minnesota DOT

A patchwork of concrete pavement and asphalt subsurface reveal experimental repairs of an ultrathin concrete overlay at the MnROAD facility near Albertville, Minnesota. For more than 30 years, Minnesota DOT has performed innovative pavement research on numerous test tracks and offsite locations.

Using the latest in pavement design, construction, and maintenance techniques, Minnesota DOT prides itself on maintaining their pavement system in good overall condition, despite the challenging climate conditions. However, adopting new technologies is not always enough to meet pavement performance targets, and decades of working under constrained budgets has led to less diversification in the selection of pavement repair and maintenance treatments. And, as shown in Table 1, pavement rehabilitation and maintenance of the system far outweigh construction of new routes.

To guide pavement activities, Minnesota DOT has maintained a robust pavement management system for many decades. Pavement condition surveys are conducted annually and used to update pavement selection procedures frequently. Since 2011, pavement type selection within new construction, rehabilitation, and maintenance projects has been primarily based on life-cycle cost-assessment procedures aimed at optimizing the lowest-cost alternative among those with equal benefits. In addition, funding for preventive maintenance treatments for pavements was covered under separate budgets, which were often diverted to cover other department priorities. Operating under this system worked well for a while. However, more recently, it has resulted in a substantial increase in shorter lived and less diverse types of pavement fixes. When managing a pavement network, it is ideal to have a similar population of projects across various conditions and ages, such that a large group of poor-condition pavements are not due for repairs or replacement at the same time. Several years ago, Minnesota DOT recognized that it needed a different approach to project selection to maintain a cost-effective pavement system in good condition.

Tom Burnham, Minnesota DOT

A road repair crew retrofits dowel bars into existing concrete pavement on the MnROAD Low-Volume Road. Placed across pavement joints, such installations extend the life of the pavement.

TABLE 1 Distribution of Minnesota DOT Pavement Activities from 2016 to 2020

Pavement Activity	Percentage of Project Miles
New/Reconstruction	6.5
Recycling	14.0
Asphalt Overlay	52.9
Concrete Overlay	8.1
Concrete Repairs	2.8
Maintenance	15.6

New performance metrics invoked by FHWA under MAP-21 guidelines coincided with the development of Minnesota DOT's new pavement type selection system (*3*). This quickly turned efforts toward developing a system that could meet the department's and FHWA's criteria. Instead of a primary focus on life-cycle cost assessment evaluations, the new procedure now aims toward a balance of three principal measures: ride quality, cost, and diversity of fixes. Meeting ride-quality metrics not only serves Minnesota pavement users better, but it also satisfies FHWA's recent requirements. Since budgets are expected to remain constrained for some time, project costs will now be evaluated for how they meet a measure defined as the asset sustainability ratio. Finally, Minnesota DOT districts will be strongly encouraged to

diversify their projects toward investment in a number of longer lived pavement selections and preventive maintenance treatments, resulting in a mix of fixes.

To satisfy each of these three criteria, Minnesota DOT worked with Stantec to develop an analysis tool to enable such assessments. Called the "Pavement Investment Evaluator" or "PIE," this software allows pavement designers and planners to more easily run pavement type selection and treatment scenarios with a given budget, while meeting the following eight pavement health indicators:

- Ride-quality index condition,
- Ride-quality index per vehicle miles traveled,
- Ride-quality index needs backlog,
- Asset–Sustainability ratio,
- Life category of treatment,
- Remaining service life range,
- Asset valuation, and
- Network costs ($, $/lane-mile and $/ESAL-lane-mile).[1]

Not yet ranked in any particular order of importance, these measures are designed to examine how and where funding is spent on a long-term and networkwide basis, not just project by project. Implementation of the new pavement selection procedure and PIE tool is currently underway, including refinement of comprehensive user manuals and training modules. Further information will be available soon on the Minnesota DOT Pavement Management website: http://www.dot.state.mn.us/materials/pvmtmgmt.html.

BENEFITS FROM COMPETITION

While Minnesota DOT envisions that its new procedure for pavement project selection will lead to maintaining or improving the overall condition of the statewide pavement system, another expected benefit is an increase in the competition between the concrete and asphalt paving industries. In recent years, multiple studies have demonstrated that increasing the number of opportunities for competitive bidding often results in overall lower costs from both industries, thus benefiting Minnesota taxpayers (*4*). An increase in the number and diversity of projects also incentivizes local paving contractors to invest in new equipment and train personnel, ultimately improving the quality of the pavements they construct and rehabilitate in Minnesota.

Improved Project Scoping

COMPREHESIVE EVALUATION WITH TRAFFIC SPEED DEFLECTION DEVICES

Traffic speed deflection devices, commonly referred to as TSDDs, are pavement evaluation equipment that measure roadway pavements' structural capacity or bearing capacity. While older pavement structural capacity measurement tools—such as the falling weight deflectometer (FWD)—are stationary testing devices, TSDDs operate at traffic speeds. These devices collect continuous data and can operate at speeds between five and 60 miles per hour, resulting in daily data collection rates of up to 300 miles. Therefore, TSDDs present a more effective and productive option for transportation agencies to gather large amounts of pavement condition data quickly. Various investigations and research studies have been undertaken in the United States, Europe, Australia, and South Africa to establish the relationship between TSDD data and FWD data. A Virginia Transportation Research Council study found that TSDD measurements yield similar and more consistent results in identifying structurally deficient sections of roads when compared to FWD (*5*). TSDD-measured deflections also have been verified using FWD measurements (*6*).

To make data collection even more cost effective and productive, some equipment manufacturers have developed TSDDs that capture additional roadway information such as cracking, roughness, and subsurface data. The iPAVe (intelligent pavement assessment vehicle) is one such advanced TSDD that measures additional roadway data.

Transportation agencies' primary motivation for adopting TSDD through

[1] Equivalent single-axle load (ESAL) is a historically accepted measure of traffic loading used during pavement design.

Courtesy of ARRB Sytems

Ready to roll with the flow of traffic, this intelligent pavement assessment vehicle—or iPAVe—is a TSDD. Using sensors on the back and the rear axle, this particular vehicle has collected data on roadway pavement functional and structural capacity for more than 25 Idaho transportation agencies.

the use of the iPAVe is the ability to perform comprehensive pavement evaluations by collecting all pertinent roadway condition data simultaneously. This also allows them to consume the data at the same time. Analyzing complete data has been proven to lead to more informed decisions when compared with looking at single data streams. One of the significant impacts of TSDD data has been pavement construction project selection. With access to comprehensive data from TSDD, transportation agencies can confidently identify ideal candidates for pavement preservation and rehabilitation activities. TSDD data enable agencies to consider the surface and structural condition of pavement sections so that pavement managers and designers are aware of scenarios where surface conditions appear good while structural conditions are poor, or where surface conditions appear bad while the sections are structurally sound. The following are case examples for three state transportation agencies that are currently utilizing TSDD data.

New Mexico With a population of 2.1 million and more than 27,000 miles of pavement, New Mexico is one of the leading states in collecting TSDD data and exploring applications for the data. New Mexico started collecting TSDD data in 2019 and has increased the collection efforts annually. The state is on track to collect more than 4,500 miles of TSDD data by the end of 2022. New Mexico DOT considers the TSDD as another tool in their toolbox for collecting actionable data on the condition of the state's roads. The department has a $20 million annual budget for pavement preservation, and it expects to better identify appropriate preservation candidates through the use of TSDD data. Accurate identification of preservation candidates will lead to long-lasting pavement preservation projects, which results in a high return on investment for New Mexico taxpayers. Although New Mexico also uses TSDD data for design–build projects, one of their top priorities is accurately identifying pavement preservation projects and appropriately designing preservation applications.

Idaho Having started data collection as early as 2017, Idaho is one of the earliest states to adopt TSDD data. Since 2018, the state has collected more than 4,800 miles of TSDD data. A study conducted for the Idaho Transportation Department showed that preservation and rehabilitation decisions made with TSDD data have a return on investment of more than 700 percent over the life of the pavements (*7*). Based on this study, the Idaho Transportation Department is taking steps to calculate a TSDD–based "remaining life" index of its pavement sections to populate the state's pavement management system.

Texas With more than 100,000 miles of pavement, Texas routinely looks for better ways of managing and maintaining the state's vast roadway infrastructure. Texas is part of a TSDD Pooled Fund Study (administered by FHWA) and has collected close to 3,000 miles of TSDD data throughout the state. It is one of the leading states in implementing TSDD data into their state pavement management system, with various districts now making pavement preservation and rehabilitation decisions based on the information. Texas relies heavily on pavement preservation treatments (such as chip seals), and the state expects its use of TSDD data for project selection to help identify roads that can gain long-term benefits from these treatments.

IMPROVED DECISIONS

Innovative technologies like TSDD play a critical role in supplying accurate data needed to make more informed decisions. Not only do TSDDs provide comprehensive data, but their use in decision making for pavement preservation and rehabilitation has been proven to produce positive returns on investment. The continuous and comprehensive data collected by TSDDs like the iPAVe enable state DOTs and practitioners to effectively and accurately filter structurally sound pavements as perfect candidates for pavement preservation treatments. Alternatively, the data also can filter out structurally poor pavements so that state DOTs do not waste pavement preservation funds on sections not best suited for preservation. As more transportation agencies use TSDD data on a routine basis, the demand for—and reliance on—pavement preservation applications is expected to increase significantly.

The Path Forward

With the maturing of the U.S. roadway system, the focus of transporation agencies is now very much directed toward pavement preservation. Recognition that preventive maintenance treatments are an effective way to increase returns on investment is transforming the way agencies are doing business. New technologies will continue to enable better project and treatment selections, and efforts to incorporate sustainable practices will continue to evolve. In the end, the overall winners will be the taxpayers and traveling public.

