Research Report
KTC-02-10/SPR208-00-1F

KENTUCKY TRANSPORTATION CENTER

College of Engineering

COMPACTION AT THE LONGITUDINAL CONSTRUCTION JOINT IN ASPHALT PAVEMENTS (KYSPR-00-208)

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COMPACTION AT THE LONGITUDINAL CONSTRUCTION JOINT IN ASPHALT PAVEMENTS (KYSPR-00-208)

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16. Abstract

The objectives of this study were to evaluate the level of compaction at the construction joint in HMA pavements on new and existing projects; to determine the level of water infiltration and segregation at the joint and its effect on joint performance; to determine the most promising joint construction methods around the nation and worldwide by reviewing specifications, experiences, and construction practices for joint construction and the prevention of joint segregation; to develop specifications and construction methods to ensure the level of density necessary at the joint for proper performance; and to review special paving equipment (attachments) for improving densification for the unsupported edge.

Four methods of joint construction were evaluated in this study. These were the notched wedge (12:1), restrained edge, joint reheater, and Joint Maker. In addition, a number of joint adhesives were used. Some of the major conclusions and recommendations from the study include:

- Contractors are consistently achieving levels of density at or near the construction joint that are within three percent of the lane density. It is recommended that specifications be written that would require contractors to achieve that level of density at or near the construction joint.
- The reheater achieved the highest joint density of all the methods; however, only one short project was included in the study. The effects of reheating the mat could not be determined during construction, but will be evaluated during long-term monitoring. The restrained-edge method of joint construction achieved the second highest overall densities and statistically was significantly better than the conventional method of construction. The notched wedge only marginally improved densities overall, while the Joint Maker showed no improvement over conventional construction techniques. It is recommended that more projects be constructed using the restrained-edge method.
- It appeared the notched-wedge method produced the lowest permeabilities at the joint.
- Preliminary performance data indicate that all projects are currently performing well with projects having joint adhesives performing as well as, or better than, projects without joint adhesives. It is recommended that other projects be constructed using joint adhesives.

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ABSTRACT

Poor compaction practices at longitudinal construction joints in hot-mix asphalt (HMA) pavements lead to premature pavement failure. The hypothesis is that poorly constructed or compacted HMA joints tend to be more permeable and allow water to enter into the pavement structure, accelerating pavement deterioration processes.

In recent years, it has become evident how critical proper longitudinal joint construction is to the life of the pavement structure. Recent water and icing problems on US 460 and US 23 in Pike County, premature pavement failures on I-75 in Scott County, and other problems found throughout the state indicate that construction joints may be allowing water to rapidly enter the pavement structure. The water appears to be causing several problems such as debonding of surface layers, mixture stripping, aging of the asphalt (oxidizing and hardening), and other associated problems, all of which accelerate pavement failure. Many pavements have been, or are in the process of being, resurfaced as a direct or indirect result of longitudinal joint deterioration.

The objectives of this study were to evaluate the level of compaction at the construction joint in HMA pavements on new and existing projects; to determine the level of water infiltration and segregation at the joint and its effect on joint performance; to determine the most promising joint construction methods around the nation and worldwide by reviewing specifications, experiences, and construction practices for joint construction and the prevention of joint segregation; to develop specifications and construction methods to ensure the level of density necessary at the joint for proper performance; and to review special paving equipment (attachments) for improving the densification of the unsupported edge.

Four methods of joint construction were evaluated in this study. These were the notched wedge (12:1), restrained edge, joint reheater, and Joint Maker. In addition, a number of joint adhesives were used. Some of the major conclusions and recommendations from the study include:

- Contractors are consistently achieving levels of density at or near the construction joint that are within three percent of the lane density. It is recommended that specifications be written that would require contractors to achieve that level of density at or near the construction joint.

- The reheater achieved the highest joint density of all the methods; however, only one short project was included in the study. The effects of reheating the mat could not be determined during construction, but will be evaluated during long-term monitoring. The restrained-edge method of joint construction achieved the second highest overall densities and statistically was significantly better than the conventional method of construction. The notched wedge only marginally improved densities overall, while the Joint Maker showed no improvement over conventional construction techniques. It is recommended that more projects be constructed using the restrained-edge method.

- It appeared the notched-wedge method produced the lowest permeabilities at the joint.

- Preliminary performance data indicate that all projects are currently performing well with projects having joint adhesives performing as well as, or better than, projects without joint adhesives. It is recommended that other projects be constructed using joint adhesives.

1.0 INTRODUCTION

Poor compaction practices at longitudinal construction joints in hot-mix asphalt (HMA) pavements can lead to premature pavement failure. The hypothesis is that poorly constructed or compacted HMA joints tend to be more permeable and allow water to enter into the pavement structure, accelerating pavement deterioration processes.

In recent years, it has become evident how critical proper longitudinal joint construction is to the life of the pavement structure. Recent water and icing problems on US 460 (Figure 1) and US 23 in Pike County, premature pavement failures on I-75 in Scott County (Figure 2), and other problems found throughout the state (Figure 3) indicate that construction joints may be allowing water to rapidly enter the pavement structure. The water appears to be causing several problems such as debonding of surface layers, mixture stripping, aging of the asphalt (oxidizing and hardening), and other associated problems, all of which accelerate pavement failure. Many pavements have been, or are in the process of being, resurfaced as a direct or indirect result of longitudinal joint deterioration.

The objectives of this study were to evaluate the level of compaction at the construction joint in HMA pavements on new and existing projects; to determine the level of water infiltration and segregation at the joint and its effect on joint performance; and to determine the most promising joint construction methods around the nation and worldwide by reviewing specifications, experiences, and construction practices for joint construction and the prevention of joint segregation. These reviews included Kentucky, other states, countries, and agencies that are involved in joint construction. Additional objectives were to develop specifications and construction methods to ensure the level of density necessary at the joint for proper performance; and to review special paving equipment (attachments) for improving the densification of the unsupported edge.

2.0 A REVIEW OF NATIONAL EXPERIENCE WITH EXPERIMENTAL LONGITUDINAL CONSTRUCTION JOINTS

A detailed literature review and phone survey of users and manufacturers of joint-construction equipment were conducted to determine the most promising construction methods to improve longitudinal construction joints in Kentucky. From this literature review and survey, three primary methods were chosen. These methods were the notched-wedge joint, restrained edge, and Joint Maker. Other methods were later added to this research effort which were showing promising results for other state departments of transportation (DOTs). These methods included reheating the cold joint and adhering the joint between adjoining lanes together with a joint adhesive (either a mastic joint tape or a hot extruded adhesive). The cutting wheel method was considered but was not tested because of questionable feasibility of statewide implementation.

Extensive joint research has been conducted by the National Center for Asphalt Technology (NCAT) and several participating DOTs. In 1992, NCAT conducted a joint study evaluating seven construction techniques in Michigan and eight in Wisconsin (NCAT Report No. 94-1). The techniques utilized and density results obtained are shown in Table 1. Of the techniques tried in Michigan, the two wedge joints gave the highest density at the joint, followed by the cutting wheel. In the Wisconsin test sections, the restrained edge had the highest density at the joint and the cutting wheel had the second highest density.

Figure 1. US 460, Pike County.

Figure 2. I-75, Scott County.

Figure 3. AA Highway.

In 1994, NCAT conducted a longitudinal joint study in Colorado and Pennsylvania. Seven different test sections were installed in Colorado, and two longitudinal joint construction techniques were used in Pennsylvania (NCAT Report No. 96-3). The techniques utilized and density results obtained are shown in Table 1. Of the seven joint types tested in Colorado, the 3:1 taper with a 1-inch offset and tack coat had the highest density, followed by the 3:1 taper removed with a cutting wheel and tack-coated. From the test section in Pennsylvania, the highest density was from the restrained edge, followed by the cutting wheel, and then the Joint Maker.

Table 1. Density at Joint in Test Sections in Michigan, Wisconsin, Colorado, and Pennsylvania.

Construction Technique	**Michigan (kg/m^3) (Ranking)**	**Wisconsin (kg/m^3) (Ranking)**	**Colorado (kg/m^3) (Ranking)**	**Pennsylvania (kg/m^3) (Ranking)**
Conventional overlap joint rolling from hot side with 6-inch overlap	2248 (4)	2129 (6)		2224 (6)
Conventional overlap joint rolling from cold side with 6-inch overlap	2209 (6)	2106 (8)		2248 (4)
Conventional overlap joint rolling on hot side, 6 inches away from joint	2225 (5)	2125 (7)		2233 (5)
3:1 taper rolled from hot side			2142 (6)	
3:1 taper rolled from cold side			2153 (5)	
3:1 taper rolled from hot side (6 inches away)			2165 (4)	
3:1 taper with 1-inch offset			2230 (1)	
12:1 wedge joint without tack	2274 (1)	2132 (5)		
12:1 wedge joint with tack	2271 (2)	2143 (3)		
Restrained edge		2198 (1)		2289 (1)
Cutting wheel	2268 (3)	2177 (2)		2264 (2)
3:1 taper removed with cutting wheel and tack-coated			2183 (2)	
3:1 taper removed with cutting wheel but no tack			2167 (3)	
Joint Maker	2196 (7)	2139 (4)		2252 (3)
Rubberized asphalt tack coat			no data	2160 (7)
3:1 taper/reheated/rolled from hot side				2113 (8)

The information contained in Table 1 indicates that the notched-wedge joint (or taper joint with a notch), cutting wheel, and restrained edge typically have had some of the highest joint densities.

3.0 CONSTRUCTION

A total of 12 construction projects were selected for various joint construction techniques over the course of this project (Table 2). Several of these projects contained multiple experimental methods. Each test site included the experimental joint construction method and a control section. These techniques are broken down into individual test locations and descriptions in Table 3.

A detailed evaluation matrix was established prior to constructing the experimental projects. Nuclear density tests, permeability/vacuum tests, and cores were taken at preselected intervals across the pavement. As shown in Figure 4, field tests and core samples were taken at the centerline on the longitudinal joint, and at six inches, 18 inches, and six feet (CL, the center of the lane) on each side of the joint.

Field testing was conducted shortly after the final compaction of the mix and prior to any traffic being placed on the pavement (Figure 5).

Field and laboratory test data are contained in Appendices A through I for each individual project.

Figure 4. Photo indicating test locations.

Figure 5. Permeability/vacuum testing being conducted on newly placed surface.

Table 2. List of Experimental Longitudinal Joint Construction Projects.

County	Route	Milepost Location of Entire Project		Joint Construction Technique	Joint Adhesive (if used)	Mixture Type and Lift Thickness	Contractor
		Starting Milepoint	Ending Milepoint				
Barren	US 68/KY 80	0.0 (Warren Co. line)	9.940	Joint Maker and Restrained Edge	Crafco	1.0" Surface	Glass Paving
Hardin-Meade	US 31W	33.040 (Meade Co. line)	37.143 (Jefferson Co. line)	Notched Wedge	Joint Tape (Tbond)	1.5" Surface	Gohmann Asphalt
Casey	US 127	15.201 (North of KY 817)	22.961(North of KY 906)	Notched Wedge	Crafco	1.5" Surface	Hinkle Contr.
Menifee	US 460	0.0 (Montgomery Co. line)	6.669 (Beaver Creek Culvert)	Joint Maker	------	1.0" Surface	Walker Const.
Laurel	KY 80 (Westbound)	4.277 (End of 4- lane)	10.585 (I-75 overpass)	Restrained Edge	------	1.5" Surface	Greer & Sons
Daviess	US 60 Bypass	7.319 (Natcher Parkway)	10.212 (US 60)	Notched Wedge	------	1.5" Surface	Owensboro Paving
Scott	US 62	End of New Construction	East of Leesburg	Notched Wedge	------	4.0" Base	Hamilton-Hinkle-Ruth
Nelson	Bluegrass Parkway	34.910	39.270 (Washington Co. line)	Infrared Reheater	------	1.5" Surface	Mago Const. & Raytech Infrared
Logan	US 431	21.682 (Lewisburg-Edwards Rd.)	31.096 (Muhlenberg Co. line)	Restrained Edge	------	1.5" Surface	Scotty’s Constr.
Pulaski	KY 80	6.628 (Hatfield Road)	19.016 (US 27)	Joint Adhesive	Crafco	1.25" Surface	Hinkle Constr.
Pulaski	US 27	25.699 (KY 452)	30.693 (Lincoln Co. line)	Restrained Edge	------	1.5" Surface	Hinkle Constr.
Webster	US 41	2.754 (KY 147)	6.035 (KY 495)	Joint Maker	------	1.0" Surface	Rogers Group

Table 3. List of Experimental Longitudinal Joint Construction Projects

County	Route	Construction Technique	Starting Milepoint	Ending Milepoint
Barren	US 68/KY 80	Control Control with Crafco Restrained Edge Restrained Edge with Crafco Restrained Edge Joint Maker & Joint Matcher	0.00 0.59 1.14 1.73 2.22 6.59	0.59 1.14 1.73 2.22 6.59 9.94
Hardin Meade	US 31W (Northbound) US 31W (Southbound)	Notched Wedge Notched Wedge with Joint Tape Notched Wedge Control Control with Joint Tape Control	34.00 35.60 35.83 2.90 3.31 3.55 (Meade Co.)	35.60 35.83 37.14 3.31 3.55 37.14 (Hardin Co.)
Casey	US 127	Notched Wedge Notched Wedge with Crafco Notched Wedge Control	15.20 18.00 18.50 20.90	18.00 18.50 20.90 22.96
Menifee	US 460	Joint Maker & Joint Matcher Control	0.00 4.73	4.73 6.66
Laurel	KY 80 (Westbound)	Control Restrained Edge Control	8.82 5.81 4.27	10.58 8.82 5.81
Daviess	US 60B (Westbound) US 60B (Eastbound)	Notched Wedge Control	7.319 7.319	10.21 10.21
Scott	US 62	Notched Wedge		
Nelson	Bluegrass Parkway	Infrared Reheater Control	35.05 35.75	35.75 36.50
Logan	US 431	Control Restrained Edge Control Trial Restrained Edge	21.68 26.45 28.95 30.90	26.45 28.95 30.90 31.10
Pulaski	KY 80	Control Crafco Joint Adhesive Control	6.63 9.26 13.71	9.26 13.71 19.02
Pulaski	US 27	Restrained Edge	25.71	30.69
Webster	US 41	Joint Maker Control	2.75 4.66	4.66 6.04

3.1 Construction Methods

3.1.1 Notched Wedge

The notched-wedge joint construction method was utilized on four research projects and on a demonstration project on US 150 (Figure 8) prior to the initiation of this study. The majority of the contractors opted to build their own notched-wedge device (Figure 6), but one contractor purchased a notched-wedge device through Trans Tech (Figure 7). Both devices produced similar joints in appearance. The joints were required to be constructed with a 0.5-inch upper and lower notch and a 12:1 taper between the upper and lower notch.

Figure 6. Made-in-house notched-wedge device.

The notched-wedge device is mounted on the edge of the paver, adjacent to the end gate, and in front of the screed. The device is then adjusted below the screed to form the wedge in the newly placed HMA. A small tow-behind roller weighing approximately 400 pounds or greater is pulled along the wedge to provide some additional compaction (Figure 8).

Figure 7. Notched-wedge device manufactured by Trans Tech.

3.1.1.1 Construction Problems

The major problems associated with the notched-wedge joint were maintaining the upper notch during compaction, raveling on the lower portion of the wedge (Figure 9), and aggregate pickup by the small wedge roller. Problems were also observed on US 62 during the construction of a notched wedge on a base course. It appeared that the notched-wedge device was placing enough drag on the paver to twist the paver sideways slightly out of plane, making it difficult to use the ski poles. A portion of this twisting appears to have been caused by material being forced under the end gate, creating additional "sideways drag" on the paver.

Figure 8. Construction of notched wedge on US 150.

Figure 9. Raveling of bottom section of wedge.

Most of the problems observed with the notched wedge were controllable. The upper notch was "over-cut" during the initial screeding to allow for compaction of the HMA. The raveling appeared to be caused by the lower notch being cut too small. This phenomenon was mostly observed on the US 150 project in which the new surface was only one inch thick. Bulging of the notch was observed on US 31W; this imperfection appears to be due to tender mix characteristics (Figure 10). It appears that the wedge was restraining the mix from pushing sideways during compaction, thus causing some bulging in the wedge.

Figure 10. Bulging upper portion of wedge.

3.1.1.2 Performance Comparison of Notched Wedge vs. Control

Core, field, and laboratory permeability data for each notched-wedge project are shown in Figures 11 through 13. The data have been normalized to the control section for each project.

As shown in Figure 11, the density at the joint improved on all projects except US 60. US 60 was the only project that was installed over a new base course. This underlying course may be increasing the average density of the control section, thus decreasing the overall difference between the notched wedge and control section. In addition, at the time the notched wedge was sampled by Kentucky Transportation Center personnel, it appeared that there was a problem with establishing a roller pattern, which may be contributing to the lower densities.

The average normalized densities for all projects indicate that the density not only increased at the joint, but also appears to have increased across the pavement. It appears the wedge is restraining the edge of the mat, thus decreasing lateral movement of the mat and increasing the density at the joint and across the entire mat.

The normalized field vacuum and laboratory permeabilities indicate that the notched wedge was less permeable at the joint than the control section (Figures 12 and 13). The data also indicate that the notched-wedge joint typically is less permeable at the joint than any other area across the pavement.

3.1.1.3 Recommendations for Notched-Wedge Construction

Recommendations for future notched-wedge construction projects include using the notched-wedge method only on 1.5-inch surface mixtures or larger, providing a strike-off plate on the small wedge compaction wheel to remove material, keeping the paving train moving to avoid segregation and raveling, and keeping the end gate down and flush with the pavement surface.

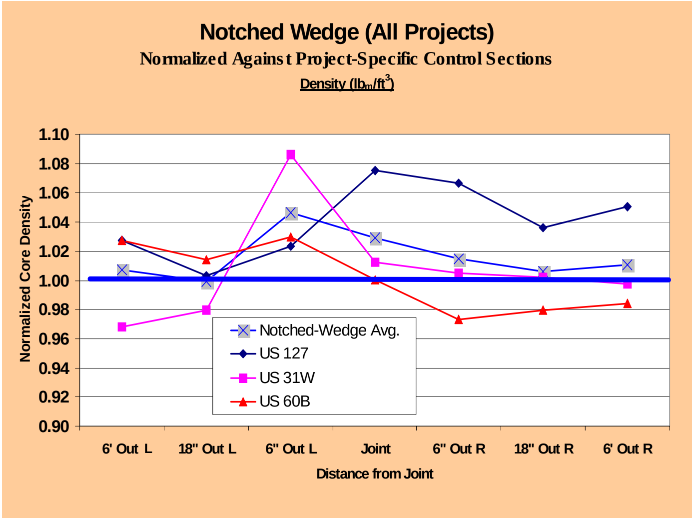

Figure 11. Normalized Core Density From Notched-Wedge Projects.

