TechBrief

The Asphalt Pavement Technology Program is an integrated national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry and academia, the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement suggestions, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

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Improving Longitudinal Joint Performance

This Technical Brief summarizes techniques used to improve longitudinal joint performance of asphalt pavements based on a cooperative FHWA and Asphalt Institute joint density effort and observations on the FHWA Enhancing Durability of Asphalt Pavements Through Increased In-Place Density Demonstration Project.

Introduction

This is the fourth of four planned Technical Briefs on ***Enhancing Durability of Asphalt Pavements Through Increased In-Place Density*** associated with the Federal Highway Administration (FHWA) Accelerated Implementation and Deployment of Pavement Technologies (AID-PT) program. The AID-PT program advances best practices and technologies for constructing and maintaining high-quality, long-lasting pavements in accordance with six goals established by Congress (1). The information used to develop the Technical Briefs was obtained through a literature review, a series of workshops, and support of 29 field density demonstration projects performed by State Departments of Transportation (DOTs) focused on mat density (2, 3, 4).

Research by FHWA focused on longitudinal joint density included a review of longitudinal joint literature, State DOT specifications, a survey of FHWA Division Offices, interviews of paving experts, State DOT site visits of projects pursuing improved joint density, and a series of over 75 longitudinal joint workshops across the country between 2012 and 2016 (5). Following completion of the research, suggestions for voluntary specifications and construction of longitudinal joints were developed for improving the performance life of the joint equal to the performance of the mat. The effort focused on developing a summary of useful practices for construction of longitudinal joints. A full report on the effort can be found on the Asphalt Institute website (5). This is the fourth in the series of the four planned Technical Briefs that are organized as follows:

1. Density Demonstration Projects and Related Specifications
2. Techniques and Tools for Improving Density
3. Overcoming Obstacles to Achieving Density
4. Improving Longitudinal Joint Performance

Background

Although several factors can influence the performance of an asphalt pavement, one of the most important factors is in-place density (6). A small in-place density increase can potentially lead to a significant increase in the service life of asphalt pavements. According to studies reviewed in the literature, a 1 percent increase in density (percent of theoretical maximum specific gravity, G_{mm}) was estimated to improve the fatigue performance of asphalt pavements between 8 and 44 percent and improve rutting resistance by 7 to 66 percent (6, 7). In addition, based on field data, a one-percent increase in density would conservatively extend asphalt pavement service life by 10 percent. The literature contains many references to increases in cost associated with different techniques available to improve longitudinal joint performance. However, the literature does not contain lifecycle cost analyses quantifying the benefits of the different techniques to improve longitudinal joint performance versus their costs (8).

A longitudinal joint occurs at the interface between two adjacent and parallel asphalt mats. Premature joint failures (Figure 1) are typically the result of a combination of low density, high permeability, segregation, improper overlap, and lack of adhesion at the interface. If joint density is much lower than mat density, the permeability of the mixture around the joints will be higher. This will allow greater flow of water into the pavement at the joints which can accelerate the rate of deterioration. Figure 2 illustrates this phenomenon showing moisture penetrating a longitudinal joint. Joint deterioration continues to be the most often cited cause of premature pavement failure (5). Improving joint construction, which improves density and decreases permeability, may be the single most important thing the asphalt industry can do to improve long-term asphalt pavement performance.

Image: Adam Hand

Figure 1. Deteriorating Longitudinal Joint.

Image: Adam Hand

Figure 2. Moisture Intrusion Illustrating Greater Permeability at a Longitudinal Joint.

There are three basic types of longitudinal joint: a butt joint, a milled or cutback joint, and a notched wedge or taper joint as illustrated in Figure 3. With the first pass of the paver, there is at least one unconfined mat edge which will form a joint. The unconfined side is referred to as the "cold side" of a joint. The second pass of the paver is confined at the joint by the cold side and is referred to as the "hot side."

