Evaluation of Longitudinal Joint Construction Techniques for Asphalt Pavements

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Longitudinal joints are often the weakest part in a hot-mix asphalt (HMA) pavement. Common problems associated with joints are the formations of longitudinal cracks along the joints, ravelling, and widening of cracks due to subsequent ingress of water. It is believed that these problems occur when there is a substantial difference in densities on either side of the joint. Normally low densities occur at the edge of the lane paved first (cold lane). This is primarily due to the fact that the edge of the cold lane is unconfined. The subsequent lane (hot lane), however, has a confined edge and, therefore, generally has higher density. Although several longitudinal joint construction techniques are specified and practiced in different states, the relative effectiveness of these methods has not been established. There is a need to evaluate the performance of these techniques and identify the best method(s). The performance of some popularly used techniques and some recently proposed techniques are evaluated. Seven techniques were attempted in a project in Michigan, and eight techniques were attempted in a project in Wisconsin. Both projects involved a dense-graded HMA surface course overlay. Each technique was used on a 152-m (500-ft) test section. Michigan wedge joint and the cutting wheel techniques gave the highest density at the joint in the Michigan project. The cutting wheel and the edge restraining device gave the highest joint density in the Wisconsin project. Evaluation of all joints by visual inspection for at least 5 years is planned. The final rankings will be based on the long-term field performance.

Constructing effective longitudinal joints has always been a problem in multilane hot-mix asphalt (HMA) pavements. Joints represent the weakest part of the pavement and are susceptible to formation of longitudinal cracks caused by stresses induced by the low temperature and heavy vehicular traffic. It is believed that the longitudinal cracks primarily result from the density gradient that is usually encountered across the joint (*1*). This density gradient can primarily be attributed to the low density at the unconfined edge when the first lane (cold lane) is paved and a relatively high density at the confined edge when the adjacent lane (hot lane) is paved. A loss in temperature during the rolling operation may also be responsible. Generally, the joint densities are about 1 to 2 percent lower than the lane density (*1–3*). Low densities at the joint also lead to ravelling.

Another problem associated with the longitudinal joint is the vertical stepoff or height differentials caused by poor construction practices or differential settlement after crack formation. This can pose a hazard to traffic during fast lane changes. It can also lead to water ponding adjacent to joints.

Many of these problems could be eliminated by using a wide paver or by adopting the echelon paving procedure wherein two adjacent pavers are used, one slightly ahead of another. Since the lanes are paved and compacted at more or less the same temperature in the echelon paving system, joint densities are consistent with the lane densities. However, it is rarely feasible to use this method, and therefore a proper alternative should be found.

Various longitudinal joint construction techniques have been proposed, specified, and practiced in different states. This study was undertaken to evaluate seven to eight different techniques and to identify the relative effectiveness of each technique.

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PROJECT DETAILS

Two HMA paving projects were selected so that seven or eight different joint construction techniques could be tried. This was accomplished in Michigan and Wisconsin in 1992. The Michigan site, constructed in September 1992, is located on the southbound lane of Interstate 69 between the Perry and Bancroft interchanges. The Wisconsin site, constructed in October 1992, is located on State Route 190 (Capitol Drive) in Brookfield, a western suburb of Milwaukee. Both projects involved a dense-graded HMA wearing course 38 mm (1.5 in.) in thickness. The HMA mix in Michigan consisted of a gradation passing 100 and 88 percent through 12.5-mm (½-in.) and 9.5-mm (⅜-in.) sieves, respectively. The HMA mix in Wisconsin consisted of a gradation passing 100 and 97 percent through 19-mm (¾-in.) and 12.5-mm (½-in.) sieves, respectively. Each project included a series of 152-m (500-ft) test sections; a different construction technique was used for each. The mix was reasonably uniform and conformed to the respective job mix formula.

CONSTRUCTION TECHNIQUES

Eight general construction techniques were used in constructing the longitudinal joints.

A—Rolling Technique A

Rolling Technique A was a conventional overlapping procedure that involved placing the mix such that the end gate of the paver extended over the top of the lane by 25 to 38 mm (1 to 1.5 in.). The height of the uncompacted mix was about 1¼ times the compacted lift thickness to ensure a requisite amount of HMA for compaction. Raking and luting with this method are minimized. Raking was done with a view to providing extra material to be compacted by the roller on the hot lane near the joint in order to achieve higher density (Figure 1).

