

Using Density, Permeability, Infiltration, and Absorption to Assess the Quality of HMA Longitudinal Joints

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by

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ABSTRACT

Longitudinal joint quality is critical to the successful performance of hot-mix asphalt (HMA) pavements. The implementation of longitudinal joint quality specifications is gaining momentum in many states, with density being the most common quality parameter. However, distress at the joint is caused by the ability of air and water to enter the pavement structure, which may be more compatible with a measure of permeability.

The objective of this study was to provide guidance for the implementation of joint quality specifications by compiling information that more completely describes the relationships of density, absorption, permeability, and infiltration. On two resurfacing projects, eight joint construction techniques were used, and the ability of each to improve joint quality was assessed. In addition, joint quality was evaluated with regard to proximity to the joint. In general, the joint heater, joint stabilizer, and notched wedge construction methods were the best performers with regard to density and permeability. Traditional rolling methods exhibited lesser quality, indicating that additional measures may be necessary to generate acceptable levels of joint quality. With regard to the most appropriate measure of quality, permeability and infiltration adequately discriminated between varying levels of joint quality, as did nuclear density. Reasonable relationships were developed between density, permeability, infiltration, and absorption. Thus, density measurements can be used for assessing joint quality while simultaneously protecting against excessive levels of permeability.

INTRODUCTION

The successful performance of hot mix asphalt (HMA) pavements is often governed by the performance of longitudinal joints. In many cases, HMA pavements have required premature maintenance actions due to failures that occur at or near the longitudinal joint. It is unfortunate when an entire lane must be rehabilitated due to a failure that is confined to a relatively small portion of the pavement. In spite of the knowledge that longitudinal joint quality is crucial, many states still do not require any testing at or near the longitudinal joint. Information is needed to more fully describe the potential for failure at the joint, as well as methods that can be used to prevent failures, so that sound decisions can be made regarding the implementation of joint specifications.

Although low density at the joint is usually blamed for joint failures, other mechanisms such as permeability, infiltration, or absorption may be more descriptive of the actual failures that occur at joints. Joint distresses are a result of excessive air and water entering the pavement structure. Thus, the primary concerns are to determine 1) what construction techniques can be used to keep air and water out of the joint, and 2) what test methods provide the most accurate predictions regarding the potential for failure.

In this study, 8 joint construction techniques were used on 2 resurfacing projects. Testing was performed in the field and in the laboratory to describe compaction at the joint, and the ability of water to enter the joint. Recommendations were made regarding the most appropriate parameters that should be used in implementing a longitudinal joint quality specification.

BACKGROUND

HMA pavements are typically constructed one lane at a time such that longitudinal joints are created as subsequent adjoining lanes are placed. The first paved lane, or “cold” lane, lacks edge confinement during compaction, and cools prior to placement of the second lane, or “hot” lane. Thus, a density gradient usually exists at the joint. If the joint area contains excessive voids, then it may be susceptible to the entrance of air and water, leading to the distresses of moisture damage, aging, binder hardening, cracking, raveling, and crack separation. As the deterioration advances, additional distresses may appear, including popouts and potholes.

Longitudinal joints were first considered to be a possible root cause of HMA pavement deterioration in the 1960s, when the joint area was determined to be a “low density zone”. (1) A well-constructed longitudinal joint should have about 1 to 2 percent lower density than the mat, but a poorly constructed joint can have 5 to 10 percent lower density than the mat. (1, 2, 3, 4, 5) Because of this, density has been the primary measure of joint quality. The most commonly used methods for determining density at a longitudinal joint are nuclear density and bulk specific gravity measurements of cores cut from the roadway. Of the available methods, the most accurate measure of joint density is generally believed to be the laboratory-derived density of cores cut from the joint. (3)

While density can certainly be an indicator of joint quality, this parameter may not be an adequate descriptor in all situations, specifically when joint adhesives and sealants are used. (6) Thus, other measures may be more appropriate for quality estimations. Permeability and infiltration have been investigated as possible alternatives, and results appear to be very promising. (2, 6, 7, 8, 9)

Joint Construction Techniques

In general, longitudinal joint construction methods can be grouped into several basic categories, including echelon paving, rolling techniques, joint adhesives and sealants, wedge construction, edge restraint devices, cutting wheels, and joint heaters. Although echelon paving is widely recognized as the most advantageous for producing high-quality longitudinal joints, it is rarely feasible due to traffic considerations and construction sequencing. (5)

Rolling techniques can be varied, but generally employ a strategy to force the overlapping mix into the joint, creating a consistent density and a smooth joint with minimal vertical differential. Rolling may be performed such that the first pass is 1) from the hot side while overlapping the cold lane slightly, 2) from the hot side approximately 6 inches away from the joint, leaving a hump of material that is later “pinched” into the joint, or 3) from the cold side, overlapping the hot lane by 6 to 12 inches. All methods

are inherently dependent upon good construction techniques, and require the appropriate quantity of material in the joint to achieve a smooth surface while tightly filling the joint area. (5, 10, 11) Rolling from the hot side with a 6 inch overlap has been traditionally recommended for getting a good bond between the hot and cold lanes. (10, 12, 13, 14) However, other studies have recommended pinching the joint from the hot side. (3, 5) Although rolling from the cold side has generated favorable results, this method is often rejected because the majority of the mat is not compacted on the first pass, allowing it to cool and become more difficult to compact. (5, 10)

Many products have been used to seal or stabilize longitudinal joints, with the primary intention of preventing the entrance of water and air, thereby reducing joint separation and preserving the integrity of the joint. Although these materials do not typically improve the density at the joint, they have demonstrated good performance by limiting the number of interconnected void spaces. (3, 6, 9, 10) Most of these products are applied to the face of the joint prior to placing the hot lane, although some are applied after both sides of the joint have been compacted.