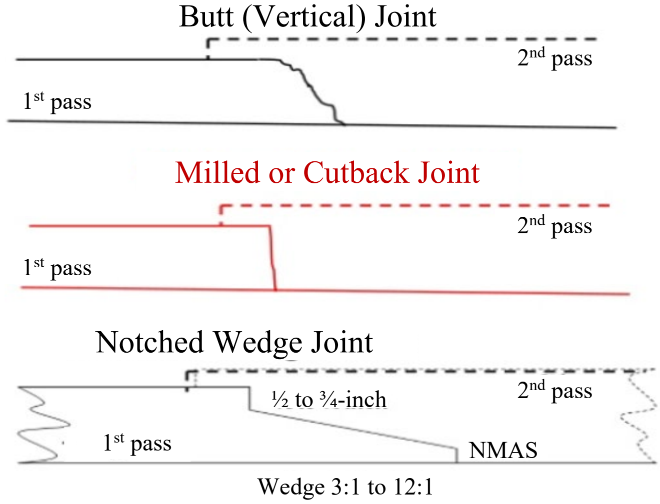

Figure 3. Longitudinal Joint Types.

Butt joints are typically created with successive parallel passes of a paver. When the first mat placed is compacted, material at the unconfined edge will sluff off with breakdown rolling as illustrated in Figure 3 as the "Butt (Vertical) Joint" and shown in Figure 4. A milled or cutback joint is formed by using a milling machine or saw to create a vertical face in the first mat after it has been compacted.

Butt joints may be better for longitudinal smoothness than notched wedge joints. The notched wedge joint has several different configurations, with slopes ranging from 3:1 to 12:1. The notch is a critical feature, since without it the slope tapers to nothing and larger sized aggregates will drag. The notch thickness can also vary, but typically will be one nominal maximum aggregate size (NMAS) of the mix. For example, a ¾ inch NMAS mix will have at least a ¾ inch notch as illustrated in Figure 3. Notched wedge joints are formed by installing a shoe on the paver screed with it up against the end gate of the screed as illustrated in Figure 5. It is important that the screed and end gates are well maintained, and properly set up when forming notched wedge joints.

Image: Adam Hand

Figure 4. Longitudinal Edge of Freshly Compacted Mat without Confinement.

Some research shows that the notched wedge joint can provide slightly higher densities than the butt joint, most likely due to the confinement offered by the wedge under the roller (8). Other research points to concerns about the limited compaction of the wedge itself (9). Methods vary from hand vibratory plates, to small tow behind rollers, to commercially available paver attachments that shape and compact the wedge through vibration.

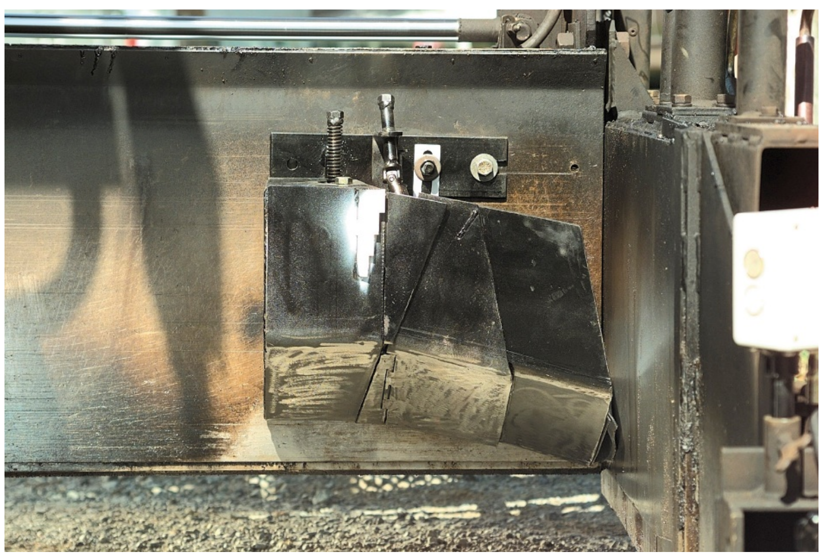

Image: Todd Mansell

Figure 5. Installed Notched Wedge Fixture.