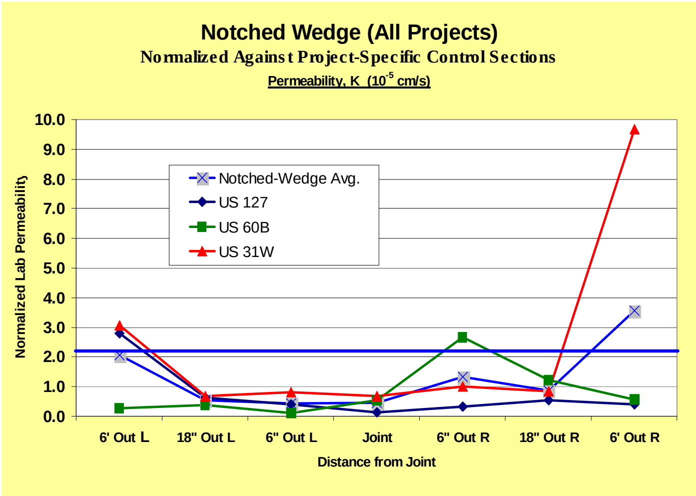

Figure 12. Normalized Laboratory Permeability From Notched-Wedge Projects.

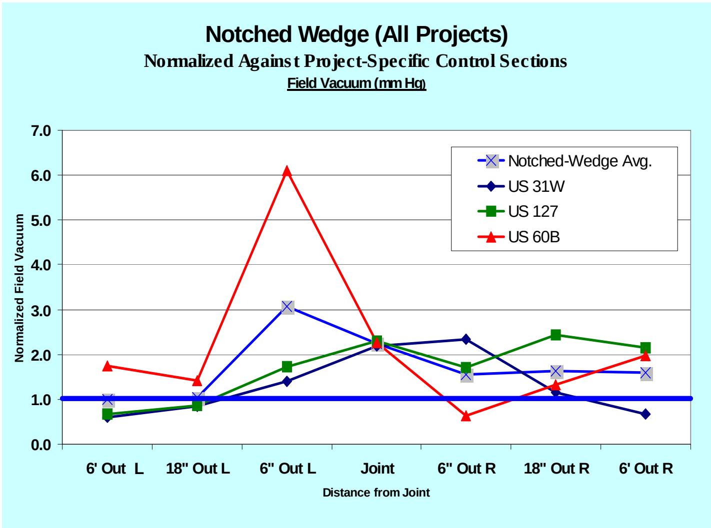

Figure 13. Normalized Field Vacuum From Notched-Wedge Projects.

3.1.2 Restrained Edge

The restrained-edge joint construction method was utilized on four construction projects. The initial restrained-edge device was purchased by Glass Paving for a cost of approximately $10,000. The restrained-edge wheel is controlled by a hydraulic arm which raises and lowers the wheel and controls the vertical force that is applied to the edge of the new mat (Figure 14). The load is set by applying just enough force to lift the edge of the adjacent main roller; the load is then reduced until the main roller is flush again with the new HMA surface.

3.1.2.1 Construction Problems

The restrained-edge device was first utilized on US 68/KY 80 in Barren County which was a one-inch lift. The device left a densely compacted, smooth face along the edge of the mat (Figure 15). The device was also tried on 1.5-inch lift on KY 80 in Laurel County. The beveled wheel did not have enough height to properly compact the uncompacted material (Figure 16). The restraining wheel caused the mixture to push up on the inside edge of the restraining wheel, creating a longitudinal ridge in the mat. It was necessary to make two passes with the breakdown roller prior to restraining the edge. This pattern allowed the mix to be compacted enough so that the beveled edge of the restraining wheel was now of sufficient height to cover the edge of the asphalt mat. Allowing for two passes with the breakdown roller and then restraining the mix likely decreased the effectiveness of the restraining method as the material had already been allowed to push to the side in an unrestrained state. It was concluded by the Study Advisory Committee (SAC) for this research project that the wheel needed to be modified and additional projects would be constructed for further evaluation (US 431 in Logan County and US 27 in Pulaski County).

Figure 14. Restrained-edge device.

Figure 15. Restrained-edge compaction of new asphalt surface.

Figure 16. Compaction of 1.5-inch surface on KY 80.

The same restraining wheel was used at the start of the US 431 project in Logan County without any modifications. Again, the restraining wheel displaced the mixture vertically where the beveled edge of the wheel was not of sufficient dimension to cover the entire uncompacted edge of the surface. Multiple passes with the restraining wheel were tried, which eliminated some of the humping, but this pattern started to push and/or pull the mix in front of the restraining wheel (Figure 17).

On the same project, the tapered section of the wheel was increased so that it covered the entire uncompacted face of the mixture (Figure 18). The mix appeared to be slightly tender and was pushing up between the main drum and the restraining wheel; additional compaction with the main drum created a longitudinal crack along the edge. The initial rolling pass was then performed with the main drum, and the restraining device was utilized on the second pass. This pattern allowed for some lateral movement in the mixture and densification prior to restraining the mixture on the second pass. This approach likely reduces the density of the mixture since it is not restrained on the first pass.

Figure 17. HMA pushing up in front of restraining wheel.

Figure 18. Wider restrained-edge wheel on US 431.

3.1.2.2 Performance Comparison of Restrained Edge vs. Control

Core, field, and laboratory permeability data for each restrained-edge project are shown in Figures 20 through 22. The data have been normalized to the control section for each project.

As shown in Figure 20, the average normalized density at the joint improved on all projects in comparison to the control section. The normalized densities in the right-hand lane from six inches to six feet out appear to have decreased in comparison to the control section. The normalized densities for the left-hand lane, which was initially restrained, are significantly higher.

The normalized field and laboratory permeabilities indicated that the restrained edge also generally reduced the permeability of the HMA at the joint in comparison to the control section (Figures 21 and 22). The data also indicate that the permeabilities in the right-hand lane were significantly higher than the control section.

3.1.2.3 Recommendations for Restrained-Edge Construction

It was recommended that on the US 27 project in Pulaski County that the wheel be modified again so that the main drum and restraining wheel are side-by-side (Figure 19). This configuration should restrain the mix not only in the horizontal plane at the edge of the pavement, but also confine it from pushing up between the rollers. It would be recommended that future restrained-edge projects use a wheel that is modified as shown in Figure 19. Modifications were unable to be made to the restraining wheel prior to the start of the US 27 project. Similar problems were observed using the existing wheel on this job.

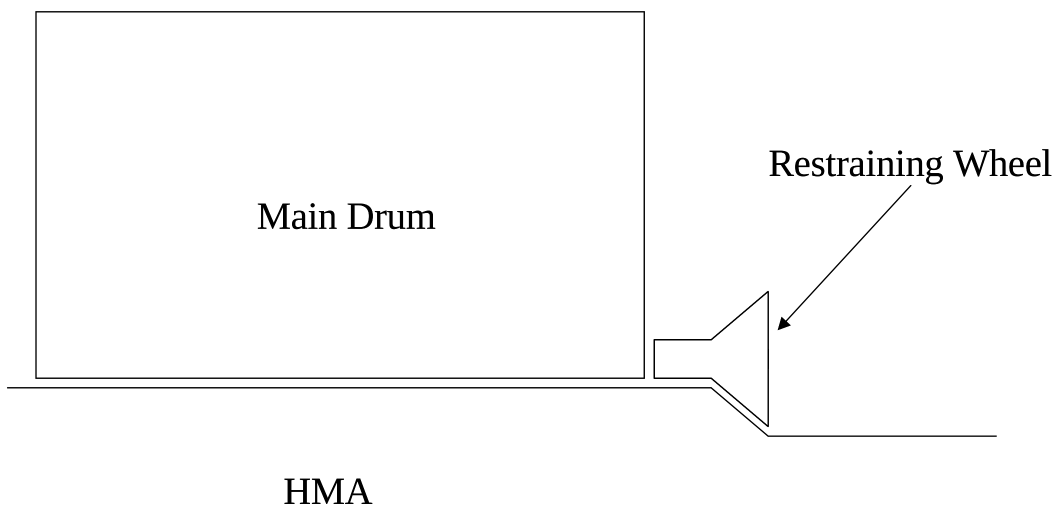

Figure 19. Diagram of proposed restraining wheel.

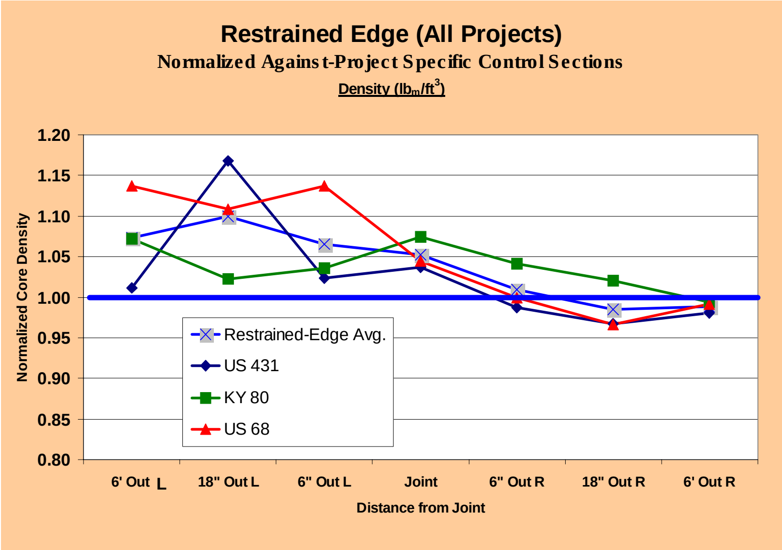

Figure 20. Normalized Core Density From Restrained-Edge Projects.

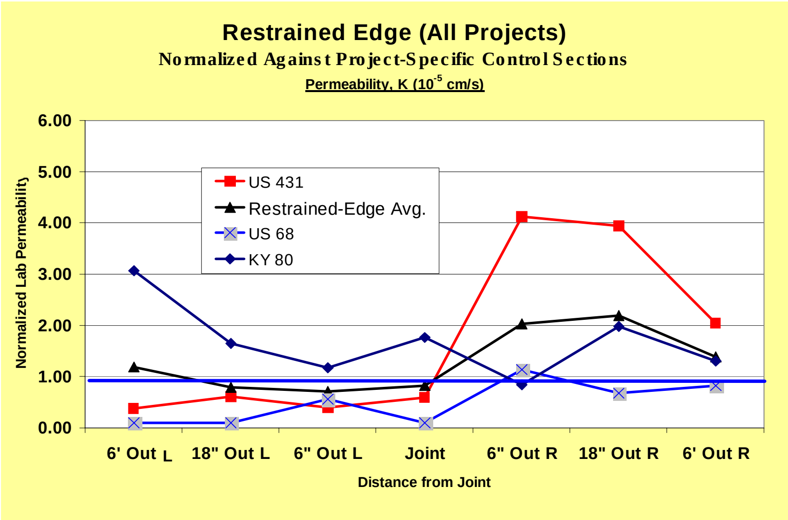

Figure 21. Normalized Laboratory Permeability From Restrained-Edge Projects.

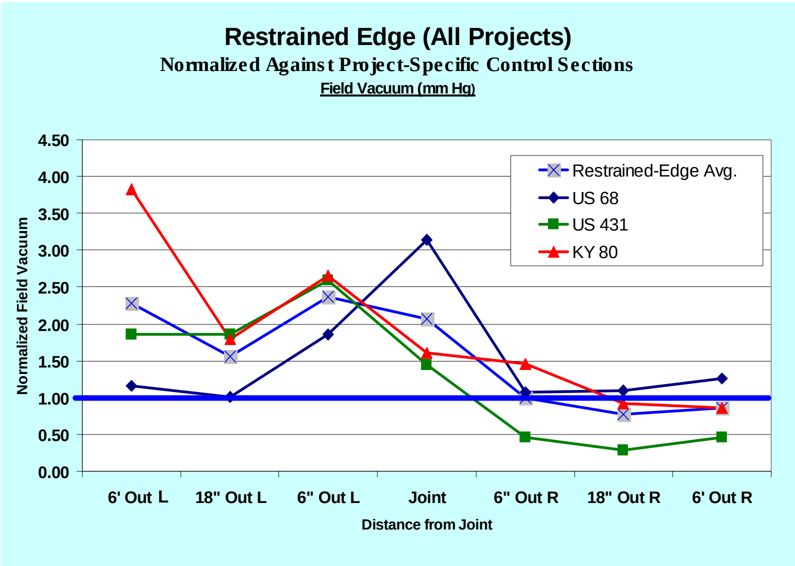

Figure 22. Normalized Field Vacuum From Restrained-Edge Projects.

3.1.3 Joint Maker

The Joint Maker system, manufactured by Trans Tech, was used on three construction projects (US 68/KY 80 in Barren Co., US 460 in Menifee Co., and US 41in Webster Co.). The Joint Maker is a non-mechanical device that is mounted on the front side of the screed next to the end gate. The Joint Maker is a large, rounded-edge metal mass that adds some initial compaction to the mixture prior to going under the paver screed. The Joint Maker is mounted approximately 0.5 inch above the bottom of the screed and is set at a 30-degree upward angle from the pavement surface (Figure 23). The Joint Maker device is shown as highlighted (red box) in Figure 24. In addition to the Joint Maker, several of the projects included the Joint Matcher and Kicker Plate also manufactured by Trans Tech. The Kicker Plate rides adjacent to the end gate and helps to form a more vertical edge for a smoother joint. The Joint Matcher automatically controls the edge gate for proper matching of the joint (Figure 25). Both the Joint Matcher and Kicker Plate may help to provide a cleaner-looking joint and contribute some to the overall density of the joint.

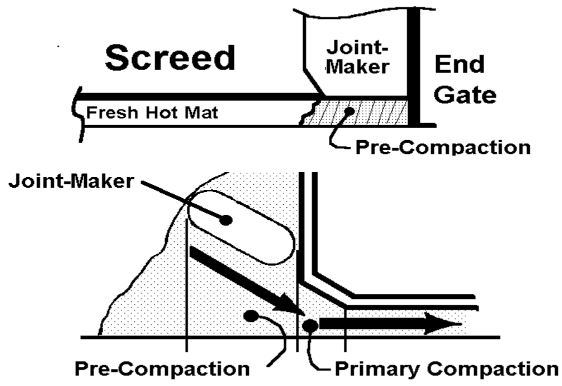

Figure 23. Joint Maker system.

Figure 24. Joint Maker mounted to paver (highlighted in red box).

3.1.3.1 Construction Problems

The Joint Maker system was initially used on the US 68/KY 80 project in Barren County. The biggest problem associated with the Joint Maker was correctly setting up the device prior to paving. The correct positioning of the device was unclear to the contractor. Dragging of the mixture was also noticed at the start of paving. This phenomenon was prevented by preheating the Joint Maker before paving.

Figure 25. Joint Matcher mounted on side of paver.

3.1.3.2 Performance Comparison of Joint Maker vs. Control

Core, field, and laboratory permeability data for each Joint Maker project are shown in Figures 26 through 28. The data have been normalized to the control section for each project.

As shown in Figure 26, the average normalized density from the three Joint Maker projects showed only slight improvement at the joint in comparison to the control section. Of the three projects, the US 68/KY 80 and US 460 projects showed improvement, but no noticeable increase in density was observed on the US 41 project.

The average normalized field and laboratory permeabilities were slightly higher at the joint from the laboratory tests and lower at the joint from the field tests. Both the lab and field results were considerably lower for the US 68/KY 80 project in Barren County. This project was the only project constructed with a 1-inch lift.

As shown in Figures 26 through 28, the US 68/KY 80 project was the only project that showed an increase in density and decrease in permeability at the joint in the experimental sections.

3.1.3.3 Recommendations for Joint Maker Construction

Based on the varying core densities and permeabilities, it appears that there is not sufficient change/improvement in either parameter to warrant further testing or use of these devices.

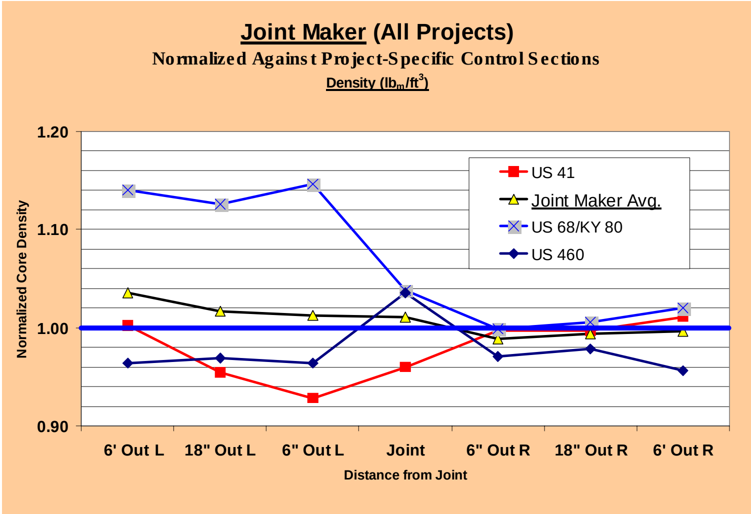

Figure 26. Normalized Core Density From Joint Maker Projects.

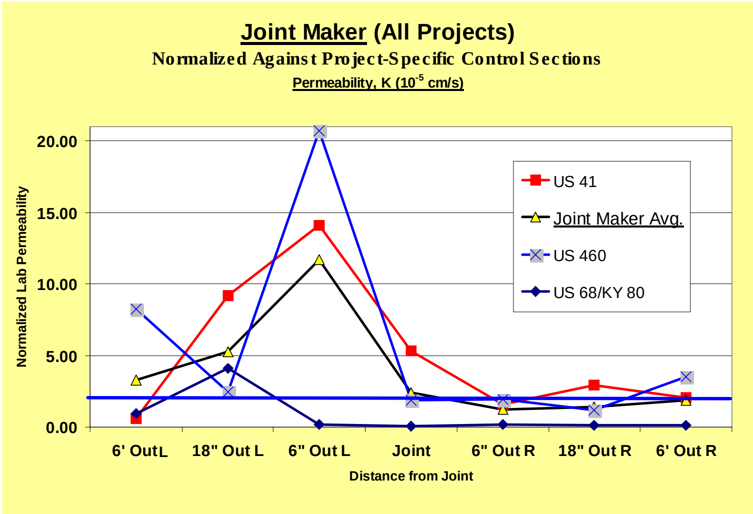

Figure 27. Normalized Laboratory Permeability From Joint Maker Projects.

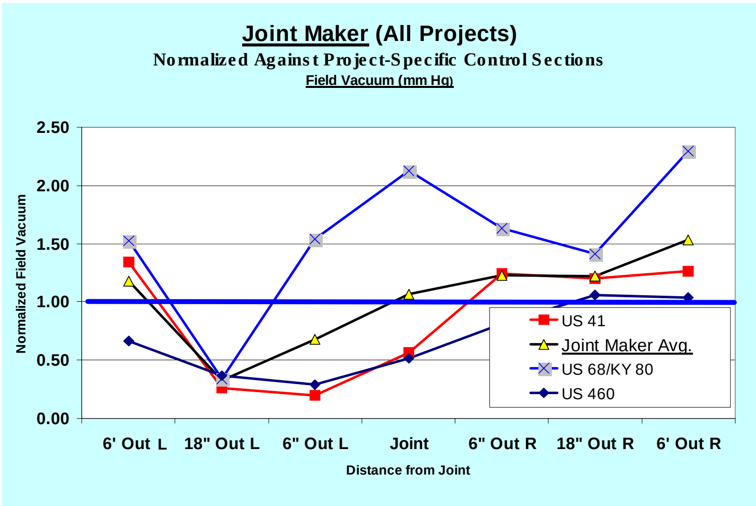

Figure 28. Normalized Field Vacuum From Joint Maker Projects.

