Longitudinal Joint Specification, Construction, and Performance for Flexible Pavements in Canada

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Abstract

Longitudinal joints are the long seams between paving lanes made by subsequent passes of the paver to cover the surface being paved. Longitudinal joints are often the weakest area of asphalt pavements and are susceptible to early deterioration. Deterioration starts when air, water, and contaminants find their way into the joint through areas of segregation, poor density, or inadequate bond between the two mats forming the joint. Addressing this weakness will greatly delay maintenance and increase overall pavement life.

One option to prevent longitudinal joint deterioration is to eliminate the joints altogether through echelon paving, which involves paving multiple lanes side-by-side at the same time with multiple pavers. Unfortunately, on most paving projects, the paving width is limited, and there is a need to maintain an acceptable level of traffic flow that prevents multi-lane paving. Consequently, most paving projects must be paved one lane at a time, which requires the construction of conventional joints.

Several techniques exist for the construction of longitudinal joints, and in Canada, user agencies are exploring innovations in materials, construction methods, and specifications for improving longitudinal joint performance. As a start, a survey was conducted of Canadian agencies to gain insight into the current specifications and practices utilized in Canada in the construction of longitudinal joints.

This paper discusses the results of the survey and the specifications and practices agencies reported to be acceptable and highly effective based on field performance. The paper also discusses a literature review on research of materials such as joint sealers or void-reducing asphalt membranes and construction practices that result in lower air void contents (higher densities) at the longitudinal joints and better performance.

Background

Pavement longitudinal joints (LJ) are the seams or connections that run parallel to the direction of the road or pavement. These joints are created when separate sections of the pavement are joined together during construction or maintenance. The purpose of longitudinal joints is to provide a smooth transition between adjacent asphalt layers, ensuring structural integrity and preventing cracking. They are typically found in multi-lane roadways, where asphalt is placed in separate lanes to facilitate construction efficiency. There are several methods for specifying and constructing longitudinal joints that have an impact on the performance long term. Premature joint failures occur at the interface between two adjacent asphalt mats due to a combination of low density, high permeability, segregation, improper overlap, and lack of adhesion at the interface. Although several factors can influence joint performance, the most important factor is in-place density (Brown et al., 2016).

The results of past studies on the effect of air voids on the fatigue and rutting performance and service life of asphalt mixtures suggest that increasing the asphalt pavement density by 1% would increase its service life by conservatively 10%. (Blankenship & Anderson, 2010; Brown et al., 2016; Howell et al., 2021; Wang et al., 2015) where service life is defined as the time from initial construction until the next rehabilitation activity. For illustration purposes, that means that an asphalt overlay constructed to 93% density might be expected to last 20 years, while the exact sample asphalt overlay constructed to 92% density would only be expected to last 18 years. (Tran et al., 2016) With longitudinal joint densities typically at 90% or less, it is expected that longitudinal joints would fail at least five years sooner than the rest of the mat. Pictures of longitudinal joints provided by Alberta Transportation at different stages of service life (Figure 1) show that longitudinal joints continue to be the weakest point on asphalt pavements and the first place to start showing distress.

a. Newly constructed; uniform appearance, tack coat applied to the interface.

b. Longitudinal joint one year after overlay

c. 8-year-old LJ with cracking and some spalling

d. 14-year-old LJ previously repaired that is cracking and spalling

Figure 1: Longitudinal joints from across Canada at different stages of service life.

Secondary cracking of primary longitudinal joint cracks occurs and can lead to block cracking, spalling, or meandering. Furthermore, failed longitudinal joints are a safety concern for road users meaning they require some form of maintenance treatment early in the pavement life. Early treatment options include crack sealing, crack filling, asphalt patching, and seal coat application. Saskatchewan highways noted that “maintenance spending on longitudinal joints takes away from the routine and preservation budget for an agency. This means that other priorities in the pavement preservation plan must be delayed, thus affecting the overall level of service of the network.”

This study was conducted to offer insight into the current specifications and practices being used in Canada in the construction of longitudinal joints.

Methodology

Canadian user agencies are actively exploring innovations in materials, construction methods, and specifications to improve the performance of longitudinal joints in asphalt pavements. These agencies recognize the importance of longitudinal joints in ensuring the longevity and structural integrity of roadways. As a start, the Soils and Materials Committee (SMC) of the Transportation Association of Canada (TAC) conducted a survey to establish a reference point for the existing state of the practice regarding longitudinal joints in Canada.