REFERENCES

1. Galehouse, L., and J. Chehovits. Energy Usage and Greenhouse Gas Emissions of Pavement Preservation Processes for Asphalt Concrete Pavements. *Compendium of Papers from the First International Conference on Pavement Preservation*, 2010, pp. 27–42.
2. MnROAD. MnROAD: Minnesota's Cold Weather Pavement Testing Facility. 2021. http://www.dot.state.mn.us/mnroad/.
3. Cornell Law School Legal Information Institute. National Performance Management Measures for Assessing Pavement Conditions. FHWA, U.S. Department of Transportation, 2021. https://www.law.cornell.edu/cfr/text/23/490.307.
4. Mack, J. W., L. G. Wathne, and F. Mu. Improving Network Investment Results by Implementing Competition and Asset Management in the Pavement Type Selection Process. *Proceedings of the 11th International Conference on Concrete Pavements*. International Society for Concrete Pavements, San Antonio, Texas, 2016.
5. Katicha, S., S. Shrestha, G. Flintsch, and B. Diefenderfer. *Network Level Pavement Structural Testing with the Traffic Speed Deflectometer.* Virginia Transportation Research Council, Charlottesville, 2020.
6. Abohamer, H., M. Elseifi, Z. U. A. Zihan, Z. Wu, N. Kebede et al. (2021). Development of an Artificial Neural Network–Based Procedure for the Verification of Traffic Speed Deflectomter Measurements. *Transportation Research Record: Journal of the Transportation Research Board,* No. 2675, 2021, pp. 1076–1088. https://doi.org/10.1177/03611981211005774.
7. Maser, K., P. Schmalzer, A. Gerber, and J. Poorbaugh. Implementation of the Traffic Speed Deflectometer (TSD) for Network Level Pavement Management. Presented at Virginia Tech Transportation Institute, 2019. https://www.vtti.vt.edu/PDFs/PE-2019/Maser2.pdf.

Effective Pavement Preventive Maintenance with Micromilling Practices

JOEL D. ULRING AND KAMAL HOSSAIN

Ulring is a pavement preservation engineer in the Minnesota Materials Lab at the Minnesota Department of Transportation in Maplewood, and Hossain is an assistant professor of civil and environmental engineering at Carleton University in Ottawa, Ontario, Canada.

Since 2010, the United States public sector has spent, on average, $90 billion annually for construction and maintenance of roads and highways throughout the country. A significant percentage of this investment goes to pavement preventive maintenance activities, a main component of an agency's pavement preservation program.

Evolving Practices

As the Minnesota Department of Transportation (DOT) preventive maintenance program evolved, it incorporated thin surface treatment strategies. Although performance of these treatments was satisfactory, ride quality wasn't being improved to the level desired or deemed attainable. While this was under review, Minnesota DOT became aware of the benefits of micromilling and noted that if incorporated with the thin surface treatments already in use, ride quality could be improved.

Micromilling has the benefits of efficiently removing surface oxidation, previously placed thin surface treatments, and minor rutting and raveling on the pavement surface. It also smooths cupped transverse cracks and local areas of roughness, and restores cross-slope drainage. When completed, the micromilled surface is smooth and clean, providing an excellent canvas for placement of a thin surface treatment. Minnesota DOT wanted to try this strategy and constructed several thin surface treatment projects [including chip seals, micro surfacing, and ultrathin bonded wearing courses (UTBWC)], incorporating micromilling on several roadways across the state to observe the results and performance.

Joel Ulring, Minnesota DOT

Minnesota may be the land of 10,000 lakes, but this state also has approximately 135,000 miles of streets and highways. To keep their roads in good condition, the Minnesota DOT is using micromilling in combination with chip seal, micro surfacing, and—as applied here—ultrathin bonded wearing courses.

Evaluating Preservation Methods

As a part of their approach to pavement preventive maintenance, Minnesota DOT has been investigating and documenting the performance of pavement preservation activities for many years. These preservation activities include crack sealing, fog seal, chip seal, micro surfacing, UTBWC, and milling and resurfacing. In 2013, Minnesota DOT implemented a program to evaluate the effectiveness of applied treatment options combining micromilling with thin surface treatments of chip seal, micro surfacing, and UTBWC.

Minnesota DOT/Joel Ulring, Minnesota DOT

In June 2014, this micromilling machine with a 12-foot milling head (*left*) was at work on US-10 in Minnesota. The result (*right*) is a surface like this stretch of US-59.

The micromilling process is similar to traditional pavement milling in that it uses a milling drum. The micromilling drum has about three times as many teeth as a typical milling drum. The additional teeth provide a tighter lacing pattern with ridge heights about one-third of those left after traditional milling. In comparison to traditional milling, this provides a smoother surface for application of thin pavement surface treatments.

Seven Minnesota DOT projects using micromilling with thin surface treatments occurred in seven districts. As the construction dates progressed from 2013 to 2016, the projects took place on roads with increasingly higher traffic volumes starting as low as 200 average daily traffic to as high as 123,000 average daily traffic. The types of surface treatments used after micromilling were chip seal, micro surfacing, and UTBWC, respectively, as average daily traffic increased. To measure performance of the treatment options tried, ride-quality data were collected during the monitoring periods of the projects.

Ride quality is measured in terms of roughness in the left and right wheel paths, then averaged and reported as a mean roughness index collected with an inertial profiler using a line laser setup. This was done to keep the data concise between multiple projects being investigated for each treatment type. The overall improvement in mean roughness indices ranged from 17 percent to 18 percent for chip seal and 26 percent to 66 percent for micro surfacing. Ultrathin bonded wearing courses improved the overall mean roughness index by 63 percent and 58 percent. Annualized cost per lane-mile to the end of treatment life is one metric used. It is calculated by dividing the total lane-mile cost of the treatment by the expected treatment life. The RoadResource.org tool provides expected treatment life for chip seals as seven years, micro surfacing as eight years, and UTBWC as 10 years. The costs for the projects were from $2,349 to $2,799 for chip seal, $3,694 to $4,543 for micro surfacing, and $4,092 to $4,879 for UTBWC.

Applying a Proven Strategy Statewide

As a result of this study, Minnesota DOT is implementing micromilling statewide when placing thin surface treatments. Several projects are constructed each year. For example, in August 2020, a project was completed in District 8, located in the southwest region of Minnesota

Joel Ulring, Minnesota DOT

After micromilling, this spray paver (*left*) is placing an ultrathin bonded wearing course on US-59 in Minnesota. The paved roadway (*right*) is nearing completion.

Joel Ulring, Minnesota DOT

This chip seal was placed on a one-year-old pavement surface on County State Aid Highway 3 in Crow Wing County, Minnesota. Although the pavement was not micromilled, it provides a good example of what a Minnesota DOT chip seal surface with fog seal looks like.

on US-59. This project involved removing and replacing the top 0.75-inch of the existing pavement by micromilling and placing a new UTBWC wearing surface on 17 miles of the roadway. The project extended north from Marshall, Minnesota, in both Lyon and Yellow Medicine counties. The micromilling ($1.00/square yard) and UTBWC ($4.55/square yard) cost a total of $5.55 per square yard and is anticipated to extend the pavement life by 10 years at a cost of $3,900 per lane-mile per year.

Noting the Benefits

Results have shown that including micromilling as part of a thin surface treatment project is a cost-effective, beneficial practice because it extends pavement life and provides smoother, safer, and longer-lasting roadways. A study led by researchers at Rutgers University in New Jersey, found that "keeping road pavement in good shape saves money, energy, and reduces greenhouse gas emissions, more than offsetting pollution generated during road construction" (*1*). A smooth road also decreases vehicle operator expenses due to repairs and fuel.

Minnesota DOT has found that performing micromilling in conjunction with thin surface treatments has not only extended the life of the pavement being treated, but also the life of the treatment itself. Micromilling the existing pavement surface prior to placing the surface treatment removes surface oxidation, minor raveling, and rutting, providing a clean surface to which the new thin surface can bond. This contributes to a longer lasting treatment, leading to fewer pavement interventions, reduced user disruptions, and lowered associated costs.

When looking at costs, the agency has reduced the treatment cost to an annualized lane-mile cost for comparison. This comparison shows that thin surface treatments are more effective than other optional treatments, such as thin mill-and-fill overlays.

REFERENCE

1. Wang, H., I. Al-Saadi, P. Lu, and A. Jasim. Quantifying Greenhouse Gas Emission of Asphalt Pavement Preservation at Construction and Use Stages Using Life-Cycle Assessment. *International Journal of Sustainable Transportation*, Vol. 14, No. 1, 2020, pp. 25–34.

VOLUNTEER VOICES

"One area of transportation that I find fascinating is airports! The destination created by the airport itself, combined with the thrill of flying, is always fascinating. As a frequent traveler, I look forward to the airport and aircraft changes. The perceived simplicity of the entire operation allows me to enjoy the finite details while the airports make it happen in the background.

—CHELSEA TREBONIAK
Owner, Critical Ops
Westlake, Ohio

The Preserved Road Ahead

Missouri DOT

JUDITH CORLEY-LAY AND JIM MOULTHROP

Corley-Lay was the director (retired) of the National Center for Pavement Preservation, headquartered in Okemos, Michigan; and Moulthrop was the executive director (retired) of FP[2], a nonprofit trade association focused on pavement preservation advocacy located in Glen Ellyn, Illinois.

Above: What is the value of good roads throughout America and how do we maintain them in the most cost-effective way? The usability, economic viability, and convenience of the road networks that crisscross every state in the nation are at stake.

Pavement preservation is a network management strategy in which structurally adequate pavements are maintained in the upper range of fair condition (fair+) to good condition. This strategy prolongs the time before rehabilitation or reconstruction is needed. Rehabilitation consists of deep treatments that may involve adding more thickness to accommodate heavier traffic than was considered in the pavement's original design. Preservation treatments cost less than alternatives such as milling, refilling, and overlay, which frequently require guardrail adjustments, reworking shoulders, and other costs. Preservation also improves performance by preventing moisture from penetrating into the base and subgrade. This slows environmental deterioration. Preservation treatments that change the friction properties of a surface also provide a safer driving surface. While there is agreement among maintenance engineers on the value of preservation, these programs face significant barriers to implementation.