3.1.4 Infrared Joint Reheater

In September of 1999, the Ray-Tech infrared joint reheater system was field-tested in New Hampshire. Information derived from cores indicated that the air voids in cores taken from the joint of the reheated section were six percent higher than cores taken four feet out from the joint. In the control section, cores at the joint had 26 percent higher air voids than cores taken four feet from the joint. This same system was used on the Bluegrass Parkway in Nelson County during the course of this study. The project was a demonstration project conducted by Ray-Tech Infrared Corporation and Mago Construction.

Figure 29. Infrared joint reheater on Bluegrass Parkway.

The purpose of the system is to reheat the initially paved surface (cold joint) and bring it up to a plastic state prior to the new, adjacent hot mat being laid. This reheating permits better consolidation of the mat at the joint, thus making the joint denser and less permeable.

Figure 30. Preheaters being pulled in front of paving train.

A total of three infrared reheaters were used on the project (Figure 29). Two infrared preheaters were pulled approximately 100 feet in front of the paver (Figure 30), and the third reheater was mounted directly onto the paver (Figure 31). The purpose of the two preheaters in front of the paving train was to supply some initial heat to the pavement to penetrate into the mix. The third heater then gives the pavement another infusion of heat which brings the "cold joint" back up to its plastic state (paving temperature). Surface temperatures after reheating are shown in Figure 32.

Figure 31. Paver-mounted reheater.

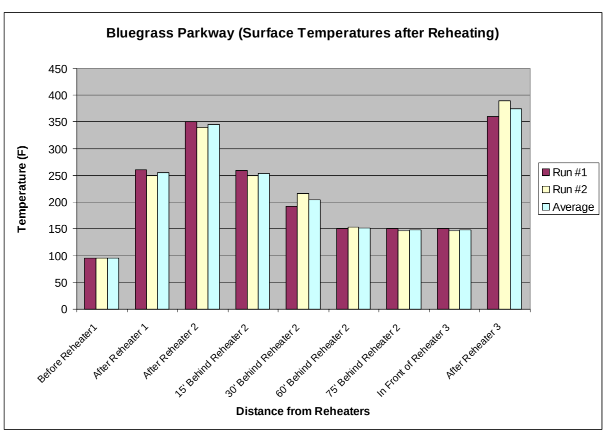

Figure 32. Change in Surface Temperatures after Reheating.

3.1.4.1 Construction Problems

The infrared heater did reheat the cold joint and bring the surface of the mix up to paving temperatures, but several problems were encountered. The temperature of the heaters had to be regulated manually because the infrared sensors that measure the pavement surface temperature and regulate the burners had not been shipped in time for this project. The maximum paving temperatures were exceeded in several areas. The contractor was unable to use "ski poles" because of the paver-mounted reheater. The reheater also required the paving train to move at a slower rate than normal to allow the infrared heat to penetrate the mat. Slower production rate and inability to use "ski poles" make this technique very unattractive to contractors.

3.1.4.2 Performance Comparison of Infrared Joint Reheater vs. Control

Core, field, and laboratory permeability data for the infrared joint reheater project are shown in Figures 33 through 35. The normalized core density is higher at the joint and across the pavement than in the control section. This density improvement cannot be attributed entirely to the reheater since it is only acting on a small area of the pavement. The data to the left of the joint may be slightly skewed since this area had been subjected to some construction traffic prior to the testing, probably increasing the density of the mat.

The normalized field and laboratory permeabilities show a decrease in permeability at the joint in comparison to the control section.

3.1.4.3 Recommendations for Infrared Joint Reheater Construction

As mentioned previously, the infrared joint reheater was not fully functional during this project. The surface of the asphalt was scorched in several areas, and blistering was observed from overheating. Better attachments need to be constructed so the reheating device does not interfere with the paving skids that largely control the smoothness of the pavement. The technique shows some promising results, but further testing is needed. Also, the equipment needs to be mounted so that it does not compromise the ride quality of the pavement or impede the speed of the paving train.

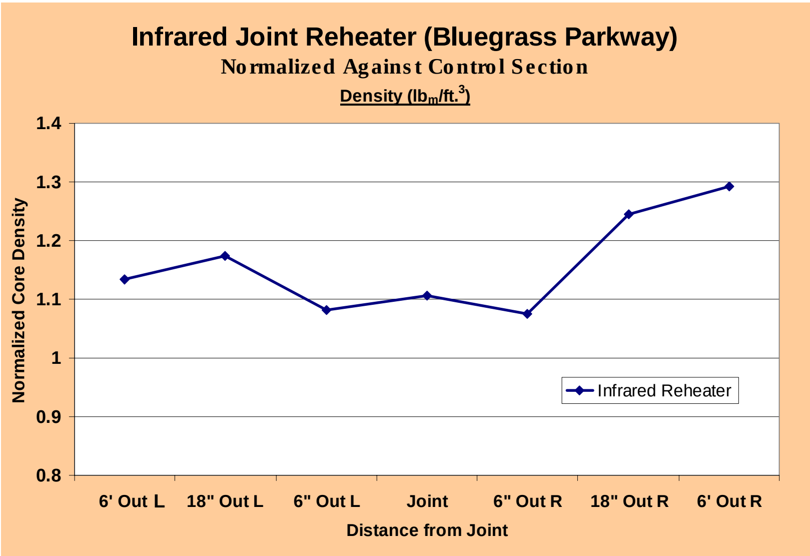

Figure 33. Normalized Core Density from Infrared Reheater Project.

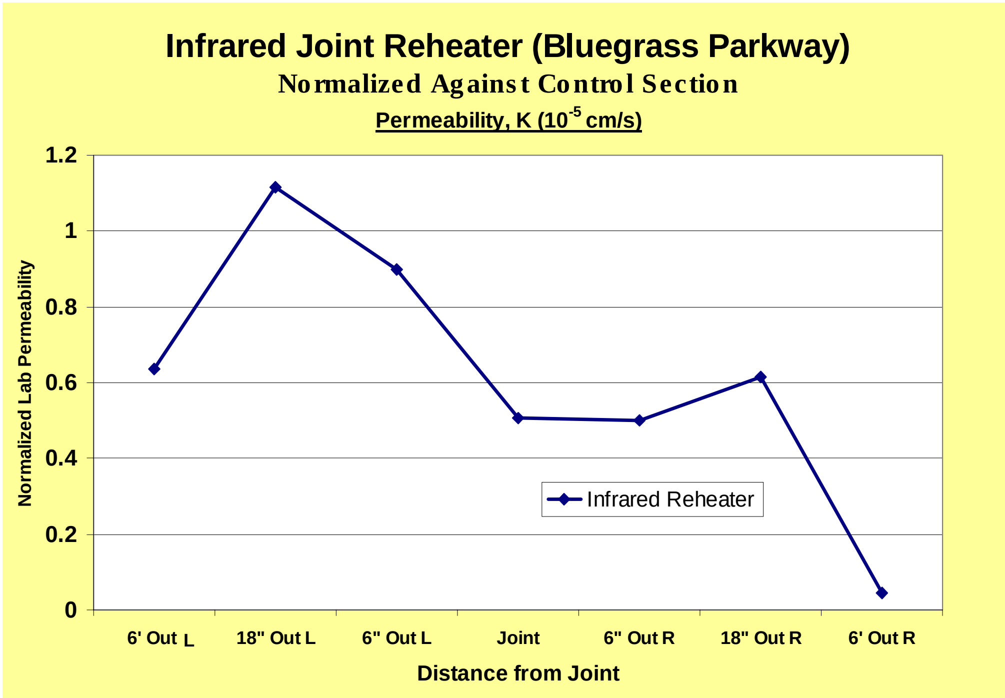

Figure 34. Normalized Laboratory Permeability from Infrared Reheater Project.

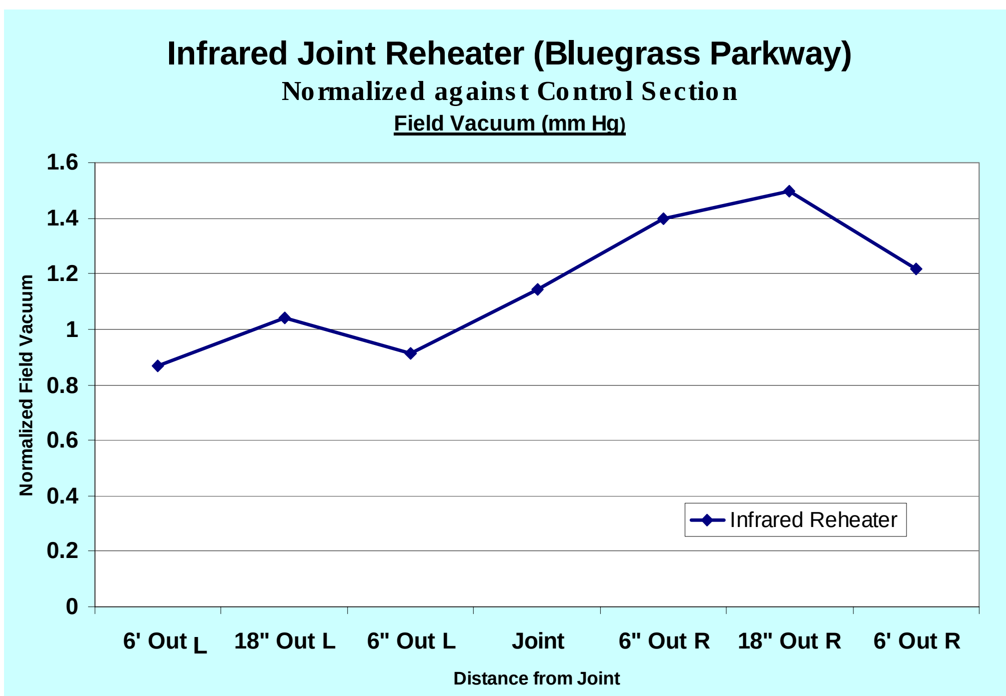

Figure 35. Normalized Field Vacuum from Reheater Project.

3.1.5 Joint Adhesives

Two types of joint adhesives were used on five of the research projects: a hot-melt poured adhesive called Crafco (Figure 36) and a HMA joint tape called Tbond (Figure 37).

Figure 36. Crafco being placed on US 68/KY 80.

Crafco Joint Adhesive

Crafco joint adhesive was used on two demonstration projects and one project let to bid. The adhesive was applied to several conventional joints, a notched-wedge joint (Figures 38 and 39), and restrained-edge joint. These applications are listed in Table 2. Crafco is a hot-poured adhesive that is applied in a similar manner to a crack sealant. The material is very tacky, and a releasing agent (Detack or Glenzoil 20) is recommended to reduce pickup by the tires on conventional traffic and construction vehicles.

Tbond HMA Joint Tape

The HMA joint tape was applied on the US 31W project in Meade and Hardin Counties in both the notched-wedge and control sections. The tape was delivered to the site in boxes and rolled out into place in 10-m (40-mm wide x 6-mm thick) rolls. The tape was attached to the pavement with occasional tacks and/or by hammering the tape onto the asphalt.

Figure 37. Asphalt joint tape being placed on notched-wedge joint on US 31W.

Figure 39. Crafco applied to notched-wedge joint on US 127.

Figure 38. Crafco bleeding through newly compacted surface on US 127.

3.1.5.1 Construction Problems

Both the Crafco and Tbond joint adhesives required additional manpower to apply. Both adhesives need to be protected during construction to avoid pickup by construction traffic. The Tbond was more labor-intensive than the Crafco material.

3.1.5.2 Performance Comparison of Joint Adhesive vs. Control

Both the Crafco and Tbond joint adhesives appeared to have reduced the permeability of the HMA at the joint. On US 68/KY 80 in Barren County, the control section treated with Crafco did have lower permeabilities (Appendix A). The Crafco material did not appear to have a large effect on the restrained-edge section; this phenomenon is likely due to the fact that the face of the restrained edge is quite dense and smooth and does not allow the Crafco adhesive to penetrate the mix at the joint. The Crafco section placed on KY 80 in Pulaski County was not tested during construction. It is anticipated that this section will be evaluated as part of long-term performance monitoring.

The Tbond joint tape used on US 31W in Hardin and Meade Counties showed a slight decrease in lab and field permeability in the control sections and significantly lower permeability in the notched-wedge sections (Appendix B). It appears that the Tbond joint adhesive placed on the slope of the notched wedge has the greatest impact on the joint. The adhesive is allowed to spread out horizontally on the slope of the notched wedge, which covers a larger horizontal surface area than placing it on a standard, butt-overlap joint (as used in the control sections). The notched wedge with the joint tape also showed an increase in density at the joint compared to the notched wedge without tape.

3.1.5.3 Recommendations for Joint Adhesive Construction

Both the Crafco and Tbond joint adhesives did decrease the permeability of the joint. However, both methods require additional personnel and coordination between contractors. The Crafco material is less labor-intensive than the Tbond. Conversations with Tbond representatives indicated that a new extrudable tape has been tried on I-70 and US 40 in Indiana. The product is less labor-intensive than the Tbond. The manufacturer's representatives also claim that trucks can drive over the material within 15 minutes after placement onto the cold joint.

The cost of the Crafco material used on the KY 80 project in Pulaski County was \$0.90 per foot. Conversations with the prime contractor indicated this cost would be substantially less if the work were performed by the prime contractor (approximately \$0.50 to \$0.60 per foot).

3.2 Comparison of Experimental Joint Construction Methods

3.2.1 Density Comparison

Of the three methods initially selected by the SAC for evaluation (notched wedge, restrained edge, and Joint Maker), the restrained-edge projects had the highest average normalized density (Figure 40). The notched wedge had the second-highest density, and the Joint Maker had the lowest of the three methods. Figure 40 also shows that the notched wedge appears to have increased the density of the mat across the entire pavement. The average normalized core densities from the infrared joint reheater project conducted on the Bluegrass Parkway in Nelson County are higher than the other three experimental methods (Figure 41). At this time, it is uncertain why the densities are higher across the entire pavement.

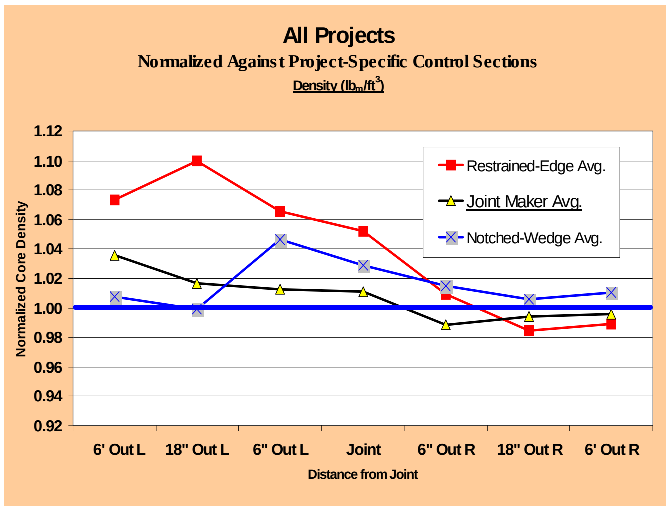

Figure 40. Average Normalized Density.

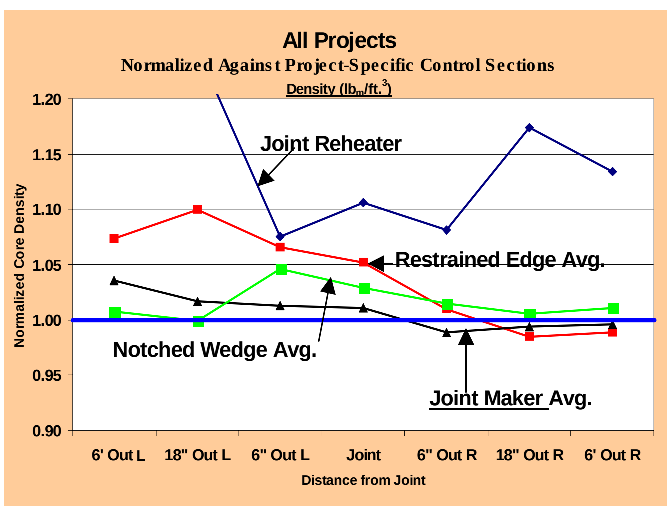

Figure 41. Normalized Average Density.

3.2.2 Permeability Comparison

In reviewing the average normalized lab and field permeabilities from the three construction methods, the notched wedge had the highest decrease in permeability of the three methods. The restrained edge had the second-highest decrease in permeability, and the Joint Maker showed a slight, if any, reduction in permeability (Figures 42 and 43). An in-depth analysis of permeability will not be conducted in this report, but will be analyzed in the final report on a companion study, entitled *Development of a Field Permeability Test for Asphalt Concrete and Permeable Bases.*

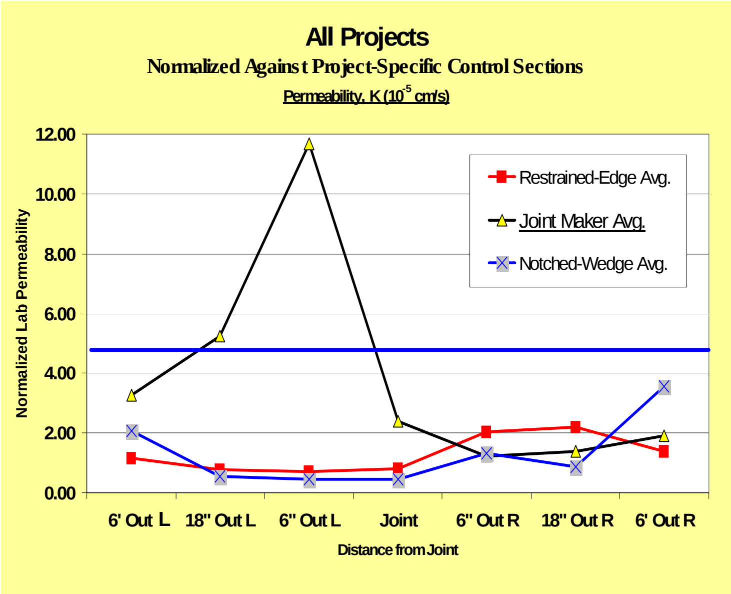

Figure 42. Average Normalized Laboratory Permeability.

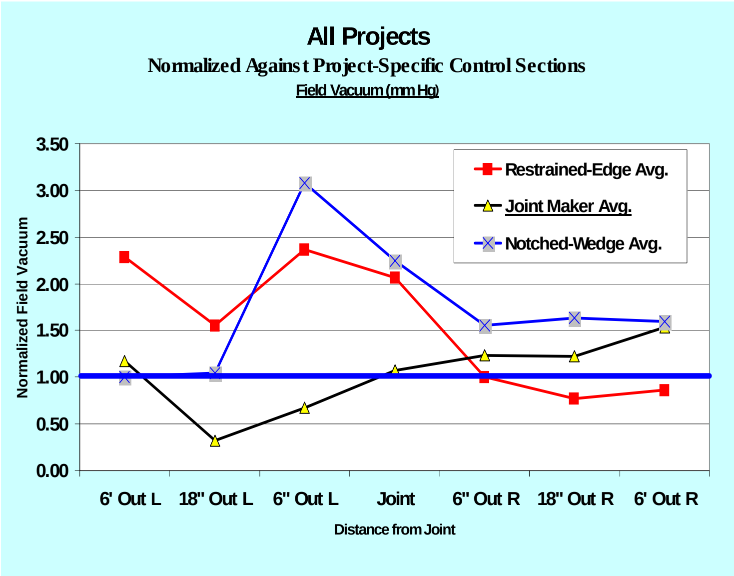

Figure 43. Average Normalized Field Permeability/Vacuum.

