Longitudinal Wedge Joint Study

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A 5-year study was undertaken to develop a technique for producing more durable longitudinal construction joints in bituminous pavements. The construction procedure evaluated involves forming the joint between adjoining lanes as two overlapping wedges. The wedge joint is formed by a steel plate attached to the paver screed. The effectiveness of the wedge joint was measured by the extent to which this procedure was able to eliminate a density gradient across the joint. Nuclear density testing was undertaken to determine the uniformity of the density across the joint and, hence, the nature of the density gradient. Density measurements were taken across the wedge joint and compared with the standard longitudinal center joint. These measurements indicated that the wedge joint had a more uniform density across the joint and a higher average density than the standard joint. The wedge joint eliminates the density gradient and, hence, lowers the potential for joint deterioration. By eliminating the vertical edge, the wedge joint eliminates the vertical dropoff and offers a safer condition for motorists making lane changes in construction areas.

The objective of this 5-year study was to develop the wedge joint technique for producing more durable longitudinal construction joints in bituminous pavements. The construction procedure involves forming the joint between adjoining lanes as two overlapping wedges. This wedge joint is formed by a steel plate attached to the paver screed, which produces a 3:1 sloped face at the edge of the first bituminous mat placed.

In placing bituminous concrete, paving the full width of the pavement in a single pass is often impossible. This problem particularly arises in the resurfacing and rehabilitation work that is now the primary focus of the New Jersey Department of Transportation capital program. As a practical necessity, then, most bituminous pavements contain longitudinal construction joints.

As is well known, these construction joints can be the weak link in the chain that eventually causes an otherwise sound pavement to deteriorate. The typical stages of distress of longitudinal joints include an initial separation, the ingress of water and incompressibles, and cracking and raveling.

No truly effective technique exists for repairing distressed longitudinal joints. Figure 1 shows a photograph of typical longitudinal joint distress on a major highway (I-295) in the vicinity of Trenton. As noted in the photograph, the department has undertaken some rather costly repair measures in an attempt to correct the severe joint distress. This repair strategy is to saw out the pavement on either side of the joint, excavate the bituminous material, and install a replacement inlay. Whether these expensive remedial measures will provide a long-term solution remains to be determined.

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One procedure for minimizing joint distress is to require that the two adjoining mats both be hot enough during construction to permit adequate compaction. In an attempt to avoid cold longitudinal construction joints, New Jersey's specifications place a 1,500-ft limit on the length of the bituminous mat that may be placed before bringing the paver back to place the subsequent lane. This method clearly has not eliminated cold joints and subsequent joint deterioration. Indeed, New Jersey's high traffic volumes often preclude enforcement of this limitation on resurfacing work.

Safety is also a consideration in constructing pavement joints. In the lane-at-a-time paving typically used on resurfacing projects, a height differential between the newly placed mat and the adjoining pavement is inevitable. This vertical stepoff can pose a hazard to traffic traveling through the construction area, especially if lane changes are required. A recent (unpublished) national survey of highway engineers including longitudinal joint construction indicated that 30 to 40 percent of the respondents were of the opinion that the stepoff was somewhat or extremely hazardous to compact cars and motorcycles.

States have used a variety of measures to deal with this perceived safety problem, including prohibiting stepoffs, limiting their height, using special signing, and limiting the time within which the adjacent lane must be paved. New Jersey's practice is to minimize the use of lane-to-lane changes in the construction work zone and to require that adjoining lanes be paved the same day. Depending on project conditions, however, exceptions to this policy do occur (e.g., on maintenance resurfacing projects).

Beginning in 1982, the New Jersey Department of Transportation began experimenting with improved longitudinal joint construction techniques. On the basis of a literature review, the most promising technique was the use of a wedge joint. The Arizona Department of Transportation was one of the first agencies to form joints using overlapping wedges. In the Arizona work, the joint was formed by a sloping shoe attached to the paving machine. This shoe produced a wedge that tapered from 2 in. to zero over a 1-ft length. After compacting the face of the wedge with a pneumatic-tired roller, the adjoining lane was paved to form the finished joint.

