CONSORTIUM FOR ASPHALT PAVEMENT RESEARCH AND IMPLEMENTATION

CAPRI-Brief

Asphalt Longitudinal Joint Current and Best Practices

Construction Methods, Materials, & Acceptance

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By

Thomas Harman
Senior Research Engineer
National Center for Asphalt Technology
Auburn University, Auburn, Alabama

Mark Buncher, Ph.D., PE
Director of Engineering
Asphalt Institute
Lexington, Kentucky

HeyNAPA.com

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Foreword

Roads are more than just pathways; they're essential to our economy and well-being. One critical aspect of roadway durability is the construction of asphalt longitudinal joints (L.J.). Done correctly, these joints help ensure long-lasting roadways; when done poorly, they result in costly maintenance and repairs.

This technical brief summarizes construction methods, joint materials, and specification approaches. In addition, it summarizes CAPRI agency and industry perspectives, updates the 2014 FHWA[1]/Asphalt Institute best practices, and identifies gaps requiring further research. By serving as a resource, this CAPRI-Brief aims to elevate construction quality and drive innovation, ensuring safer and more reliable roads for the future.

Section 1 is adapted from the best practices developed by the FHWA and Asphalt Institute (2014). The Appendix provides a comprehensive update.
https://www.asphaltinstitute.org/engineering/longitudinal-joint-information/

Section 1 – CAPRI-Brief Summary of Best Practices

Planning and Design Phase:

1. Evaluate traffic control for echelon paving possibilities to reduce cold joints.
2. For mill-fill projects, consider one lane at a time to avoid unconfined edges and ensure milled surface cleanliness.
3. Review and allow cut-back joint methods prevalent in the US airfield projects and UK roadways.
4. Offset joints by at least 6 inches between layers unless overlaying concrete pavement.
5. Strategically place surface lift joints to bypass wheel paths, striping, and centerline rumble strips.
6. Have clear specifications for joint placement, testing, and acceptance.
7. Ensure lift thickness is at least 4x Nominal Maximum Aggregate Size (NMAS) for coarse mixes and 3x NMAS for fine mixes.
8. Select less permeable surface mixes using the appropriate/smallest NMAS mix.
9. Consider warm mix asphalt (WMA) technology for late-season paving and to serve as a compaction aid.
10. Consider using a notch wedge joint for a 1.5 to 3-inch lift thickness.
11. Separate bidding for tack coat to ensure sufficient application.
12. Discuss joint-related topics in the pre-paving meeting, including options for treating the cold-side of the joint.

[1] Federal Highway Administration

13. Prioritize paving from low to high elevations for efficient water flow.
14. Evaluate joint enrichment methods post-construction to increase longevity.

During Pavement Placement:

1. Avoid mix segregation.
2. Ensure a smooth paving operation without interruptions. Utilize material transfer vehicles.
3. Utilize a string line for first-pass straightness.
4. Apply an ample and uniform tack coat.
5. Ensure seamless truck-paver coordination/operation.
6. Maximize paver automation for joint density.
7. Synchronize paver and auger speeds.
8. Extend augers close to end gates to prevent segregation.
9. Properly set the end gate.
10. Keep the vibrator screed activated.
11. Ensure 1-inch overlap for butt or notched wedge joints; 0.5-inch for milled joints.
12. Avoid excessive luting/raking. *Don't starve the joint.*
13. Aim for the hot-side joint to be slightly elevated post-rolling.

Treating the Cold Side Joint:

1. Consider infrared joint heaters, especially for cold-weather paving.
2. Consider joint adhesives for durability and sealing.
3. Consider innovative materials designed to reduce or fill the voids at the joint.
4. At a minimum, tack the joint face.

Rolling and Compaction:

1. Compact unconfined edge with a vibratory roller.
2. Compact confined edge with a vibratory roller without immediate overlap.
3. Use rubber tire rollers for intermediate rolling near the joint.

Specification Approaches:

1. Steps for implementing new joint specifications include collaboration with industry, training, baseline establishment, incremental changes, and a robust evaluation plan.
2. Aim for a minimum joint density of 2% lower than the mat density or at least 90% TMD[2].
3. Target in-place air voids of less than 7-8% for surface mix types on high-volume roadways.
4. Ensure consistency in density testing locations around the joint.
5. Use 6-inch cores centered over joints for density analysis. For the notched-wedge joint, center cores over the middle of the wedge.
6. Implement a payment scale based on TMD percentages.
7. Consider incentive/disincentive payment to drive innovation.
8. Contractors should include longitudinal joint testing in their quality control.

[2] Theoretical Maximum Density, TMD

Section 2 – Methods for Longitudinal Joint Construction

Agencies specify or allow different joint details, such as the butt, notched wedge, Maryland, and cut-back joint, as well as material approaches (Section 3). The most common approach for longitudinal joint construction creates a vertical edge called a **butt joint**, Figure 1. For the unconfined edge, some lateral movement in the asphalt layer is inherent during the compaction processes. This can result in lower density and higher permeability of the material, which can negatively impact performance.

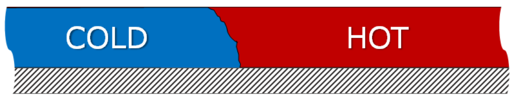


Figure 1. Vertical Edge of a Conventional Butt Joint.

The relationship between in-place air voids and permeability is depicted in Figure 2 (NCAT Report 03-02, R. Mallick et al.). Currently, most states accept longitudinal joint densities of 90.5 to 91 percent TMD with full payment, which is 9.5 to 9 percent air voids. Several states allow with a penalty to leave asphalt mix in place with longitudinal joint densities as low as 86 percent TMD or 14 percent air voids. Based on permeability, these acceptance levels appear suspect, especially for larger NMAS mixes and coarse aggregate gradations.

