EFFECTIVENESS OF INFRARED JOINT HEATERS FOR BITUMINOUS PAVEMENTS

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

EFFECTIVENESS OF INFRARED JOINT HEATERS FOR BITUMINOUS PAVEMENTS

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INTRODUCTION

The longitudinal joint between adjacent paving lanes is often the weakest part of bituminous pavement and the area where cracking first appears. Water penetration of cracks soon results in ravelling and loss of paving material, particularly when freeze-thaw cycles are involved. The problem is caused by lower density at the edge of the first lane placed where there is no confinement during compaction rolling. By the time the second lane is placed (the edge of which is confined by the first lane) the temperature of the initial lane has cooled below the point where additional rolling will significantly increase density. One method of alleviating this problem is to place bituminous mixtures with two pavers in echelon so that two lanes can be placed and rolled at the same temperature. Unfortunately, echelon paving is not permitted on two-lane projects where traffic must be maintained, which is the usual condition. In this case, an alternative procedure is used in which the paver is equipped with an infrared joint heater for warming the cooled edge of the initially placed lane. This method was recommended as the result of a Departmental study made in 1963 (1).

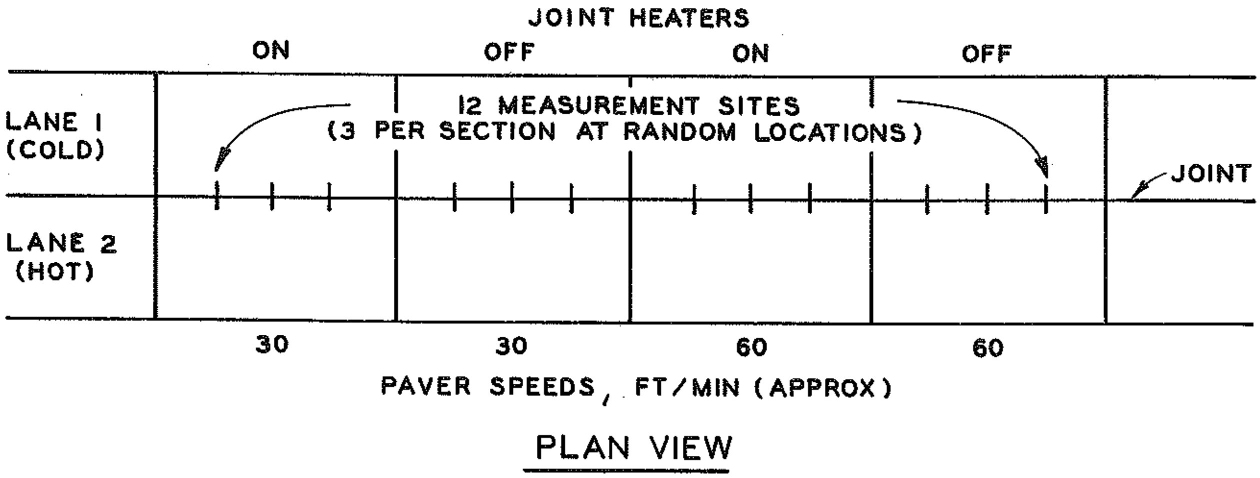
Additional studies were reported by the Transportation Research Board in 1964 concerning comparisons of various joint construction methods, with and without the use of joint heaters (2). Results of these studies indicated a low density zone at the edge of the initially paved lane and a higher density zone at the abutting edge of the new lane. This condition was not present in joints formed of hot material when paving the lanes together in echelon. Other reported findings were:

1) Overlapped rolling produced the highest densities in the initial lane in semi-hot joint construction. Semi-hot construction in the study involved laying the second lane while the first lane was at temperatures ranging from 120 to 140 F.

2) There was no clearcut superiority over any of the procedures used in cold-joint construction (temperature of initial lane less than 120 F) from the standpoint of density in the initial lane.

3) Infrared heating slightly improved density that could be obtained in the initial lane, but did not improve resulting tensile strength.

Current Department specifications (3) require that bituminous mixtures be placed either with two pavers in echelon (where permissible) or with one paver equipped with an approved joint heater when the temperature of the initially placed mat is less than 170 F.