In adapting this wedge joint for trials in New Jersey, two modifications were made. The first was to use a steeper sloping face (6:1 versus 3:1) to reduce the potential for raveling. The second was to supplement the use of the wedge joint with infrared heating. Supplemental heating of longitudinal joints has been used with at least some success with conventional vertical butt joints, for example, by Foster et al. (*1*). The theory was that such supplemental heating could be used with particular effectiveness with the wedge joint by softening

FIGURE 1 Typical longitudinal joint distress and repair.

the wedge immediately before placement of the second (overlapping) mat, thereby providing a denser, more homogeneous joint.

RESEARCH METHODOLOGY

The primary measure used to gauge the effectiveness of the wedge technique was the extent to which this procedure was able to eliminate a density gradient across the joint. The significance of joint density gradients was pointed out by Foster et al. (*1*). In 1964, Foster (*1*) summarized the results of density tests on cores taken from variously constructed longitudinal joints. One of the primary findings of that study was that in poor-performing (cold) joints, a low-density zone occurs at the joint in the lane first paved (i.e., the unconfined joint edge) and a high-density zone in the adjoining lane (the confined edge). Foster (*1*) concluded that eliminating this differential is the basic problem in constructing a durable longitudinal joint. He theorized that this differential density is a major factor permitting the initial opening of the joint and the subsequent inevitable process of distress. However, he compared only various types of conventional butt joints.

By virtue of geometry alone, the wedge joint technique was expected to provide a more monolithic, better-performing joint. By eliminating the vertical shear plane in the conventional butt joint, the finished joint should be more resistant to opening as a result of traffic or temperature changes. In order to test this assumption, a program of nuclear gauge testing was undertaken to determine the uniformity of density across the joint and, hence, the nature of any density gradient. As shown in Figure 2, at a given location, those density measurements were taken directly over the joint and 1 ft on either side.

This program of density testing was performed on five resurfacing projects. On three of those projects, a control section consisting of the conventional butt joint was incorporated to provide a specific basis of comparison with the wedge joint. No formal testing was performed to determine the relative safety advantage of the wedge joint as compared to the conventional vertical joint. That the wedge joint does, in fact, possess such an advantage seemed intuitively obvious.

JOINT CONSTRUCTION TECHNIQUES AND EQUIPMENT

Figure 3 shows the sequence of operations involved in constructing a typical New Jersey butt-type joint. After placing the first bituminous mat, the subsequent lane overlaps the first lane by 2 to 4 in. (Figure 3a). The overlapped material is pushed back with a lute, creating a bump (Figure 3b). Rolling in the first lane overlaps the subsequent lane by about 6 in. (Figure 3c). In the subsequent lane, the roller pinches the material into the joint (Figure 3d).

Wedge Joint Construction

As shown in Figure 4, the longitudinal wedge joint consists of two overlapping wedges. The 3:1 inclined face of the joint is formed in the first bituminous mat placed by a sloping steel plate (Figure 5), which is attached to the inside corner of the paver screed extension. A typical wedge plate installation is shown in Figure 6. The plate is mounted about ⅜ to ½ in. above the existing pavement. The specific dimensions of the wedge joint plate and the attachment details vary with paver models.

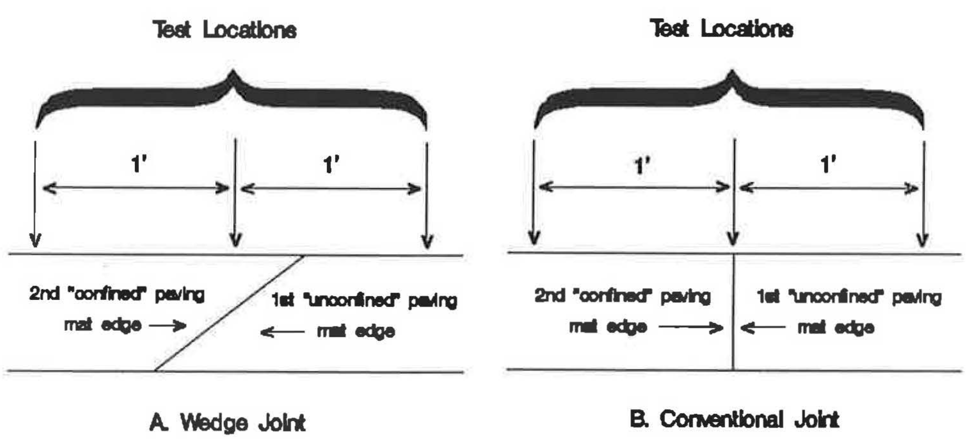

FIGURE 2 Density test layout.

