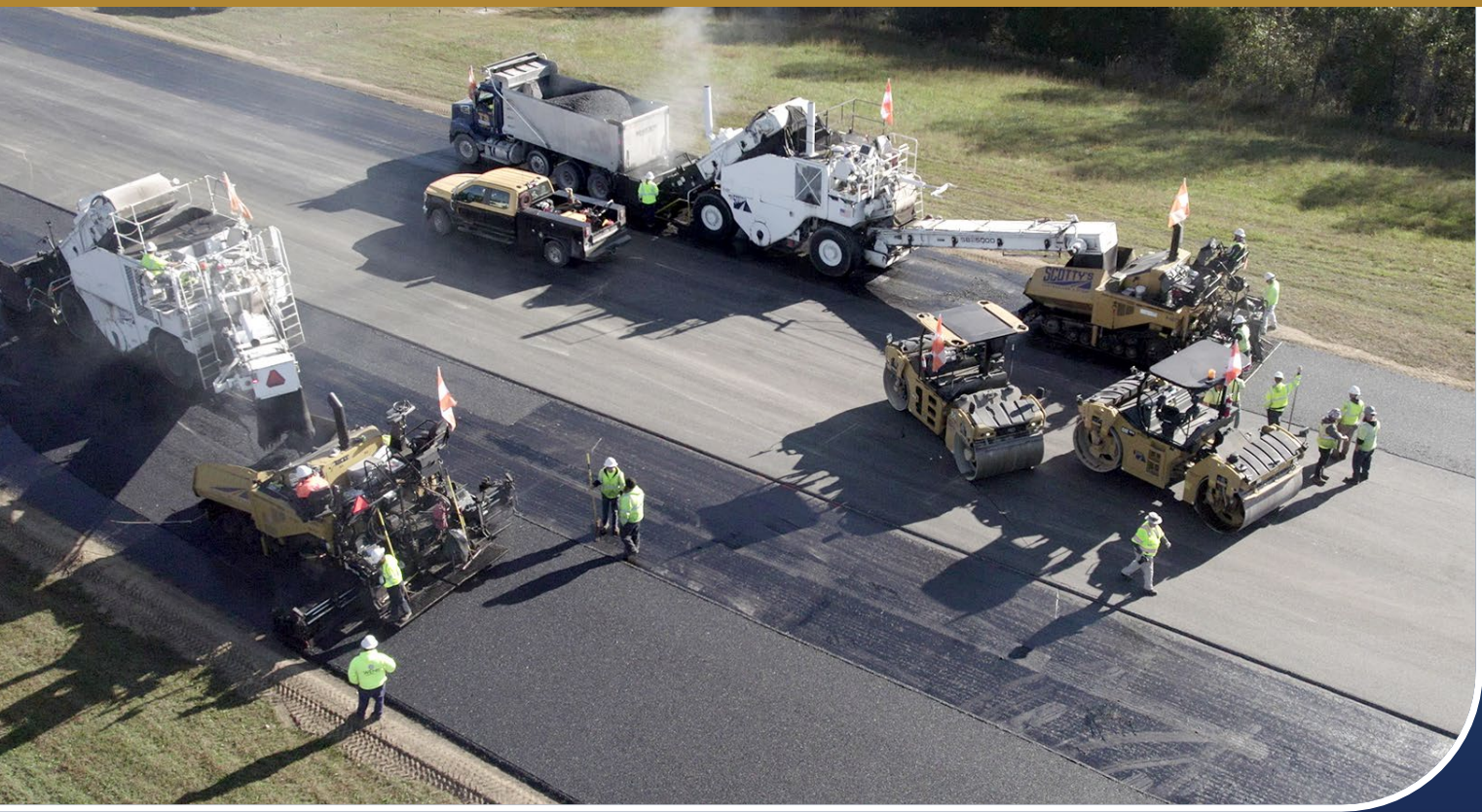
AAPTP
Airport Asphalt Pavement Technology Program

Improving Performance of Longitudinal Joints in Airfield Asphalt Pavements

Volume 1: Literature Review of Construction Techniques to Improve the Performance of Longitudinal Joints and a Review of Longitudinal Joint Maintenance for Airfield Pavements

July 2025



Credit: NAPA

PREPARED FOR:

Airport Asphalt Pavement Technology Program

Randy West
Carolina Rodezno
Adriana Vargas
Raquel Moraes
National Center for Asphalt Technology (NCAT) at Auburn University

David Peshkin
Greg Duncan
Jim Bruinsma
Applied Pavement Technology (APTech)

Christopher Williams
Paul Ledtje
Andrew Becker
Iowa State University

The Airport Asphalt Pavement Technology Program (AAPTP) is a cooperative agreement effort between the **National Asphalt Pavement Association** (NAPA) and the **Federal Aviation Administration** (FAA) to advance asphalt pavements and pavement materials. The AAPTP advances solutions for asphalt pavement design, construction, and materials deemed important to airfield reliability, efficiency, and safety. The program leverages NAPA's unique technology implementation capabilities with assistance from the FAA and industry to advance deployment and adoption of innovative asphalt material technologies.

Acknowledgments

This project was funded by the Airport Asphalt Pavement Technology Program (AAPTP) as part of a cooperative agreement with the National Asphalt Pavement Association (NAPA) and the Federal Aviation Administration (FAA). The authors would like to acknowledge Dr. Richard Willis (NAPA's Vice President for Engineering, Research, & Technology) and project panel members, including Brett Williams, Ray Brown, Jon Young, Debbie Schwerman, Christopher Unzicker, Timothy Martin, James Anderson, Jeremy Robinson, and Wesley Mittlesteadt, for overseeing the project and reviewing the project deliverables.



Credit: NAPA

Foreword

Federal Aviation Administration (FAA) advisory circular (AC) 150/5370-10H, *Standards for Specifying Construction of Airports* (dated Dec. 21, 2018), requires that longitudinal joints be cut back and an asphalt tack coat or other approved product be applied to the cut face prior to placing an adjacent lane. Contractors may also be permitted to use joint heaters to aid in constructing longitudinal joints. However, despite the FAA's requirement to cut back longitudinal joints and the additional, rigorous joint density acceptance requirement, both of which have been in place for nearly two decades, longitudinal joint cracking and raveling continue to be leading causes of deterioration in airfield asphalt pavements. While FAA AC 150/5380-6C, *Guidelines and Procedures for Maintenance of Airport Pavements* (dated Oct. 10, 2014), provides guidance on sealing cracks at joints, there remains a need to evaluate improved materials and methods.

A new method with potential for preserving joint integrity in flexible highway pavements is the use of a void-reducing asphalt membrane (VRAM). VRAM products are typically a hot-applied, highly polymer-modified liquid asphalt membrane that is applied prior to paving, directly beneath the future location of the longitudinal joint. As the hot asphalt mat is paved, the heat causes the highly polymer-modified membrane to migrate upward into the mat at the joint, filling air voids and reducing permeability from the bottom up.

Another relatively recent innovation with potential to reduce longitudinal joint deterioration substantially is the use of rapid-penetrating emulsions (RPEs). RPEs are asphalt emulsions specially formulated to penetrate quickly into low-density asphalt pavements, where they fill interconnected air voids, reduce permeability, and fill small cracks. RPE products can be applied using distributor trucks equipped with fog nozzles, either immediately after construction or later in the pavement's service life. Application rates can be adjusted based on permeability, texture, amount of air voids, and pavement age. Therefore, VRAM and RPE technologies have the potential to improve pavement performance at longitudinal joints.

This study examined VRAM, RPE, and other approaches to reducing the deterioration of longitudinal joints on airfield asphalt pavements based on experiences and field trials on highway pavements. The project deliverables are presented in three volumes:

- Volume 1—A literature review of VRAM, RPE, and other techniques to improve longitudinal joint performance, as well as a literature review of longitudinal joint maintenance for airfield pavements.
- Volume 2—Project reports on inspections of existing VRAM installations and documentation of new applications of VRAM and RPE at airports.
- Volume 3—*Best Practices Manual for Longitudinal Joint Maintenance*.

This document corresponds to Volume 1.

Table of Contents

Airfield and Highway Longitudinal Joint Construction Practices and Techniques for Improved Construction 1
Introduction 1
Airfield Longitudinal Joints 2
Highway Longitudinal Joints 4
Techniques for Improved Construction 6
Literature Review Summary 15
Airport Pavement Longitudinal Joint Maintenance 16
Introduction 16
Crack Sealing and Crack Filling 16
Partial- and Full-Depth Crack Repair 17
Infrared Heating 19
Microsurfacing 20
Rapid-Penetrating Emulsion (RPE) 22
Fog Seal 24
Rejuvenating Seals 25
Literature Review Summary 31
References 33

List of Figures

Figure 1. Cutback Joint [7] 2
Figure 2. Joint Cutting Tool on a Roller Compactor 3
Figure 3. State DOTs Without Longitudinal Joint Density Specifications [5, 16, 17, 18, 19, 20] 4
Figure 4. (a) Coring Diagram for Measuring Longitudinal Joint Density for Butt Joints and (b) Notched Wedge Joints [21] 6
Figure 5. Maryland Joint Method Used in Minnesota [25] 6
Figure 6. VRAM Working Principle [26] 7
Figure 7. States with Experience Using VRAM [28, 29] 8
Figure 8. Joint Adhesive Application 10
Figure 9. Joint Heater Train [42] 13
Figure 10. Joint Heater Mounted on a Paver [42] 13
Figure 11. Mastic Repair on Longitudinal Joints at Minneapolis Airport [52] 17
Figure 12. Partial-Depth Crack Repair in Flexible Pavement [47] 18
Figure 13. Full-Depth Crack Repair in Flexible Pavement [47] 18
Figure 14. A 2-ft (.6-m), Partial-Depth Slot Paving with a Perimeter Seal in Ohio [54] 19
Figure 15. Infrared Heating Repair at Kuujjuaq Airport [58]. 20
Figure 16. Microsurfacing over a Longitudinal Joint on I–94 near St. Cloud, MN [61] 21
Figure 17. (a) RPE Application Versus (b) Diluted SS-1h Application [66] 22
Figure 18. (a) RPE as a Longitudinal Joint Preventative Treatment Immediately Following Application, (b) After Penetrating the Joint (center), and (c) Drying [66] 23
Figure 19. RPE-Treated Joint During Spring Melt Event Showing Water Resistance [66] 23
Figure 20. (a) RPE Remedial Application to Low Joint-Density Area Immediately After Application and (b) After Penetration and Drying on U.S. Highway 53 in Chippewa County, WI [44] 24
Figure 21. Fog Seal Versus VRAM Field Samples: (a) Permeability and (b) Air Voids [45] 25
Figure 22. Application of Rejuvenating Seal to Treat a Longitudinal Joint [71] 26
Figure 23. (a) Highway Pavement Joint 3 Years After Treatment with JOINTBOND® Rejuvenating Seal and (b) the Control (Untreated) Joint After 3 Years [72] 27
Figure 24. (a) JOINTBOND® and (b) RePlay™ Application on a Longitudinal Joint [39] 27
Figure 25. JOINTBOND® Application on the Longitudinal Joint [20] 28
Figure 26. (a) Hypothesized Behavior of Rejuvenating Seal Products and (b) Field Data Obtained from Binder Extracted and Recovered from Field Cores After 0, 6, 12, 24, 30, and 48 Months of Treatment Application [74] 30
Figure 27. FN of Different Rejuvenating Seal Products, Before and After Treatment Application [74] 30

List of Tables

Table 1. Iowa DOT Payment for Longitudinal Joint Density [21] 5
Table 2. Recommended VRAM Application Rates [28] 7
Table 3. LJS Application Rates for Illinois [31] 9
Table 4. Summary of Maintenance Techniques for Longitudinal Joints 32

List of Acronyms and Abbreviations

AAPTP	Airport Asphalt Pavement Technology Program
AC	Advisory circular
ASTM	ASTM International
DOT	Department of Transportation
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FN	Friction number
FOD	Foreign object debris
HMA	Hot-mix asphalt
IDOT	Illinois Department of Transportation
IDT	Indirect tensile
LJS	Longitudinal joint sealant
MnDOT	Minnesota Department of Transportation
NAPA	National Asphalt Pavement Association
NCAT	National Center for Asphalt Technology
PWL	Percent within limits
RPE	Rapid-penetrating emulsion
TMD	Theoretical maximum density
VRAM	Void-reducing asphalt membrane

Airfield and Highway Longitudinal Joint Construction Practices and Techniques for Improved Construction

This section summarizes a critical review of literature on airfield and highway longitudinal joint construction practices, including the use of void-reducing asphalt membranes (VRAMs), joint adhesives, joint heaters, and joint sealants, that have been used to improve joint performance.

