Construction of Durable Longitudinal Joints – The Courage to Use Innovations Pays Off

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ABSTRACT

Poorly constructed longitudinal joints will likely lead to joint opening, cracking and ravelling. There are a number of factors that should be considered for cold joint construction that may impact its durability. They include the shape of the unsupported edge, the amount of overlap, the method of raking and compaction of the mix at the joint. However, the best way of avoiding future issues with cold joints is to eliminate them by using hot joints.

The City of Hamilton has decided to use innovative paving technology to address the joint quality issues. Wherever possible, the City uses hot joints by specifying echelon paving. When feasible, particularly on major paving projects, the City requires the use of Shuttle Buggy® materials transfer vehicle (MTV) in order to eliminate thermal and gradation segregation. Wherever the use of echelon paving is not practical, the City has started using infrared joint heaters. 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.

Also, the new warm asphalt technology is now being implemented by the City. Lowering the mix temperature results in reduced aging of asphalt binder, reduced fumes and odours and other environmental benefits. An ongoing study in the City shows that the quality of longitudinal joints in warm asphalt paving is better than in conventional HMA paving; the joints were tight and better compaction and lower permeability can be achieved.

The Region of Waterloo has been paving rural projects in echelon also using a Shuttle Buggy® MTV since 2006. To date more than 50 projects have been placed using this method, none of which have required any centreline/longitudinal joint repairs.

This paper describes practical aspects of the applied technology and shows photos of construction and the results obtained in the field. The results show that the courage to implement the innovative technology in joint construction pays off and the quality of longitudinal joints is significantly improved. This should reflect in better long term performance of asphalt pavements in the City of Hamilton and the Region of Waterloo.

1.0 INTRODUCTION

The majority of surface distresses observed in asphalt pavements are related to one of the following three major issues: insufficient compaction of the pavement mat; poor compaction of longitudinal joints; and segregation. Poorly compacted longitudinal joints result in joint cracking, opening and ravelling. This leads to severe erosion of the mix at the joints creating a gap between traffic lanes, poor rideability and general acceleration of pavement wear and perception of failure by the public.

There are a number of factors that should be considered for cold joint construction that may impact its durability. They include the shape of the unsupported edge, the amount of overlap, the method of raking and compaction of the mix at the joint. However, the best way of avoiding future issues with cold joints is to eliminate them and using hot joints.

2.0 LONGITUDINAL JOINT CONSTRUCTION METHODS

Conventional longitudinal cold joint construction methods often lead to the joint being the weakest portion of a hot-mix asphalt (HMA) pavement. Due to the weak joint structure, the pavement is more likely to form distresses and exhibit poor performance. The weakness and poor performance in this area will eventually expand throughout the remainder of the pavement surface, producing a pavement with poor rideability and failure under the perception of the public [1].

The City of Hamilton and the Region of Waterloo, both in southwestern Ontario, are integrating the use of various innovative joint construction techniques to avoid using cold joints with HMA. The City of Hamilton has used three joint construction methods since 2007 to produce better quality joints in urban projects. These methods include: paving in echelon (with and without MTV); reheating joints using infrared joint heaters; and placing warm mix asphalt (WMA) rather than conventional HMA. Paving in echelon is carried out on larger urban roads while the joint heater is used on lower volume urban roads. The joint heaters are also used in applications on high volume roads where echelon paving is not feasible, such as bridges and low traffic circles.

The Region of Waterloo has been paving rural projects in echelon with an MTV since 2006. To date more than 50 projects have been placed using this method, none of which have required any centreline repairs.

2.1 Echelon Paving

The City of Hamilton has been using echelon paving for high traffic urban projects since 2007. When the projects are paved in echelon, each paver is supplied with HMA by a different truck and the pavers remain within typically not more that 10 m of each other. The short distance between the pavers ensures that the joint is hot when the second paver places HMA adjacent to it. However, in some cases the distance can be longer, even as long as one block. If the distance is longer, the mix temperature is checked regularly in order to make sure that it does not drop below a minimum of 100°C, the limit for a hot joint. Photograph 1 shows echelon paving on Garth Street in Hamilton in 2008.

Photograph 1   Echelon paving on Garth Street in Hamilton in 2008.

