NCAT Report 02-03

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DISCLAIMER

ABSTRACT

Premature deterioration of multilane hot mix asphalt (HMA) pavements can occur at the longitudinal joints in the form of cracking and raveling. The National Center for Asphalt Technology (NCAT) initiated a national study of evaluating various longitudinal joint construction techniques in 1992 in an effort to select technique(s) which improve the performance of longitudinal joints. Test sections were constructed in Michigan, Wisconsin, Colorado, Pennsylvania, and New Jersey. This paper gives the 6-year performance evaluation of eight different techniques utilized on a paving project in Pennsylvania in 1995.

In Pennsylvania, longitudinal joint constructed using rubberized joint material gave the best performance closely followed by the joint made with cutting wheel. Test sections using rolling from hot side 152 mm away from the joint and the New Jersey wedge joint also performed reasonably well with no significant cracking. The remaining four test sections using edge restraining device, joint maker, rolling from hot side, and rolling from cold side developed cracking at the longitudinal joint to different extents.

It has been recommended to specify minimum compaction level at the longitudinal joint to ensure its improved performance.

KEY WORDS: Hot mix asphalt, asphalt pavement, construction, longitudinal joint, performance

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BACKGROUND

Premature deterioration of multilane hot mix asphalt (HMA) pavements can occur at the longitudinal joints in the form of cracking and raveling. These distresses are caused by relatively low density and surface irregularity at the joints. A density gradient also exists across a typical longitudinal joint. Such a density gradient is caused by the low density at the unconfined edge when the first lane (hereinafter called the cold lane) is paved, and a relatively high density at the confined edge, when the adjacent lane (hereinafter called the hot lane) is paved. It is not uncommon to encounter densities at the joint which are significantly lower than those away from the joint (*1*, *2*, *3*). There is a need to identify suitable joint construction technique(s) which will minimize or eliminate cracking and raveling problems at the joint and improve its performance.

The National Center for Asphalt Technology (NCAT) initiated a national study of evaluating various longitudinal joint construction techniques in 1992 with the cooperation of the state departments of transportation and the HMA industry. This study involves the evaluation of different longitudinal joint construction techniques used on five projects since 1992: (a) seven techniques on I-69 in Michigan (1992), (b) eight techniques on State Route 190 in Wisconsin (1992), (c) seven techniques on I-25 in Colorado (1994), (d) eight techniques on State Route 441 in Pennsylvania (1995), and (e) twelve techniques on State Route 9 in New Jersey (1996). Only the Pennsylvania project is discussed in this paper. The other projects have been reported elsewhere (*4*, *5*, *6*).

OBJECTIVE

The objective of this research project in Pennsylvania was to construct longitudinal joints using eight different techniques and recommend technique(s) which result in improved long-term performance of the joint.

TEST PLAN AND CONSTRUCTION DETAILS

Eight different techniques of constructing longitudinal joints were used on State Route 0441 (Section 004) in Lancaster County (Station 169+00 to 129+00).

All test sections were constructed on September 11-12, 1995. Work began at Station 171+00 (intersection with SR 0241). The northbound lane of this two-lane highway (Figure 1) was paved first. Each test section was 152 m (500 feet) long. The joints were constructed in the ID-2 wearing course, 38 mm (1.5 inch) thick, placed on ID-2 binder course 50 mm (2 inches) thick. The gradation of the wearing course mix was as follows: 100% passing 12.5 mm, 98% passing 9.5 mm, 68% passing 4.75 mm, 45% passing 2.36 mm, 25% passing 1.18 mm, 15% passing 0.6 mm, 11% passing 0.3 mm, 8% passing 0.15 mm, and 5.0% passing 0.075 mm sieve. The asphalt content was 6.0 percent. An AC-20 asphalt cement tack coat was used on the vertical edge of the first paved lane in all sections except No. 7 which used a rubberized asphalt tack coat instead. The ambient temperature during paving ranged from 9°C to 22°C (48°F to 72°F). HMA in the adjacent (hot) lane was placed such that the end gate of the paver extended over the top of the first (cold) lane by about 25-50 mm (1-2 inches). Luting was done with a view to provide extra material to be compacted by the roller in the hot lane near the joint in order to achieve high density. However, instead of just bumping the mix back to the hot lane (which is desirable), it was pushed approximately 150 to 450 mm (½ to 1½ feet) over the hot lane. Breakdown rolling was accomplished with a vibratory roller.

Figure 1. General View of State Route 441 (Lancaster County)

The following is a description of eight techniques used along with relevant construction information.