The average normalized laboratory permeabilities from the reheated joint on the Bluegrass Parkway in Nelson County are equal to that of the notched-wedge projects (Figure 44). This comparison does not hold true for the field permeabilities (Figure 45).

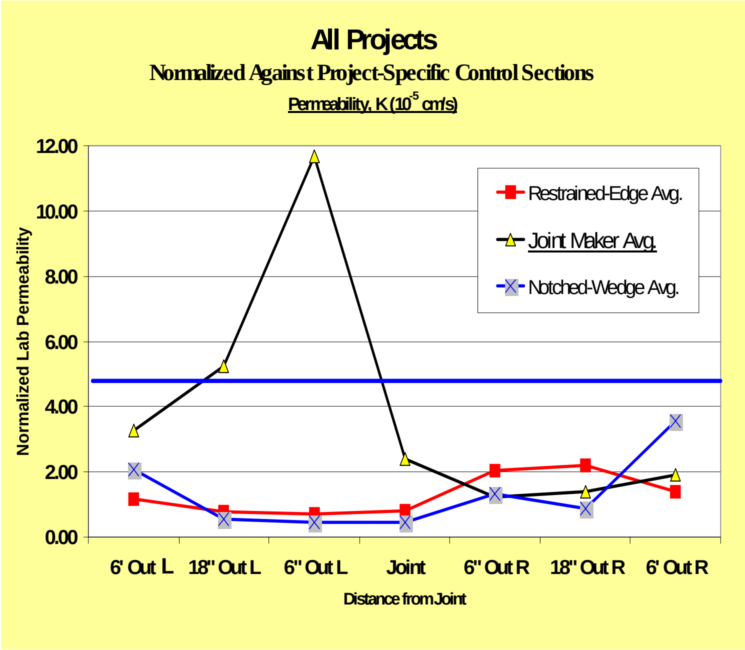

Figure 44. Average Normalized Laboratory Permeability for All Projects.

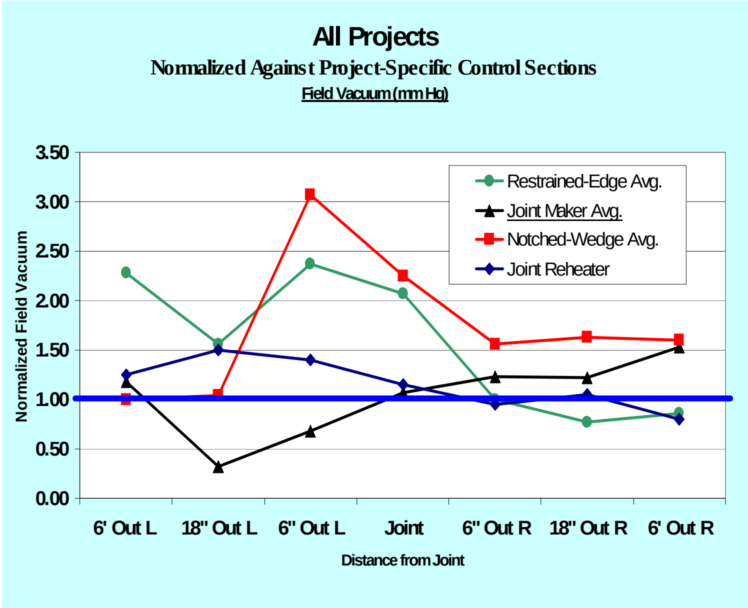

Figure 45. Average Normalized Field Permeability/Vacuum for All Projects.

3.2.3 Analysis of Distributions of Field Densities

When collecting field density data, the research team used a Troxler Model 3430 nuclear density gauge. This device is not a thin-lift gauge; the penetration is several inches deep. Therefore, the recorded density was not only from the asphalt surface layer, but also partially from the underlying pavement layers. This phenomenon resulted in density readings that were less than the densities calculated from acceptance cores obtained in the field.

Figures 46 through 52 show the comparisons of the accumulative distribution functions between the field density measurements made by the research team and the calculated densities obtained from the acceptance cores for seven of the projects. US 27, Pulaski County, and KY 80, Pulaski County are not included because no field density data were collected, but these projects will be used for performance evaluations. In addition, US 62, Scott County, and Bluegrass Parkway, Nelson County, are not included because of limited data. The relationships appear to be similar for all of the projects except for US 431 in Logan County (Figure 52). For that project, the distribution functions match more closely than the other projects. The reason for this relationship is not immediately clear.

Because the relationships between the distribution functions were so similar for six of the seven projects evaluated, it was decided to combine all of the projects and develop a "general" calibration relationship between the field density measurements and the densities calculated from the acceptance cores. Figure 53 shows the results. Plotting the density values from each distribution function in Figure 53 at chosen percentages (on the vertical axis) yields the relationship shown in Figure 54. A linear regression analysis of that data results in the following calibration equation:

$$\text{Percent Density}_{cores} = 0.3982*(\text{Percent Density}_{KTC}) + 57.662 \qquad \text{Eq. 1}$$

A very high R^2 of 0.99 indicates a consistent and stable calibration between the nuclear density gauge and the cores. Therefore, the field data can be used directly for *comparative* purposes without correction.

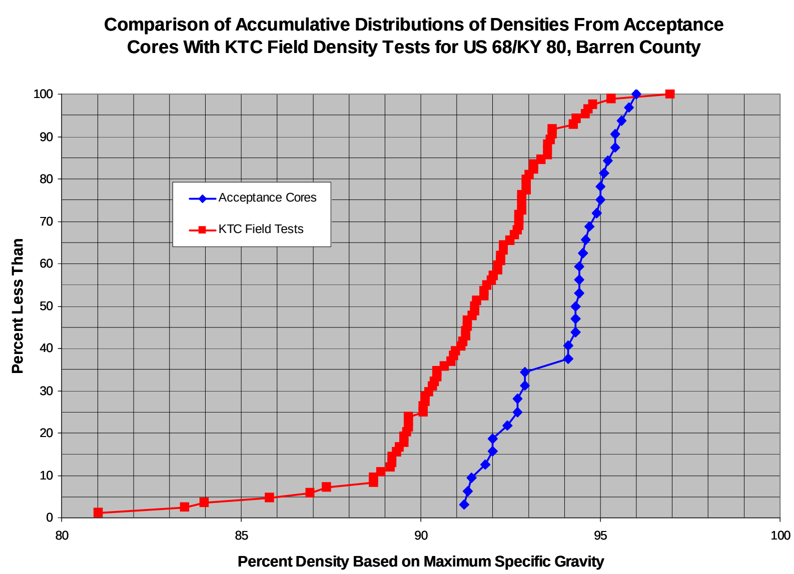

Figure 46. Accumulative Distributions of Densities From Acceptance Cores Compared With KTC Field Density Tests, US 68/KY 80, Barren County.

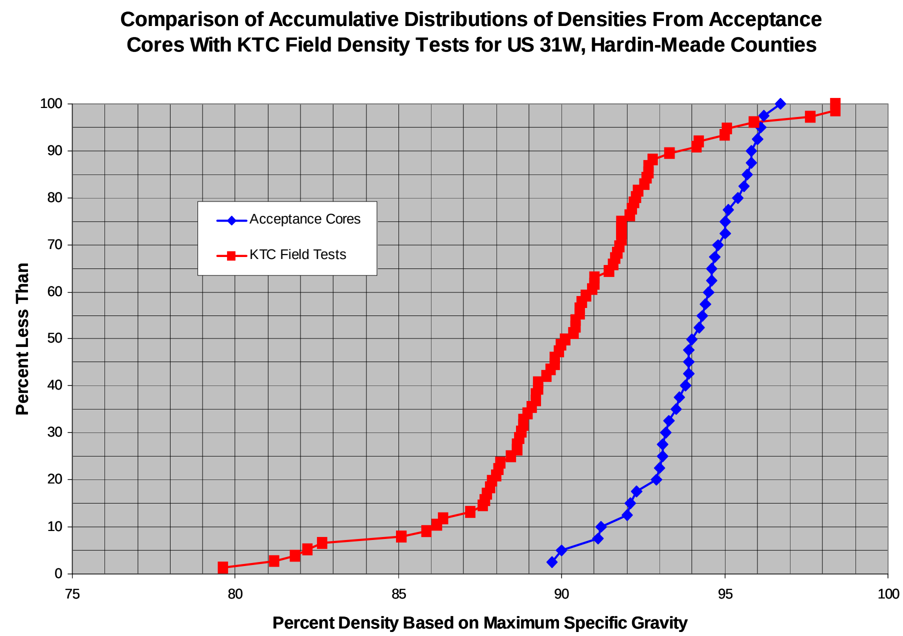

Figure 47. Accumulative Distributions of Densities From Acceptance Cores Compared With KTC Field Density Tests, US 31 W, Hardin-Meade Counties.

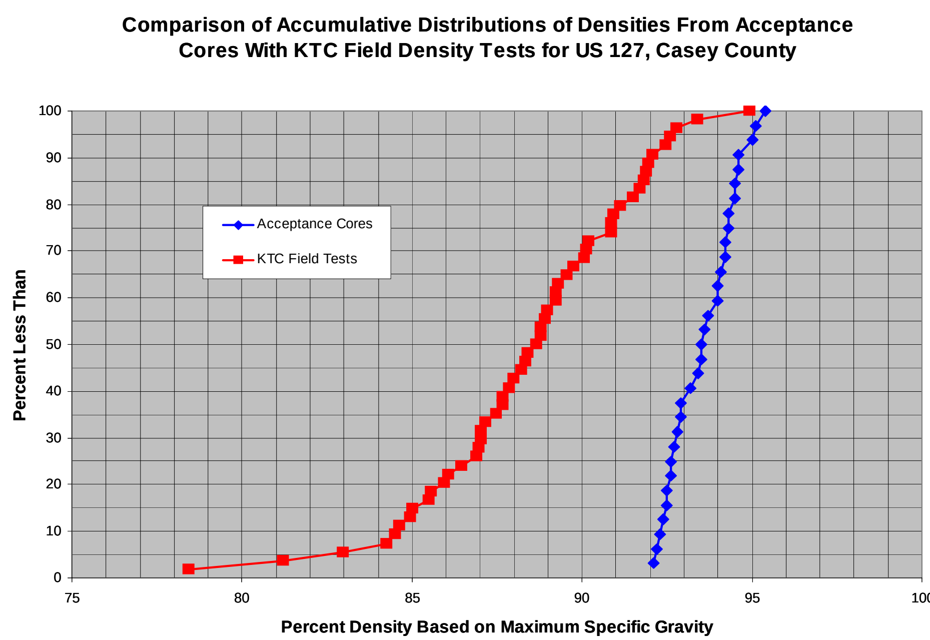

Figure 48. Accumulative Distributions of Densities From Acceptance Cores Compared With KTC Field Density Tests, US 127, Casey County.

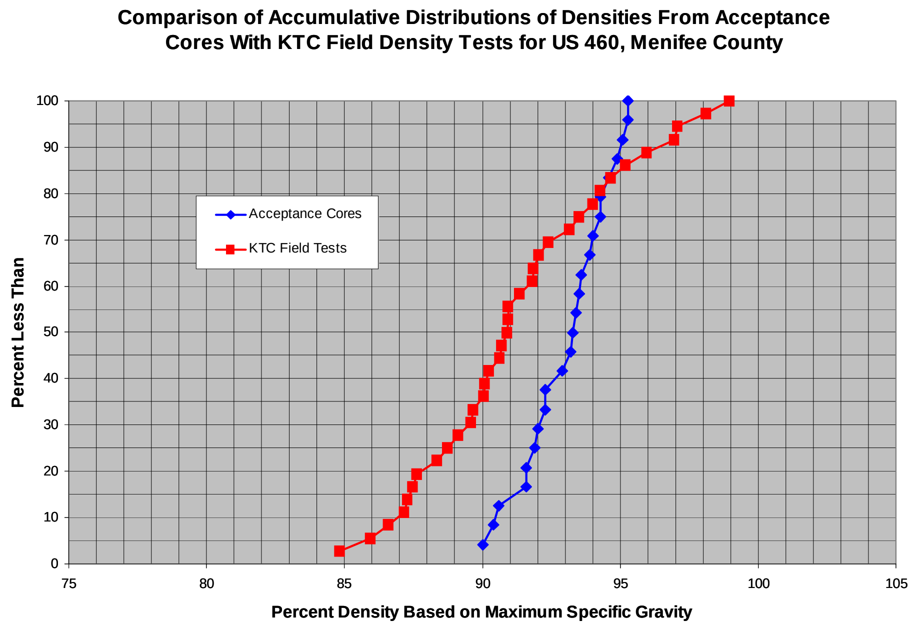

Figure 49. Accumulative Distributions of Densities From Acceptance Cores Compared With KTC Field Density Tests, US 460, Menifee County.

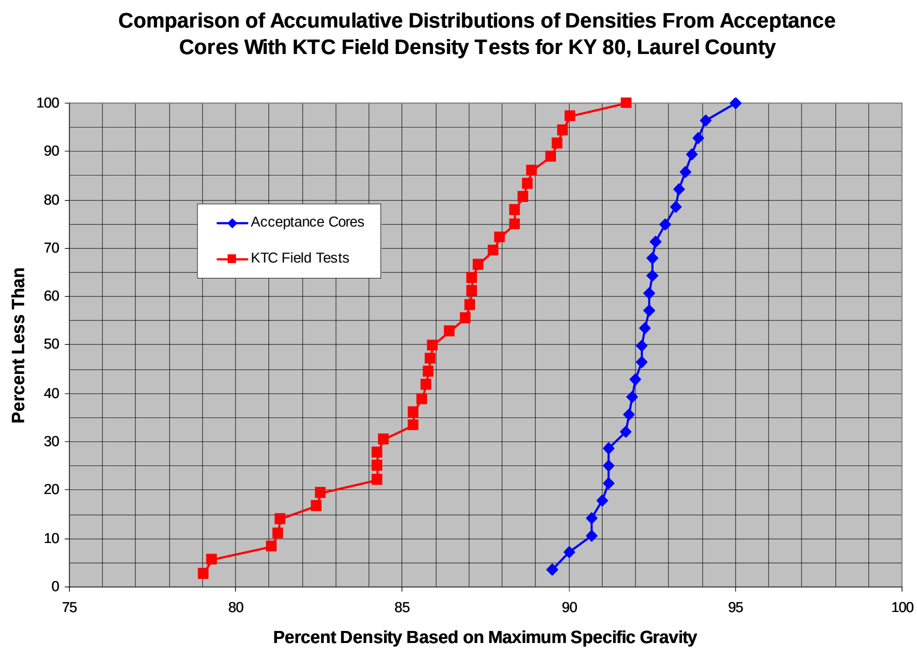

Figure 50. Accumulative Distributions of Densities From Acceptance Cores Compared With KTC Field Density Tests, KY 80, Laurel County.

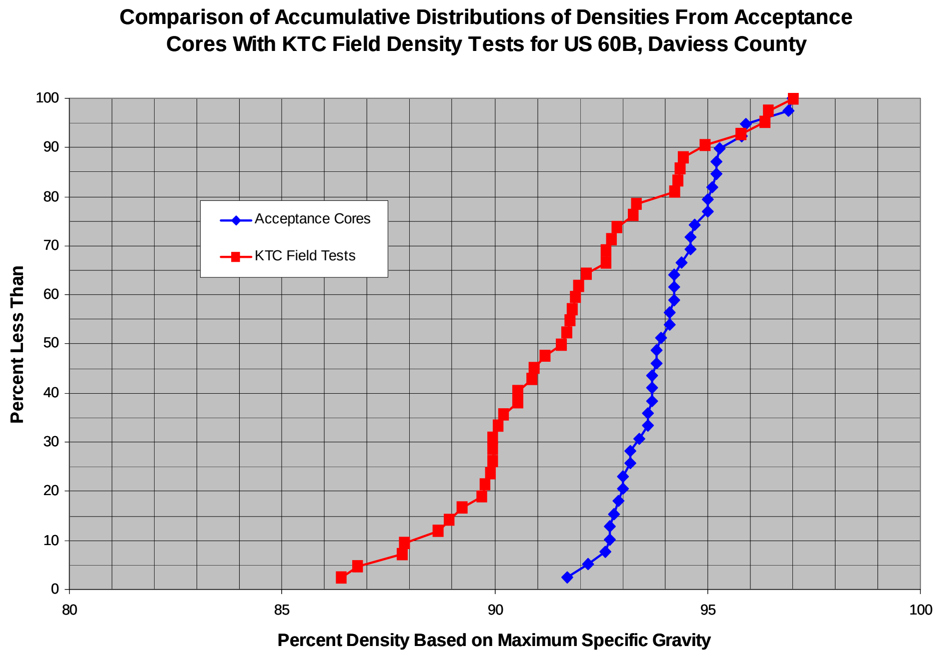

Figure 51. Accumulative Distributions of Densities From Acceptance Cores Compared With KTC Field Density Tests, US 60B, Daviess County.

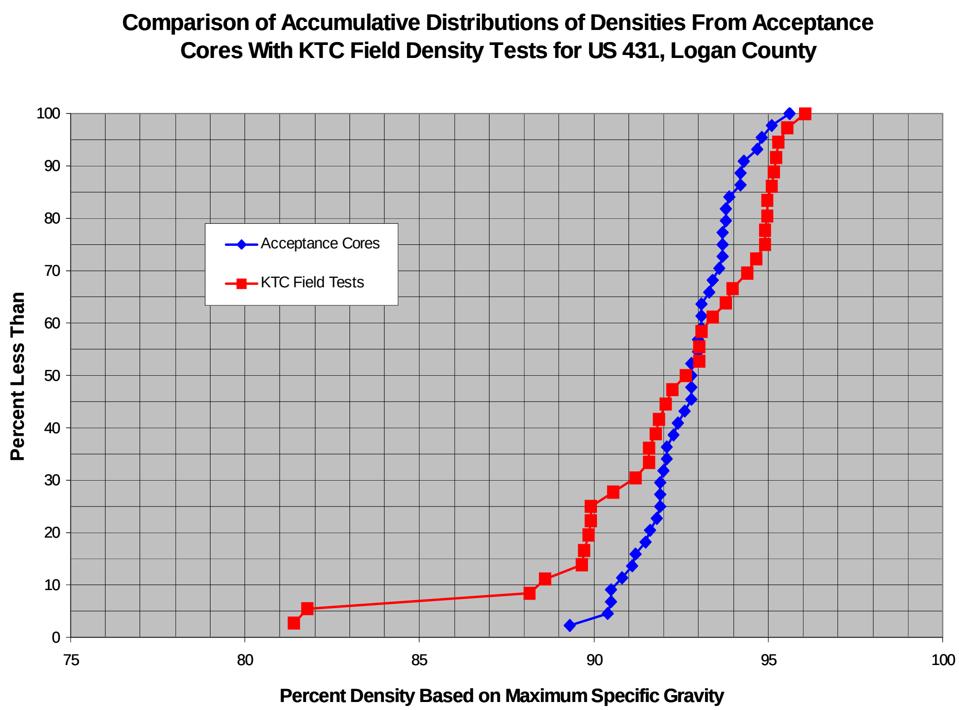

Figure 52. Accumulative Distributions of Densities From Acceptance Cores Compared With KTC Field Density Tests, US 431, Logan County.