Introduction

The most common performance issue observed in airport flexible pavements is premature deterioration at longitudinal joints due to cracking and raveling [1, 2, 3]. Premature deterioration can occur due to lower density near the joint, which increases permeability. Increased permeability leads to moisture and freeze-thaw damage and faster oxidation of the asphalt, making the joint more susceptible to cracking caused by thermal expansion and contraction of the pavement. Raveling of the joints is a particular concern for airfield pavements, as it can generate foreign object debris (FOD) that can damage aircraft.

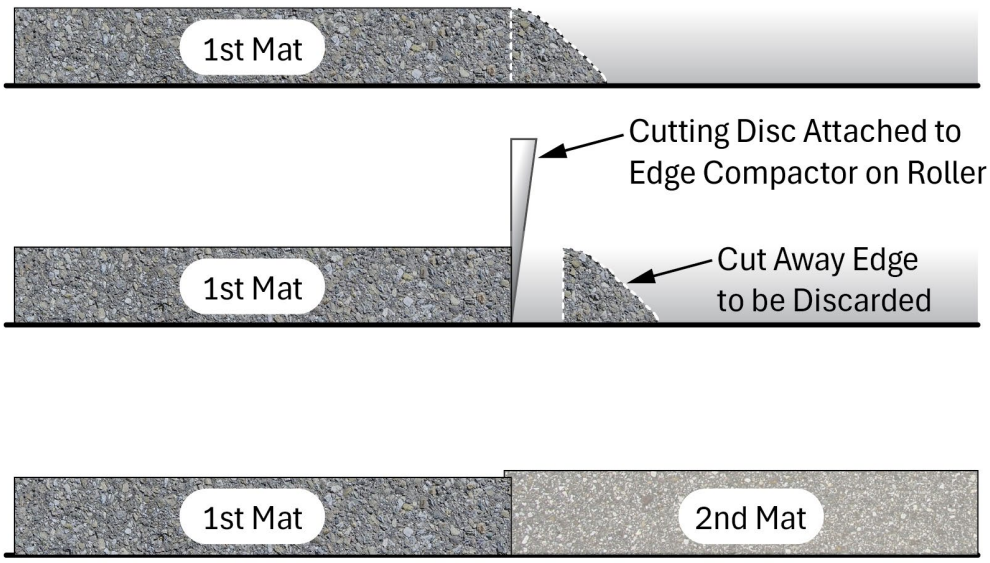
Longitudinal joints in flexible pavements are created during construction due to the paving of multiple lanes. When the first lane is constructed, its unconfined edges lack lateral support to restrain the mix from spreading during compaction. Airport taxiways, runways, and aprons typically contain several longitudinal joints, creating a maintenance problem when these joints are subjected to aircraft traffic and environmental conditions. Therefore, it is critical to ensure that good procedures are used for constructing and maintaining longitudinal joints in airport flexible pavements.

Numerous studies have evaluated various joint construction techniques and joint treatments to improve the performance of longitudinal joints on highways, but few have focused on airfields. However, it is plausible that results from longitudinal joint studies of flexible highway pavements could be applied to airfield pavements. Prior research has shown that mixtures with low air void content values of 3 to 5 percent are more durable than those with air void contents of 7 to 10 percent [2]. Several treatments and techniques have been demonstrated to reduce air voids, improve density, add sealing material to the joint, or reduce the permeability of the surface, all of which should mitigate joint deterioration. However, the literature does not clearly identify which method or treatment is the most effective over long periods of service [4, 5].

Airfield Longitudinal Joints

The current Federal Aviation Administration (FAA) advisory circular (AC) 150/5370-10H, *Standard Specification for Construction of Airports* (dated Dec. 21, 2018), requires that longitudinal joints be cut back and that an asphalt tack coat be applied to the cut face before placing an adjacent lane. The tack coat material is specified in Item P-603 Emulsified Asphalt Tack Coat, which references ASTM D3628, *Standard Practice for Selection and Use of Emulsified Asphalts*. The previous specification, FAA AC 150/5370-10G (dated July 21, 2014), also allowed the use of "other products" besides asphalt tack coats, if approved by the engineer; however, this option was removed in the current specification.

Creating the cutback joint involves cutting and removing a portion of the mix with low density at the edge of the first-pass paving lane (see Figure 1). The FAA requires a cutting wheel or pavement saw to cut up to 3 inches (76 mm) of the unconfined edge of the lane [6]. Some roller compactors are equipped with a cutting tool (as shown in Figure 2).



Source: NAPA

Figure 1. Cutback Joint [7]



Source: Applied Research Associates, Inc.

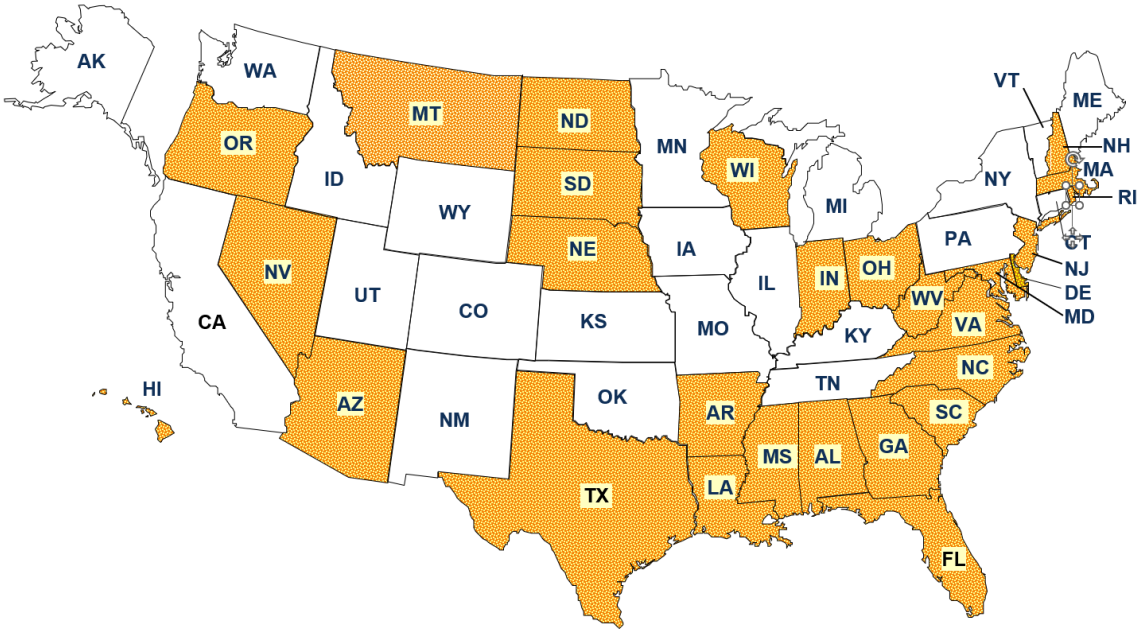
Figure 2. Joint Cutting Tool on a Roller Compactor

A laydown plan in the FAA specification is required to reduce the number of cold joints; it contains the width and sequence of paving lanes. The main longitudinal joint construction technique consists of offsetting the new longitudinal joint by at least 1 ft (30 cm) from the course immediately below and cutting back the material abutting the joint. A tack coat is applied to the newly exposed vertical face of the pavement before the next paving pass with a hot asphalt mixture is placed against it [6].

To further ensure good longitudinal joint construction techniques are used, a joint density requirement is also included in the FAA specification. Joint density acceptance is based on the percent within limits (PWL) for each lot of plant-produced asphalt mix. A lot is defined as one-day's production divided into 400- to 600-ton sublots. The specification states that each sublot shall be tested for in-place mat and joint density as a percentage of the theoretical maximum density (TMD) using cores of at least 5 inches (127 mm) in diameter. Joint cores shall be centered over the longitudinal joint at locations directed by the Resident Project Representative, in accordance with ASTM D3665, *Standard Practice for Random Sampling of Construction Materials*. The relative density of the joint cores is determined by dividing the bulk specific gravity by the average TMD for the lot. The lot is deemed acceptable if it is equal to or exceeds 90-percent PWL, achieved when the average joint density is consistently within 90.95 to 94.05 percent, and the standard deviation is 1.55 percent or less. If the PWL is less than 80 percent, the contractor is stopped until the reason for low density has been determined. A 5-percent reduction to the pay factor for the lot is applied if the PWL is less than 71 percent.

Highway Longitudinal Joints

In highway pavements, poor density at longitudinal joints is also prevalent. Thus, numerous methods for mitigating this problem have been evaluated [8, 9, 10, 11, 12, 13, 14]. Many State departments of transportation (DOTs) use a longitudinal joint density specification to ensure durable longitudinal joints. Research by Purdue University indicated that only 12 State DOTs had a longitudinal joint density requirement in their specifications in 2011, but this number had increased to 24 by 2018 (see Figure 3).



Source: NAPA

Figure 3. State DOTs Without Longitudinal Joint Density Specifications [5, 15, 16, 17, 18, 19]

The longitudinal joint specifications typically include payment adjustments based on the average relative density achieved at the joint. In Iowa, the average joint density is calculated as a percentage of the average mat density, as shown in Equation (1) [20]. Average joint density is used to adjust the pay, which can result in incentives or disincentives (see Table 1).

$$Avg\ Joint\ Density = 100 \times \frac{AvgJointG_{mb}}{AvgMatG_{mb}} \quad (1)$$

Where:

$AvgJointG_{mb}$= Average bulk specific gravity of the mix at the joint.
$AvgMatG_{mb}$ = Average bulk specific gravity of the mat.

Table 1. Iowa DOT Payment for Longitudinal Joint Density [20]

Avg. Joint Density (%)	Payment Adjustment ($/ft)
< 95.0[1]	0.16 × Avg. Joint Density – 15.2
95.0 – 97.0	$0.00
> 97.0[2]	0.1333 × Avg. Joint Density – 12.93

[1]Disincentive is not to exceed $0.80/ft.
[2]Incentive is not to exceed $0.40/ft.

In Minnesota, the pay factor is calculated by combining the effects of mat density, confined edge density, and the unsupported edge density. Both the confined and unconfined densities are the longitudinal joint densities. The pay factor is calculated using different combinations, as shown in the following three cases:

- Case 1: Total Pay Factor = (Pay Factor A) × (Pay Factor B) × (Pay Factor C).
- Case 2: Total Pay Factor = (Pay Factor A) × (Pay Factor B) × (Pay Factor B).
- Case 3: Total Pay Factor = (Pay Factor A) × (Pay Factor C) × (Pay Factor C).

Where:

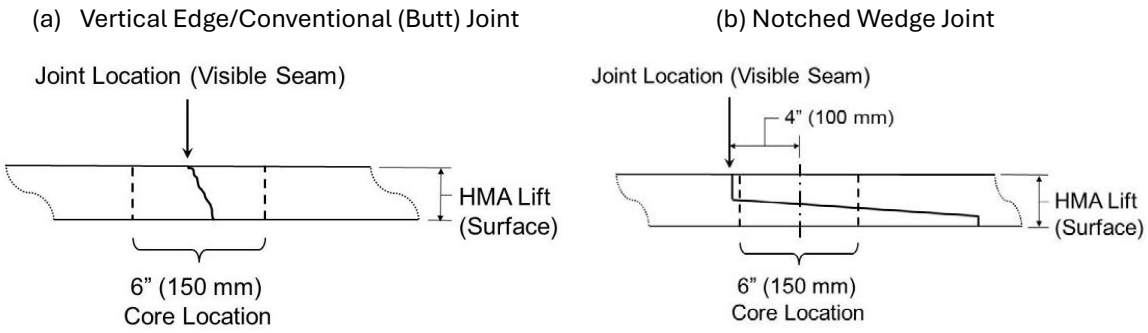
Pay Factor A = Mat density.
Pay Factor B = Confined edge density.
Pay Factor C = Unsupported edge density.

In cases where no cores are obtained from the longitudinal joint, a pay factor of 1.00 is used for Pay Factor B, Pay Factor C, or both [21].

Different transportation agencies have used different joint construction methods, such as the butt, notched wedge, and Maryland joint techniques, as well as material-based approaches [22]. The use of longitudinal joint specifications has led to innovation by contractors and construction material producers to ensure low air voids at the joint are achieved. Adhesives have been used at the joints as a practical solution for low density [23].

The State of Iowa uses butt and notched wedge joints, as shown in Figure 4. The cold lane is milled to create a vertical edge face.