2.2 Echelon Paving with MTV

Although, the City of Hamilton uses mainly echelon paving or joint heaters on the majority of their paving projects, echelon paving with a Shuttle Buggy® MTV is used by the City on major paving projects where designed traffic loadings are very high. It is considered critical that the joints on these projects are constructed to the highest quality and that no future joint maintenance or repairs are necessary. One of such location was the perpetual pavement placed on the Red Hill Valley Parkway (RHVP) in Hamilton in 2007. Recently purchased by the City infrared cameras allow careful monitoring of the temperature distribution in the asphalt mat at the paving and compaction stages. Photograph 2 shows the echelon paving with Shuttle Buggy® MTV on the RHVP. More information on this joint construction is given in Section 3.0, Case Studies.

Photograph 2 Echelon paving with Shuttle Buggy® MTV on the RHVP in Hamilton in 2007.

The Region of Waterloo uses echelon paving with a MTV on all rural projects when possible. The ideal situation would be to use this method on every rural project; however, the ability to do so is limited by the short summer paving season. While a road is being paved in echelon with a MTV, the road must be closed for use for one to two days. The road is not entirely closed for property access; however, public may not use the road until the mat has been sufficiently compacted, at which time the public is able to access properties adjacent to the paving project. The paving season is limited by the Canadian climate but for echelon paving with a MTV, it is also restricted by the school year. Most children in the Region of Waterloo, like most of Canada are transported to elementary and high school by bus in rural communities. In the Region of Waterloo, contractors cannot use echelon paving with a MTV during the school season (September to June) due to the challenges and inconveniences to bus routes and scheduling.

During construction, one MTV is capable of supplying two pavers with continuous asphalt so that paving does not have to be interrupted at any point. All benefits associated with using a MTV in any paving situation also apply to echelon paving projects. These benefits include the continual mixing of the HMA which greatly reduces segregation in the mix and the smooth road surface that is produced by continual paving. The cost of using a MTV is minimal in comparison to the entire project cost and is determined on a per tonne of HMA rate (typically $2.00 per tonne).

Although the road is closed to the user for one to two days during projects paved in echelon with a MTV the benefit to the owner and user significantly outweigh this challenge. The Region of Waterloo has experienced excellent joint performance to date on these projects and none of which have required any joint maintenance. Paving in echelon with a MTV removes the centreline joints and the pavement therefore has better performance than when cold joints are present. The good performance of the centreline of the pavement eliminates the need for regular joint maintenance which is a savings for the owner. The elimination of joint maintenance also reduces user costs that would generally include time due to delays during construction and expenses due to vehicle maintenance related to poor rideability and surface condition.

Echelon paving with a MTV increases the safety of the construction crew and road users as the road is closed to traffic during construction. The safety of the construction crew is greatly increased by eliminating the traffic in the work zone and this in return allows the crew to be more productive and they are able to place more HMA daily. Road users not only put construction crews in danger in work zones they also significantly increase the probability of vehicle accidents. Construction zones generally have stops and lowered speeds that are not common to the road which can result in accidents if drivers are distracted. Head on collisions make up one third of all collisions in work zones in Canada while rear end collisions are the second greatest including almost 20 percent of all collisions. In Ontario 77 percent of fatal work zone accidents occur on rural roads in comparison to urban roads and 78 percent happen on undivided roads versus divided roads [2]. Safety of road users and construction crews is a paramount concern and is an added benefit of echelon paving with a MTV.

2.3 Paving with Joint Heaters

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. Photograph 3 shows an infrared joint heater used on paving projects in Hamilton in 2008.

Photograph 3 Infrared joint heater used on paving projects in Hamilton in 2008.

The effectiveness of the joint heater in raising the temperature of the joint may be somewhat affected by the weather conditions as high wind conditions can limit the abilities of the heater.

2.4 Warm Mix Asphalt

The new warm mix asphalt (WMA) technology is now being implemented by the City of Hamilton. Lowering the mix temperature results in reduced aging of asphalt binder, reduced fumes and odours and other environmental benefits. An ongoing study that involves the City of Hamilton, Centre for Pavement and Transportation Technology (CPATT), McAsphalt Industries and King Paving Ltd. shows that the quality of longitudinal joints in WMA paving may be better than in conventional HMA paving; the joints appeared tight and higher compaction could be achieved. The study is described in a technical paper [3] presented at the CTAA 2008 conference in Saskatoon. WMA may produce a tighter joint as the temperature differential for continuous paving is reduced. The heat loss associated with WMA is less, which makes it more versatile during various weather conditions. The permeability testing at the joints conducted under the study indicated that permeability of the WMA is generally less than the permeability of conventional hot-mix asphalt (HMA).