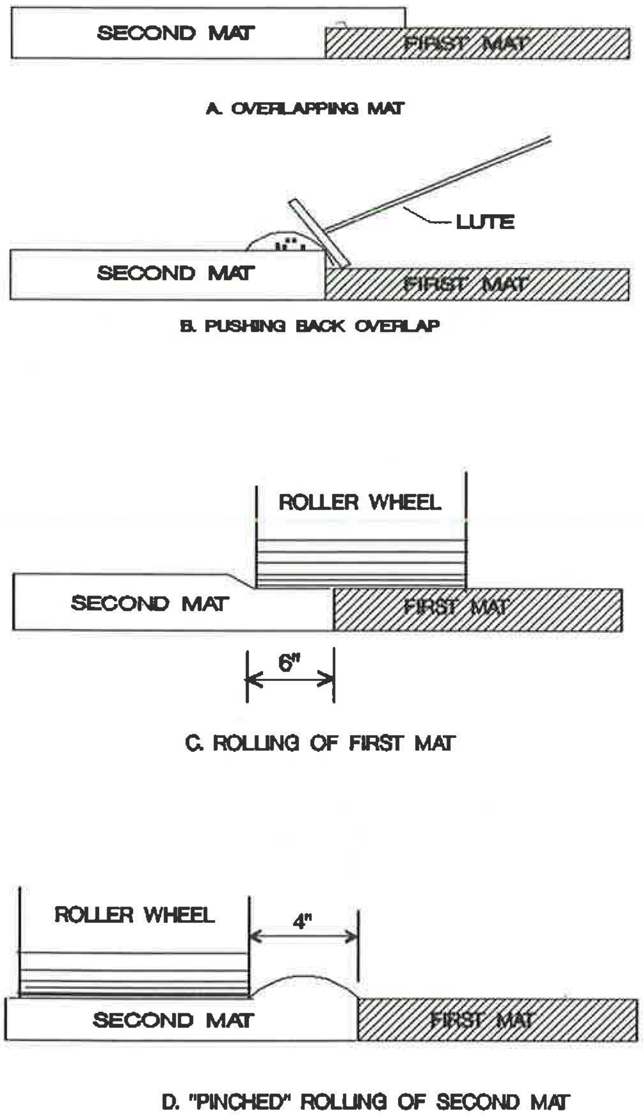

FIGURE 3 Construction of typical butt joint.

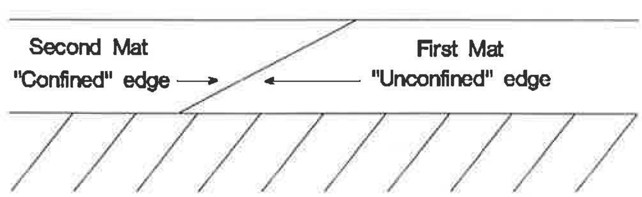

FIGURE 4 Cross section of wedge joint.

After the initial mat is placed using the wedge-forming plate, the mat is rolled to the top of the unconfined edge. In this operation, the roller should not extend more than 2 in. past the top of the unconfined edge (Figure 7). The inclined face of the wedge edge should not be compacted. Leaving the unconfined edge in an uncompacted state permits a more homogeneous bond with the second mat, thereby providing a denser finished joint. The appearances of the unconfined wedge edge and the rolling operation are shown in Figures 8 and 9, respectively.