Challenges

INSUFFICIENT FUNDING

To keep a transportation system in a state of good repair, public agencies need transportation infrastructure funding not only for pavements but for bridges and other assets such as sidewalks, trails, and bikeways. Other infrastructure, such as the electrical grid, water and sewer systems, and high-speed Internet, have needs as well and must be maintained to keep America at the forefront of international competition. Using data from the U.S. Department of Transportation, the Road Information Program reported that the backlog in funding was nearly $1 trillion (*1–2*). In the past five years, nearly 30 states have increased their fuel taxes to help counter this shortfall, but much remains to be done.

LEGISLATIVE SLUGGISHNESS

The development of transportation legislation is usually a bipartisan effort, but the formation of the current law was

particularly challenging because of the evenly split makeup of a 50–50 Senate. Without a decisive majority, agreement on the contents of the bill required a great deal of consideration and negotiation. It was a protracted process further hindered by the desires of the U.S. House of Representatives' many varied constituencies that the representatives tried to include in the bill.

After much discussion over more than a two-year period, President Joe Biden signed into law the Infrastructure Investment and Jobs Act, now commonly referred to as the Bipartisan Infrastructure Law. This robust bill authorizes more spending for highways and bridges than has been seen in a generation. The bill provides a $351 billion increase over current highway trust fund–funding levels for five years—a 34 percent increase. Final passage of the nearly 3,000-page bill was the culmination of more than 18 months' work that began in anticipation of the September 30, 2020, expiration of the Fixing America's Surface Transportation Act, which was the long-term highway reauthorization bill at that time.

OVERLOADED STATE AND LOCAL AGENCIES

State agencies face significant challenges in establishing and maintaining their preservation programs. Most state agencies are overseen by a board of transportation or other oversight group, whose members may be political appointees and may not understand the impact of deferred maintenance and preservation. Although some system expansion is necessary to keep pace with population growth and reduce congestion, the need for preservation should be considered in developing capital expansion programs.

Leadership changes in state agencies occur more frequently than they did a generation ago, and each change can alter priorities and introduce the need to reemphasize preservation to new leaders.

Transportation Asset Management Plans (TAMPs) are required of all state agencies, and the plans have a financial component that links agency spending for capital expansion, maintenance and preservation, and rehabilitation to agency network performance goals. Implementing the inclusion of preservation and maintenance activities into the overall financial plan that has historically focused on new construction is a significant challenge for many state agencies.

Better education for the public is needed to ensure that they, as the agency's customers, give due consideration to the full scope of what a preferred project may require over its service life. The public needs to understand the costs of common activities and the future costs to maintain a road over a 30-year (or longer) horizon.

Training is needed on a continuing basis for agency personnel, in part due to reorganization and staff reductions, but also due to normal job progression. Agencies now outsource most preservation work and assign inspectors who are trained and certified for new construction of asphalt and concrete. Certification of inspectors and contractors in preservation is key to obtaining quality project results. Training also is needed for those selecting projects for treatment, testing materials for preservation treatments, and preparing contract specifications. New undergraduates from university engineering programs could benefit from classes—such as the one at the University of Arkansas, Fayetteville, discussed on Page 10—to give them the tools they will need to become entry-level maintenance engineers focused on preservation.

Local agencies face many of the same issues faced by state agencies. Often, small agencies have a single engineer handling a wide variety of system needs, which dilutes attention to roadways. In addition, they frequently face a lack of consistent and adequate funding to maintain their networks.

Reasons for Optimism

Despite these challenges, there are reasons to be optimistic about the future of pavement preservation. In May 2021, a virtual national pavement preservation conference attracted 818 attendees—600 from state, provincial, or local transportation agencies. This indicates a high level of interest in the subject. Other web-based training also is available, including industry-sponsored training sites, FHWA webinars, and industry webinars. Another indicator of strong and continuing support from state agencies is the AASHTO Transportation System Preservation Technical Services Program, funded with voluntary state contributions from more than 45 states each year. There are several university centers focused on preservation that provide training, outreach, and research to support pavement preservation programs.

The agency TAMPs require each agency to take a longer-term view of their system. The longer view, coupled with financial accountability for system performance, works in favor of preservation of existing infrastructure.

As part of its recent reorganization, the Transportation Research Board (TRB) Technical Activities Division created a new section of the Transportation Infrastructure Group. The Infrastructure Management and System Preservation Section includes standing committees on pavement maintenance, pavement preservation, and pavement management systems to encourage collaboration between these committees and with others outside this section.

University engineering programs continue to deliver high-quality graduates and provide a robust source of new talent and ideas. This is a cause for optimism and a call to action to tap these resources for future pavement preservation and maintenance engineers.

THE ROAD AHEAD WITH QUARTER-MILE VISIBILITY

Managing infrastructure is not done effectively when funding levels are uncertain. A long-term infrastructure bill with appropriate funding for preservation, maintenance, and rehabilitation will allow agencies to develop and carry out multiyear work plans that cost-effectively maintain network conditions. The focus now should be on what needs to be done, rather than what can be done with short-term funding extensions.

The AASHTO Transportation System Preservation Technical Services Program model can continue to develop new talent and strengthen existing programs. A

Ohio DOT

Hard at the task, an Ohio Department of Transportation crew applies chip seal on a stretch of SR 697 in Van Wert County. When practitioners and researchers have sufficient long-term funding, they can better maintain roads using preservation practices that provide more resilient and long-lasting surfaces. When compared to replacement, many preservation treatments are more economical, as well.

training module on concepts of network-level management for leadership and legislative positions can be developed. Following the lead of a few universities, modules on maintenance, preservation, and network analysis can be incorporated into the college curriculum for students with a transportation focus.

Some changes can be made to make preservation practices more consistent, increase competition on preservation projects, and potentially reduce unit costs. More consistency in specifications across state lines—perhaps by implementing the recently developed and passed AASHTO specifications and construction guidelines for common pavement preservation treatments—would enable contractors to expand their work areas and increase competition. Implementation of innovations currently requires a vendor to market and build test sections for each state agency and frequently in multiple districts within each state agency. Going to an independently monitored regional test section approach could reduce the time to implementation and decrease the cost of innovation.

Research needs have been identified in areas including asset management, project selection and design, materials, construction and contracting, performance, and benefits. Increased collaboration between TRB committees, AASHTO committees, state agencies, FHWA, and industry groups could ensure that the most valuable research is completed, and necessary implementation actions are funded.

THE ROAD AHEAD WITH 10-MILE VISIBILITY

An integrated national plan is needed for many types of infrastructure renewal, such as water and sewer systems and the electrical grid. Some systems requiring long-term plans will require new systems while others will require new thinking related to the distribution of assets to meet future needs, such as water in the U.S. West. Additionally, there will be a need

To keep a transportation system in a state of good repair, public agencies need transportation infrastructure funding not only for pavements but for bridges and other assets such as sidewalks, trails, and bikeways.

to determine how best to maintain all of these systems in the future.

Some thought has been given to incorporating sustainability and resiliency into pavement decisions. These approaches need to be developed and implemented. New materials, methods, and additives will be developed, and a national repository of information to distribute information regarding these changes would help improve our understanding of successes and failures. There also is a need to address the fundamental processes for funding local roads and streets, and to determine if the trickle-down process from state agency funds is the best approach.

When agencies do not have rational processes in place for dealing with short-term financial crises, maintenance and preservation budgets frequently get cut first. Is this the best option? The public and legislators need to understand the cost of maintaining roads and the value of using preservation treatments to prolong the time before major rehabilitation and reconstruction.

Conclusions

The transportation system in the United States is, and has been, an integral part of American culture, a hallmark of our ability to compete internationally, and a means of providing the travelling public with the ability to enjoy the many wonderful features of this nation. Ensuring that this system is adequately funded, maintained, and preserved is the responsibility of many, and the need to work together to ensure the health of our infrastructure is great.

REFERENCES

1. U.S. Department of Transportation. *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance Report, 24th ed.* Washington, D.C., 2021. https://doi.org/10.21949/1521794.
2. The Road Information Program (TRIP). *The U.S. Freight Network's Critical Role in the Supply Chain.* Washington, D.C., Dec. 2021. https://tripnet.org/reports/the-u-s-freight-networks-critical-role-in-the-supply-chain-december-2021.

VOLUNTEER VOICES

"I was drawn to the transportation community through my love of driving. Being able to do research and have a career focused on my passion is rewarding. What keeps me in transportation are the people. Not only are they brilliant, kind, and thoughtful, but they also are some of my closest friends.

—SHANNON ROBERTS
Assistant Professor of Industrial Engineering
University of Massachusetts, Amherst

Dylan Calluy, Unsplash

It's Electric! Now What?

CATHY FRYE

The author is a freelance editor for *TR News* at the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine in Washington, D.C.

Since the invention of the automobile, drivers have experienced that panoply of emotions—surprise, dread, panic—when noticing the fuel gauge on or near "E", meaning *empty!* Although electric vehicle (EV) sales in the United States tripled from 2016 to 2020 (*1*), range anxiety—concerns about depleting a charge before reaching the destination—is a major obstacle to greater EV adoption (*2*).

In response, the Infrastructure Investment and Jobs Act includes provisions to invest $7.5 billion for a national network of EV chargers in the United States. Although helpful, static charging—stopping to charge—takes vehicles out of service. For long-range travel, this may be impractical. For fleet vehicles, such as taxis and delivery trucks, such downtime may be economically infeasible. Dynamic charging—in which battery-operated EVs charge while in motion—offers a solution, and the research to refine it soon may be coming to a road near you (see box).

Above: The road ahead for electric vehicles includes multiple solutions for charging batteries while stopped, as well as while in motion.

Keeping EVs Charged

"If you can charge wirelessly at home, at work, and even when you're on the way, you never have to think about charging your car and you eliminate range anxiety," notes Burak Ozpineci, a scientist working on dynamic wireless charging at Oak Ridge National Laboratory in Tennessee (*3*). Research supported by the Vehicle Technologies Office of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy and performed at Oak Ridge has tackled some dynamic charging complexities. For example, custom magnetic coils, silicon carbide-based power electronics, and novel controls and shielding technology handle stray electromagnetic emissions around charging coils (and the heat they may produce). Another issue has been the varying sizes of the air gap between the vehicle's coil and the coil in the road surface. Whether for a light-duty passenger car across a six-inch air gap or a medium-duty delivery truck across an 11-inch air gap, Oak Ridge's 20-kilowatt system can wirelessly charge the vehicle's coil with greater than 92 percent power transfer efficiency. The charge is similar to that from a wired system.