2.5 Cold Joints

Cold joints are still used by other agencies on the majority of paving projects in Ontario and Canada at large. The rules of constructing cold joints are generally known although they are still subject to number of studies [4 to 11]. Unfortunately these rules are not always followed, although "… Using the proper construction techniques, the cost of building a durable longitudinal joint is no more expensive than building a poor longitudinal joint." [4]. The main problem with longitudinal cold joints is low compaction and therefore high air voids at the joint mainly due to the presence of uncompacted material in Lane 1 as shown in Figure 1 and Photograph 4. The density at that area can be as low as 80 percent. Two cases of poorly constructed longitudinal joints are presented in Section 3.0, Case Studies.

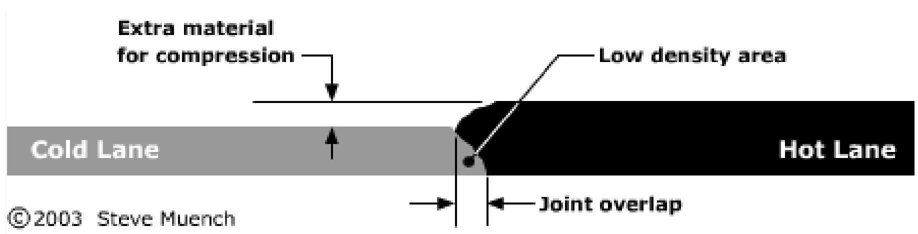


Figure 1 Low density area in cold longitudinal joint.

Photograph 4 Low density area in cold longitudinal joint.

The general rules of cold longitudinal joint construction are [4]:

- Specify and measure joint density – the density of the mix at the longitudinal joint should be within 1.5 percent (maximum 2.0 percent) of the mainline mat density;
- Compaction of the first lane – the drum of the roller should extend over the edge of the lane by approximately 150 mm to prevent the cracking along the edge and somewhat increase the density of the material at the edge;
- Overlap of the mix from Lane 2 to Lane 1 – the amount of transverse overlap should be in the range of 25 mm to maximum 40 mm (on cut joints, the overlap should be about 10 mm to 15 mm);
- Raking the longitudinal joint – if the proper amount of mix is placed in the right place, no raking is necessary; and
- Compaction of the longitudinal joint – start the compaction from the hot site positioning the drum of the wheel of a pneumatic tire roller a short distance over the top of the joint. It should be noted that the National Center for Asphalt Technology (NCAT) reports [5] that much better results were achieved when rolling from the hot side with the edge of the roller about 150 mm from the joint on the hot side during the first pass in vibratory mode and then the second pass overlapping the cold side by about 150 mm.

The conventional method of compacting longitudinal joints from the cold side with the drum on Lane 1 with only 150 mm to 300 mm extending over the joint and over Lane 2 is very inefficient and will likely lead to deficient densites at the joint and then joint cracking and ravelling in the future.

Other methods of longitudinal joint construction including joint makers, cutting wheels, rubberized joint material, edge retaining devices, wedged joints and different patterns of compaction are described in NCAT report 02-03 [5]. Of those methods, applying a rubberized joint material or using a cutting wheel to remove the uncompacted material in Lane 1 are considered the most effective.

3.0 CASE STUDIES

Both the City of Hamilton and the Region of Waterloo have placed many projects throughout recent years using various hot and warm joint technologies. Examples of these projects are included below.

3.1 Echelon Paving

Jerseyville Road in Hamilton was constructed in 2007 in two portions, one with echelon paving and the second with joint heaters. The road is on the west side of Hamilton in a residential area. Photograph 5 shows the pavement condition near the centreline on the section that was paved in echelon. The pavement condition is excellent; the texture is tight with no cracks or ravelling although the path of the centreline is visible.

Compaction testing was done at the joint and in the centre of the mat and the results were 93.0 percent in both locations. The compaction results proved to be consistent across the mat.

Photograph 5 Pavement condition of Jerseyville Road paved in echelon in 2007.

