The Use of Infrared Joint Heaters to Improve HMA Longitudinal Joint Density

Vince Aurilio, P.Eng.
President
VA Asphalt Pavement Technologies Inc.
Brampton, Ontario

Bob Kieswetter, P.Eng.
President
Heat Design Equipment Inc.
Kitchener, Ontario

THE USE OF INFRARED JOINT HEATERS TO IMPROVE HMA LONGITUDINAL JOINT DENSITY

ABSTRACT

Premature failure of asphalt longitudinal construction joints continues to be a concern of roadway authorities throughout North America. In Canada, improving joint performance often ranks as a priority amongst roadway agencies. The key factor affecting joint performance is generally insufficient compaction (high air voids). If left unattended (i.e., with little or no maintenance), the joint issues will greatly impact the overall performance of the pavement.

Infrared heaters that pre-heat the joint prior to paving the second lane have been successfully used for over twenty years and are becoming more common as a very effective method to improve joint density and performance. Independent studies have shown that using joint heaters provides lower in-place air voids and permeability, and ultimately improves the bond resulting in longer durability. The City of Hamilton has specified the use of infrared joint heaters since 2007 where maintaining a hot joint is not viable. In Alaska, Ground Penetrating Radar (GPR) is being evaluated in conjunction with joint heaters to verify joint density.

This paper will provide an in-depth review of the construction issues associated with longitudinal joint construction. The review will include current use of infrared joint heaters, and the associated specifications along with observed performance improvements.

RÉSUMÉ

La défaillance prématurée des joints de construction longitudinaux en asphalte continue de préoccuper les autorités routières partout en Amérique du Nord. Au Canada, l'amélioration de la performance des joints est souvent une priorité parmi les agences routières. Le facteur clé affectant la performance des joints est généralement un compactage insuffisant (vides d'air élevés). S'ils sont laissés sans surveillance (c'est-à-dire avec peu ou pas d'entretien), les problèmes de joint auront un impact considérable sur la performance globale de la chaussée.

Les radiateurs infrarouges qui préchauffent le joint avant de paver la deuxième voie sont utilisés avec succès depuis plus de vingt ans et sont de plus en plus courants en tant que méthode très efficace pour améliorer la densité et la performance des joints. Des études indépendantes ont montré que l'utilisation de réchauffeurs de joints réduit les vides d'air en place et la perméabilité, et améliore finalement la liaison, ce qui entraîne une durabilité plus longue. La ville de Hamilton a spécifié l'utilisation d'appareils de chauffage à infrarouges depuis 2007 lorsque le maintien d'un joint chaud n'est pas viable. En Alaska, le radar à pénétration de sol (GPR) est évalué en conjonction avec des chauffe-joints pour vérifier la densité des joints.

Cet article fournira un examen approfondi des problèmes de construction associés à la construction de joints longitudinaux. L'examen comprendra l'utilisation actuelle des radiateurs à infrarouges, les spécifications associées ainsi que les améliorations de performances observées.

1.0 INTRODUCTION

The problem with poor performance of the longitudinal joint is typically related to the cold joint and/or lack of compaction of the unconfined edge of pavement. It has generally been accepted that the requirements for joint compaction are typically 1.5 to 2.0 percent lower than the main lane requirement and often specified. However, this requirement is generally not met, and the in-place air voids are much higher than desired or expected. The noted compaction problems can be largely controlled through proper construction techniques and equipment. These concerns highlight the need to 'raise the bar' with respect to improving joint density and the implementation of joint density specifications.

The longitudinal or construction joint is the edge between two separate passes of the paver; typically, the first pass is generally unconfined during compaction and regularly becomes 'cold', while the second pass is placed hot and usually well confined by the first pass. The first pass (or the unconfined edge) generally leaves an area of low density along the edge of the mat. The challenges of good joint construction are depicted in Figure 1.