The notched wedge joint has a safety and production advantage because contractors can continue paving without an edge drop-off. For butt joints, the maximum allowable drop-off while keeping traffic open is typically 1.5 to 2.0 inches. If the mat is thicker than this, the contractor has to back up and pave the adjacent lane by the end of the paving shift. This can be problematic, especially in situations where the optimum paving plan from a scheduling perspective (i.e., least traffic interruption) results in an unconfined mat edge. Use of notched wedge joints provides a more traversable edge for traffic, therefore eliminating the need for immediately paving a match pass.

Practices for Planning, Design and Mixture Selection for Improved Longitudinal Joints

Thinking about and planning for longitudinal joints is a key step to constructing longitudinal joints. Pre-paving meetings can include discussion of the type of joint to be used, phasing or sequence of lane placement, quality assurance measures, and role of each paving crew member has in achieving joint density. Construction sequencing can be planned so that any overlap of material at the joint does not impede the flow of water transversely across the pavement (e.g., like shingles on a roof from lower to higher elevation). When placing multiple lifts, the longitudinal joint should be offset horizontally between layers by at least 6 inches. Joints should not be placed in the wheel path since they will be exposed to far more direct traffic and deteriorate more rapidly as illustrated in Figure 6.

Image: Adam Hand

Figure 6. Accelerated Deterioration of Longitudinal Joint Placed in the Wheel Path.

The most obvious way to avoid a cold joint is to pave more than one lane at a time, either by using a paver capable of paving multiple lanes in one pass, or by paving in echelon with two or three pavers side-by-side offset slightly longitudinally as shown in Figure 7. This minimizes the number of cold joints. Since the mat is hot on both sides of the longitudinal joint when rolled (hence the name "hot joint"), the densities are closer to those in the middle of the mat. The opportunity to pave in echelon is usually limited to airfields, new construction, and rare major highway rehabilitation projects with reduced traffic congestion.

If constructing a hot joint is impractical or too expensive, there are other ways to circumvent the unsupported edge cold joint and sequent low-density area. The unsupported edge can be eliminated by milling or cutting to create a vertical confined edge (Figure 3). For mill and fill projects, the contractor can mill and pave a lane before milling the adjacent lane. Both sides of the paving mat will have a confined edge and therefore the joint density will be higher. However, there are disadvantages to this method that include delaying the milling contractor while waiting for the paving operation and thus increasing cost. It is also difficult to thoroughly clean the corners created at the milled edges before paving, especially at night. Figure 8 illustrates a milled and properly cleaned edge with tack coat.

Image: Adam Hand

Figure 7. Echelon Paving Operation.

Image: Adam Hand

Figure 8. Properly Prepared Milled Joint Face.

For the common scenario where a new lift is paved, like an overlay or a surface course on an intermediate course, the unsupported edge of the mat from the first pass is cut back or milled. This creates a clean vertical face prior to the second pass of the paver as illustrated in Figure 3. Milling or cutting also removes some (3 to 6 inches) of the asphalt at the longitudinal joint with the lowest density that occurs at the unsupported edge of the mat. Ideally, this is done after the mat has been rolled but is still warm.

Cutting back has primarily been done on airfield pavements using walk-behind wet saws, which is time and cost intensive. Furthermore, it is not possible if there is traffic in the adjacent lane. For highway paving, a joint cutting tool has been adopted that is typically mounted directly on a roller so no additional equipment is needed. The disc-shaped cutting tool is similar in principle to a pizza cutter, as shown in Figure 9. Some cutting tools have vertical faces while others have a vertical face and a face that is at a 60-degree angle from vertical. This technique can be faster, cleaner, and less expensive than sawing.

Image: Adam Hand

Figure 9. Joint Cutting Tool on Compactor.