3.2 Echelon Paving with MTV

The RHVP is a very busy major arterial road in Hamilton linking Lincoln Alexander Parkway with Queen Elizabeth Way (QEW). At its full capacity, the road will carry up to 90,000 vehicles per day. The perpetual pavement on the RHVP was designed for 50 years and consists of 370 mm of subbase, 150 mm of granular base, 80 mm of Rich Bottom Mix (RBM), 70 mm of Superpave 25.0 lower binder course, 50 mm of Superpave 19.0 upper binder course and 40 mm of Stone Mastic Asphalt (SMA) surface course. The project paving specifications required that the longitudinal joint compaction should be not less than 91.5 percent. The specified minimum compaction of the mat was 93.0 percent. All asphalt layers were paved in echelon using a Shuttle Buggy® MTV. The compaction requirements were met on the RHVP; tight specification required improved compaction patterns (more rollers operating close to the paver screeds, for instance). Photograph 6 shows the compacted SMA mat on the RHVP; the longitudinal joint is almost invisible.

Photograph 6 Stone Mastic Asphalt surface course placed on the Red Hill Valley Parkway in Hamilton using echelon paving with MTV in 2007.

Sawmill Road between the towns of Conestoga and Bloomingdale in the Region of Waterloo was constructed in the summer of 2007. A portion of the road was constructed using echelon paving and an MTV for the surface course and the other portion was paved using conventional cold joints. The cold joint portion was essential due to timing and inability to use the echelon and MTV system during the school year. The road is a rural arterial with portions at 80km/hr between the two towns. The traffic volume is relatively high as this is a common commute for many local residents. The surface course of Sawmill Road is a high stability HL 3 mix that was placed in 2007. The pavement is in excellent condition; the surface is tight and the joint is almost invisible. Photograph 7 shows the pavement condition at the centreline of the road. Compaction testing was carried out on site and the results indicate consistency between the joint and centre of the mat with values of 96.0 percent and 94.0 percent, respectively.

Photograph 7 Pavement condition of Sawmill Road paved in echelon with an MTV in 2007.

3.3 Paving with Joint Heaters

A joint heater was used for the placement of the Superpave 12.5 FC2 mix over milled pavement on Rymal Road in Hamilton in November 2008. Photograph 8 shows the paving operation on Rymal Road using a joint heater. Compaction of the mat ranged from 95.0 percent to 95.8 percent while the average compaction of the longitudinal joint was 94.2 percent.

Photograph 8 Placement of Superpave 12.5 FC2 surface course using infrared joint heater on Rymal Road in Hamilton in 2008.

A portion of Jerseyville Road was placed using joint heaters as echelon paving was not feasible due to road and shoulder dimensions. Photograph 9 shows the condition of the pavement in the joint heater section of Jerseyville Road.

Compaction results indicate consistency throughout the mat including at the joint. Compaction of the longitudinal joint was about 95.0 percent and mat compaction was about 94.0 percent.

Photograph 9   Pavement condition near the centreline of Jerseyville Rd paved with joint heaters.

3.4 Warm Mix Asphalt

The WMA technology was used for paving on Garth Street in Hamilton in 2008. A 40 mm thick lift of Superpave 12.5 FC2 Warm Asphalt incorporating a modified PG 64-28 asphalt cement was placed using echelon paving over a new binder course. Asphalt compaction was checked using a nuclear densometer. The compaction of the mat ranged from 93.5 percent to 96.5 percent while the compaction of the longitudinal joint generally ranged from 93.0 percent to 96.0 percent. Photograph 10 shows the placement of the WMA surface course and longitudinal joint compaction on Garth Street.

Photograph 10 Placement of warm mix asphalt Superpave 12.5 FC2 surface course and hot joint compaction on Garth Street in Hamilton in 2008.

3.5 Cold Joints

A portion of Sawmill Road was placed conventionally with cold joints and one lane at a time in 2007. Photograph 11 shows the pavement condition of this section of Sawmill Road. There were multiple cracks and small depression observed along the longitudinal joint. The cracked particles at the joint will likely soon erode and start potholes. Due to the presence of the depression, it was impossible to measure the density at the joint using a nuclear densometer.