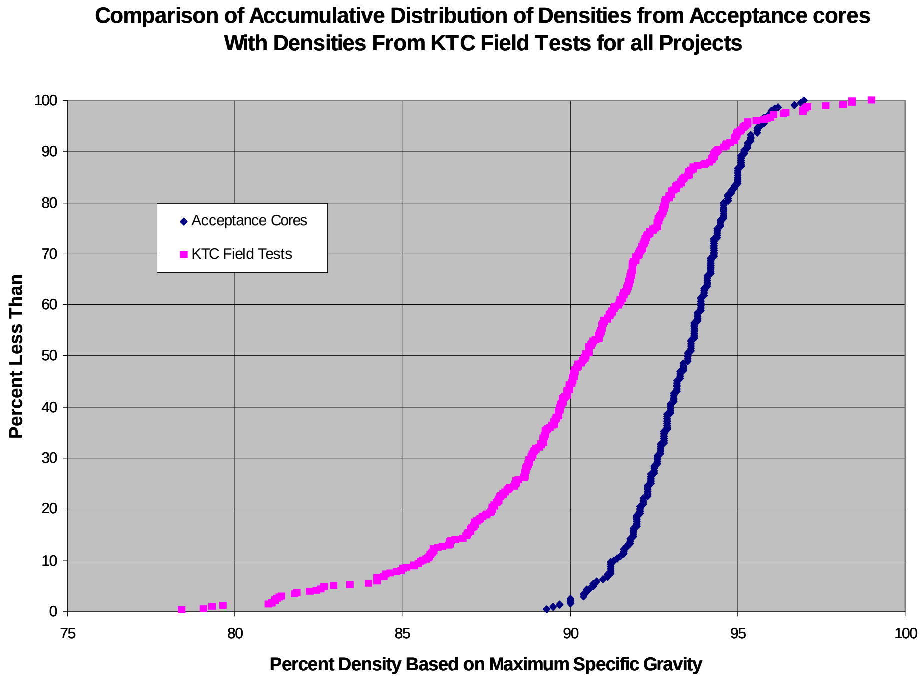

Figure 53. Accumulative Distributions of Densities From Acceptance Cores Compared With KTC Field Density Tests for All Projects.

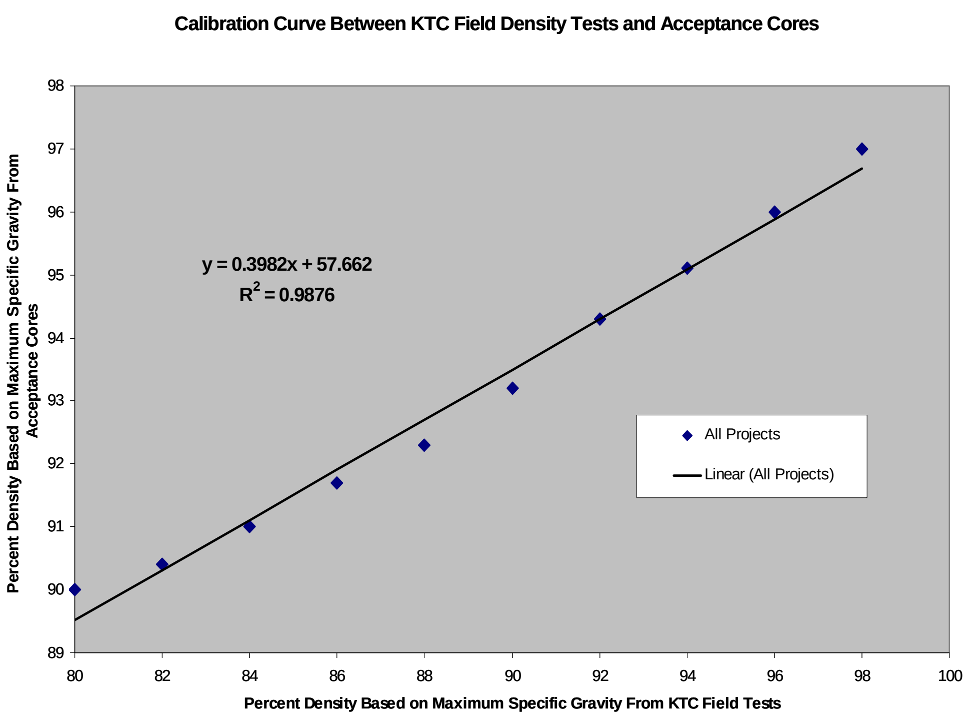

Figure 54. Relationship Between Percent Density From KTC Field Tests and Percent Density From Acceptance Cores

As considered previously, pavement densities generally increase from the construction joint to the center of the paving mat. Figure 55 shows the accumulative distribution functions of all percent densities (based upon the maximum specific gravity) calculated from the densities obtained by KTC personnel in the field. It should be noted that the reported percent densities in Figure 55 are calculated from the nuclear density gauge and were not recalculated using Equation 1. The data in Figure 55 and in the figures that follow were not recalculated because they are used only for comparative or relative analyses. Therefore, the percent densities that are reported are less than what would be reported from acceptance cores. The accumulative distributions in Figure 55 were calculated from all of the control sections (conventional method of joint construction) from all projects in this study. Figure 55 clearly shows the general progression of increasing density from the joint to the center of the mat, with densities at 18 inches from the joint being almost identical to densities at the center (six feet from the joint) of the mat. Figure 55 indicates that the contractor can consistently maintain a density at the joint that is 2.5 to 3.0 percent below the density at the center of the mat without any special compaction effort.

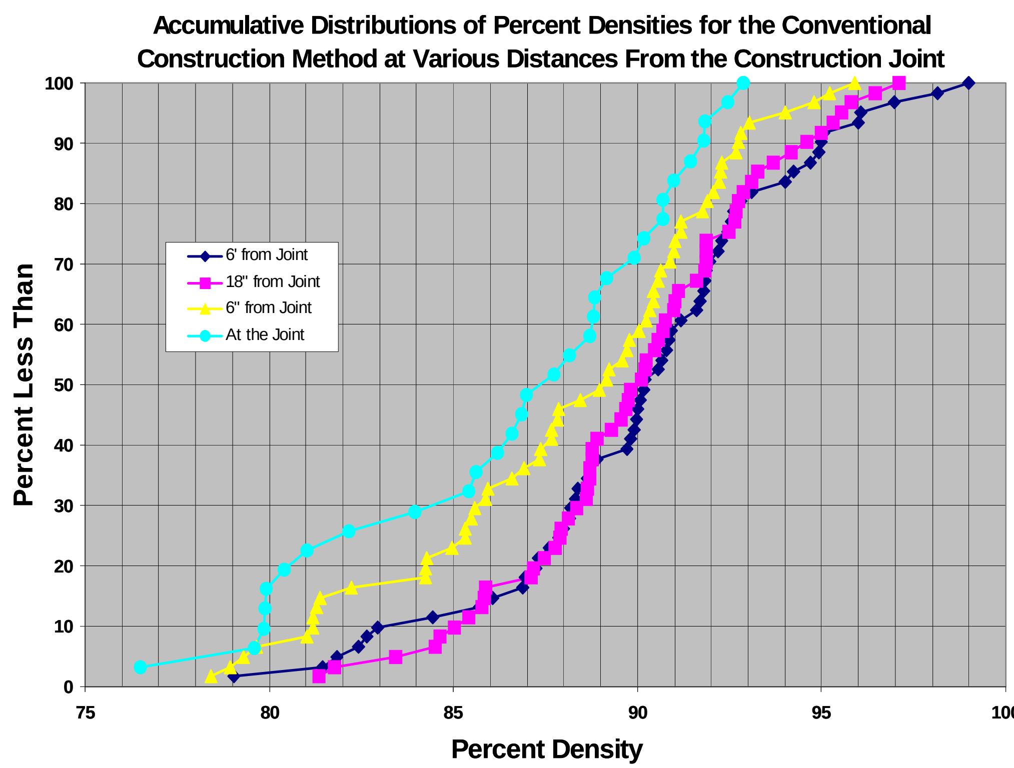

Figure 55. Accumulative Distributions of Percent Densities for the Conventional Construction Method at Various Distances From the Joint.

It has been stated previously that the restrained-edge method had the highest average joint densities, with the notched wedge having the second highest and the Joint Maker having the lowest average. The results of a more in-depth analysis of that information are shown in Figures 56 through 59. Figure 56 is a comparison of the conventional method with the other three construction methods at the joint. That figure shows that the notched wedge and the conventional method had very similar distribution functions, indicating that the notched wedge did not significantly improve density at the joint. The Joint Maker appeared to yield more erratic results, indicated by the wide variation in the data. The restrained edge was clearly superior at the joint.

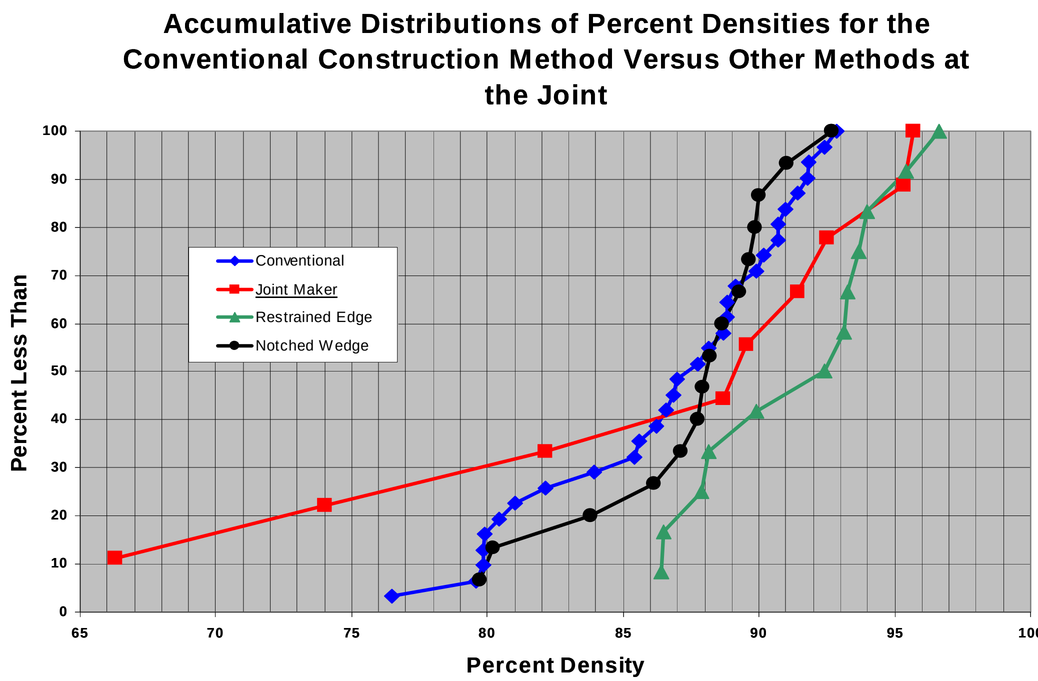

Figure 56. Accumulative Distributions of Percent Densities at the Joint for the Conventional Construction Method Versus Other Methods.

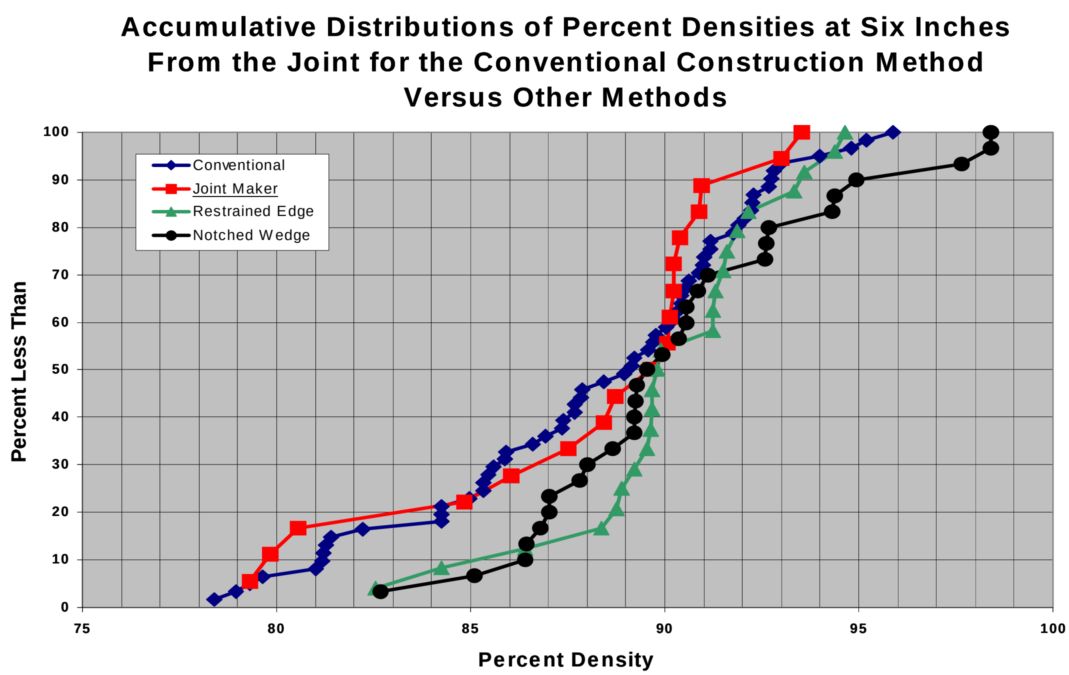

Figure 57. Accumulative Distributions of Percent Densities at Six Inches From the Joint for the Conventional Construction Method Versus Other Methods.

Figure 57 illustrates the same relationship between the four methods for data obtained at six inches from the construction joint. The notched wedge and the restrained edge yielded higher densities at six inches than did the conventional method while the Joint Maker shows no improvement over the conventional method.

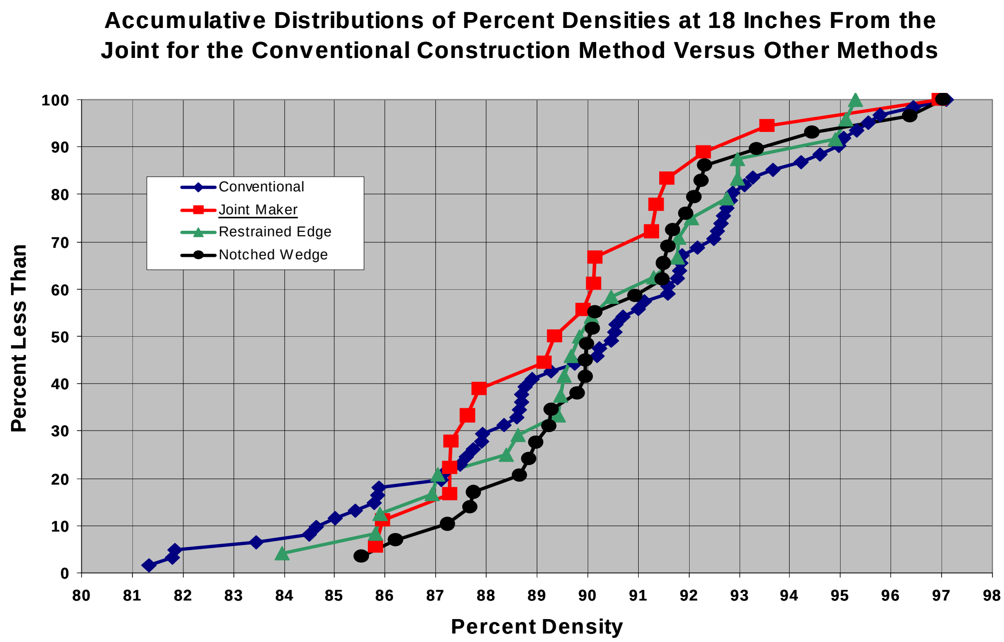

Figure 58. Accumulative Distributions of Percent Densities at 18 Inches From the Joint for the Conventional Construction Method Versus Other Methods.

Figure 58 shows that all of the methods produced similar results at 18 inches from the construction joint. However, the Joint Maker had consistently lower densities than did the conventional method. At the fiftieth percentile, the Joint Maker was approximately one percent less than the conventional method.

Figure 59 is an analysis of the same information collected at six feet from the construction joint (center of the paving mat). Again, the Joint Maker and the notched wedge showed no improvement over the conventional method. However, the restrained edge produced significantly higher densities than the conventional method. In addition, the results were considerably more uniform or consistent as indicated by the "steepness" of the distribution curve.

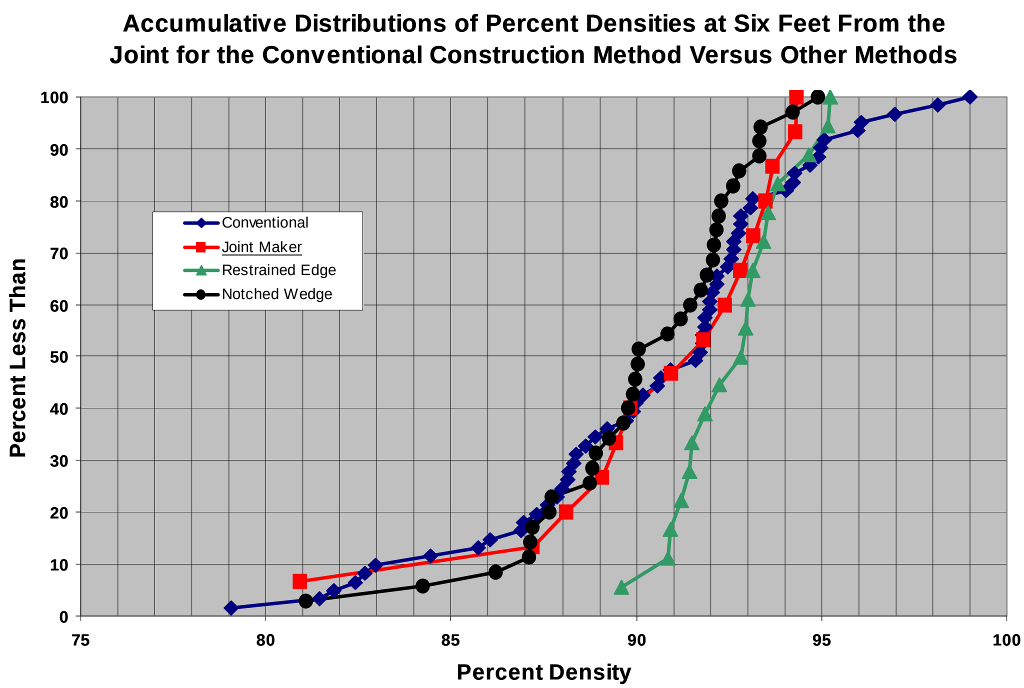

Figure 59. Accumulative Distributions of Percent Densities at Six Feet From the Joint for the Conventional Construction Method Versus Other Methods.

