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Effect of Longitudinal Joint Construction and Density on Asphalt Pavement Performance –
Phase I – State of the Practice

2. Author(s)

Moses Akentuna, Ph.D., P.E.
Saman Salari, P.E.

3. Performing Organization Name and Address

Louisiana Transportation Research Center
4101 Gourrier Avenue
Baton Rouge, LA 70808

4. Sponsoring Agency Name and Address

Louisiana Department of Transportation and Development
P.O. Box 94245
Baton Rouge, LA 70804-9245

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13. Abstract

The construction of longitudinal joints to specified densities significantly impacts the performance and service life of asphalt pavements. Ensuring proper compaction is essential to creating impermeable joints that can withstand water infiltration, prevent moisture damage, and enhance long-term performance. Various entities, including state departments of transportation, industry organizations, and research institutions, have conducted extensive studies and developed guidelines to enhance the performance of longitudinal joints. The objective of this study was to comprehensively review existing literature on the current best practices for longitudinal joint construction.

To achieve the aim of the study, the research team gathered and critically reviewed available literature regarding the best practices for longitudinal joint construction and the utilization of different techniques and materials to improve longitudinal joint density. In addition, the research team evaluated the payment schedules for longitudinal joint density construction used by different states in

the US by reviewing standard specification documents employed by these states. The research team identified eight commonly used joint construction techniques for enhancing longitudinal joint density in asphalt pavements. These techniques included adopting the echelon or tandem paving techniques; modifying the rolling pattern; specifying various joint types (e.g., butt, tapered, or notched wedge) based on field conditions; using edge restraining or pre-compaction devices; employing infrared joint heaters; using cutting wheels; applying joint adhesives; and using joint sealers. The aforementioned techniques, except for the technique for modifying the rolling pattern, may require additional equipment or materials, potentially increasing construction costs. Twenty-three states were found to specify minimum densities for longitudinal joints. The minimum longitudinal joint density requirements for these states ranged from 88 to 93% of the theoretical maximum specific gravity (G_{mm}). Sixteen out of the 23 states that have minimum longitudinal joint density requirements have instituted payment schedules that offer incentives or disincentives for achieving higher or lower joint densities, respectively. Despite advancements in longitudinal joint construction specifications, challenges remain in consistently achieving high-quality longitudinal joints. Further study is necessary to explore the feasibility of establishing a minimum longitudinal joint density requirement for the state of Louisiana.

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DOTD Chief Engineer

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By
Moses Akentuna, Ph.D., P.E.
Saman Salari, P.E.

Louisiana Transportation Research Center
4101 Gourrier Avenue
Baton Rouge, LA 70808

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Louisiana Transportation Research Center

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October 2023

Abstract

The construction of longitudinal joints to specified densities significantly impacts the performance and service life of asphalt pavements. Ensuring proper compaction is essential to creating impermeable joints that can withstand water infiltration, prevent moisture damage, and enhance long-term performance. Various entities, including state departments of transportation, industry organizations, and research institutions, have conducted extensive studies and developed guidelines to enhance the performance of longitudinal joints. The objective of this study was to comprehensively review existing literature on the current best practices for longitudinal joint construction.

To achieve the aim of the study, the research team gathered and critically reviewed available literature regarding the best practices for longitudinal joint construction and the utilization of different techniques and materials to improve longitudinal joint density. In addition, the research team evaluated the payment schedules for longitudinal joint density construction used by different states in the US by reviewing standard specification documents employed by these states. The research team identified eight commonly used joint construction techniques for enhancing longitudinal joint density in asphalt pavements. These techniques included adopting the echelon or tandem paving techniques; modifying the rolling pattern; specifying various joint types (e.g., butt, tapered, or notched wedge) based on field conditions; using edge restraining or pre-compaction devices; employing infrared joint heaters; using cutting wheels; applying joint adhesives; and using joint sealers. The aforementioned techniques, except for the technique for modifying the rolling pattern, may require additional equipment or materials, potentially increasing construction costs. Twenty-three states were found to specify minimum densities for longitudinal joints. The minimum longitudinal joint density requirements for these states ranged from 88 to 93% of the theoretical maximum specific gravity (G_{mm}). Sixteen out of the 23 states that have minimum longitudinal joint density requirements have instituted payment schedules that offer incentives or disincentives for achieving higher or lower joint densities, respectively. Despite advancements in longitudinal joint construction specifications, challenges remain in consistently achieving high-quality longitudinal joints. Further study is necessary to explore the feasibility of establishing a minimum longitudinal joint density requirement for the state of Louisiana..

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Implementation Statement

The findings of this research will serve as a guide for the conduct of additional studies to modify Section 502 of the Louisiana DOTD Standard Specifications and include a minimum longitudinal joint specification with pay adjustment schedules. Furthermore, the findings of this study will lead to improved practices for longitudinal joint construction and extended pavement service life in Louisiana.

Table of Contents

Technical Report Standard Page 1
    Project Review Committee 3
    LTRC Administrator/Manager 3
    Members 3
    Directorate Implementation Sponsor 3
Effect of Longitudinal Joint Construction and Density on Asphalt Pavement Performance – Phase I – State of the Practice 4
    Abstract 5
    Acknowledgments 6
    Implementation Statement 7
    Table of Contents 8
    List of Tables 9
    List of Figures 10
    Introduction 11
        Problem Statement 11
    Objective and Scope of Study 14
    Literature Review 15
        Techniques for Joint Density Construction 15
        Current State of Practice for Minimum Density Specification 23
    Summary and Conclusions 34
    Recommendation 36
    Acronyms, Abbreviations, and Symbols 37
    References 38

List of Tables

Table 1 Connecticut DOT Pay Adjustment Values for Pavement Joint Density [31]....... 26
Table 2. Unconfined Edge Density Deduction Table for Illinois DOT [7]....................... 27
Table 3. Longitudinal Joint Density Pay Values for Kentucky [8] 27
Table 4. Joint Density Test Lot Pay Factor for Nebraska DOT [12]................................ 29
Table 5. New York DOT's Quality Adjustment for Longitudinal Joint Density [27]....... 30
Table 6. Lot by Lot Payment Schedule for Longitudinal Joints [13]................................ 30
Table 7. Joint Density Pay Adjustments for Rhode Island DOT [37]............................... 31
Table 8. Incentive/Disincentive for Longitudinal Joint Density [14] 32

List of Figures

Figure 1. Longitudinal joint (a) construction and (b) deterioration [3] 13
Figure 2. (a) Rolling from hot side with 6-in. overlap on cold mat (b) rolling from cold side with 6-in. overlap on hot mat, and (c) rolling from hot side 6-in. away from joint [21]. 16
Figure 3. (a) Wedge-notched and (b) butt joint schematic for Connecticut DOT 18
Figure 4. Tapered wedge joint schematic for New York DOT 18
Figure 5. Notched wedge joint schematic for Massachusetts DOT.................................. 18
Figure 6. Edge restraining device [33].. 19
Figure 7. (a) Tractor-towed preheater and (b) paver-mounted heater (30) 20
Figure 8. (a) Joint cutting and (b) removal procedure [33]... 21
Figure 9. Joint adhesive application [36]... 22
Figure 10. (a) Overband and (b) Jband application [1, 39]... 23
Figure 11. Minimum longitudinal joint specifications for different states in the US 24
Figure 12. Notched wedge joint coring procedure for Connecticut DOT [31]................. 26
Figure 13. 6-in. diameter coring at (a) tapered wedge joint and (b) butt joint locations .. 29

Introduction

Problem Statement

The performance and durability of asphalt pavements are influenced by various factors, including the quality of construction techniques used during the installation process. One critical aspect that significantly impacts the performance of asphalt pavements is the construction of longitudinal joints and the achievement of specified density levels at the joints. Longitudinal joints are formed when two adjacent asphalt lanes are constructed during the paving operation. These joints are created in situations where the width of the pavement exceeds the paving width of the equipment. Longitudinal joints are critical to the performance of asphalt pavements as they provide continuity to the laid asphalt mat. However, longitudinal joints generally have lower density than the rest of the pavement because of the formation of an unconfined edge during placement of the cold asphalt mat and the temperature difference between the freshly paved asphalt lane (hot mat) and the previously paved asphalt lane (cold mat); see Figure 1. Higher air voids observed in longitudinal joints result in weaker pavement at the joints and facilitate water infiltration into the pavement [1, 2, 3].