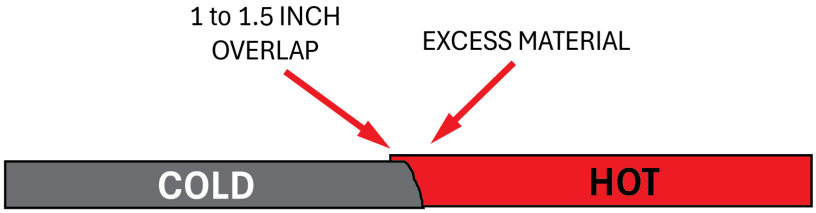
(a) Vertical Edge/Conventional (Butt) Joint
(b) Vertical Edge/Conventional (Butt) Joint



Source: Used with permission from Iowa Department of Transportation

Figure 4. (a) Coring Diagram for Measuring Longitudinal Joint Density for Butt Joints and (b) Notched Wedge Joints [20]

Figure 5 shows how the Maryland joint is constructed in Minnesota. The Maryland joint resulted from efforts by asphalt contractors to improve density. This method involves a small overlap at the joint with the adjacent pavement lane. The overlap is about .25 inches (6 mm) thick and extends 1.0 to 1.5 inches (25 to 38 mm) onto the adjacent pavement lane.



Source: Adapted from Minnesota Asphalt Pavement Association 2014

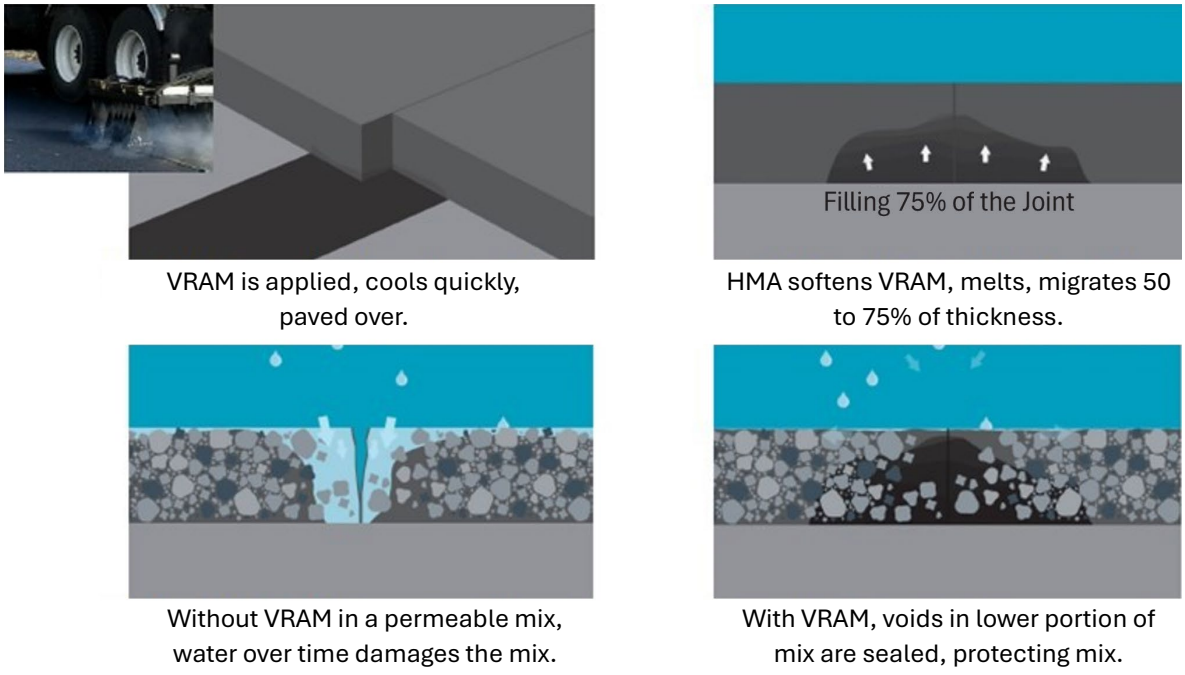
Figure 5. Maryland Joint Method Used in Minnesota [24]

Techniques for Improved Construction

The following sections focus on techniques used to improve the construction of longitudinal joints: VRAM, joint adhesives, joint heaters, and joint sealants.

Void-Reducing Asphalt Membrane (VRAM)

VRAM is a hot-applied, highly polymer-modified liquid asphalt membrane applied prior to paving beneath where the longitudinal joint will be. When the hot asphalt mat is paved over the VRAM, the heat causes the highly polymer-modified membrane to melt and migrate upward into the mat at the joint, filling air voids and reducing permeability from the bottom up. Figure 6 shows the basic principles behind the use of VRAM.



VRAM is applied, cools quickly, paved over.

HMA softens VRAM, melts, migrates 50 to 75% of thickness.

Without VRAM in a permeable mix, water over time damages the mix.

With VRAM, voids in lower portion of mix are sealed, protecting mix.

Source: Asphalt Materials, Inc.

Figure 6. VRAM Working Principle [25]

The VRAM composition includes an asphalt binder, an elastomeric polymer, a wax modifier, and at least one of the following: i) fumed silica or fumed alumina, ii) a saponified fatty acid and a resin acid gelling compound [26]. The composition is resistant to flow when applied and migrates into hot-mix asphalt (HMA) in the area of the longitudinal joint to reduce air voids and water permeability. The composition becomes tack-free quickly after application. It bonds to asphalt, concrete, brick, stone, and metal.

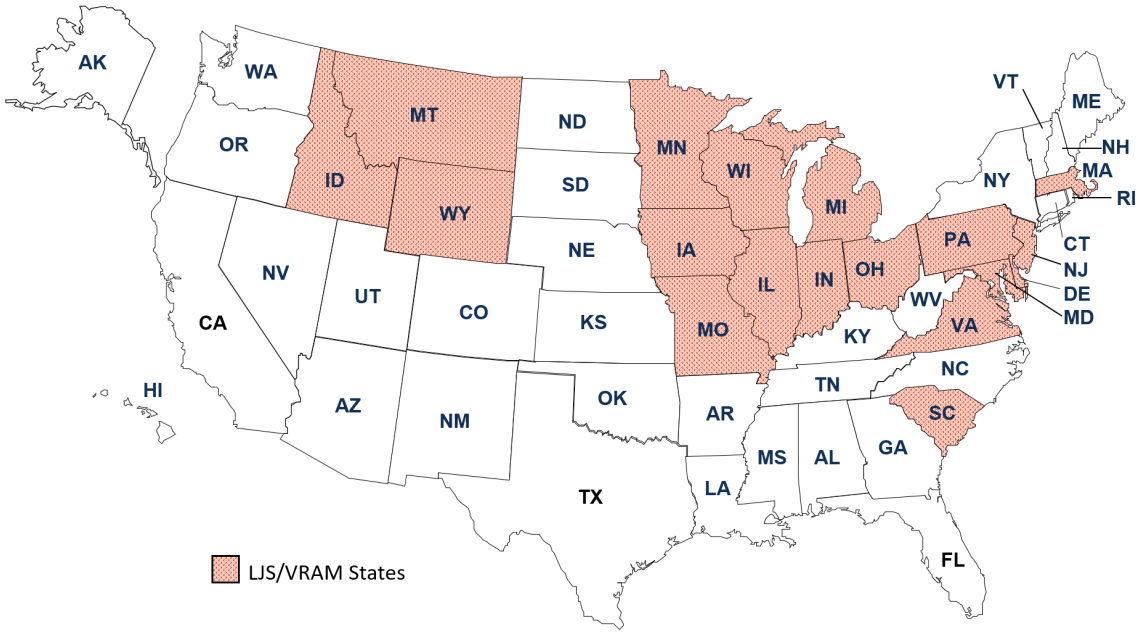
VRAM is used for its efficient application, wide coverage, fast-acting, upward-moving, long-lasting, and cost-saving benefits. VRAM is believed to migrate into the air voids of the new mat at the joint, filling up 50 to 70 percent of the air voids. The amount of migration depends on the heat of the mix and the time of compaction.

VRAM can be applied underneath the HMA at the longitudinal joint or at the vertical face of the first pass of the asphalt pavement mat [26]. The application rates recommended by the producer are shown in Table 2.

Table 2. Recommended VRAM Application Rates [27]

HMA Mixtures		
Overlay Thickness, inches (mm)	**VRAM Width, inches (cm)**	**Application Rate, lb/ft (kg/m)**
1.00 (25)	18 (45)	1.15 (1.71)
1.25 (31)	18 (45)	1.31 (1.95)
1.50 (38)	18 (45)	1.47 (2.19)
1.75 (44)	18 (45)	1.63 (2.43)
2.00 (50)	18 (45)	1.80 (2.68)

VRAM has been used on highway projects in at least 18 States. Figure 7 shows States that currently have some experience with VRAM.



Graphic Source: NCAT. Data Source: https://thejointsolution.com.

Figure 7. States with Experience Using VRAM [27, 28]

The Wisconsin DOT sponsored a research project to synthesize information about best practices for longitudinal joint construction using promising materials and methods. The study indicated that reducing mixture permeability at and near the joints was the most promising method to improve joint performance. Based on the information gathered, VRAM seemed to be a promising material to utilize during construction. The researchers recommended constructing trial sections with VRAM using preliminary provisions developed by the Minnesota DOT (MnDOT) and provided in the report's appendix, but it was also noted that more research was needed to understand the material properties that impacted performance in Wisconsin [27].

The Illinois DOT (IDOT) has the most extensive history with VRAM, with hundreds of projects to date. IDOT refers to VRAM as longitudinal joint sealant (LJS). IDOT began using LJS in 2002, and thus the agency has long-term performance experience with this product [27]. Trepanier et al. [29] analyzed pavements that were at least 12 years old and indicated that LJS provided a 3- to 5-year life extension of the joint area. A life-cycle cost analysis indicated that the performance benefit of LJS is three to five times the initial cost of the installation. IDOT fully implemented the use of LJS in the 2018 construction season. The estimated cost of LJS (VRAM) is about $2 per linear foot.

In Illinois, when LJS is specified, the application rate is based on the type of asphalt mixture and the thickness to be placed above the LJS, as shown in Table 3. The surface on which

the LSJ is placed should be thoroughly cleaned and dry before application. The LJS can be applied before or after the placement of the tack coat. The LJS width should be 18 ± 1.50 inches (450 ± 38 mm), centered under the longitudinal joint of the HMA to be placed. Care should be used to prevent double application when resuming placement [30].

Table 3. LJS Application Rates for Illinois [30]

LJS Application Rate, lbs/ft (kg/m)			
Lift Thickness, inches (mm)	**Coarse-Graded Mixture (IL-19.0, IL-19.0L, IL-9.5, IL-9.5L, IL-4.75)**	**Fine-Graded Mixture (IL-9.5FG)**	**SMA Mixture (SMA-9.5, SMA-12.5)[1]**
0.75 (19)	0.88 (1.31)		
1.00 (25)	1.15 (1.71)		
1.25 (31)	1.31 (1.95)	0.88 (1.31)	
1.50 (38)	1.47 (2.19)	0.95 (1.42)	1.26 (1.88)
1.75 (44)	1.63 (2.43)	1.03 (1.54)	1.38 (2.06)
2.00 (50)	1.80 (2.68)	1.11 (1.65)	1.51 (2.25)
≥2.25 (56)	1.96 (2.92)		

[1]SMA = stone matrix asphalt.

The Montana DOT has a current project to determine the efficacy of using VRAM to mitigate deterioration at longitudinal joints. During the first inspection in 2021, there were no performance issues; however, it was however noted that the VRAM had bled through the HMA and chip seal and was visible on the road surface [28].

The Indiana DOT recently adopted the use of VRAM for longitudinal joints, beginning in September 2022 [31]. A life cycle analysis performed by the Indiana DOT showed that every dollar invested in VRAM would yield at least $2 in savings from avoided and deferred maintenance costs [27].

MnDOT sponsored a research project to evaluate the use of a VRAM product to improve the performance of longitudinal joints in asphalt mixtures. A section containing VRAM and a control section were constructed on the same highway. The study evaluated field cores from both sections for performance-related properties. Cores were tested using the disk compact tension and semi-circular bend tests. Additionally, falling head permeability and air void determinations were carried out. Cores were cut into two halves (top and bottom) to identify differences in air voids. The results showed that cores with VRAM had lower permeability, lower air void contents, higher bond energy, and higher fracture energy compared to the cores from the control section. A field survey of the test sections did not show any distress of concern after exposure of the pavement to one winter [32].