Thanks to an Oak Ridge–designed polyphase magnetic coil coupling, smaller coils can achieve higher power density. The three-phase system features rotating magnetic fields between layers of coils. This gives the research team's coil a smaller footprint than other coils in use for wireless charging. Even at the larger 300-kilowatt level, Oak Ridge's ground-based coil "is about the size of an extra-large pizza, while the coil on the car is about the size of a small or medium pizza," notes Omer Onar, who leads the lab's Vehicle Power Electronics Research Group.

Using a different approach, a project in Indiana is creating a quarter-mile road built with magnetized concrete. As part of ASPIRE (Advancing Sustainability through Powered Infrastructure for Roadway Electrification), a National Science Foundation–funded research and development initiative to accelerate sustainable and equitable transportation electrification, West Lafayette–based Purdue University and the Indiana Department

Richard Unten, Flickr

Dynamic charging can help keep EV batteries charged, but a culture change from the mindset of "running the tank down to almost empty" may be needed. For an EV, thinking of it more like a smartphone than a gas-powered vehicle may help smooth the transition.

of Transportation are aiming for road construction in 2023 (*4*).

As Nadia Gkritza, a professor at Purdue's Lyles School of Civil Engineering and the ASPIRE campus director leading the research explains, "The goal is to bring the charge to the vehicle rather than to make the vehicle stop at a charging station (*5*). This particular technology involves slabs made with magnetizable concrete." The proprietary blend of concrete and magnetic particles incorporates ferrite particles sourced from e-waste recyclers (*6*). Through a coil embedded in the roadway, Gkritza's team circulates a high-frequency current and generates a magnetic field. "That field is then picked up by a compatible coil on an electric vehicle and converts it back to electricity that can power the motor directly or charge the battery."

The Road Ahead

Upcoming pilot electrification projects include the Utah Inland Port Authority in Salt Lake City, the Central Florida Expressway in Orlando, and developing projects across the nation (*7*). In 2023, Detroit, Michigan, long considered the birthplace of the U.S. auto industry, plans to deploy the first mile of electrified roadway in the United States (*8–9*).

Buckle up! The shift to zero-emission vehicles is bringing relief to EV owners and visible changes to the road ahead.

REFERENCES

1. DeSilver, D. Today's Electric Vehicle Market: Slow Growth in U.S., Faster in China, Europe. Pew Research Center, June 7, 2021. https://www.pewresearch.org/fact-tank/2021/06/07/todays-electric-vehicle-market-slow-growth-in-u-s-faster-in-china-europe/.
2. van den Berg, R. How to Say Goodbye to EV Range Anxiety. *Automotive World*, Sept. 23, 2021. https://www.automotiveworld.com/articles/how-to-say-goodbye-to-ev-range-anxiety/.
3. Oak Ridge National Laboratory. Hands-Free: Wireless Charging System Advances Electric Vehicle Convenience. May 18, 2021. https://www.ornl.gov/news/hands-free-wireless-charging-system-advances-electric-vehicle-convenience.
4. Pyzyk, K. Indiana DOT, Purdue Developing Wireless EV Charging for Highways. *SmartCities Dive*, July 2021. https://www.smartcitiesdive.com/news/indiana-dot-purdue-developing-wireless-ev-charging-for-highways/603774/.
5. Resources Radio. Episode 172: Magnetized Charging: The Future of Electric Vehicle Charging? with Nadia Gkritza. https://www.resources.org/resources-radio/magnetized-concrete-the-future-of-electric-vehicle-charging-with-nadia-gkritza/.
6. Hannon, K. Could Roads Recharge Electric Cars? The Technology May Be Close. *New York Times*, Nov. 29, 2021. https://www.nytimes.com/2021/11/29/technology/electric-cars-magnetic-roads.html.
7. *Utah State Today*. ASPIRE Engineering Research Center and Electreon to Launch Electrified Roadway Demo in Utah. Mar. 9, 2022. https://www.usu.edu/today/story/aspire-engineering-research-center-and-electreon-to-launch-electrified-roadway-demo-in-utah.
8. Electric & Hybrid Vehicle Technology International. US to Build its First-Ever "Electric Road" That Wirelessly Charges EVs as They Drive. Feb. 1, 2022. https://www.electrichybridvehicletechnology.com/news/charging-technology/us-to-build-its-first-ever-electric-road-that-wirelessly-charges-evs-as-they-drive.html.
9. Descant, S. Wireless, In-Road Vehicle Charging Coming to Detroit. Government Technology, Feb. 8, 2022. https://www.govtech.com/fs/wireless-in-road-vehicle-charging-coming-to-detroit.

Resources for Further Information

Clearing the Skies with Research on Electric Vehicles
https://www.nationalacademies.org/trb/blog/clearing-the-skies-with-research-on-electric-vehicles

TRB Snap Search: Electric Vehicles
https://onlinepubs.trb.org/onlinepubs/snap/ElectricVehicles.pdf

ASPIRE Overview
https://aspire.usu.edu/industry/overview/

Leslie Myers

Senior Asphalt Pavement Engineer, FHWA

Leslie Myers finds a human connection everywhere she looks in the transportation field. "Transportation research connects you to people," she notes. "No matter how diverse the research subject may be, it always ultimately ties back to public safety, well being, and the environment." This view began to take shape when Myers first worked for FHWA between 2002 and 2008. It continued to solidify when she received her doctorate in civil and environmental engineering from the University of Florida, Gainesville, and later joined the civil engineering faculty at Pennsylvania's Villanova University in 2009. By 2010, when she became the principal for Myers McCarthy Consulting Engineers, a woman-owned small business, the human connection behind transportation research remained even as the research subjects grew more diverse.

In 2019, when Myers rejoined FHWA to work in the Office of Preconstruction, Construction, and Pavements, she brought this perspective along. Since then, she has served as the program manager of the Mobile Asphalt Technology Center (MATC), a fully functional asphalt laboratory housed in a tractor–trailer that travels to construction projects around the country. The program introduces new and emerging asphalt materials and construction technologies to the states and industry on a highly individualized basis. "Part of my job is to help agencies and their industry partners explore new practices or technologies that may ultimately lead to improved pavement quality, durability, sustainability, and safety," she explains. MATC's onboard, state-of-the-art asphalt testing lab and the field-equipment loan program can provide states and paving contractors with a try-before-you-buy scenario. Whether providing hands-on education, technology demonstrations, specification reviews, or asphalt materials and mixture testing, the results are the same—through Myers' leadership, the MATC experience informs cost-effective decisions and can move advanced asphalt technologies out of the research phase and into practice.

"When we bring the MATC to a state for a month-long site visit, there is a lot of responsibility to provide the most impact as part of the experience to members of the asphalt pavement community," Myers admits. A program of MATC's size and complexity involves a lot of forward planning with contingencies, communication of initiatives and technical findings, technology transfer, and outreach efforts. During COVID-19, "instead of the MATC team going to paving sites, the asphalt mix and materials came to MATC at Turner-Fairbank Highway Research Center in McLean, Virginia. We supported the Florida, Maine, California, Rhode Island, and Ohio [departments of transportation] DOTs with virtual site visits," she notes.

"There is much more to pavements than what meets the eye—there are subtle complexities—and that is what makes pavements so exciting to study."

Myers is well equipped to lead this effort. Her multimodal research experience is broad, having extended outside the pavement industry in the areas of airport and railroad infrastructure, highway safety, and transportation agency policy issues. She knows the materials side, as well, with research on asphalt mixture specifications, asphalt and concrete materials quality assurance, the use of recycled materials, and expertise in flexible pavement design. "There is much more to pavements than what meets the eye. There are subtle complexities, and that is what makes pavements so exciting to study," she adds. Myers' appreciation for pavement is reflected in the numerous classes she has developed and taught, as well as the many articles, papers, and reports she has authored or co-authored. Her passion for transportation also shows in the 30 research projects for which she served as principal or co-principal investigator, and awards like the Walter J. Emmons Award for Best Paper at the Annual Association of Asphalt Paving Technologists (AAPT) Conference—awarded twice—and Villanova's College of Engineering Teaching Award. For the Transportation Research Board (TRB), Myers chairs the Design and Rehabilitation of Asphalt Pavements Committee. She has been a frequent National Cooperative Highway Research Program (NCHRP) project panel member, as well as a panel member for the National Cooperative Rail Research Program (NCRRP) and the Transit Cooperative Research Program (TCRP).

"TRB is the nerve-center of transportation research," Myers explains. "For young engineers, TRB's annual conference is the great awakening—Annual Meeting workshops, poster sessions, and committee meetings are all great places to start building connections to others who are passionate about what we do. It isn't just a conference, it is *the* transportation community."

Although Myers believes "transportation provides many avenues for a practitioner or researcher to explore over the course of a career," she admits it can be difficult to maintain evolution through research that leads to application. "But," she explains, "therein lies the need to effectively transfer findings to practitioners who can ultimately affect change. When starting a new project, pavement researchers should ask themselves: How would different transportation owners apply and use elements of this research? Our future in pavement engineering lies in strategic thinking, preparedness, and adaptation."

Timothy E. Barnett

Traffic Operations and Safety Engineer, Alabama Transportation Institute

Tim Barnett is someone who can point to a specific day and time when he started out on his career path. The catalyst was a minor car crash while he was on his way to school. He describes this as "nothing serious, but the crash happened at an oddly configured intersection in my hometown." This experience left him thinking about the design of the intersection.

Soon after, Barnett recalls that he focused a school project on determining "what the steps would be to redesign the intersection where the crash occurred." He met with Richard Kramer, Huntsville, Alabama's city transportation director, to discuss redesign ideas for the intersection and left with advice on his design, along with a copy of the *Manual on Uniform Traffic Control Devices* and an invitation to return in a week to discuss his plan.