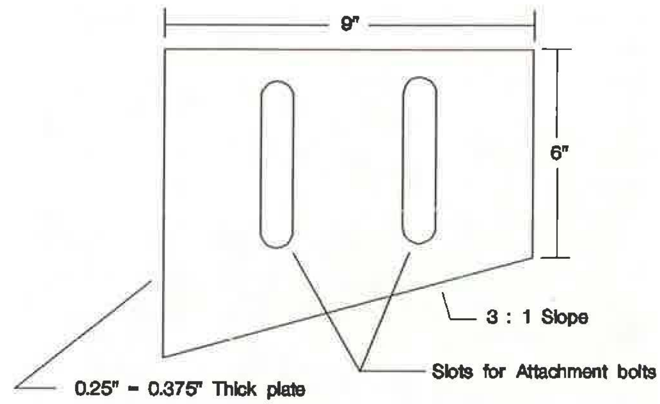

FIGURE 5 Typical wedge plate design.

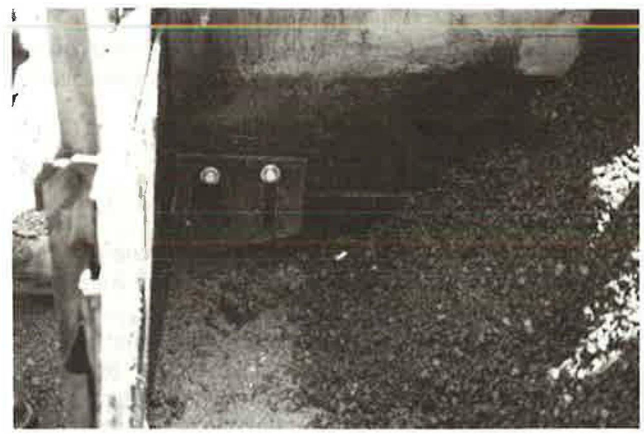

FIGURE 6 Typical attachment of wedge plate to paver.

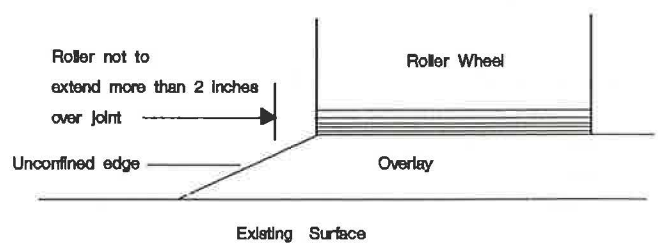

FIGURE 7 Compaction procedure at unconfined wedge edge.

When the second paving mat is placed, an infrared heater attached to the side of the paver heats the unconfined joint edge. This preheating and softening of the joint edge and the adjoining mat is designed to provide a more monolithic joint and to increase the achievable density across the joint.

The second paving mat overlaps the first by 2 to 3 in. (Figure 10a). This overlapped material is pushed back with a lute 3 to 4 ft from the edge of the second mat (Figure 10b). No special rolling is necessary for the completed wedge joint.

Infrared Heater

The infrared heater is designed to heat the surface of the unconfined wedge edge to a depth of about 1½ in. The heater

FIGURE 8 Initial unconfined wedge edge.

FIGURE 9 Rolling the mat at the wedge edge.

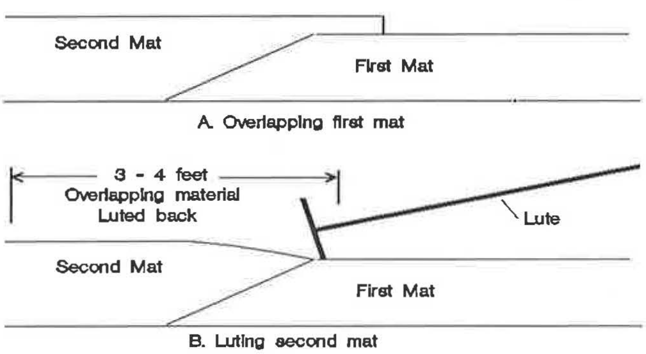

FIGURE 10 Placing the second mat.