The Federal Highway Administration (FHWA) has identified in-place density as a significant factor influencing the long-term durability of longitudinal joints. According to the existing literature, low density and water infiltration into a longitudinal joint can reduce its service life by 36% [4]. To address the problems caused by lower longitudinal joint density, some state agencies in the US have incorporated density specifications for longitudinal joints. These specifications aim to guide the contractor's compaction process while emphasizing the importance of measured density for acceptance. Notably, Alaska, Colorado, Illinois, Kentucky, Minnesota, Missouri, Montana, Nebraska, Pennsylvania, Utah, Vermont, West Virginia, and other DOTs have established specific longitudinal joint density specifications accompanied by payment schedules that offer incentives for achieving enhanced density and impose penalties for lower density levels [5, 6, 7, 8, 9, 10, 11, 12, 13, 14]. The quality of longitudinal joints constructed primarily depends on two key factors: joint construction techniques and achieved density [15, 16]. Joint construction techniques involve the methods employed to create a seamless and strong connection between the adjacent asphalt mats. Common techniques include edge milling, tack coat application, and hot asphalt placement. Proper execution of these techniques ensures the joint has adequate bond strength, preventing the deterioration of the joint and areas in proximity to the joint.

Current Louisiana DOTD specifications for longitudinal joint construction include recommended hot mat overlap width and height, maximum deviation in grade at joints, and minimum joint offset for multiple layer construction. Furthermore, Louisiana DOTD recommends that top-layer joints be kept 6 to 9 in. from the centerline of two-lane highways [17]. To assess the effects of different construction techniques on longitudinal density performance, researchers at LTRC conducted a study to evaluate the effects of different tack coat materials on longitudinal density. Based on the findings of the study, the researchers reported that longitudinal joints constructed with a trackless polymer-modified tack coat exhibited relatively higher densities than those constructed with un-modified emulsions. In addition, the researchers evaluated the effects of cold joint tamping on density and reported that when the joints were untamped, there was no statistical difference between the densities of joints constructed with SS-1 and trackless tack coat materials. However, minor statistical differences in densities were observed between joints constructed with SS-1 and trackless tack coat materials when the cold joints were tamped [18].

The state of the practice for longitudinal joint construction and density is evolving. To optimize the performance of asphalt pavements, it is essential to understand the state of the practice regarding longitudinal joint construction and density. State transportation agencies, industry organizations, and research institutions have been actively involved in studying and improving these aspects of pavement construction to enhance the durability of asphalt pavements. As more research is conducted, new techniques and materials are being developed that can improve the performance of longitudinal joints. These new techniques and materials have the potential to extend the service life of asphalt pavements and reduce the cost of maintenance.

Figure 1. Longitudinal joint (a) construction and (b) deterioration [3]

(a) (b)

Objective and Scope of Study

The objective of this study was to conduct a literature review regarding the current best practices for longitudinal joint construction.

To achieve the aim of this study, the research team collected and critically reviewed literature regarding best practices for longitudinal joint construction and the use of various techniques and materials for improving longitudinal joint density. The research team also assessed the payment schedules for longitudinal joint density used by different states in the US. The literature search for this study included, but was not limited to, standard sources such as the Transportation Research Information Database (TRID), the Computerized Engineering Index (COMPENDEX), the National Technical Information Services (NTIS), and standard specifications documents for different states.

Literature Review

Techniques for Joint Density Construction

A detailed literature review was conducted as a part of this study to synthesize techniques used by various road agencies to construct longitudinal joints in asphalt pavements for improved density. Based on the literature review, eight techniques were identified to be frequently used by road agencies for longitudinal joint construction, which included [19, 20]:

- adopting the echelon or tandem paving technique;
- modifying the rolling pattern;
- specifying different joint types (i.e., butt, tapered, or notched wedge) for different field conditions;
- using edge restraining or pre-compaction devices;
- using infrared joint heaters;
- using cutting wheels;
- using joint adhesives; and
- using joint sealers.

A brief description of each technique is shown in the following sections:

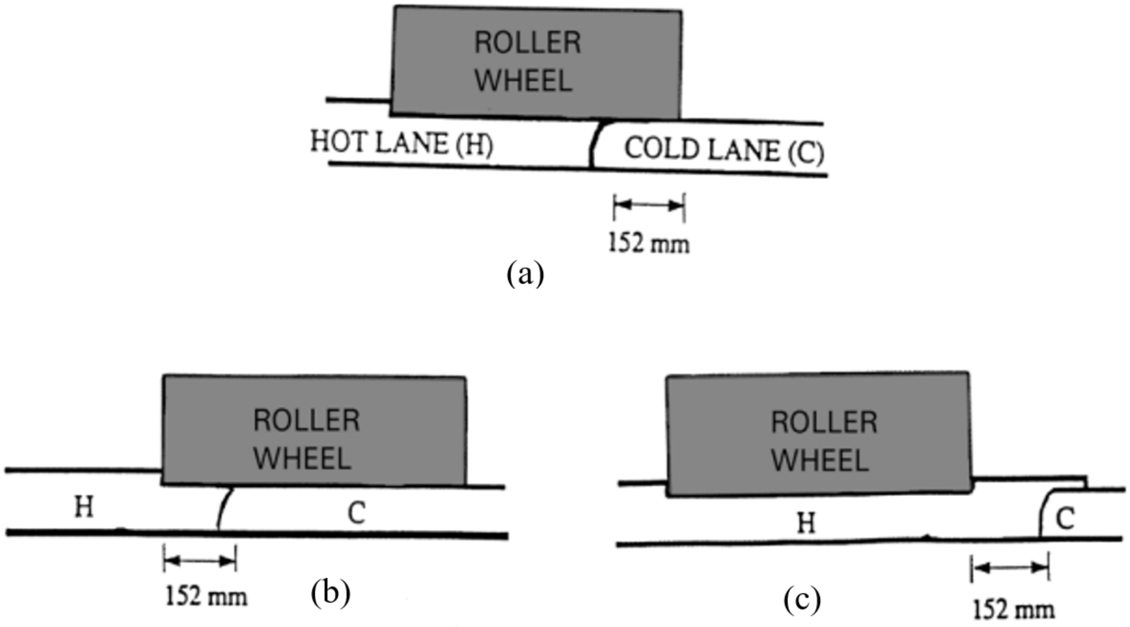
Adopting Echelon or Tandem Paving Technique

The echelon paving technique involves the concurrent construction of adjacent hot mats, ensuring better compaction and reducing the likelihood of joint failure. In this technique, two or more pavers are operated simultaneously, one behind the other. This technique can help to improve longitudinal joint density by ensuring that a newly placed asphalt mat does not cool before the contiguous lane is paved. Tandem paving is a variation of echelon paving where two pavers are spaced farther apart, allowing for limited traffic usage of the road. Although echelon or tandem paving is an effective technique for eliminating longitudinal joints or enhancing joint density, it is rarely used because it requires more equipment and labor, is difficult to coordinate, and can be disruptive to traffic [19, 20].