At the next meeting, the 13-year-old Barnett pitched his redesign ideas to a room full of adults, including "several engineers from the Alabama Highway Department, the precursor to the Alabama Department of Transportation [DOT]." Impressed, Kramer told Barnett to come back when he turned 16 if he wanted a job. Barnett did and was hired as a summer intern, a position that grew into a full-time job while he earned his bachelor's and master's degrees in civil engineering at the University of Alabama, Huntsville (UAH).

Barnett spent 20 formative years with the city of Huntsville. For the first 10 years, he worked for Kramer before Kramer retired. He also worked with Daniel Turner, founding director of the University Transportation Center for Alabama, who was then the director of the Transportation System Management Association (a joint effort of the University of Alabama, Tuscaloosa, and the cities of Huntsville and Tuscaloosa). Barnett credits Turner with showing him "how research could be used to advance transportation engineering and address safety."

In his progression from intern to city traffic engineer, Barnett received a broad education. "Working for a city, you are involved at all levels and in all aspects of transportation: planning, design, construction, and operations," he explains. As a UAH lecturer, he stressed the importance of learning how all the parts of the transportation system work together. He would tell his students, "to be an adept transportation engineer, a comprehensive understanding of transportation planning, roadway and bridge design, construction methods, utilities, right-of-way, operations, and safety is necessary."

"Research needs to be both accessible and understandable for the practitioner."

In 2004, Barnett took a position with Alabama DOT as a division right-of-way engineer and was soon promoted to division design engineer, a role in which he implemented "many of the traffic engineer and roadway geometric concepts I learned from my mentor, Mr. Kramer, who created the SuperStreet concept in the late 1980s." SuperStreet introduced the initial restricted crossing U-turn intersection form commonly used today. "From my experience building a few SuperStreet routes, I persuaded the state to implement the SuperStreet concept on a heavily congested highway," Barnett recalls. "The success of the first project phase led to additional phases, including unique intersection geometrics and traffic operations not in use anywhere else in the states—if not the world." Alabama DOT's chief engineer noticed and offered Barnett the position of state traffic and safety operations engineer, which Barnett describes as the "high point in my career—the role where I could use all of the knowledge I gained over the previous 25 years to help reduce the likelihood of serious crashes in Alabama."

This position got Barnett involved at the national level with organizations like AASHTO, the Institute of Transportation Engineers (ITE), FHWA, and the Transportation Research Board (TRB). The author of numerous road safety publications, Barnett is the vice chair of ITE's Vision Zero Standing Committee, which aims to eliminate all traffic fatalities and severe injuries while increasing safe, healthy, equitable mobility for all. He currently chairs the TRB panel for NCHRP Project 17-81, "Proposed Macro-Level Safety Planning Analysis Chapter for the *Highway Safety Manual*" and has a long history of TRB committee involvement.

Retired from Alabama DOT since 2018, Barnett is now an Alabama Transportation Institute research engineer who promotes research as "essential to build knowledge and provide clarity to complex concepts." Specific to road safety research, he cautions, "the models developed can be too complex to be appreciated or rely on inputs that simply are not available to practitioners. Research needs to be both accessible and understandable for the practitioner."

One may quip that Barnett's career started "by accident." Yet, it is no accident that he still taps into the mindset of that middle school student who recognized a needed safety improvement and went about achieving it in a determined and straightforward way.

INFLUENCER

Kyle Taniguchi

Kyle Taniguchi is a transit planner for Nelson\Nygaard Consulting Associates in Seattle, Washington. He also is the former co-chair of the Public Transportation Young Members Subcommittee, as well as a member of the Young Members Coordinating Council (YMCC) and the Standing Committee on Bus Transit Systems.

How would you describe the Public Transportation Young Members Subcommittee?
Our subcommittee's primary mission is to connect young professionals with the chairs of the 12 public transportation standing committees. Our subcommittee also works to advance initiatives to encourage networking and professional development opportunities. This includes helping our members get the most out of the TRB Annual Meeting.

How did the co-chairs work together?
I worked closely with my co-chair, Simon Berrebi, to ensure that we had regular leadership team check-in calls. We conducted email or phone check-ins after YMCC and Public Transportation Group meetings. When we had enough for a full agenda, we would convene a meeting of our subcommittee's leadership team—typically two or three times a year.

What do you think helped you to be successful in this role?
I have held numerous leadership positions at organizations (including Young Professionals in Transportation and the Institute of Transportation Engineers), which helped me grow my leadership skills and prepared me for this role.

If you had an opportunity to go back in time and do things differently, what would you change about taking on or performing this role?
I have no regrets. During my two years as co-chair, COVID-19 upended how our subcommittee did business but our leadership team was able to pivot quickly to adapt to changing conditions. Last year, we had a fully virtual subcommittee meeting with some interactive polling questions and discussion that I thought was innovative for its time.

What advice do you have for other young professionals who may hesitate to take on a similar leadership role?
My suggestion for anyone even remotely interested in a leadership role is to take the plunge and volunteer. It is a great experience, both to grow your professional network and build your leadership skills. I found that serving as co-chair was very rewarding.

Transportation Influencer highlights the journey of young professionals active in TRB. Have someone to nominate? Send an e-mail to TRNews@nas.edu.

Let's Hear from You!

In each issue, we pose a sometimes light and fun transportation-related question that allows you to share your thoughts with other readers. To answer, **click here** or e-mail us at **TRNews@nas.edu** and follow these simple steps:

1. In the subject line, include **"Volunteer Voices: [the question you're answering]"**;
2. Answer the question thoughtfully, but keep it brief—up to about 150 words;
3. Add whether you are a TRB member or volunteer, and list the committees you are involved with; and
4. Add TRNews@nas.edu to your contacts so we avoid your spam folder when we tell you you're going to be published.

That's it! Like all *TR News* content, your response may be edited for grammar, length, and TRB style. When the issue with your quote is published, you'll get a PDF of the page featuring your response and photo.

Now that you have the details, here's the question:
If you could go back in time, what would you change about transportation, and why?

We've Seen What Works and What Right Looks Like

In December 2021, the Conference of Minority Transportation Officials (COMTO) named April Rai as its new president and chief executive officer. Rai comes to COMTO with more than 15 years of management experience as deputy executive director for the Women's Transportation Seminar International (WTS), chief executive officer for the National Organizations for Youth Safety, and manager and affairs analyst in the Office of the Dean at the University of Maryland School of Nursing in Baltimore. Rai responded to questions on her new role and her background.

What drew you to the position of COMTO president and chief executive officer?
The ability to continue focusing on equity in transportation was the main draw. In my previous role as the deputy executive director at WTS, I had the opportunity to focus on the advancement of women in leadership positions. At COMTO, I have the opportunity to expand on that work and focus on additional underrepresented groups within transportation, including racial minorities, people with disabilities, and veterans. In addition, I am drawn to supporting historically underutilized businesses. These include small businesses, women-owned businesses, minority-owned businesses, and veteran-owned businesses.

What are some of your priorities as president and chief executive officer?
I want to strengthen the workforce pipeline to the transportation industry in three ways:

1. Through scholarship programs so students can get financial support to pursue education and join the industry.
2. Through *paid* internships so that young people can gain real-world experience in transportation disciplines and see the variety of professions in transportation. If they enjoy working with their hands, I want to get them connected to apprenticeship programs for technicians, drivers, and mechanics. We also need those in roles like environmental planning and engineering, as well as those who oversee logistics, finance, and communications. If we want to meet our infrastructure goals, we need more young people joining the transportation profession as soon as possible.
3. Through strengthening mentorships of professionals in transportation to help them reach new levels in their careers. We must provide real support once they enter the industry and steward them toward advancement. In a hybrid world, managers must be intentional about ensuring the professional development of their staff. I also want COMTO chapters to be a place that can help fill the gaps in skills that our members may need but may not get through their jobs. By thinking strategically about how we can fill these skill gaps, we can help our members become eligible for and attain positions on boards and as leaders in transportation.

April Rai (*above*), president and chief executive officer of the Conference of Minority Transportation Officials in Washington, D.C., shares her insights with Karen Febey, TRB senior report review officer.

What unique role do you think COMTO has in working toward greater equity in transportation?
COMTO has the benefit of 50 years of championing equity in transportation. We have done a lot of listening about the challenges, implementation, and disparities in the industry. We have seen what works and what *right* looks like. We are ready to share that as broadly as possible so everyone looking to implement equity programs can be successful.

How do you think TRB and COMTO can best collaborate on shared initiatives?
In the memorandum of understanding between TRB and COMTO, we agreed to work together on a variety of diversity action items. I would like to be more intentional in our collaboration and learn from the work of TRB's Special Committee on Diversity, Equity, and Inclusion to help broaden the reach of the committee. We also are committed to strategic cross-promotion of initiatives that move our shared goals forward.

What do you like to do when you are not working?
Since the pandemic started, I have made a point to read a book every day. Doing so has helped ground me. Some of the books I read cross a wide range of topics and intent—from the Bible; *Dare to Lead,* an inspirational book by Brené Brown; and *Social Movements for Good,* a book by Derrick Feldmann about how companies and people can create change.

For more information about COMTO's work and membership, see https://comtonational.org/.

CONSENSUS STUDY REPORT

Keeping DUKW Boat Passengers Safe

MARK HUTCHINS

The author is a senior program officer at the Transportation Research Board, National Academies of Sciences, Engineering, and Medicine, in Washington, D.C.

U.S. Army, Wikimedia Commons

The iconic amphibious DUKW vehicle was designed to bring supplies from ship to shore during World War II. DUKW was an acronym for General Motors' manufacturing codes (D for the 1942 model, U for amphibious, K for all-wheel drive, and W for dual rear wheels). The nickname "DUCK" came from the soldiers who used these vehicles. DUKWs first saw combat in Operation Husky, a 1943 invasion of the Italian region of Sicily.