is mounted on the paver in front of the screed with a height of about 2 in. above the previously placed mat. The typical heater and mounting are shown in Figure 11. The heater consists of four ribbon burners mounted in a rectangular stainless steel box (15 in. wide × 76 in. long × 4 in. deep). The heater is suspended from the paver with a pair of support pipes. The heater is fueled by an LP vapor withdrawal cylinder. The manufacturer furnishes the heater ready to mount

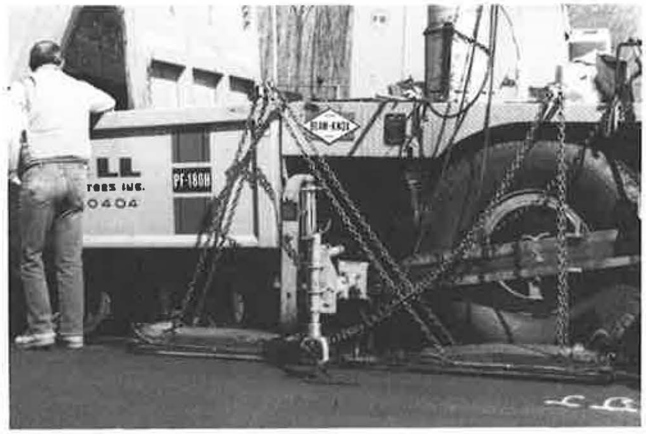

FIGURE 11 Typical heater mounting.

with all necessary hoses, regulators, and electrical connections.

RESULTS AND ANALYSIS

The testing program consisted of making density measurements across the joints on each of three projects in which both the wedge joint and conventional joint were used (the controlled experiments) and testing on three projects in which only the wedge was used (the uncontrolled experiments). On each project, from 5 to 17 test locations were selected for density measurements. The nuclear testing was done with a Troxler Model 3411 B gauge.

Controlled Experiments

Routes US-40 and US-322, Section 2D, Atlantic County

In July 1984, the wedge joint technique was used in constructing all of the longitudinal joints in the 1½-in.-thick top course on this resurfacing project, except for a 300-ft control section. In the control section, the joint between the inside and outside eastbound lanes was constructed using the conventional technique.

Average density data for the wedge and butt joints are shown in Figure 12 and presented in Table 1. Examination of the plotted data indicates that the wedge joint technique was successful in achieving the goal of a generally higher, more uniform density. A statistical analysis of the differences in means confirms that density across the wedge joint does not differ significantly on this project. The butt joint density data display the typical density gradient pattern reported in the literature. The density measurements in the first paving mat and those directly over the joint are significantly lower than those for the second paving mat.

Route NJ-10, Sections 2G and 3G, Morris Plains

In July 1986, the wedge joint technique was used to construct the longitudinal joint in the 2-in.-thick top course on this

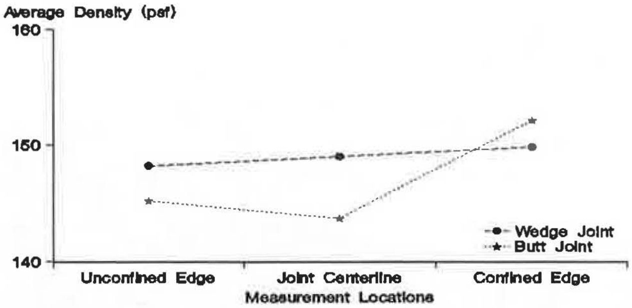

FIGURE 12 Comparative joint density measurements, Routes 40 and 322, Section 2D.

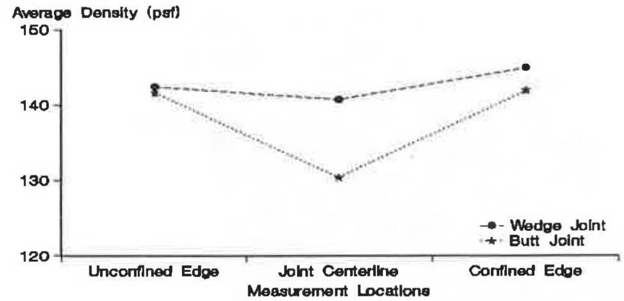

FIGURE 13 Comparative joint density measurements, Route 10, Sections 2G and 3G.

resurfacing project, except for an approximately 500-ft test section in which the conventional butt joint was installed for comparison purposes. The control section was located in the eastbound roadway between the railroad bridge and the Route NJ-53 bridge.