Compaction at the joint was done from the hot side of the lane being constructed wherein a major portion of the roller wheel remained on the hot side with about 152 mm (6 in.) overlap on the cold lane (Figure 1). This rolling technique is considered to be an efficient way to compact the longitudinal joint because a major portion of the roller weight travels on the hot lane. The mix is pushed into the joint area by the roller until a level surface is obtained. A good bond with the cold lane is normally achieved by this technique (*4,5*).

B—Rolling Technique B

The placement procedure for Rolling Technique B was the same as for Technique A; however, the rolling of the longitudinal joint differed.

Compaction at the joint was performed with a major portion of the roller wheel travelling on the cold side (previously placed lane) with about 152 mm (6 in.) of the roller wheel on the hot side of the joint (Figure 1). This procedure is believed to pinch the joint. However, since the major portion of the roller weight lies on the already compacted cold lane, much compactive effort is believed to be wasted. During the period that the roller is operated from the cold side of the joint, the hot side cools, thus causing a timing problem in the subsequent compaction.

C—Rolling Technique C

Technique C was also similar to Technique A, except that the compaction was begun with the edge of the roller about 152 mm (6 in.) away from the joint on the hot side (Figure 1).

It is believed that the HMA is laterally pushed toward the joint by this technique and subsequent rolling at the joint pinches the material into the joint, leading to high density. This technique is generally preferred when the mix is tender and in the case of relatively thick lifts. Technique C is believed to be an improvement over Technique A.

D—Wedge Joint Without Tack Coat

As mentioned earlier, a major problem faced in conventional longitudinal joints is the presence of a density gradient across the joint, which leads to the formation of longitudinal crack at the joint. To avoid this, the joint between the adjacent lane is constructed as two overlapping wedges. The wedge joint is formed by tapering the edge of the lane paved first (Figure 2). The taper is then overlapped when the subsequent adjacent lane is placed. A taper of 1:12 (vertical: horizontal) was used on both the Michigan and Wisconsin projects.

The taper was formed by attaching a steel plate to the paver screed. After the initial lane was placed and tapered to the required slope the lane was compacted with the roller, not extending more than 51 mm (2 in.) beyond the top of the unconfined edge (*6*). In Michigan the inclined unconfined face of the wedge was compacted with a small roller attached to the paver. A small roller was not available for the Wisconsin project. The inclined face was not tack-coated in this section. The adjacent lane was placed the next day.

E—Wedge Joint With Tack Coat

Technique E was similar to Technique D, except that a tack coat was applied over the unconfined, inclined face of the cold lane before the overlapping wedge was placed and compacted.

Tack coating is generally done to prevent the ingress of water and to obtain good adhesion between the lanes.

F—Restrained Edge Compaction

The restrained edge compaction technique involves use of an edge-compacting device that provides restraint at the edge of the first lane constructed. The restraining device consists of a hydraulically pow-