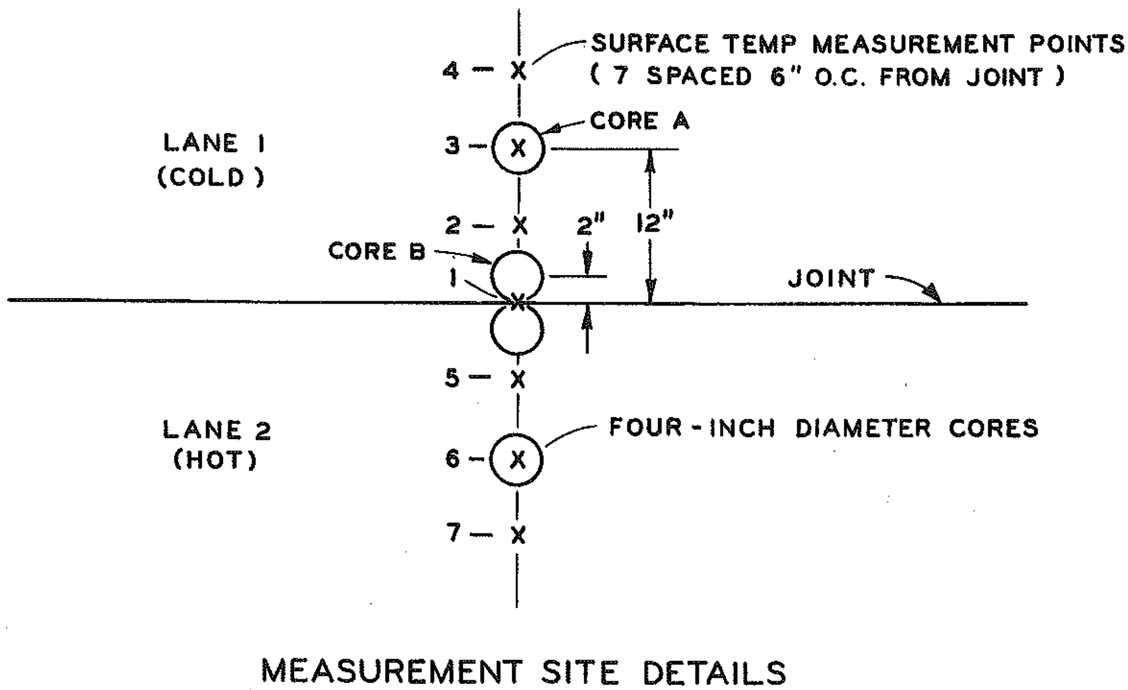


Figure 1. Experimental test section plan for evaluating infrared longitudinal joint heaters on one project. Evaluation measurements were made while paving in lane No. 2.

At a meeting of Department engineers and representatives of the Michigan Asphalt Paving Association, the merits of longitudinal joint heaters were discussed further. The contractors questioned the effectiveness of joint heaters as currently used and suggested discontinuing their use. One negative factor discussed was that the presently used higher paver speeds (40 to 60 ft/minute) did not provide as much heat to the surface as did the slower speeds (25 to 30 ft/minute) which were used in the evaluation tests. The Department, however, felt that heating the cooled joint by means of heaters should be continued.

As a result of this meeting, a research study was initiated in 1976 to determine whether the use of joint heaters, as required by the Department, are effective for obtaining adequately compacted longitudinal joints between lanes of bituminous pavement (4).

RESEARCH PROCEDURE

The evaluation procedure used in the present study consisted of measuring, in the vicinity of the longitudinal joint, the ability of infrared joint heaters to significantly alter three fundamental characteristics of a newly placed bituminous layer, i.e., density, tensile strength, and temperature. Four test sections were selected on each of five resurfacing projects with three measurement sites selected at random locations along the longitudinal joint in each section (Fig. 1). A total of 60 measurement sites were included in this study. At each measurement site, temperature profiles and core samples were obtained at the specific locations shown in Figure 1.

Compaction Evaluation

The use of a joint heater, if effective, should result in greater densities in the cold lane near the joint than would be obtained if a joint heater was not used. Cores were obtained soon after paving at the locations shown in Figure 1 and taken to the laboratory for density determinations using the water displacement method. Profiles of density values across the joint are shown in Figure 2 for the four combinations of two paver speeds and two joint heater operations. The values shown in Figure 2 are averages for all projects included in the study. Because density levels can vary between projects due to different mixtures, and because there could be mixture differences between adjacent hot and cold lane materials, the values shown are the ratios of the density of the selected point to the density obtained from core A at point 3 in the cold mat.

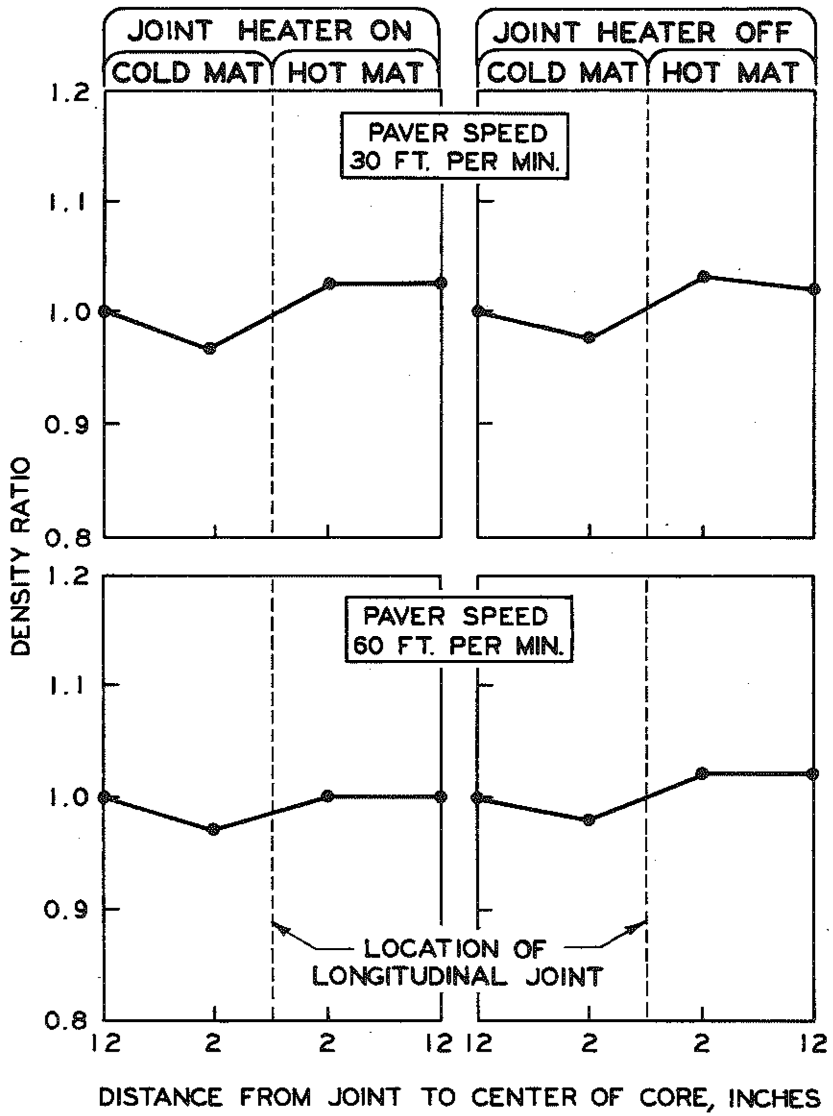


Figure 2. Density of asphalt surfacing at various distances from longitudinal joint at two paving speeds.