Modifying the Rolling Pattern

The rolling pattern can be modified to improve longitudinal joint density. For example, the roller can be placed closer to the joint on the first pass from the hot side and then rolled from the hot side on subsequent passes with varying overlap width into the cold mat. In addition, longitudinal joints can be rolled from the cold mat in the first pass, with varying overlap widths, into the hot mat. Figure 2 shows different joint rolling patterns used by contractors and owner agencies [21].

Figure 2. (a) Rolling from hot side with 6-in. overlap on cold mat (b) rolling from cold side with 6-in. overlap on hot mat, and (c) rolling from hot side 6-in. away from joint [21].



Although selecting the most effective rolling pattern to achieve higher densities at the joints remains a subject of considerable debate among researchers, most state agencies favor one technique (joint pinching) over the others. States such as Arkansas, Illinois, Maryland, Nebraska, Pennsylvania, and many others recommend that the first roller pass at a longitudinal joint be made entirely on the hot mat with the compression wheel more than or equal to 6 in. (150 mm) from the joint; see Figure 2c. These states further recommend that the second pass be made by overlapping the longitudinal joint no more than 12 in. (300 mm) on the cold mat [7, 12, 13, 19, 22, 23]. This technique, known as "joint pinching," has been shown by other researchers to result in a ridge of asphalt mat on the hot mat that may not be fully compacted after subsequent roller passes, especially in cases where there is excessive joint luting or raking, which is attributed to improper joint overlap construction [2, 24]. States such as Louisiana, Maryland, New Hampshire, New Jersey, New York, and Ohio require overlap widths ranging from 0.5 to 2 in. to minimize luting or raking [17, 23, 25, 26, 27, 28]. Other researchers have shown in field studies that the joint pinching technique utilized in both notched and butt joints is effective for increasing joint density as compared to the other approaches shown in Figures 2a and 2b [29, 30]. According to guidelines provided by the state of New York, contractors are required to perform the initial pass of a roller in the direction towards the paver, operating on the hot mat. During this pass, contractors are advised to ensure that the roller drum overlaps 6 to 8 in. onto the cold mat; see Figure 2a. The second pass should be made to the joint, with the roller moving away from the paver along the same path as before. Subsequent roller passes are made on the hot mat [27]. Kandhal and Rao demonstrated in a previous study that the technique used by the state of New York is effective in producing higher joint densities than other joint rolling techniques [21]. For unconfined edges, most states require that compaction equipment extend 6 in. beyond the edge of the mat [19].

Specifying Different Joint Type

Road agencies in the US specify different joint types for different field conditions. For example, Connecticut DOT specifies that contractors use notched wedge joints when constructing longitudinal joints with lift thicknesses between 1.5 and 3 in., except for base course mixtures (i.e., S1 mixtures). Further, the agency requires butt joints to be used for lifts less than 1.5 in. or greater than 3 in. and for base course mixtures [31]. In addition, the New York DOT recommends tapered wedge joints for 12.5 and 9.5 pavement courses with thicknesses less than or equal to 2.5 in. and the butt joint for any other pavement courses [27]. The Nebraska DOT gives contractors the option of constructing a wedge-notched joint or a butt joint when constructing multiple adjacent asphalt mats. In contrast, Massachusetts DOT recommends that contractors use a longitudinal wedge joint when installing hot mix asphalt (HMA) pavement layers with thicknesses ranging from 1.25 to 3.75 in. [12, 32]. Figures 3 to 5 show different configurations of wedge-notched and but joints used by selected road agencies [27, 31, 32]. The type of joint selected can affect the density of the joint, so it is important for an agency to choose the right type for the specific field conditions [29].

Figure 3. (a) Wedge-notched and (b) butt joint schematic for Connecticut DOT

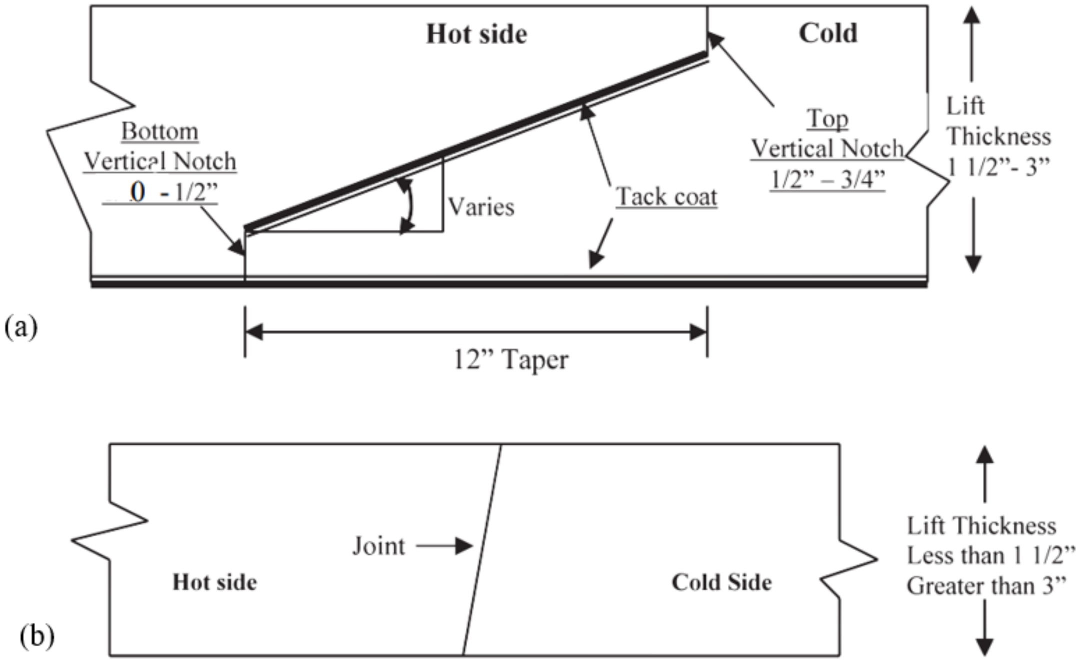


Figure 4. Tapered wedge joint schematic for New York DOT

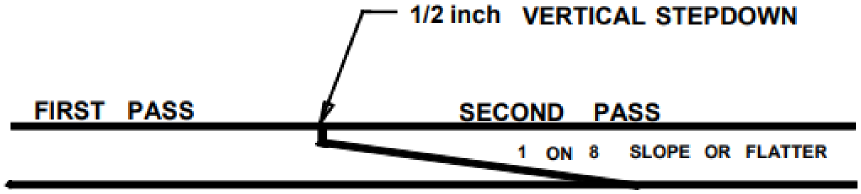
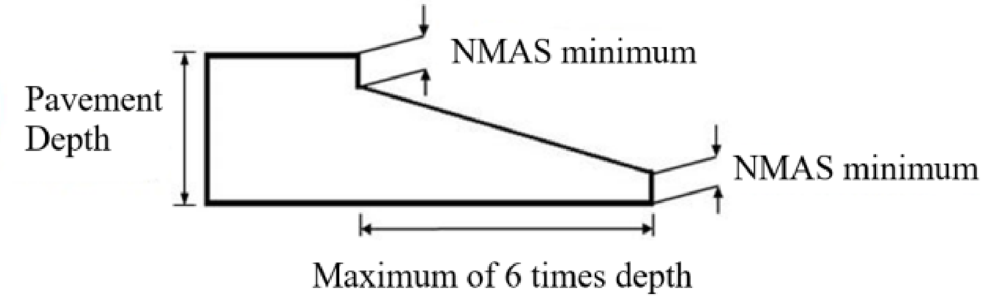