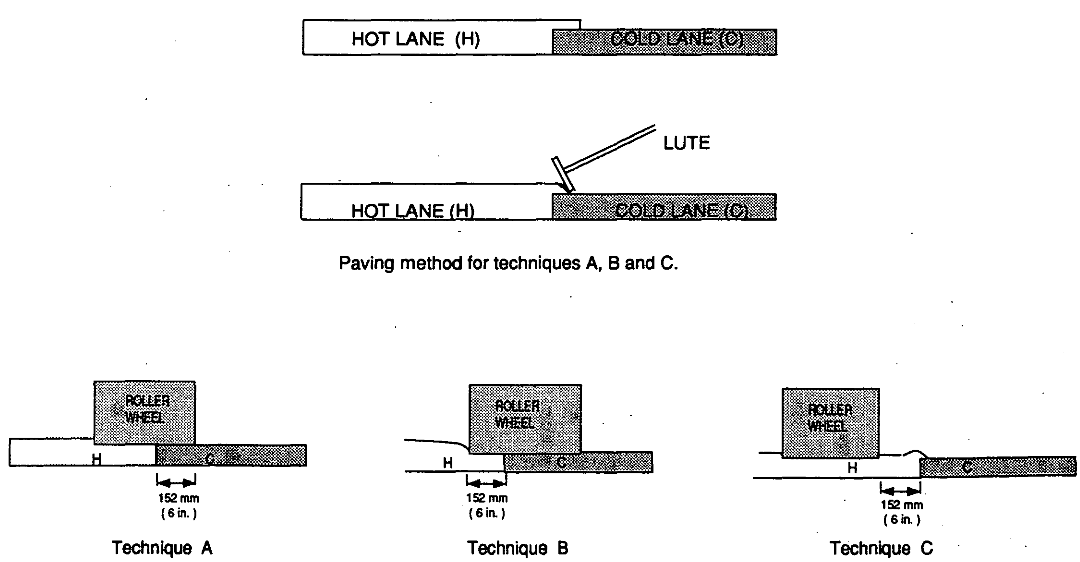

FIGURE 1 Rolling techniques A, B, and C.

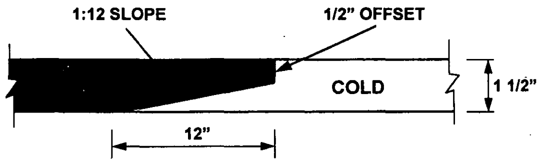

FIGURE 2 Michigan wedge joint (1:12 taper).

ered wheel (Figure 3) that rolls alongside the compactor's drum, simultaneously pinching the unconfined edge of the first lane toward the drum, providing lateral resistance (*7*). This technique is believed to increase the density of the unconfined edge.

The adjacent lane is then abutted against the initial lane edge. Compaction was performed using Technique A.

G—Cutting Wheel

The cutting wheel technique involved cutting 38 to 51 mm (1½ to 2 in.) of the unconfined, low density edge of the initial lane after compaction while the mix was still plastic. A cutting wheel 254 mm (10 in.) in diameter mounted on an intermediate roller is generally used (*7*). The cutting wheel can be also mounted on motor graders, which was the case in Michigan.

A reasonably vertical face at the edge is obtained by this process, which is then tack-coated before the placement of the abutting HMA. Compaction was performed using Technique A. This method generally results in an increase in density near the edge of the hot lane (*1,7*). Although the density gradient decreases, it has been reported that the tensile strength does not increase significantly (*1*).

H—AW-2R Joint Maker

Technique H was an automated joint construction technique and a recent innovation in joint-making technology. It consisted of a device (Figure 4) attached to the side of the screed at the corner during construction. The device forces extra material at the joint through the extrusion process before the screed. A kicker plate is attached to the side of the paver to lute back the overlapped HMA mix without the help of a lute man. It is claimed that proper use of the joint maker ensures high density and better interlocking of aggregates at the joint.

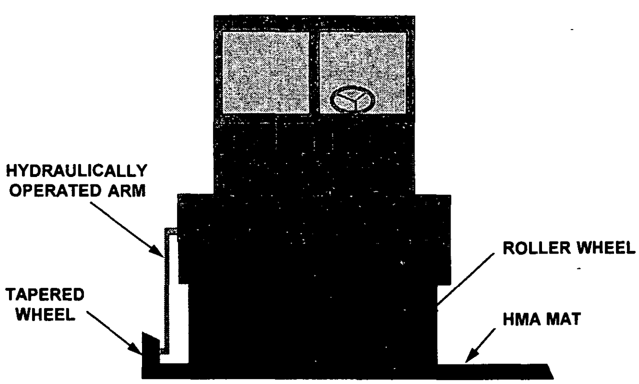

FIGURE 3 Edge-restraining device mounted on roller.

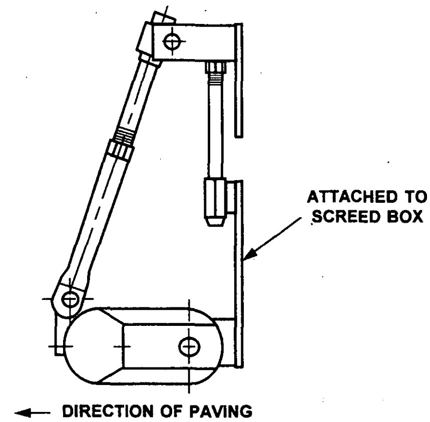

FIGURE 4 Joint maker.