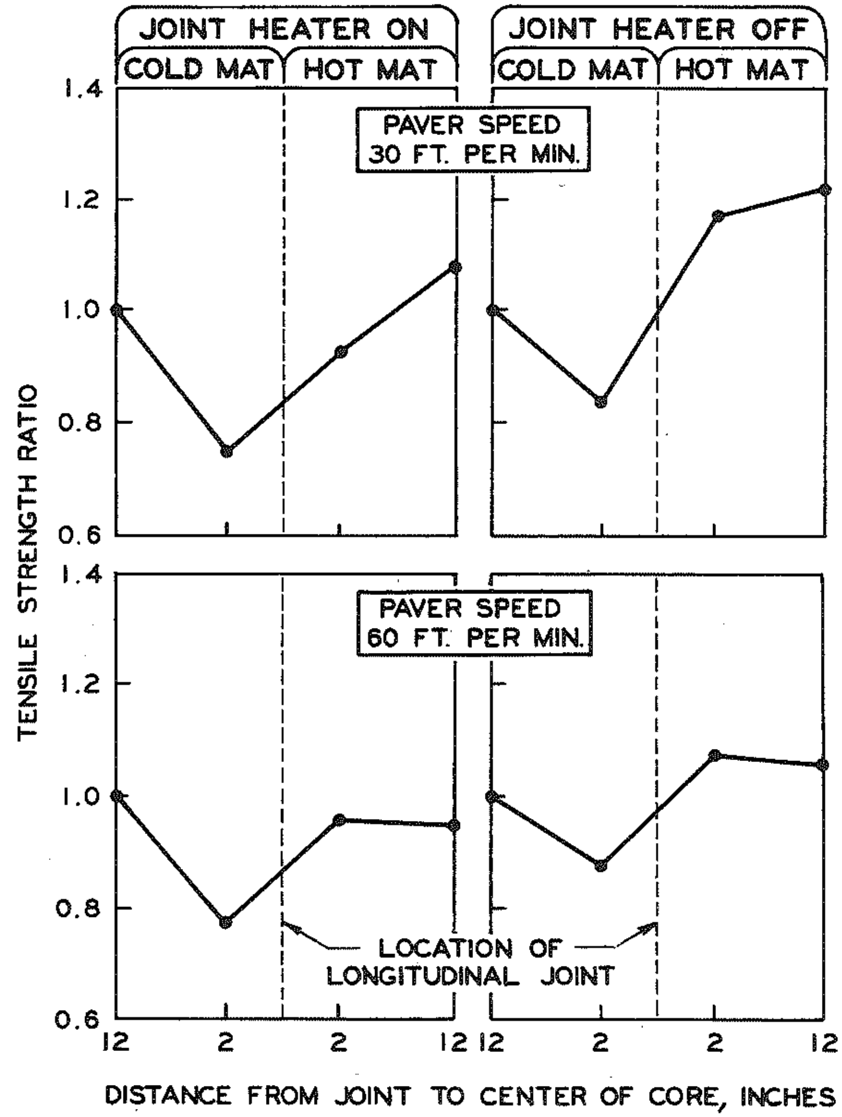


Figure 3. Tensile strength of asphalt surfacing at various distances from longitudinal joint at two paving speeds.

Density values in Figure 2 show that a low density zone at the joint is built into the lane which is paved first (cold lane). Further, the density 1 ft into the cold lane is generally much less than that in the lane paved last (hot lane). The use of a joint heater does not improve this tendency either at fast (approximately 60 ft/minute) or slow (approximately 30 ft/minute) paver speeds.

Tensile Strength Evaluation

The tensile strength of the bituminous overlay in the region of the longitudinal joint is probably the most important characteristic which should benefit if joint heaters are effective. Adequate tensile strength is needed at the longitudinal joint to resist cracking due to thermal contraction across the lane width. The tensile strength of each core was measured in the laboratory using the Indirect Tensile Test Method (5). This test can be performed directly on core samples of any thickness normally used in paving layers. By properly marking each core to indicate its orientation in the pavement, the core can be tested for tensile failure along a plane (originally a vertical plane in the pavement) parallel to any desired direction in the pavement.

Tensile strength values are presented in Figure 3 for the four combinations of paver speed and joint heater operation. The tensile strength values shown are the ratios of the tensile strength of the selected point to the tensile strength obtained at point 3 (core A). These values, the averages for the five projects, follow the same trend as density values, as might be expected. Low strengths exist adjacent to the joint in the cold lane despite the use of joint heaters.