Figure 5. Notched wedge joint schematic for Massachusetts DOT



Using Edge Restraining or Pre-Compaction Devices

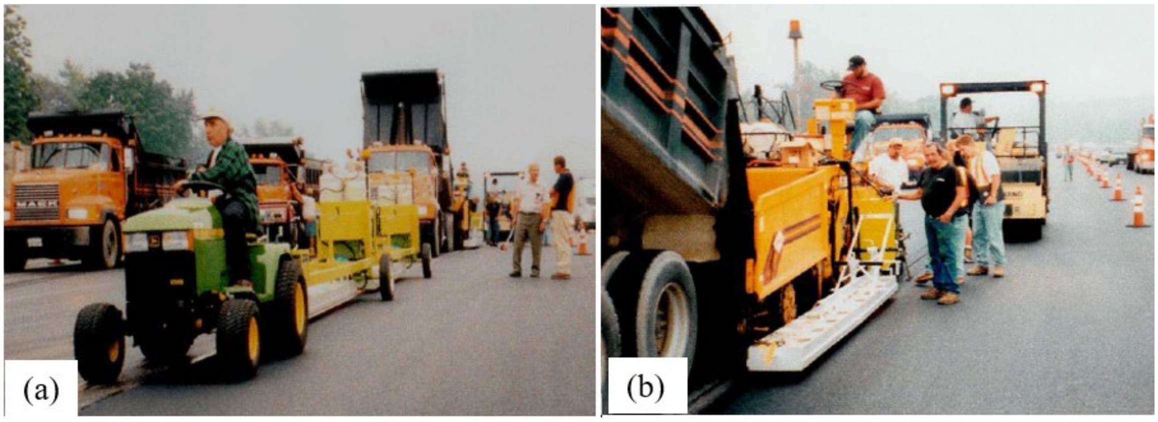
Edge restraining devices help to prevent the hot asphalt from spreading out at the edges of the lane; whereas, pre-compaction devices help to compact the edge of the asphalt mat before roller compaction. To improve the density of the unconfined edges when laying the cold mat, Massachusetts DOT mandates the utilization of appropriate machinery to contain the longitudinal edge of the HMA mixture, ensuring that a nearly vertical edge is formed. Additionally, the agency advises that when the contractor's placement activities cannot establish a confined and near vertical edge, the longitudinal edge of the surface course be saw cut completely and eliminated, creating a clean vertical surface before the adjoining course of HMA is placed [32]. The Missouri DOT requires the use of edging plates at both ends of the finishing machine to improve longitudinal joint density [10]. Figure 6 shows a typical edge-restraining device fixed to a roller, which is commonly used in Europe [33]. The Illinois DOT specifies the use of a strike-off device for the formation of a wedge joint prior to compaction [7]. A major drawback of using edge restraining or pre-compacting devices is that it may require additional equipment and skilled labor, which may affect the cost of construction [19].

Figure 6. Edge restraining device [33]

Using Infrared Joint Heaters

Infrared joint heaters can be used to improve longitudinal joint density and make the joints more durable. Infrared heaters heat the asphalt at the joint, which enhances workability and makes it easier to compact. The infrared heaters consist of two or three preheaters, towed by a small tractor ahead of the paver, and one paver-mounted heater. The pre-heaters and paver-mounted heater are placed approximately 2 to 3 in. from the pavement surface and across the edge of the joint to achieve a target temperature of 340˚F at the joint of the cold mat before placement of the hot mat. Figure 7 shows an image of a tractor-towed preheater and a paver-mounted heater [33]. Alaska DOT recommends the use of infrared heaters to achieve specified joint densities [5]. Using infrared heaters requires extra equipment, which may lengthen the safety train and pose safety hazards for the construction crew and users of the road [19].

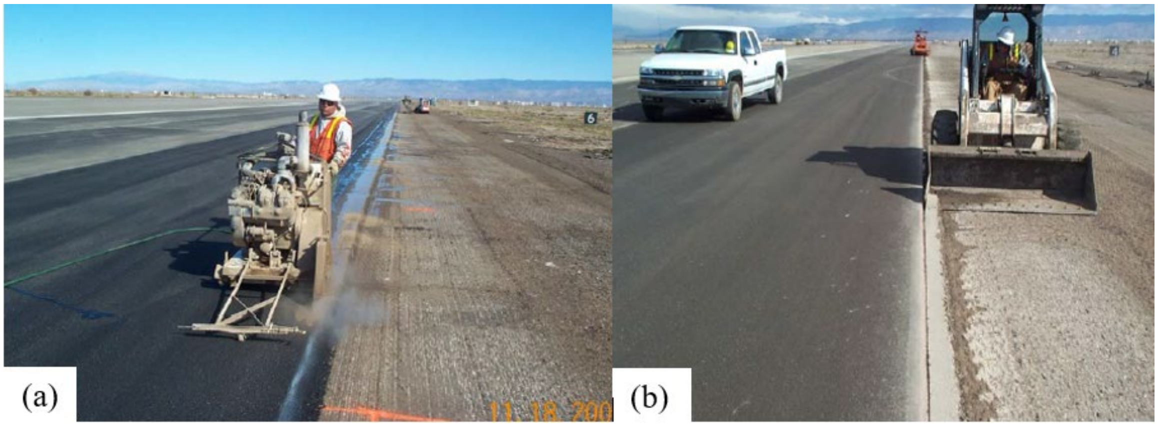
Figure 7. (a) Tractor-towed preheater and (b) paver-mounted heater (30)



Using Cutting Wheels

Cutting wheels can be used to cut the asphalt at the edge of a cold mat where a joint is to be formed. This can help to remove any loose material and create a clean, smooth, and vertical surface, which enhances the compaction of the adjoining hot mat. Figure 8 shows a typical joint cutting and removal procedure [33]. Agencies such as the District of Columbia, Hawaii, Massachusetts, and Vermont DOTs require the cutting of longitudinal joint edges to achieve a near vertical edge before placing the adjacent hot mat [15, 32, 34, 35]. Using cutting wheels for joint density enhancement may be expensive since it requires extra equipment, labor, and disposal of a cut portion of a newly laid mat [19].