CONSTRUCTION DETAILS AND DEVIATIONS

Michigan Project

A Blaw-Knox tracked PF 510 paver-finisher equipped with an extendable Omniscreed III was used for HMA paving. Compaction was accomplished using a 9-Mg (10-ton) double-drum, Hyster roller for breakdown rolling (one pass). A 13-Mg (14-ton) Ingersoll Rand roller was used (two passes) to complete the compaction. All rolling was performed in static mode. This rolling pattern had been developed by the contractor for the paving project.

It was observed during the construction operation that the 51-mm (2-in.) overlap of the hot lane when luted back had a tendency to segregate. This segregation can be attributed to the substantial amount of material (about 12 percent) passing the 12.5-mm (½-in.) sieve and retained on a 9.5-mm (⅜-in.) sieve. This segregation caused a coarse open texture near the joint (usually on the hot side) that could not be completely eliminated during compaction.

The wedge joint had a vertical offset (lip) of 13 mm (½ in.) and then a taper of 1:12, as shown in Figure 2. It is believed that with this type of wedge joint the intermediate size aggregates in the hot lane are accommodated in the stepped portion of the cold lane rather than being feathered to zero thickness, which can lead to potential ravelling.

One of the screed's detachable extensions had been modified to provide the 13-mm (½-in.) lip or offset and 1:12 taper. The modification consisted of tilting down the outer edge of the extension approximately 20 to 25 degrees with a fabricated wedge at the top of the screed for rigidity.

The restrained edge compaction device was not available for the Michigan project; therefore, Technique F could not be included.

The following temperatures were documented at the time of the construction:

- Ambient temperature: 8 to 14°C (46 to 58°F),
- Mat temperature behind the paver: 143 to 147°C (290 to 297°F),
- Mat temperature following breakdown rolling: 116°C (240°F), and
- Mat temperature following three roller passes: 91°C (195°F).

Wisconsin Project

A Blaw-Knox PF-200 paver-finisher with Omniscreed III was used for placing the mix. A Bomag BW 202 AD was used for breakdown rolling. All rolling was accomplished in static mode.

Construction Techniques A, B, and C were carried out using flush joint placement of the mix. No luting was carried out. This placing technique required the close attention of the paver operator, which was not always possible. If the hot lane is placed only 3 mm (1/8 in.) away from the edge of the cold lane as a result of oversight, a built-in crack results.

The wedge joint had a plain taper of 1:12 and, unlike the Michigan project, did not consist of a vertical offset of 13 mm (1/2 in.) at the top. The wedge face of the first lane was not compacted with a small roller as was done in Michigan.

Construction Technique F, using the Bomag compactor with the edge-restraining device, presented some practical problems. Initially the Bomag edge compactor was applied to the edge of the freshly placed material, as was originally intended. This procedure caused severe shoving and tearing along the edge of the joint because the edge compactor could not cover the full face of the uncompacted mixture.

Subsequently the joint was constructed by initially compacting the entire surface of the paving lane before the use of the Bomag edge compactor. This deviation reduced the layer thickness and provided the intended edge configuration at the joint for the edge compactor to be effective.

The mix temperature behind the paver was between 135° and 149°C (275° and 300°F).

FIELD AND LABORATORY TESTING

Core samples of 152 mm (6 in.) in diameter were obtained at the joint (encompassing the cold and the hot lanes equally) and at about 610 mm (2 ft) away from the joint in the hot lane to determine density values. No cores were obtained from the cold lane.

Cores were taken at five locations within a test section at about 30 m (100 ft) apart, beginning at 15 m (50 ft) from the starting point of the section. At each location, cores were taken at the joint and the hot lane so that any variation in the compaction level within the test section would be reflected in the joint density as well as the lane density.

Laboratory Testing

The cores obtained from the two projects were checked for thickness of the surface course before and after sawing. Bulk specific gravities (ASTM D2726) of the sawed cores from the joint and the hot lane were determined. Rice specific gravities (ASTM D2041) were also determined and compared with the result obtained at the HMA plant. The means and standard deviations of the density results were calculated for all sections. Percentage of total air voids was also determined. From the results, it was observed that there was a large variation in the data within a typical section. This could be attributed either to high variability in the construction technique or that there were only five core samples available per section for testing. The mix composition was reasonably uniform based on the project test data. The joint construction techniques were evaluated and ranked tentatively based on the average density at the joint (average of five cores). Michigan wedge joint, cutting wheel, and edge-restraining device gave relatively higher densities at the joint compared with the other remaining techniques used on both projects.

