Void Reducing Asphalt Membrane – A Bottom-up Solution to Longitudinal Joints

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Longitudinal Construction Joints



Issues

- Cannot achieve the same density at the joint as in the mat
- Water and air intrusion accelerates damage
- Longitudinal construction joints
 - Commonly, the first area requiring maintenance on a pavement

Why do joints fail early?



Improving Longitudinal Joint Performance 3

DOT Study

Air Voids from Joint Towards Center of Lane

Air Voids from Unconfined Centerline Joint



Centerline going towards interior of mat \longrightarrow

Effect of Air Voids on Pavement Service Life

Reduction in Expected Service Life



If the center of the mat is at 7% voids or less, but the joint is at 11% voids, the joint fails 5 years earlier than the rest of the pavement.

Longitudinal Joint Improvement Plan

- Early 2000 timeframe
- Illinois DOT (IDOT) recognized need for better joint performance
- Failure mechanism permeability
- Concept fill a portion of the voids with an asphalt product from <u>bottom up</u>, a <u>Void Reducing</u> <u>Asphalt Membrane (VRAM)</u>



Falling head permeameter

A Materials Approach to Improve Joint Performance



Apply a heavy band of polymer modified binder in the area where the new paving joint will <u>be placed</u>



Place the first paving pass over half the width of the band of polymer modified binder



Polymer modified binder migrates into the HMA at the joint

Void Reducing Asphalt Membrane (VRAM)



- Thick application of hot-applied, <u>polymer-modified asphalt (~ 1 gal/sq</u> yd for 1 ¹/₂" overlay)
- Application of an 18" band applied <u>before</u> paving in the location of the new longitudinal joint
- Application of a 9" band on mill and fill projects

Application of VRAM

- VRAM should be applied between 265F and 320F or as recommended by the supplier.
- Exact placement location of VRAM should be discussed prior to performing on the project.



SR-119 Elkhart Co, IN

VRAM Material Features

- Migration upward from heat of mix and compaction to reduce permeability at the joint
 - Voids filled to 50% or more of overlay height filled over the width of the application
- Bonds to the underlying pavement and bond at the joint
- Crack resistance at the joint



Placed <u>under</u> the intended area for an overlay longitudinal construction joint

Application of VRAM

- Vehicles may cross over the VRAM once cooled to 130F or less. Do not permit vehicles to stop on or drive longitudinally on top of the VRAM.
- A guideline is placed for the applicator to follow.



VRAM Application



18" wide VRAM application



Non-tracking < 30 min



1st pass covering half VRAM width

Effect of VRAM on Voids at Joint

Example

- HMA @ 5.5% AC, @ 1.5" thick/square yard = 9 lb of AC
- VRAM @ 1.47 lb/ft 18" equates to 8.8 lb AC/square yard
- Total AC in HMA + VRAM = 10.3%
- For 10-13% air voids @ joint, VRAM would occupy 2/3 of overlay height



VRAM Application Logistics



- Contractors may fear VRAM application will slow down paving operation. The time required is minimal.
- Once the milling and sweeping operations are completed, VRAM is applied. VRAM application is similar in speed to tack coat application.
- When the VRAM distributor is far enough ahead, tack coat can be applied to the rest of the lane.
- The VRAM is cool enough to allow traffic to cross by the time the emulsion tack coat breaks.

Maryland DOT VRAM Video



Mill and Fill VRAM Applications

- When only one-half of the joint is exposed, VRAM is applied at onehalf the prescribed width and rate and adjacent to the center of the joint.
- Over 475 lane miles of mill and fill projects have been treated with VRAM since 2002.