Cutting the edge in a straight or smooth flowing line facilitates a uniform and proper overlap when the joint is closed. Depending on the compactor and cutter geometry it may not be practical if there is traffic in an adjacent lane.

With milling, sawing, or cutting it is possible to correct crooked longitudinal joints, also making them straight and thereby leading to improved joint density consistency. This is done by adequately marking the planned cut or milling edge. A marked and cut edge straightening a crooked mat edge is illustrated in Figure 10.

Image: Adam Hand

Figure 10. Crooked Unsupported Edge Cut with Cutting Tool on a Compactor.

The use of joint heaters has undergone a resurgence in the asphalt industry. Longer, more efficient infrared heaters with automation to match the speed of the paver provide uniform heat along the joint, eliminating overheating and underheating, which had been long-standing concerns. Some States have shown joint heaters can be used to improve joint density. They are more commonly used in northern States. Some contractors in Alaska have purchased joint heaters to help meet the State DOT's longitudinal joint density incentive specification, even though the heaters are not required by the State DOT.

Additional tools used to improve longitudinal joint performance are joint adhesives applied to seal the face of open unconfined joints. These materials can be emulsions, asphalt binder or hot-applied, rubberized asphalt. Some of these materials and processes are proprietary. While this practice is not very common, it appears to improve adhesion and sealing of the joint (8).

The use of the smallest nominal maximum aggregate size (NMAS) mixture that is appropriate for the application can help with obtaining joint density. Smaller NMAS mixtures are less permeable at a given in-place air void level, so they can produce a more impermeable joint. Gradations that plot on the fine side of the 0.45 power curve, rather than the course side, for any NMAS, are typically easier to compact and less permeable. Adequate lift thickness is also an important factor in achieving density, at the longitudinal joint and elsewhere. Lift thickness to NMAS ratios (t/NMAS) of at least 4 for coarse gradations and 3 for fine gradations provide for more attainable compaction and in-place density.

An important final planning consideration is to have a remedial action plan in case adequate density is not being obtained. Such a plan can include a procedure to determine the reason for low density, to make a decision about what is going to be changed to prevent it from continuing to occur, and to address the low-density joints that have already been constructed.

Practices for Longitudinal Joint Construction

There are many practices for paving. The same practices for paving apply when constructing a longitudinal joint. Several will be highlighted here that directly relate to the construction of a longitudinal joint to optimize its long-term performance. A well-constructed longitudinal joint starts with proper paver setup and operation. Highlights include:

- The screed end gates flat on the existing surface, so mixture does not exit out beneath the side of the end gate.
- A uniform feed of material to and in front of the screed at mid-auger depth for a uniform head of material.
- Auger and tunnel extensions installed when extending a screed so that a uniform, unsegregated, feed and head of material exist in front of the screed.
- Automatic grade controls or joint matching shoes properly setup and operating.
- Straight edge on the first lane constructed and proper mixture overlap during construction of subsequent, adjoining passes.
- A balanced paving operation to minimize stops and starts.

Practices for joint construction will vary depending on whether the joint being constructed is on the cold or hot side.

Cold Side: During Laydown and Compaction.

It is important to operate the paver in a straight line so the joint can be uniformly matched with the next pass of the paver. A straight first pass allows the paver operator to make a consistent and uniform pass that will be easier to match on the second pass. The use of a linear reference, like a string line or string line marked with paint, to guide the paver to ensure a straight first pass is helpful. A steering guide can then be installed on the paver that the operator uses to drive the paver in the correct position as illustrated in Figure 11. Note the paver operator's chair is swung so the operator can clearly see the paint marking and focus on the target.

When rolling the unsupported edge, there are two prevailing methods used to achieve density. The first method, and the one most commonly used, is that the first pass of the vibratory roller drum be extended over the edge of the mat by at least 6 inches. This practice will ensure that the compactive effort of the roller is applied in a vertical direction on the unconfined edge and will greatly reduce any tendency for the asphalt mixture to shove sideways during the compaction operation.