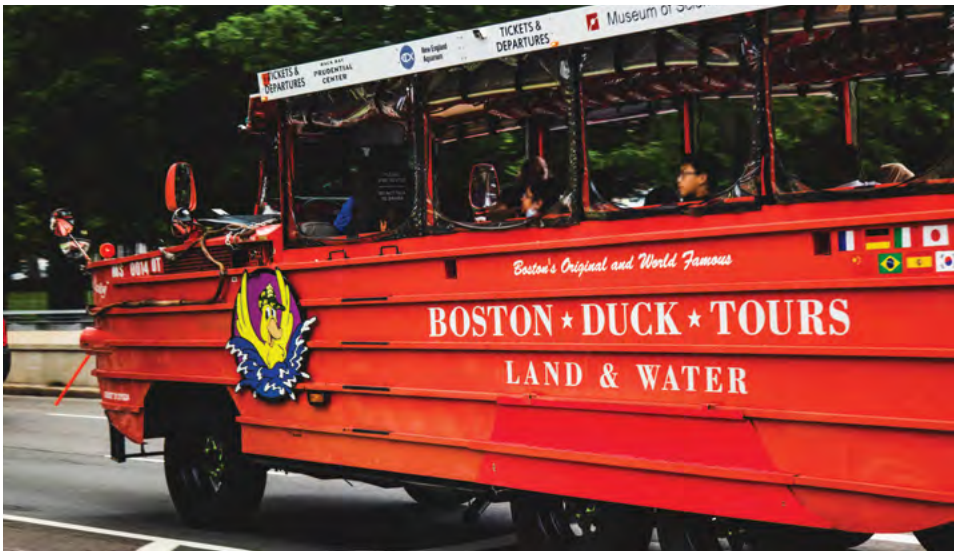
DUKWs are amphibious vessels first produced during World War II and long used for sightseeing tours. For some time, the safety of these vessels has been an area of special concern for the U.S. Coast Guard (USCG) and the National Transportation Safety Board (NTSB). After a mass-fatality sinking in 1999 that cost 13 lives, USCG made significant changes in how it oversees the DUKWs under its jurisdiction. When another DUKW sank in 2018, costing 17 lives, government and industry representatives looked for new solutions by revisiting their previous responses and recommendations.

Essentially, DUKWs are military cargo trucks that float. Although tour operations using the historic vessels from World War II have attempted to meet modern safety standards to the extent possible, some hazards of the original design remain. DUKWs designed for sightseeing tours—such as Stretch DUKWs from the 1990s and Truck Ducks built in the early 2000s—have remedied some, but not all, of these remaining hazards. Individual vessels within DUKW fleets also exhibit a significant amount of variability because of many adaptations that have occurred over time.

When compared with more modern small passenger vessels, DUKWs are at greater risk of sinking—and sinking more quickly. DUKWs sit low in the water and can be swamped by waves easily. Additionally, the requirements for operating on land mean that these historic vessels had numerous locations where water could enter the hull. Maintenance procedures and operating restrictions have been used to compensate for the vessel's design shortcomings.

Both the NTSB and USCG identified the presence of canopies as a contributing factor to DUKW fatalities. Tour operators use canopies and, in some cases, clear plastic side curtains, to provide customer comfort during tours. However, if the vessel sinks, these enclosures can prevent passengers from escaping. After the 2018 casualty event, NTSB and USCG recommended that tour operators remove canopies.

In the summer of 2020, USCG asked TRB to provide guidance on additional actions that could increase safety on DUKWs



Yassine Khalfalli, Unsplash

Duck tours are seen on land and in water in popular tourist locations, such as Boston, Massachusetts.

Petty Officer 3rd Class Lora Ratliff, USCG

Recovery operations lift Stretch Duck 7 from Table Rock Lake in Branson, Missouri, where it capsized on July 19, 2018, during a severe weather event with thunderstorms, high waves, and area winds of up to 70 miles per hour.

used for commercial passenger service. The resulting 2021 *TRB Special Report 342: Options for Improving the Safety of DUKW Type Amphibious Vessels* examines actions that may improve survivability for the vessel and its passengers. It also reviews vessel design, engineering, and outfitting options to provide reserve buoyancy and prevent flooding, and assesses the potential for additional restrictions on operating areas to provide a safer environment for waterborne tours. The report evaluates the advisability of wearing life jackets while on the water and covers methods for improving safety operations.

The report committee reviewed the designs for canopies and side curtains currently in use. While DUKW tour operators have made design changes since the 1999 casualties occurred, the committee found that improvements are still needed.

The risks to passengers on DUKWs can vary depending on the vessel, operating area, and operator diligence. The committee's recommendations to USCG distinguish between higher risk and lower risk operations. The most rigorous measures only target higher risk operations. The factors defining higher and lower risk operations are related to vessel design, systems, and operating area and, unless physically altered, are considered permanent features of the vessel and its environment. Issues related to operations management, such as insufficient crew training and lack of proper maintenance, could be addressed by improving safety management practices that could apply to any passenger vessels and could be monitored by USCG.

For World War II DUKWs, Stretch Ducks, and Truck Ducks, the committee recommended using risk assessment for DUKW operations. Specific recommendations follow, including those that mitigate certain hazards associated with flooding and survivability, operating areas, restrictive canopies, life jackets, and safety operations.

For a full list of recommendations, see the report at https://nap.nationalacademies.org/catalog/26447.

COOPERATIVE RESEARCH PROGRAMS NEWS

Peer Exchange Series for State DOT CEOs

This research aims to organize, support, deliver, and document a series of six in-person state department of transportation (DOT) chief executive officer (CEO) peer exchanges that will provide information for them to use to fulfill their responsibilities more effectively. A peer exchange will be held in each of the six AASHTO regions, with attendance open to any CEO.

To support the events, High Street Consulting Group has received an $875,543, 24-month contract [National Cooperative Highway Research Program (NCHRP) Project 20-24(139)] to identify current issues that will be the focus of discussions, prepare briefing materials to motivate discussions, convene an invited group of executives, facilitate these executives' discussions, and document the events.

For further information, contact Ann Hartell, TRB, at 202-334-2369 or AHartell@nas.edu.

MOPED AND MOTOR SCOOTER (50 CC OR LESS) SAFETY

Despite having similar risks and roadway safety challenges, mopeds and seated motor scooters are seldom held to the same safety and training standards and considerations as motorcycles. As a result, there is a public perception of mopeds and seated motor scooters that is fundamentally different from motorcycles when it comes to safety precautions, such as the use of personal protective gear, most importantly helmets.

Sean Benesh, Unsplash

New BTSCRP research will investigate safety issues unique to moped and seated motor scooter riding and provide intervention strategies, practical policy recommendations, and educational programs.

The University of South Florida has received a $349,999, 24-month contract [Behavioral Traffic Safety Cooperative Research Program (BTSCRP) Project BTS-19] to produce a report and supporting tools.

For further information, contact Richard Retting, TRB, at 202-334-2418 or RRetting@nas.edu.

AUTOMATED PAVEMENT CONDITION SURVEY PRACTICES AT AIRPORTS

Airport agencies have implemented automated pavement data collection for years. It is important to learn from their experience and process improvements.

This research aims to document existing practices from a range of geographically and size-diverse airports. The study is intended to produce a concise synthesis that showcases practices, integration of automated data collection into pavement management systems, and efforts needed for reporting pavement condition. The intended audience is airport agencies and staff responsible for airfield pavement maintenance management systems.

Woolpert has received a $45,000, 12-month contract [Airport Cooperative Research Program (ACRP) Synthesis 11-03/Topic S09-09] to document airport practices, challenges, and lessons learned in conducting automated pavement condition surveys.

For further information, contact Jordan Christensen, TRB, at 202-334-2317 or JChristensen@nas.edu.

LEVERAGING ARTIFICIAL INTELLIGENCE AND BIG DATA TO ENHANCE SAFETY ANALYSIS

This research will investigate the use of artificial intelligence, machine learning, and big data to provide the information needed to power key data-driven, public and proprietary safety analysis tools, as well as predictive and other systemic safety tools.

The University of Washington has received a $650,000, 30-month contract (NCHRP Project 17-100) to identify potential data sources; identify or develop the requisite data preparation and extraction algorithms for use in safety analysis; document each source's coverage, frequency of collection, granularity, accessibility to practitioners, and cost; and develop guidance for managing data using a format that can be accessed by various tools.

For further information, contact Roberto Barcena, TRB, at 202-334-2544 or RBarcena@nas.edu.

PEDESTRIAN AND BICYCLE SAFETY IN BUS/BUS RAPID TRANSIT CORRIDORS

This study aims to examine the state of practice in bus transit corridor planning, design, and construction as it relates to pedestrian and bike safety, public health, and equity. The focus will be on dedicated bus lanes and their relationship to safety, public health, and equity. The study will include the interaction of buses with bicyclists, pedestrians, and vehicles—especially those at bus stops, driveways, and intersections.

Thomas Loizeau, Unsplash

A TCRP study will look at dedicated bus lanes and the safety of bicyclists, pedestrians, and other vehicles.

Texas A&M Transportation Institute has received a $45,000, 18-month contract [Transit Cooperative Research Program (TCRP) Project J-07/Topic SA-54] to perform a literature review, survey agencies, hold follow-up interviews with selected agencies to develop case examples, identify knowledge gaps and suggestions for research to address those gaps, and document findings.

For further information, contact Mariela Garcia-Colberg, TRB, at 202-334-2361 or MGColberg@nas.edu.

CONNECTED AUTOMATED VEHICLE TECHNOLOGIES AND TRAFFIC INCIDENT MANAGEMENT

Guidance is needed to prepare emergency responders for the deployment of connected automated vehicle (CAV) technologies. This guidance includes a summary of such technologies and their impact on incidents and incident response that will be useful to a broad range of emergency responders. It also includes effective practices: strategies, processes, procedures, and standards that address the needs of emergency responders; recommendations for incorporating emergency responder perspectives into the development of CAV technologies; a report documenting the research; and products designed for training, presentation, informational, or other purposes and suitable for use within the CAV technology and emergency response communities.

Gannett Fleming has received a $249,584, 15-month contract [NCHRP Project 20-102(16)] to perform the research and develop guidance for emergency responders.

For further information, contact Zuxuan Deng, TRB, at 202-334-2305 or ZDeng@nas.edu.