1. Joint Maker

This is an automated joint construction technique, and a recent innovation in joint making technology. It consisted of a boot-like device about 75 mm wide (Figure 2) which is attached to the side of the screed at the corner during construction. The device forces extra material at the joint through an extrusion process prior to the screed. A kicker plate is also furnished which 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. Prior to the use of the joint maker in the test section, the supplier adjusted the height and angle of attack of this device mounted on both sides of the paver. The first lane was placed in the morning and the adjacent lane was placed in the afternoon. The kicker plate worked well on this project. Rolling of the joint was done from the hot side with 152 mm (6 inches) overlap on cold side.

2. Rolling From Hot Side

Different techniques for rolling longitudinal joints have been attempted in the past. In this test section, 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 inches) overlap on the cold lane (Figure 3a). The first lane was placed in the morning and the adjacent lane was placed in the afternoon. The breakdown roller made two passes (forward and backward) in vibratory mode on the hot side with about 152 mm overlap on the cold side.

3. Rolling From Cold Side

Rolling in the first pass was done in the static mode with a major portion of the roller wheel on the cold side with about 152 mm (6 inches) of the roller wheel on the hot side of the joint (Figure 3b). This technique is believed to produce a “pinching” effect on the joint. The second backward pass was made in the vibratory mode with roller on the hot side with about 152 mm (6 inch) overlap on the cold side. However, timing in this type of rolling is critical. When the roller is operated on the cold side, the hot side undergoes cooling which can make it difficult to achieve the desired compaction level.

4. Rolling From Hot Side 152 mm (6 inch) Away From Joint

Compaction in this method was started with the edge of the roller about 152 mm (6 inches) from the joint on the hot side (Figure 3c) during the first pass in