Image: Adam Hand

Figure 11. Pavement Marking and Target for Operator Mounted to Paver.

Alternatively, the contractor can make the first pass of the vibratory roller back 6 inches from the unsupported edge, and then extend the drum over the unsupported edge on the second pass. This option may limit the lateral movement of the mat under the roller. However, there are concerns that longitudinal stress cracks can develop at the edge of the roller drum from the first pass. This can result in a longitudinal tear parallel to edge of the longitudinal joint. The same can occur regardless of whether the mat edge is supported or unsupported.

When pneumatic rollers are used, the edge of the outside tire near the joint should not be placed either on top of or over the mat edge. The outside edge of the tire should be held back from the unconfined mat edge about 6 inches. This will prevent rounding of the edge of the mat, prevent the mat from shoving laterally as a result of the high pressure in the pneumatic tires, and prevent excessive pickup when the rubber tires pass over the edge and pick up any tack coat. The contractor should monitor the density of the unsupported edge with a density gauge during construction as part of the quality control (QC) process.

Hot Side: During Laydown and Compaction. Prior to paving the hot side, the existing face of the joint should receive an application of the same material being used as tack coat for the mat (e.g., emulsion or asphalt cement). Alternatively, a proprietary joint adhesive material could be used.

Having a sufficient amount of material (adequate height of material) on the hot side of the joint is critical to achieving density. Mat rolldown, which is typically about ¼ inch per 1 inch of mat thickness for dense-graded mixtures, should be considered when selecting the amount of material. If insufficient mixture is provided at the joint (a "starved joint") the roller will bridge the material at the joint. When insufficient material is provided, the roller bridges onto the cold side of the joint and no further densification will occur on the hot side, resulting in low density as shown in Figure 12. After compaction, the hot side should be slightly higher than the cold side (about 0.1 inches) to ensure no bridging of the roller from starving material occurred.

Image: University of Nevada Reno

Figure 12. Bridging by Pinching with Drum on Cold Mat on the First Roller Pass.

There should be a sufficient overlap of material from the hot side to the cold side of the joint. An overlap of ±0.5 inches, depending on the type of mixture being used, is normally sufficient. This amount of overlap provides just enough material on top of the joint to allow for proper compaction without having extra material, which can lead to crushed aggregate and bridging of the rollers. It is also important to avoid luting overlap material (i.e., raking) as it could create a situation that starves the joint. If the correct amount of material is in the right place, there should be minimal, if any, luting needed. At most a very light bump with a lute to get the excess material over the joint may be useful.

When luting is done, it is generally not performed consistently and should not be broadcast across the new lane. This practice leads to both low joint density and segregated mat surface as illustrated in Figure 13. Luting may, of course, be involved with joint construction when there are cross streets, turnouts, matching drainage inlets, etc., being paved. Figure 14 illustrates proper butt joint construction using the paint marking and steering guide method shown in Figure 11 that does not involve bumping with a lute.