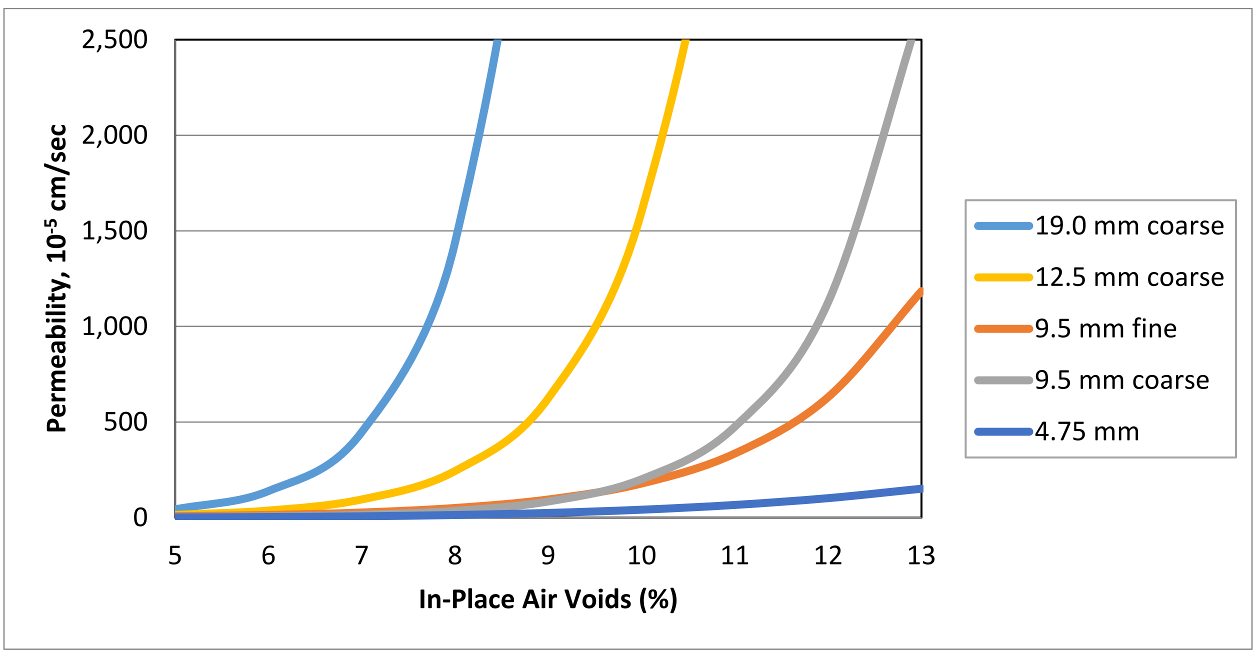


Figure 2. In-place Air Voids versus Permeability for 5 common surface mixes (coarse- and fine-gradations).

Contractors employ several common breakdown roller patterns to achieve compaction at the joint and mitigate the potential for poor density, Figure 3.

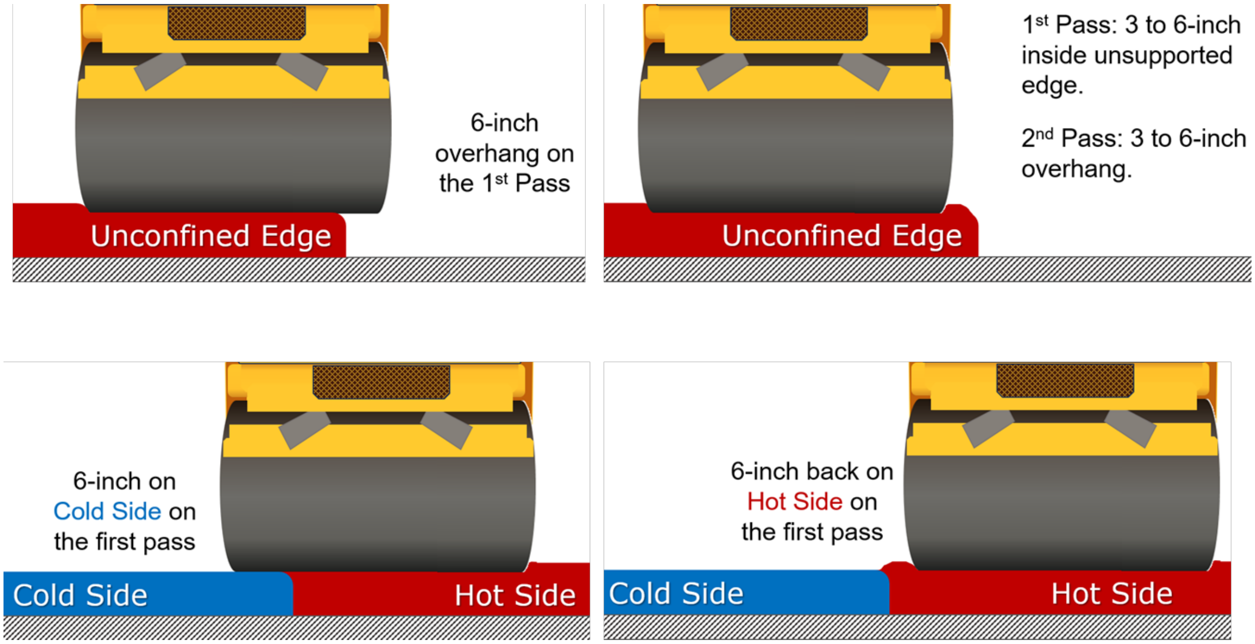


Figure 3. Common Breakdown Roller Patterns for Butt Joint Construction.

Generally, the amount of roll-down of the new mix is about ¼ inch per inch of thickness. Therefore, if the layer being placed needs to be 2 inches thick after compaction, the loose mix needs to be placed 2.5 inches thick.

There is no expert consensus on which breakdown roller patter works best, however it is critical the breakdown roller keeps close to the paver especially in cool weather. The approach where the breakdown roller is overhanging 6 inches on the first pass of the unconfined edge anecdotally appears to be the most common practice.

A **notched wedge joint** is designed to improve the compaction and bonding between adjacent lanes of asphalt. This joint features a tapered, or "wedged," edge on one side of the newly laid asphalt mat rather than a vertical edge, Figure 4. The notch allows for better initial compaction by the paving equipment and aims to minimize low-density areas that are prone to premature failure. The design is believed to improve the quality and longevity of the seam between adjacent lanes, reducing maintenance needs and enhancing road performance.