UNCONTROLLED TERMINAL EVACUATIONS: PLANNING, RESPONSE, AND RECOVERY

Previous uncontrolled mass evacuations in the United States have shown gaps in response and recovery. Challenges include the general physical and psychological care of the evacuees; effective critical communication with the general public; managing incorrect information and disinformation; the importance of building trust while effectively communicating, understanding, and managing needs and resource distribution; and the recovery and reunification of the evacuees with loved ones and property.

Salus Solutions has received a $399,996, 18-month contract (ACRP Project 04-26) to develop a comprehensive guide covering types of uncontrolled evacuation events for airports of representative sizes and characteristics.

For further information, contact Matthew J. Griffin, TRB, at 202-334-2366 or MJGriffin@nas.edu.

The Aviation Industry's COVID-19 Recovery

The National Academies of Sciences, Engineering, and Medicine's Aeronautics and Space Engineering Board, part of the Division on Engineering and Physical Sciences, convened two virtual workshops in 2021 to address the many COVID-19–related issues facing the aviation industry.

FLYING IN THE COVID-19 ERA

The first workshop, Flying in the COVID-19 Era: Science-Based Risk Assessments and Mitigation Strategies on the Ground and in the Air, was held in February 2021. It considered operational and procedural best practices to mitigate COVID-19 transmission risks experienced throughout the travel chain from the departure airport entrance to the destination airport exit. The workshop also identified areas where more research is needed to address any gaps in understanding that were revealed.

FROM DEPARTURE ENTRANCE TO DESTINATION EXIT

Workshop presenters discussed health risks for passengers, as well as airline and airport employees. Related to issues encountered on the airplane, presenters considered cabin airflow modeling, cleaning requirements, food distribution, and seating. At the airport, they considered risk mitigation related to physical layout and queuing spacing while in lines for tickets, security, boarding, and deplaning. For airline and airport employees, issues of concern included those related to luggage handling, passenger check-in, and working with contracted food establishments. For the passenger experience, presenters discussed touchpoints while checking in, passing through Transportation Security Administration and border control checkpoints, retrieving luggage, and encountering other passengers. Finally, presenters and participants discussed possible next steps for understanding and preventing virus transmission while using commercial air transportation.

Erik McLean, Unsplash

Empty gate seats are a reminder of how the COVID-19 pandemic influenced air travel and the aviation industry. How was aviation able to bounce back? What changes will stay? What additional changes are still to come? Two informative workshops shed some light on this complex topic—from protecting passengers and workers to procedure and cabin design changes and the economics of it all.

AVIATION AFTER A YEAR OF PANDEMIC

Held in June 2021, the second workshop—Aviation after a Year of Pandemic: Economics, People, and Technology—focused on economics, personnel, technology, and next steps when considering effects of COVID-19 on the aviation industry. The workshop consisted of six sessions that addressed the following topics:

1. An overview of the COVID-19 pandemic and its effects on the airline industry;
2. Policies and procedures of airlines, airports, government agencies, and other stakeholders;
3. Aircraft design and flight operations, personnel, and performance, including the design of future aircraft intended to reduce the risk of disease transmission and possible changes to the training of airline crewmembers concerning interactions with passengers;
4. Airports, ground transportation, and air traffic management;
5. How the pandemic has influenced the economics of the aviation industry and what can be done to mitigate these effects and ensure the long-term viability of the industry; and
6. Summary and discussion of the previous sessions.

ADDITIONAL INFORMATION

Proceedings of a Workshop: Flying in the COVID-19 Era is available on the National Academies Press website at https://nap.edu/26426. *Proceedings of a Workshop: Aviation after a Year of Pandemic* is available on the National Academies Press website at https://nap.edu/26375.

For information about the Aeronautics and Space Engineering Board, visit https://www.nationalacademies.org/aseb. To learn more about the Division on Engineering and Physical Sciences, visit https://www.nationalacademies.org/deps.

MEMBERS *ON THE MOVE*

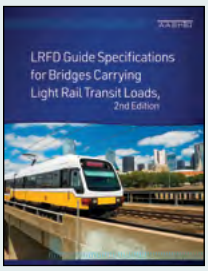
Steve Dickson, TRB Executive Committee ex officio member, left his position as FAA Administrator in March.

Genevieve Giuliano, TRB Executive Committee chair emeritus and director of the University of Southern California (USC) METRANS Transportation Consortium, stepped down on June 30, 2022, after 20 years. She will remain at USC as a professor in the Sol Price School of Public Policy's Urban Planning and Spatial Analysis Department.

Ed Leonardo, director of the TRB Meetings Department, retired on June 1, 2022, after nearly eight years of service.

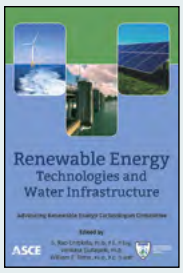
Jonathan Schneider, former chair of the Young Members Aviation Subcommittee and member of the Airport Terminals and Ground Access Committee, has become a project engineer with Airport Design Consultants in Ellicott City, Maryland.

Paul J. Wiedefeld, Washington Metropolitan Area Transit Authority general manager and chief executive officer, retired in May. He is a former TRB committee member, project panel chair, and panel member.



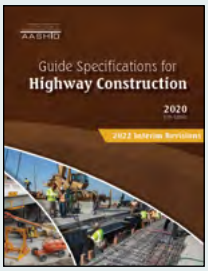
LRFD Guide Specifications for Bridges Carrying Light Rail Transit Loads, 2nd Edition
AASHTO, 2022, 39 pp., AASHTO member, $25; nonmember, $34; 978-1-56051-781-8.

This PDF download addresses the design of bridges subjected to light rail transit loadings, or both light rail transit and conventional highway traffic loadings. The new edition provides additional definitions common to the rail industry, clarifies the application of live loading and derailment loading, and revises language to improve consistency with the *AASHTO LRFD Bridge Design Specifications, 9th Edition*. Pricing provided is for a single-user PDF download.



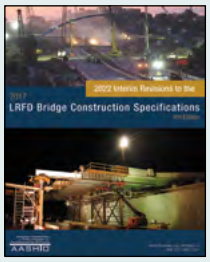
Renewable Energy Technologies and Water Infrastructure
ASCE, 2022, 260 pp., $110; 978-0-7844-8366-4. Edited by S. Rao Chitikela, Venkata Gullapalli, and William F. Ritter.

This book provides readers with a critical review of policy, regulation, science, and engineering with respect to the development and application of renewable energy technologies to the effective operation of water infrastructure. Detailed topics include renewable energy policy and regulatory requirements, microhydro power, biofuels, biogas-to-energy combined heat and power, fuel cells for clean water, sustainable desalination, geothermal energy, solar and wind energy toward resilient water infrastructure, application of renewables for monitoring water quality, and proven renewable energy applications to water infrastructure.



Guide Specifications for Highway Construction, 10th Edition: 2022 Interim Revisions
AASHTO, 2022, 102 pp., AASHTO member, $100; nonmember, $135; 978-1-56051-769-6.

These interim revisions to the guide specifications contain only supplemental material, not the complete text of the manual. Provided is an update on best practices for pavement preservation, including emulsified asphalt chip seal, hot-applied asphalt chip seal, micro surfacing, emulsified asphalt fog seal, diamond grinding, and slurry systems.



2022 Interim Revisions to the 2017 LRFD Bridge Construction Specifications, 4th Edition
AASHTO, 2022, 8 pp., AASHTO member or nonmember, free download; 978-1-56051-776-4.

These specifications, which employ the load and resistance factor design (LRFD) methodology, are intended for use in the construction of bridges. Designed to be used in conjunction with the *AASHTO LRFD Bridge Design Specifications, 9th Edition*, these interim revisions include changes to the sections on steel structures and bridge joint deck seals.

The titles in this section are not TRB publications. To order, contact the publisher listed.

TRB PUBLICATIONS

Transportation Research Record 2675
Issue 12

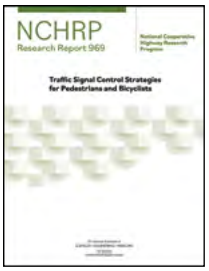
Among the topics explored in this volume are the effect of socioeconomic and demographic factors on crash occurrence, analysis of retrofit and scrappage policies for the Indian road transport sector in 2030, an economic feasibility analysis of charging infrastructure for an electric ground fleet at airports, and life-cycle assessment of asphalt pavements with recycled post-consumer polyethylene. This issue also includes papers from the TRB Graduate Research Award Program on Public-Sector Aviation Issues.

2021; 1,431 pp. For more information, visit http://journals.sagepub.com/home/trr.

Transportation Research Record 2676
Issue 1

The topics presented in this issue include pavement fatigue damage simulations, effects of hazmat train speed restrictions, drone delivery reliability for time-sensitive medical supplies, automatic speech recognition for air traffic control communications, and the influence of bridge fires on the properties of concrete and steel components.

2022; 810 pp. For more information, visit http://journals.sagepub.com/home/trr.



Traffic Signal Control Strategies for Pedestrians and Bicyclists
NCHRP Research Report 969

This report provides tools, performance measures, and policy information to help agencies design and operate signalized intersections in a way that improves safety and service for pedestrians and bicyclists while still meeting the needs of motorized road users.

2022; 182 pp.; TRB affiliates, $73.50; TRB nonaffiliates, $98. Subscriber categories: highways, pedestrians and bicyclists, design.

Access Management in the Vicinity of Interchanges
NCHRP Research Report 977

This two-volume report will assist transportation practitioners in making access management decisions for locations in the vicinity of interchanges. The first volume provides a practitioner's guide with an overview of common interchange configurations and the known impacts of access management on crossroads at these locations. The second volume presents a research overview summarizing the state of the practice, literature review, data collection, and operational and safety analyses that provides input to the practitioner's guide.

2022; 84 pp.; TRB affiliates, $88.50; TRB nonaffiliates, $118. Subscriber categories: highways, design, and transportation, general.

SAGE is the publisher of the *Transportation Research Record: Journal of the Transportation Research Board* (TRR) series. To search for TRR articles, visit http://journals.sagepub.com/home/trr. To subscribe to the TRR, visit https://us.sagepub.com/en-us/nam/transportation-research-record/journal203503#subscribe.