Temperature Evaluation

Surface temperatures were measured immediately after the paver passed the measurement site in both lanes across the joint (points 1 to 7). A second temperature profile was obtained three minutes after the paver had passed. This final profile was made to provide a measure of the amount of heat transferred to the cold mat (lane 1) by the joint heater. If a significant amount of heat was put into the cold mat by the heater and if the heat penetrated to some beneficial depth, then the material near the joint should cool less rapidly where the heater was used than where it was not used.

Temperature profiles are shown in Figure 4 for each of the four combinations of paver speed and joint heater operation. Because of the strong influence of ambient conditions (sunshine, wind speed, shade, etc.), the

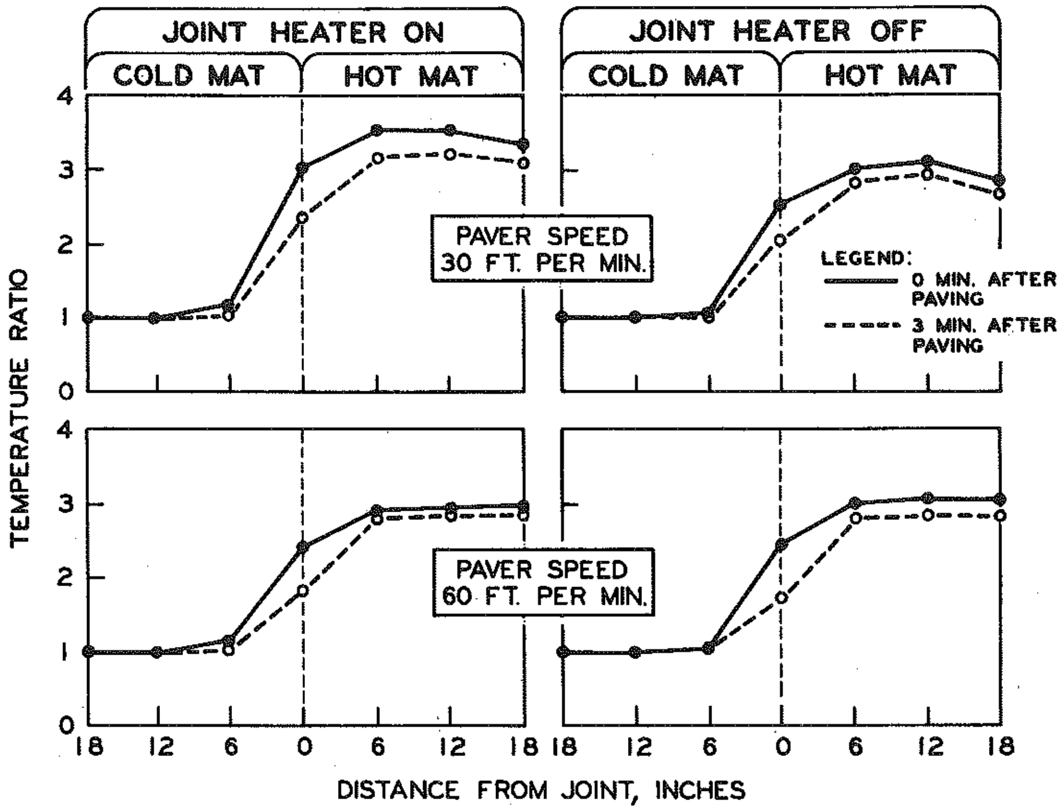


Figure 4. Temperature profiles showing the effectiveness of infrared longitudinal joint heaters at two paver speeds.

temperature measured at each point was divided by the temperature measured at point 4, 18-in. from the joint in the cold lane. It was felt that this point would not be appreciably affected by the process of paving lane 2. The values in Figure 4 are averages for all projects tested.

Temperature profiles of Figure 4 indicate no significant beneficial increase in temperature from the use of joint heaters. At the slow paver speed the initial temperature at the joint was somewhat higher when a heater was used. At the joint, however, fresh hot material is lapped into the cold mat by the paver and was partially pushed back onto the hot mat at the time these surface temperature measurements were made. Initial temperatures at the joint may, therefore, be biased toward higher values than actually exist within the underlying material in the cold lane edge.

Any significant amount of heat put into the edge of the cold mat by a joint heater should, however, be indicated by higher temperatures after some time, say three minutes. Temperature values at the joint after three minutes show no difference regardless of whether or not a joint heater is used.

In addition to the temperature profile measurements, the surface temperature of the cold mat was measured immediately in front of the joint heater and again at the same location immediately after the joint heater had passed. Average temperatures measured in this manner are shown in Table 1 along with the increase in surface temperature and the amount of propane fuel used by the heater on each project. Figure 5 shows no relationship between the increase in surface temperature, and fuel consumption, or initial surface temperature measured ahead of the heater.

TABLE 1
SUMMARY OF SURFACE TEMPERATURE AND FUEL CONSUMPTION MEASUREMENTS

Project	Paver Speed	Surface Temperature, F			Fuel Consumption, lb
		Ahead of Heater	Behind Heater	Increase	
M 66	Slow	130	155	25	3.0
	Fast	107	120	13	3.5
M 61	Slow	84	133	49	5.5
	Fast	73	146	73	4.0
M 55	Slow	116	150	34	9.5
	Fast	116	206	90	5.0
I 96	Slow	80	165	85	13.5
	Fast	82	190	108	10.5
M 21		Information Not Obtained			

Effect of Ambient Temperature

Data presented thus far do not show the influence of ambient temperatures on the effectiveness of joint heaters. During the course of this study only one project was paved during cold weather conditions so the amount of data by which ambient temperature effects can be compared, is limited. Including all projects, however, temperatures as measured on the already paved surface of lane 1 ranged from 40 to 121 F. The relationship between the temperature of the paved surface (lane 1) and the density and tensile strength properties adjacent to the joint are shown in Figures 6 and 7, respectively. The ratios shown are the values obtained from cores for lane 1 next to the joint (core B) divided by the values for lane 1, 12-in. away from