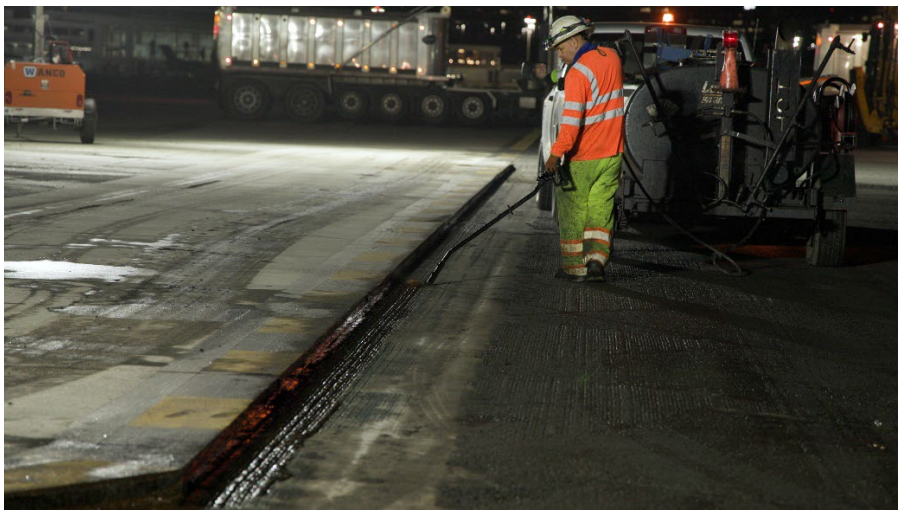
Three airport paving projects were built in Illinois using VRAM. The Pekin Municipal County Airport project was built in 2019, the Decatur Airport project was built in 2020, and the

Coles County Airport project was built in 2021. These projects were evaluated in this Airport Asphalt Pavement Technology Program (AAPTP) research project.

Other Joint Adhesives

Joint adhesives are typically hot-applied, polymerized asphalt products that provide an adhesive bond at the longitudinal cold construction joint in asphalt pavements. With this technique, the cold lane is paved with an unconfined edge, followed by the application of the joint adhesive on the face of the cold lane right before the placement of the hot lane, as shown in Figure 8. State DOTs such as New Jersey, Ohio, and Alaska routinely specify proprietary joint sealants.

The products are typically applied in a 1/8-inch (3-mm) band. The joint adhesive's purpose is to waterproof the joint and provide improved resistance to thermal expansion and contraction. The joint adhesive is supplied as a solid material and must be melted in a jacketed double-boiler melting unit and heated to the application temperature. For application, a pressure-fed wand is used with an applicator shoe attached to the end of the wand to spread the material uniformly. The typical application temperature is 380 °F, with a maximum heating temperature of 400 °F [4, 33].



Source: NAPA

Figure 8. Joint Adhesive Application

NCAT conducted several longitudinal joint studies between 1992 and 2002 to evaluate various joint construction techniques in Michigan, Wisconsin, Colorado, and Pennsylvania [34, 35, 36, 37]. The evaluations in Colorado and Pennsylvania included joint adhesives. The following techniques were included in these studies:

- Rolling from the hot side.
- Rolling from the cold side.
- Rolling from the hot side 6 inches away from the joint.

- Edge-restrained device.
- Cutting wheel with tack coat.
- Cutting wheel without tack coat.
- Joint maker (Pennsylvania only).
- Tapered (1:3) joint with vertical offset (Colorado only).
- Joint sealant (referred to in these reports as rubberized asphalt tack coat).
- Wedge (1:3) and infrared heating (Pennsylvania only).

After a 6-year field performance evaluation, the study concluded that the longitudinal joint constructed using the joint sealants yielded the most durable joints with no significant cracking, even though the joint densities in those sections were not the highest. The joint sealant was a rubberized asphalt binder with a thickness of about 1/8 inch (3 mm). The joint made with the cutting wheel provided the second-best technique. One of the recommendations from the study was to use joint sealants to obtain consistent performance of longitudinal joints.

Research conducted as part of the AAPTP in 2007 consisted of an extensive literature review on the construction of longitudinal asphalt joints and interviews with experienced airfield engineers to develop technical guidance for FAA best practices. One of the recommendations from the best practices document was that other cold joint construction techniques (besides cutback joints), such as the notched wedge joint, rubberized asphalt tack coat (joint sealant), and their combination, should be considered by the FAA, taking into account airfield traffic, aircraft gross weights, and climate. The authors suggested that thick tack coats may be more effective than most commonly used thin tack coats of asphalt emulsion [4].

A study conducted by Morgan in 2009 evaluated the effect of joint adhesive products on the performance of longitudinal paving joints in New York. Seven overlay pavement projects were evaluated with three different joint adhesives. The adhesives were placed with either a 2-inch (50 mm) or 4-inch (101 mm) bead using standard crack sealing equipment. A wedge joint was combined with joint adhesives for six of the projects. The seventh project utilized a butt joint in combination with a joint adhesive. All the projects except one had a corresponding control section. Field evaluations of the test sections were performed for up to 3 years. Except for the 4-inch (101 mm) bead section in one of the projects, the longitudinal joint of sections with adhesive were performing well or better than the control sections, but long-term performance monitoring of the sections was recommended [23].

The Tennessee DOT (TDOT) investigated several joint construction techniques in three field projects that included joint adhesives, joint sealers, and infrared joint heaters. The evaluation was based on density, permeability, indirect tensile (IDT) strength, water absorption, and X-ray tomography. Performance parameters consistently characterized the longitudinal joint construction quality, with lower air void contents yielding lower

permeability and higher IDT strengths. The joints constructed with the infrared heater were reported to be the best early-life performers, with lower air voids and permeability and increased IDT strength. Sections with joint adhesives showed a slight reduction in air voids and IDT strength and reduced permeability based on field cores. On the other hand, water absorption testing indicated that joint sealers might prevent water from penetrating the joint, but permeability results showed no reduction [38].

In 2011, a study for the Arkansas DOT evaluated numerous joint construction techniques that included notched wedge joint makers, joint heaters, joint stabilizers, joint sealants, and different rolling patterns. Density measurements and field permeability tests were performed for each test section. The authors reported that the most successful techniques were the joint heater, joint stabilizer, and notched wedge joint maker. The joint sealants were believed to have reduced the permeability in the limited area of their application but did not improve the adjacent material [19].

A recent study conducted by the U.S. Army Engineer Research and Development Center evaluated joint adhesive products' tensile properties, including elongation and failure load at different temperatures. The laboratory study included the evaluation of joints prepared using joint adhesives, a typical emulsified tack coat, and no adhesive (only cold/hot adhesion). Laboratory results suggested that joint adhesives could improve asphalt joint performance compared to current airfield pavement construction practices [39].

Joint Heaters

Joint heaters have been successfully used during the construction of highway pavements to reheat the cold, uncompacted edge and achieve the desired joint density during the paving operation. The principle is that after the placement of the cold lane, the joint can be heated prior to the placement of the hot lane to improve the adhesion between the sides of the joint and compaction of the joint area.

Joint heaters have been used for many years, and the technology has evolved with improvements such as more efficient heaters and automation synchronized with paver speed, which has reduced issues related to overheating and underheating the mix [40]. Joint heaters typically employ propane-powered, high-efficiency infrared technology. The heater panels can be mounted on a trailer pulled by a motorized tractor that travels ahead of the paver, as shown in Figure 9, or they can be attached to the side of the paver, as shown in Figure 10. This technique is considered the best approximation of echelon paving in cases where proper echelon paving is not possible [19].



Source: Ray-Tech Infrared

Figure 9. Joint Heater Train [41]



Source: Heat Design Equipment, Inc.

Figure 10. Joint Heater Mounted on a Paver [41]

Longitudinal joint studies by Williams [19] and Huang [38], conducted in Arkansas and Tennessee, have shown that infrared heaters can increase longitudinal joint density. Joint heaters have also been used successfully in asphalt airfield pavements. Examples of commercial and military airports that have used joint heaters include Petersburg James A.

Johnson Airport in Alaska, Wheeler-Sack Army Airfield at Fort Drum in New York, Fort Stewart-Hunter Army Airfield in Georgia, and the Québec City Airport, among others.[1]

Daniel and Real [42] conducted a field study in New Hampshire using an infrared joint heater on the base, binder, and surface layers of a full-depth asphalt pavement. Density and strength measurements were taken along the joint and in the travel lanes for the infrared-heated sections and their corresponding control sections. Statistical analysis determined that the infrared-heated sections were better in terms of permeability and indirect tensile strength. In addition, based on an evaluation 1 year after construction, the infrared-heated joints had less cracking and segregation than the control section.

The current FAA standard, AC 150/5370-10H, allows the contractor to use joint heaters to achieve density at the joint. The standard specifies that the electrically powered infrared heating equipment should consist of one or more heaters capable of heating and softening the pavement joint. The joint heaters should be configured to heat an area up to 18 inches (457 mm) wide and 3 inches (76 mm) deep. In addition, AC 150/5370-10H specifies that the joint heaters should provide a uniform temperature increase throughout the layer, with a temperature range of 200 to 300 °F (93 to 149 °C).

Joint Sealers

Joint sealers are applied to the pavement surface after both sides of the joint have been compacted. Typically, joint sealers are polymerized maltene-based emulsion products composed of a petroleum resin oil base and styrene-butadiene rubber (SBR) copolymer emulsified with water [27, 43]. This product penetrates the pavement's surface and alters the chemistry of the asphalt binder to help reduce joint deterioration. Typical application rates recommended by suppliers are between 0.06 and 0.15 gal/yd^2 (.27 and .68 L/m^2) [44].

Montgomery and Haddock [45] conducted a study to investigate joint sealer materials (referred to as fog seal) for use on longitudinal joints in Indiana and compared the performance of the joint sealers to VRAM treatments. The products evaluated were an SS-1h emulsion (a slow-setting cationic emulsion with low viscosity made using hard base asphalt) and an AE-NT trackless tack. Laboratory testing of both laboratory-prepared and field samples was used to assess permeability. The researchers concluded that the fog seals reduced the permeability of the longitudinal joint when compared to control samples that did not receive a joint sealer application.

[1]Personal communication with Bob Kieswetter (Heat Design Equipment Inc.) July 2022.

Literature Review Summary

This portion of the literature review summarized airfield longitudinal joints, highway longitudinal joints, and techniques used to improve the construction of longitudinal joints in highways, including VRAM, other joint adhesives, joint heaters, and joint sealers. Of these techniques, joint heaters are currently allowed by the FAA; however, the longitudinal joint construction procedure is limited to the cut-back method with the application of an asphalt tack coat to the cut face. Some of the treatments summarized in this document—particularly a rubberized asphalt binder (joint sealant) and VRAM—have shown potential for improving the performance of longitudinal joints in highway flexible pavements and, therefore, should be considered for further assessment in airfield pavements.

Airport Pavement Longitudinal Joint Maintenance

This section synthesizes information on available treatments and techniques used successfully in highway and airport pavements to treat and maintain longitudinal joints.

Introduction

FAA AC 150/5370-10H [6] requires that longitudinal joints be cut back and an asphalt tack coat be applied to the cut face before placing an adjacent lane. Contractors may also be permitted to use joint heaters to aid in constructing longitudinal joints. Despite the FAA's requirement to cut back longitudinal joints and the additional, rigorous joint density acceptance requirement—both of which have been in place for nearly two decades—longitudinal joint cracking and raveling continue to be leading causes of deterioration in airfield asphalt pavements. While FAA AC 150/5380-6C, *Guidelines and Procedures for Maintenance of Airport Pavements* (dated Oct. 10, 2014) [46], provides guidance on sealing cracks at joints, further evaluation of improved materials and methods is still needed.

Crack Sealing and Crack Filling

Crack sealing consists of cleaning and sealing cracks with a bituminous compound to prevent water from entering the pavement structure and causing further damage. This treatment is suitable for low- to medium-severity cracks and has a life expectancy of 2 to 7 years, depending on crack and pavement condition, sealant material, and construction procedures [46].

Current FAA specifications do not specifically address longitudinal joint repair but refer to general crack repair, including cracks caused by poorly constructed lane joints [6, 46]. Although other agencies consider crack sealing and filling as two different methods that vary in the amount of crack preparation and type of sealant used, in AC 150/5380-6C, the FAA does not distinguish between the two [47]. Depending on geographic location, climate, and past sealant performance, hot- or cold-applied sealant may be selected.

In a survey of standard airport pavement maintenance practices, most airports reported performing routine crack sealing using a hot-poured bituminous sealant. In contrast, only a small portion of survey respondents use cold-applied sealants. Additionally, most airports route cracks before sealing [48].