Longitudinal joints have also been constructed by forming wedges at the unsupported edges. This technique employs a paver “shoe” or “boot” that forms the unconfined edge of the mat into a taper. This shape is believed to reduce the amount of transverse migration of the cold lane during compaction, and also provides a graduated surface for placing overlapping material which enhances heat transfer during placement of the hot lane. An additional advantage of this method is that it provides a safer edge for vehicles to traverse. Arizona and New Jersey were the first states to experiment with and implement a wedge joint (15), although the most prominent form of the wedge is the Michigan wedge, or notched wedge. The notched wedge has been reported to aid in increasing density at the joint (2, 10, 14, 16)

The edge restraint method is somewhat similar to the wedge method in that an additional fixture is used at the end of the screed to provide a confining force to the unsupported edge. However, the resulting edge is typically much more vertical in nature than the wedge methods. For this method, a tapered wheel is attached by a hydraulic arm to the roller to prevent lateral movement of the mat as the cold lane is compacted. (2, 14, 17)

A cutting wheel can be used to create a vertical joint face after the cold lane is paved. Generally, this involves mounting a cutting wheel to an intermediate roller or other motorized equipment, so that the wheel removes the outer portion of lower density material (usually 6 to 8 inches) at the free edge. This allows for a dense, vertical support against which the hot lane can be paved. This method has generated good joint performance, and is currently used for airport HMA pavement construction. (3, 5, 10, 13) The primary disadvantages are that joint quality is highly dependent upon the ability of the operator to cut a straight joint, and the contractor is forced to “waste” the excess material that is cut from the joint.

The joint heater is a method that has been investigated for at least 25 years, and is based on the premise that if the cold lane is heated just prior to placing the hot lane, the echelon paving format is recreated. Recent joint heaters employ propane-powered high efficiency infrared technology to heat the joint area to a relatively soft condition. This technique has been reported to reduce segregation, increase joint density, and provide a very smooth joint. (2, 8, 15, 18) The heater panels can be customized for project conditions, but typically consist of four infrared panels mounted on a trailer that is towed slightly ahead of the paver (at paving speed), and an additional panel that is mounted on the side of the paver.

OBJECTIVES

The primary object of this study was to generate a recommendation for the use of longitudinal joint construction techniques and test methods that have the greatest potential for accurately creating and assessing quality, and can be easily implemented within an existing quality control/quality assurance (QC/QA) program. Specific objectives were to determine the ability of each technique to affect quality at and near the joint, to determine the most advantageous measure of joint quality for QC/QA purposes, and to explore relationships between joint characteristics that could facilitate the successful implementation of joint quality specifications.

SCOPE

Two resurfacing projects were chosen for this study, each utilizing a 12.5mm asphalt mixture. The first was a 5-lane section of U.S. Highway 167, and the second was a three-lane section (2 lanes plus a climbing lane) of U.S. Highway 65. In each case, the test joint was the joint between unidirectional lanes of traffic, thus eliminating any confounding effects caused by the cross-sectional shape of the roadway. Test sections were situated to avoid areas of difficult geometry or other features that could negatively impact typical construction procedures. On each project, 8 longitudinal joint construction techniques were used to construct 500-foot sections, described as follows:

- Joint Adhesive (CF). A Crafco brand polymerized joint adhesive, supplied by Southern Star Materials, Inc., was applied to the joint face just prior to placement of the hot lane. The purpose of the material was to bond the hot and cold lanes together while reducing the permeability at the joint.
- Joint Heater (JH). An infrared joint heater, supplied by Heat Design Equipment, Inc., was used to heat the cold lane to a temperature of approximately 230°F. The hot lane was immediately placed and compacted.
- Notched Wedge (NW). The notched wedge joint maker, marketed by TransTech Systems, Inc., was used to form a one-half inch notch and a 1:12 wedge. No special compaction devices (i.e., tag-along rollers, etc.) were used to provide initial compaction to the wedge.
- Joint Stabilizer (JB). JointBond[®], a post-applied polymerized emulsion product, was sprayed onto the joint area after final rolling was completed and the mat had cooled significantly. A spray bar was used to apply a 3-foot wide strip of product to the joint, covering the joint and 18 inches to either side of the joint. The JointBond product was supplied by Pavement Technology, Inc.
- Tack Coat (TC). A standard tack coat (SS-1) was applied to the cold joint face by aiming the outer nozzle of the spray bar directly at the joint face during tack coat application. This product was included in the study as a potential alternative to the joint adhesive.
- Hot Overlap (HO). This method was one of 3 rolling patterns included in the study. In this method, the first pass of the roller was in the vibratory mode with the roller on the hot side, overlapping the cold side of the joint by approximately 6 inches. This method was the control section for each project.
- Hot Pinch (HP). This rolling method required the first pass of the roller to take place in vibratory mode on the hot side, approximately 6 inches away from the joint. During the first pass, the material at the joint formed a hump that was “pinched” into the joint on subsequent passes. This method, as directed by Arkansas specifications, was used as the control method. This technique was also used for test sections not involving a specific rolling pattern.
- Cold Roll (CR). In this rolling method, the first pass of the roller was performed in static mode on the cold side of the joint, overlapping the hot side by 6 to 12 inches. The remainder of the mat was compacted on subsequent passes.

Within each 500 foot section, 3 testing locations were established, and at each location, core locations were marked at the joint (J), 6 inches to the hot side of the joint (6H), 6 inches to the cold side of the joint (6C), 12 inches to the hot side of the joint (12H), and 12 inches to the cold side of the joint (12C). A mat density location (M) was also established within each section at a distance of 5 feet from the joint.

First, nuclear density testing was performed at all testing points (12C, 6C, J, 6H, 12H, and M) using a Troxler 3430 nuclear gauge. Each reported density was the average of five density readings: one taken directly over the core location, and 4 taken at evenly spaced points around the perimeter of the core location. Density values were reported in pounds per cubic foot (pcf), and percent density was calculated based on the average maximum theoretical specific gravity of the mixture, as measured during production. A core correction factor was established for each project based on cores tested according to AASHTO T 166.