Figure 8. (a) Joint cutting and (b) removal procedure [33]



Using Joint Adhesives

Joint adhesives are applied to the edge of the cold mat where the joint will be formed before the placement of the hot mat. The joint adhesive enhances the bond between the hot and cold mats, thereby reducing the permeability of the joint. A reduction in permeability at the joint improves the durability of the joint [19]. Figure 9 shows the application of joint adhesive at the edge of a cold mat [36]. Connecticut, Illinois, Massachusetts, Nebraska, Rhode Island, Utah, Virginia, West Virginia, and other DOTs require the application of joint adhesives for both butt and or notched wedge joint construction to improve performance. Materials typically used as joint adhesives by these agencies include rubberized joint sealants, styrene-butadiene diblock or triblock copolymer or styrene-butadiene rubber-modified asphalt, cationic and anionic asphalt emulsions, and polymer-modified asphalt emulsions [7, 12, 14, 16, 32, 37, 38]. A major disadvantage of using joint adhesives is the increased cost of construction due to the use of additional equipment and manpower. In addition, joint adhesives have not been shown to consistently reduce permeability at longitudinal joints [19].

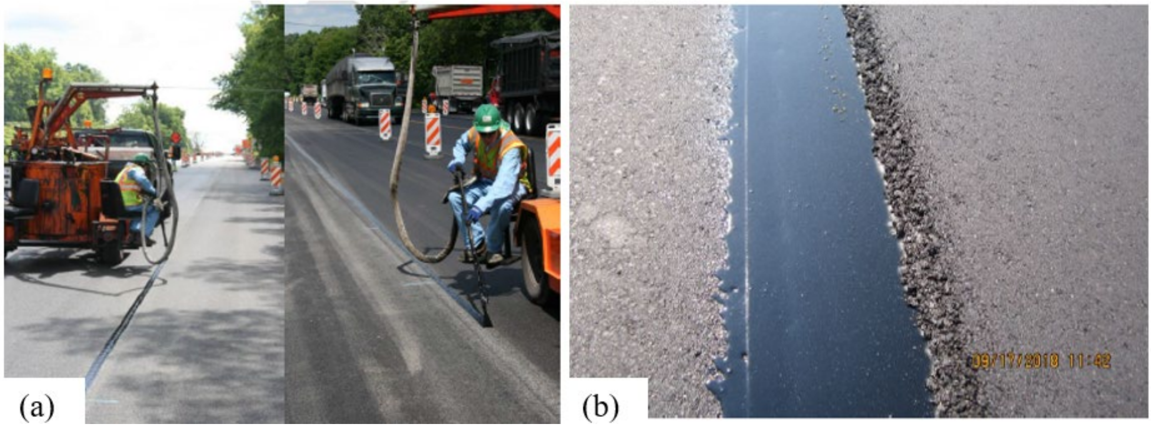
Figure 9. Joint adhesive application [36]

Using Joint Sealers

Joint sealers can be used to seal the joint and prevent water infiltration, which may help mitigate raveling and other forms of pavement damage. There are two ways of using joint sealants to minimize water infiltration at longitudinal joints: (1) the sealant can be applied beneath the pavement layer at the joint location before placing the cold and hot mats, and (2) the sealant can be applied on the finished surface at the joint location (i.e., “overbanding”). When joint sealants are applied beneath the joint of the surface layer, they migrate upward into the air voids of the surface course during the compaction process with a vibratory roller. This migration effectively seals the joint, preventing the infiltration of water and air into the lower pavement layers. The migration height of the sealant determines its overall effectiveness. Two proprietary joint sealants commonly placed underneath asphalt pavement joints include QuikSeam and Jband sealants. These two sealants have been shown to be effective in minimizing the permeability of longitudinal joints in field test sections in Illinois [1, 33, 39, 40]. Figure 10 shows the overband and Jband application processes [1, 39].

Some road agencies, such as Alaska, Pennsylvania, Utah, and West Virginia DOTs, recommend the application of joint sealants on a finished road surface under different conditions to minimize permeability [5, 13, 14, 16]. For example, Alaska DOT recommends sealing the surface of all longitudinal joints within a sublot where the longitudinal joint density test result for a surface mixture is less than 91.0%. Furthermore, according to the guidelines set by the Alaska DOT, contractors are required to apply sealants at a maximum rate of 0.15 gallons per square yard, ensuring that it is at least 12 in. wide and centered on the longitudinal joint [5]. Similarly, the Utah DOT recommends the use of an overband, an 8-in. protective asphalt coating that seals the longitudinal joint of the final riding surface. The aforementioned approach is typically proposed by the contractor and approved by the engineer [14]. According to the West Virginia DOT specifications, contractors are required to seal all joints at a minimum of 3 in. on each side of the joint with a heated PG 64S-22 binder when joint densities are less than 92% on 25% or more of the total project lots. Although joint sealant applications have the capability of minimizing permeability at the joints, they tend to increase the cost of construction. In addition, researchers have shown that joint sealants do not consistently minimize the permeability of pavement sections in the field [19].

Figure 10. (a) Overband and (b) Jband application [1, 39]

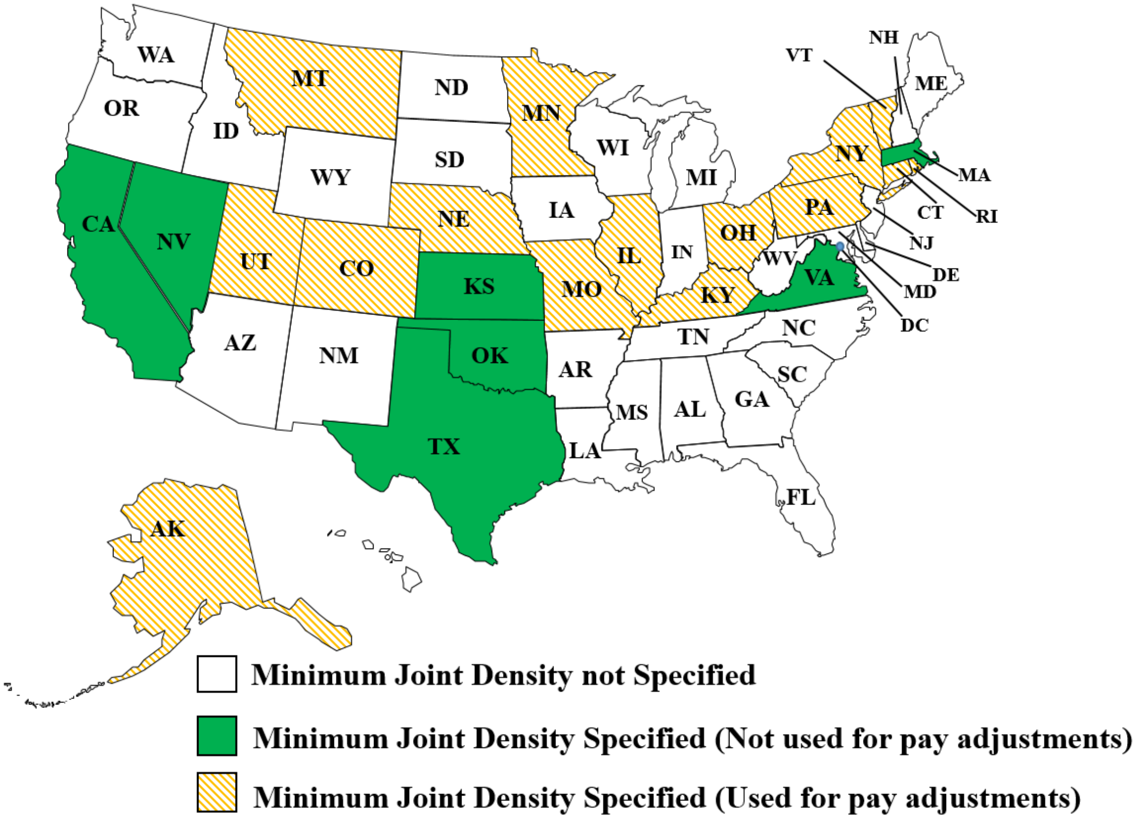


Current State of Practice for Minimum Density Specification

As part of the literature review for this study, each standard specifications document for the 50 states in the US, together with that of the District of Columbia, were collected and reviewed to identify states that specify minimum longitudinal joint density and states that do not. Figure 11 presents a summary of information collected from the specifications documents of 50 states in the US and that of the District of Columbia (DC) regarding the minimum longitudinal joint density for asphalt pavement construction. Twenty-three states out of the 50 states and DC were found to specify a minimum density for longitudinal joint construction. The specified minimum longitudinal joint density requirements for these 23 states ranged from 88 to 93% of the theoretical maximum specific gravity (G_{mm}). Some of these states have a unique way of specifying the minimum longitudinal joint density. For example, Virginia DOT requires contractors to compact longitudinal joints to densities not less than 95% of the target control strip density [38].