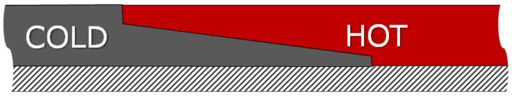


Figure 4. Tapered Edge of the Notched Wedge Joint.

The Pennsylvania DOT compared the densities of the notched wedge joint to the butt joint for the 2011 and 2012 paving seasons, Table 1. See Section 4 to learn more about PennDOT's journey in advancing their longitudinal joint specification.

Table 1. PennDOT Joint Density Comparison.

Longitudinal Joint Method	**Avg. Densities 2011 Paving Season**	**Avg. Densities 2012 Paving Season**
Notched Wedge	91.7% of TMD	91.7%
Butt Joint	90.3%	90.7%

Figure 5 shows how the "Maryland Joint" is constructed in Minnesota. The Maryland joint was the result of efforts by asphalt contractors to improve density. The Maryland joint method involves a small overlap at the joint with the adjacent pavement lane. The overlap is about ¼ inch thick and extends 1.0 to 1.5 inches onto the adjacent pavement lane.

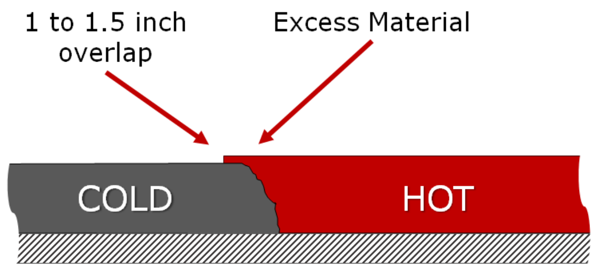


Figure 5. Maryland joint method, commonly used in Minnesota.

CAPRI State Agency Perspective, caution: butt joints with overlap can cause excess wear on the cutting edge of winter maintenance plows.

The **milled or cut-back** method removes a portion of the newly laid, compacted asphalt along the longitudinal joint to create a clean, vertical face. This method aims to create a more seamless and durable joint by removing any irregularities or low-density areas, providing a better surface for compaction and fusion between adjacent lanes.

For rehabilitation projects where the existing pavement is milled and filled, agencies can elect to mill and fill one lane at a time, which eliminates the unconfined edge. Care must be taken to thoroughly clean the milled surface for this approach to be effective, or debonding can occur.

An asphalt paver **edge restraining device** is a tool or attachment used with an asphalt paving machine that helps maintain the shape, consistency, and density of the edges of the laid asphalt mat. It acts as a physical barrier, containing and supporting the uncompacted edge of the asphalt mat to help ensure a straight and uniform edge while minimizing edge deformation during the compaction process. This device can be especially valuable in achieving denser, less permeable edges, reducing-edge cracking, and increasing the overall life of the asphalt pavement.

The **Joint Maker** is an automated joint construction technique. It consisted of a boot-like device about 3 inches wide, which is attached to the side of the screed at the corner during construction. The device forces extra material at the joint through an extrusion process prior to the screed. A kicker plate is also furnished and attached to the side of the paver to lute back the overlapped mix without the help of a lute raker. It is claimed that proper use of the joint maker ensures high density and better interlocking of aggregates at the joint.

Lastly, **echelon** paving can be employed to eliminate the cold joint. Echelon paving is where two or more pavers work side-by-side in parallel lanes to minimize the time between the placement of adjoining lanes. This approach aims to create a seamless, high-quality longitudinal joint by allowing the edges of adjacent asphalt mats to be compacted while they are still hot, thereby improving the bond between them and reducing potential weaknesses that could lead to premature failure. Echelon paving is particularly beneficial for ensuring uniform compaction and improving the longevity of the road surface.

Section 3 – Materials for Longitudinal Joint Construction & Maintenance

Various materials have been developed to improve longitudinal joint performance, which are placed during construction or maintenance, each with unique properties and applications. Below is a list of some common materials used for improving asphalt longitudinal joints:

Joint Adhesives (*aka Rubberized Asphalt Tack Coat*): Joint adhesives are specialized, rubberized asphalt-based compounds applied to the near vertical joint face before the adjacent lane is paved. These adhesives enhance the bonding between the two lanes, improve overall joint performance, and reduce the infiltration of water, thereby extending the pavement's lifespan.

Joint Sealers: Joint sealers are applied on completed longitudinal joints at widths typically 1- to 2-feet wide to fill any gaps and prevent or limit water infiltration. These products are often considered rejuvenators, and their application over the joint is often referred to as **overbanding**. These materials are designed to adhere well to asphalt and remain flexible over time, accommodating the natural expansion and contraction of the road surface.

Fog Sealers: Fog sealers are applied similar to joint sealers described above, except the material is a slow-setting diluted asphalt emulsion. A light application of diluted emulsion is sprayed on the surface at widths typically 1- to 2-feet centered on the longitudinal joint. This overbanding treatment enriches the asphalt surface at the joint and offers some protection against aging and water damage.

Crack Sealing & Filling: These are specialized treatments for cracks that appear over time, which can also be used with deteriorating longitudinal joints. Crack sealing involves cleaning and filling the cracks with a hot-applied, rubberized sealant.

Micro-surfacing: Micro-surfacing is a protective seal coat that combines asphalt emulsion, aggregate, mineral filler, and water. It corrects surface irregularities and provides a new, skid-resistant surface. While not directly a joint treatment, a well-applied micro-surface can help extend the lifespan of the entire road, including its joints. Several states have used narrow-width micro-surfacing targeted on the longitudinal joint.

VRAM – Void Reducing Asphalt Membrane: VRAM is a pre-applied, liquid membrane that reduces air voids in the asphalt layer when it is placed and compacted. It improves the density and bonding at the joint, resulting in a more durable and long-lasting road surface. Illinois DOT asphalt specifications refer to VRAM as a *Longitudinal Joint Sealant* (LJS). Under article 406.06(h)(2) of their standard specification, LJS application rates have been developed for coarse, fine, and SMA[3] mixtures of varying NMAS and lift thicknesses (*revised 8/1/23*).