Next, field permeability tests were conducted using the Gilson AP-1B field permeameter at the 6C, J, 6H, and M core locations. The coefficient of permeability was calculated according to Equation 1.

$$k = \left(\frac{aL}{At} \right) \ln \left(\frac{h_1}{h_2} \right)$$

Equation 1

where:

k = coefficient of permeability, cm/s $\times 10^{-5}$

a = inside cross-sectional area of standpipe, cm²

L = length of the sample, cm (thickness of the asphalt mat)

A = cross-sectional testing area, cm²

t = elapsed time between h_1 and h_2 , s

h_1 = initial head, cm

h_2 = final head, cm

The coefficient of permeability is a fundamental measure of the water flow through a medium. However, it is based on the assumption that water flows only vertically through the pavement layer. In reality, the water can move both vertically and laterally, meaning that the basic assumptions associated with the test are rarely (if ever) truly met. Therefore, infiltration, which is simply a measure of the quantity of water that enters the pavement during a given time, may be a more appropriate measure of the pavement's ability to take on water and its susceptibility to moisture-related distresses. Infiltration rate was calculated according to Equation 2 (6):

$$Inf = \frac{a(h_1 - h_2)}{At}$$

Equation 2

where:

Inf = infiltration, cm/hr

a = inside cross-sectional area of standpipe, cm²

h_1 = initial head, cm

h_2 = final head, cm

A = cross-sectional testing area, cm²

t = elapsed time between h_1 and h_2 , hr

After completion of all non-destructive testing, cores were cut at the 6C, J, and 6H locations in three locations of each of the eight test sections. In addition, one core was cut in each test section at the M location, resulting in 10 cores per section. A total of 160 cores were cut (2 jobs, 8 sections, 10 cores per section). The cores were then transported to the laboratory where they were tested for bulk specific gravity according to the SSD method as described by AASHTO T166 and the vacuum sealing method as outlined in AASHTO T331. Percent density was computed for each specimen as a percentage of the average theoretical maximum specific gravity measured during production. In order to provide an additional measurement of the entrance of water into the mixture, percent absorption was calculated for each specimen, according to AASHTO T166.

TEST RESULTS AND ANALYSIS

Test results were divided into two segments – those describing density and those describing the potential for water to enter the pavement. A complete summary of experimental factors is given in Table 1.

TABLE 1 Summary of Experimental Factors

Projects (2)	Construction Methods (8)	Distance from Joint (6)*	Responses (6)
Hwy. 167	Joint Adhesive (CF)	12C	Nuclear Density (NG)
Hwy. 65	Cold Roll (CR)	12H	T166 Density (SSD)
	Hot Overlap (HO)	6C	T331 Density (VS)
	Hot Pinch (HP)	6H	
	Joint Stabilizer (JB)	J	Absorption
	Joint Heater (JH)	M	Permeability
	Notched Wedge (NW)		Infiltration
	Tack Coat (TC)		

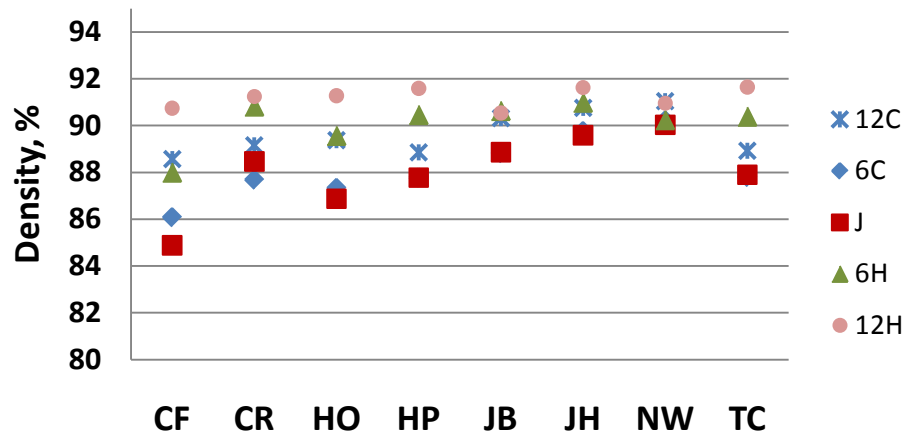
*12C and 12H distances used only for nuclear density measurements

The average values of the density are shown graphically in Figure 1. For nuclear density, the joint stabilizer (JB), joint heater (JH), and notched wedge (NW) methods appeared to generate similar densities at and away from the joint, while the joint adhesive (CF), rolling methods (HO, CR, and HP), and tack coat (TC) methods exhibited practically significant differences at various distances from the joint. The joint heater (JH) and notched wedge (NW) methods generated the highest joint densities, followed by cold roll (CR), joint stabilizer (JB), and tack coat (TC). The lowest joint densities were present in the joint adhesive (CF) section.

Core density by AASHTO T166 displayed similar trends, although the variations in density were much less pronounced. The highest joint densities were obtained for the joint heater (JH) and joint stabilizer (JB) methods, while the lowest densities were associated with the joint adhesive (CF) and tack coat (TC) methods. The largest differences between densities at and away from the joint were noted for the hot overlap (HO), hot pinch (HP), and tack coat (TC) methods.

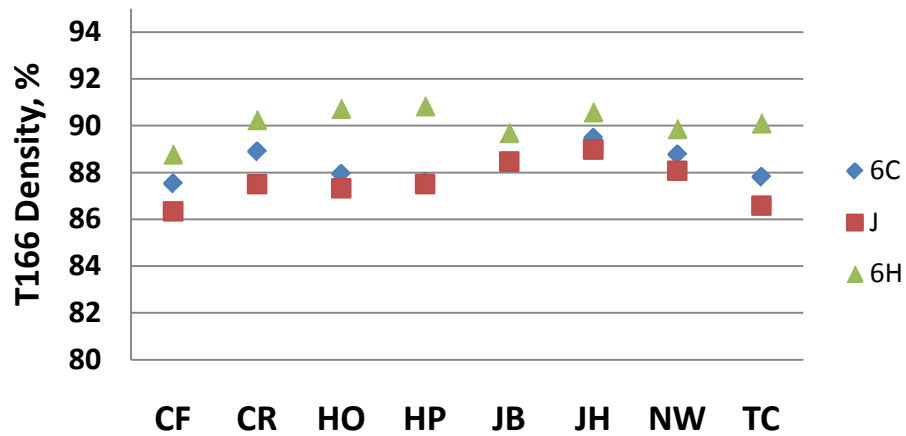
For the vacuum sealing method, the magnitudes of density were considerably lower than for the other methods. This was not unexpected since the vacuum sealing method tends to result in lower densities than the SSD method, especially for lower density specimens as is typical of joint cores. This is primarily due to the inherent difficulties in obtaining a true saturated-surface-dry specimen condition during testing. Overall, the T331 core density test results showed that the joint heater (JH) and notched wedge (NW) methods were superior at achieving higher densities, while the joint stabilizer (JB) and joint adhesive (CF) methods were not successful. The joint stabilizer appeared much more capable when judged by the other measures of density. No suitable explanation was determined for this phenomenon.