The average density results for the wedge and butt joints are shown in Figure 13 and presented in Table 2. The plotted density data for this project indicate that the wedge joint provided greater, more uniform density. The average density at the confined joint edge was statistically higher than at the other two transverse test locations. However, whether this statistically significant difference (amounting to approximately 4 lb/ft^3) is an important difference in terms of joint performance is doubtful. Examination of Figure 13 clearly indicates a marked density gradient in the conventional butt joint, with the density directly over the joint being signifi-

TABLE 1 NUCLEAR DENSITY MEASUREMENTS, ROUTES 40 AND 322, SECTION 2D

Wedge Joint

Location	Unconfined	Over Joint	Confined
1	152.1	148.8	150.5
2	150.0	147.2	147.1
3	150.1	147.2	148.0
4	149.2	150.1	149.0
5	148.3	150.6	151.2
6	145.7	150.2	153.1
7	148.5	148.4	150.2
8	146.7	148.8	149.0
9	146.0	147.5	149.9
10	145.3	151.0	149.8
Average	148.2	149.0	149.8

Butt Joint(Standard)

Location	Unconfined	Over Joint	Confined
1	148.3	141.1	151.3
2	150.6	146.2	152.5
3	149.6	148.7	150.9
4	147.6	145.3	149.3
5	144.8	146.7	152.6
6	138.5	145.5	153.4
7	144.4	142.0	151.7
8	146.5	141.9	149.1
9	138.1	136.7	155.2
10	143.1	142.6	154.8
Average	145.2	143.7	152.1

TABLE 2 NUCLEAR DENSITY MEASUREMENTS, ROUTE 10, SECTIONS 2G AND 3G

Wedge Joint

Location	Unconfined	Over Joint	Confined
1	136.6	139.4	141.8
2	144.6	138.8	135.9
3	133.1	137.6	144.5
4	135.6	138.6	145.4
5	141.6	139.9	141.1
6	144.7	141.1	141.2
7	146.7	142.7	146.1
8	142.4	139.3	149.2
9	143.4	142.4	145.1
10	144.5	142.6	144.5
11	145.4	134.9	149.8
12	144.1	145.6	146.9
13	143.4	137.2	145.0
14	144.2	142.6	145.8
15	143.4	142.5	149.9
16	143.4	144.2	146.0
17	144.5	142.6	145.8
Average	142.4	140.7	144.9

Butt Joint(Standard)

Location	Unconfined	Over Joint	Confined
1	138.8	125.8	140.1
2	141.6	128.2	142.6
3	143.4	130.0	141.1
4	142.7	128.3	141.2
5	143.1	137.2	144.9
6	143.5	130.0	141.8
7	137.6	122.2	141.6
8	140.6	133.4	139.1
9	143.1	137.4	143.2
10	140.0	129.0	141.5
11	141.6	121.6	141.5
12	140.3	129.9	140.5
13	142.0	137.0	143.2
14	142.0	137.4	143.8
15	143.5	127.9	142.6
Average	141.6	130.4	141.9

cantly lower than that attained in either of the adjoining paving mats.

Route I-78, Sections 6F and 7F, Warren County

In May 1986, the wedge joint technique was used in constructing the joints in the top course and two lifts of binder from Station 369 + 00 (Bloomsbury Road) to Station 432 + 00 (Asbury Road) except for a 300-ft butt joint control section. The control section was located between Stations 387 + 00 and 390 + 00 in the outside and center westbound lanes. The top course was 2 in. thick, and each of the two binder courses was 3 in. thick and variable.

The average density results for the wedge and butt joints are shown in Figure 14 and presented in Table 3. The plotted data indicates the wedge joint results on this project were similar to those observed on Route NJ-10. The wedge joint displayed approximately equal densities in the first paving mat and over the centerline of the joint but somewhat higher densities in the second (confined) paving mat. Here again, the butt joint displayed a pronounced density gradient. The density measurements were the lowest directly over the joint.