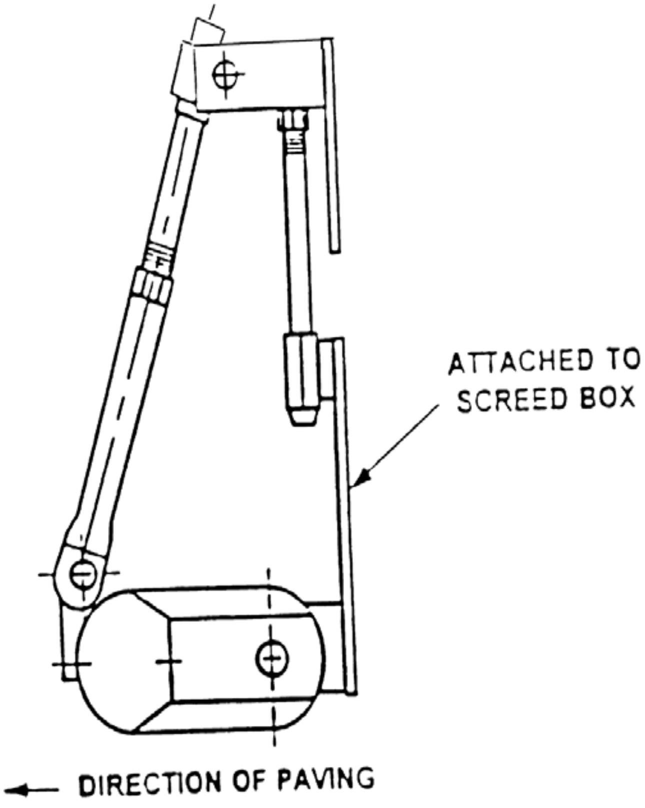

Figure 2. Joint Maker

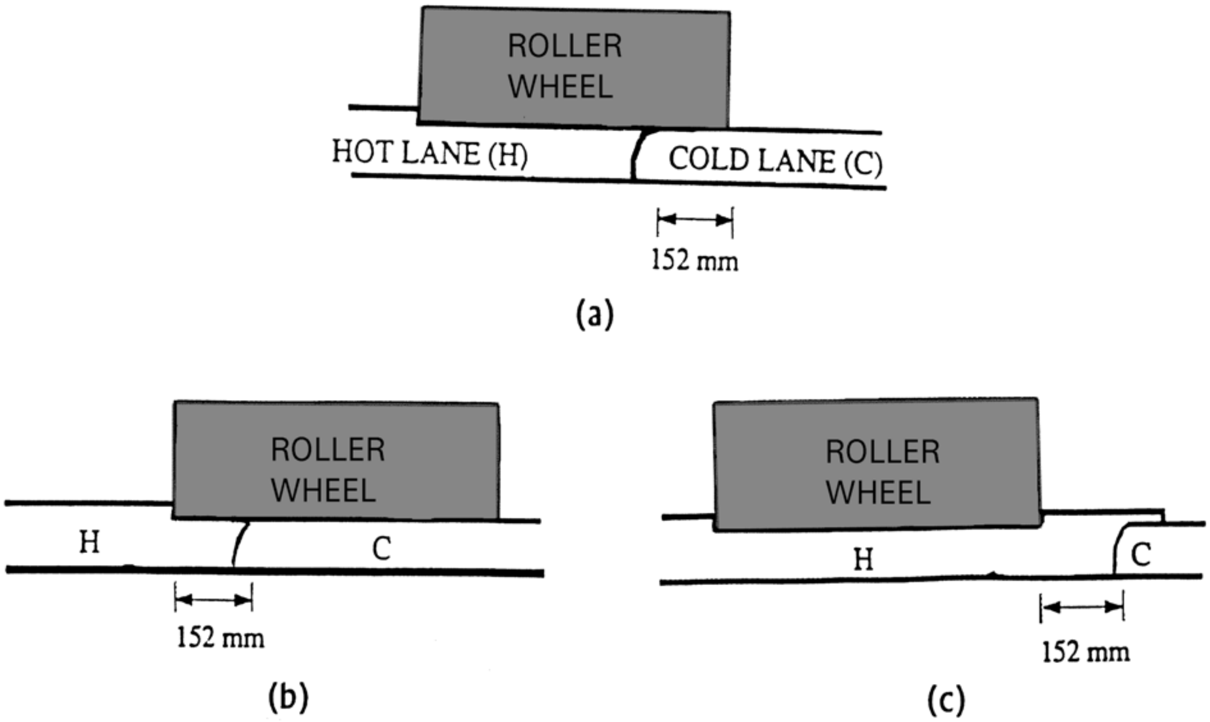

Figure 3. (a) Rolling From Hot Side, (b) Rolling From Cold Side, and (c) Rolling From Hot Side 152 mm Away From Joint

vibratory mode. The lateral pushing of the material toward the joint during the first pass of the roller is believed to crowd the mix and produce a high density at the joint. 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 pushed towards the joint. The second pass was made in a vibratory mode with the roller overlapping the cold side by about 152 mm (6 inches). The first lane was paved in the morning and the adjacent lane was placed in the afternoon.

5. Cutting Wheel

The cutting wheel technique involves cutting 25-50 mm (1-2 inches) of the unconfined, low density edge of the initial lane after compaction, while the mix is still plastic. A 250 mm (10 inch) diameter cutting wheel mounted on an intermediate roller or a motor grader is generally used for the purpose (7). A roller with a cut wheel attachment was used on this project.

A reasonably vertical face at the edge was obtained by this process which was then tack coated with an AC-20 asphalt cement before the placement of the abutting HMA in the afternoon. Compaction was performed by rolling from the hot side with about 152 mm (6 inch) overlap on the cold side. The cutting wheel method generally results in an increase in density at the joint because the low density edge of the mat is cut and discarded.

6. Edge Restraining Device

The restrained edge compaction technique utilizes an edge-compacting device which provides restraint at the edge of the first lane constructed. The restraining device consists of a hydraulically powered wheel which rolls alongside the compactors drum, simultaneously pinching the unconfined edge of the first lane towards the drum providing lateral resistance (Figure 4). The edge restraining wheel is approximately 75 mm (3 inches) wide and has a bevel