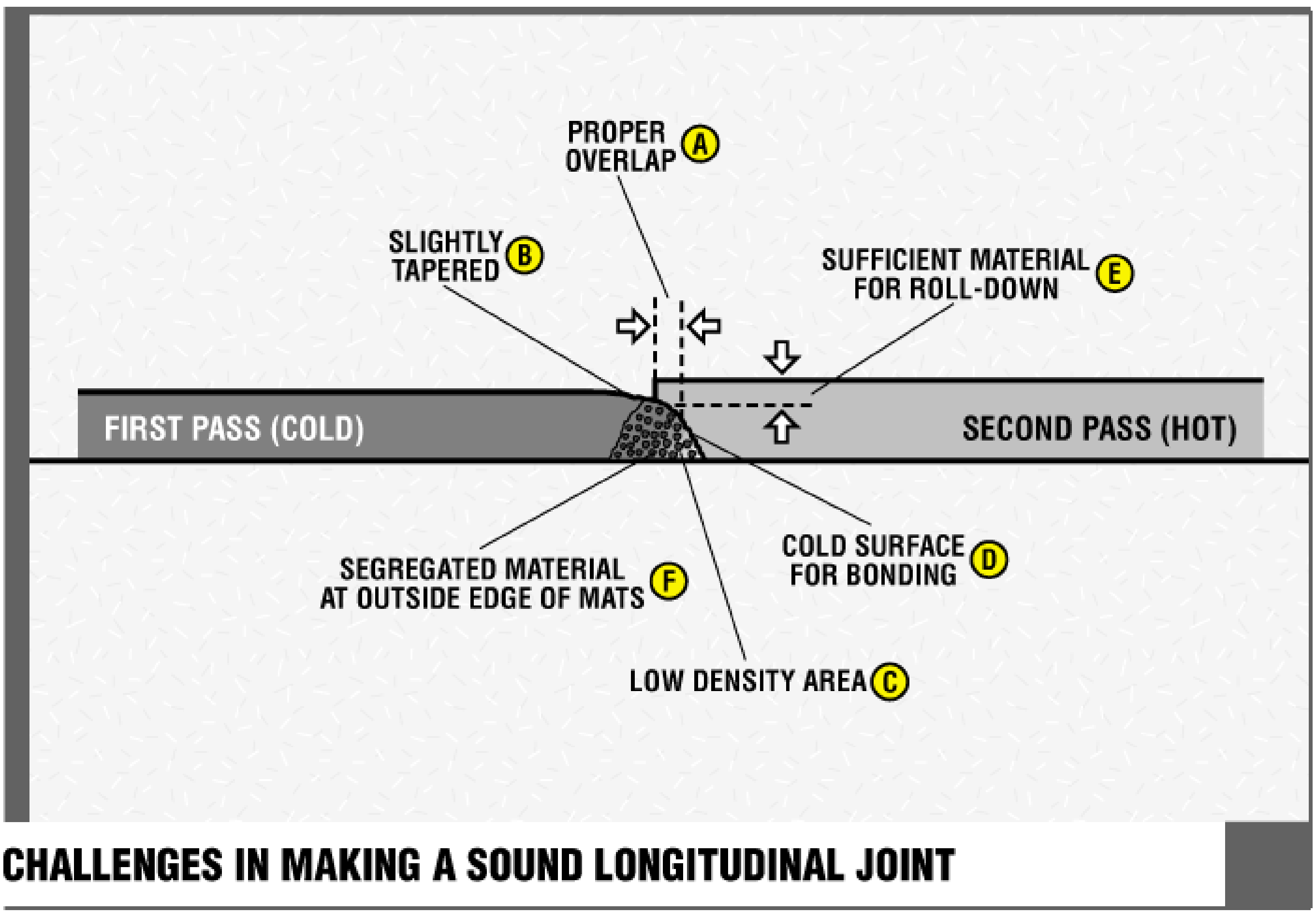

Figure 1. ASTEC Technical Bulletin 130

Longitudinal joints that are not constructed properly tend to fail prematurely generally resulting in cracking and loss of mix or raveling and eventually potholes. Properly constructed joints on the other hand provide the desired long-term performance, which results in lower maintenance and rehabilitation costs. The following photographs (Figure 2) show the contrast between poor performing and well-constructed (i.e., good performing joints).

Figure 2. Contrast Between Poorly-Constructed (left) and Well-Constructed (right) Longitudinal Joint

2.0 IMPORTANCE OF COMPACTION

It is well known that good compaction is critical to ensure long-term pavement performance. One of the key factors affecting joint performance is generally insufficient compaction or low density (i.e., high air voids). Low density or high in-place air voids can lead to numerous distresses (e.g., ravelling, moisture damage, cracking etc.), reduced fatigue life, and accelerated ageing; resulting in raveling and moisture damage. Achieving the proper density or good compaction is essential. Generally, in-place air voids greater than 7 percent results in inter-connected interstitial voids in the pavement that exacerbate the ingress of water and air. This affects the overall durability of the longitudinal joint. Essentially, the joint 'opens-up' prematurely and becomes the inherent weak spot in the pavement. It is estimated that every 1 percent increase in air voids from the target in-place air voids of 7 percent (i.e. 93 percent compaction) can lead to 10 percent decrease in the life of the pavement [1, 2]. These findings have been reported and validated by the Asphalt Institute and NCAT over the years.