Agencies were asked to provide details on the following questions:

1. What kind of longitudinal joint specification does your agency use? a) Method Specification, b) Density Specification, or c) No Specification?
2. In lieu of a construction specification, does your agency complete/require any pre/post-construction longitudinal joint treatment?
3. Have you utilized the notched wedge or other methods (i.e., cutting back edge) for the unconfined mat?
4. Do you use joint adhesive material or other materials along vertical face of unconfined mat?
5. Do you have a specification or special provision for re-heating the longitudinal joint?
6. Please indicate how effective your agency's longitudinal joint specification is: Extremely Effective, Acceptable, or Ineffective.
7. Are you envisioning any future changes to your LJ requirements?

Responses were received from eight agencies in total, with seven provincial and one local agency (City of Ottawa). The following section details and analyzes the responses received while also providing a summary of best practices available in the literature.

Kinds of Longitudinal Joint Specifications

There are two types of specifications for longitudinal joints in asphalt pavements commonly used by agencies; method specifications and density specifications, which are described in detail below.

<u>Method Specifications</u>

A method specification for longitudinal joints outlines the specific procedures and techniques that should be followed during the construction of these joints. It provides a step-by-step guide to ensure that the longitudinal joints are constructed correctly and meet the desired performance standards. The purpose of a method specification is to ensure consistency, quality, and durability of longitudinal joints across different construction projects.

A typical method specification for longitudinal joints may include the following elements:

- Surface preparation: The specification will outline the required surface preparation steps before placing the new asphalt layer adjacent to the existing pavement. This may include cleaning the surface, removing loose debris, and ensuring a smooth and uniform surface.
- Application of tack coat: The specification will specify the type and application rate of tack coat or asphalt emulsion to be used. It will detail the surface preparation required for applying the tack coat and the proper method of application to ensure adequate bonding between the new and existing asphalt layers.
- Joint construction: The specification will describe the recommended joint construction methods, including the joint width, depth, and geometry. It may provide guidelines on joint widening, chamfering, or other techniques to enhance load transfer and reduce stress concentrations.
- Compaction: The specification will outline the compaction requirements for the longitudinal joint. It will specify the compaction equipment, frequency, and target density to ensure proper bonding and density of the asphalt layers at the joint.

- Quality control: The specification will detail the quality control measures that need to be implemented during the construction process. This may include requirements for sampling and testing of materials, compaction control, and joint performance evaluation. It may also specify the frequency of inspections and the acceptable tolerances for various parameters.
- Temperature considerations: The specification will address the temperature requirements during the construction of longitudinal joints. It may include guidelines on the acceptable temperature range for placing the new asphalt layer, as well as measures to prevent premature cooling or overheating of the joint area.
- Documentation: The specification may require documentation of the construction process, including records of material deliveries, quality control test results, and construction procedures. This documentation ensures traceability and accountability throughout the project.

It's important to note that method specifications may vary depending on local practices, climate conditions, and specific project requirements. User agencies, in collaboration with industry experts, develop and update these specifications based on research, field experience, and lessons learned from previous projects.

<u>Density Specifications</u>

A density specification for longitudinal joints in asphalt pavements defines the required compaction level or density that should be achieved in the vicinity of the joint during the construction process. It provides guidelines and targets to ensure that the asphalt layers at the longitudinal joint are adequately compacted, promoting structural integrity and preventing premature failure.

A density specification for longitudinal joints typically includes the following components:

- Target density: The specification will specify the desired density or compaction level to be achieved at the longitudinal joint. This may be expressed as a percentage of the maximum theoretical density (e.g., 93% or 90%).
- Compaction equipment: The specification may outline the type of compaction equipment recommended for achieving the target density. This can include vibratory rollers, pneumatic tire rollers, or other specialized compaction machinery.
- Compaction temperature: The specification may address the temperature considerations during compaction. It may specify the acceptable temperature range at which compaction should take place to ensure optimal compaction and bonding of the asphalt layers.
- Compaction sequence: The specification may outline the sequence of compaction operations, particularly if multiple layers are involved. It may specify the compaction sequence for each layer and provide guidelines on overlapping the roller passes at the longitudinal joint to ensure uniform compaction.
- Quality control testing: The specification may require periodic quality control testing to assess the achieved density at the longitudinal joint. This can involve in-place density testing methods such as nuclear density gauge or core sampling, which provide measurements of the compacted asphalt's density and air void content.
- Acceptance criteria: The specification may define the acceptance criteria for density measurements at the longitudinal joint. It may specify the maximum allowable air void content or the minimum required density percentage that should be achieved. These criteria ensure that the joint meets the specified performance requirements.