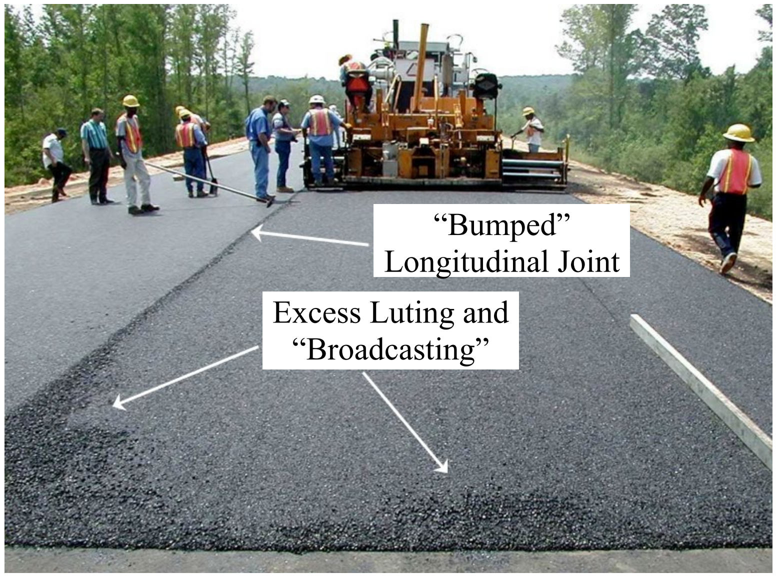

Image: Adam Hand

Figure 13. Excess and Inconsistent Luting and Broadcasting at Joints.

Image: Adam Hand

Figure 14. Paint Marking and Steering Guide Method Butt Joint without Luting or Bumping.

Using this method, the confined edge of the joint is compacted with the first pass of the vibratory roller drum on the hot mat, staying back from the joint 6 to 8 inches on the first pass. The second pass should then overlap onto the cold mat 4 to 6 inches. With this method, it is important to 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. An important concern with this method is that if an insufficient depth of HMA is placed (starving the joint), the roller will bridge over and not compact the hot materials completely.

Use of pneumatic rollers for intermediate rolling (not finish rolling) of the hot side of the joint to knead the loose material into the joint can be effective. The edge of the front outside tire should rest on the inside edge of the joint, and the back outside tire can then straddle over basically centered on the joint. Pneumatic rollers should not be operated close to an unsupported joint edge because excessive lateral movement may occur.

The contractor should monitor the density of the supported edge with a density gauge during construction as part of the QC process.

Practices for Specifying and Testing Joint Density

A variety of approaches have been used by DOTs to improve longitudinal joint quality. Each DOT and project represent a unique set of circumstances. While there is not a single approach perfectly suited for every DOT or application, the following information related to non-Federal, State-specific specifications are provided as information for DOTs considering implementing or changing specifications to improve longitudinal joint performance.

The first decision an agency could make is related to the use of a density (i.e., end-result) specification versus the use of a specific material (i.e., means and method) specification. Discussion on both types follows.

Density Specification

For development of State DOT density specifications, QC may include construction of a test strip used to identify the optimal placement and compaction techniques for the longitudinal joints. Under this process, the test strip construction would occur using the same materials, equipment, structure, and importantly production rate that is planned for actual construction. The mat and joint roller patterns can be determined by monitoring of the densities with a density gauge. Joint density measurements would be made on both sides of longitudinal joints. Multiple cores can be taken from the test section to correlate density gauges.

Past research and current experience indicate that acceptable joint density is typically about 2 percent lower than the mat density specified by State DOTs (10, 11, 12, 13). For example, if 100 percent pay were provided at a mat density of 93 percent of G_{mm}, then 100 percent pay could be provided for joint density of 91 percent of G_{mm}. The specific criteria will depend on the individual State's quality measure. Incentives and disincentives could be applied for higher or lower densities. If the density at a joint is low enough (e.g., <90 percent of G_{mm}) a State DOT may require corrective action. This could be done by over banding with an emulsion or PG binder at a width of 4 ± 1 inches centered on the visible joint. An addition of sand blotter can be made to the seal after the over banding is applied. There are some techniques used to repair low density joints such as milling and filling, but they result in two longitudinal joints, rather than one, and the two joints are closer to the wheel paths. An example of such a repair is shown in Figure 15 illustrating the potential pitfalls of such a treatment.

The use of cores for density acceptance testing, rather than gauges, is preferred for both mat and joint density (14). Some DOTs use density gauges to eliminate patching of core holes. If used, density gauges should be correlated to cores. Density gauge readings should be taken on each side of the joint and parallel to the joint while offset about 2 inches from the visible joint.