3.0 LONGITUDINAL JOINT RESEARCH

The National Center for Asphalt Technology (NCAT) started evaluating longitudinal joint construction in the early 1990's. One of the first studies completed and reported by NCAT was in 1996. Seven different longitudinal joint construction techniques were used on Interstate 25 in Colorado in 1994 [3]. Various techniques were studied including different rolling procedures, the use of cutting wheel, and rubberized joint tack coat. In about the same time a similar study was also undertaken in Pennsylvania on I-79; this study included the use of the New Jersey type wedge joint. These early studies indicated the 3:1 taper or wedge joint and rolling the joint from the hot side provided better densities. Various other significant studies were reported in 2002 also by NCAT [4, 5].

The notched wedge joint consists of joint taper placed on the first pass of the mat as shown in Figure 3 [3]. A paver attachment on the screed forms the mat edge into a tapered section (Figure 4) that is about 0.3 m (1 ft.) from the edge and the notch depth relates to the nominal maximum aggregate size of the mix. The second or hot pass overlaps the cold mat notch by about 12.5 to 25 mm (0.5 to 1 inch) and is bumped back to the notch to ensure enough material at the notch for adequate compaction. The notched wedge joint also provides more surface area to properly tack the joint to ensure good bond at the joint.

Figure 3. Notched Wedge Joint Attachment [3]

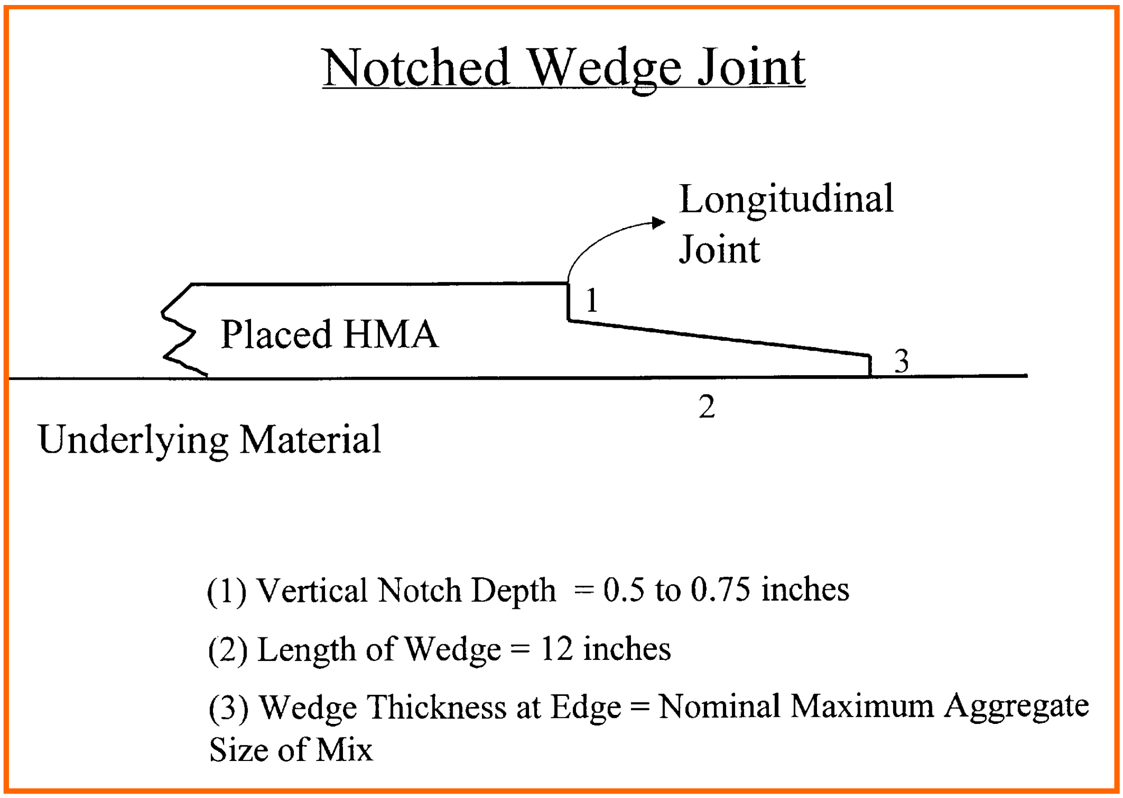

Figure 4. Details of the Notched Wedge Joint [4]

In addition, the notched wedge joint provides a safe ramp for traffic transition between the cold lane and the yet unpaved portions of the hot lane. Other techniques such as cutting wheels, joint makers and edge restraining devices have also been used over the years to improve joint density to varying degrees of success.