Field Testing

It was decided that additional nuclear density readings should be obtained in each section to supplement the limited core data. This was done to ensure an adequate sample size so that statistically valid conclusions could be drawn. Visual inspections of the joints were also carried out in April 1993, as reported in Table 1.

The nuclear readings were obtained at nine locations at about 15 m (50 ft) apart within a section. In Michigan, at each location, nuclear density tests were performed right at the joint and at 305 mm (1 ft) away from the joint on both the cold and hot side. In Wisconsin, however, the readings were taken at the joint and at 305 mm (1 ft) away on the cold side only for each section. The densities obtained on the cold side of the joint have been analyzed in this paper for both projects.

TABLE 1 Summary Statistics for Density at Joint

Section	Michigan Project					Wisconsin Project			
	Construction Technique	No. of Joints Tested	Average Density Kg/cu.m	Standard Deviation Kg/cu.m	Coeff. of Variation %	No. of Joints Tested	Average Density Kg/cu.m	Standard Deviation Kg/cu.m	Coeff. of Variation %
A	Roller Tech. A	9	2248.42	15.36	0.68	9	2129.97	20.54	0.96
B	Roller Tech. B	9	2209.96	19.35	0.88	9	2106.15	22.09	1.05
C	Roller Tech. C	9	2225.34	26.81	1.20	9	2125.17	33.40	1.57
D	Wedge Joint w/o Tack	9	2274.71	17.53	0.77	7	2132.02	24.84	1.17
E	Wedge Joint w/Tack	9	2271.51	12.08	0.53	9	2143.29	26.50	1.24
F	Edge Restr. Device	****	****	****	****	8	2198.63	33.98	1.55
G	Cutting Wheel	9	2268.18	32.30	1.42	9	2177.15	25.16	1.16
H	AW-2R Joint Maker	9	2196.76	25.04	1.14	9	2139.26	24.55	1.15

**** Edge restraining device was not used in Michigan project

A regression analysis was carried out between the core densities and the corresponding nuclear density readings taken at the same locations in each project. The correlation determined for each project was then used to convert all nuclear densities into corresponding core densities for all the sections. This resulted in nine density values at the joint (encompassing the cold and hot lanes equally) and nine density values 305 mm (1 ft) away from the joint in the cold lane for each test section. Density of the cold lane was preferred because this lane has the unconfined edge during rolling and therefore can be used for comparative purposes.

Table 1 provides a summary of statistics (sample size, average density, standard deviation, and coefficient of variation) for the joint density values obtained in Michigan and Wisconsin projects. Table 2 provides a summary of statistics for the density values obtained 305 mm (1 ft) away from the joint in the cold side of both projects. The theoretical maximum specific gravity values of the mixtures used in Michigan and Wisconsin were 2.497 and 2.532, respectively. These values can be used to calculate the air voids at the joint and away from the joint in each test section.

ANALYSIS OF DATA

Michigan Project

The density values at the joint and away from the joint in the cold lane were analyzed statistically as reported in Tables 1 and 2, respectively. As expected, the standard deviation or the coefficient of variation is generally higher for joint densities compared to the densities away from the joint in the cold lane. Among the three rolling techniques, Technique A provided the least variation and therefore was the most consistent.

It is also surprising to note that the densities at the joint are generally higher than those away from the joint. This might have resulted from the extra compactive effort applied at the joint by the roller operator. Under normal circumstances, densities tend to be lower at the joint.

