Development and Evaluation of Longitudinal Joint Sealant in Illinois

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The Illinois Department of Transportation (IDOT) is continually looking for ways to improve long-term performance of pavements. One particular area of concern is the rapid deterioration of longitudinal joints in hot-mix asphalt (HMA) pavements. In 2001, IDOT performed several field trials on construction projects that were already underway. These trials included installing two different longitudinal joint sealant products for short segments to determine the constructability of the treatment. This report was published as an internal department report to capture the information for monitoring purposes.

Additional projects were constructed using the materials from this report to evaluate them over longer test sections. A report on those additional projects was prepared and published separately, also as an internal department report.

This treatment has seen exceptional performance in Illinois and a third report will be developed to document the long-term performance of these materials. This report is now being released externally to share the information from the early projects with other states. No revisions have been made to the content of the original report during this release.

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16. Abstract

Longitudinal joint deterioration of hot mix asphalt pavement is often caused by low joint density that allows the infiltration of water and air into the pavement. The problem is not confined to the joint interface. Low density is typically found several inches from the joint on both the unconfined and confined edges. Previous joint seals have been applied to the joint interface but this does not address the low density of the joint area.

This report summarizes five field trials of two products, the Emulsicoat Jband and the Quik Pave Products QuikSeam. Both products extended between 6 to 9 inches on both sides of the joint in order to address the entire low density area. Both products are a solid prior to covering with the Hot Mix Asphalt (HMA) surface course. The heat of the HMA surface course softens the joint sealant. The pressure from compacting with a vibratory roller causes the joint sealant to migrate upward into the surface course air voids. The result is a joint area that prevents water and air infiltration into the lower pavement lifts and that significantly decreases infiltration within the HMA surface course. Effectiveness of the products was determined by using a field permeameter and visually monitoring joint sealant migration in cores. Results of these tests are included with the report.

The results of the field trials show that both products significantly decreased joint permeability. Different trials were used to evaluate formulation changes to increase migration levels. The Jband and QuikSeam formulations evaluated in the fifth trial migrated respectively to within 0.5 and 0.625 inch of the top of the HMA surface course. Results and observations from the five field trials are included in this report. The report also includes a detail of the lab procedure that was used to minimize the number of field trials.

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Final Report

Evaluation of Longitudinal Joint Sealant in Illinois

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ABSTRACT

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TABLE OF CONTENTS

CONTENTS PAGE

DISCLAIMER

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LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Longitudinal joint deterioration of Hot Mix Asphalt (HMA) pavement has been observed as a problem throughout Illinois. The problem at the longitudinal joint is the low density that allows the infiltration of water and air into the pavement. The infiltration of water may affect the durability of the pavement by causing stripping which can lead to cracking and raveling. Infiltration of air can produce a higher rate of oxidation that causes the asphalt binder to become brittle and increases the potential for cracking. The infiltration of water and air can shorten the life-span of the pavement.

The problem of longitudinal joint deterioration is not confined to the joint interface. Low density is typically found several inches from the joint on both the unconfined and confined edges. Previous joint seals have been applied to the joint interface but this does not address the low density of the surrounding joint area.

Two products, the Emulsicoat Jband and the Quik Pave Products QuikSeam, were evaluated to determine the potential in minimizing joint deterioration. Both products extended between 6 to 9 inches on both sides of the joint in order to address the entire low density area. Both products are a solid prior to covering with the HMA surface. The heat of the HMA surface softens the joint sealant. The pressure from compacting with a vibratory roller causes the joint sealant to migrate upward into the surface voids. The result is a joint area that prevents water and air infiltration into the lower pavement lifts and that significantly decreases infiltration within the HMA surface course.

Five field trials were used to evaluate various formulations of the two products. The formulation was changed after each trial to improve migration height into the HMA surface course. Changes made to the joint sealant formulations were the sole responsibility of the Supplier. The Illinois Department of Transportation (IDOT) specified the desired result of the product but was not involved in determining what changes to make to the formulations. The goal was to create a product that would soften and melt upwards into the HMA surface course, but would remain stiff enough to

allow traffic to pass over the material without tracking prior to HMA surface course placement. It is that desired balance that makes determining the ideal formulation difficult.