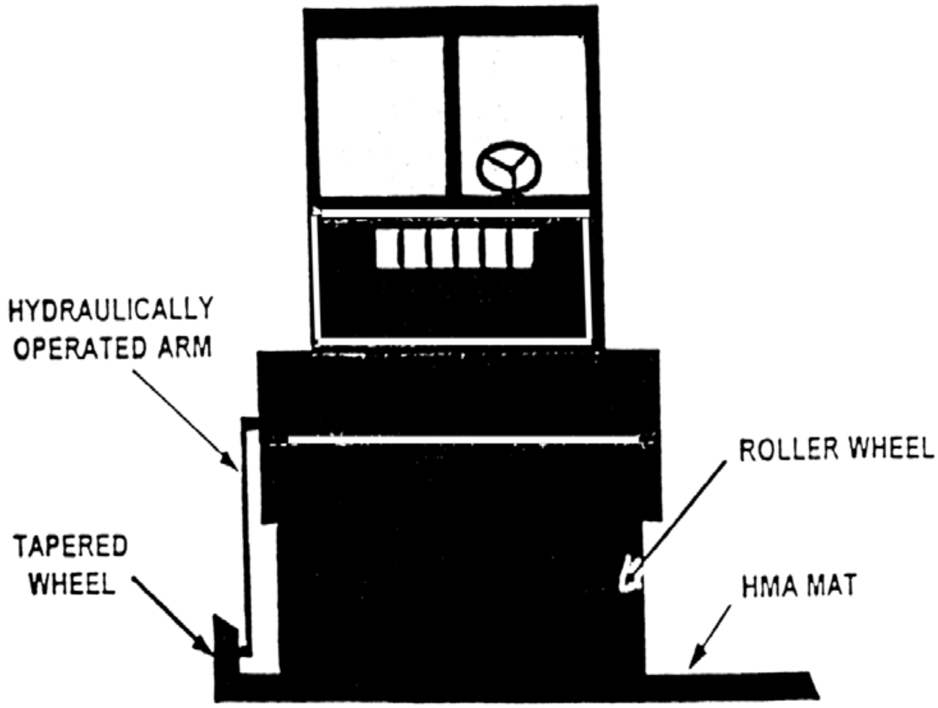

Figure 4. Edge Restraining Device

of about 45 degrees. This technique is believed to increase the density of the unconfined edge. When the edge restraining device was lowered, the edge of the steel wheel roller was about 152 mm (6 inches) away from the edge. Two passes were made by the roller in static mode with the device lowered. Approximately 75 to 125 mm (3 to 5 inches) of the longitudinal edge of the first lane was restrained with the wheel attachment. Once completed, the longitudinal joint face of the first lane (cold side) had an approximate 45 degree compacted slope. The original breakdown roller then finished the rest of the lane in vibratory mode including the 152 mm (6 inches) which were not rolled when the edge restraining device was lowered. The adjacent lane was placed in the afternoon and compacted from hot side.

7. Rubberized Asphalt Tack Coat

The unconfined edge of the first paved lane adjacent to the joint was formed normally by the paver screed in this experimental section. A rubberized asphalt tack coat (Crafco pavement joint adhesive Part Number 34524) was applied on the face of the unconfined edge of the first paved lane. The thickness of the tack coat was about 3 mm (1/8 inch). The adhesive was in a heated, jacketed asphalt trailer equipped with a pump to dispense and circulate the adhesive. The adhesive was applied manually with a two-handed dispensing wand. The adhesive was thick and appeared to be the consistency of a thick pancake mix. A slow application speed appeared to work best in providing an even coating thickness over the entire vertical joint face. The adhesive hardened quickly, and after a short period the adhesive felt slightly tacky to the touch. About 135 to 180 kg (300 to 400 lbs) of the adhesive was estimated to be used in the 152 m (500 feet) long test section. The first lane was paved in the morning and the adjacent lane was paved in the afternoon. Rolling of the joint was done from the hot side.

8. New Jersey Wedge (3:1)

In this technique a wedge joint consisting of a 3:1 taper was formed during the construction of the cold side by using a sloping steel plate attached to the inside corner of the paver screed extension (*8*). The breakdown roller made a forward and backward pass in vibratory mode working from the outside of the lane towards the inside of the lane. The breakdown roller stayed approximately 75 to 125 mm (3 to 5 inches) away from the top edge of the wedge joint slope. No tack coat was applied to the longitudinal wedge joint. During the second pass of the paver in the afternoon to place the adjacent lane, an infrared heater was used to heat the edge of the previously placed layer to a surface temperature of about 93ºC (200ºF). Obtaining and maintaining an adequate and consistent temperature at the wedge joint face was a problem on this project because the infrared heater was mounted on a trailer and not attached to the paver. Due to delays in receiving HMA from the plant several areas were heated too high because the heater either stopped or moved too slow. Rolling of the joint was done from the hot side.

Immediately after construction, nine pavement cores each were obtained from each test section directly over the joint (including half cold side and half hot side) and 305 mm (12 inches) away from the joint in the first paved (cold) lane. The bulk specific gravity of the cores was then determined according to ASTM D2726. The density data was then analyzed statistically. The percent air voids were also calculated using the theoretical maximum density (TMD) of the paving mixture. It was not possible to use nuclear density gauge to measure density at the joint because of seating problems. These joints have been evaluated by a team of engineers at least once a year since construction. The last visual performance evaluation was made on July 2, 2001, about six years after construction. The density and the performance data were evaluated and the joint construction technique(s) which resulted in good joints have been identified in subsequent sections.

TEST RESULTS AND VISUAL EVALUATIONS

Table 1 gives the summary statistics for density and air voids of cores taken right over the joint (including both cold and hot side) and 305 mm (12 inches) away from the joint on cold side (first paved lane).

Table 1. Summary Statistics for Density and Air Voids of Cores Taken at the Joint and Away From the Joint

Section No. and Joint Type	Density at the Joint, kg/m^3		Air Voids^a at the Joint, Percent		Air Voids* 305 mm(12 in) Away From the Joint on Cold Side	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1. Joint maker	2252	23	9.2	0.94	6.1	0.99
2. Rolling From Hot Side	2224	36	10.3	1.49	6.2	1.10
3. Rolling From Cold Side	2248	59	9.3	2.36	4.7	1.29
4. Rolling from Hot Side 152 mm Away	2233	32	10.0	1.29	5.6	1.35
5. Cutting Wheel	2264	53	8.7	2.16	5.3	1.27
6. Edge Restraining Device	2289	45	7.7	1.78	5.0	1.32
7. Rubberized Joint Material	2160	38	12.9	1.53	6.4	0.99
8. New Jersey Wedge 3:1	2113	54	14.8	2.15	8.4	0.84