As an example of a highway agency's maintenance of longitudinal joints, the Michigan DOT recommends using overband crack fill to repair cracks at longitudinal joints up to 1 1/4 inches (31 mm) wide, either as a standalone treatment or in combination with a pavement seal. In an airport environment, overband applications may pose some risk, as they may increase pavement roughness and be susceptible to snowplow damage. A sealant that fails to bond and is pulled out of the crack will be a source of FOD [49].

For wide cracks, the use of hot-applied mastic material is recommended. This product combines fine-engineered aggregate with an asphalt-based, polymer-modified thermoplastic binder. The fine aggregate in the mastic is designed to give the material more body to fill the void, provide stability for compression resistance, and meet load bearing requirements while still allowing the material to flow. The modified binder contains polymers and oils to help resist shoving and cracking. Application is simple: the material is dispensed into a manual box screed or wheeled mastic applicator and slowly dragged across the surface of the cracked pavement. Routing the crack allows the mastic to adhere better and helps the material accommodate large movements. Mastic has been used in airport pavements to perform various repairs, including sealing wide transverse and longitudinal cracks and joints (see Figure 11), filling potholes, and leveling depressed transverse cracks. The simple procedure and short set times can minimize shutdowns on airport operations [49, 50, 51].

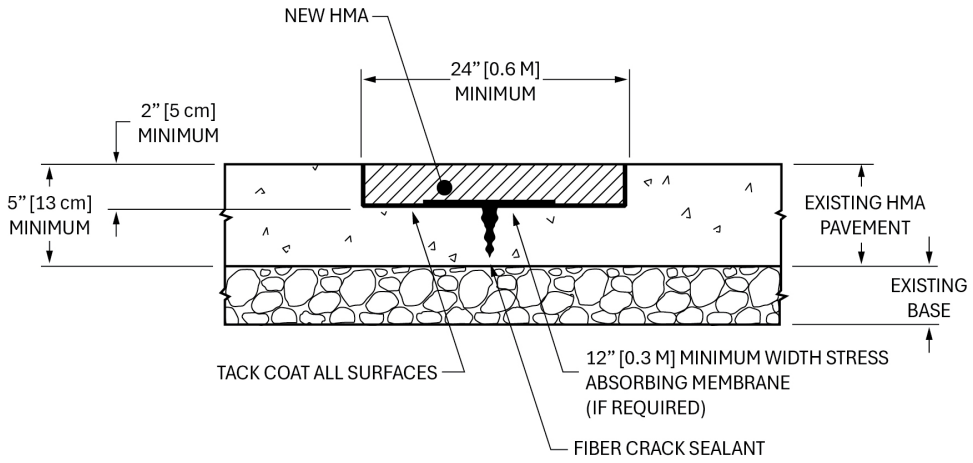


Source: Crafco, Inc.

Figure 11. Mastic Repair on Longitudinal Joints at Minneapolis Airport [51]

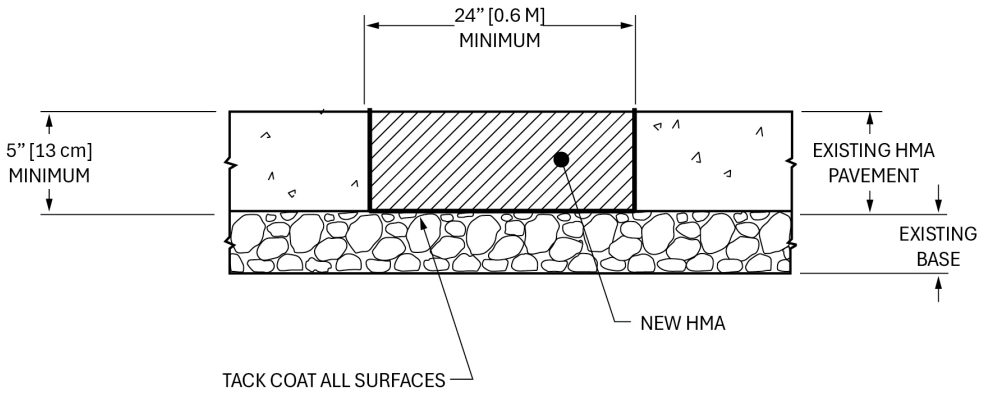
Partial- and Full-Depth Crack Repair

In severely deteriorated longitudinal joints, the affected area may be repaired by saw cutting or milling out the material and replacing it with new HMA for pavements 5 inches (127 mm) or greater in thickness, the milling depth ranges from 2 to 3 inches (50 to 76 mm), while in thinner pavements, the procedure is to be performed at full depth. The minimum width of the repair area is 24 inches (0.6 m), centered on the crack [46]. After removing the distressed pavement, a tack coat must be applied to the bottom and sides of the repair area. The new asphalt mix is then placed and compacted with a steel drum roller. Figure 12 shows a schematic for partial-depth crack repair, and Figure 13 shows a schematic for full-depth crack repair, as found in FAA AC 150/5380-6C.



Source: FAA

Figure 12. Partial-Depth Crack Repair in Flexible Pavement [46]



Source: FAA

Figure 13. Full-Depth Crack Repair in Flexible Pavement [46]

These repairs are common in airport pavements and are reported to have very good or good performance [48]. However, this method is significantly more expensive than other repair alternatives and requires a long time to complete, which can impact airport operations [52].

Among highway agencies, DOTs in Michigan, Minnesota, Ohio, and Tennessee also report using this technique, with repair widths ranging from 1 to 3 ft (30 to 91 cm) centered on the longitudinal joint [50, 53, 54]. The Ohio DOT requires the application of a 4-inch (10-cm)-wide perimeter seal over the joints of the repair, as shown in Figure 14. It is recommended that density requirements be considered for these repairs; however, contractors have resisted such conditions by citing variability in the repair lengths and widths, along with frequent equipment setup, as challenges to achieving consistent density [53].



Source: Ohio DOT

Figure 14. A 2-ft (.6-m), Partial-Depth Slot Paving with a Perimeter Seal in Ohio [53]

Infrared Heating

Infrared heating technology can be used to assist in the repair of low- to medium-severity cracks. The method consists of heating the area surrounding the crack with an infrared system, adding rejuvenators, or removing the material and replacing it with a high-asphalt content, fine-graded asphalt mix. The material is then compacted to create a strong thermal bond between the existing pavement and the new or rejuvenated asphalt [55, 56].

Infrared equipment uses propane to cause ignition within a ceramic cloth that heats up to a temperature range of 1500 to 1800 °F (800 to 1000 °C), emitting infrared radiation. When asphalt is exposed to this radiation, the rays are absorbed as heat, making the damaged area malleable enough at a sufficient depth to rework [56]. Specialized infrared heating machines have been developed for longitudinal crack repair and consist of multiple infrared heating devices arranged in a long train.

In airports, documented experiences with infrared heating focus on using this technology during construction to heat the cold joint. Successful runway and taxiway repair projects have been reported in Kuujjuaq Airport in northern Québec (shown in Figure 15), Jean Lesage International Airport in Québec City, Wheeler-Sack Army Airfield at Fort Drum in New York, and Vancouver International Airport [57]. However, these reports were made shortly after conducting the repair and long-term performance data is not available.



Source: Heat Design Equipment, Inc.

Figure 15. Infrared Heating Repair at Kuujjuaq Airport [57].

Microsurfacing

Microsurfacing consists of a mixture of polymer-modified asphalt emulsion, mineral aggregate, water, and additives [58]. The treatment is applied uniformly over the pavement surface with a spreader box to address weathering and raveling, improve friction, fill surface irregularities, and protect the pavement structure from moisture intrusion. Microsurfacing may also be used to fill ruts 0.5 inches (12 mm) or greater in depth using a special rut-filling box to cover the width of the wheel path [58, 59].

Some State agencies, such as Illinois, Minnesota, North Dakota, Pennsylvania, and West Virginia, have reported using microsurfacing successfully to maintain or repair longitudinal joints in highway pavements [53, 60, 61]. For joints with moderate to severe deterioration, the fine aggregate in the microsurfacing can fill the joint and restore the surface profile [62]. When extensive spalling occurs, milling can be performed before treatment application to achieve longer-term performance [50]. Alternatively, the microsurface may be placed in two lifts, with the first pass applied only within the deteriorated joint and the second pass extending several inches on each side, as reported by IDOT [53]. Raised pavement markings and thermoplastic paint must be removed before application and re-installed upon completion. The material is typically applied using a rut box or a small production slurry seal/microsurfacing machine at 18 to 24 inches (45 to 60 cm), centered on the joint.

One documented instance of microsurfacing implementation for longitudinal joint maintenance is Interstate 494 (I–494), a high-traffic urban freeway in Minneapolis, MN [60]. The longitudinal joints in the composite pavement had opened as much as 3 inches (7 cm)

wide and 4 inches (10 cm) deep. Treatment options were constrained by available funding and the need to minimize traffic disruptions. MnDOT elected to treat the nearly 167,000 linear ft (50 km) needing repair with a Type II microsurface at $0.50 per linear ft ($1.64/m), significantly lower than the estimated $4.83 to $9.66 per linear ft ($15.84 to $31.68/m) required to mill and fill the joints. After 3 years, the microsurfacing had performed well, with only a few cracks showing at the intersection of transverse and longitudinal joints. Due to the successful outcome of the I–494 project, MnDOT continues to use microsurfacing to repair deteriorated longitudinal joints. Figure 16 shows an example of another interstate project on I–94 near St. Cloud.



Source: Minnesota DOT

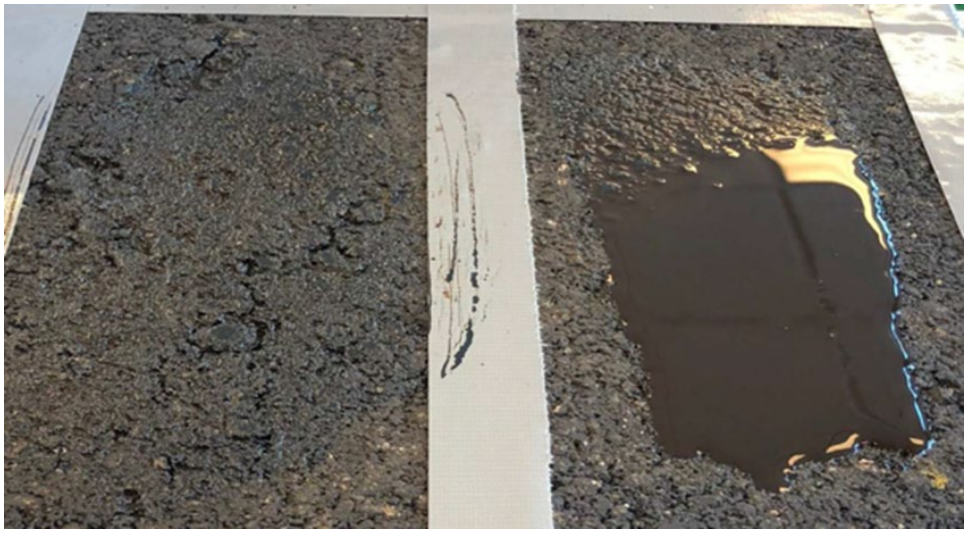
Figure 16. Microsurfacing over a Longitudinal Joint on I–94 near St. Cloud, MN [60]

The Pennsylvania DOT also reported using microsurfacing as a durable, cost-effective treatment for longitudinal joint repair. A project on I–79 was completed at approximately 25 percent of the cost and 60 percent of the time compared to the traditional mill and fill method. In addition, microsurfacing does not generate joints to seal and maintain, while milling and filling results in two joints close to the wheel paths [61].

In airports, microsurfacing is typically applied over the entire pavement surface to inhibit raveling and oxidation and correct minor distresses. Specifications for this treatment fall under FAA Item P-629 Thermoplastic Coal Tar Emulsion Surface Treatments, which states that microsurfacing may be used on airport pavements serving airplanes less than 60,000 lbs (27,216 kg) or in other instances with FAA approval [6]. Although routine use does not appear to be common, the treatment has been highly rated by those who have tried it [63, 48]. The primary safety concern for applying microsurfacing in airport pavements is the potential loss of bond and the generation of FOD [64].

Rapid-Penetrating Emulsion (RPE)

RPEs are asphalt emulsions formulated to penetrate the interconnected voids beneath the pavement surface, reducing air and water intrusion without decreasing surface texture. While traditional crack seal asphalt emulsions only seal the surface, RPE can rapidly soak into the pavement, decreasing permeability (see Figure 17). Supplied at 35- to 45-percent solids, RPE application rates can be adjusted based on pavement characteristics such as age, permeability, and texture, ranging from 0.05 to 0.15 gal/yd^2 (0.23 to 0.68 L/m^2) [65]. For application, a standard distributor truck equipped with fog nozzles is recommended, with an additional separate distributor to prevent the mixing of materials to avoid contamination [43].