Nuclear Density



(a)

Core Density - T166



(b)

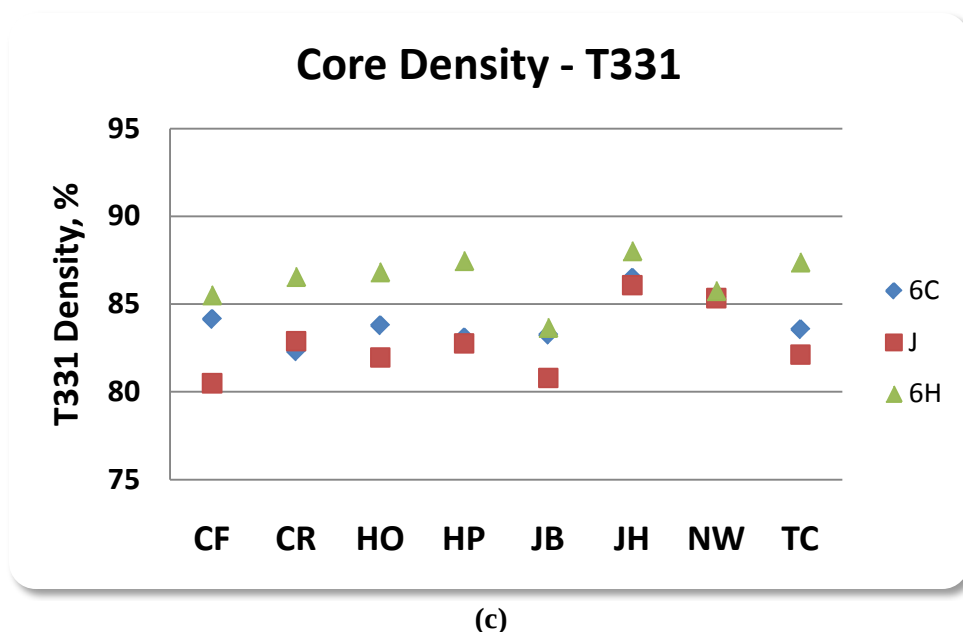
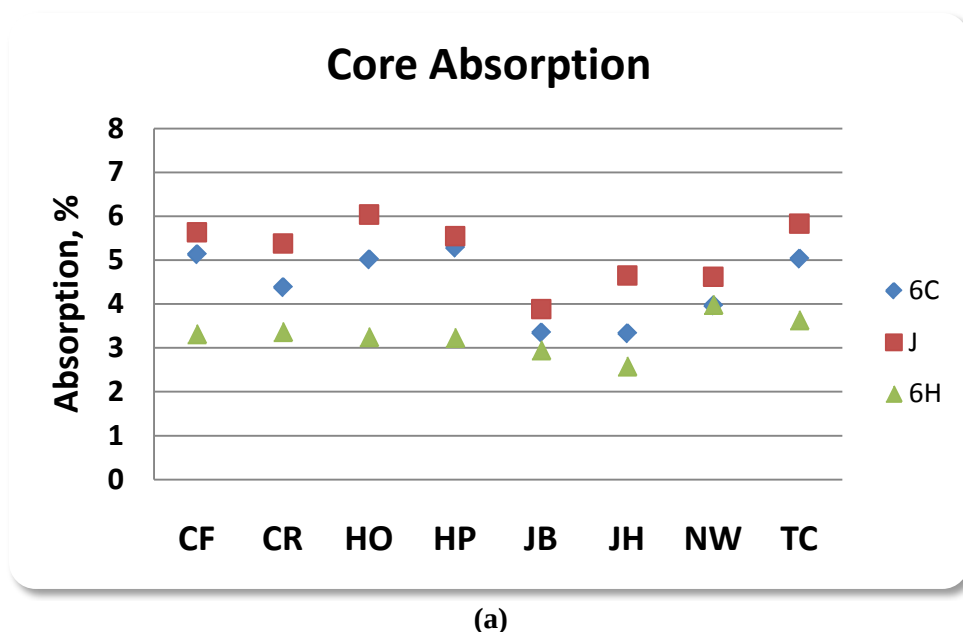


FIGURE 1 Density test results according to a) nuclear, b) SSD, and c) vacuum sealing methods.

Absorption, permeability, and infiltration results are given in Figure 2. Absorption computations yielded values of approximately 3 percent for most specimens at the 6H distance, but higher values were obtained at the J and 6C distances. The JB method was most successful at limiting absorption at the joint, while the HO method was least successful.

Field permeability and infiltration results indicated a more varied performance among the various joint construction methods than most other parameters. The JB, JH, and NW methods were the best performers, creating joints with levels of permeability and infiltration that were fairly similar to that away from the joint. Larger deviations were present for the CF, CR, HO, and HP methods.