^{a} Based on Theoretical Maximum Density (TMD) of 2480 kg/m^3

The joint density values were used to group the different joint construction techniques. The rankings were done by Duncan's Multiple Range Test. The air voids values would have provided the same ranking because the same TMD was used to calculate the air voids from the density values. Figure 5 shows the results. Letters such as A, AB, B, and C indicate different groups within which the core densities do not differ significantly at significance level (p) of 0.05. The

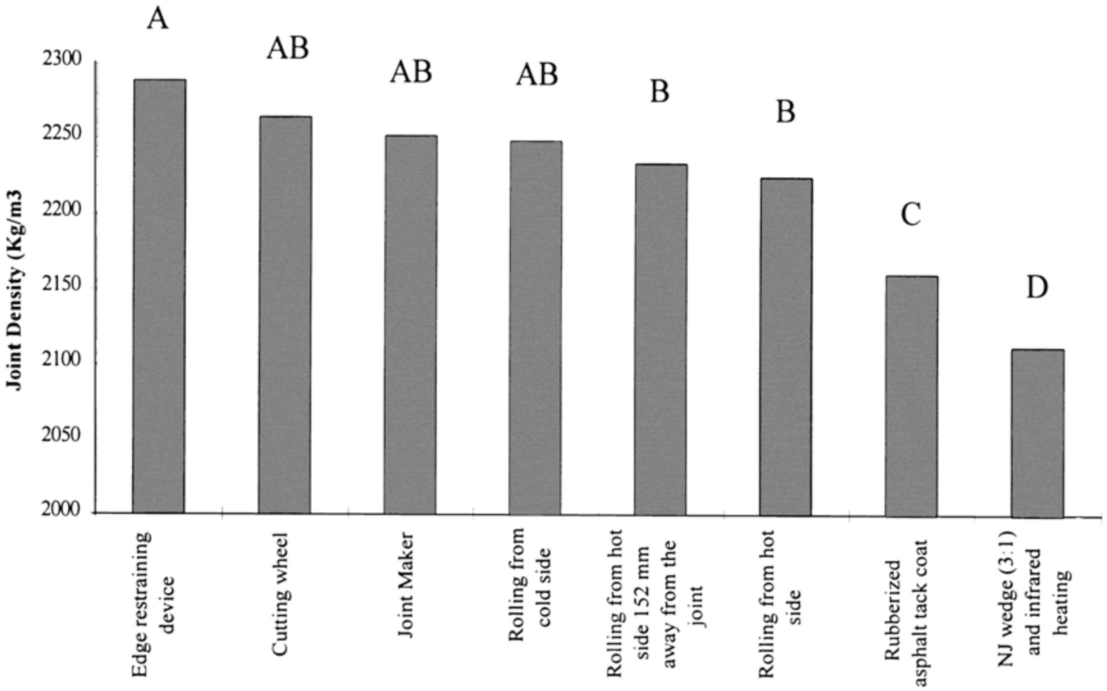

Figure 5. Joint Density Obtained With Different Techniques Showing DMRT Groups

edge restraining device (Group A) produced the highest density followed by cutting wheel, joint maker, and rolling from cold side techniques, all of which (Group AB) produced similar densities. Rolling from hot side 152 mm (6 inches) away from joint and rolling from hot side produced the next lower densities, followed by the rubberized asphalt material tack coat and NJ wedge (3:1) techniques. It should be noted that rolling from the hot side generally gave higher density compared to rolling from cold side in NCAT longitudinal joint projects in other states.

The cores taken directly over the joint were also examined visually. None of the cores fell apart at the joint. There was good interlocking of aggregate particles from both lanes at the joint in all sections except the section which used cutting wheel for obvious reasons.

Visual evaluations of the joints have been conducted annually since the construction of the project in September 1995. The last visual inspection was made by a team of four evaluators on July 2, 2001 about six years after construction. The detailed observations are given in Table 2. The overall rating considered the percent length of the joint which developed cracking, the average width of the crack, and the percent length and severity of raveling observed in the cold mat just adjacent to the joint usually because of inadequate density. The development and severity of crack at the joint was considered very important in overall rating. The eight

Table 2. Six-Year Field Evaluation of Longitudinal Joints (Average of Four Evaluators)