Figure 5 shows the ranking of the techniques based on the joint density values. Fisher's Protected Least Significant Difference

	SECTION	AVERAGE JOINT DENSITY Kg/cu. m	CONSTRUCTION TECHNIQUE
BEST			
	D	2274.84	WEDGE JOINT W/O TACK
	E	2271.48	WEDGE JOINT W/ TACK
	G	2268.11	CUTTING WHEEL
	A	2248.41	ROLLING TECH. A (HOT SIDE W/ 6" OVERLAP)
	C	2225.34	ROLLING TECH. C (HOT SIDE 6" AWAY FROM JOINT)
	B	2209.96	ROLLING TECH. B (COLD SIDE W/ 6" OVERLAP)
	H	2196.82	AW-2R JOINT MAKER
WORST			

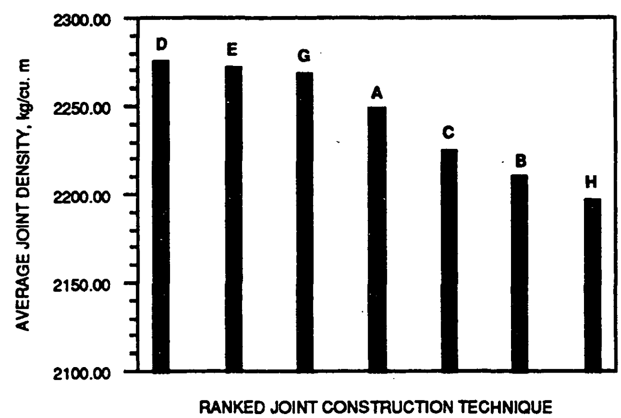

FIGURE 5 Ranking based on joint density (Michigan project).

TABLE 2 Summary Statistics for Density 305 mm Away from Joint in Cold Lane

Section	Michigan Project				Wisconsin Project		
	Construction Technique	Average* Density Kg/cu.m	Standard Deviation Kg/cu.m	Coeff. of Variation %	Average* Density Kg/cu.m	Standard Deviation Kg/cu.m	Coeff. of Variation %
A	Roller Tech. A	2260.61	5.56	0.25	2249.40	24.67	1.10
B	Roller Tech. B	2194.25	13.43	0.61	2250.24	23.99	1.07
C	Roller Tech. C	2182.46	7.89	0.36	2261.27	12.15	0.54
D	Wedge Joint w/o Tack	2259.51	4.28	0.19	2297.20	5.61	0.24
E	Wedge Joint w/Tack	2261.82	5.05	0.22	2268.83	18.92	0.83
F	Edge Restr. Device	****	****	****	2248.10	19.37	0.86
G	Cutting Wheel	2192.17	18.21	0.83	2204.77	14.89	0.68
H	AW-2R Joint Maker	2194.25	12.72	0.58	2238.79	24.90	1.11

**** Edge restraining device was not used in Michigan project

* The number of locations tested was same as Table 1.

(LSD) Procedure (*8*) was used to group different techniques, as shown in Figure 5. This procedure involves multiple comparison of treatment means and testing for equality of means. The joint construction technique represents the treatment in this case. The vertical lines shown in the first column of Figure 5 bracket various groups. For example, Techniques D, E, and G belong to one group because the differences in their densities are statistically insignificant. Based on the groupings, the Michigan wedge joint (with and without tack coat) and the cutting wheel gave highest densities at the joint. It should be noted that the density obtained right at the joint of the Michigan wedge is contributed mostly by the tapered edge of the cold lane, as evident in Figure 2. Among the three rolling techniques, Technique A gave the highest density at the joint, followed by Technique C.

The joints were also ranked based on the percentage of relative density, which was obtained as follows:

$$\text{Relative density (\%)} = \frac{\text{density at the joint}}{\text{density away from the joint}} \times 100$$

This was done to normalize the usual variations in the compaction levels from section to section. The resulting rankings are given in Figure 6 and are quite different from those based on the absolute density values at the joint (Figure 5). The validity that should be given to the rankings based on relative density is debatable, especially when the densities at the joint are generally higher than those away from the joint, as mentioned earlier.

This project was inspected visually in April 1993 after the first winter. Joints are more likely to open during winter. Table 3 provides a summary of general observations, such as those on surface texture, cracking, and ravelling at the joint. Overall the cutting wheel test section appears to be the best in appearance at the present time, followed by the Michigan wedge test section. Visual observations are planned for at least 5 years. The rankings may change on the basis of the long-term field performance of the joints in the future. Whether a tack coat is necessary for the Michigan wedge joint is also likely to be resolved based on the long-term field performance.