When using cores, 6-inch diameter cores are preferred over 4-inch diameter cores to get a more representative sample (14). Core location can have a significant impact on measured density results, especially for longitudinal joints. Cores taken on the cold side of a joint typically have lower densities when compared to those from the hot side. Core densities will typically increase as the distance from the joint increases. There is not clear consensus on the location that cores should be taken, although many agencies locate the cores where half the material represented comes from each mat. This allows for the G_{mm} to be based on the average of the two sides (i.e., the cold and hot sides). Cores from butt joints would be centered over the visible joint while cores from notched wedge joints would be centered over the wedge. The center of the core would be half-way between the visible joint and the end of the wedge.

Several DOTs have been evaluating non-destructive mat and joint density profiling systems (DPS) that can estimate continuous or entire mat or joint density (15, 16). The technologies are correlated to cores, like nuclear density gauges. However, the advantage of these techniques is the continuous measurements as opposed to randomly obtaining a limited number of density measures.

Image: Adam Hand

Figure 15. Longitudinal Joint Repair Illustrating Disadvantages of Use.

Materials Method Specifications

Illinois DOT uses a materials and method specification that has been shown to be very effective. A longitudinal joint sealant (LJS) is placed 18 inches wide on the centerline of where a joint is to be placed. The goal of this approach is to fill air voids and seal the joint from the bottom up. The material used is a performance graded (PG) binder PG 88-28. The placement thickness varies based on planned overlay thickness, but it is commonly about 3/16 of an inch. Vehicles can cross the material after about 30 minutes without tracking. After the asphalt mat is placed, the LJS migrates up through the mat about 75 percent of the overlay thickness. If an emulsion tack is applied before a LJS, the tack needs to be fully cured.

The LJS can be applied with a pushcart, drag box, roll-out tape or heavy-duty pressure distributor. When applied with a heavy-duty pressure distributor, the spray bar can either be horizontal or vertical to the direction of travel. Density as a percent of G_{mm} is not measured. The presence of the LJS changes the G_{mm}. This requirement was fully implemented for the 2018 construction season by Illinois DOT and it estimates the cost is about $2 per linear foot.

Implementation Considerations

Implementation of a joint specification, whether it is a density (i.e., end-result) specification or material and method specification (e.g., longitudinal joint sealant), could be done in a series of steps with a DOT and industry working together. Some steps that maybe considered include:

- Offering training on longitudinal joint construction and factors affecting performance.
- Establishing a baseline of existing joint densities by gathering data from projects or randomly selecting projects.
- Consideration of the items in the "Planning, Design and Materials Selection" section.
- Developing the initial specification with industry input and provide training on it prior to initial implementation.
- Implementing joint specification changes in phases.
- Starting with pilot or shadow projects prior to full implementation. The specification can have a slightly lower initial minimum density and then plan to increase the minimum with time so contractors can see what the impact of the new specification will be.
- Continuing to monitor performance and making appropriate adjustments to the specification over time. Evolution of the specification may be necessary over time.

Summary

Longitudinal joint performance is essential for long-term pavement performance. Practices have been identified to improve chances of achieving desired joint density levels and optimized joint performance. While these field practices may be useful, they are not always followed even though they generally may not involve an extensive amount of additional expense or elaborate equipment. Improved performance of longitudinal joints can be obtained based on the information presented in the sections titled:

- Practices for Planning, Design and Mixture Selection for Improved Joint Performance.
- Positive Practices for Longitudinal Joint Construction.
- Practices for Specifying and Testing Joint Density.
- Implementation Considerations.

Longitudinal joint performance is a high-priority item for the FHWA, many DOTs, contractors, equipment manufacturers, and material suppliers. Ultimately, the goal is to approach the same level of compaction in the longitudinal joint as is obtained for mat density. The information presented in this technical brief can be used by DOTs working in partnership with industry to make progress on this goal.

This fourth Technical Brief in the series of four planned on ***Enhancing Durability of Asphalt Pavements Through Increased In-Place Density*** presented an effort as part of a larger project to improve in-place density achievable for asphalt pavements across the country. The other three Technical Briefs describe the density demonstration projects and related specifications, techniques and tools for achieving density, and overcoming obstacles to achieving density.