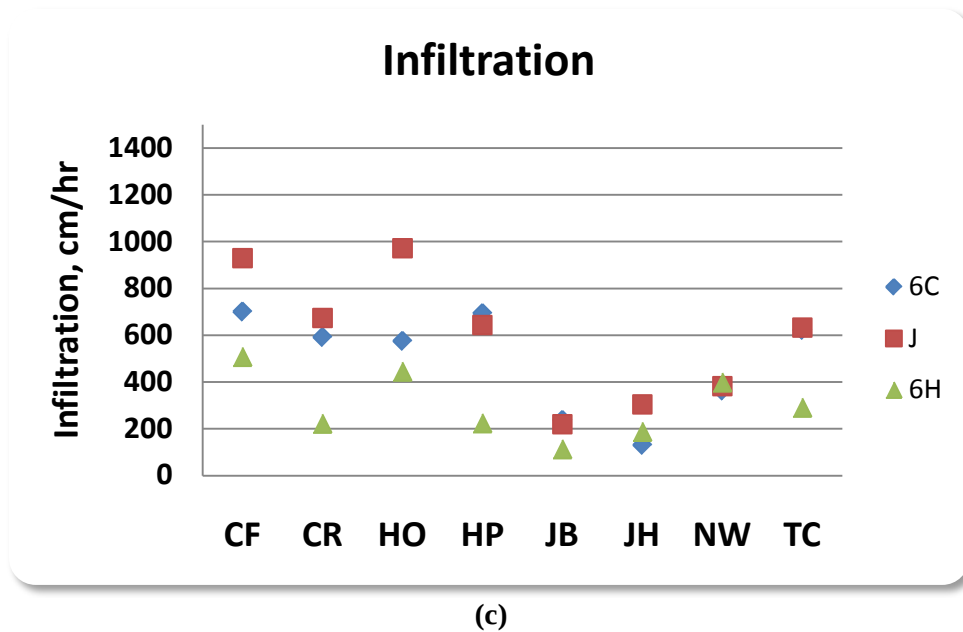
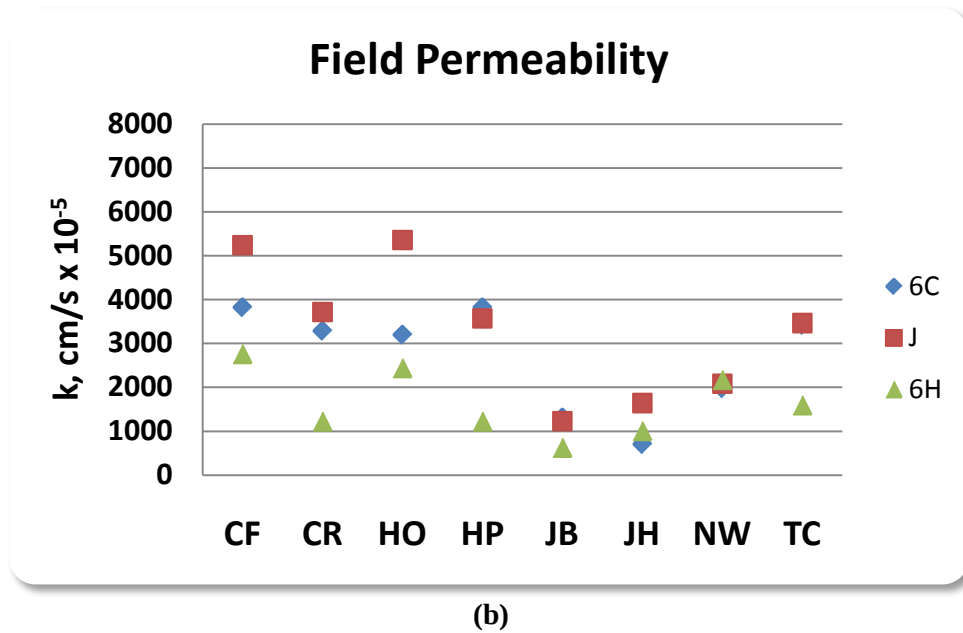


FIGURE 2 Test results for a) absorption, b) permeability, and c) infiltration.

Statistically, the test results were analyzed using analysis of variance (ANOVA) and means tests to determine which test methods were most able to discern significant differences between the various joint construction techniques, as well as differences in properties at the various distances from the joints, while also accounting for differences inherent among the two projects. In selecting a tool for QC/QA purposes, it is important that the test method chosen is capable of detecting differences in properties when differences truly exist. Thus the methods detecting the greatest number of significant differences would

be most advantageous in QC/QA efforts. A summary of p-value results from the ANOVA is shown in Table 2. A p-value of less than α indicates significance. In all cases, α was taken to be 0.05.

TABLE 2 Summary of ANOVA for Effects of Construction Technique and Distance from Joint

	<i>p-values describing the significance of factors for each test parameter</i>					
	Nuclear Density	Density by T166	Density by T331	Absorption	Permeability	Infiltration
Method	<0.0001	.0049	0.0009	0.0001	<0.0001	<0.0001
Distance	<0.0001	<.0001	<0.0001	<0.0001	<0.0001	<0.0001
Method*Dist	0.5698	0.6180	0.6396	0.3300	0.0338	0.0288

In every case, the method used to construct the joint was found to significantly affect the test results. Also, distance from the joint significantly affected all responses. This means that all test methods were able to discriminate between various levels of each response, and that all methods have merit and warrant further investigation as a QC/QA tool for longitudinal joint quality. For permeability and infiltration, the interaction of method and distance was significant. This interaction showed that for these two responses, method and distance were interrelated. Specifically, the JB and JH methods produced low permeability values at and away from the joint, while the other methods indicated high permeability and infiltration at the joint, but lower values away from the joint.

The next step was to evaluate which of the methods and distances displayed statistical significance. Using a means test, methods and distances were analyzed. Results are displayed in Table 3, indicating the mean and rank for each. Brackets are used to group methods having a lack of statistically significant differences (i.e., similarities) between those methods. In some cases, similarities were the result of mean values that were very close in magnitude. In other cases, the spread of the data (i.e., variation of the parameter) was large enough to mask potential differences. In general, the nuclear density, permeability, and infiltration tests showed the least overlap in groupings, and were most able to differentiate between varying levels of quality. With the exception of the T331 density measure, the JB, JH, and NW methods were consistently ranked as superior performers. None of the rolling patterns showed exemplary performance. Therefore, additional measures may be necessary during construction to create high quality joints.

The CF method, intended to seal the joint, did not perform as well as expected. It was reasonable that density results did not improve over traditional methods, but it was anticipated that permeability would; however, this was not the case. Upon further investigation, it was surmised that the product may have reduced permeability in the finite area of application, but did not positively affect the surrounding material. Since the field permeability test involves a six-inch diameter test area and not just the joint face, the CF method was unable to demonstrate a decrease in permeability for the entire joint area.

Regarding proximity to the joint, the rankings followed the expected trend with the mat having the best performance (i.e., highest densities and lowest absorption, permeability and infiltration). The joint cores had the weakest performance (i.e., lowest densities and highest absorption, permeability and infiltration). As expected, cores cut from the hot side of the joint were generally better performers than those cut from the cold side. For all response parameters except nuclear density, statistically significant differences were noted for all distances, meaning that proximity to the joint was clearly differentiated. For nuclear density, the 6H and 12C samples were similar, as were the 6C and J samples. Because a significant change in quality existed at distances of just 6 inches from the joint, areas of poor density or permeability may not be detected if a test is performed near the joint rather than on the joint. For this reasons, joint quality testing should be performed directly on the joint.