Table 2. Excerpt from Illinois DOT LIS Specification.

"LJS Half-Width Application Rate, lb/ft (kg/m) 1/			
Lift Thickness, in. (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)
¾ (19)	0.44 (0.66)		
1 (25)	0.58 (0.86)		
1 ¼ (32)	0.66 (0.98)	0.44 (0.66)	
1 ½ (38)	0.74 (1.10)	0.48 (0.71)	0.63 (0.94)
1 ¾ (44)	0.82 (1.22)	0.52 (0.77)	0.69 (1.03)
2 (50)	0.90 (1.34)	0.56 (0.83)	0.76 (1.13)
≥ 2 ¼ (60)	0.98 (1.46)		

1/ The application rate includes a surface demand for liquid. The thickness of the LJS may taper from the center of the application to a lesser thickness on the edge of the application, provided the correct width and application rate are maintained."

Rapid Penetrating Emulsion (RPE) and Rejuvenating Seals: RPE and rejuvenating seals are emulsions designed to penetrate deep into the asphalt surface, restoring its original properties and reversing some effects of aging. These treatments are typically used for older pavements but can also benefit the longevity of new longitudinal joints.

[3] Stone Matrix Asphalt

Section 4 – Common Mistakes to Avoid in Asphalt Longitudinal Joint Construction

Constructing a durable and effective asphalt longitudinal joint is a critical aspect of road quality. However, there are common mistakes that can compromise joint performance and longevity. Here's a summary of **three things not to do**:

- Using a lute rake to move material away from the joint can compromise its integrity. This often results in a lower density at the joint, making it susceptible to water infiltration and premature wear, Figure 6.

Figure 6. Improper Use of the Lute Rake.

- An uneven, wavy joint edge can lead to inconsistent/variable density between the adjoining lane of asphalt. This not only looks unprofessional but also weakens the joint, making it prone to cracking and other forms of distress, Figure 7.

Figure 7. Examples of Uneven Unconfined Joint Edge (Butt & Notched-wedge Joints).

- Inconsistent operation of the paver, such as a non-uniform head of material fed by the auger, can cause variations in material density along the joint. This results in a weaker seam that's more susceptible to damage over time. Figure 8.

Figure 8. Example of the Proper Head of Material in the Auger Chamber, where about half of the Auger is Exposed.

By avoiding these common mistakes, contractors and agencies can improve the quality of asphalt longitudinal joints, resulting in roadways that are more durable, safer, and require less frequent maintenance.

Image sources: Asphalt Institute.

Section 5 – CAPRI Agency and Industry's Perspectives

In the fall of 2023, the Virgina DOT hosted CAPRI in Fairfax, VA. The general session included several L.J. presentations and a discussion on longitudinal joint best practices, specifications, construction, and performance.

The Evolution of PennDOT's Specification: A Journey of Improvement
(Timothy Ramirez, Laboratory Testing Section)

In the mid-1990s, Pennsylvania's Department of Transportation (PennDOT), embarked on a path of innovation. Their objective? To enhance road construction standards, with a particular focus on improving joint density in asphalt pavements.

<u>The Initial Study and the S.R. 441 Experiment</u>: 1995 marked the beginning when PennDOT collaborated with NCAT. The product of this partnership was a study carried out on S.R. 441 in Lancaster County. This two-lane roadway became the canvas for PennDOT's experimentation. Using a Marshall Mix Design with a specification of 6.0% P_b and 9.5mm NMAS, the agency tested eight different joint techniques.

The findings of this study are documented in NCAT Report 02-03 (Kandhal, et al.), released in February 2002. Among the various techniques, edge restraining device, cut-back method (*reported as cutting wheel*), joint maker, and rolling from the cold side initially stood out based on joint density. Additional techniques, which included two additional rolling patterns (rolling from the hot side with and without holding back 6 inches), rubberized joint sealant, and the then New Jersey Wedge (without a notch and a gradient of 3:1), were also explored. After six years of in situ service, the rubberized joint sealant and the cutting wheel ranked as the best approach, closely followed by rolling from the hot side and NJ Wedge.

Interestingly, 27 years on, the S.R. 441 roadway stands as a testament to the effectiveness of these techniques. However, the journey wasn't without its challenges. One particular hiccup was that the lute raker was found to be ineffective during the construction phase.

<u>Updates and Refinements</u>: PennDOT, in partnership with Industry, recognized the importance of continuous improvement. In 2000, the L.J. specifications were updated. The revised standards dictated that the compaction should be up to 90% of TMD, and the joints should either be Vertical (Butt) Joint or Notched Wedge Joint. The years 2003 and 2006 saw further updates. But by 2006, it became evident that the method specification wasn't universally effective. Maintaining poorly constructed joints was becoming prohibitively expensive.

In response, between 2006 and 2007, PennDOT embarked on an intensive campaign to boost joint density. Special provisions were established, and the results were encouraging. In 2007, joint density averaged 87.8% of TMD across 18 projects. By 2008, this value had increased to 88.9% over 43 projects. 2009 witnessed a slight decline, averaging 88.2% of TMD.

Incentivizing Excellence: Understanding the importance of joint density for road longevity, PennDOT pivoted towards a system that combined end-results specification with incentives and disincentives. This new system introduced evaluations where a 6-inch core was taken over the joint or center of the notch-wedge joint. On average, one core was examined every 2500 feet, with each lot averaging 5 cores. By 2020, standards were again adjusted, this time setting the PWL Lower Limit at 91.0% of TMD. If the joint density fell below 88%, the joint had to be sealed with PG 64-22.

Reflecting on the Achievements: The focus on continuous improvement and the iterative approach bore fruit. By 2013, across 168 projects, the average joint density stood at an impressive 91.4% for joints and 93.9% for the roadway. The composition of the surface mixes was predominantly 9.5mm (75%), with 12.5mm mixes making up the remaining 25%.