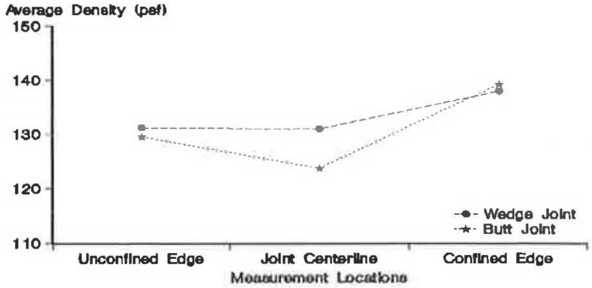

FIGURE 14 Comparative joint density measurements, I-78, Sections 6F and 7F.

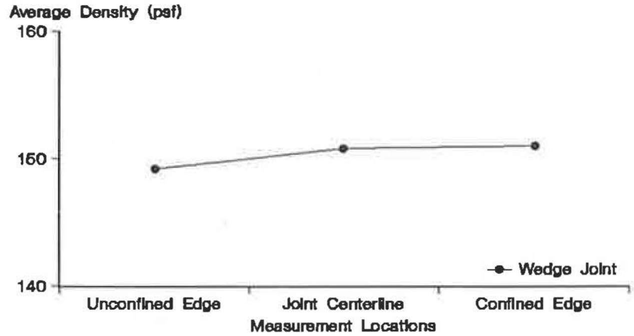

FIGURE 15 Joint density measurements, I-80, Section 4BB.

Uncontrolled Experiments

Route I-80, Section 4BB, Paterson

In July 1985, the wedge joint technique was used in constructing all of the joints in the 2-in. top course in this resurfacing project. No butt joint control section was provided. The average density results are shown in Figure 15 and presented in Table 4. On this project, the wedge technique succeeded in eliminating the joint density gradient. A statistical analysis indicates that no significant difference in density across the finished wedge joint.

Route US-206, Sections 6B, 5A, 4B, and 3B, Red Lion

In May 1984, the wedge joint was used in constructing all the longitudinal joints in the 2-in. top course of this resurfacing project. Supplemental (infrared) heating was not used in constructing the wedge joints on this project. The average density results are shown in Figure 16 and presented in Table 5. As shown in Figure 16, the finished wedge joint displayed no statistically significant density gradient across the joint.

TABLE 3 NUCLEAR DENSITY MEASUREMENTS, I-78, SECTIONS 6F AND 7F

Wedge Joint

Location	Unconfined	Over Joint	Confined
1	130.3	134.7	140.6
2	130.7	133.9	138.7
3	132.3	129.9	140.3
4	134.3	130.3	137.1
5	136.5	136.7	139.9
6	132.8	130.7	137.2
7	127.5	128.9	134.5
8	130.5	124.5	136.6
9	130.2	132.8	137.2
10	127.3	128.9	137.5
Average	131.2	131.0	138.0

Butt Joint(Standard)

Location	Unconfined	Over Joint	Confined
1	131.4	129.1	136.2
2	131.4	119.7	139.3
3	120.4	124.4	142.2
4	126.4	121.0	140.3
5	133.9	123.1	141.3
6	131.3	123.5	139.7
7	132.2	125.7	136.4
Average	129.6	123.8	139.3

TABLE 4 NUCLEAR DENSITY MEASUREMENTS, I-80, SECTION 4BB

Wedge Joint

Location	Unconfined	Over Joint	Confined
1	144.0	148.9	148.8
2	149.2	142.7	149.8
3	150.0	149.7	151.2
4	147.7	154.7	155.4
5	151.1	149.5	139.2
6	147.9	154.1	156.4
7	154.6	155.8	156.1
Average	149.2	150.8	151.0

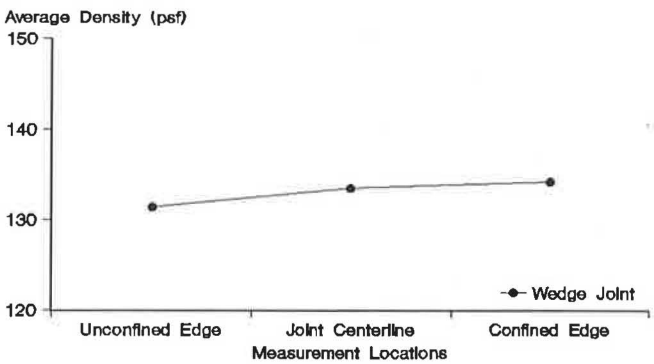

FIGURE 16 Joint density measurements, Route 206, Sections 3B, 4B, 5A, and 6B.