TABLE 3 Summary of Construction Method and Distance Rankings by Response Parameter

Nuclear Density (%)	T166 Density (%)	T331 Density (%)	Absorption (%)	Permeability (cm/s x 10⁻⁵)	Infiltration (cm/hr)
JH 91.0	JH 90.5	JH 88.2	JB 2.72	JB 815	JB 147
NW 90.8	JB 90.0	NW 86.7	JH 2.84	JH 880	JH 166
JB 90.2	NW 89.8	HO 86.1	NW 3.60	NW 1774	NW 326
CR 89.9	HO 89.7	TC 85.9	CR 3.77	TC 2192	TC 401
HP 89.8	CR 89.6	CR 85.5	CF 3.78	CR 2232	CR 409
TC 89.8	TC 89.4	CF 85.3	HO 3.84	HP 2502	HP 453
HO 89.5	HP 89.2	HP 85.1	TC 3.93	CF 3074	CF 557
CF 88.4	CF 88.9	JB 82.9	HP 4.23	HO 3257	HO 591
M 92.4	M 92.6	M 89.7	M 1.36	M 748	M 143
12H 91.2	6H 90.1	6H 86.4	6H 3.29	6H 1630	6H 299
6H 90.1	6C 88.3	6C 84.0	6C 4.44	6C 2696	6C 490
12C 89.6	J 87.6	J 82.7	J 5.27	J 3288	J 595
6C 88.2					
J 88.1					

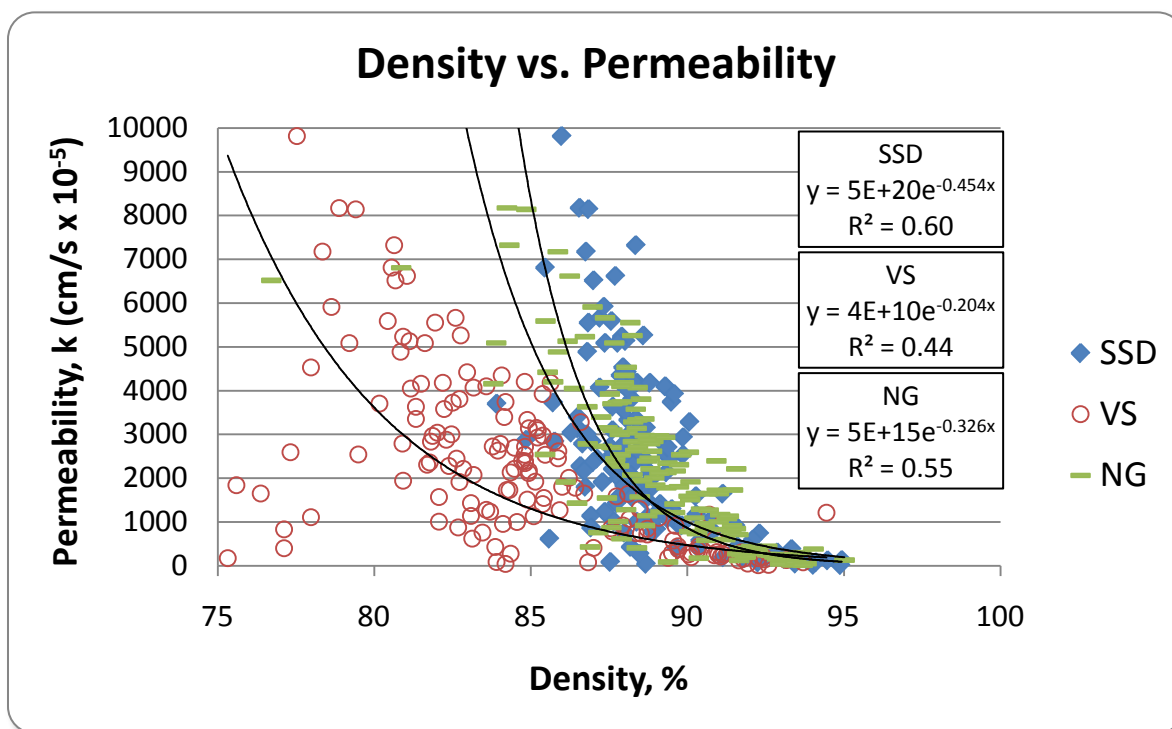
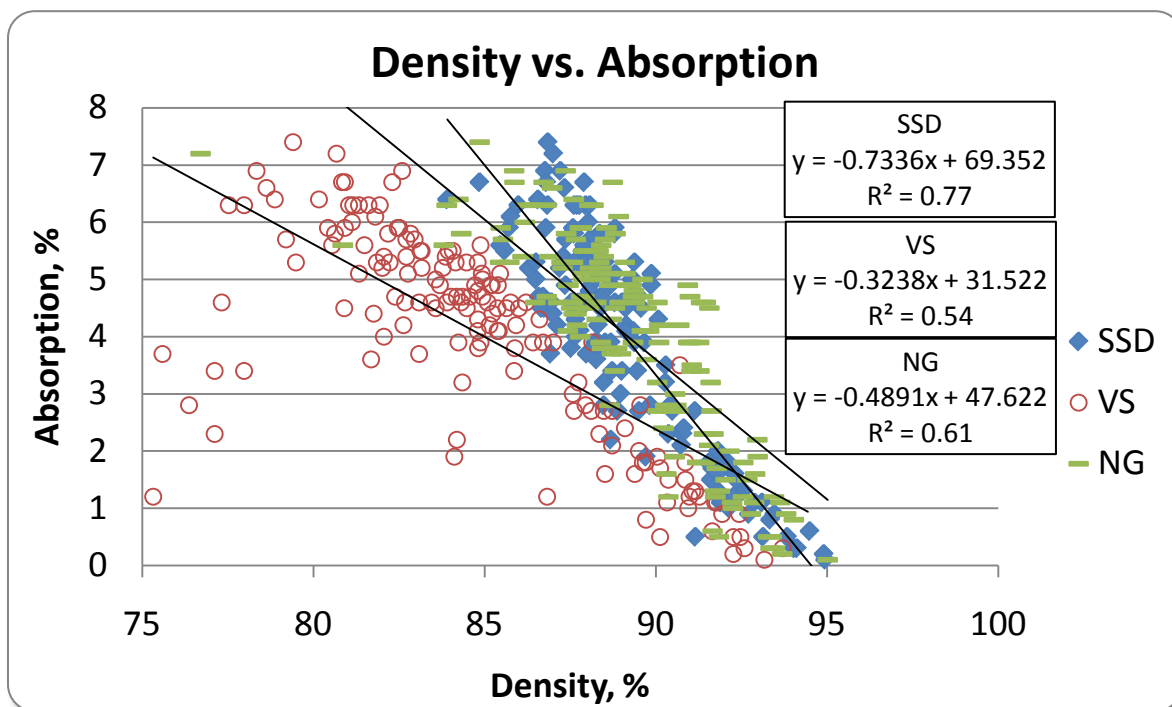
CF=joint adhesive, JB=joint stabilizer, JH=joint heater, NW=notched wedge, TC=tack coat, CR=cold roll, HO=hot overlap, HP=hot pinch

Relationships of Methods

When considering the various methods that can be used to measure the quality of longitudinal joints, each has advantages and disadvantages. The nuclear density method is capable of generating a large number of density measurements in a short time frame and in a non-destructive manner, but the accuracy of the readings is dependent upon the quality of the correction factor. In most cases, the correction factor is determined by a comparison with core density values measured by the T166 method, which carries its own difficulties in accurately measuring specimens with higher void contents. The vacuum sealing method may be able to more accurately detect the lower density values, but is less precise than the SSD method.