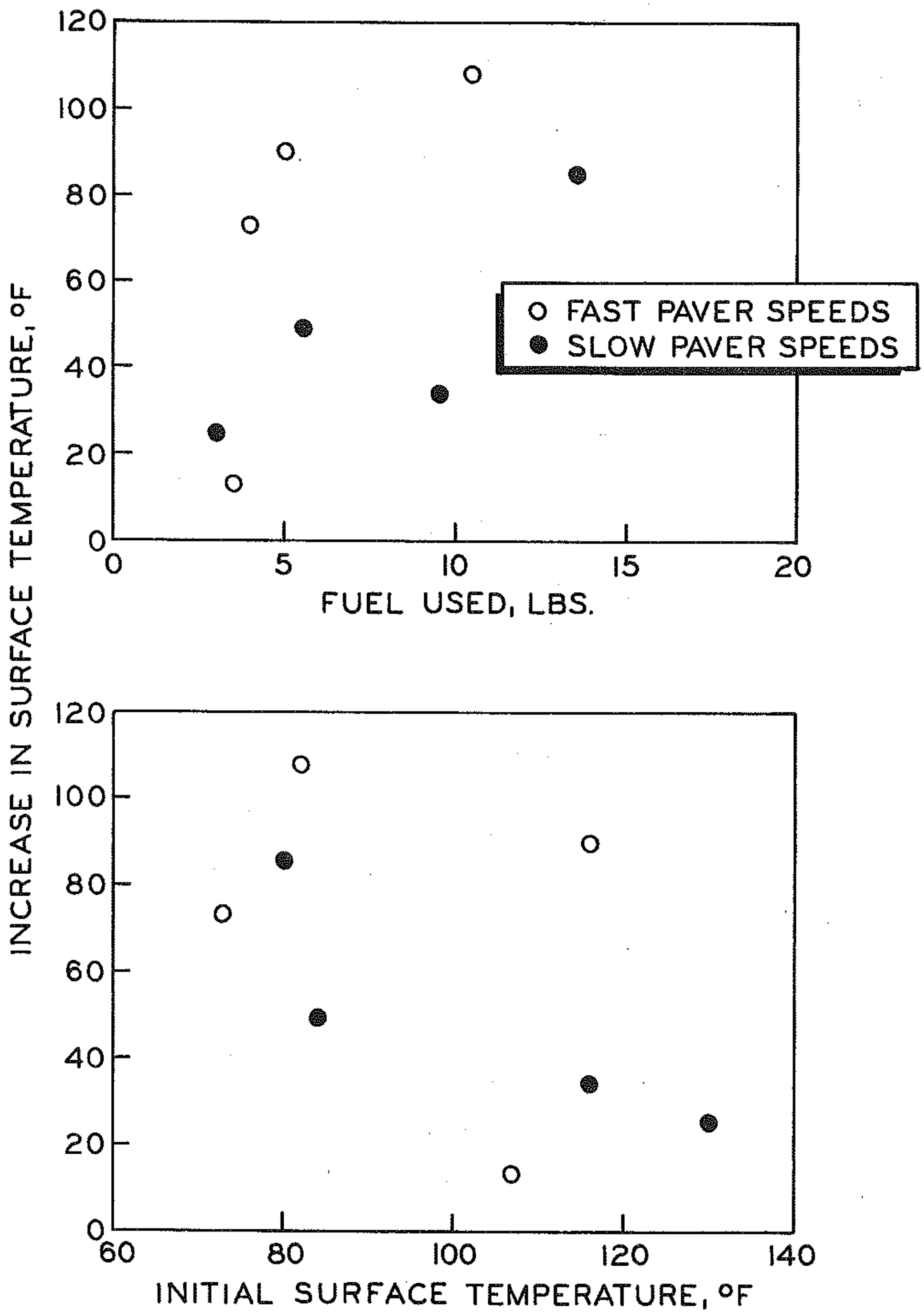


Figure 5. Relationship between increased surface temperature, joint heater fuel consumption and initial temperature of the cold mat surface immediately in front of the heater.