Among the 23 states that have minimum longitudinal joint density requirements, 16 of them have instituted payment schedules that offer incentives for achieving higher joint densities and impose penalties for lower joint densities; see Figure 11. The longitudinal joint construction specifications for the 16 states have been summarized in subsequent sections of this report. It is worth noting that some of the remaining 27 states and the District of Columbia that do not specify minimum joint densities do provide guidance for the proper construction of joints to achieve higher joint densities [17, 23, 25, 26].

Figure 11. Minimum longitudinal joint specifications for different states in the US



Alaska

Section 401-3.17 of the Alaska specification recommends that the longitudinal joints of all top lifts be compacted to a minimum density of 91% G_{mm}. Contractors are required to take longitudinal joint cores centered on the visible surface joint location and in the engineer's presence for joint density measurements. When the longitudinal joint density test result for a top lift sublot is less than 91% G_{mm}, contractors are required to seal the surface of all joints with an appropriate sealant. Joint sealants are to be applied at a maximum rate of 0.15 gal/yd^2 and centered on the longitudinal joint at a minimum width of 12 in. Alaska DOT measures the longitudinal joint density for all surface lifts for price adjustment using the following criteria:

- If the average top lift joint density is less than 91% G_{mm}, a disincentive of $3.00 per linear foot will be deducted.
- If the average top lift joint density is greater than 92% G_{mm}, an incentive of $1.50 per linear foot will be added.

Contractors will receive full incentive without joint density testing when they construct the top lift longitudinal joint in echelon (hot lapped joint) while the temperature of the adjacent mat is greater than 200˚F within 3 in. of the joint [5].

Colorado

Section 401.17 of the Colorado DOT standard specifies that longitudinal joints should be compacted to a target density of 92% G_{mm}, with a plus or minus 4% tolerance. Joint cores should be taken with the coring position centered at the visible joint location between the hot and cold mats for joint density measurements. Colorado DOT applies the appropriate pay factor when the joint density falls within or outside the specified tolerance limit [6].

Connecticut

Connecticut DOT specifies percent within limit (PWL) joint density values ranging from 90 to 98% G_{mm} in Section 4.06.04-2(b) of their standard specifications document. For butt joints, Connecticut DOT recommends that density cores be taken from the hot side, with the edge of the core within 1 in. of the longitudinal joint. Density cores for notched wedge joints are to be taken from the hot mat such that the center of the core is 5 in. from the visible joint on the hot mat side; see Figure 12. According to the Connecticut DOT, the measured joint density values will be subjected to the price adjustment values presented in Table 1 [31].

Figure 12. Notched wedge joint coring procedure for Connecticut DOT [31]

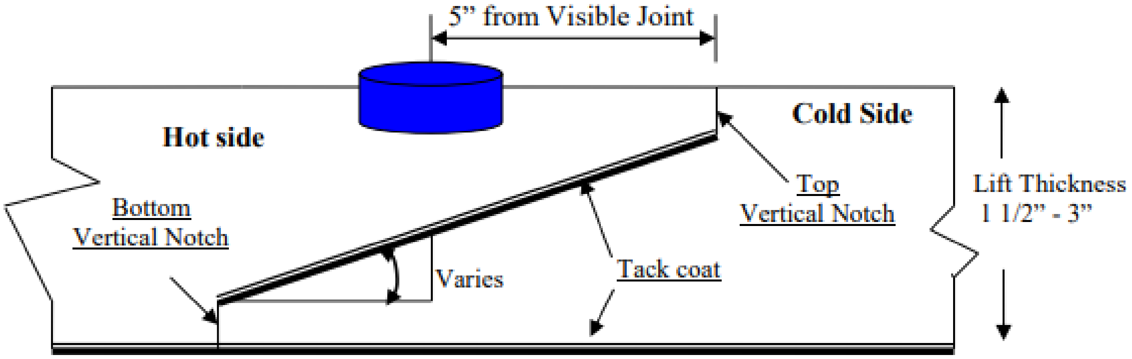


Table 1 Connecticut DOT Pay Adjustment Values for Pavement Joint Density [31]

Joint Density (% G_{mm})	Percent Adjustment
97.1 – 100	$-1.667 \times (\text{ACRPD} - 98.5)$
93.5 – 97.0	$+2.5$
92.0 – 93.4	0
91.0 – 91.9	$+1.667 \times (\text{ACRPD} - 92)$
89.0 – 90.9	$-7.5 \times (91 - \text{ACRPD})$
88.0 – 88.9	$-15 \times (90 - \text{ACRPD})$
87.0 – 87.9	-30
86.9 or less	Remove and replace (curb to curb)

Note: ACRPD: Average Core Result Percent Density; %Gmm: Percent of theoretical maximum specific gravity.

Illinois DOT

Illinois DOT recommends different joint density control limits for different types of mixtures depending on the joint type (i.e., confined or unconfined edge). For confined edges, the joint density values range from 92.0 to 97.4% G_{mm}. The minimum joint density values for unconfined edges range from 90.0 to 91.0% G_{mm}. Longitudinal joint density test cores shall be taken at locations 4 in. from the pavement edge. The density at confined edges can be determined from a one-minute nuclear density reading or a field core measurement. For unconfined edges, the density shall be determined from an average of three one-minute nuclear density readings or a single core density. Illinois DOT makes monetary deductions for unconfined edges with densities less than 90% G_{mm}, as specified in Table 2, for every sublot. A sublot is equivalent to a 0.1-mile (160 m) pavement section [7].

Table 2. Unconfined Edge Density Deduction Table for Illinois DOT [7]

Density (% G_{mm})	Deduction/Sublot
≥90%	$0
89.0 – 89.9%	$1,000
88.0 – 88.9%	$3,000
<88.0%	Outer 1.0 ft. (300 mm) will require remedial action acceptable to the Engineer

Kentucky Transportation Cabinet

Section 402.03 of the Kentucky standard specifications requires contractors to obtain field cores from surface mixtures at longitudinal joints for density measurements. These cores should be taken with the circumference of the core bit within 3.0 ± 0.5 in. of the joint. Table 3 shows the pay factor values applied by the state of Kentucky to constructed pavement sections for different ranges of in-place joint density values [8].