The Tennessee Department of Transportation (TN DOT) conducted a similar study in 2009 to evaluate various methods to construct longitudinal joints. The key findings of the study are presented in Figures 5 and 6. Based on this study the use of the infrared joint heater provided better overall density (i.e., lowest air voids) and the lowest permeability [6]. A similar study conducted in Alabama validated the TN DOT findings.

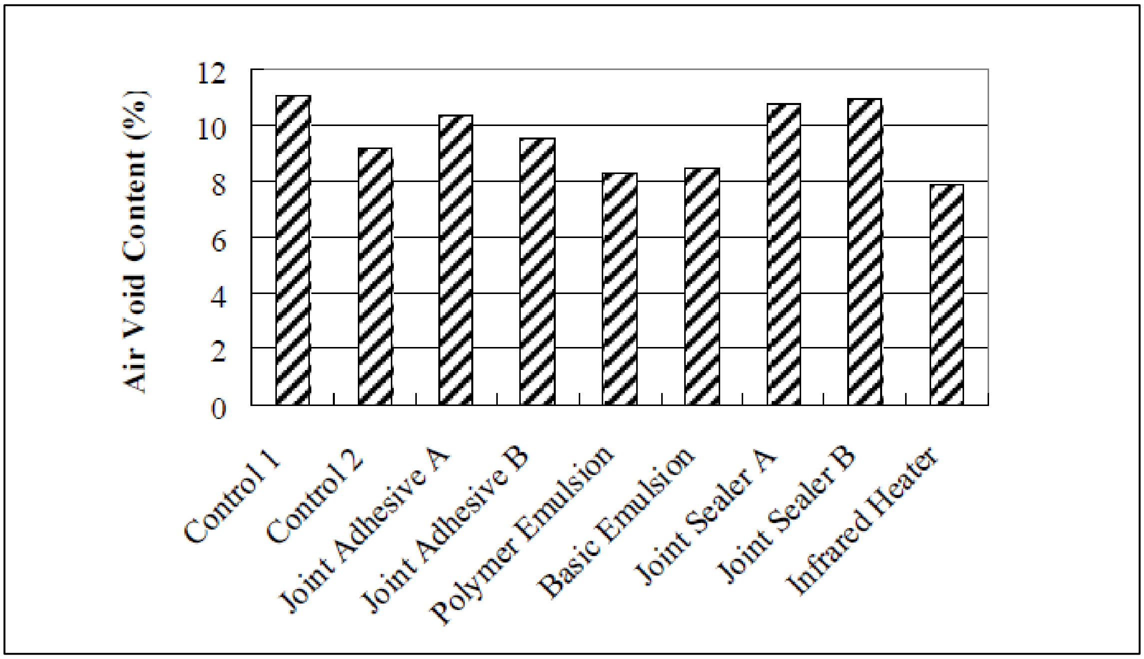

Figure 5. Tennessee DOT [6] Study Air Voids

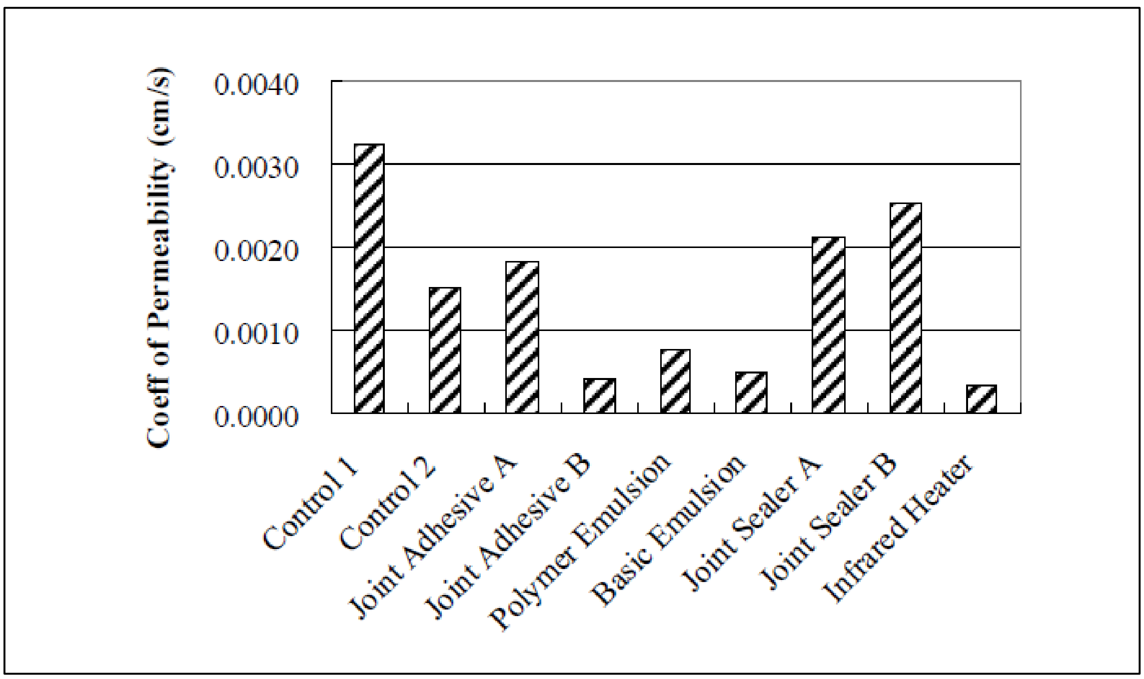

Figure 6. Tennessee DOT [6] Study on Joint Permeability

The Authors [6] stated the following conclusions:

"The infrared heater exhibited the best performance among all the joint construction techniques used in the study. The infrared heater was effective in reducing air void content and water permeability and increasing IDT strength. The air voids distribution obtained from the X-ray CT images shows that the effectiveness of infrared heater in improving joint quality was through increasing the compaction degree of longitudinal joint deep to the overlay bottom and thus making the joint denser."

4.0 JOINT CONSTRUCTION – BEST PRACTICES

It is often difficult for knowledgeable practitioners to agree on the best way to construct and compact the longitudinal joint. One thing that most agree on is the need to specify joint density. In reality it may be that a combination of several different techniques are required to construct quality longitudinal joints.

The answer to good longitudinal joint construction requires several aspects of the paving operation. Often the best method of providing good longitudinal performance is to eliminate the joint entirely. This can be done by paving the road in a single pass if possible. With the advent of new pavers this has become more common approach if traffic staging during construction permits this option and traffic safety is not compromised. This is a good option for new construction projects that are constructed away from traffic.

The most common method and often touted as the best method is to pave two or multiple lanes in echelon as shown in Figure 7. This method provides a hot joint between the two passes and facilitates good compaction. The best practices include good workmanship by the paving crew, for instance paving in a straight line and providing proper overlap of 25 mm ensures adequate material at the joint which will generally result in better compaction and a better joint. The paving crew must also be careful with handwork; the joint is typically set-up and 'bumped' back with a lute to provide a good joint. If the mix is back cast this usually results in the appearance of segregation or coarse surface texture, which does not perform properly.