References

1. Federal Highway Administration, *Accelerated Implementation and Deployment of Pavement Technologies Annual Report*, Report HIF-16-031, 2016.
2. Aschenbrener, T., E.R. Brown, N. Tran, and P. Blankenship. *Demonstration Project for Enhanced Durability of Asphalt Pavements through Increased In-place Pavement Density*. NCAT Report 17-05, National Center for Asphalt Technology, Auburn, AL, 2017.

3. Aschenbrener, T., F. Leiva, and N. Tran. *FHWA Demonstration Project for Enhanced Durability of Asphalt Pavements through Increased In-place Pavement Density, Phase 2*. FHWA-HIF-19-052, Federal Highway Administration, Washington, D.C., 2019.
4. Aschenbrener, T., F. Leiva, N. Tran, and A. Hand. *FHWA Demonstration Project for Enhanced Durability of Asphalt Pavements through Increased In-place Pavement Density, Phase 3*. FHWA-HIF-20-003, Federal Highway Administration, Washington, D.C. 2020.
5. Buncher, M.S. and C. Rosenberg, *Best Practices for Constructing and Specifying HMA Longitudinal Joints, A Co-operative Effort between the Asphalt Institute and the Federal Highway Administration*, Final Report, Asphalt Institute, Lexington, KY, 2012.
6. Brown, E.R., Kandhal, P.S., Roberts, F.L., Kim, Y.R., Lee, D., and Kennedy, T.W, *Hot Mix Asphalt Materials, Mixture Design and Construction*, Third Edition, Second Printing, NAPA Research and Education Foundation, Lanham, MD., 2016.
7. Tran, N., P. Turner, and J. Shambley. *NCAT Report 16-02R: Enhanced Compaction to Improve Durability and Extend Pavement Service Life: A Literature Review.* National Center for Asphalt Technology, Auburn, AL, 2016.
8. McDaniel, R. S., A. Shah, and J. Olek. *Longitudinal Joint Specifications and Performance*. Publication FHWA/IN/JTRP-2012/29. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2012.
9. *Improvement of Widening Joint Design and Construction Practices for Flexible Pavements*, Florida DOT Project #BDX93, Final Report, Florida Department of Transportation, Tallahassee, FL., 2015
10. Kandhal, P.S., T.L. Ramirez, P.M. Ingram, *Evaluation of Eight Longitudinal Joint Construction Techniques for Asphalt Pavements in Pennsylvania*, NCAT Report 02-03. 2002.
11. Sebaaly, P.E., and J.C. Barrantes, *Development of a Joint Density Specification Phase I: Literature Review and Test Plan*, NDOT Research Report No. RDT04-043, 2004.
12. Estakhri, C.K., *Support for the Implementation of a Longitudinal Joint Density Specification for Hot-Mix Asphalt Concrete*, Texas Transportation Institute, Project 5-1757, January 2006.
13. Mallick, R.B., P.S. Kandhal, R. Ahlrich, and S. Parker, *Improved Performance of Longitudinal Joints on Asphalt Airfields*, AAPTP Project 04-05, December 2007.
14. Aschenbrener, T. and N. Tran, *Optimizing In-Place Density Through Improved Density Specifications*, Transportation Research Record, Vol. 2674, Issue 3, 10.1177/0361198120908224, 2020.
15. Wilson, B., S. Sebesta, and T. Scullion, *Evaluation of the Rolling Density Meter for Rapid Continuous Measurement of Asphalt Mixture Density,* FHWA/TX/-17/0-6889-R1, Texas A&M University, College Station, TX, 2019.
16. Hoegh, K., T. Steiner, E.Z. Teshale, and S. Dai, *Minnesota Department of Transportation Case Studies for Coreless Asphalt Pavement Compaction Assessment,* Transportation Research Record, Vol. 2674, Issue 2, 10.1177/0361198120907582, 2020.

Improving Longitudinal Joint Performance

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