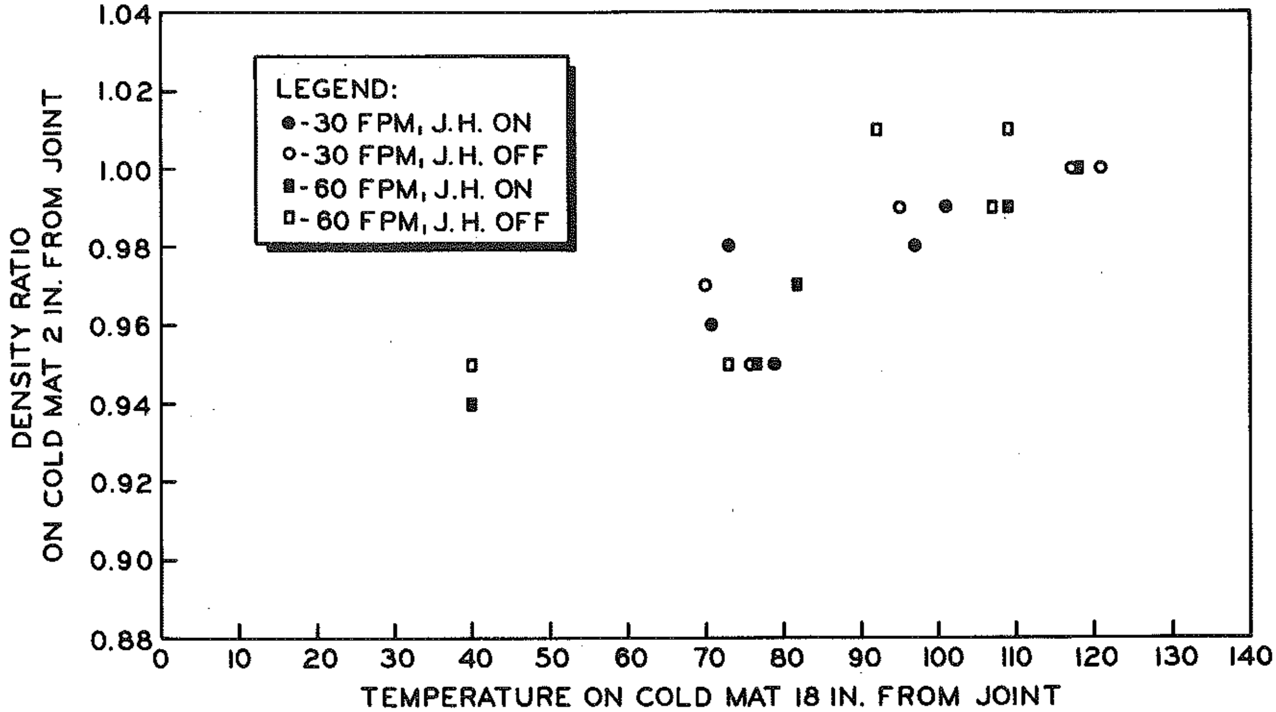


Figure 6. Influence of ambient temperature on effectiveness of infrared longitudinal joint heaters indicated by density ratios and pavement surface temperature.

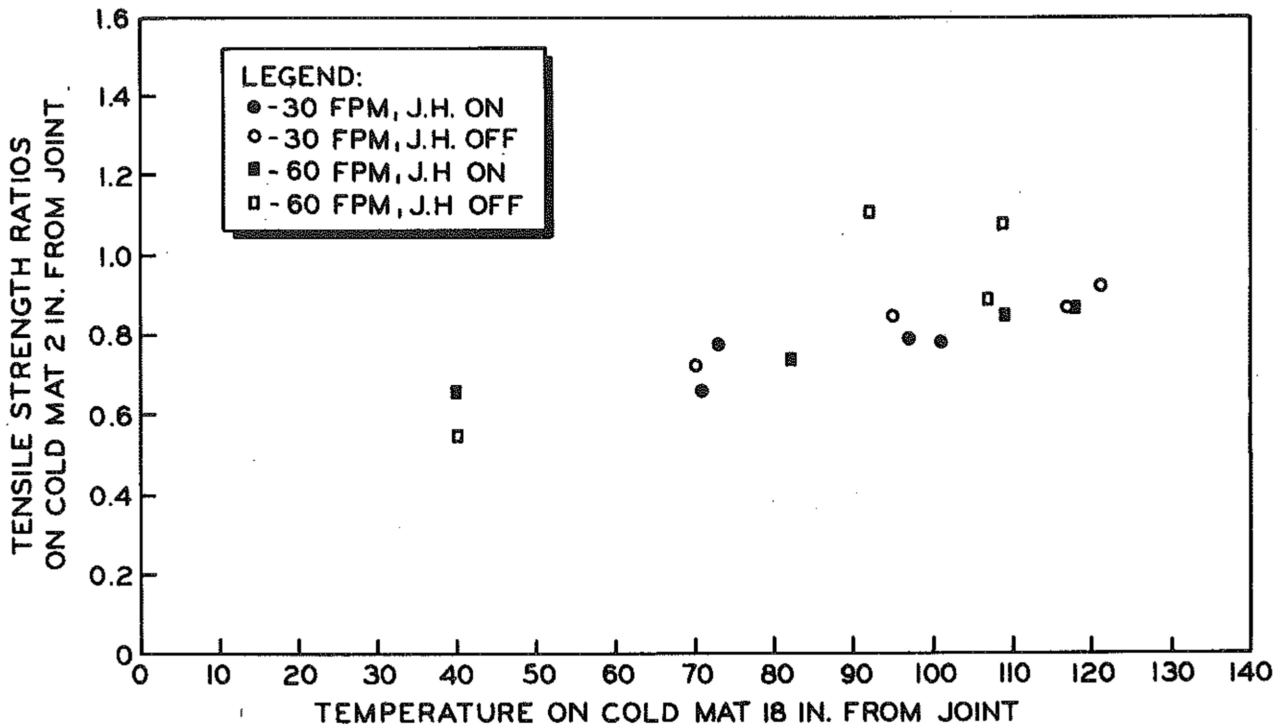


Figure 7. Influence of ambient temperature on effectiveness of infrared longitudinal joint heaters as indicated by tensile strength ratios and pavement surface temperature.

the joint (core A). Any benefit due to the use of joint heaters should be indicated by generally higher values for these properties than values obtained where joint heaters were not used. Such an influence might be expected at low temperatures, but no such trend is shown.