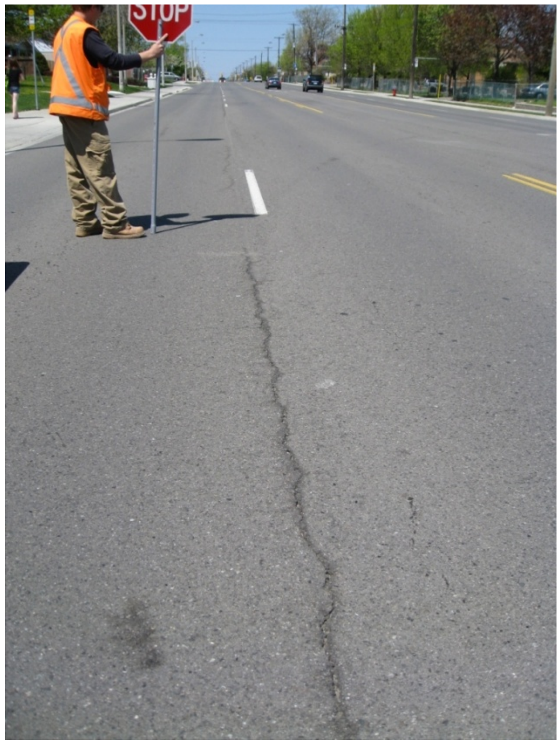
Photograph 11 Pavement condition at centreline of Sawmill Road paved with cold joints.

Mohawk Road between Upper Wentworth and Upper Sherman in Hamilton, was paved in 2007 using cold joints. Photograph 12 shows the current pavement condition of this section. The relatively new joint has already cracked. A small depression was also observed along this longitudinal joint. Due to this depression, it was impossible to measure compaction using a nuclear densometer at the joint.

4.0 CONCLUSIONS

The best way of avoiding future issues with longitudinal cold joints is to eliminate them and use hot joints. The innovative technologies include echelon paving, with and without MTV, and using joint heaters. The warm mix asphalt technology is considered promising; however, more studies are required. If a cold joint is unavoidable, the rules of proper cold joint construction should be strictly followed. It is critical that asphalt compaction at longitudinal joints is specified as in Section 2.5 and tested.

The results of this investigation show that the courage to implement the innovative technology in joint construction pays off and the quality of longitudinal joints can be significantly improved. This should reflect in better long term performance of asphalt pavements in the City of Hamilton and the Region of Waterloo.



Photograph 12 Pavement condition at centreline of Mohawk Road paved with cold joints.

REFERENCES

1. Kandhal P and Rao S, “Evaluation of Longitudinal Joint Construction Techniques for Asphalt Pavements”, Transportation Research Record No. 1469, Flexible Pavement Construction Issues, 1994.

2. Bushman R, Chan J and Berthelot C, “A Canadian Perspective on Work Zone Safety, Mobility and Current Technology”, 5th Transportation Specialty Conference of the Canadian Society for Civil Engineering, Saskatoon, Saskatchewan, June 2004.

3. Tighe S, Moore G, MacTaggart C and Davidson K, “Evaluating Warm Asphalt Technology as a Possible Tool for Resolving Longitudinal Joint Problems”, Canadian Technical Asphalt Association Proceedings, Saskatoon 2008.

4. Scherocman J, “Construction of Durable Longitudinal Joints”, Technical Report, December 2004.

5. Kandhal P, Ramirez T and Ingram P, “Evaluation of Eight Longitudinal Joint construction Techniques for Asphalt Pavement in Pennsylvania”, National Center for Asphalt Technology, NCAT, Auburn, AL, February 2002.

6. Asphalt Institute, “HMA Construction, Construction of Hot Mix Asphalt Pavements”, Manual Series No. 22 (MS-22), Second Edition.

7. Asphalt Institute, “The Asphalt Handbook”, Manual Series No. 4 (MS-4), 7th Edition, 2007.
8. Sebaaly E , Fernandez G and Hoffman B, “Evaluation of Construction Techniques for Longitudinal Joints in HMA Pavements”, Asphalt Paving Technology 2008, Journal of the Association of Asphalt Paving Technologists, Volume 77, 2008, page 143 to 182.

9. PAPA/PenDOT, Winter 2007-2008, “Best Practices for HMA Longitudinal Joint Construction”, Power Point Presentation.

10. US Army Corps of Engineers and Federal Aviation Administration, “Hot Mix Asphalt Paving Handbook”, Section 17, Joint Construction, 2000.

11. Ontario Ministry of Transportation, “Longitudinal Joint Compaction Improving Paved Lanes:, Road talk vol. 10, Issue 2, 2004.