Figure 7. Echelon Paving

There seems to be some consensus that rolling the joint from the hot side with a 150 mm (6 inch) offset from the joint is one of the best methods of compacting the joint. The first roller pass is usually made in the vibratory mode with the entire roller wheel on the hot lane and about 150 mm (6 inches) from the joint. This method pushes the material between the roller and joint towards the joint during the initial roller pass, which crowds the mix at the joint producing a higher density [4, 5]. This method is particularly recommended by some asphalt paving technologists for tender mix or thick lifts, which have the potential for the mix to be readily pushed towards the joint [4, 5].

5.0 GOOD BOND IS IMPORTANT

Proper bond between the first and second passes is essential to ensure long lasting joint performance. Sometimes longitudinal joints fail because the hot and cold sides are not adequately bonded. A tack coat is typically applied to the cold side before paving the hot side to promote good bonding at the longitudinal edge of the mat. There are also proprietary products (e.g., rubberized asphalt tack coat) on the market to seal the joint to improve the bond.

Heating the cold side while placing the hot side using an infrared heater has also become a viable option to promote good joint bond, in addition to improving density and permeability at the joint.

6.0 INFRARED TECHNOLOGY FOR PATCH REPAIR

The Hot in Place Patch Repair (HIPPR) technique uses infrared technology to heat and remix existing distressed asphaltic concrete. The infrared process works by using propane mixed with air to increase heat. In turn, this extreme heat is absorbed by a patented ceramic blanket that, when heated, emits approximately 18,500 BTUs per square foot. In less than ten minutes the blanket can heat the asphalt to approximately 175°C (350°F) up to 60 mm (2.5") deep (i.e., typical full thickness of the wearing course) over an area as large as 9.5 m^2 (102 square feet). Deeper heat penetration may be achieved with additional time (ten-minute heating cycles).

The indirect infrared heat will not burn the asphalt as it progressively heats the surface and the heat penetrates deep into the mix. The result is asphalt that is equivalent to plant mix. In most cases, additional mix is added from a heated hot box to bring the grade of the patch to the proper height. The area is then compacted to form a seamless patch [9].

7.0 INFRARED JOINT HEATER

As discussed previously, early joint deterioration leads to costly repairs and replacement of centerline/lane edge longitudinal joints.