In attempting to summarize all of the density data obtained from this study, a statistical analysis was performed to determine the level of significance of the perceived improvement in density produced by the various methods over the conventional method using the means and the standard deviations of the four data sets shown in Figure 59. Assuming that the data sets in Figure 59 are close to being normally distributed, and testing at a the five-percent significance level, the results are as follows:

Joint Maker	*Not Significant*
Notched Wedge	*Slightly Significant*
Restrained Edge	*Significant*

It appears from that analysis that the most beneficial method in terms of increased density was the restrained edge.

When a two-lane highway is paved, or a multi-lane facility is paved under traffic, usually only one lane is paved at a time. This sequence allows the mat on the first lane paved to cool before the adjacent lane is paved (resulting in a hot HMA mat placed against a cold mat). Some contractors have indicated that it can be difficult to achieve density at the construction joint on the "hot" mat side because a portion of the roller drum must ride on the "cold" mat. To test the validity of that statement, the accumulative distributions of the ratios of the "hot" mat density to the "cold" mat density (across the joint) at six inches from the joint on either side were plotted in Figure 60. There is one distribution for the conventional construction method and one for all of the other experimental methods combined. The results in that figure indicate that 59 percent of the time, the "hot" side was denser for the conventional method, and 70 percent of the time, the "hot"side was denser for the other methods. It appears that the "hot" side is usually denser because of the presence of the stiff, cold side against which to compact.

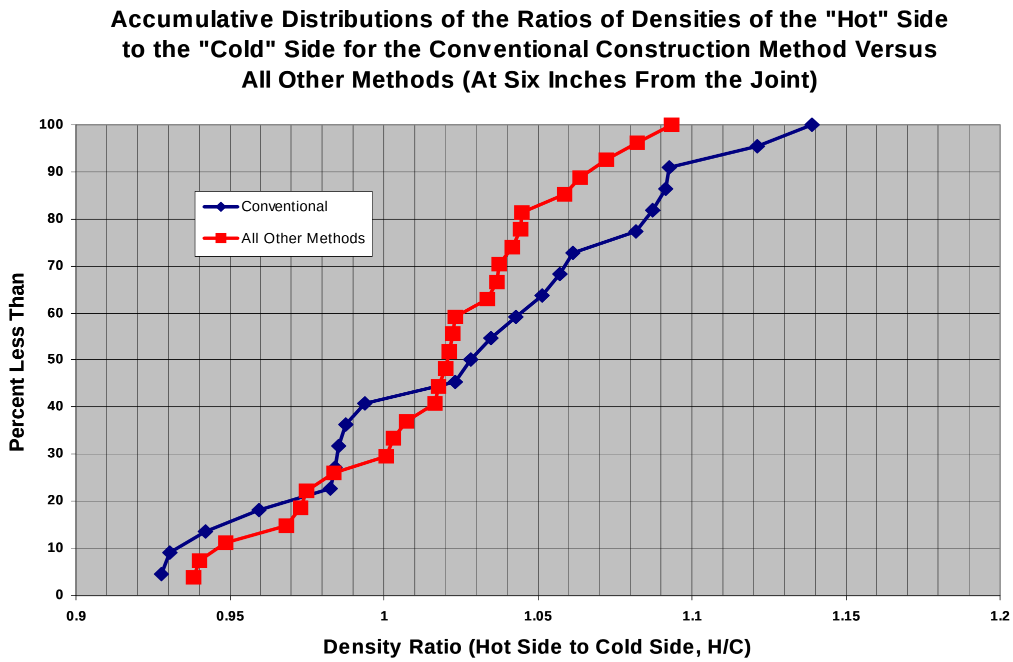

Figure 60. Accumulative Distributions of the Ratios of the “Hot” Side Densities to the “Cold” Side Densities for the Conventional Method and All Other Methods.

4.0 PERFORMANCE EVALUATION

4.1 Long-Term, Field Performance Evaluation (NCAT Studies)

Long-term, field performance information derived from the NCAT studies in Michigan, Wisconsin, Colorado, and Pennsylvania indicate that joints with higher density usually perform better. Conventional joints treated with Crafco joint adhesive appear to be exceptions to that rule. The Crafco material placed on conventional joints have some of the lowest recorded densities at the joint but are performing the best under long-term monitoring. Table 4 shows the ranking of the projects by long-term performance and construction density at the time of installation.

Table 4. Long-Term, Field Performance and Construction Density Comparison of Sections in Michigan, Wisconsin, Colorado, and Pennsylvania.

Construction Technique	Michigan Performance & Density Ranking (3 years)	Wisconsin Performance & Density Ranking (4 years)	Colorado Performance & Density Ranking (5 years)	Pennsylvania Performance & Density Ranking (6 years)
Conventional overlap joint rolling from hot side with 6-inch overlap	(5) (4) *	(6) (6)		(7) (6)
Conventional overlap joint rolling from cold side with 6-inch overlap	(7) (6)	(8) (8)		(8) (4)
Conventional overlap joint rolling on hot side, 6 inches away from joint	(6) (5)	(7) (7)		(3) (5)
3:1 taper rolled from hot side			(7) (6)	
3:1 taper rolled from cold side			(5) (5)	
3:1 taper rolled from hot side (6 inches away)			(6) (4)	
3:1 taper with 1-inch offset			(4) (1)	
12:1 wedge joint without tack	(1) (1)	(3) (5)		
12:1 wedge joint with tack	(2) (2)	(2) (3)		
Restrained edge		(1) (1)		(5) (1)
Cutting wheel	(3) (3)	(5) (2)		(2) (2)
3:1 taper removed with cutting wheel and tack- coated			(2) (2)	
3:1 taper removed with cutting wheel but no tack			(3) (3)	
Joint Maker	(4) (7)	(4) (4)		(6) (3)
Rubberized asphalt tack coat			(1) (no data)	(1) (7)
3:1 taper reheated/rolled from hot side				(4) (8)

* (Performance Ranking)(Density Ranking)
For both the performance and density rankings, 1 = best

4.2 Short-Term, Field Performance Evaluation (Kentucky Projects)

Between 1999 and 2000, eight of the 12 joint projects listed in this study were constructed. Performance information is contained in Table 5. Visual performance data indicate that cracking is occurring in a number of the projects. Cracking was observed in the restrained-edge section of the KY 80 project in Laurel County (Figures 61 and 62) and in the control section on the US 31W project in Hardin and Meade Counties (Figure 63). It appears the crack in the control section on US 31W was located over an old construction joint. In addition, two other projects (US 460, Menifee County and US 68/KY 80, Barren County) have slight-to-moderate cracking.

The cracking that was observed in the restrained-edge section of KY 80 in Laurel County is occurring in the area that had "pushed up" between the main drum and restraining wheel during construction. Cracking was also observed in this location on the mat on US 431 in Logan County during construction using the same roller and restraining wheel. However, the crack on US 431 disappeared during compaction and currently no crack is visible.

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Figure 61. Cracking in restrained-edge section on KY 80.

Figure 62. Cracking in restrained-edge section on KY 80.

Figure 63. Cracking in control section on US 31W.

Table 5. Field Performance Information, Kentucky Sites.

Route/County	Construction Technique	Starting and Ending Milepoints	Cracking at Joint		Location of Crack (Milepoint)	Raveling of Adjacent Mat		Rating**	Comments
			Length (feet)	Severity*		% of Length	Severity *		
US 68 KY 80/Barren	Control	0.0-0.59	4	slight	0.15	0 - 10	slight	8.9	
	Control with Crafco	0.59-1.14	20	slight-moderate	1.05	0 - 10	slight	8.9	Crack in Crafco section 1 ft. from joint.
	Restrained Edge	1.14-1.73				0 - 20	slight	9.8	
	Restrained Edge with Crafco	1.73-2.22				0 - 10	slight	9.9	
	Restrained Edge	2.22-6.59				0 - 20	slight	9.8	
	Joint Maker & Joint Matcher	6.59-9.94				0 - 10	slight	9.9	
US 31W/Hardin (Norhtbound)	Notched Wedge	34.0-35.60				40	mod.	9.6	Several feet of cracking at joint or to side of joint in first control section.
	Notched Wedge with Joint Tape	35.60-35.83							
	Notched Wedge	35.83-37.14							
US 31W/Meade (Southbound)	Control	2.90-3.31	100	moderate				8.5	
	Control with Joint Tape	3.31-3.55				50	mod.	9.4	
	Control	3.55 (Meade Co.) -37.14 (Hardin Co.)				60	mod.		
US 127/Casey	Notched Wedge	15.20-18.00							
	Notched Wedge with Crafco	18.0-18.50							
	Notched Wedge	18.50-20.90							
	Control	20.90-22.96							
US 460/Menifee	Joint Maker	0.00-4.73	200	moderate				9.0	Cracking in cut area.
	Control	4.73-6.66	40-50	moderate				9.0	Cracking in superelevated section.
KY 80/ (Westbound) Laurel	Control	8.82-10.58				60 - 70	slight	9.3	Tear in restrained-edge section at 8.07 approx. 175 ft. long. Located in superelevated section.
	Restrained Edge	5.81-8.82	800	moderate		0 - 10	slight	9.9	
	Control	4.27-5.81				50 - 60	slight	9.5	
US 60B/Daviess (Westbound)	Notched Wedge	7.32-10.21						9.5	Slight separation at joint in many places in control section (not cracked).
US 60B/Daviess (Eastbound)	Control	7.32-10.21						9.7	
US 62/ Scott	Notched Wedge								
Bluegrass Pkwy/ Nelson	Infrared Reheater	35.05-35.75				50	slight	9.5	
	Control	35.75-36.50				30	mod.	9.3	
US 431/ Logan	Control	21.68-26.45				0 - 10	slight	9.9	
	Restrained Edge	26.45-28.95				0 - 10	slight	9.9	
	Control	28.95-30.90							
	Trial Restrained Edge	30.90-31.10							
KY 80/ Pulaski	Control	6.63-9.26						9.5	Crafco section appears to be a little tighter than control.
	Crafco Joint Adhesive	9.26-13.71						9.6	
	Control	13.71-19.02						9.2	
US 27/ Pulaski	Restrained Edge	25.71-30.69							
US 41/ Webster	Joint Maker	2.75-4.66						9.9	
	Control	4.66-6.04						9.9	

*Severity = none, slight, moderate, or severe **Rating = 1 (poor) to 10 (good)

5.0 CONCLUSIONS

- Construction field data indicate that the infrared reheater had the highest increase in density of all the methods tried. However, this statement is based on only one project, and because this field project was limited in scope, an in-depth statistical analysis was not presented in Section 3.2.3 of this report. Also, the effects of the reheating process on the HMA pavement are not known and will only be determined through long-term monitoring. An additional field project using this process may be warranted, if paver attachments did not interfere with the "ski poles" and the reheaters do not slow the paving train.

- The restrained- edge method resulted in the second-highest increase in density and statistically yielded the greatest amount of increase in density overall. However, the restrained-edge wheel needs to be modified as shown in Figure 19.

- The notched-wedge method yielded the third-highest increase in density. However, statistically, this method produced only a marginal increase overall when compared with the conventional method of construction. Of all the projects, the notched wedge appeared to be the easiest to construct. Although an in-depth analysis of permeability was not conducted in this study, the notched wedge had one of the highest reductions in permeability at the joint.

- The Joint Maker method did not improve density at any location, and the statistical analysis indicated that the method was not statistically different from the conventional construction method. Additional projects with this device are not recommended.

- From Figure 55, it appears that contractors are currently achieving densities at the joint that are two to three percent less than densities at the center of the mat. These densities are being achieved without any special method or compactive effort (conventional construction). This data can be used as a basis for a future specification.

- From Figures 56 through 59, it appears that the restrained edge, and to a lesser degree, the notched wedge improved density, not only at the joint, but also all the way across the mat. However, at 18 inches from the joint, this effect was not as discernable as at the other locations.

- In this study, 59 percent of the time, the "hot" side of the paving joint was denser than the "cold" side when using conventional construction techniques. The "hot"side was denser 70 percent of the time when using the other experimental construction methods.

- The preliminary performance data indicate all projects are performing well, with only minimal cracking on two of the projects.

- Projects with joint adhesives appear to be performing as well or better than those sections of projects without adhesives.

6.0 RECOMMENDATIONS

- Based on Figure 55, it is recommended that a specification be written for acceptance of longitudinal joint densities for asphalt surface pavements that requires the contractor to achieve a density (within 3.0 inches of the joint) that is within three percent of the current specification for lane density.

- It is recommended that additional projects be constructed using the restrained-edge method with a modified wheel as shown in Figure 19.

- Based on the preliminary performance data, it is recommended that more projects be constructed using joint adhesives.

- It is recommended that all of the projects included in this study be monitored in the future under the KTC long-term monitoring project (*KYSPR-02-107*).

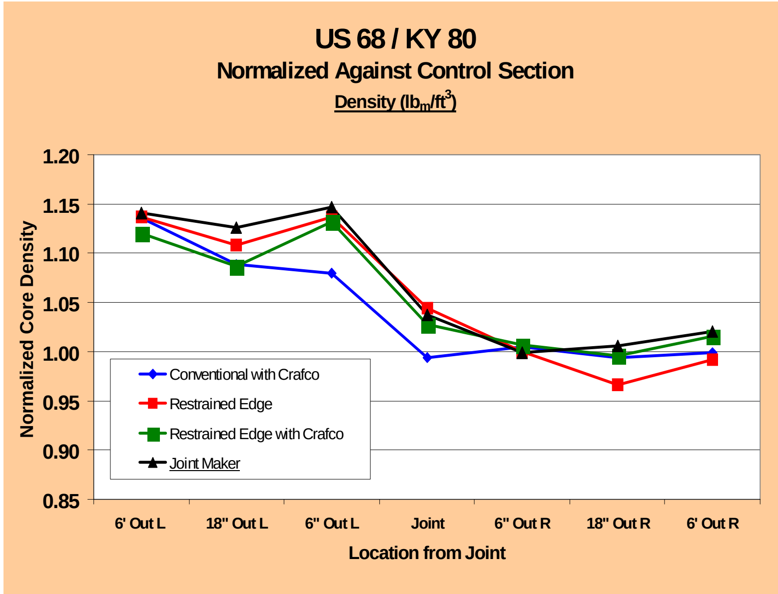
ACKNOWLEDGMENTS

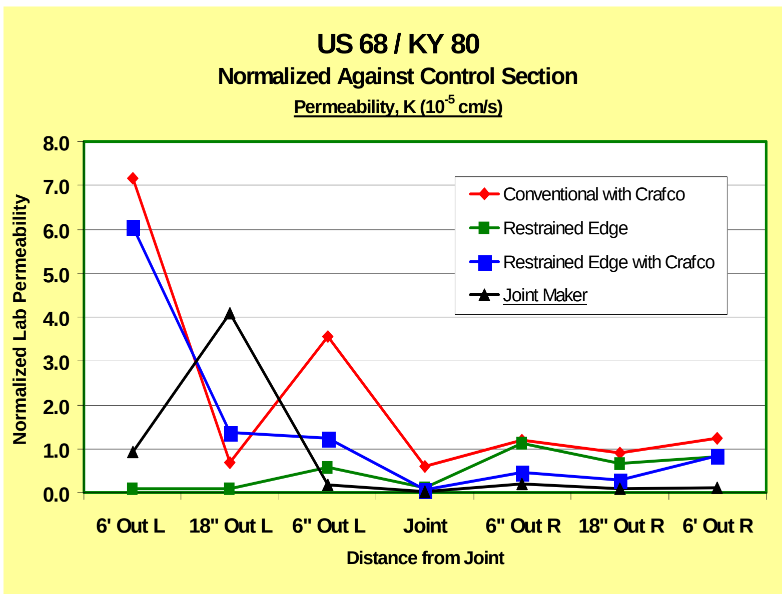
Information provided by Prithvi S. Kandhal and Allen Cooley of NCAT, Tim Ramirez of Pennsylvania DOT, Bill Niemi of Wisconsin DOT, and Don Watson of Georgia DOT.

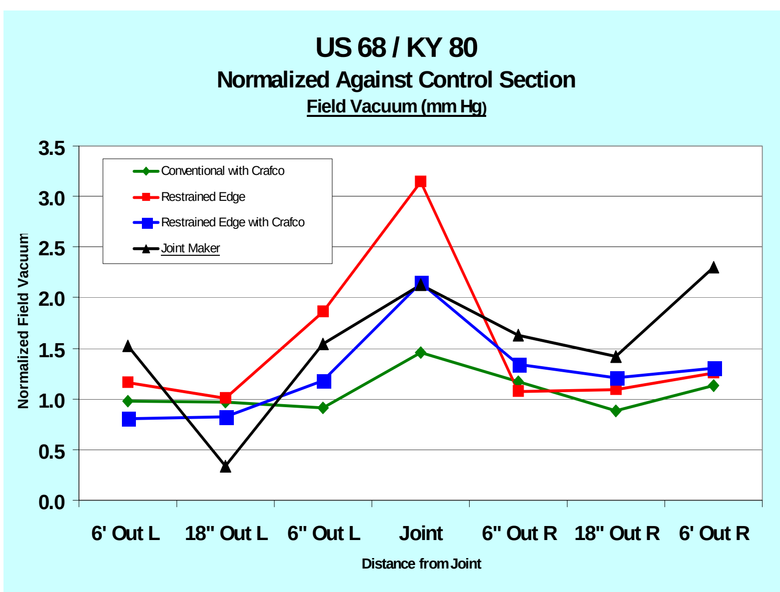
Special thanks is given to Mr. Allen Myers, Chairman of the SAC, for his advice and consultation. In addition, his editorial work on this report is appreciated. Acknowledgment is also given to the other members of the SAC for their guidance.