Density specifications for longitudinal joints are crucial to ensure the uniform compaction of asphalt layers, including the joint area. Achieving the specified density helps minimize the risk of moisture infiltration, increases load transfer capability, and improves the overall performance and durability of the pavement.

It is important for construction teams to adhere to the density specification, implement appropriate compaction practices, and conduct quality control testing to verify compliance. By following these specifications, engineers can ensure that longitudinal joints in asphalt pavements are properly compacted, resulting in a long-lasting and reliable roadway infrastructure.

Figure 2 shows that agencies in Canada follow different practices, with 50% of the respondent following method specifications and 25% using density specifications.

Figure 2: Kinds of LJ specification used by Canadian agencies.

Use of Pre- or Post-Construction Longitudinal Joint Treatment

A pre- or post-construction longitudinal joint treatment refers to a specific procedure or technique applied to the longitudinal joint in asphalt pavements either before or after the initial construction phase. (Buncher et al., 2012) These treatments are implemented to enhance the performance, durability, and longevity of the longitudinal joint, addressing potential issues such as cracking, water infiltration, and premature joint failure.

Figure 3 shows that two of the eight respondents complete/require pre/post-construction longitudinal joint treatment.

Figure 3: Canadian Agencies using pre/post-construction LJ treatment.

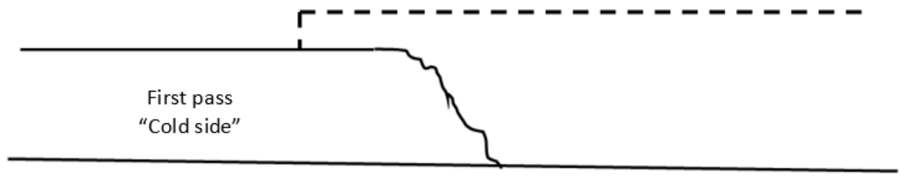
It is important to note that British Columbia uses a post-construction treatment in lieu of a longitudinal joint specification. British Columbia requires the use of an approved joint sealant to be applied to the longitudinal joint post-construction. A joint sealant is a material (typically asphalt emulsion) designed to fill and seal the joint gap between two adjacent asphalt layers, as illustrated in Figure 4. The purpose of the sealant is to prevent water infiltration, reduce the risk of debris accumulation, and enhance the overall performance and durability of the joint.

Manitoba's post-construction treatment is a route and seal of the longitudinal joint within five years of construction. Routing cuts a groove or channel along the length of the joint, which is thoroughly cleaned to remove any debris, loose particles, or contaminants. This cleaning process ensures optimal adhesion and bonding of the sealant to the joint surfaces. The sealant is poured or placed into the joint following the manufacturer's instructions for proper application, including recommended application temperature, curing time, and thickness. Performing a longitudinal joint route and seal within five years of construction helps address any joint distress that may have developed since the initial construction, prevent further cracking or deterioration, and extend the pavement's service life.

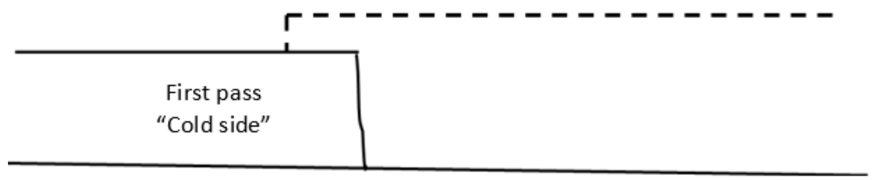
Figure 4: Joint Sealer being applied by a distributor over the LJ after both lanes have been placed.

Types of Cold Longitudinal Joint Construction

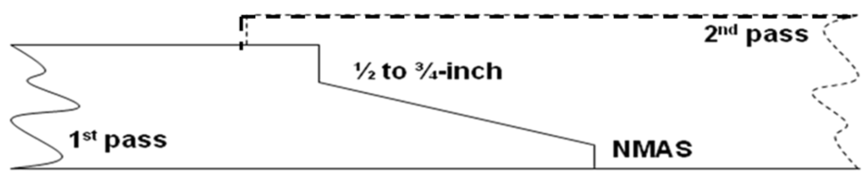
There are three types of conventional (cold) longitudinal joint construction. The most common is the paver-laid butt joint (Figure 5a), where the material on the first pass (referred to as the "cold side") can seek its own slope down to the previous surface. The second type is the milled or Cutback butt joint (Figure 5b) created by physically sawing with a cutting tool or milling into the cold side of the previous mat. This provides a nearly vertical edge to compact against, and it eliminates the area of low-density material at the edge of the first mat. (Asphalt Institute, 2020) The third type of joint is called a notched-wedge joint, where a notched wedge attachment placed on a paver creates a mechanically interlocked joint between adjacent asphalt layers (Figure 5c). The initial pass has a tapered face with a slope from 3:1 to 12:1. It is recommended that the notched depth be at least the thickness of one nominal maximum aggregate size of the asphalt mix.