I-74 west of Crawfordsville, Indiana

Milled Surface Preparation for VRAM Application

- Compressed air may be used to remove dust and fine materials from the area where VRAM will be applied.
- Roads posted < 45 miles/hour, should use compressed air to clean the surface where VRAM will be placed.
- Final cleaning within 24 hours of the placement of VRAM



VRAM under Rumble Strips



- Rumble strips/corrugations
 - Being used on an increasing basis for safety
 - Placed in the weakest area of the pavement, centerline joint or outside edge of paving creating early failure
- VRAM under centerline or edge rumble strips to reduce air/water permeability

VRAM Special Provision

Test	Test Requirement	Test Method
Dynamic shear @ 88°C (unaged), G*/sin δ, kPa	1.00 min.	AASHTO T 315
Creep stiffness @ -18°C (unaged), Stiffness (S), MPa m-value	300 max. 0.300 min.	AASHTO T 313
Ash, %	1.0 - 4.0	AASHTO T 111
Elastic Recovery, 100 mm elongation, cut immediately, 25°C, %	70 min.	AASHTO T301
Separation of Polymer, Difference in °C of the softening point (ring and ball)	3 max.	ASTM D7173, AASHTO T53

VRAM Application Table for 18" Application Width					
	Application Rate, lb/ft				
Overlay Thickness, in	Coarse-Graded	Fine-Graded	SMA / SP5		
1	1.15	0.80			
11/4	1.31	0.88			
11/2	1.47	0.95	1.26		
1 ³ / ₄	1.63	0.95	1.38		
≥2	1.80	0.95	1.51		
Tolerance	±10%	±10%	±10%		

Current States with VRAM Experience



Types of Roads using VRAM





Interstate: Ohio DOT I-77

State: Indiana SR-26





Urban: Indianapolis DPW 56th St

County: Champaign Co, IL Dewey-Fisher Road



VRAM application of a 9" band applied <u>before</u> paving in the location of the new longitudinal joint



Calibrating VRAM application rate



Calibrating VRAM application rate



Paving over VRAM application



New pavement placed over VRAM after compaction

Determining Migration of VRAM by Digital Image Analysis (DIA)



- Used a 20 MP camera and ImageJ software to determine the grey-level of each core slice in 5mm increments from the bottom to the top of the core
- Relies on the contrast of the aggregate vs. asphalt
- DIA migration and penetration affected by voids (shadows), crushed aggregate, segregation, larger aggregates, core height, measurement area, etc.
 - Note more voids at centerline
- Actual migration and penetration affected by VRAM amount, voids and void size and connectivity, substrate texture, mix temperature, compaction
- Developed by Brian Hill of IDOT

Preparation and naming scheme



The 6" diameter cores were frozen before saw cutting into one-inch thick slices.



Each core had three cuts to make two slices and rounded ends. Six faces were measured on each core. Example on naming: Core 1: 1a, 1b, 1c, 1d, 1e, 1f Core 4 had only one cut with a and b sides

Migration by digital image analysis (DIA)



 Control core – Since asphalt content does not vary from bottom to top, it is vertical.

Migration by digital image analysis (DIA)



- RT and L3 (higher rate, right of joint, average of four)
- Migration of 35 mm, or 55%.

Migration by digital image analysis (DIA)



- RT and L1 (higher rate, right of joint, average of four)
- Migration of 30 mm, or 47%.

Testing Fracture Properties



- Illinois Flexibility Index Test (I-FIT)
 - Semi-Circular Bend (SCB) configuration and specimen loading equipment
 - 50mm/min strain controlled
 - Test Temperature 25°C
 - Energy calculated to propagate crack through specimen

Modified I-FIT for Composite Specimen



- Modified specimen geometry and directional considerations to accommodate a composite specimen
- Flexibility Index calculations identical to I-FIT testing

VS





FI Data from 15 Year-old IDOT Projects



FI Data for NJ Turnpike Cores



- VRAM cores LTB-L3 represent the lower VRAM application rate, with a migration of 20 mm.
- IDOT's FI criteria for lab-compacted specimens is a minimum of 8.0. Field cores, with higher air void levels, are known to have higher FI values.
- Based on these values, the joints over the VRAM are expected to perform much better than the control joints.
- This difference in performance may not be noticed for at least a few years.