Systematic Approach for Determining Construction Contract Time: A Guidebook
NCHRP Research Report 979

This guidebook provides state departments of transportation with information for producing consistently credible, reliable, and defensible contract time estimates.

2022; 180 pp.; TRB affiliates, $73.50; TRB nonaffiliates, $98. Subscriber categories: administration and management, construction, maintenance and preservation.

Load Rating of Bridges and Culverts with Missing or Incomplete As-Built Information
NCHRP Synthesis 571

Load ratings are used, in part, to allocate federal funding to agencies and to plan for repairing, replacing, and rehabilitating bridges. This synthesis gathers and presents information on the methods that states currently use to perform load ratings of bridges and culverts with missing or incomplete as-built information and, in doing so, to establish the current state of practice.

2022; 118 pp.; TRB affiliates, $60.75; TRB nonaffiliates, $81. Subscriber categories: bridges and other structures, materials, safety and human factors.

Preparing Your Airport for Electric Aircraft and Hydrogen Technologies
ACRP Research Report 236

This report offers an introduction to the emerging electric aircraft industry, estimates potential market growth, and provides information to help airports estimate the potential impacts of electric aircraft on their facilities and prepare to accommodate them.

2022; 174 pp.; TRB affiliates, $73.50; TRB nonaffiliates, $98. Subscriber categories: aviation, planning and forecasting, terminals and facilities.

Examples of Facility Space Provided for Community Use at Airports
ACRP Synthesis 116

This synthesis provides the first body of literature to focus on the use of facilities that airports may provide in order to support local economic and social sustainability.

2022; 68 pp.; TRB affiliates, $52.50; TRB nonaffiliates, $70. Subscriber categories: aviation.

Assessing Equity and Identifying Impacts Associated with Bus Network Redesigns
TCRP Synthesis 159

This synthesis documents the current practice of how transit providers are defining, assessing, and addressing the equity impacts of bus network redesigns, including and beyond FTA's Title VI regulatory requirements.

2022; 88 pp.; TRB affiliates, $57.75; TRB nonaffiliates, $77. Subscriber categories: planning and forecasting, policy, public transportation.

To order the TRB titles described in Bookshelf, visit the TRB online bookstore, https://www.mytrb.org/MyTRB/Store, or contact the Business Office at 202-334-3213.

MEETINGS, WEBINARS, AND WORKSHOPS

July

6–8 **Traffic Signal Systems Committee Midyear Meeting**
Irvine, California
For more information, contact Rich Cunard, TRB, at 202-334-2965 or RCunard@nas.edu.

11–15 **International Conference on Bridge Maintenance, Safety, and Management***
Barcelona, Spain
For more information, contact James Bryant, TRB, at 202-334-2087 or JBryant@nas.edu.

14 **TRB Webinar: New Facilities and Systems Methods in HCM7**
For more information, see https://webinar.mytrb.org/Webinars.

18–21 **TRB Annual Automated Road Transportation Symposium**
Garden Grove, California
For more information, contact Rich Cunard, TRB, at 202-334-2965 or RCunard@nas.edu.

24–27 **Annual Workshop on Transportation Law**
Portland, Oregon
For more information, contact Bob Shea, TRB, at 202-334-3209 or RShea@nas.edu.

Please contact TRB for up-to-date information on meeting cancellations or postponements. For Technical Activities meetings, visit https://www.TRB.org/calendar/calendar.aspx or e-mail TRBMeetings@nas.edu. For information on all other events or deadlines, inquire with the listed contact.

25–27 **Geospatial Data Acquisition Technologies in Design and Construction Summer Committee Meeting**
Washington, D.C.
For more information, contact Brian Roberts, TRB, at 571-217-3233 or BRoberts@nas.edu.

August

1–14 **AASHTO Committee on Design Meeting in Conjunction with TRB Committees on Performance Effects of Geometric Design and Roadside Safety Design***
Kansas City, Missouri
For more information, contact Brian Roberts, TRB, 571-217-3233, BRoberts@nas.edu.

3 **TRB Webinar: Incorporating a Complex Transportation System in the New HCM7**
For more information, https://webinar.mytrb.org/Webinars.

4–5 **Bridging Transportation Researchers Conference***
Online
For more information, contact Anusha Jayasinghe, TRB, at (202) 334-2401 or AJayasinghe@nas.edu.

16 **TRB Webinar: Temporary Pavement Markings and Removal in Work Zones**
For more information, see https://webinar.mytrb.org/Webinars.

16-19 **National Hydraulic Engineering Conference***
Atlanta, Georgia
For more information, contact Brian Roberts, TRB, at 571-217-3233 or BRoberts@nas.edu.

23 **TRB Webinar: Integrating Performance, Asset, and Risk Management is Value-Add**
For more information, see https://webinar.mytrb.org/Webinars.

24–27 **National TRB Tools of the Trade Conference**
Boise, Idaho
For more information, contact Claire Randall, TRB, at 202-334-1391 or CRandall@nas.edu.

September

6–9 **International Conference of the International Society for Intelligent Construction***
Guimaraes, Portugal
For more information, contact Nancy Whiting, TRB, at 571-217-2956 or NWhiting@nas.edu.

12–16 **TRANSED: Mobility, Accessibility & Demand Response Transportation Conference**
Online
For more information, contact Bill Anderson, TRB, at 202-334-2514 or WBAnderson@nas.edu.

19–21 **Conference on Scenario Planning in Transportation**
Washington, D.C.
For more information, contact Claire Randall, TRB, at 202-334-1391 or CRandall@nas.edu.

27–29 **SNAME Maritime Convention***
Houston, Texas
For more information, contact Scott Brotemarkle, TRB, at 202-334-2167 or SBrotemarkle@nas.edu.

*TRB is co-sponsor of the meeting.

To subscribe to the TRB E-Newsletter and keep up to date on upcoming activities, go to www.trb.org/Publications/PubsTRBENewsletter.aspx and click on "Subscribe."

INFORMATION FOR CONTRIBUTORS TO **TR NEWS**

TR News welcomes the submission of articles for possible publication in the categories listed below. All articles submitted are subject to review by the Editorial Board and other reviewers to determine suitability for *TR News*; authors will be advised of acceptance of articles with or without revision. All articles accepted for publication are subject to editing for conciseness and appropriate language and style. Authors review and approve the edited version of the article before publication. All authors are asked to review our policy to prevent discrimination, harassment, and bullying behavior, available at https://www.nationalacademies.org/about/institutional-policies-and-procedures/policy-of-harrassment.

ARTICLES

FEATURES are timely articles of interest to transportation professionals, including administrators, planners, researchers, and practitioners in government, academia, and industry. Articles are encouraged on innovations and state-of-the-art practices pertaining to transportation research and development in all modes (highways and bridges, public transit, aviation, rail, marine, and others, such as pipelines, bicycles, pedestrians, etc.) and in all subject areas (planning and administration, design, materials and construction, facility maintenance, traffic control, safety, security, logistics, geology, law, environmental concerns, energy, technology, etc.). Manuscripts should be no longer than 3,000 words. Authors also should provide tables and graphics with corresponding captions (see Submission Requirements). Prospective authors are encouraged to submit a summary or outline of a proposed article for preliminary review.

MINIFEATURES are concise feature articles, typically 1,500 words in length. These can accompany feature articles as a supporting or related topic or can address a standalone topic.

SIDEBARS generally are embedded in a feature or minifeature article, going into additional detail on a topic addressed in the main article or highlighting important additional information related to that article. Sidebars are usually up to 750 words in length.

POINT OF VIEW is an occasional series of authored opinions on current transportation issues. Articles (1,000 to 2,000 words) may be submitted with appropriate, high-quality graphics, and are subject to review and editing.

RESEARCH PAYS OFF highlights research projects, studies, demonstrations, and improved methods or processes that provide innovative, cost-effective solutions to important transportation-related problems in all modes. Research Pays Off articles should describe cases in which the application of project findings has resulted in benefits to transportation agencies or to the public, or in which substantial benefits are expected. Articles (approximately 750 to 1,000 words) should delineate the problem, research, and benefits, and be accompanied by the logo of the agency or organization submitting the article, as well as one or two photos or graphics. Research Pays Off topics must be approved by the RPO Task Force; to submit a topic for consideration, contact Nancy Whiting at 202-334-2956 or nwhiting@nas.edu.

OTHER CONTENT

TRB HIGHLIGHTS are short (500- to 750-word) articles about TRB-specific news, initiatives, deliverables, or projects. Cooperative Research Programs project announcements and write-ups are welcomed, as are news from other divisions of the National Academies of Sciences, Engineering, and Medicine.

BOOKSHELF announces publications in the transportation field. Abstracts (100 to 200 words) should include title, author, publisher, address at which publication may be obtained, number of pages, price, Web link, and DOI or ISBN. Publishers are invited to submit copies of new publications for announcement (see contact information below).

SUBMISSION REQUIREMENTS:

- **Articles** submitted for possible publication in *TR News* and any correspondence on editorial matters should be sent to the *TR News* Editor, Cassandra Franklin-Barbajosa, cfranklin-barbajosa@nas.edu, 202-334-2278.
- Submit **graphic** elements—photos, illustrations, tables, and figures—to complement the text. Photos must be submitted as JPEG or TIFF files and must be at least 3 in. by 5 in. and 2 megabytes with a resolution of 300 dpi. Large photos (8 in. by 11 in. with a minimum of 4 megabytes at 300 dpi) are welcome for possible use as magazine cover images. A detailed caption must be supplied for each graphic element.

Note: Authors are responsible for the authenticity of their articles and for obtaining written permissions from publishers or persons who own the copyright to any previously published or copyrighted material used in the articles, **as well as any copyrighted images** submitted as graphics.

TRANSPORTATION RESEARCH BOARD
500 Fifth Street, NW
Washington, DC 20001

ADDRESS SERVICE REQUESTED

NATIONAL ACADEMIES *Sciences Engineering Medicine*

The National Academies provide independent, trustworthy advice that advances solutions to society's most complex challenges.
www.nationalacademies.org

TRN339