As previously stated, density is the most prominent measure of in-place HMA pavement quality, although a measure that describes the ability of water and air to enter the pavement structure provides a more fundamental indication of the potential for typical joint distresses. The data presented in this study suggest that the permeability and infiltration tests do, in fact, provide adequate discrimination for levels of varying quality. The primary disadvantage of these measures are that the test methods are somewhat labor intensive, and are not currently included in most QC/QA programs. Thus, it would be advantageous

to determine what commonalities exist between parameters, and whether density could be used to adequately describe absorption, permeability or infiltration. These relationships are presented in Figure 3.



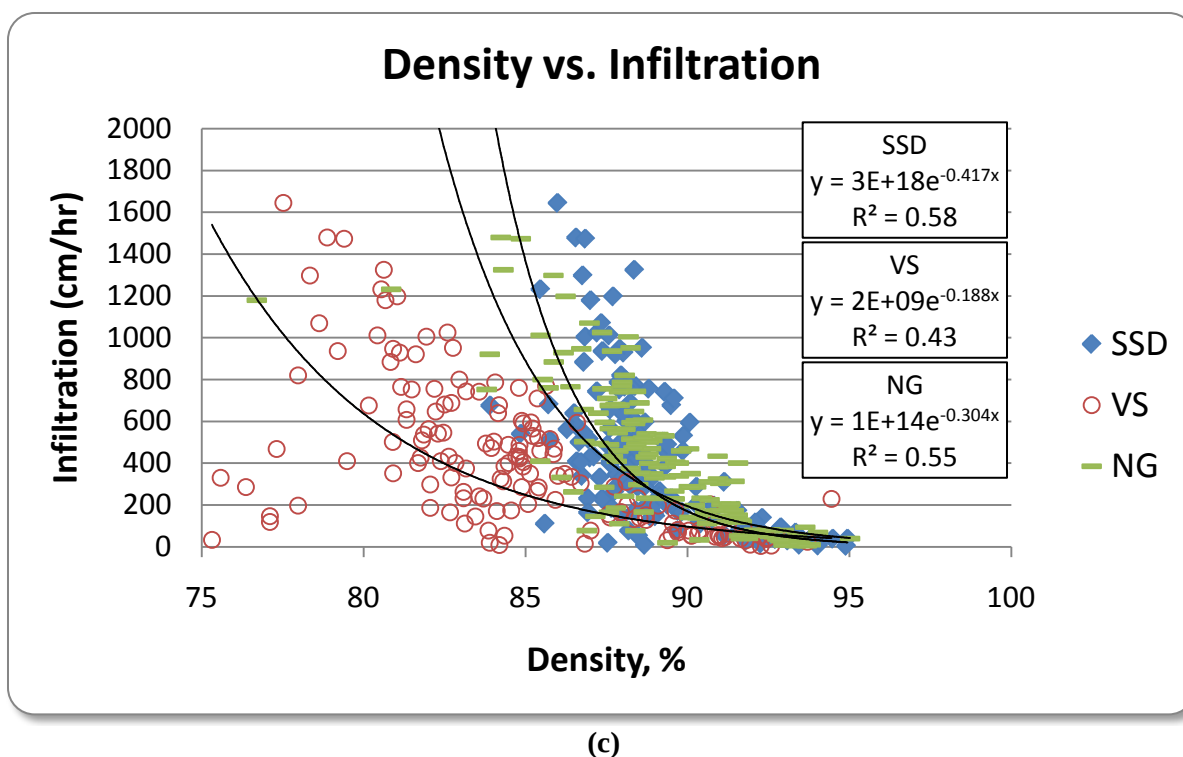


FIGURE 3 Relationships of density and absorption, permeability, and infiltration.

In general, absorption decreased with increasing density, and the relationship was most nearly linear. The relationship of absorption to density by the SSD method provided the strongest relationship ($R^2 = 0.77$), which is reasonable since absorption values are calculated based on measurements recorded during the SSD test procedure. According to AASHTO T166, the paraffin coating method should be used to more accurately determine density when the absorption values exceed 2 percent. Absorption values of 2 percent related to approximately 91 percent density, and at low absorption levels, there was fair agreement among the various measures of density. As density decreased, the values began to deviate, with a considerable amount of scatter for the vacuum sealing method. Although the relationship between absorption and density by the nuclear gauge was relatively weak ($R^2 = 0.61$), the practical advantages of this method may outweigh its lack of precision.

The exponential relationships of density and permeability were fairly weak; however, a definite trend of increasing permeability with decreasing density was evident. Additionally, as permeability increased, the data exhibited increased scatter, suggesting that it is more difficult to achieve repeatable results for highly permeable pavements. It was also noted that the lowest values of permeability occurred most consistently at density levels of 92 percent or greater. Similar trends were evident for the relationship of density and infiltration.

Upon further inspection of the density and permeability / infiltration relationships, natural groupings of data appeared to separate the data into three levels of quality. Specifically, the relationship of nuclear density and infiltration is highlighted in Figure 4. Most highway QC/QA specifications, including Arkansas, require a minimum in-place mat density of 92 percent. For density values greater than 92 percent, the infiltration values are limited to approximately 100 cm/hr. This indicates that good mat quality could be described by the corresponding limits of 92 percent minimum density and 100 cm/hr maximum infiltration. Another natural break in the data occurred at approximately 89 percent density. Coincidentally, for states that currently have a joint density requirement, this value is typically 2 to 3 percent less than that required for the mat (i.e., 89 to 90 percent). Thus, acceptable joint quality could be

described as a minimum of 89 percent density and a maximum of 500 cm/hr infiltration. Densities below 89 percent and infiltration values greater than 500 cm/hr would indicate poor quality.