	SECTION	AVERAGE % RELATIVE DENSITY	CONSTRUCTION TECHNIQUE
BEST			
	G	103.47	CUTTING WHEEL
	C	101.97	ROLLING TECH. C (HOT SIDE 6" AWAY FROM JNT)
	B	100.72	ROLLING TECH. B (COLD SIDE W/ 6" OVERLAP)
	D	100.67	WEDGE JOINT W/O TACK
	E	100.43	WEDGE JOINT W/ TACK
	H	100.12	AW-2R JOINT MAKER
	A	99.46	ROLLING TECH. A (HOT SIDE W/ 6" OVERLAP)
WORST			

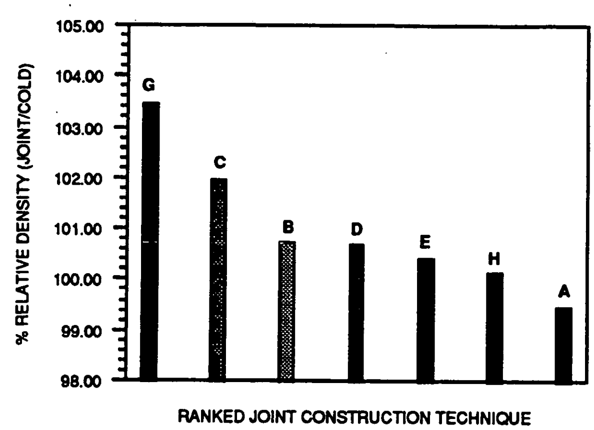

FIGURE 6 Ranking based on percent relative density (joint/cold) (Michigan project).

Wisconsin Project

The density data at the joint and away from the joint in the cold lane were analyzed statistically as reported in Tables 1 and 2, respectively. Again, as expected, the standard deviation or the coefficient of variation is generally higher for joint densities compared to the densities away from the joint in the cold lane. Among the three rolling techniques, Technique A has the least variation and is therefore the most consistent. Unlike the Michigan project, the densities at the joint are generally lower than the corresponding densities away from the joint.

Figure 7 shows the ranking of the techniques based on the joint density values and also the groupings (bracketed by vertical lines in the first column) based on Fisher's Protected LSD Procedure. Based on the groupings, the edge-restraining device and the cutting wheel gave the highest densities at the joint, followed by the wedge joint and the joint maker. Among the three rolling techniques, Technique A gave the highest density at the joint, followed by Technique C.

Figure 8 shows the ranking of the techniques based on the percentage of relative density discussed earlier. This ranking is slightly different from that based on the absolute joint density (Figure 7). However, the cutting wheel and the edge-restraining device give the highest relative density as a group.

The Wisconsin project was also visually inspected in April 1993 after the first winter. The general observations are given in Table 3. Overall, the cutting wheel and the edge-restraining device test sections seem to be the best in appearance. Again, the visual observations will be continued for at least 5 years. Therefore, the rankings are subject to change based on the long-term field performance of the joints.

CONCLUSIONS

Based on the density data obtained at the joint, and the visual inspection of the joints after the first winter (6 to 7 months after construction), the following conclusions can be drawn:

- The coefficient of variation is generally higher for joint densities compared to the densities 305 mm (1 ft) away from the joint in the cold lane. Among the three rolling techniques, Technique A yielded the least variation in the joint densities on both projects and therefore appears to be the most consistent.

TABLE 3 Summary of Field Visual Evaluation of Longitudinal Joint Construction Techniques

Section	Michigan Project				Wisconsin Project		
	Construction Technique	Cracking	Ravelling	Other Observations	Cracking	Ravelling	Other Observations
A	Roller Tech. A	None to Slight	None	Open texture on cold side	None to Slight	Slight to Moderate	A few areas did not ravel at all.
B	Roller Tech. B	None to Slight	None	Open texture on cold side	None to Slight	Slight to Moderate	A few areas did not ravel at all.
C	Roller Tech. C	None to Slight	None	Open texture on cold side	None to Slight	Slight to Moderate	A few areas did not ravel at all.
D	Wedge Joint w/o Tack	None	None to Slight	Ravelling on hot side due to improper luting	None to Slight	None to Slight	Ravelling in cold side only, Hot mat slightly above the cold mat, Narrow groove at the joint
E	Wedge Joint w/Tack	None to Slight	None to Slight	Ravelling on hot side due to improper luting	None to Slight	None to Slight	Ravelling in cold side only, Hot mat slightly above the cold mat, Narrow groove at the joint
F	Edge Restr. Device	****	****	****	None	None	Hot mat slightly above the cold mat, Physical appearance is good
G	Cutting Wheel	None to Slight	None	Surface texture uniform at the Joint	None	None	Hot mat slightly above the cold mat, Section appears comparable to Section F
H	AW-2R Joint Maker	None to Slight	None	Open texture on the cold side	None	None	Half inch wide groove at the joint, Section ranks third in appearance