OPERATION OF THE JOINT HEATERS

Infrared joint heaters are attached to the paver and are placed over the edge of the previously laid mat just ahead of the screed. Figure 8 shows two different locations of the heater with respect to the joint which were observed during the study. In the location shown at the left of the figure, the joint heater is positioned so that 10 in. of the cold mat was under the heater. The joint heater shown in the righthand diagram, however, is centered over the joint so that the exposed edge will receive a concentration of heat and thus, presumably, result in a better bond with material being placed in the hot mat.

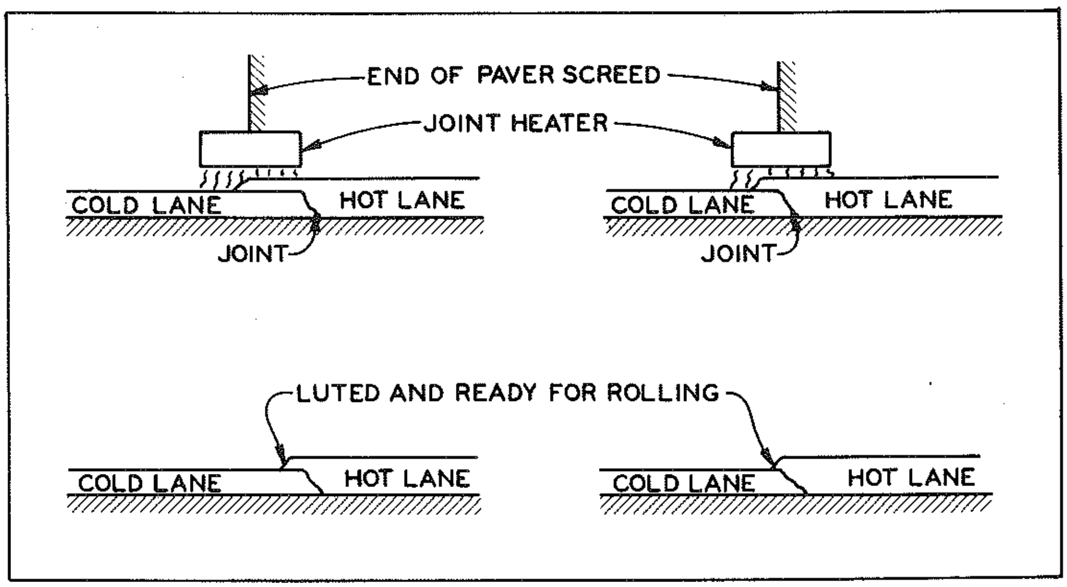


Figure 8. Location of infrared joint heater in relation to the longitudinal joint.

Table 1 summarizes fuel consumption and heating capacities for the joint heaters involved in this study. Included in Table 2 are the amounts of fuel used in the test sections where the heaters were evaluated along with the amount of fuel which could be expected to be used at the heater's rated capacity. As shown in the table, actual fuel consumption ranged from less than half to nearly three times the amount expected.

TABLE 2
INFRARED JOINT HEATER FUEL
CONSUMPTION DATA

Project	Joint Heater		Test Section Fule Consumption, lb			
	Model	Rating BTU/hr	Section Length, ft	Paver Speed		Expected Fuel Use, lb*
				Slow	Fast	
M 66	Aeroil Hepr-8L	240,000	1,260	3.0	---	8.5
			1,300	---	3.5	4.4
M 61	Aeroil Hepr-8L	240,000	1,425	5.5	---	9.6
			1,300	---	4.0	4.4
M 55	Infra-Ray ASJ0	**	1,300	9.5	---	8.7
			1,200	---	5.0	4.0
I 96	Infra-Ray ASJ0	**	987	13.5	---	6.6
			1,000	---	10.5	3.4
M 21	Information Not Obtained					

* Based on heater rating of 240,000 BTU/hr and 19,880 BTU/lb of propane.
** Information not available.

In spite of the relative differences in the amounts of fuel used there were no measurable effects obtained by using joint heaters, as discussed in previous sections, nor any differences in the effectiveness of the different model heaters.

Heat Transfer Considerations

In addition to test data already presented, it is of interest to consider the potential for joint heater effectiveness from a theoretical viewpoint. A recently published paper (6) describes a finite difference program for computing temperature profiles generated within bituminous paving layers by heaters which are used in connection with heater-scarifier surface recycling. In this computer model the principles of heat transfer along with thermal characteristics of paving mixtures are used to relate the heater temperature and exposure times, i.e., paver speeds, to temperatures generated at various depths within the pavement layers. Figure 9 shows the relationship between temperatures at various depths in the bituminous surfacing and the heater temperature and the length of time the surface is exposed to the heat source. Infrared heat is generated by joint heaters in the same manner as in several heater-scarifier units modeled in this program. Table 3 summarizes heat and temperature characteristics for several different heater types. It is obvious that some discrepancies in temperature exist, especially temperatures on the surface of the bituminous layer.