Section No., Sta., Type	Cracking at Joint		Raveling of Adjacent Mat (Cold Side)		Average Rating[b]	Comments
	% Length	Av. Width (mm)	% Length	Severity[a]		
1. (169 to 164) Joint maker	85	9.5	0	none	5.50	Crack is straight.
2. (164+00 to 159+00) Rolling from hot side	99	6.25	0	none	4.75	Crack is more jagged and appears shallower than Section 1.
3. (159 to 154) Rolling from cold side	88	9.5	0	none	4.62	Crack appears deeper than Sections 1 and 2; longer localized areas of 12.5 mm wide crack.
4. (154 to 149) Rolling from hot side 152 mm away	6	3	8	slight	8.75	Joint not visible in most of the section, crack shows up intermittently for short lengths.
5. (149 + 144) Cutting wheel	6	6.25	0	none	9.12	Joint not visible in most of the section, two short lengths of cracking.
6. (144 to 139) Edge restraining device	35	4.75	8	slight	6.75	Crack is intermittent; slight raveling in between cracks.
7. (139 to 134) Rubberized joint material	0	--	2	slight	9.88	Joint not visible except for some spots of joint material.
8. (134 + 129) N.J. Wedge 3:1	3	2	4	slight	7.75	There is 50-75 mm wide raveling on the joint in about 75% of the section, cracking in a few locations only.

[a] Severity = none, slight, moderate or severe

[b] 0 = unacceptable; 2 = poor; 4 = fair; 6 = good; 8 = very good; and 10 = excellent

techniques have been ranked (based on average ratings of 4-5 evaluators) from best to worst every year except year 1999 as shown in Table 3. The numerical ratings given in parentheses in Table 3 are not consistent because the number of evaluators varied from 4 to 5. Nonetheless, the ranking orders given for the four years (1997, 1998, 2000, and 2001) are essentially reasonable. Rankings obtained in year 1996 are not included because no joint had developed cracking after one year. Only some raveling was observed at the joint in some test sections: N.J. wedge and Edge restraining device sections had moderate raveling whereas rolling from cold side section had slight to moderate raveling. Over the six years, the rankings of some test sections have changed as shown in Table 3. This is explained later.

OBSERVATIONS

Based on the review of the test results and visual observations over the 6-year period, the following observations are made:

Density at the Joint

The performance ranking of different joint construction techniques evaluated by NCAT in Michigan, Wisconsin, and Colorado appears to have been generally influenced by the overall density at the joint obtained by the technique (4, 5, 6). The joints with high densities generally showed better performance than those with relatively low densities. A majority of highway agencies specify mainline mat density not less than 92 percent of the theoretical maximum density (or no more than 8 percent air voids). Some agencies have started or are considering to specify 2 percent lower density at the joint (or no more than 10 percent air voids) to improve the quality of HMA joints based on NCAT’s study.

The density test data in Table 1 obtained in this Pennsylvania project generally shows satisfactory compaction at the joint as well as 305 mm (12 inches) away from the joint on cold side (first paved lane). The percent air voids in the mat away from the joint range from 4.7 to 6.4 percent except the New Jersey wedge section which had 8.4 percent average air void content when constructed. The average air void contents at the joint range from 7.7 to 10.3 percent in case of the first six test sections and are considered satisfactory. Only the last two sections, rubberized joint material and New Jersey wedge, have excessive average air void contents at the joint. This indicates that relatively high compaction levels were generally achieved at the joint on this project compared to HMA projects where no special attention is given to joint compaction resulting in air void contents usually exceeding 10 percent. This is reflected in overall good performance of joints in many test sections after 6-year service (Table 2). Relatively high density at the joint in most test sections appears to have masked the influence of joint density on the performance ranking. Moreover, the joint performance was also influenced by different joint construction implements or treatments used. For example, Test Section 7 with rubberized joint material had 12.9 percent average air void content at the joint but had the best performance after 6 years (Tables 2 and 3). Section 8, which used New Jersey wedge, had 14.8% average air void content at the joint which appears to have caused 50-75 mm wide raveling at the joint. Unlike Michigan wedge joint which has a vertical notch (generally 12.5 to 19 mm high), the New Jersey wedge joint does not have a notch, which makes it difficult to achieve good compaction at the joint. Relatively high compaction levels have been obtained at the joint with the use of Michigan type notched wedge joints (4, 5, 6). The Michigan wedge has 12:1 slope compared to 3:1 slope in New Jersey wedge and, therefore, is an added safety feature.

Based on the general performance of the joints after 6 years on this project, it appears that the air void contents at the joint should not be allowed to exceed 10 percent.

Table 3. Yearly Rankings of Joint Construction Techniques[a]

1997 (July)	1998 (July)	2000 (October)	2001 (July)
1. Rolling hot side (9.8)	1. Rubberized joint material (9.8)	1. Cutting wheel (9.0)	1. Rubberized joint material (9.88)
2. Rolling cold side (8.8)	2. Cutting wheel (9.4)	2. Rubberized joint material (7.75)	2. Cutting wheel (9.12)
3. Rubberized joint material (8.2)	3. Rolling from hot side (8.8)	3. N.J. wedge (7.5)	3. Rolling hot side 152 mm (8.75)
4. Joint maker (8.0)	4. Rolling from hot side 152 mm away (8.4)	4. Rolling from hot side 152 mm (7.25)	4. N.J. wedge (7.75)
5. Cutting wheel (7.8)	5. Joint maker (7.8)	5. Edge restraining device (6.5)	5. Edge restraining device (6.75)
6. Rolling hot side 152 mm (7.0)	6. Edge restraining device (6.4)	6. Joint maker (4.5)	6. Joint maker (5.50)
7. Edge restraining device (6.5)	7. Rolling from cold side (6.0)	7. Rolling from hot side (4.25)	7. Rolling from hot side (4.75)
8. N.J. wedge (4.0)	8. N.J. wedge (5.6)	8. Rolling from cold side (3.0)	8. Rolling from cold side (4.62)