**** Edge restraining device was not used in Michigan project

	SECTION	AVERAGE JOINT DENSITY kg/cu .m	CONSTRUCTION TECHNIQUE
BEST	F	2198.58	EDGE RESTRAINING DEVICE
	G	2177.12	CUTTING WHEEL
	E	2143.32	WEDGE JOINT W/ TACK
	H	2139.31	AW-2R JOINT MAKER
	D	2132.10	WEDGE JOINT W/O TACK
	A	2130.02	ROLLING TECH. A (HOT SIDE W/ 6" OVERLAP)
	C	2125.21	ROLLING TECH. C (HOT SIDE 6" AWAY FROM JNT)
WORST	B	2106.15	ROLLING TECH. B (COLD SIDE W/ 6" OVERLAP)

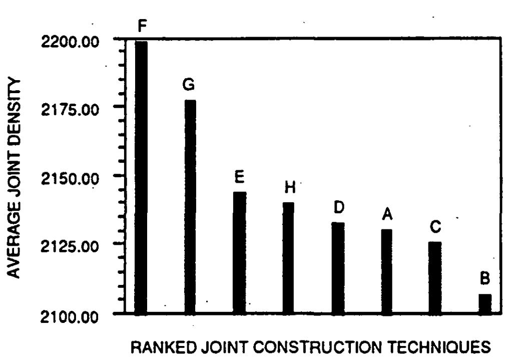

FIGURE 7 Ranking based on joint density (Wisconsin project).

	SECTION	AVERAGE % RELATIVE DENSITY	CONSTRUCTION TECHNIQUE
BEST	G	98.75	CUTTING WHEEL
	F	97.81	EDGE RESTRAINING DEVICE
	H	95.57	AW-2R JOINT MAKER
	A	94.69	ROLLING TECH. A (HOT SIDE W/ 6" OVERLAP)
	E	94.48	WEDGE JOINT W/ TACK
	C	93.98	ROLLING TECH. C (HOT SIDE 6" AWAY FROM JNT)
	B	93.61	ROLLING TECH. B (COLD SIDE W/ 6" OVERLAP)
WORST	D	92.81	WEDGE JOINT W/O TACK

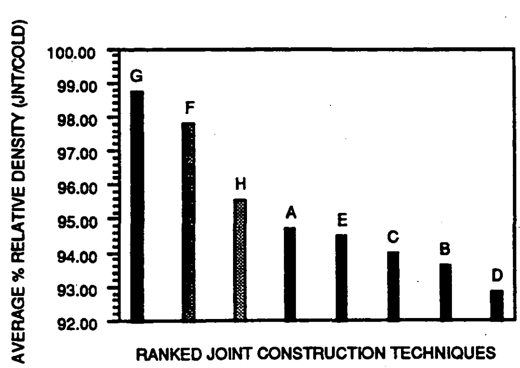

FIGURE 8 Ranking based on percent relative density (joint/cold) (Wisconsin project).

• On the Michigan project, the Michigan wedge joint (with and without tack coat) and the cutting wheel techniques, as a group, yielded the highest density at the joint. After the first winter since construction, the cutting wheel test section appeared to be the best in appearance based on visual inspection, followed by the Michigan wedge test sections.

• On the Wisconsin project, both the edge-restraining device and the cutting wheel techniques gave the highest densities at the joint, followed by the wedge joint and the joint maker. The cutting wheel and the edge-restraining device test sections also appear to be the best in appearance after the first winter since construction.

• Among the three rolling techniques, Technique A gave the highest density at the joint, followed by Technique C on both the Michigan and Wisconsin projects.

The visual evaluation of joints on both projects will be continued for at least 5 years. It is quite possible that the tentative rankings reported in this paper may change based on the long-term field performance (in terms of cracking, ravelling, and surface texture at the joint).

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