Recognizing that reheating the cold & uncompacted edge immediately before the second paver pass could improve in-place joint density, Heat Design Equipment Inc. (HDE) developed a paver attached longitudinal joint heater. HDE infrared joint heaters are currently being used in various parts of the US and Canada. The list of projects completed continues to grow from Florida to Alaska in the USA and from Newfoundland to British Columbia in Canada. HDE joint heaters have been used on major highways including I-40 in Tennessee and Highways 401 and 402 in Ontario, on several major Army airbases including Fort Drum in New York and Fort Stewart in Georgia, as well as international airports e.g., Halifax. The first airport project was in Quebec City in 1996.

The infrared joint heater works on the same principle as the infrared patcher. The heater is attached to the paver as shown in Figure 8 [9].

HDE uses a vaporizer to ensure a consistent pressure of propane to the system at temperatures down to -25°C (-15°F). The liquid propane, which is drawn from the bottom of a standard LPG cylinder, is heated in the vaporizer and converted to gas. Using a vaporizer empties the tanks completely without any “freeze up,” which is the most common problem among any vapor system. This happens because the heating system draws more vapor propane than the tank can naturally produce. More importantly, the vaporizer ensures a constant pressure to the infrared heater ensuring uniform consistent heat throughout the day as the tank empties. The vaporizers are used on all joint heaters and all asphalt patchers larger than 36 square feet. The HDE mini heaters operate on 20-to-40-pound vapor draw cylinders.

HDE joint heaters are designed to be expanded depending on paving requirements. Slower paver speeds may require an HDE 300-PA, within 10 minutes it can be changed into a HDE 500-PA for highway paving. After the initial installation, the JMH-PA can be attached to any brand of paver within 10 minutes, as all electrical and propane connections are quick connect.

Figure 8. Heat Design Infrared Joint Heater

Each unit is pre-wired for electronic ignition and both manual and automatic modes. When operating on automatic, the heater will switch from operating pressure (35 psi) to low pressure (5 - 10 psi). If there is a delay in the paving operation and paving is stopped, the unit will switch to low and heat the joint slowly without burning the mix. When the paving operation resumes, the heat will switch to operating pressure. The heating width can be adjusted based on paving width by sliding the heater along the 50 mm (2") chrome shaft.

The HDE JMH can also be used for longitudinal joint repair to ensure a better watertight joint and prevent accelerated deterioration. It is particularly cost effective when the joint has widened to such an extent, that joint filler will not stay, or when the cracks have spread to the adjacent joint. By reheating the asphalt, it can be reworked and new asphalt can then be added to fill in any voids in the pavement. This process creates a lasting seamless repair. One of the early and most important joint repair projects was fixing 1000 feet of unacceptable joint on Pennsylvania Avenue using a trailer mounted joint heater (Figure 9) in front of the White House, Washington D.C. The work was done under review and acceptance by the Federal Highway Administration.

Figure 9. Trailer Mounted Joint Heater used for Pennsylvania Avenue Joint Repair [9]

8.0 ALASKA DOT EXPERIENCE

The Alaska DOT has employed a density specification since 2017 with excellent success. A summary of the 2017 data is presented in Table 1 [8].

The results clearly show that improved joint density (as increased compaction) is not only achievable, but the compaction is typically as good as the main lane. Contractors are achieving this using the HDE paver attached infrared joint heater.

Table 1. Alaska DOT 2017 Compaction Summary

Compaction Summary - 2017 Data		
	% Compaction	
	Bulk/MSG	Bulk/MSG
	Panel	Joint
SB-L1 Average Panel Density (20 Cores)	94.8	
NB-L1 Average Panel Density (17 Cores)	95.4	
SB-L2 Average Panel and Joint Densities (33 Cores)	94.9	94.1
SB-L3 Average Panel and Joint Densities (3 Cores)	95.5	93.4
NB-L2 Average Panel and Joint Densities (28 Cores)	94.7	95.0
Project Averages	**94.9**	**94.5**
Max	97.6	97.8
Min	92.3	90.9
Note:		
50 of 101 (50%) of Panel Cores 95.0% or Higher		
26 of 64 (41%) of Joint Cores 95.0% or Higher		

Work to evaluate joint compaction and improve the overall performance in 2021 continues. The Alaska DOT first started using Intelligent Compaction (IC) at the Sitka Airport in 2013. Various demonstration projects were completed and in 2016 the PaveIR was specified on the Glenn Highway-Hiland to Eklutna [8]. The first demonstration of PaveScan Rolling Density Meter (RDM) was performed on the same project in September 2016.