Costs

The costs associated with the use of the wedge joint technique have been estimated on the basis of information supplied by New Jersey contractors, resident engineers, and an infrared heater supplier. The purchase price of the infrared heater reportedly ranges from $1,000 to $4,000, depending on the size of the heater and number of burners (BTU rating). The total cost of acquiring and installing the wedge joint plate, the heater mounting, and propane tank is approximately $650. The daily operating cost of the heater is insignificant. For example, the Route NJ-3, Section 2J, project required only about $10 of propane (30 lb) per day for each 1,000 tons of bituminous concrete placed in a 2-in.-thick overlay.

CONCLUSIONS

The results of the extensive program of field density testing undertaken in this study indicate that the wedge joint technique produces higher, more uniform density than the conventional butt joint technique. These observed improvements in density, combined with the elimination of the vertical shear plane in the conventional butt joint, suggest that the wedge joint procedure will provide a finished joint that is more resistant to opening under the effects of traffic and weathering. Furthermore, after 5 years of testing and analysis, the wedge joint construction on five projects shows none of the deteri-

TABLE 5 NUCLEAR DENSITY MEASUREMENTS, ROUTE 206, SECTIONS 3B, 4B, 5A, AND 6B

Wedge Joint

Location	Unconfined	Over Joint	Confined
1	127.3	133.7	133.1
2	134.1	133.3	135.2
3	133.1	125.8	134.3
4	130.3	132.7	134.6
5	127.8	131.6	130.9
6	134.3	137.5	133.8
7	133.9	135.4	134.2
8	132.1	133.7	134.3
9	129.8	137.6	137.2
Average	131.4	133.5	134.2

oration or raveling that had been observed in the standard joint.

In addition to improved performance, the wedge joint offers two other advantages. First, by eliminating the vertical edge, the wedge joint is safer for motorists making lane changes in the resurfacing construction area. Second, use of the wedge joint with supplemental heating eliminates the need to pull back the paver to avoid cold joints, thereby providing the contractor with greater flexibility and production capability. This elimination of the pullback requirement also has the potential for improving the riding quality of the finished pavement by reducing the number of transverse joints in the surface course.

Although this study of the effectiveness of the wedge joint procedure was limited to resurfacing projects, certain of the observed results are equally applicable—and the benefits equally desirable—on new construction. The wedge joint with supplemental heating is therefore recommended for use in constructing surface mixes (top and bottom layer) both on new bituminous pavement construction and resurfacings.

One point still unsettled, however, is whether supplemental heating should be required for bituminous mixtures other than surfacing mixes. Construction personnel have expressed the opinion that it may not be necessary, because base course joints have historically not been a factor in pavement distress. They agree that the safety feature of the wedge joint—elimination of the edge dropoff—is important for all mixes on resurfacing work. Under these circumstances, the conclusion is that the wedge joint should also be used on base course construction on both new and overlay projects, except that the use of supplemental heating should be a contractor option. The merits of this approach should be verified by research as a part of the normal implementation process.

RECOMMENDATIONS

1. Specifications. It is recommended that the Department adopt the wedge joint technique as the standard method for constructing longitudinal joints in all bituminous paving.
2. Further Research. It is recommended that the merits of eliminating the use of supplemental heating in base course wedge joint construction be evaluated by research as part of the implementation process.

REFERENCE

1. C. R. Foster, S. B. Hudson, and R. S. Nelson. Constructing Longitudinal Joints in Hot-Mix Asphalt Pavements. *Highway Research Record 51*, HRB, National Research Council, Washington, D.C., 1964.

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