[a] Evaluations were conducted by 4 to 5 evaluators, average ratings are given in parenthesis (Scale of rating: 0 = unacceptable; 2 = poor; 4 = fair; 6 = good; 8 = very good; and 10 = excellent

Performance Rankings

As mentioned earlier, yearly rankings of joint construction techniques are given in Table 3. The final six-year detailed evaluation is given in Table 2.

Table 3 indicates that the yearly rankings changed from 1997 to 2001. This was expected because some joints appear better in the early life of the HMA pavement but deteriorate faster later when subjected to extreme environmental conditions, especially during cold winters. Examples are test sections with rolling from hot side, rolling from cold side, and joint maker. On the other hand, some joints are not in top rankings in the early life but maintain their integrity and are durable. Examples are test sections with rubberized joint material, cutting wheel, and rolling from hot side 152 mm away.

As shown in Table 2, the test section with rubberized joint material (Figure 6) has performed the best after six years, closely followed by the test section with cutting wheel (Figure 7). Both sections have not developed any significant cracking. The use of rubberized joint material involves normal paving procedures except that this material is applied as a tack coat on the vertical edge of the first paved lane in lieu of AC-20 asphalt cement. It is surmised that this material keeps the joint sealed and does not allow any cracking to occur because it can stretch when pavement lanes contract transversely during cold weather. This probably keeps water from entering at the longitudinal joint. The rubberized joint material also showed the best performance in seven test sections constructed on I-25 in Colorado in 1994 (5, 6), and evaluated after five years in December 1999.

Figure 6. Closeup of Joint with Rubberized Asphalt Tack Coat, Joint Between Yellow Stripes Is Hardly Visible, Pencil Pointing to Excess Tack Coat on the Surface in a Few Spots Helped Locate the Joint

Figure 7. General View of Section Where Cutting Wheel Used, No Significant Cracking Can Be Seen, Joint Not Visible in Most of the Section

Cutting wheel has been used widely by HMA contractors in construction of longitudinal joints for airport runway pavements because the Federal Aviation Administration usually specifies a minimum density at the longitudinal joints. However, the quality of longitudinal joints using cutting wheel is dependent upon the skill of the operator in making a straight cut and the skill of the paver operator in matching the cut if it is not straight.

Test sections using rolling from hot side 152 mm away (Figure 8) and the New Jersey wedge also performed reasonably well after six-year service with no significant cracking. The joint is hardly visible in the former section except where intermittent cracking is seen. Although hardly any cracking can be observed, the New Jersey wedge without any notch developed raveling in a width of 50 to75 mm at the joint as mentioned earlier. A vertical notch similar to Michigan joint would have prevented the raveling by accommodating the mix aggregate particles of the hot mat in the notch and also achieving relatively higher compaction level as was observed on Michigan test project (*6*).

Sections using edge restraining device and joint maker (Figure 9) developed cracking in about 35 and 85 percent of the length of the 152-m (500-feet) test sections, respectively. Edge restraining device was able to achieve better compaction at the joint (7.7% air voids) compared to the joint maker which achieved 9.2% air voids (Table 1). The average width of crack in section using edge restraining device is 4.75 mm (3/16 inches) as compared to average width of 9.5 mm (3/8 inches) in section using joint maker. However, similar to cutting wheel, the quality of longitudinal joint made with the edge restraining device depends on the skill of the roller operator who has to do the hard task of keeping the device right at the edge of the loose mat. This is indicated by intermittent cracks in this section (Table 2).

Figure 8. General View of Section Where Rolling Was Done from Hot Side 152 Mm Away from the Joint, No Significant Cracking Can Be Seen, Joint Not Visible in Most of the Section

Figure 9. Section Where Joint Maker Used, an Almost Straight Crack with an Average Width of 9.5 Mm Can Be Seen Between the Yellow Stripes

Rolling from hot side (Figure 10) and rolling from cold side (Figure 11) finished last with cracking in 99 and 88 percent of length, respectively, of the test section. However, rolling from cold side resulted in a wider and deeper crack compared to rolling from hot side. It should be noted all test sections except nos. 3 and 4 were rolled from hot side with an overlap of about 152 mm on cold side. This was done based on NCAT's experience in other states where rolling from hot side generally gave higher density than rolling from cold side because a vibratory roller can be used effectively in the first pass.