(a) (b)

Source: Asphalt Materials, Inc.

Figure 17. (a) RPE Application Versus (b) Diluted SS-1h Application [65]

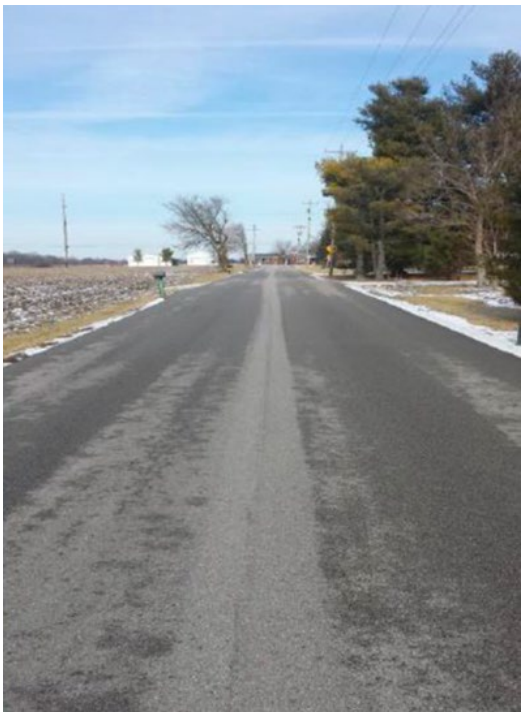
As a post-construction option to treat and maintain longitudinal joints, RPE is typically applied at 0.10 gal/yd^2 (0.45 L/m^2) over an 18-inch (45 cm) width centered at the joint [43]. Restriping is required if used over paint markings. To ensure the complete penetration of the RPE treatment and avoid excess residue curing on the surface, the RPE application rate should be adjusted as needed (see Figure 18). Usually, a new pavement surface will allow full penetration of the RPE treatment due to its low density and minimal surface contamination from dust and debris. Due to its ability to rapidly penetrate a surface, RPE is usually non-tracking within 0.5 hr and achieves water resistance within 1 hr (see Figure 19).



(a) (b) (c)

Source: Asphalt Materials, Inc.

Figure 18. (a) RPE as a Longitudinal Joint Preventative Treatment Immediately Following Application, (b) After Penetrating the Joint (center), and (c) Drying [65]



Source: Asphalt Materials, Inc.

Figure 19. RPE-Treated Joint During Spring Melt Event Showing Water Resistance [65]

Once cured, the RPE treatment is expected to fill existing voids and reduce the air void content at and near the longitudinal joint, decreasing the mixture permeability (Figure 20). Bahia et al. [43] reported that nuclear density testing following the RPE treatment could be misleading due to changes in the mixture's theoretical maximum specific gravity (G_{mm}).



(a) (b)

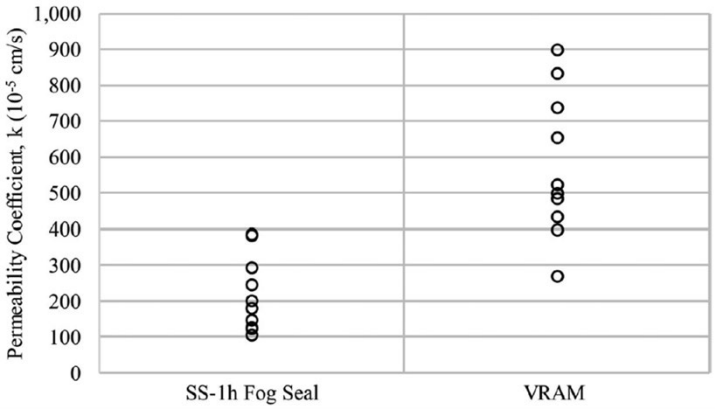
Source: Wisconsin Highway Research Report (WHRP)

Figure 20. (a) RPE Remedial Application to Low Joint-Density Area Immediately After Application and (b) After Penetration and Drying on U.S. Highway 53 in Chippewa County, WI [43]

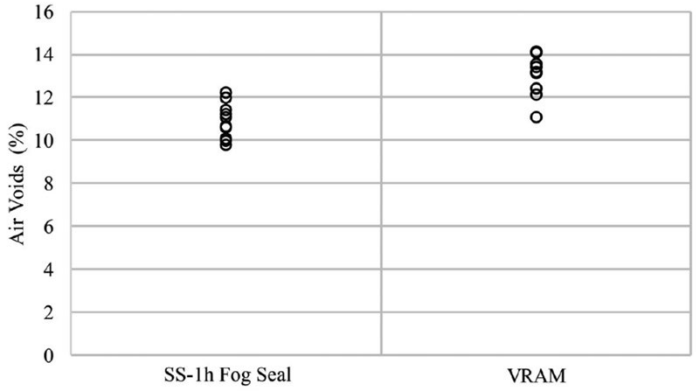
Fog Seal

A fog seal is defined as "a light spray application of diluted asphalt emulsion used primarily to seal an existing asphalt surface to reduce raveling and enrich dry and weathered surfaces'' [66]. Due to their sealing capability, fog seals can reduce air and water intrusion into the pavement surface and thus decrease its susceptibility to oxidation and moisture-induced damage [67]. The fog seal should have low viscosity to effectively penetrate the voids and avoid excess residue on the surface, which can reduce pavement friction. Thus, a slow-setting emulsion diluted with water at a 1:1 ratio (one part water to one part emulsion) is often used. As a post-construction option to treat and maintain longitudinal joints, fog seal application rates can range from 0.03 to 0.15 gal/yd^2 (0.14 to 0.68 L/m^2). Restriping is required if used over paint markings.

Montgomery and Haddock [45] evaluated an SS-1h fog seal and a VRAM as construction techniques to reduce longitudinal joint failure in Indiana. The SS-1h fog seal emulsion was applied in a 24-inch (60 cm)-wide band centered on the longitudinal joint after both lanes of asphalt surface mixture were placed. The VRAM product was applied 18-inches (45 cm) wide, centered on the longitudinal joint, before both lanes of asphalt surface mixture were placed. Results indicated that higher permeability and air voids were obtained from the field samples treated with VRAM compared to the SS-1h fog seal treatment (see Figure 21).



(a)



(b)

Source: Joint Transportation Research Program

Figure 21. Fog Seal Versus VRAM Field Samples: (a) Permeability and (b) Air Voids [44]

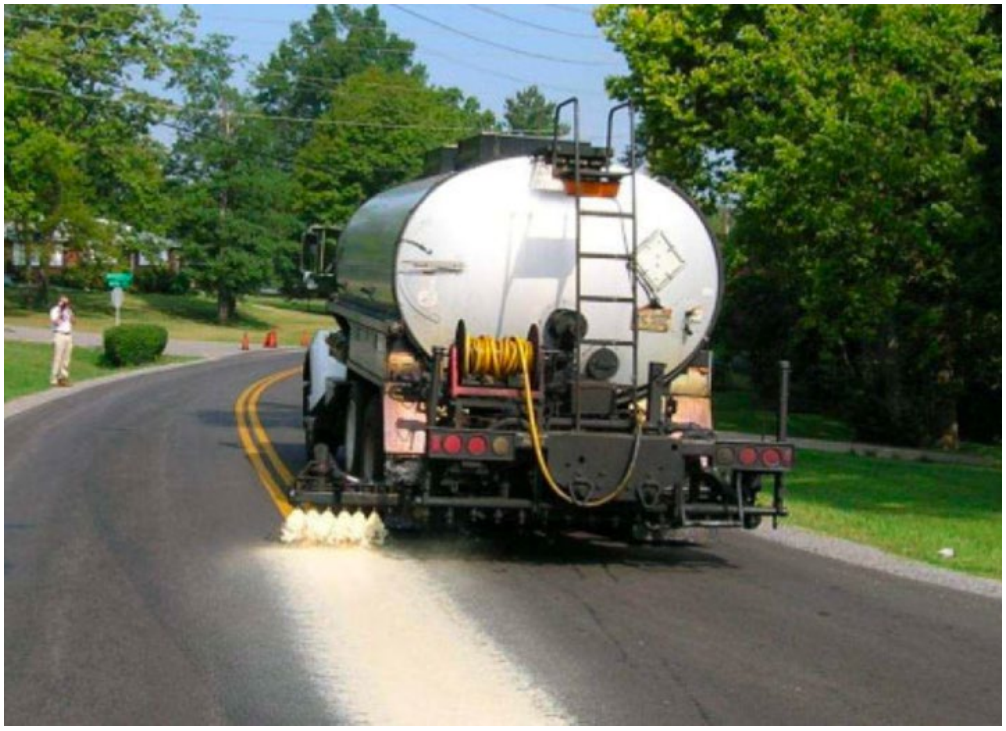
Montgomery and Haddock [45] also observed a significant difference between the control (untreated) samples and the samples treated with two fog seal products (SS-1h and a trackless tack) when evaluating the permeability of laboratory-prepared samples. Statistical analysis indicated that permeability was affected by the presence of a fog seal treatment, irrespective of the material type. The authors recommended that fog seal treatment be reapplied at 5- to 7-year intervals when treating longitudinal joints.

Rejuvenating Seals

Rejuvenating seals can be applied to existing asphalt pavement surfaces and longitudinal joint areas to preserve their functional and structural integrity from age hardening and subsequent deterioration. Designed to penetrate the asphalt material near the pavement surface to renew the hardened/oxidized binder, rejuvenators may or may not be combined with emulsified asphalt binders (to produce rejuvenating seals) and other materials (e.g., polymers) to seal low-severity surface cracks and inhibit raveling.

Rejuvenators used in rejuvenating seals are undiluted or diluted petroleum- or bio-based oils with chemical and physical characteristics selected to restore the properties of the aged asphalt binder in the surface layer. For optimal restoration of the aged asphalt binder properties, consideration should be given not only to the viscosity-reducing capacity of the rejuvenator but also to its chemical composition. Furthermore, the degree of diffusion of the rejuvenator into the aged binder is of the utmost importance since it will allow changes in the intermolecular agglomeration and self-assembly of the asphalt polar micelles, affecting the overall performance properties of the aged asphalt mixes [68]. While not meant to soften the underlying asphalt, the newly rejuvenated binder has lower stiffness than the aged asphalt on the pavement surface. It can protect the underlying surface from further deterioration mainly due to raveling and top-down cracking [69].

As a post-construction option to treat and maintain longitudinal joints (see Figure 22), the application rates of rejuvenating seals can vary from 0.015 to 0.10 gal/yd^2 (0.068 to 0.45 L/m^2. Restriping is suggested if used over paint markings. These specialty-developed surface treatments can inhibit the premature deterioration of longitudinal joints by penetrating the pavement surface and interacting with the existing asphalt binder (see Figure 23).



Source: Pavement Technology, Inc.

Figure 22. Application of Rejuvenating Seal to Treat a Longitudinal Joint [70]



(a) (b)

Source: D&D Emulsions, Inc.

Figure 23. (a) Highway Pavement Joint 3 Years After Treatment with JOINTBOND® Rejuvenating Seal and (b) the Control (Untreated) Joint After 3 Years [71]

Huang and Shu [38] evaluated two rejuvenating seal technologies (JOINTBOND® and RePlay™) as construction techniques to reduce longitudinal joint failure in Tennessee (see Figure 24). JOINTBOND® is a polymerized maltene-based (no asphalt) emulsion, while RePlay™ is an 88-percent, agricultural-based joint sealer. The rejuvenating seals were spray-applied to the joint area after pavement compaction. The application rates were 0.08 gal/yd^2 (0.36 L/m^2) for JOINTBOND® and 0.03 gal/yd^2 (0.14 L/m^2) for RePlay™. Water absorption test results on field cores indicate that the rejuvenating seals prevent water from penetrating the pavement joints. However, permeability testing did not confirm these results.



(a) (b)

Source: University of Tennessee at Knoxville

Figure 24. (a) JOINTBOND® and (b) RePlay™ Application on a Longitudinal Joint [38]

Williams [19] performed a field study on construction techniques to improve the quality of longitudinal joints in Arkansas. The rejuvenating seal product included in the study was JOINTBOND®, which was applied at a rate of 0.11 gal/yd^2 (0.50 L/m^2) onto the joint area after final rolling was completed and the mat had cooled significantly. A spray bar was used to apply a 3-ft (91 cm)-wide strip of the product to the joint, covering the joint and 18 inches (45 cm) to either side of the joint (see Figure 25). The other two construction techniques evaluated in the study were a joint adhesive product (Crafco® Pavement Joint Adhesive) and a standard tack coat (SS-1h). Results indicated that the JOINTBOND® treatment was more effective than the other two materials in reducing absorption, permeability, and infiltration levels at the longitudinal joint. The use of the joint adhesive resulted in the lowest joint density, while the use of JOINTBOND® and tack coat treatments only resulted in moderate joint densities.