Appendix A

FIELD AND LABORATORY ANALYSIS
(US 68/KY 80, Barren County)

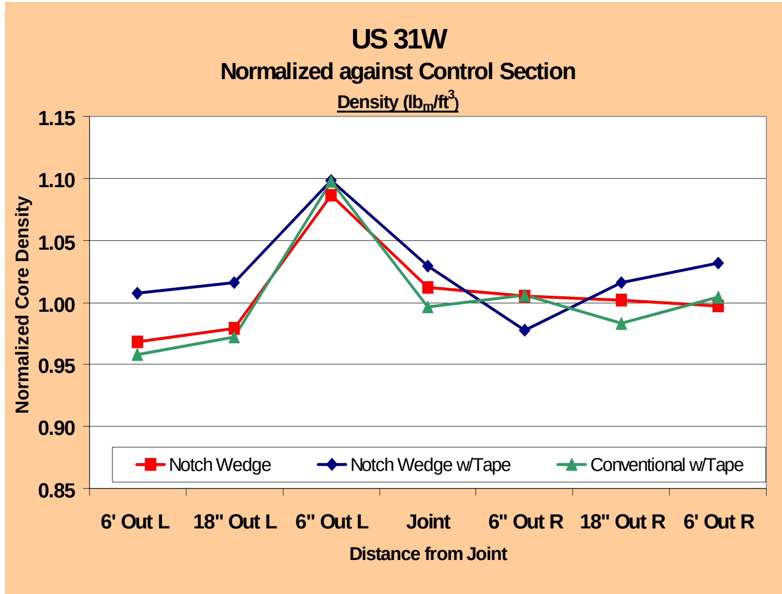

US 68 / KY 80
Normalized Against Control Section
Density (lb_m/ft^3)
Normalized Core Density
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
Conventional with Crafco
Restrained Edge
Restrained Edge with Crafco
Joint Maker
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Location from Joint

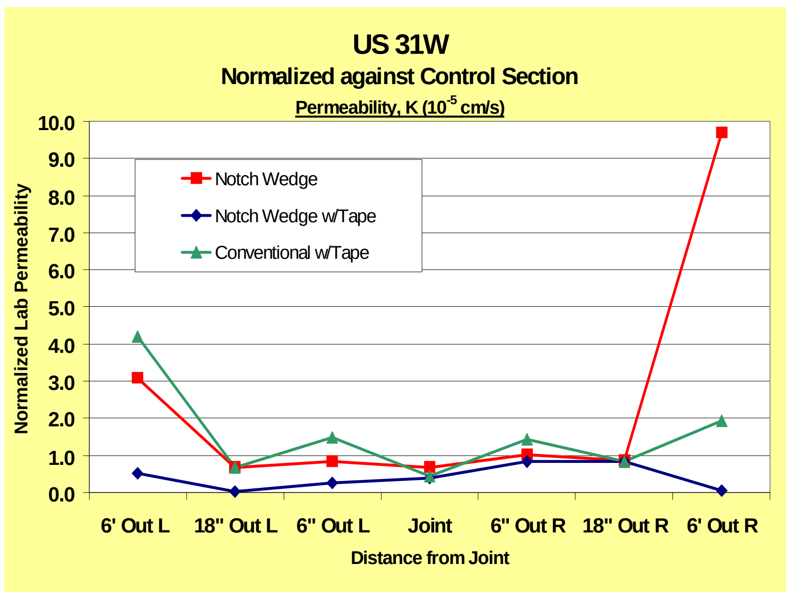

US 68 / KY 80
Normalized Against Control Section
Permeability, K (10^{-5} cm/s)
Normalized Lab Permeability
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Conventional with Crafco
Restrained Edge
Restrained Edge with Crafco
Joint Maker
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

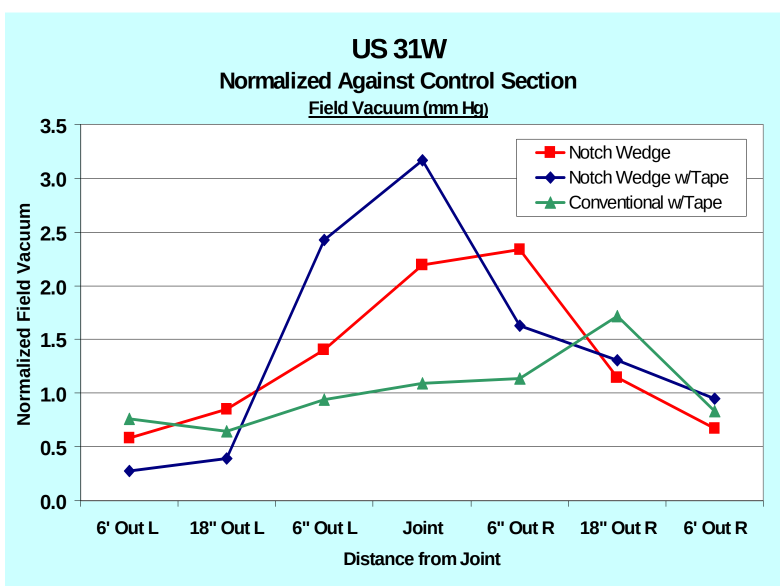

US 68 / KY 80
Normalized Against Control Section
Field Vacuum (mm Hg)
Normalized Field Vacuum
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Conventional with Crafco
Restrained Edge
Restrained Edge with Crafco
Joint Maker
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

Appendix B

FIELD AND LABORATORY ANALYSIS (US 31W, Hardin and Meade Counties)

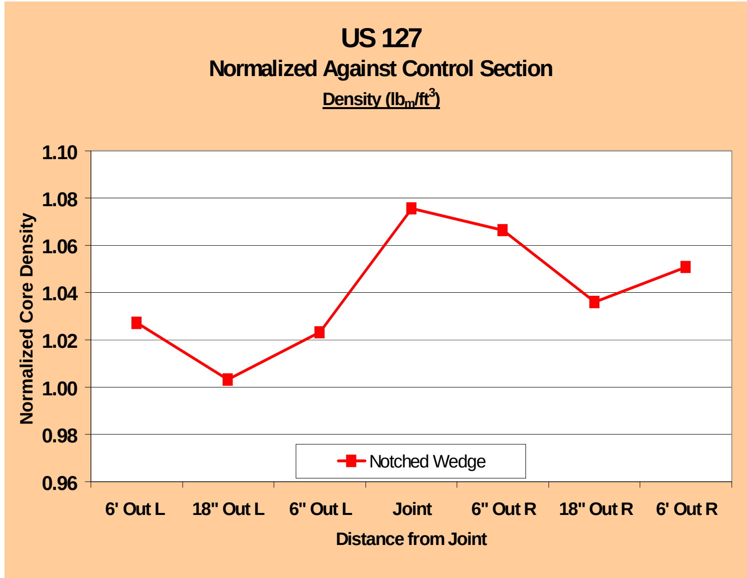

US 31W
Normalized against Control Section
Density (lb_m/ft^3)
Normalized Core Density
1.15
1.10
1.05
1.00
0.95
0.90
0.85
Notch Wedge
Notch Wedge w/Tape
Conventional w/Tape
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

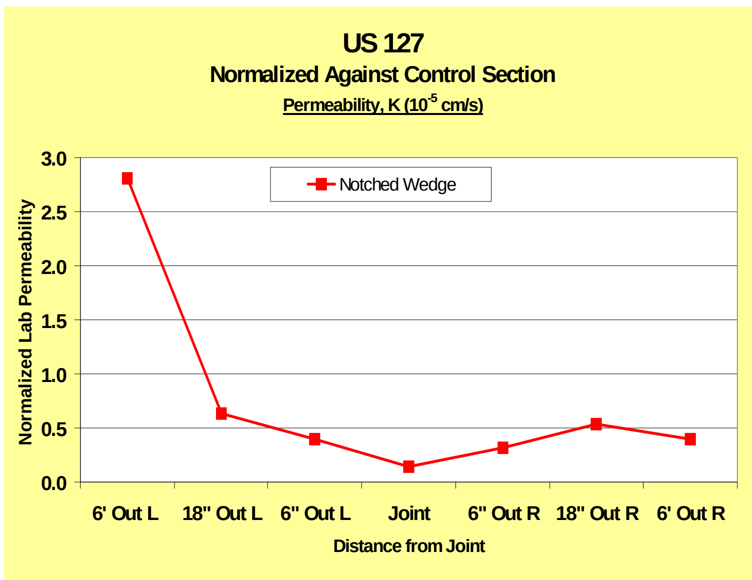

US 31W
Normalized against Control Section
Permeability, K (10^{-5} cm/s)
Normalized Lab Permeability
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Notch Wedge
Notch Wedge w/Tape
Conventional w/Tape
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

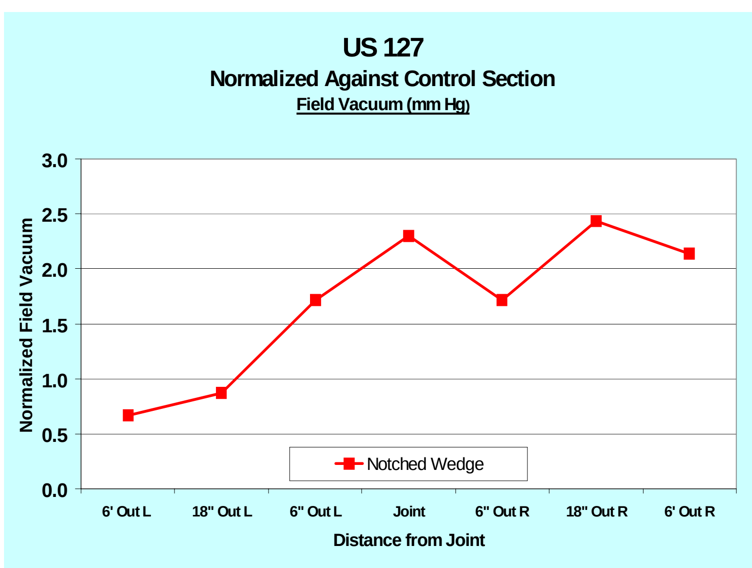

US 31W
Normalized Against Control Section
Field Vacuum (mm Hg)
Normalized Field Vacuum
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Notch Wedge
Notch Wedge w/Tape
Conventional w/Tape
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

Appendix C

FIELD AND LABORATORY DATA ANALYSIS
(US 127, Casey County)

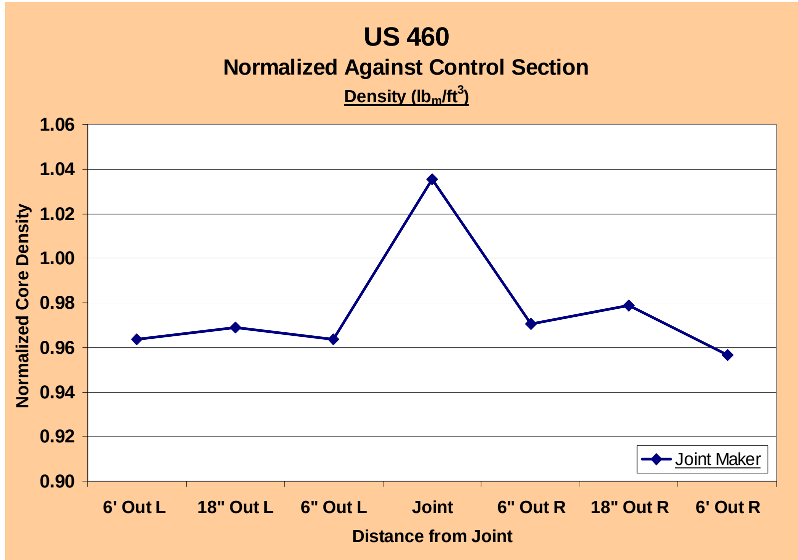

US 127
Normalized Against Control Section
Density (lb_m/ft^3)
Normalized Core Density
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
Notched Wedge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

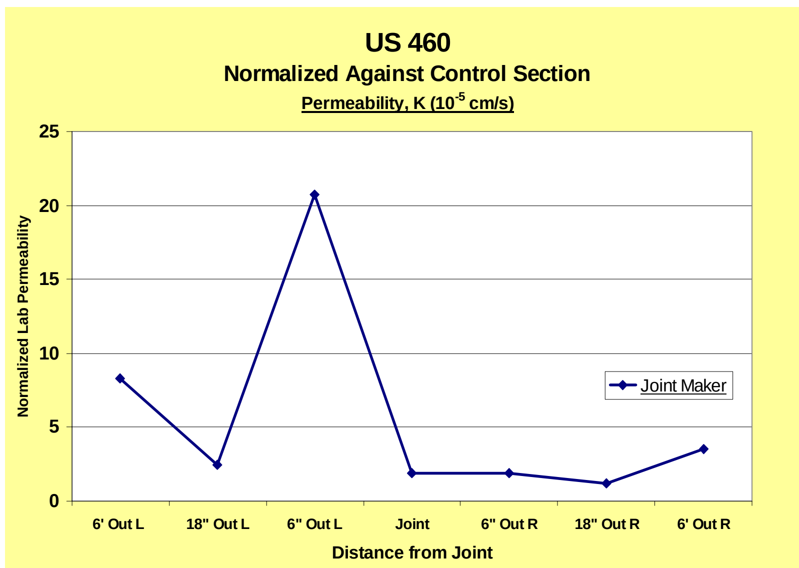

US 127
Normalized Against Control Section
Permeability, K (10^{-5} cm/s)
Normalized Lab Permeability
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Notched Wedge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

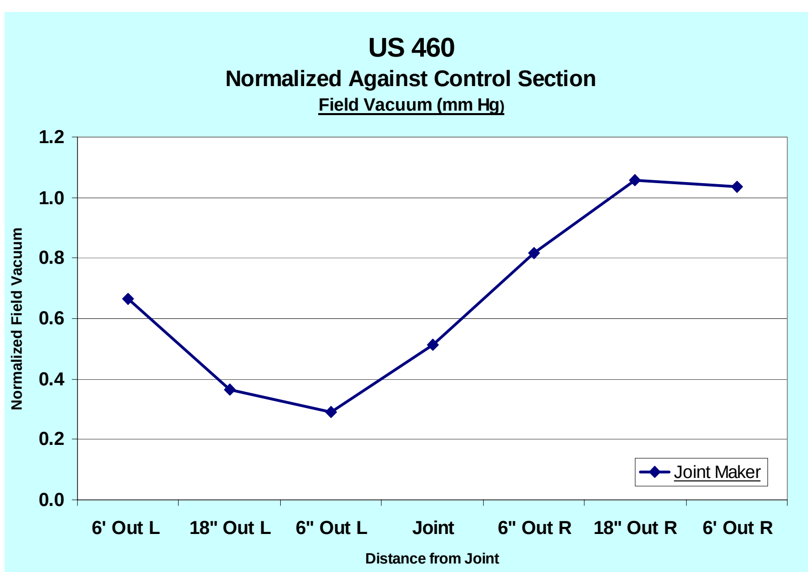

US 127
Normalized Against Control Section
Field Vacuum (mm Hg)
Normalized Field Vacuum
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Notched Wedge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

Appendix D

FIELD AND LABORATORY ANALYSIS
(US 460, Menifee County)

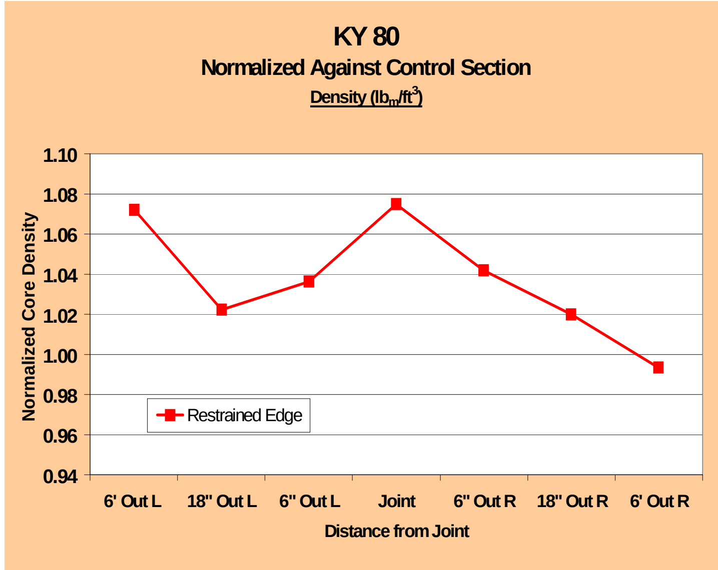

US 460
Normalized Against Control Section
Density (lb_m/ft^3)
Normalized Core Density
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.90
Joint Maker
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

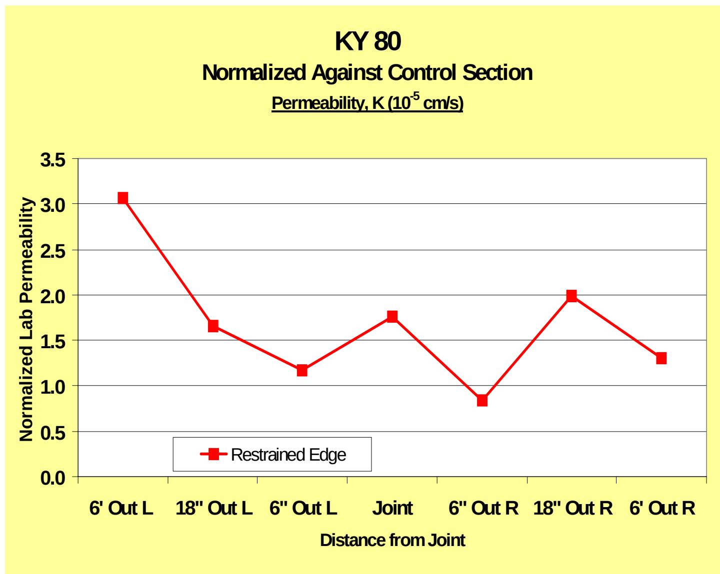

US 460
Normalized Against Control Section
Permeability, K (10^{-5} cm/s)
Normalized Lab Permeability
25
20
15
10
5
0
Joint Maker
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

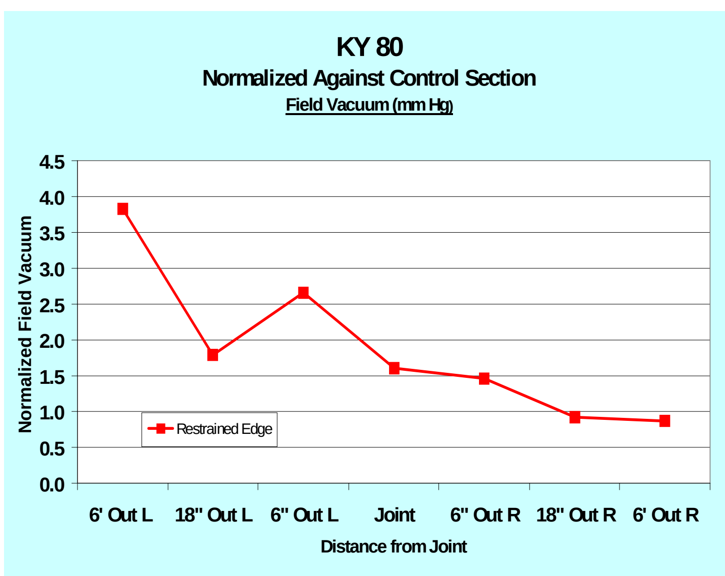

US 460
Normalized Against Control Section
Field Vacuum (mm Hg)
Normalized Field Vacuum
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Joint Maker
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

Appendix E

FIELD AND LABORATORY ANALYSIS
(KY 80, Laurel County)

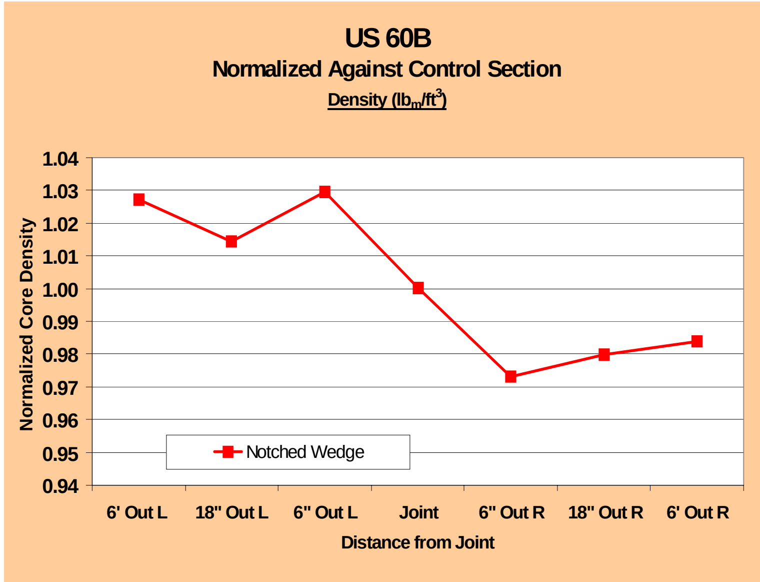

KY 80
Normalized Against Control Section
Density (lb$_m$/ft^3)
Normalized Core Density
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
0.94
Restrained Edge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