Fast forward to 2023, PennDOT's pursuit of excellence culminated in an outstanding average joint density of 93.5% of TMD.

The Evolution of Ohio DOT's Road Construction Specifications: A Focus on Joint Density *(Eric Biehl, State Asphalt Materials Engineer)*

Ohio DOT has been at the forefront of ensuring road durability, particularly in the area of joint density. ODOT has undertaken various initiatives to address this significant aspect of road construction.

Initial Challenges: One of the pressing issues ODOT faced was an early joint failure rate of approximately 25% in 12.5 mm surface mixes. In 2016, this translated to a substantial cost implication, ranging between $35,000 to $60,000 per linear mile of joint maintenance. The department predominantly utilized Superpave for heavy-duty applications, while the Marshall method was employed for the rest.

Existing Specifications and Early Interventions: ODOT's current specification, known as the "446 density acceptance," required contractors to extract ten 4-inch cores per production day, with three of these specifically designated as joint cores. For joint cores, a 4-inch core that’s 6 inches from the center of the core from the joint was the standard.

However, by 2013, a discerning trend was observed: the cores exhibited a density that was about 4% lower than the desired standard. This prompted ODOT to explore approaches with lower risk.

Learning from PennDOT: Taking cues from the successes of PennDOT, ODOT embarked on trial projects in 2014. These trials revealed that "starving the joint" was a prevalent issue. With this knowledge, 2015 saw the introduction of a new joint density specification (SS-806), modeled after PennDOT's standards. One significant shift was the movement towards a 5% pay deduction in density standards rather than 10%. This change, while seemingly minor, had a considerable impact.

Queries and Recommendations:

Dealing with Old Cracking Joints: A significant concern was the best practice for addressing old cracking joints, especially if they were in the lower layer. ODOT recommends that milling should penetrate deep enough to encompass the deteriorated sections. At the very minimum, sealing these problematic joints was crucial.

A Contractor's Lens on L.J. Construction: Insights from a Construction Company
(Bart A. Moody, Vice President of Asphalt Estimating & Engineering)

Bart Moody, Kokosing Construction Company, Ohio, brings a unique perspective from the trenches of road construction. With the company's reach spanning the mid-west and the mid-Atlantic and boasting 20 plant and terminal locations across Ohio, Moody's insights shed light on the intricacies of the construction industry.

The Bidding Landscape: In the competitive world of construction, even a difference of a few hundred dollars can make or break a deal. Moody highlighted a poignant example, where, on a massive $6.6M job, Kokosing lost the bid by a mere $500 dollars. This underscores the tight margins and the high stakes involved in the business.

The Delicate Balance between Innovation and Specification: Moody emphasized the importance of not being overly prescriptive in project specifications. He believes that giving contractors room to innovate can often lead to better, more efficient solutions. When developing specifications, it is important to keep in mind that as the risk rises, so does the price. This calls for a delicate balance where both the agency and the contractor understand and respect each other's concerns and constraints.

Appreciation for ODOT's Approach: Moody lauded ODOT for their constructive communication with the industry. He appreciated ODOT's efforts in developing their longitudinal joint density specification. He pointed out that Table 447.05-1, with its 5% disincentive, effectively captures contractors' attention and steers them towards delivering quality without being overly punitive.

The Call for Flexibility and Change: Kokosing has engaged in various voluntary trials, experimenting with different joint techniques like tapered wedge, notched wedge, and more. Moody remarked that there's considerable cutting back of joints in Ohio to align with specifications. However, he cautioned against changing multiple variables simultaneously - it's best to change one thing at a time to understand its impact properly.

Moody also made a case against just focusing on aesthetics. A visually pleasing joint doesn't necessarily mean it's well-compacted. While private projects like parking lots may prioritize aesthetics, they might not always be the best in terms of durability.

Open Discussion – Agency Perspectives

Fifteen additional CAPRI State DOTs revealed a mix of satisfaction and concern about joint quality, underpinned by various specifications, practices, and incentives. Climate, particularly the presence or absence of freeze-thaw cycles, influences joint performance and state policies, where many of the southeastern states opt for no joint specifications (see le 9). Here are the general themes from the discussion:

- *Joint Density Specifications*: The presence or absence of joint specifications varies widely among states.
- *Joint Quality*: Some states believe their joints are satisfactory, while others are taking measures to improve joint quality.
- *Safety Features*: Rumble strips are becoming a common addition, but they present challenges related to water retention and reflection cracking.
- *Innovative Techniques*: States are exploring methods like VRAM, notch wedges, and joint heaters.
- *Incentive/Disincentive Systems*: These mechanisms aim to motivate contractors to innovate.