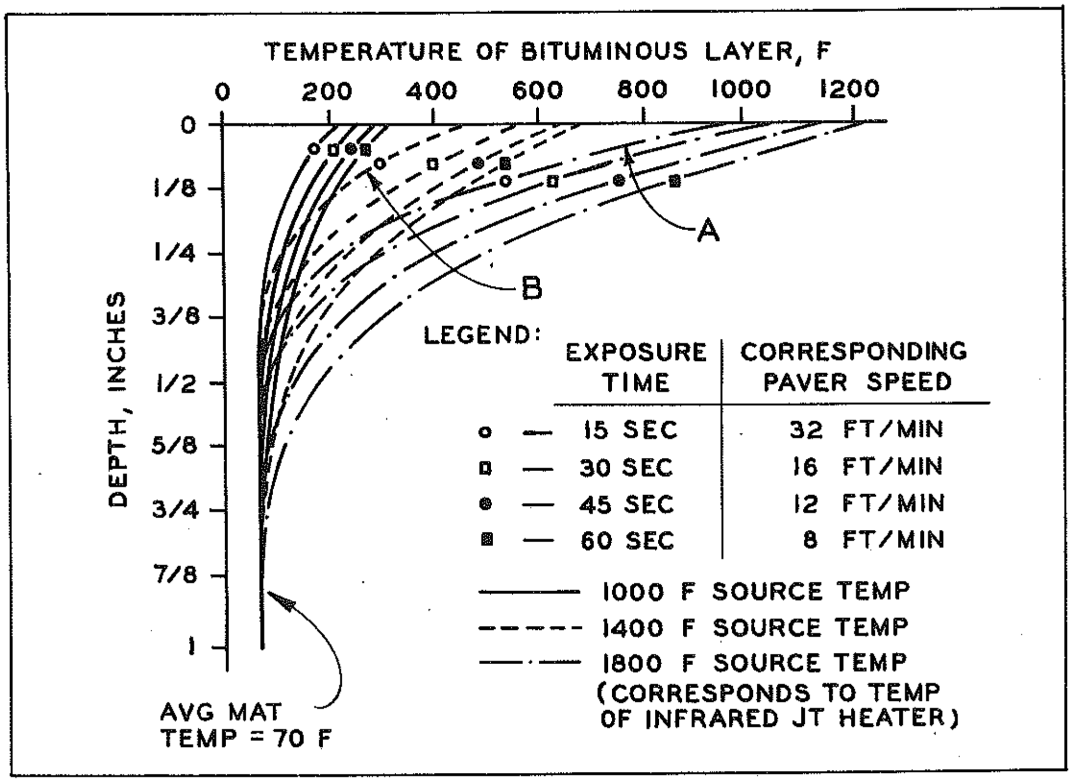


Figure 9. Temperatures at various depths within a bituminous surfacing layer as a function of temperature of the heat source and exposure time (after Ref. 5).

The curves of Figure 9 along with heater information from Table 3 can be used to estimate the potential effectiveness of joint heaters. Curve A in Figure 9 is a temperature profile which can theoretically be generated by an 1,800 F heater moving at a speed of 32 ft/minute. Effective heat penetration is about 1/2 in. A surface temperature of nearly 1,000 F, however, is indicated on Curve A. Curve B indicates slightly less than 3/8 in. of heat penetration for a 1,400 F heater with a surface temperature of approximately 450 F which more closely agrees with the measured values shown in Table 3.

TABLE 3
HEATING CAPACITIES AND TEMPERATURE CHARACTERISTICS
OF SEVERAL TYPES OF BITUMINOUS PAVEMENT HEATERS

Heater	Rated Heater Output, BTU/hr/sq ft	Heater Temperature, °F	Measured Surface Temperatures, °F
Aeroil I-R Joint Heater*	36,000		138**
Infra-Ray I-R Joint Heater*			178**
Pavement Reclaiming Joint-Heater	36,000	2,400	220° at 1/4 in. below surface (1)
Cutler Repaver	60,000 - 70,000	1,700 - 1,800	440° at 12 to 20 fpm
Jim Jackson Heater-Scarifier	71,000		320 (7)

* Heaters used on projects in this study.
** Average surface temperature measured immediately behind the joint heater for all projects where each heater was used.

This analysis indicates that the very surface of the cold mat, the upper 1/4 in., might be heated enough to enhance bonding with the hot material as it is placed and compacted. However, the amount of reheated paving material in the cold mat would not be enough to result in further densification or in an increase in tensile strength.

CONCLUSIONS

Data obtained during this study show that when paving multiple lane bituminous highway surfaces, a zone of low density and low tensile strength is built into the longitudinal joint of the lane which is paved first. Results also show that the use of infrared joint heaters does not alleviate this situation, regardless of paver speeds or ambient temperature conditions.

It should be pointed out that the joint heaters observed during this study were not operated in the same manner on all of the projects. Heaters were centered over different locations with respect to the edge of the cold mat. Paver locations, with respect to the cold edge, and also the amount of hot material lapped into the cold mat, were not consistent from job to job. Fuel consumption ratings were not available for the heaters and the heat rating, in BTU, was available for only one of the heaters involved (Table 1).

Consideration of heat transfer principles, although not the main procedure used in this study, indicates that reheating of the material at the joint is limited to about 3/8 in. of effective penetration. Increased depth of that penetration would require greater exposure times through the use of slower paver speeds or longer heaters. This would not, however, eliminate the low density zone unless some excess hot material was lapped and rolled into that region of the cold mat. Heating to a depth of 1/4 in. on the vertical face of the cold material at the joint might contribute to better bonding with the hot material, but this effect could not be measured in this study.

RECOMMENDATIONS

On the basis of the measurements and observations made during the course of this study the following recommendations seem warranted.

1) The use of joint heaters, as currently specified, should be discontinued.

2) The problems originating from low density and tensile strength at the longitudinal joint could be alleviated by: confining the edge of the first lane in some manner during its compaction; paving both lanes at the same time; or, cutting away the low density, low strength zone prior to paving the second lane.

These methods would not, however, eliminate reflective cracking due to a longitudinal joint or crack existing in the underlying pavement. Increasing the density and strength in the area near the joint, however, would probably reduce disintegration of the material which is often present in the vicinity of the reflective crack at the longitudinal joint.

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