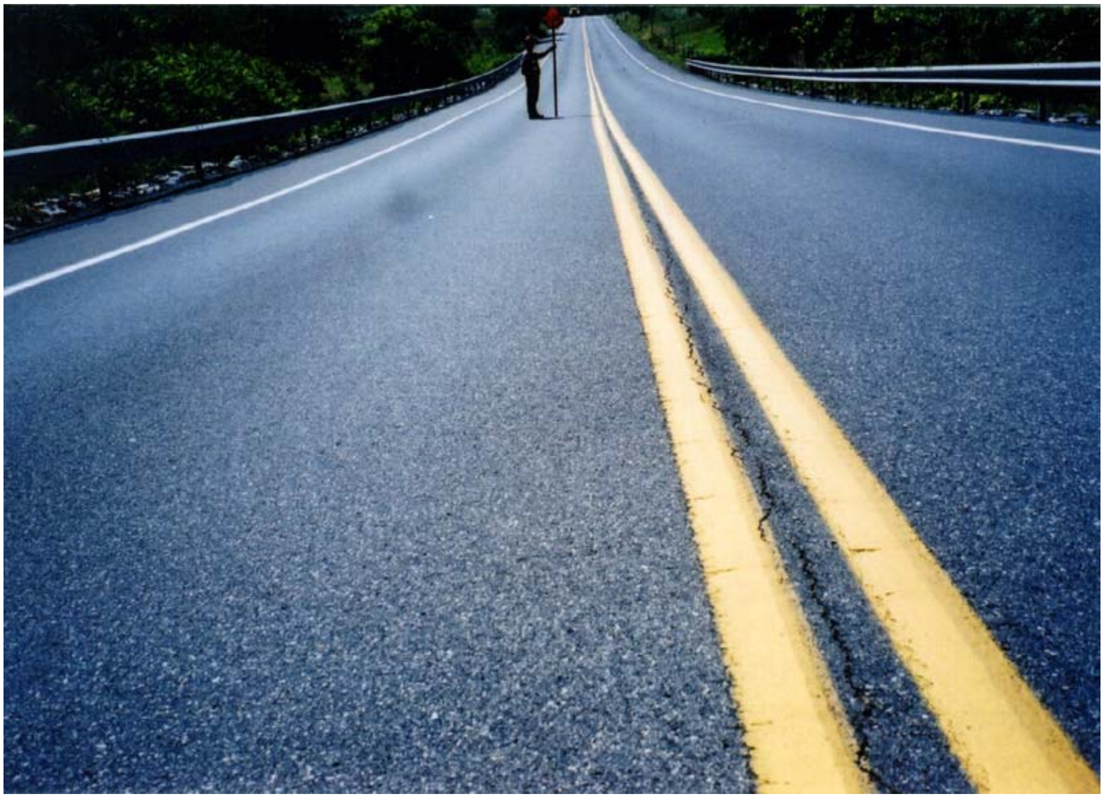

Figure 10. Section Where Rolling Was Done from Hot Side with 152 Mm Overlap on Cold Side, a Jagged Crack Can Be Seen Between the Yellow Stripes

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are drawn and recommendations made based on the six-year field performance of longitudinal joints constructed with different techniques in Pennsylvania and relevant NCAT experience (5, 6) in Michigan, Wisconsin, and Colorado.

- Longitudinal joint constructed using rubberized joint material gave the best performance with no significant cracking, closely followed by the joint made with cutting wheel. However, the quality of joint with cutting wheel is dependent upon the skill of the operator in making a straight cut and the skill of the paver operator in matching the cut edge if it is not straight.
- Test sections using rolling from hot side about 152 mm (6 inches) away from the joint and the New Jersey wedge also performed reasonably well with no significant cracking. However, the section with New Jersey wedge (without any notch) showed 50-75 mm wide raveling at the joint which probably could have been minimized by using Michigan type notched wedge joint.

Figure 11. Closeup of Jagged Cracking in the Section Rolled from Cold Side, the Crack Is Generally Wider and Deeper than That in Section Rolled from Hot Side

- Remaining test sections using edge restraining device, joint maker, rolling from hot side, and rolling from cold side developed cracking at the longitudinal joint to a different extent.
- It is recommended to use rubberized joint material (Crafco pavement joint adhesive 34524 or equal) or notched wedge joint to obtain consistent performance of longitudinal joint.
- Rolling of the longitudinal joint should be conducted from hot side, preferably 152 mm (6 inches) away from the joint.
- It is recommended to specify minimum compaction level at the longitudinal joint (generally two percent lower than that specified for the mat away from the joint). Compaction levels at the joint need to be determined by taking cores. It is not possible to use nuclear density gauge because of a seating problem on the joint.

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