Table 3. Longitudinal Joint Density Pay Values for Kentucky [8]

Pay Value	Test Result (% G_{mm})
1.05	92.0 – 96.0
1.00	90.0 – 91.9 or 96.1 – 96.5
0.95	89.0 – 89.9
0.90	88.0 – 88.9 or 96.6 – 97.0
0.75	<88.0 or >97.0

Minnesota DOT

Section 2360 of the Minnesota standard requires contractors to compact the confined edges of a mat to minimum densities of 91 and 92% G_{mm} for pavement sections with 4 and 3% design air void contents, respectively. Contractors are required to compact the unconfined edges of pavement mats to minimum densities of 89.5 and 90.5% G_{mm} for sections with 4 and 3% design air void contents, respectively. Cores for longitudinal joint density measurements are to be taken with the circumference of the core barrel within 6 in. from the edge of the mat on both sides of the mat. The agency recommends that joint density be measured in one lot per day, but in two lots per day if the total daily weight is greater than 5000 tons. Minnesota DOT makes price adjustments based on the measured joint densities using incentive and disincentive schedules presented in Tables 2360.5-6 and 2360.5-7 of the Minnesota DOT Standard specifications document [9].

Missouri DOT

In Section 401.7.6 of the Missouri standard, the minimum density requirement within 8 in. of an unconfined pavement edge is 2.0% below the specified density of the constructed mat. Cores for joint density measurements should be taken 6 in. from the joint near the centerline and 12 in. from the joint near the shoulder. Missouri DOT's standard further recommends that the established rolling procedure be used instead of density tests, with certain conditions, if no deficient cores are found in the initial 25% of production. The agency applies pay adjustments for longitudinal joint density to the entire paved mat. The average density of joint cores from each lot will be used to determine if the specifications are met. In the event that payment reductions (i.e., disincentives) become necessary, the lower adjusted contract unit price of the PWL or unconfined joint will be implemented. Based on the average density of the joint cores obtained from each lot, pay adjustments will be applied in accordance with Section 403.23.7.4.1(b) of the Missouri standard specifications [10].

Montana DOT

Section 401.03.21 of the Montana standard specifications requires contractors to construct longitudinal joints of new plant-produced mixtures with either a notched-wedge or tapered-edge joint at slopes ranging from 4H: 1V to 6H: 1V. The agency recommends that joint areas be compacted to a minimum density of 91% G_{mm} for all mixtures and 90% G_{mm} for 9.5-mm mixtures with thicknesses less than 36 mm. Cores for joint density measurements should be taken centered at the joint area to include both the hot and cold mats. A monetary incentive is paid to contractors when the density of the longitudinal joint for each lot meets certain criteria. The pay adjustment is calculated using a simple formula, and the amount of the adjustment is based on the length of the longitudinal joint and the unit cost (unit cost of $4.50 per foot of joint currently used). The pay factor is 0.05 when the average density of the longitudinal joint in a given lot is from 92.0 to 95.0% and the range is 3 or less [11].

Nebraska DOT

As per Section 1082 of the Nebraska specifications book, it is recommended that contractors obtain field cores for the purpose of measuring longitudinal joint density at a lateral distance of 1 inch from the edge of the top mat. Pay factors for longitudinal joint density values for each mixture type are computed according to the schedule presented in Table 4 [12].

Table 4. Joint Density Test Lot Pay Factor for Nebraska DOT [12]

Joint Density	Mixture Type-SPS	Mixture Type-SPR	Mixture Type-SPH
93.0 0r greater	102%	102%	102%
92.0 to 92.9	100%	102%	102%
91.0 to 91.9	98%	100%	102%
90.0 to 90.9	98%	98%	100%
89.0 to 89.9	98%	98%	98%
88.9 or Less	98%	98%	98%

New York DOT

Contractors in New York State are required to use different compaction methods (i.e., 50, 60, 70, and 80 series compaction methods) depending on the type of mixture being placed. According to Section 404-3.09(c) of the New York Standard, longitudinal joints in the asphalt surface courses for 50 and 60 series compaction methods are subject to performance assessments using core density testing. It is the responsibility of the contractor to select the appropriate joint construction method (i.e., butt or tapered wedge joint) to achieve the optimum joint density. Cores will be taken at the joint location for each joint type, as shown in Figure 13. The average density of each joint core is determined, and the appropriate pay factors are applied based on the quality unit values and equations presented in Table 5 [27].

Figure 13. 6-in. diameter coring at (a) tapered wedge joint and (b) butt joint locations

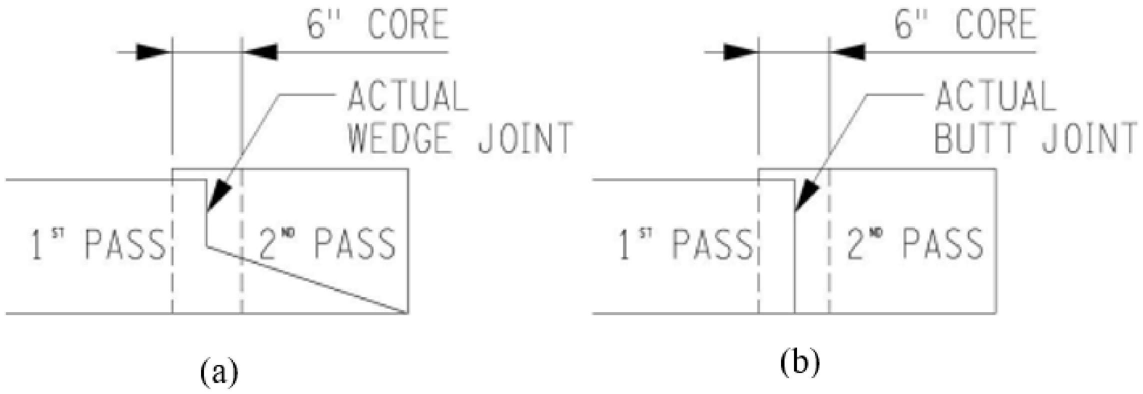


Table 5. New York DOT's Quality Adjustment for Longitudinal Joint Density [27]

Average Core Density (%G_{mm})	Segment Quality Unit (QU)
Density ≥ 93.0	4
86.0 ≤ Density < 93.0	$1.143 \times \text{Average Core Density} - 102.3$
Density < 86.0	-4

Ohio DOT

According to Section 447.05 of the Ohio DOT standard specifications document, a joint density lot (each lot is further divided into 2500-ft. sublots) comprises the entire length of the cold longitudinal joint on the project. Contractors are required to take three cold longitudinal joint cores from each sublot, with the edge of the coring barrel at a distance not less than 4 in. from the edge of the mat. The agency will apply pay factor values based on the measured cold joint core densities using pay schedules as specified in Tables 446.04-1 and 446.04-2 of the Ohio standard specifications document [28].

Pennsylvania DOT

Section 405.3 of the Pennsylvania standard requires contractors to retrieve one core per 2500-ft. longitudinal joint sublot. Cores obtained at vertical (butt) joints should be centered at the visible line at the surface between the adjacent mats. For notched wedge joints, it is recommended to place cores in a centered position, either 6 in. or one half the width of the joint taper away from the joint line, following the direction of the wedge. The measured core densities are used to apply pay factors according to the schedule presented in Table 6 [13].

Table 6. Lot by Lot Payment Schedule for Longitudinal Joints [13]

Lot Percent Within Limit (PWL)	Amount
PWL ≥ 81	$\frac{(\text{PWL} - 20)}{20} \times \$7{,}500$ [Incentive]
PWL = 50 to 80	$0
PWL ≤ 49	$\frac{(50 - \text{PWL})}{50} \times -\$12{,}500$ [Disincentive]

Rhode Island DOT

To assess joint densities, Section 401.03.6 of the Rhode Island Standard requires contractors to obtain one core for every 3000 ft. or less of longitudinal joint constructed.