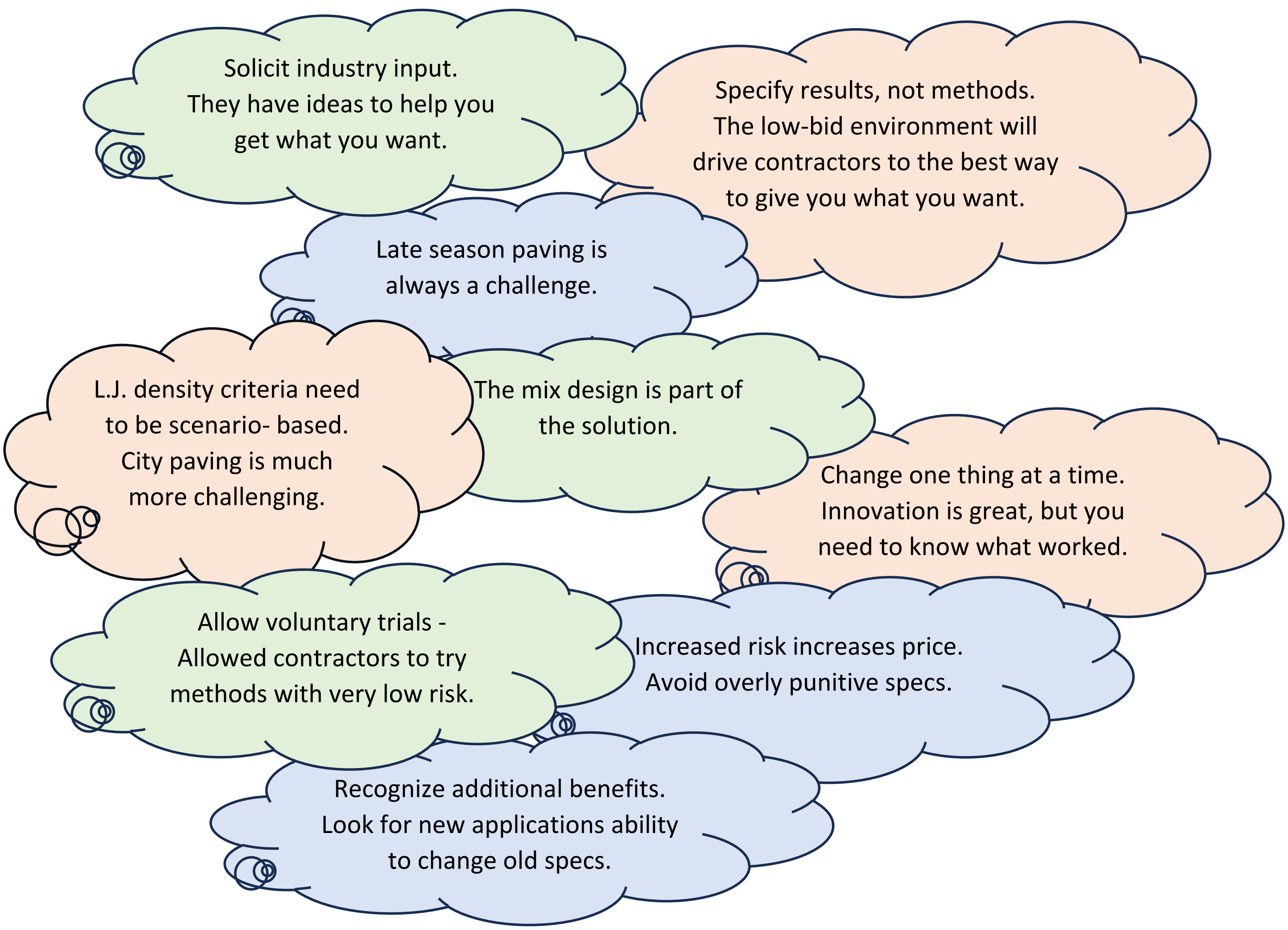
Figure 9. Four U.S. Climate Regions based on FHWA.

Table 3. Summary of Agency Perspectives/Approaches.

State	Perspective/Approaches	State	Perspective/Approaches
AL	• No L.J. specification. • Common use of Open-Graded Friction Course (OGFC). • Raveling concerns at L.J. with SMA. • Safety measures include rumble strips, which sometimes cause water retention. • Offset of 6" between lifts.	**NC**	• No L.J. specification. • Do not perceive it as an issue. • Lack of freeze-thaw cycles.
FL	• No L.J. specifications, attributed to the state's climate and lack of freeze-thaw cycles. • FAA adoption of state specifications for specific aircraft weight.	**ND**	• Joint specification introduced recently. • Offers incentives/disincentives. • Notched wedge and butt joints with overlap are common. • Centerline rumble strips introduced but present challenges.
GA	• No L.J. specification. • Use of mill and fill; contractors mill ahead of paving. • Emphasis on tacking joint faces. • Introduction of rumble strips. • Addition of asphalt binder to the mix. • Offset of joints between layers.	**NE**	• Joint specifications for a decade. • Preference for the notched wedge. • Additional tack application on windy days.
IL	• VRAM (LJS)	**NY**	• Has an L.J. specification. • Limited number of projects receive incentive bonuses. • Core testing is seen as intense.
IN	• 2010, started going prescriptive: • Joint adhesive. • Overbanding/sealant. • Recently added VRAM (only on Category 4 Roadways). • Rumble strips are common, but still use sealant.	**TN**	• Special provisions with incentives and disincentives. • Some contractors use joint heaters. • Specified joint adhesives. • Post-construction follow-up with overbanding.
MI	• Use special provisions with piloted specifications. • Implementation of incentive/disincentive approach. • Adoption of echelon paving for bonuses.	**VA**	• No L.J. specification. • Emphasized continuous focus on joint quality and training. • Concerns about Superpave affecting joint performance.
MS	• No joint density specification.	**WI**	• Requires notch wedge for thicker overlays. • Joint height specification to prevent starving.

			• Joint evaluation initiatives in recent years. • Incentive/disincentive approach. • Investigation into VRAM.
MO	• Has a specification, but not for confined joints (mill and fill). • Overall, joint density specification works. • Moisture problem in certain regions. • Adjustments to 12.5mm mixes. • Exploration into BMD and VRAM. • Rumble strips likened to miniature potholes.		

Additional Discussion.



Section 6 – Research Gaps and Opportunities

A. **Lack of Long-term Performance.** Most joint studies include post-construction and 3 to 6 years of service. Tennessee DOT and Pennsylvania DOT have L.J. studies from the late 1990s that are still in service.

B. **Understanding the Role Between Densities, Permeability, and Acceptance.** It is assumed improved density ensures improved performance; however, agencies are accepting densities that still have high permeability.

C. **We need long-term test sections for innovative approaches**, like RPE and VRAM, where:
  - RPE and competing products (top-down).
  - VRAM and competing products (bottom-up).
  - With control sections.
  - In Freeze/Thaw zones.
  - With dedicated research bodies committed to follow up.

D. **Explore the role and benefits of non-destructive technologies (NDT)**, like:
  - Dielectric Profiling Systems / Ground Penetrating Radar
  - Paver-mounted Thermal Profiling
  - Intelligent Compaction

E. **Best Practices for Centerline Rumble Strips**.

HeyNAPA Links (www.HeyNAPA.com)

The following documents and pages were referenced when responding to the following question, "*What is the best way to specify an asphalt longitudinal joint to ensure durability and long life*?"