The PaveScan RDM provides approximately 10 Dielectric readings per foot of travel at 4 mph walking speed per antenna generated from 400,000 pulses per second processed with Equivalent Time Sampling to produce 60 scans (dielectric readings). A photograph of the PaveScan RDM is shown in Figure 10. A plot of the percent compaction versus the dielectric readings is presented in Figure 11 based on the Alaska DOT research.

The current Alaska DOT specification requires a minimum joint compaction of 92 percent based on the maximum theoretical density. The joint density bonus increases linearly from 92.0 to 96.0 percent in 0.1 percent increments. A full bonus of 5 percent ($2.00/ft.) is achieved at 96 percent compaction. Joint sealant is required for all sections with lower than 92 percent compaction, including bridge decks [8].

Figure 10. PaveScan Unit measuring Joint and Mainlane Percent Compaction [8]

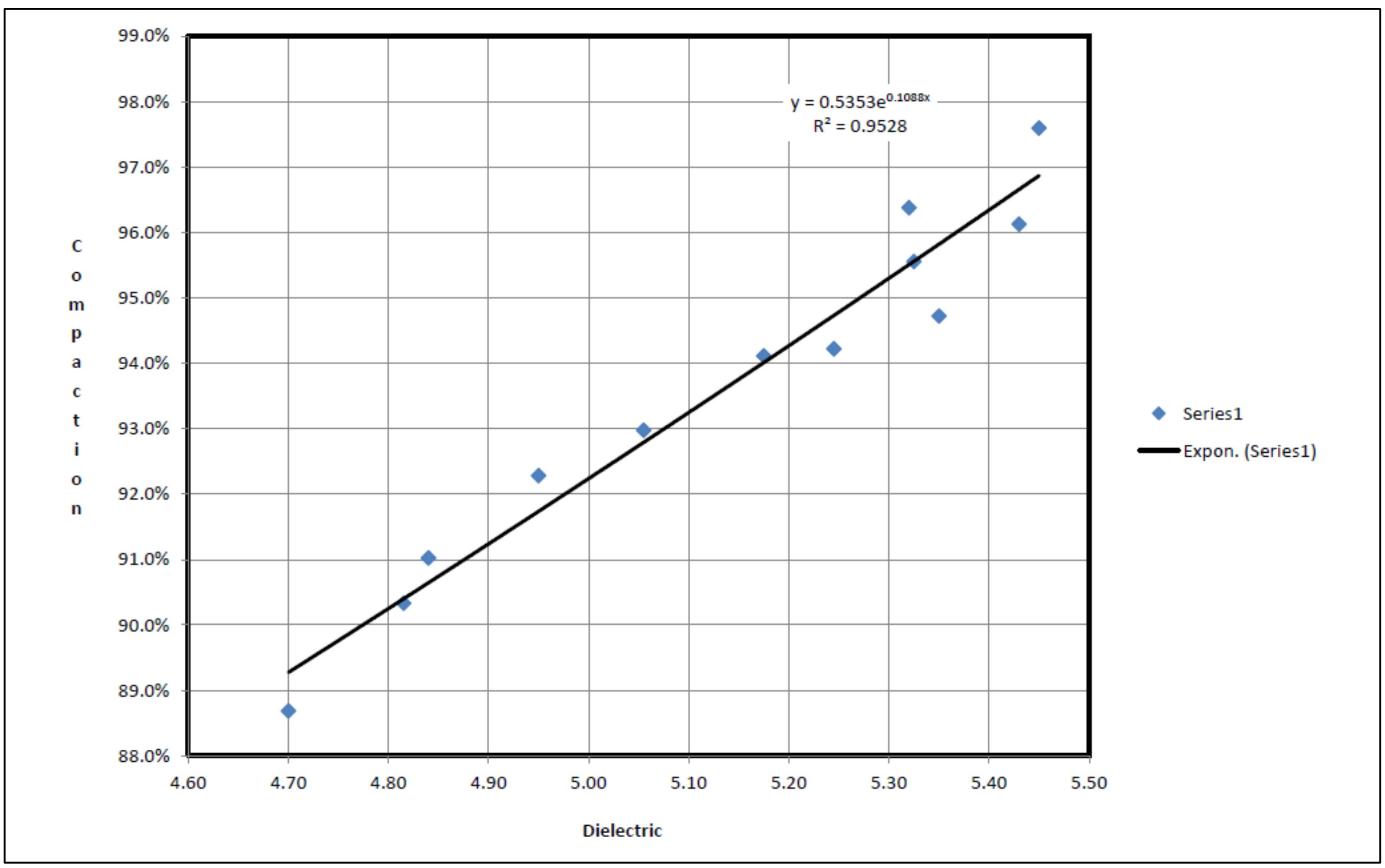

Figure 11. Plot showing Percent Compaction vs. Dielectric Reading [8]

9.0 USE OF INFRARED JOINT HEATER IN ONTARIO

9.1 City of Hamilton

The City of Hamilton has been using infrared joint heaters since 2007 for low volume urban projects and high-volume urban projects that are not accessible for echelon paving. The use of joint heaters allows for paving with one paver but ensuring that the longitudinal joint is hot when the paver places the second lane of HMA.