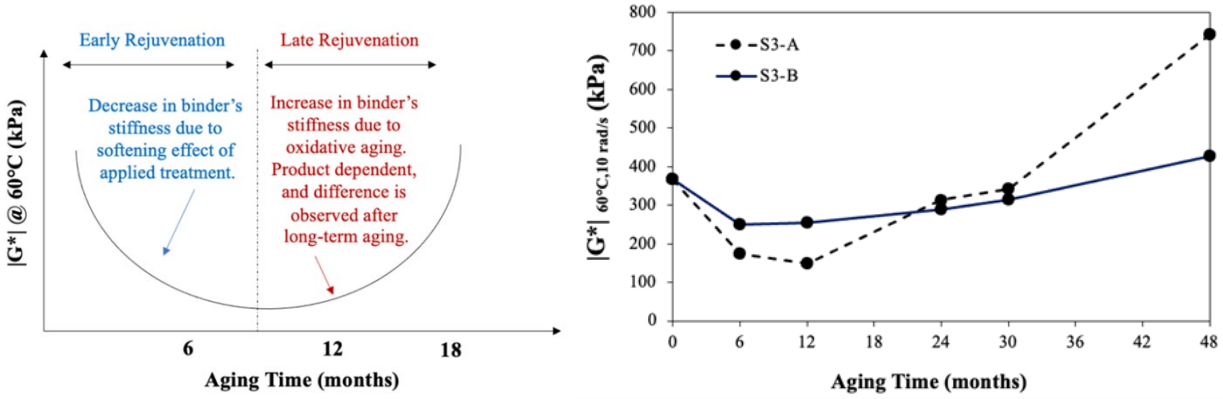
Source: Pavement Technology, Inc.

Figure 25. JOINTBOND® Application on the Longitudinal Joint [19]

For airports, rejuvenating seals are for use on any pavements on which aircraft do not operate, including shoulders, overruns, roads, and parking areas. These treatments are applied to rejuvenate the upper 3/8-inch (9 mm) of oxidized (aged) asphalt binder without causing an unacceptable reduction in the friction characteristics of the pavement section. The specification for these treatments falls under FAA Item P-632 Bituminous Pavement Rejuvenation, which states that rejuvenating seals may be used on airport pavements, except runways and acute-angled exit taxiways, at airports serving airplanes less than 60,000 lbs (27,216 kg) [72]. This specification evaluates the rejuvenation capability of rejuvenating seal products by rheological parameters (e.g., complex modulus [|G*|] and phase angle [δ] at 140 °F [60 °C]) of binders extracted and recovered from the upper 3/8

inch (9 mm) of treated pavement surfaces 30–45 days after the products' application. Pavement friction characteristics tested between 24 and 96 hr after the application of rejuvenating seal products and tested at no less than 180 days or greater than 360 days after the application are also included in the FAA P-632 specification.

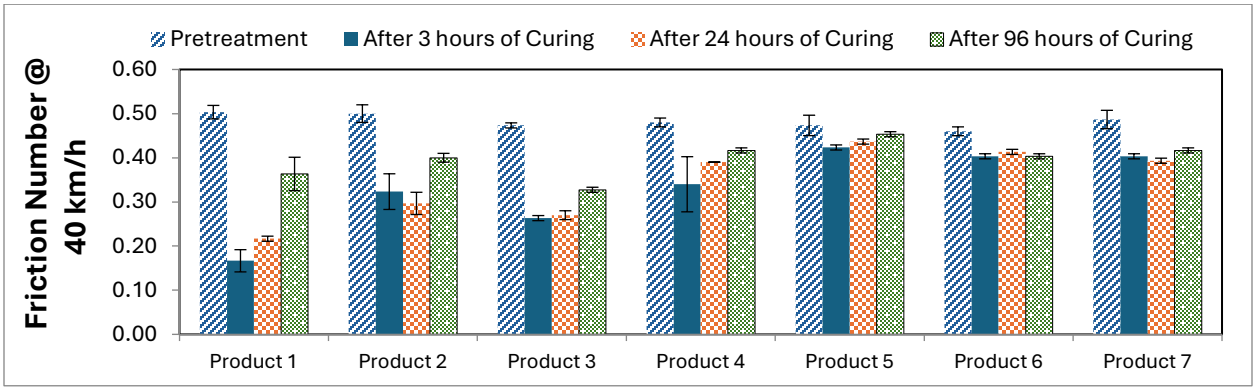
The FAA P-632 specification has also been used to evaluate the rejuvenation performance of rejuvenating seals for highway pavements. Since 2018, the National Center for Asphalt Technology (NCAT) has investigated the field performance and effectiveness of rejuvenating seal products commercially available in the United States, where the rejuvenating capability of each product has been assessed considering rheological parameters of the extracted asphalt binders and surface friction measurements obtained before and after the application of the treatments. The NCAT study noted that one drawback of the FAA P-632 specification is that the evaluation is based on the rheological properties of the extracted binders 30–45 days after the application of the rejuvenating products. As indicated in Figure 26(a), the NCAT field study showed that the restoration capacity of a rejuvenating seal treatment increases rapidly after application as a result of the decrease in asphalt binder stiffness, but then begins to slowly decrease with oxidative aging as a result of the embrittlement of the binder. Therefore, the aging time of 30–45 days after the application of the rejuvenating products can be misleading for the assessment of a product's long-term effectiveness. By using the dynamic shear rheometer, the rheological evaluation of asphalt binders extracted and recovered from field cores has shown that, when comparing two products applied over a 6-year-old pavement containing 25 percent RAP, product S3-A was more effective than product S3-B in decreasing binder stiffness (|G*|) for up to 12 months of field aging. As field aging progressed to 24 months, a change occurred, and the binder treated with product S3-B presented lower |G*| values for up to 48 months after treatment application. However, immediately after application, both products showed a similar reduction of binder stiffness.



Source: NCAT

Figure 26. (a) Hypothesized Behavior of Rejuvenating Seal Products and (b) Field Data Obtained from Binder Extracted and Recovered from Field Cores After 0, 6, 12, 24, 30, and 48 Months of Treatment Application [73]

Regarding the effect of rejuvenating seal products on the friction of a treated pavement, the NCAT field evaluation indicates that friction decreases immediately after treatment application. The pavement surface frictional properties as a function of speed were measured per ASTM E1911 using the dynamic friction tester. As presented in Figure 27, results show that some of the sprayed products resulted in a substantial initial drop in friction number (FN), but the friction results improved with time. However, other products resulted in a smaller decrease in initial friction and maintained the FN through a 96-hr curing period. Therefore, to ensure safety, the coefficient of friction of the existing pavement surface should be measured before and after the rejuvenating seal treatment is applied. After 3 hr of curing, friction values similar to those before the treatment application should be obtained. Lastly, after 96 hr of curing, the applied rejuvenating seal product should not have adverse effects on the friction of the pavement compared with the friction of the control section.



Source: NCAT

Figure 27. FN of Different Rejuvenating Seal Products, Before and After Treatment Application [73]

Literature Review Summary

This portion of the literature review synthesized information on techniques for longitudinal joint maintenance. The current practice at airports is to seal the cracks or perform partial- or full-depth repairs, depending on the level of deterioration. However, new technologies have emerged that have been put into practice for highway pavements and may apply to airport pavements as well. Although some information is still limited, particularly regarding long-term performance, alternatives such as microsurfacing, infrared heating, RPEs, fog seals, and rejuvenating seals show promise as cost-effective methods for maintaining longitudinal joints. Table 4 provides a summary of the options listed in this report.

Table 4. Summary of Maintenance Techniques for Longitudinal Joints

Method	Advantages	Considerations
Crack sealing and crack filling	• Widely used, easy to perform. • Specified in FAA AC 150/5380-6C.	• Higher levels of deterioration may use mastic instead of sealant, but documented experience for airfields is limited.
Partial- and full-depth repair	• Specified in FAA AC 150/5380-6C. • Very good or good performance reported.	• More expensive than other options. • Time consuming; can impact airport operations.
Infrared heating	• Relatively fast. • Forms a strong thermal bond between the existing asphalt and the new or rejuvenated material.	• Requires special equipment. • Limited documented experience and performance.
Microsurfacing	• Cost-effective method for sealing longitudinal joints.	• Increased FOD potential compared to other options. • No experience in airfields for longitudinal joint applications.
RPEs	• Can be used on any mixture type/design scenario, although penetration is affected by mix design variables. • Spray-applied at pre-calculated rate using standard asphalt emulsion distributor. • Can be applied at any time following construction. • Expected to fill voids and reduce air void content at and near the longitudinal joint.	• Restriping is required if used over paint markings. • Limited documented experience and performance for airports.
Fog seals	• Effective for decreasing permeability. • Lower permeability and air voids were obtained from longitudinal joint field samples treated with a fog seal (SS-1h) compared to a VRAM treatment.	• Limited penetration of asphalt residue is expected, which could affect pavement surface friction. • Recommended reapplication at 5- to 7-year intervals when treating longitudinal joints. • Limited documented experience and performance for airports.
Rejuvenating seals	• Can inhibit the premature deterioration of longitudinal joints by penetrating the pavement surface and interacting with the existing asphalt binder. • Potential for reducing absorption, permeability, and infiltration levels at the longitudinal joint.	• Restriping is suggested if used over paint markings. • Will cause a temporary reduction of pavement surface friction. • Limited documented experience and performance for airports.

References

[1] J. Trepanier and J. Senger, "A Materials Approach to Improving Asphalt Pavement Longitudinal Joint Performance," in *Presentation at the 2021 Transportation Research Board Annual Meeting*, 2021.

[2] M. Akpinar and M. Hossain, "Longitudinal Joint Construction for Hot Mix Asphalt Pavements," Kansas Department of Transportation, Topeka, 2004.

[3] P. S. Kandhal and R. B. Mallick, *Evaluation of Various Longitudinal Joint Construction Techniques for Asphalt Airfield Pavements,* Paper presented at the 2007 FAA Worldwide Airport Technology Transfer Conference, Atlantic City, NJ, 2007.

[4] R. B. Mallick, P. S. Kandhal, R. Ahlrich and S. Parker, "Project 04-05: Improved Performance of Longitudinal Joints on Asphalt Airfield," Airport Asphalt Pavement Technology Program (AAPTP), 2007.

[5] S. Zinke and J. Mahoney, "Evaluation of Longitudinal Joint Density Specification on 2012 Polymer Modified Warm-mix Asphalt Projects in Connecticut," Connecticut Department of Transportation, 2015.

[6] FAA, "Advisory Circular: Standard Specifications for Construction of Airports," Federal Aviation Administration (updated by errata 19 August 2020), 2018a.

[7] L. Spring, *Achieving Quality Joint Construction,* Presented at the Nova Scotia Asphalt User Producer Association 6th Annual Meeting, n.d..

[8] G. K. Chang, V. L. Gallivan and Q. Xu, "Assess Asphalt In-Place Density with Intelligent Compaction Measurements," in *Asphalt Pavements: Proceedings of the International Conference on Asphalt Pavements*, ISAP 2014, 2014.

[9] A. Hekmatfar, A. Shah, G. Huber, R. McDaniel and J. E. Haddock, "Modifying Laboratory Mixture Design to Improve Field Compaction," in *Road Materials and Pavement Design*, 2015.

[10] R. D. Horan, G. K. Chang, Q. Xu and V. L. Gallivan, "Improving Quality Control of Hot-Mix Asphalt Paving with Intelligent Compaction Technology," *Transportation Research Record,* vol. 2268, no. 1, p. 82–91, 2012.

[11] E. Kassem, E. Masad, A. Chowdhury and G. Claros, "Influence of Field Compaction Pattern on Asphalt Pavement Uniformity," in *Asphalt Paving Technology: Association*

of Asphalt Paving Technologists–Proceedings of the Technical Sessions, Vol. 77, 2008.

[12] E. Masad, A. T. Scarpas, A. Alipour, K. R. Rajagopal and C. Kasbergen, "Finite Element Modelling of Field Compaction of Hot Mix Asphalt. Part I: Theory," *International Journal of Pavement Engineering,* vol. 17, no. 1, p. 13–23, 2014.