- Airfield Asphalt Pavement Technology Program Project 04-05 REPORT: Improved Performance of Longitudinal Joints on Asphalt Airfield
    - Airfield Asphalt Pavement Technology Program Project 04-05 REPORT: Improved Performance of Longitudinal Joints on Asphalt Airfield - Page 34 **89%**
    - Airfield Asphalt Pavement Technology Program Project 04-05 REPORT: Improved Performance of Longitudinal Joints on Asphalt Airfield - Page 19 **89%**
    - Airfield Asphalt Pavement Technology Program Project 04-05 REPORT: Improved Performance of Longitudinal Joints on Asphalt Airfield - Page 151 **88%**
- FHWA 2016 Annual Report: ACCELERATED IMPLEMENTATION AND DEPLOYMENT OF PAVEMENT TECHNOLOGIES
    - FHWA 2016 Annual Report: ACCELERATED IMPLEMENTATION AND DEPLOYMENT OF PAVEMENT TECHNOLOGIES - Page 12 **88%**
- Longitudinal Joints: Problems and Solutions
    - Longitudinal Joints: Problems and Solutions - Page 4 **88%**
- Perpetual Asphalt Pavements: A Synthesis
    - Perpetual Asphalt Pavements: A Synthesis - Page 31 **88%**
- Perpetual Pavements: A Synthesis
    - Perpetual Pavements: A Synthesis - Page 31 **88%**
- NCAT Report 02-03: EVALUATION OF EIGHT LONGITUDINAL JOINT CONSTRUCTION TECHNIQUES FOR ASPHALT PAVEMENTS IN PENNSYLVANIA
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APPENDIX

FHWA/Asphalt Institute Recommendations

The following is the summary of recommendations developed from a joint FHWA/Asphalt Institute project on Longitudinal Joint Best Practices *(March 2014)*.

During Planning and Design

1) Evaluate traffic control requirements to see if echelon paving could be utilized in any facet of a project to minimize the number of traditional cold joints.
2) For mill and fill jobs, evaluate traffic control requirements to require the contractor to mill and fill one lane at a time, eliminating unconfined edges. Care should be taken to thoroughly clean the milled surface, especially at the confined corner.
3) Assess project scope, traffic control and safety requirements for the practicality of evaluating the method of cutting back the joint. This method is routine on airfield projects in the U.S. and is done on roadways in the United Kingdom, with much success.
4) Offset the longitudinal joints horizontally between layers by at least 6 inches, when placing multiple lifts. This does not apply when placing asphalt mix over portland cement concrete (PCC), as it's often preferred to stack the joints directly over the PCC joint.
5) Plan the location of the longitudinal joint in the surface lift to avoid wheel paths, recessed pavement markings, and striping whenever possible.
6) Assure there are well-defined specifications for the placement and quality assurance testing of the longitudinal joints (See Section 5).
7) Use a lift thickness that is at least 4 times the Nominal Maximum Aggregate Size (NMAS) of coarse gradation mixes and 3 times the NMAS for fine gradation mixes. Adequate lift thickness will facilitate compaction for better density.
8) Consider the use of less permeable surface mixes by using:
   - Smallest NMAS mix that is appropriate for the application (will not rut).
   - Using a finer versus coarser gradation.
9) Consider using warm mix asphalt as a compaction aid, especially in late-season paving.
10) Consider the use of the notch wedge joint (versus traditional vertical edge or butt) for lift thicknesses between 1.5 to 3 inches. Several agencies have found that the notch wedge joint provides higher densities on average than the butt joint.
11) Pay for tack as a separate bid item (as opposed to being an incidental requirement) to facilitate getting a sufficient amount of material applied.
12) Include items related to the longitudinal joint as discussion topics for the pre-paving meeting. These include the joint type to be used, planned locations of joints, testing requirements, and locations, construction practices, etc.
13) Planning the lane sequence so as to pave from low to high. This will provide a shingle effect, preventing the overlapped joint material from impeding water flow on the surface. The hot (confined)-side of the joint may be slightly higher than the cold (unconfined)-side.
14) To increase the longevity of the joint after it has been constructed, and perhaps as a remedial action for not meeting a minimum density, evaluate the various "joint

enrichment" approaches. These include applying various surface sealer products at widths 1 to 2 feet or "overbanding" with PG binder at a width of around 4 inches.

During Pavement Lay Down Operations:

1) Follow best practices to avoid mix segregation.
2) Balance plant production, trucking, lay down, and rolling operations to ensure a constantly moving paving operation without stops and starts. Material Transfer Vehicles (MTVs) can help.
3) Use a string line and follow it with a guide attached to the paver in order to produce a straight (or smooth for curves) pass on the first pull.
4) Apply adequate tack coat uniformly to the full width of the paving lane.
5) Ensure the dump person guides the trucks correctly to the paver without bumping or interrupting the constant speed of the paver and not letting the hopper run low.
6) Use paver automation. A critical element to getting joint density is having sufficient depth of material at the longitudinal joint on the hot-side.
   - A joint matcher provides the best opportunity to place the correct depth to match the cold side consistently. The optimal mounting location is a few feet in front of the auger.
   - The use of a ski (versus the joint matcher) is ideal to achieve smoothness but is not ideal to consistently match the joint by providing the optimum depth of asphalt mix.
   - Multiple lifts offer the opportunity to use a ski on intermediate lifts for smoothness and a joint matcher on surface lift for a good joint.
   - Another way of achieving both smoothness and joint density is to use a joint matcher when closing a joint but run a ski on the mat's other side.
7) Coordinate paver and auger speed to allow for a uniform head of material across the entire width of the paver. Maintain paver and auger speed.
8) Extend augers and tunnels to within 12 to 18 inches of the end gate to ensure a continual supply of fresh material flows out to the gate and is not pushed (segregated).
9) Set the end gate properly to firmly seat on the existing pavement surface.
10) Ensure the vibrator screed is turned on all the time, even when the boss or inspector is not around. If paver automation is set correctly, the operator should not need to stand on the screed.
11) When closing a butt or notched wedge joint, overlap by 1 inch, +/- ½ inch. If the joint is milled or cut back, the overlap should be approximately ½ inch.
12) Avoid luting or raking the overlapped material, assuming the proper overlap (previous bullet). If the overlap exceeds 1.5 inches, carefully remove the excess with a flat-end shovel. Do not broadcast excess material across the mat.
13) Place enough material on the hot-side of the joint so that, after rolling, the surface is slightly higher (0.1 inch) than the cold side. This ensures the joint was not starved of material and no bridging of the roller occurred, allowing for good compaction at the hot-side of the joint.