a. Paver laid butt joint



b. Milled or Cutback butt joint or mi



c. Notched wedge joint

Figure 5: Conventional (Cold) Joint Construction Methods.

Although none of the Canadian agencies responded to have experience with the notched wedge, agencies in the United States that have adopted the use of notched wedge generally noted an increase in joint density and an improvement in the long-term performance of their longitudinal joints. (Asphalt Institute, 2020).

Use of Joint Adhesives and Sealants

A joint adhesive is a polymer-modified asphalt material applied to the face of the first paving pass to promote bonding between adjacent asphalt layers at the longitudinal joint, as illustrated in Figure 6. Another type of joint sealant is the voids-reducing asphalt membrane (VRAM) that is applied to the longitudinal joint area prior to placing the surface layer of asphalt, as illustrated in Figure 7.

The objective of the joint sealant and VRAM is to decrease the permeability of the asphalt surface layer along the longitudinal joint by decreasing the amount of interconnected air voids. (Winkelman, 2019)

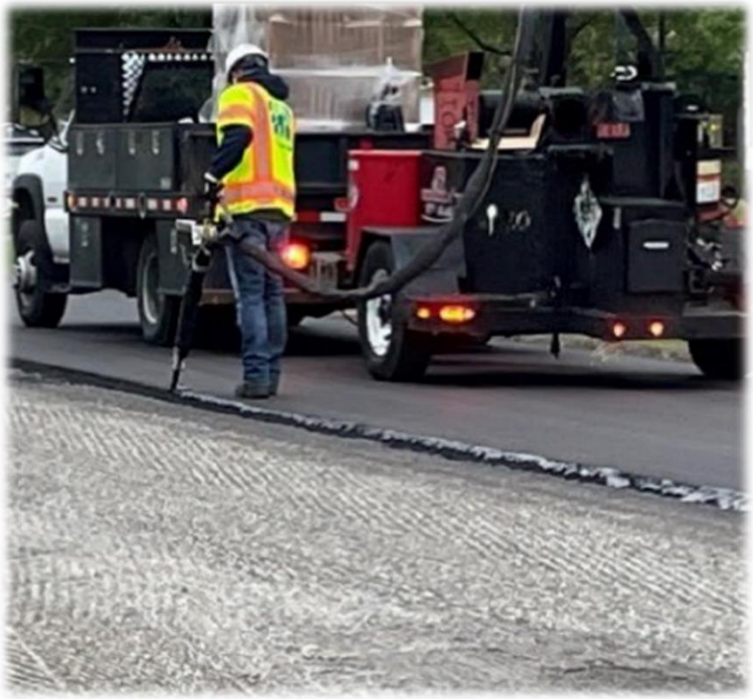


Figure 6: Application of Joint Sealant to the face of the first pass.

Figure 7: Application of joint adhesive (VRAM) prior to placing a surface layer of asphalt.

Although none of the Canadian agencies responded to specifying the use of joint sealants, literature search shows documented improved performance from agencies in the United States. For instance, the Illinois Department of Transportation (IDOT) constructed test pavements with two types of longitudinal joint sealants compared to a control section. The IDOT test pavements were evaluated after 12 years and found to have longitudinal joints that exhibited significantly better performance than the control joint sections and were in similar or better condition than the rest of the pavement. (Trepanier et al., 2021). Laboratory testing of cores showed decreased permeability and increased crack resistance of mix near joints with longitudinal joint sealants used, compared with similar asphalt mix without the longitudinal joint sealant. The life extension of the joint area was approximately 3–5 years, and the benefit was calculated to be three to five times the initial cost. (Trepanier et al., 2021).