Joint cores should be centered within 2 in. of the midpoint of the sloped portion of a notched-wedge joint or within 1 in. of the midpoint of a butt joint. All cores taken from butt joints should be 6 in. diameter. A pay adjustment will be applied by the agency based on the measured in-place joint density values using Table 7 [37].

Table 7. Joint Density Pay Adjustments for Rhode Island DOT [37]

In-Place Joint Density (%G_{mm})	Pay Adjustment
93.0% and greater	+2%
92.0% to 92.9%	+1%
91.0 % to 91.9%	0%
90.0% to 90.9%	-5%
89.0% to 89.9%	-15%
88.0% to 88.9%	-25%
87.0% to 87.9%	-35%
Below 87%	-100%

Utah DOT

In Section 02741-5 of the Utah specifications book, longitudinal joints are required to be constructed at a minimum density of 91.5% G_{mm}. Contractors are required to obtain cores from longitudinal joints for density verification. The agency will pay the longitudinal joint incentive or disincentive per ton of the hot mat placed, following the schedule provided in Table 8 [14].

Table 8. Incentive/Disincentive for Longitudinal Joint Density [14]

%G_{mm} Bassed on Minimum of Four Samples	Incentive/Disincentive ($/Ton)
>99	2.00
96 – 99	1.50
92 – 95	1.00
88 – 91	0.00
84 – 87	-0.26
80 – 83	-0.60
76 – 79	-0.93
72 – 75	-1.27
68 – 71	-1.60
64 – 67	-1.93
60 – 63	-2.27
56 – 59	-2.60
52 – 55	-5.00
<52	Apply $5 penalty and Overband

Vermont DOT

Vermont DOT specifies in Section 406.15 of their standard book that field cores should be taken from longitudinal joint locations for density verification. Cores obtained from butt joints are to be centered at the visible joint line at the surface; whereas, those obtained from tapered joints shall be offset from the visible surface joint line by approximately 50% of the taper width, as directed by the engineer. Based on the measured core densities, Vermont DOT applies pay factors according to the schedule outlined in Section 406.15(c) of the Vermont standard specifications document [15].

West Virginia DOT

According to Section 401.6.4.2.2 of the West Virginia standard specifications document, longitudinal joint density testing shall be performed on all constructed joints between traveled lanes. The agency recommends that joint density testing be performed after both lanes of the joint are constructed. Joint density testing shall be performed with a nuclear or non-nuclear density gauge, with the gauge positioned 4 in. from the constructed joint. In addition, the agency recommends that density testing be performed on only longitudinal joints constructed on surface courses. For each lot of material placed, the average joint density shall be calculated as the average of the sublot results. The agency evaluates the measured density results based on upper and lower specification limits of 97.0 and 90.0% G_{mm}, respectively. Pay factor values are applied by the agency based on the schedule provided in Table 401.13.3B of the West Virginia standard specifications document [16].

Summary and Conclusions

The construction of longitudinal joints to specified densities significantly impacts the performance and service life of asphalt pavements. Adequate compaction ensures that the joint is impermeable to water infiltration, reducing the potential for moisture damage and promoting long-term performance. Insufficient density can lead to higher air voids, which compromise the strength of the material at the joint and increase the risk of crack initiation and propagation. Conversely, overcompaction may cause joint raveling or crushing, diminishing its ability to withstand traffic loads. The understanding and implementation of best practices for longitudinal joint construction and density have evolved. State departments of transportation, industry organizations, and research institutions have conducted extensive studies and developed guidelines to improve the performance of longitudinal joints. These guidelines often cover joint preparation, compaction techniques, temperature differentials, and material selection. Advances in construction equipment, such as intelligent compaction systems, have also contributed to improved joint density control.

The objective of this study was to conduct a literature review regarding the current best practices for longitudinal joint construction. To achieve the aim of this study, the research team collected and critically reviewed available literature regarding best practices for longitudinal joint construction and the use of various techniques and materials for improving longitudinal joint density. In addition, the research team assessed the payment schedules for longitudinal joint density used by different states in the US by reviewing standard specifications documents employed by these states. The research team identified eight construction techniques that are commonly used to achieve improved longitudinal joint density in asphalt pavements: (1) adopting the echelon or tandem paving technique; (2) modifying the rolling pattern; (3) specifying different joint types (i.e., butt, tapered, or notched wedge) for different field conditions; (4) using edge restraining or pre-compaction devices; (5) using infrared joint heaters; (6) using cutting wheels; (7) using joint adhesives; and (8) using joint sealers. All these techniques, except the technique for modifying the rolling pattern, may require the use of additional equipment, material, and labor, which may increase the cost of construction. Some of these techniques are selected by agencies because the benefits obtained from improved performance offset the additional cost of construction. It was observed from the literature review that different rolling patterns are effective under different conditions. Therefore, state agencies select different rolling patterns based on experience and what works under specific field conditions [19].

Based on the review of different state specifications documents, 23 states were found to specify a minimum density for longitudinal joint construction. The specified minimum longitudinal joint density requirements for these states ranged from 88 to 93% of the theoretical maximum specific gravity (% G_{mm}). Some of these states have a unique way of specifying the minimum longitudinal joint density. Sixteen out of the 23 states that have minimum longitudinal joint density requirements have instituted payment schedules that offer incentives for achieving higher joint densities and impose penalties for lower joint densities. These pay factors are usually applied per foot of longitudinal joint or per ton of asphalt mixture within a lot for a given longitudinal joint.

Despite advancements in longitudinal joint construction specifications, challenges persist in achieving consistently high-quality longitudinal joints. Issues such as inadequate compaction, joint segregation, and improper construction practices continue to impact pavement performance. Continuous research, industry collaboration, and advancements in construction practices will further improve the state of the practice, ensuring the long-term performance of asphalt pavements.

Recommendation

Based on the findings of the study, it is recommended that an additional study be conducted to explore the potential of establishing minimum density requirements and instituting incentive and disincentive pay schedules for longitudinal joint construction in Louisiana. The proposed study will use field experiments, observations, and pavement performance evaluations to assess the effects of different longitudinal joint construction techniques on pavement distress and service life. In addition, the study will aim to further refine construction techniques, optimize material properties, and develop innovative longitudinal joint construction concepts by integrating emerging technologies such as real-time monitoring and quality control systems.

Acronyms, Abbreviations, and Symbols

Term	Description
ACRPD	Average Core Result Percent Density
COMPENDEX	Computerized Engineering Index
DC	District of Columbia
DOT	Department of Transportation
cm	centimeter(s)
FHWA	Federal Highway Administration
˚F	degree Fahrenheit
ft.	foot (feet)
gal/yd^2	gallons per square yard
G_{mm}	theoretical maximum specific gravity
HMA	hot mix asphalt
in.	inch(es)
LADOTD	Louisiana Department of Transportation and Development
LTRC	Louisiana Transportation Research Center
lb.	pound(s)
m	meter(s)
mm	millimeter(s)
NMAS	nominal maximum aggregate size
NTIS	National Technical Information Services
PG	Performance Grade
PRC	Project Review Committee
PWL	percent within limit
TRID	Transportation Research Information Database

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