[13] P. E. Sebaaly, G. Fernandez and B. Hoffman, "Evaluation of Construction Techniques for Longitudinal Joints in HMA Pavements," *Journal of the Association of Asphalt Paving Technologists–Proceedings of the Technical Sessions,* vol. 77, 2008.

[14] N. Tran, P. Turner and J. Shambley, "Enhanced Compaction to Improve Durability and Extend Pavement Service Life: a Literature Review," Federal Highway Administration, Auburn, AL, 2016.

[15] E. M. Y. Kim, Evaluation of Asphalt Longitudinal Joint Construction and Practices in South Carolina, Master's thesis. Clemson University, 2017.

[16] R. S. McDaniel, A. Shah and J. Olek, "Longitudinal Joint Specifications and Performance," Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, 2012.

[17] P. E. Sebaaly and J. C. Ramírez Barrantes, "Development of a Joint Density Specification, Phase I: Literature Review and Test Plan," 2004.

[18] H. Wang, Z. Wang, T. Bennert and R. Weed, "Specification Limits and Pay Adjustment for Longitudinal Joint Density of Asphalt Pavements: Case Study in New Jersey," *Transportation Research Record,* vol. 2573, no. 1, p. 98–106, 2016.

[19] S. G. Williams, "HMA Longitudinal Joint Evaluation and Construction," University of Arkansas, Arkansas State Highway and Transportation Department, 2011.

[20] Iowa DOT, "Standard Specifications for Highway and Bridge Construction," Iowa Department of Transportation, 2015.

[21] Minnesota DOT, "Standard Specifications for Road and Bridge Construction," Minnesota Department of Transportation, 2022.

[22] M. S. Buchanan, "Evaluation of Notched-Wedge Longitudinal Joint Construction," *Transportation Research Record,* vol. 1712, no. 1, p. 50–57, 2000.

[23] R. L. Morgan, "Centerline (Longitudinal) Joint Adhesive Performance: Two to Three-Year Review," Transportation Research and Development Bureau, New York State Department of Transportation, 2009.

[24] Minnesota Asphalt Pavement Association, "Longitudinal Joint Construction," *Paving Progress,* October 2014.

[25] T. Thomas, "Material Solutions to Improving Centerline Joint Performance," 17 February 2021. [Online]. Available: https://www.nationalacademies.org/event/02-17-2021/trb-webinar-centering-seams-maintaining-centerline-joints-in-asphalt-pavements.

[26] A. J. Kriech, H. L. Wissel, T. P. Reece and M. Keller, "Patent Application Publication (10)". United States Patent Pub. No.: US 2016 / 0271610 A1, Patent Application Publication, vol. 1, no. 19, pp. 1–5 2016.

[27] Asphalt Materials, Inc., "J-Band®: The Bottom-Up Joint Solution," 2022. [Online]. Available: https://thejointsolution.com/. [Accessed October 2022].

[28] C. DeAustin, B. deMontigny, S. C. Sillick and V. Callejas, "2021 Annual Report for the Montana Department of Transportation Research Programs," Montana Department of Transportation, 2021.

[29] J. Trepanier, J. Senger, T. Thomas and M. Exline, "Materials Approach to Improving Asphalt Pavement Longitudinal Joint Performance," *Transportation Research Record,* vol. 2676, no. 2, p. 429–439, 2021.

[30] Illinois DOT, "Standard Specifications for Road and Bridge Construction," Illinois Department of Transportation, 2022.

[31] Indiana DOT, "401-R-750 Void Reducing Asphalt Membrane for HMA 220901," Indiana Department of Transportation, 2022.

[32] R. C. Williams, J. Podolsky and J. Kamau, "Use of J-Band to Improve the Performance of the HMA Longitudinal Joint," Minnesota Department of Transportation, 2020.

[33] Crafco, "Product Data Sheet–Pavement Joint Adhesive, Part No. 34524," Crafco, Inc. Preservation Products, 2017.

[34] P. S. Kandhal and S. S. Rao, "Evaluation of Longitudinal Joint construction Techniques for Asphalt Pavements (Michigan and Wisconsin Projects–Interim Report)," National Center for Asphalt Technology, Auburn, AL, 1994.

[35] P. S. Kandhal and R. B. Mallick, "Longitudinal Joint Construction Techniques for Asphalt Pavements," National Center for Asphalt Technology, Auburn, AL, 1997.

[36] P. S. Kandhal and R. B. Mallick, "A Study of Longitudinal Joint Construction Techniques in HMA Pavements (Interim Report–Colorado Project)," National Center for Asphalt Technology, Auburn, AL, 1996.

[37] P. S. Kandhal, T. L. Ramirez and P. M. Ingram, "Evaluation of Eight Longitudinal Joint Construction Techniques for Asphalt Pavements in Pennsylvania," National Center for Asphalt Technology, Auburn, AL, 2002.

[38] B. Huang and X. Shu, "Evaluation of Longitudinal Joints of HMA Pavements in Tennessee," Tennessee Department of Transportation, 2010.

[39] W. J. Robinson, J. D. Doyle and J. A. Harrison, "Laboratory Tensile Performance of Joint Adhesive for Asphalt Pavements," U.S. Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS, 2019.

[40] M. Buncher and C. Rosenberger, "Best Practices for Constructing and Specifying HMA Longitudinal Joints: A Co-operative Effort between the Asphalt Institute and the Federal Highway Administration," Asphalt Institute, FHWA, 2012.

[41] Ray-Tech, "Ray-Tech Infrared," 2022. [Online]. Available: https://raytechinfrared.com/. [Accessed 25 October 2022].

[42] J. S. Daniel and W. L. Real, "Field Trial of Infrared Joint Heater to Improve Longitudinal Joint Performance in New Hampshire," *Transportation Research Record,* vol. 1946, no. 1, p. 157–162, 2006.

[43] H. Bahia, D. Swiertz, P. Low and Y. Zhang, "Material Specifications for Longitudinal Joint Construction, Remediation, and Maintenance," Wisconsin Department of Transportation, 2021.

[44] Pavement Technology, Inc., "JOINTBOND® Asphalt Joint Stabilizer," 2017.

[45] S. R. Montgomery and J. E. Haddock, "2017," Purdue University, West Layfayette, IN, Fog Seal Performance on Asphalt Mixture Longitudinal Joints.

[46] FAA, "Advisory Circular: Guidelines and Procedures for Maintenance of Airport Pavements," Federal Aviation Administration, 2014.

[47] T. L. Moses, J. L. Hulsey and B. Connor, "Airport Manager's Guide for the Maintenance of Asphalt Pavements of General Aviation Airports," California Department of Transportation, 2009.

[48] J. J. Hajek, "Airport Cooperative Research Program (ACRP) Synthesis 22: Common Airport Pavement Maintenance Practices," Transportation Research Board, Washington, DC, 2011.

[49] D. Cheng, R. G. Hicks and R. D. Smith, "Manual for Asphalt Pavement Repair and Resurfacing Preparation," San Jose State University, Mineta Transportation Institute, 2022.

[50] Minnesota DOT, "MnDOT Pavement Preservation Manual," Minnesota Department of Transportation, 2020.

[51] M. Sucee, "Effective Treatment of Large Cracks in Our Airport Taxiways and Runways," 2016. [Online]. Available: https://www.captg.ca/docs/pdf/16Presentations/Effective_Treatment_Large_Cracks_Airport_Taxiways_Runways.pdf.

[52] V. Speller, A Study on Optimizing Infrared Heating Technology for Asphalt Pavement Maintenance and Rehabilitation, Master's thesis. University of Waterloo, 2019.

[53] G. M. Duncan, L. Sibaja Vargas, S. B. Seeds, D. Peshkin, M. Sminchak and S. Sophocleous, "Longitudinal Joint Repair Best Practices for the Ohio Department of Transportation," Ohio Department of Transportation, Columbus, OH, 2017.

[54] Michigan DOT, "Capital Preventive Maintenance Manual," Michigan Department of Transportation, 2020.

[55] L. Uzarowski, V. Henderson, M. Henderson and B. Kiesswetter, "Innovative Infrared Crack Repair Method," in *2011 Conference and Exhibition of the Transportation Association of Canada. Transportation Successes: Let's Build on Them*, Edmonton, Alberta, 2011.

[56] V. Speller, F. Y. Liu and S. Tighe, "Incorporating Infrared Heating Technology in Crack Repair Operations for Airport Runways and Taxiways," in *2019 Canadian Society for Civil Engineering Annual Conference Proceedings*, 2019.

[57] B. Kieswetter, Use of Infrared Heaters in Asphalt Pavement Construction & Repair, Ottawa, Canada, 2013.

[58] ISSA, *ISSA A-143, Recommended Performance Guideline for Micro Surfacing,* Glen Ellyn, IL: International Slurry Surfacing Association, 2010.

[59] J. Lee and T. Shields, "Treatment Guidelines for Pavement Preservation," Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, IN, 2010.

[60] L. Galehouse and L. Scofield, "Maintenance and Longevity of Longitudinal Joints," *TR News,* p. 15–19, May-June 2022.

[61] D. Poleti, "Longitudinal Joint Repair–Mill & Fill vs. Microsurfacing," Pennsylvania Department of Transportation, 2020. [Online]. Available: https://www.pa.gov/content/dam/copapwp-pagov/en/penndot/documents/about-us/penndot2020/virtual-innovation-week/virtual-exhibit-hall/documents/microsurfacing%20longitudinal%20joints.pdf.

[62] OHMPA, "The ABCs of Longitudinal Joints," 2013.

[63] E. Humphries and S.-J. Lee, "Evaluation of Pavement Preservation and Maintenance Activities at General Aviation Airports in Texas: Practices, Perceived Effectiveness, Costs, and Planning," *Transportation Research Record,* vol. 2471, no. 1, p. 48–57, 2015.

[64] D. C. Ploeger, R. B. Chapman, D. G. Peshkin and D. J. Speidel, "Airport Cooperative Research Program (ACRP) Report 138: Preventive Maintenance at General Aviation Airports, Volume 1: Primer," Transportation Research Board, Washington, DC, 2015.

[65] A. Eicher and C. Higginbotham, Use of Penetrating Asphalt Emulsions to Address High-Void Pavement Areas, Purdue University, 2019.

[66] Asphalt Institute, MS-19: The Basic Asphalt Emulsion Manual (Fourth Edition), Lexington, KY: Asphalt Institute, Asphalt Emulsion Manufacturers Association, 2008.

[67] N. Prapaitrakul, T. Freeman and C. J. and Glover, "Analyze Existing Fog Seal Asphalts and Additives: Literature Review," Texas A&M University, Texas Transportation Institute, College Station, TX, 2005.

[68] R. Moraes, "Evaluation of Bio-Based Recycling Agents," in *58th Petersen Asphalt Research Conference*, Laramie, WY, 2021.

[69] D. Hanson, G. King, M. Buncher, J. Duval, P. Blankenship and M. Anderson, "Techniques for Prevention and Remediation of Non-Load Related Distresses on HMA Airport Pavements (Phase I)," Airfield Asphalt Pavement Technology Program, 2009.

[70] J. Calvert, "Pavement Preservation with Fog Seal Application of Rejuvenators and Seal Coats," 2010. [Online]. Available: https://www.pavementpreservation.org/wp-content/uploads/2010/04/122753345041486491100.pdf.

[71] K. Holton, "Longitudinal Joint Preservation and More," in *51st Annual Mid-Atlantic Quality Assurance Workshop*, 2018.

[72] FAA, "Advisory Circular: Standard Specifications for Construction of Airports, Item P 632: Asphalt Pavement Rejuvenation," Federal Aviation Administration, 2018.

[73] R. West, B. Powell, D. Timm, N. Tran, F. Yin, N. Moore, T. Harman, B. Bowers, A. Vargas, C. Rodezno, R. Moraes Puchalski, C. Chen, S. Chowdari Gatiganti, J. Nelson, G. Julian, A. Taylor, M. Kmetz and E. Turochy, "Phase VIII (2021–2024) NCAT Test Track Findings," National Center for Asphalt Technology, Auburn University, 2024.

[74] A. J. T. Hand, T. Aschenbrener and M. Buncher, "TechBrief: Improving Longitudinal Joint Performance," Federal Highway Administration, Washington, DC, 2020.

[75] L. Shanley, "Development and Evaluation of Longitudinal Joint Sealant in Illinois," Illinois Department of Transportation, Bureau of Materials and Physical Research, Springfield, IL, 2019.

[76] R. Moraes, "Evaluation of Rejuvenating Fog Seals," *Asphalt Technology News,* vol. 31, no. 1, p. 1–4, 2019.