Use of Joint Heaters

Joint heaters are specialized equipment used to preheat the "cold side" of the longitudinal joint and are designed to improve the bond between adjacent asphalt layers by increasing the temperature of the joint surfaces. Typically, an infrared heater is mounted on the paver and aimed at the cold joint side, as shown in Figure 8. It is possible to heat the cold side to about 93°C (200°F) with this method. (Kandhal et al., 2002).

Figure 8: Joint heater mounted to a paver.

Ontario was the only agency that responded that there is a special provision in their specification to allow the use of joint heaters on select projects at the discretion of the designer. Other provinces did not have a specification for joint heaters and provided additional comments citing challenges with reaching uniform temperature as part of the reason.

Effectiveness of Joint Specifications

To assess the effectiveness of a longitudinal joint specification, an agency would consider various evaluation methods and criteria. Figure 9 ultimately shows the perception of the agencies on how well the longitudinal joints performed in terms of preventing joint failure, reducing cracking, and maintaining pavement integrity.

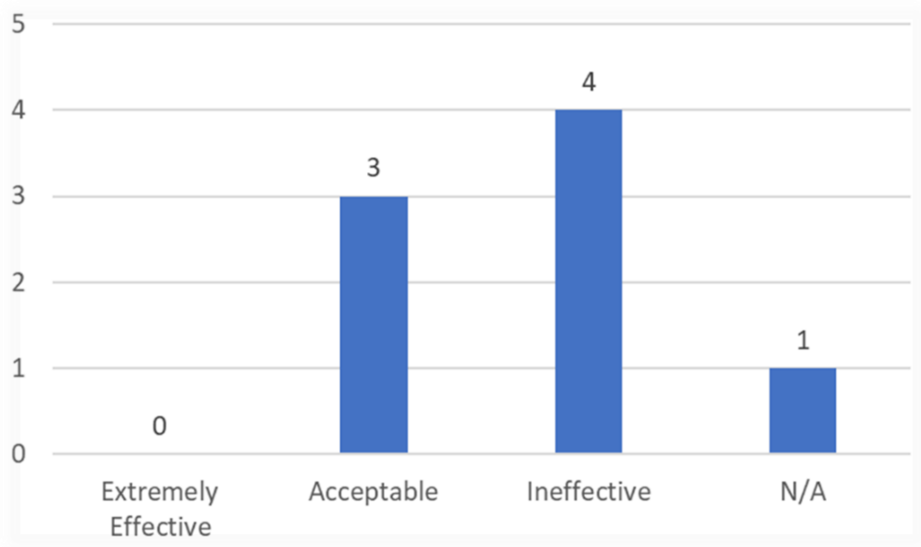


Figure 9: Canadian agencies' response: How effective is your LJ specification?

Quebec was the only province that responded to having a longitudinal joint specification that is acceptable to extremely effective (logged as "acceptable" in the survey responses). Quebec Ministry of Transportation (MTQ) has a combination of method specification and density specification for the longitudinal joint. One of the requirements of the method specification component requires the first pass of the roller to extend by 150mm from the unsupported edge, as illustrated in Figure 10, to avoid tearing.

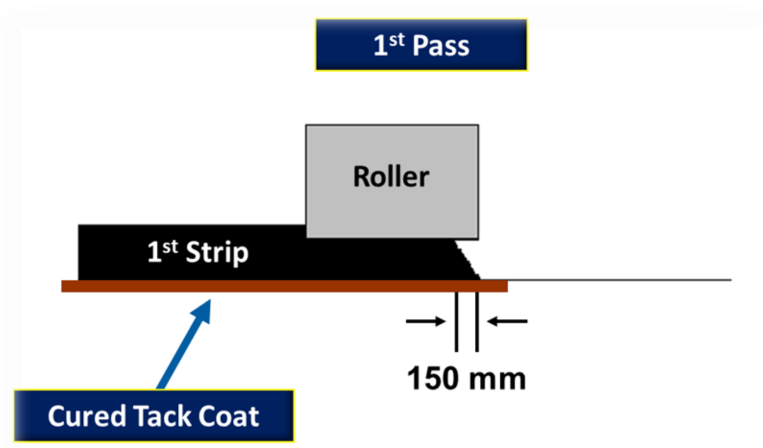


Figure 10: Unsupported Edge Compaction (Quebec Ministry of Transportation).

For the supported edge joint, the requirement is for the tack coat to be applied to the vertical face, the first pass on the hot side is set 150mm from the joint, and the second pass requires vibration mode overlapping the joint by 150mm, as shown in Figure 11.