VRAM Performance History



- 9 IDOT VRAM Experimental Test Sections Placed in 2002 – 2003
- Illinois DOT took cores for testing 3 of these in 2017
 - District 7 US-51 Elwin
 - District 1 US-50 Richton Park
 - District 2 IL-26 Cedarville

VRAM Field Performance IDOT D7 Elwin US-51 after 15 Years



VRAM Joint transition to control



VRAM section

VRAM Field Performance IDOT D2 Cedarville IL-26 after 14 years



VRAM Test Section

All pictures were taken in 2017



Transition from Control Section to VRAM Section



Control Section

VRAM Field Performance IDOT D1 IL-50 Richton Park after 14 years



VRAM Test Section



Control Section

VRAM Performance History - PennDOT



- VRAM Experimental Test Section Placed on I-81 in November 2018
- Photos taken in 2020 show dramatic difference in longitudinal joint performance between control section and VRAM section

VRAM Performance History

A Materials Approach to Improving Asphalt Pavement Longitudinal Joint Performance

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- Illinois DOT developed
 VRAM concept in 2000
- IDOT labels VRAM as Longitudinal Joint Sealer (LJS) in its' specification
- IDOT studied performance history of VRAM and wrote a research paper that was presented at Transportation Research Board (TRB) in 2021

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- The IDOT LJS test pavements were evaluated after twelve years and found to have longitudinal joints that exhibited significantly better performance than the control joint sections and were in similar or better condition than the rest of the pavement.
- Laboratory testing of cores showed decreased permeability and increased crack resistance of mix near joints with LJS as compared to similar mix without LJS.
- The life extension of the joint area is approximately three to five years, and the benefit is calculated to be three to five times the initial cost.

LCCA Model for HMA Overlay Without LJS



- It has been IDOT's experience to receive approximately 15 years of service for a first generation HMA overlay on either fulldepth HMA or Portland cement concrete pavements.
- This experience is reflected in the life cycle models and is the baseline that was used for comparison. The figure on the left depicts the existing LCCA framework has maintenance activities prescribed at fiveyear intervals.
- The joint routing and sealing includes both the centerline joint and the shoulder joints.

LCCA Model for HMA Overlay With LJS



Maintenance activities for the scenario with LJS have been pushed back to account for the extended life and the performance benefits of the material.

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- Additionally, the centerline joint routing and sealing for the section with LJS was removed.
- The initial data indicated the life extension achieved when adding LJS is approximately three to five years.

Life Cycle Cost Analysis Results

Year - n	A - LJS	A – No LJS	Annual Savings
20	\$16,744.42	\$19,502.75	\$2,758.33

Year - n	NPV- LJS	NPV – No LJS	Net Present Savings
20	\$249,116.12	\$290,151.64	\$41,035.52

- The difference of these values was compared to calculate the annual savings.
- The net present values for each scenario were calculated and the net present value savings were calculated.

Cost Benefit of LJS



- To better understand the benefit of the LJS material, IDOT used the difference in net present values of the section without LJS and the section constructed with LJS minus the cost of LJS.
- Taking that value and dividing by 5,280 gives the cost benefit of this construction practice in similar units to the average awarded price of \$2.39 per linear foot.
- This was initially completed for the 20-year analysis but was repeated for 16, 17, 18, and 19-year analyses to better understand the progression of the results.
- The benefit of this construction practice is three to five times the cost of the material.

IDOT VRAM Study Summary

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- Many approaches to improving the performance of asphalt pavement longitudinal joints have been tried by various agencies with mixed or marginal success.
- IDOT looked at a bottom-up material approach to seal the voids in the lower-density longitudinal joint area, with the result being lower permeability and an improvement in predicted laboratory flexibility and field performance.
- The high polymer LJS material has rut resistant and crack resistant binder properties and has been easily imbedded into the construction process of surface courses.
- The life extension of the joint area is approximately three to five years, and the benefit is calculated to be three to five times the initial cost.

VRAM Summary

- Provides a <u>material solution</u> to reducing air voids at the longitudinal joint thereby reducing air and water permeability
- Multiple field projects in place for 15+ years demonstrate improved long term joint performance
- Reduces need for joint maintenance and increases the life of the pavement
- Illinois DOT has documented that VRAM is an investment that pays dividends of three to five times its cost

Questions?

For more information go to https://www.thejointsolution.com