Treating the Cold Side Joint Face

1) Consider the use of infrared joint heaters, especially in cold weather paving. Studies have shown that heaters can improve joint density by 1-2%. Equipment improvements include longer and more efficient infrared heaters and automation with paver speed to minimize overheating or under-heating.
2) Evaluate the use of joint adhesive (JA), which is a hot-applied rubberized asphalt sealant applied to the open face of longitudinal joints. The use of this material is growing, as agencies believe it seals and improves the durability of the joint. Research also indicates improved performance. Various JA products are available.
3) At a minimum, tack the face of the joint with the same material (emulsion or asphalt cement) being used to tack the mat.
   - If using an emulsion, double tack the joint face.
   - Alternatively, consider using a PG binder to provide greater residual binder.
   - The best material to treat the open face, although the most expensive, is a JA.

During Rolling and Compaction

1) Compact the unconfined edge of the mat with the first pass of vibratory roller drum extended out over the edge of the mat approximately 6 inches.
   - An alternative method is to make the first pass of the vibratory roller 6 inches back from the unconfined edge, and then extend the drum out over the unconfined edge on the second pass. With this method, watch for stress cracks that may develop parallel to, and 6 inches off, the joint. The best method to roll the edge may be mix and lift thickness dependent.
2) Compact the confined edge of joint with the first pass of vibratory roller drum on the hot mat but staying back from the joint 6 to 8 inches on first pass. The second pass should then overlap onto the cold mat 4 to 6 inches. With this method, watch for any stress cracks developing in the mat that are parallel and 6 to 8 inches off the joint.
   - An alternative method is to have the first pass of the vibratory roller on the hot mat overlapping 4 to 6 inches onto the cold mat. A major concern with this method is that if an insufficient depth of asphalt mix is placed (starving the joint), the roller will bridge over and not compact the hot material completely.
3) Encourage the use of rubber tire rollers for intermediate rolling (not finish rolling) of the hot side of the joint to knead the loose material into the joint. The edge of the front outside rubber tire should run just on the inside edge of the joint, and the back outside tire can then straddle over the joint. Rubber tire rollers should not be operated close to the unsupported joint edge due to excessive lateral movement.

Specification Approaches and Examples

Figure 10. Relationship between Risk and Innovation.

1) States that do not significantly address the quality of longitudinal joints in their specifications have historically found that their joint densities, when taken, are on average 2-5% lower than their mat densities. Multiple research projects have recommended specifying a minimum joint density of 2% lower than the mat density, and/or a minimum of 90% theoretical maximum density (TMD), which is 10% in-place air voids.
2) For the asphalt mat and the joint to be relatively impermeable, in-place air voids need to be less than 7-8%, with most surface mix types used on high-volume roadways. Yet, good joint construction practices typically achieve between 8-10% in-place air voids. This is the reason the area around the longitudinal joint will often deteriorate before the rest of the mat, and why achieving the highest possible in-place joint density is critical.
3) The exact testing location around the longitudinal joint will have a major influence on the relative joint density measurement value. Densities just off the unsupported edge will typically be lower than those just off the confined edge or substantially away from the joint. Densities on either side tend to increase as the distance increases from the joint.
4) Within State agency specifications, there is a wide variation regarding mat density requirements, testing method (cores versus gauges), frequency, analysis (PWL versus average), incentives/disincentives, etc. There is an even greater degree of variation regarding how States address longitudinal joints in their specifications. At the beginning of this project, approximately one-third of States had some type of minimum density requirement at the joint. While there is no single best approach for every agency or application, the following acceptance criteria are suggested as a starting point for States looking to implement a longitudinal joint specification. These assume a large enough project where a statistically based sample size is attainable.

- Cut 6” cores, centered directly over visible joint for butt joints, or centered over wedge for wedge joint. These core locations provide an approximate 50/50 split between the two lots, whose Rice values can then be averaged and used.
- Example: Pay scale for longitudinal joint density:
  - ≥ 92% of TMD: earns a maximum bonus.
  - Between 92% and 90% of TMD: 100% pay and pro-rated bonus.
  - < 90% of TMD: reduced payment, and require the joint be sealed by either overbanding (with a PG binder) or a surface seal product.
- For joint densities less than 92%, knowing the joint is still likely permeable, consider sealing either by overbanding or the use of a surface seal product.

5) A contractor’s quality control program should include the following.
   - Construct a complete longitudinal joint as part of the test strip.
   - Determine the optimum rolling pattern for density at the joint.
   - Monitor joint density for each lane and both edges with a density gauge that is calibrated to mat cores. Set the gauge parallel to the joint, with the gauge edge offset 2” from the visible joint. The gauge cannot seat properly if placed directly over the joint. Take the average of 2 (or 4) 1-minute readings, rotating 180 degrees between each.
6) Key steps in implementing a new longitudinal joint specification:
   - Agency and industry work together
   - Training (best practices, possible alternatives)
   - Establish a baseline of existing joint densities (randomly selecting projects to test)
   - Make incremental changes (trying different techniques, products, or specs)
   - If requiring a minimal density for the first time, take incremental steps:
     i) The first year require “report only” (calculate any bonus/penalty without adding/subtracting dollars)
     ii) Gradually increase density requirement to reach 90%, or possibly higher, as it can be shown to be accomplished on a regular basis.
   - Evaluation Plan: Measure densities to compare to baseline densities, monitor joint performance, etc.