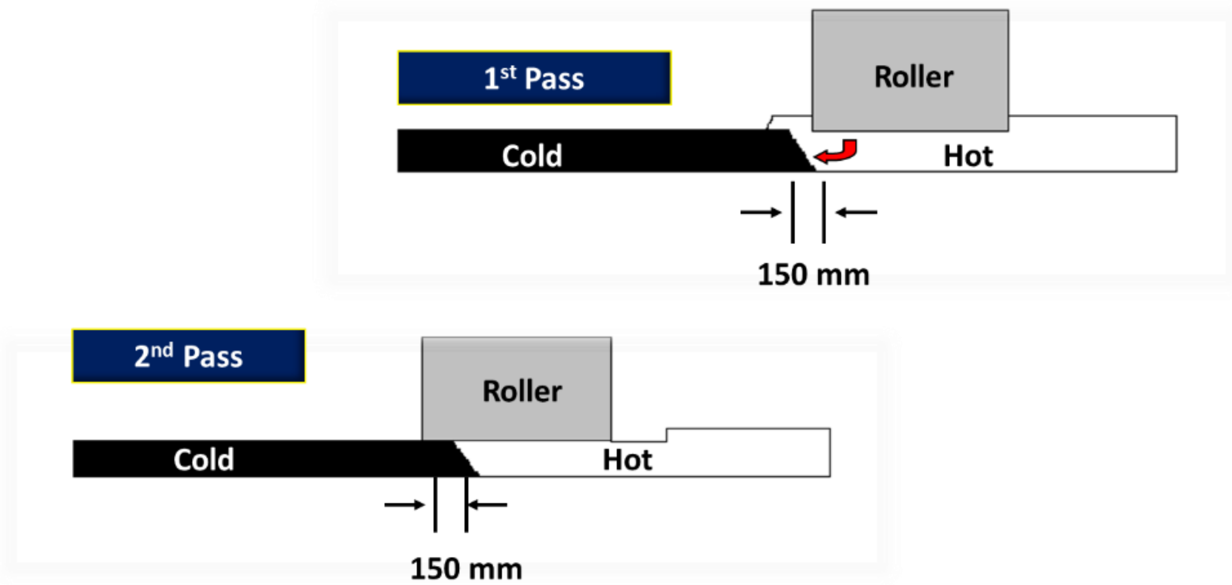


Figure 11: Supported Edge Compaction (Quebec Ministry of Transportation).

The density component of MTQ's longitudinal joint specification is a minimum requirement of 90 percent of the maximum relative density, tested with a nuclear density gauge. Compaction cores are required if the nuclear density gauge testing is below 90 percent.

Plans to Change Current Joint Specifications

Lastly, the survey asked if agencies were planning to make changes to their longitudinal joint specifications in the future. Figure 12 shows that 50% of the respondents are considering updates explained below.

Alberta Transportation is considering alternate construction methods, just as notched edge joints, the incorporation of VRAM, and joint sealants. Their survey respondents also noted the implementation of a longitudinal joint density specification where the joint compaction is two percent lower than the mat density.

Manitoba is considering the implementation of density specification.

Ontario's Ministry of Transportation noted plans to either fully implement an edge compaction specification or consider non-destructive methods such as Density Profiling Systems, which is a technology used to measure and evaluate the density of compacted asphalt layers in real time. It provides information about the uniformity and quality of the pavement's compaction.

Quebec's Ministry of Transportation plans to implement a penalty or price adjustments if longitudinal joint specifications are not met by the contractor.

Figure 12: Canadian agencies planning to make changes to their LJ specifications in the future.

Conclusions

This paper has presented the findings of a survey conducted among Canadian agencies to assess the specifications and practices for longitudinal joints based on field performance. Through the analysis of the survey responses, combined with a comprehensive literature review, valuable insights have been gained regarding the materials and construction practices that contribute to lower air void contents and higher densities at longitudinal joints, ultimately leading to improved performance. Emphasis on achieving higher densities and lower air void contents at longitudinal joints through the implementation of recommended materials and practices is crucial in ensuring the long-term performance and durability of asphalt pavements.

Based on the survey responses and literature review, it can be concluded that Canadian agencies recognize the importance of appropriate specifications and practices to achieve better performance of longitudinal joints. The utilization of joint sealers, void-reducing asphalt membranes, and construction techniques that result in lower air void contents and higher densities at the joints have been identified as effective approaches for improving longitudinal joint performance. Continued research and collaboration within the industry will contribute to the advancement of longitudinal joint practices and specifications, leading to the development of more resilient and durable asphalt pavements.

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