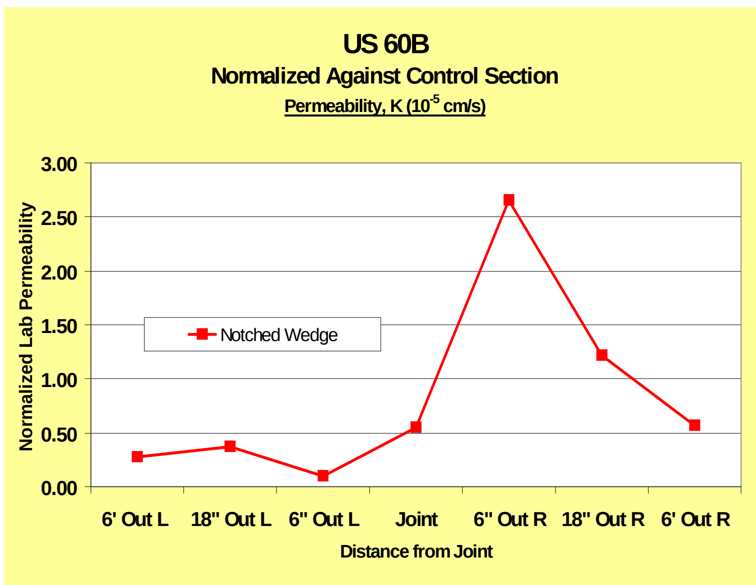

KY 80
Normalized Against Control Section
Permeability, K (10^{-5} cm/s)
Normalized Lab Permeability
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Restrained Edge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

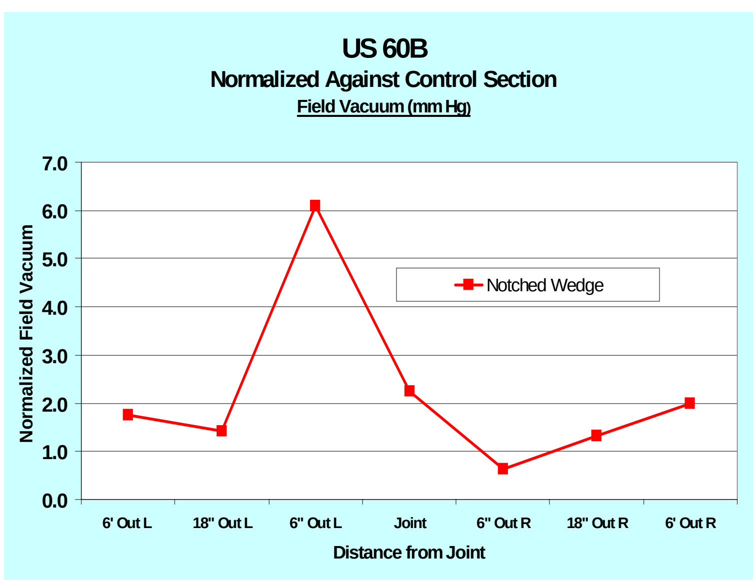

KY 80
Normalized Against Control Section
Field Vacuum (mm Hg)
Normalized Field Vacuum
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Restrained Edge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

Appendix F

FIELD AND LABORATORY ANALYSIS
(US 60B, Daviess County)

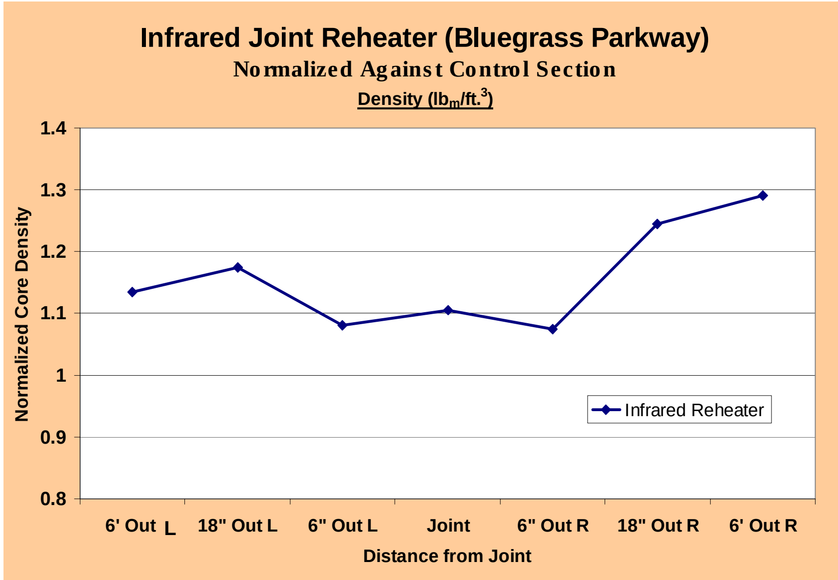

US 60B
Normalized Against Control Section
Density (lbm/ft3)
Normalized Core Density
1.04
1.03
1.02
1.01
1.00
0.99
0.98
0.97
0.96
0.95
0.94
Notched Wedge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint


US 60B
Normalized Against Control Section
Permeability, K (10-5 cm/s)
Normalized Lab Permeability
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Notched Wedge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

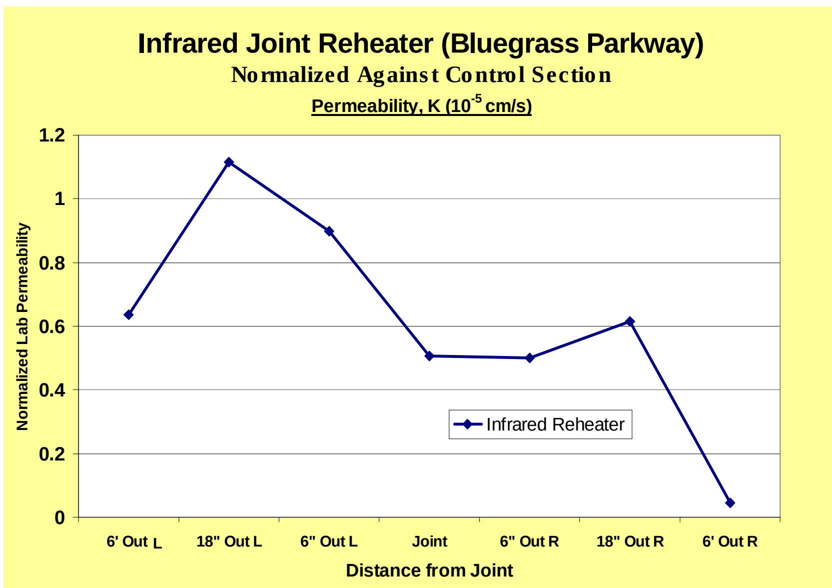

US 60B
Normalized Against Control Section
Field Vacuum (mm Hg)
Normalized Field Vacuum
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Notched Wedge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

Appendix G

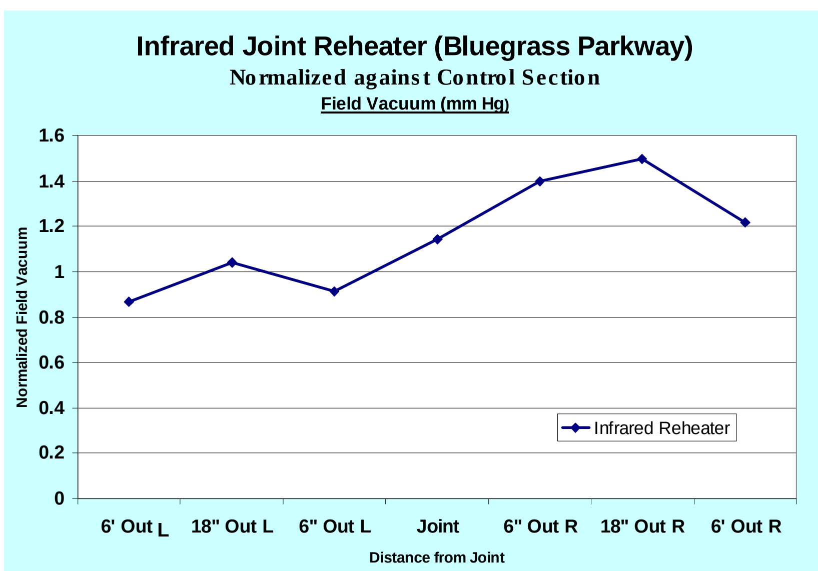
FIELD AND LABORATORY ANALYSIS
(Bluegrass Parkway, Nelson County)



Infrared Joint Reheater (Bluegrass Parkway)
Normalized Against Control Section
Density (lbm/ft.3)
Normalized Core Density
1.4
1.3
1.2
1.1
1
0.9
0.8
Infrared Reheater
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint



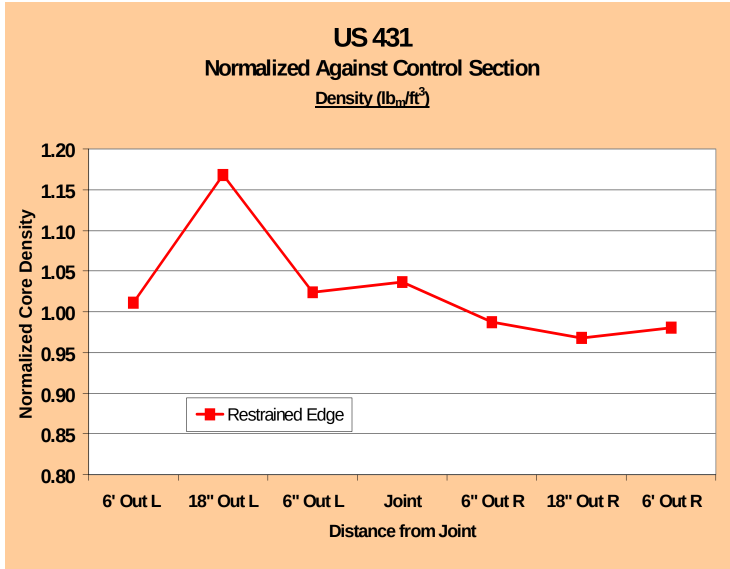
Infrared Joint Reheater (Bluegrass Parkway)
Normalized Against Control Section
Permeability, K (10-5 cm/s)
Normalized Lab Permeability
1.2
1
0.8
0.6
0.4
0.2
0
Infrared Reheater
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

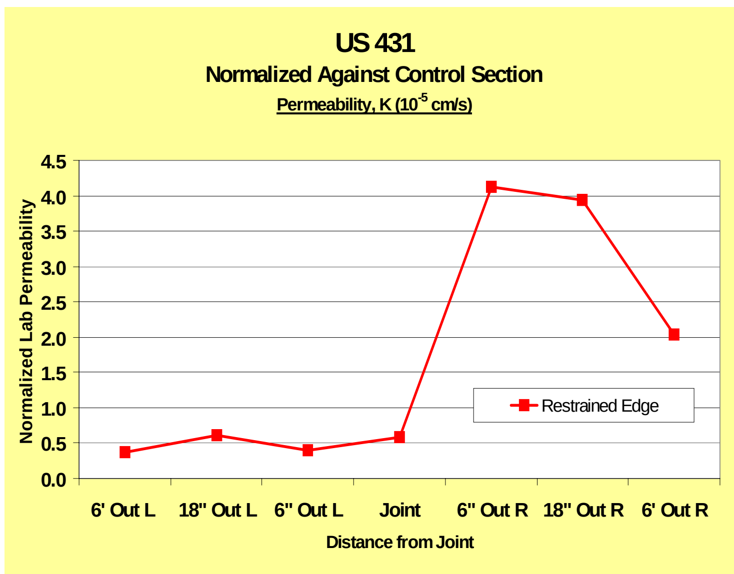


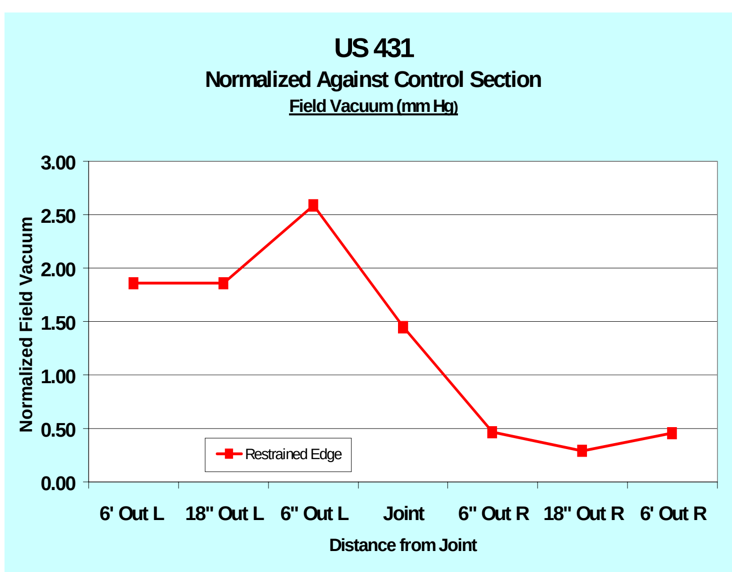
Infrared Joint Reheater (Bluegrass Parkway)
Normalized against Control Section
Field Vacuum (mm Hg)
Normalized Field Vacuum
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Infrared Reheater
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

Appendix H

FIELD AND LABORATORY ANALYSIS
(US 431, Logan County)

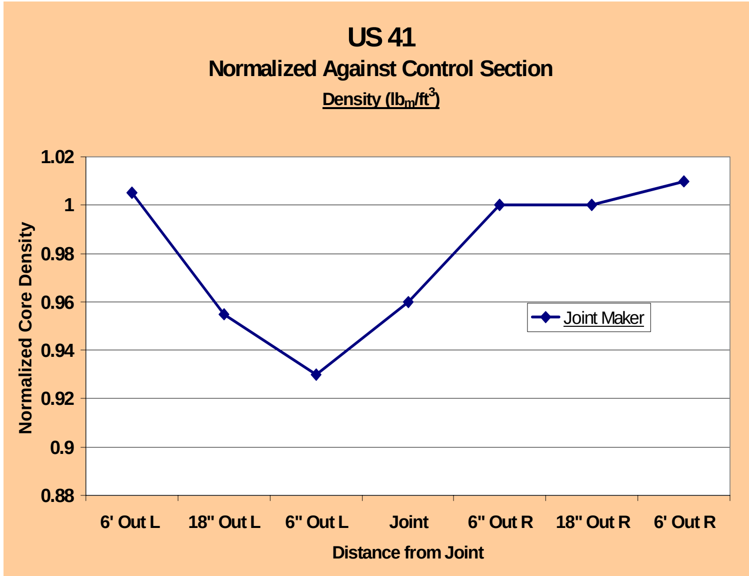

US 431
Normalized Against Control Section
Density (lbm/ft3)
Normalized Core Density
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
Restrained Edge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

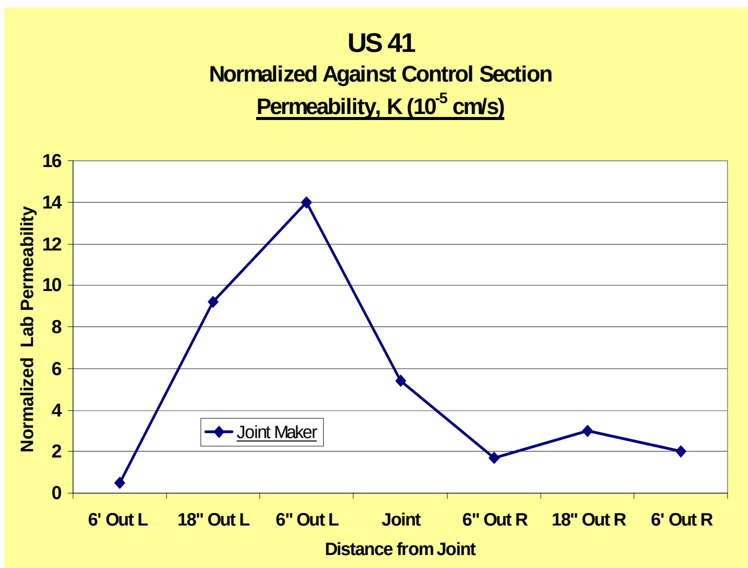

US 431
Normalized Against Control Section
Permeability, K (10-5 cm/s)
Normalized Lab Permeability
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Restrained Edge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

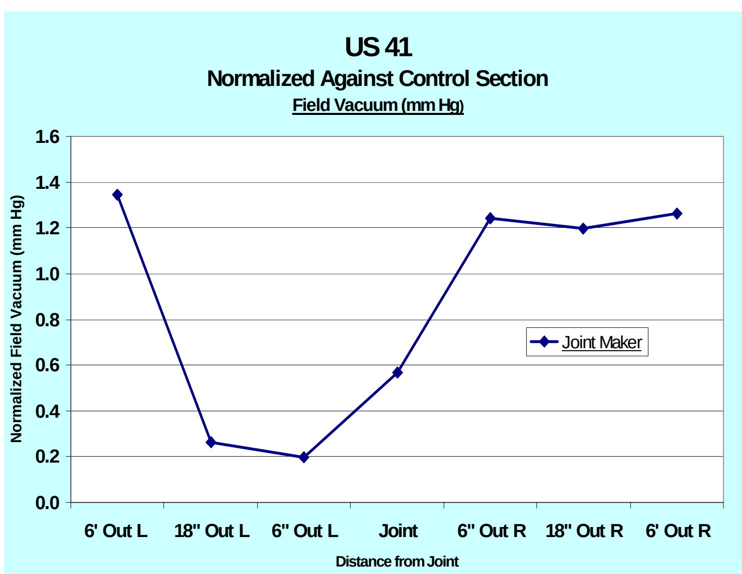

US 431
Normalized Against Control Section
Field Vacuum (mm Hg)
Normalized Field Vacuum
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Restrained Edge
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint

Appendix I

FIELD AND LABORATORY ANALYSIS
(US 41, Webster County)


US 41
Normalized Against Control Section
Density (lb_m/ft^3)
Normalized Core Density
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
Joint Maker
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint


US 41
Normalized Against Control Section
Permeability, K (10^{-5} cm/s)
Normalized Lab Permeability
16
14
12
10
8
6
4
2
0
Joint Maker
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint


US 41
Normalized Against Control Section
Field Vacuum (mm Hg)
Normalized Field Vacuum (mm Hg)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Joint Maker
6' Out L
18" Out L
6" Out L
Joint
6" Out R
18" Out R
6' Out R
Distance from Joint