Absorption could also be used as a QC/QA tool, especially in cases where T166 is already routinely used. A density of 92 percent and an infiltration rate of 100 cm/hr corresponded with approximately 2 percent absorption, whereas a density of 89 percent and infiltration rate of 500 cm/hr corresponded with approximately 4 percent absorption when density was measured by the SSD or NG methods. Although higher joint densities would likely produce significant improvement in joint density and it may be desirable in concept to require that joints meet the same requirements as the mat, it is generally accepted that joint quality may be slightly less than that of the mat. Therefore, the limits expressed herein are believed to be reasonable.

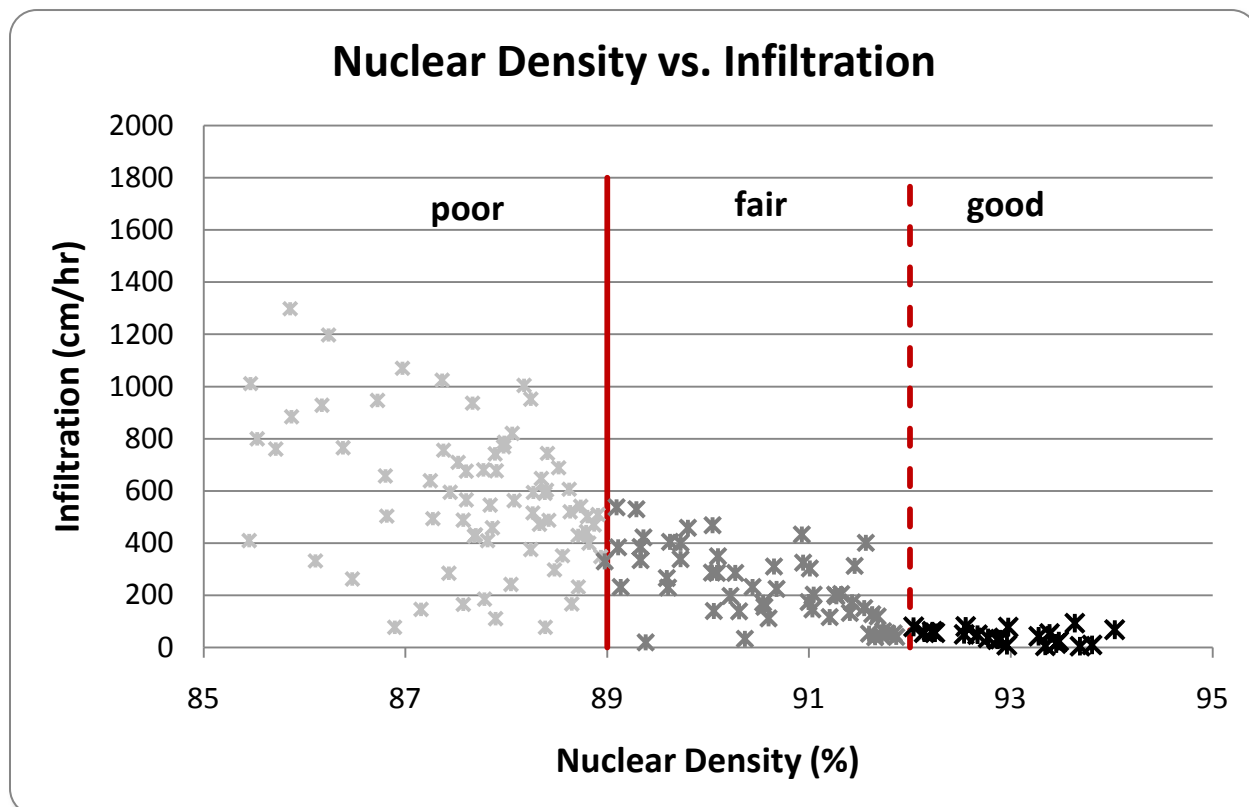


FIGURE 4 Ranges of quality based on nuclear density and infiltration.

CONCLUSIONS AND RECOMMENDATIONS

When implementing an appropriate method for measuring longitudinal joint quality in HMA pavements, the method must be able to distinguish between varying levels of quality, must be related to the potential for applicable pavement distresses, and must be feasible for incorporation into the existing quality system. The data collected in this study was intended to provide a basis for decisions relative to the implementation of a longitudinal joint quality specification.

In this study, 8 longitudinal joint construction techniques were assessed for two construction projects using performance parameters relating to density and permeability. Testing was performed at the longitudinal joint, on the hot and cold sides of the joint, and in the central portion of the compacted mat. General conclusions include:

- In general, the joint heater (JH), joint stabilizer (JB), and notched wedge (NW) methods consistently demonstrated superior performance as measured by density, absorption,

permeability, and infiltration. Traditional rolling techniques and joint adhesives were not as successful in producing similar quality at and away from the joint.

- In terms of distinguishing between varying levels of quality produced by the various joint construction techniques, the nuclear density gauge, permeability, and infiltration parameters (tested in the field) were better able to discriminate than absorption or core density by the SSD and vacuum sealing methods (tested in the laboratory).
- All testing methods were capable of discerning significant differences in quality relating to proximity to the joint. Significant differences in quality were consistently identified at a distance of only 6 inches from the joint.
- Fairly strong relationships were developed between the various quality measures. Of the three density measures, the SSD method consistently provided the strongest relationship to absorption, permeability, and infiltration.
- For the relationship of density and permeability / infiltration, natural groupings of infiltration data were segmented at 92 and 89 percent density, suggesting that these minimum density values are appropriate specification limits. These values also correlate with 2 percent and 4 percent absorption, respectively.

Although permeability and infiltration provide a more fundamental description of the potential for the distresses typical of a longitudinal joint, density measurements are already commonly used for QC/QA purposes. Because the relationships of density, absorption, permeability, and infiltration are consistently and adequately defined, it is recommended that longitudinal joints possess a minimum of 89 percent density measured by the nuclear gauge or AASHTO T166, and no more than 4 percent absorption as measured by T166. If T331 is used, provisions must be made to account for the differences in measured density. These values correspond with permeability and infiltration values that are consistent and appropriate for producing quality longitudinal joints.

No specific recommendation is made regarding a mechanism for specifying the particular construction technique that should be used to form longitudinal joints. In many cases, good construction practices may be sufficient to produce quality joints. However, if additional steps are desired to improve quality, the methods that provided the greatest benefit in this study were the joint heater, the joint stabilizer, and the notched wedge.

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