Quality assurance testing results clearly indicate that the compaction achieved at these joints is the same or very close to the compaction in the middle of the mat [7].

9.2 MTO Special Provisions

The Ministry of Transportation of Ontario (MTO) continues to evaluate joint density specifications. In West Region, the MTO specifies the use of infrared joint heaters by a Non-Standard Special Provision (NSSP), which has been used on most contracts for several years.

The MTO is also exploring different ways of measuring the density at the joint; for instance, the latest 'trials' include coring on the joint itself to measure the percent compaction. The NSSP also includes the End Result Specification (ERS) for joint density based on a lower limit of 1.5 percent lower than the main-lane compaction, where the lower limit is 90.5 percent. Cores where typically obtained on the confined and unconfined edges staggered and offset by 150 mm from the joint. The specification was phase-in over a three-year period and is now part of the ERS for acceptance of HMA on MTO contracts. The trials with coring on the joint continue in 2021; discussion is underway to evaluate and compare joint density using the infrared joint heater as well as PaveScan (GPR) to verify compaction. The Ontario specifications are commonly based on meeting temperature requirements and do not permit over-heating the mat.

Figure 12. HDE Infrared Joint Heater Attached to the Paver [9]

10.0 CONCLUSIONS

Several longitudinal joint compaction techniques have been suggested to increase density and provide the proper confinement to improve joint construction. It is essential that owner agencies (provincial and municipal) develop and implement compaction requirements for longitudinal joints. Improved joint densities result in longer lasting, more durable pavements. It is therefore reasonable to believe that this leads to less maintenance and rehabilitation and ultimately lower life cycle costs.

The use of infrared joint heaters is effective in providing lower air voids and permeability and should be considered in the construction of long-lasting durable longitudinal joints. HDE has designed a joint heater that provides uniform effective heating to promote improved bonding and joint density. The feedback by owner agencies and paving contractors is very positive with respect to the cost effectiveness of the infrared joint heater compared to paving in echelon. Various highway departments have clearly shown that higher pavement density (lower air voids) is achievable. In some cases, the percent compaction is trending towards the main-lane compaction. The specification that offers incentives and disincentives for joint density appear to be the most effective in achieving improved density and promoting innovation.

REFERENCES

[1] Aurilio V, Raymond C. "The Development of End Result Specifications for Pavement Compaction", Transportation Research Record No. 1491, Construction, Specifications and Management, Transportation Research Board, National Research Council, National Academies, Washington, D.C., pp 11-17 (1994).

[2] Linden RN, Mahoney JP, Jackson NC. "Effect of Compaction on Asphalt Concrete Performance", Transportation Research Record No. 1217, Asphalt Construction, Premature Rutting, and Surface Friction Courses, Transportation Research Board, National Research Council, National Academies, Washington, D.C., pp 20-28 (1989).

[3] National Asphalt Pavement Association (NAPA). Building the Notched Wedge Joint, TAS-126, Lanham, Maryland (1998).

[4] Kandhal PS, Mallick RB. "A Study of Longitudinal Joint Construction Techniques in HMA Pavements (Interim Report – Colorado Project)", Report No. 96-03, National Center for Asphalt Technology (NCAT), Auburn, Alabama (1996).

[5] Kandhal PS, Ramirez TL, Ingram PM. "Evaluation of Eight Longitudinal Joint Construction Techniques for Asphalt Pavements in Pennsylvania", Report No. 02-03, National Center for Asphalt Technology (NCAT), Auburn, Alabama (2002).

[6] Huang B, Shu X, Chen J, Woods M. "Evaluation of Longitudinal Joint Construction Techniques for Asphalt Pavements in Tennessee", Journal of Materials in Civil Engineering, 22 (11), pp 1112-1121 (2010).

[7] Uzarowski L, Moore G, Halloran M, Henderson V. "Construction of Durable Longitudinal Joints – The Courage to Use Innovations Pays Off", Presented at the Vancouver, British Columbia Conference, Transportation Association of Canada (2009).

[8] Searcy R, Giessel R. "Mapping Asphalt Compaction with 2.5 Million Tests in 22 Nights on the Glenn Hwy", Presented at the Alaska Asphalt Summit, Anchorage, Alaska (2017).

[9] Heat Design Equipment Inc. https://www.asphaltheater.com (2021).