Various methods were used to determine the effectiveness of the joint sealants. The lab permeameter, which measures the vertical flow of water, confirmed that the joint sealant did prevent water from migrating into the pavement below the HMA surface course. Field permeability testing was used to determine the amount of water flow in the HMA surface course. Field permeability results on control sections were much greater than the $100x10^{-5}$ cm/sec desired values. The joint sealant significantly decreased the field permeability. Typically results were at least half the permeability of the control sections. Although the permeability was significantly decreased, it was still above the $100x10^{-5}$ cm/sec desired value. Nuclear density readings were also taken at and around the joint. Since the presence of joint sealant would affect the maximum specific gravity of the HMA surface course, the density could only be used to look at potential differences between sites at best. Thus, field permeability tests were more representative of changes resulting from the joint sealant than density tests. The best test for the migration level of the joint sealant was to break open cores and visually determine how much migration had occurred. The ability to determine migration visually was validated by infra-red (IR) scans.

QuikSeam

Quik Pave Product's QuikSeam joint sealant was used on three trials. On IL 10/121 it was determined that the use of joint sealant was promising but the migration was not as much as desired. The backing on the joint sealant, used for packaging, was initially left in place because it was suppose to melt with the joint sealant. However, it was later determined that the backing did not melt and would need to be removed prior to placing the HMA surface course. The project on IL 40 was used to evaluate changes that had been made to the original formulation to increase migration levels. The three new formulations did not migrate as much as that on IL 10/121 and further formulation changes were needed. Both the IL 10/121 and IL 40 consisted of small joint sealant samples less than 3 feet in length. The third trial on US 51 consisted of 100-foot test sections and two different formulations were evaluated. The material on the US 51 project was applied in two 9-inch wide applications. The first application consisted of placing a 9-inch strip so that approximately 2 inches of joint sealant would remain exposed after the first lane was paved. The second application was placed adjacent to the first application and lapped up onto the edge of the first lane paved to allow for more joint sealant at the joint interface. The downside of two applications was the additional labor. The upside of two applications was the additional material at the joint. The best migration of the QuikSeam occurred on US 51 with one of the formulations migrating to within 5/8 inch of the top of the HMA surface. The surface was 1 ½ inches thick so the original 3/16 inch of material migrated to a height of approximately 7/8 inch.

Jband

Emulsicoat's Jband product was used on three trials. The initial trial was placed under the flooring surface course of a retention pond in Indiana. The Jband material did migrate high enough in some areas to cause flushing. Since the HMA surface course material used for the retention pond had lower voids and higher asphalt content than typical IDOT HMA surface course mixtures, the results of the Jband on this project were inconclusive. The project at the Lakes at Riverbend subdivision in Mahomet, Illinois was used to evaluate Jband when using a conventional IDOT HMA surface course. Approximately 525 feet of Jband was applied at the centerline joint. While the Jband did decrease permeability, the migration height into the surface was not as high as desired. The Jband did not appear to have tracking problems but the project was also done in the cool weather of November which may have been a factor. The third project on US 51 consisted of two 100-foot test sections. One test section consisted of placing Jband 12 inches wide while the other section consisted of placing Jband 18 inches wide. The best migration of the Jband was observed on the US 51 project as the Jband migrated to within ½ inch of the top of the HMA surface. The surface was 1 ½ inches thick so the original 3/16 inch of material migrated to a height of approximately 1 inch.

Lab Procedure

Field trials were very time and labor intensive. A lab procedure was developed based on the material and migration levels of the Jband at the Lakes at Riverbend subdivision. The lab procedure was a good tool to determine if formulation changes were worth taking to the field. Several joint sealant formulations were never tested in the field because the lab procedure indicated there would be little, if any, additional migration from previous formulations. Since the joint sealant migration is sensitive to construction practices, the lab procedure is only a relative measurement of change and not directly related to field migration. The lab procedure helped to determine the formulations that were used on US 51. The migrations of both the QuikSeam and the Jband were better than experienced on previous trials. Further verification of the lab procedure to better predict other potential formulations and products is recommended.

Conclusion

Overall, it was determined that the joint sealant was more effective in decreasing permeability than applying an extra bituminous prime coat or applying nothing at all. Construction practices may affect migration. The amount of heat transferred from the overlying HMA surface course and the pressure applied by the rollers have a large affect on the amount of joint sealant migration that occurs. The heat provides the ability for the joint sealant to melt and the pressure provides the necessary force to promote migration. However, the ability of the various joint sealants to withstand traffic without tracking still remains a concern. An evaluation of tracking would be more effective with larger test sections. Thus a demonstration project utilizing a longer test section to fully evaluate constructability issues is recommended. Additional formulation adjustment to maximize migration while minimizing tracking is also recommended. Based on the previous trials, a larger scale test section would help to better evaluate placement and construction issues. It is not recommended to implement the use of joint sealant until constructability issues and cost effectiveness are evaluated. Finally, performing yearly visits to the various field trials to monitor and document performance is also recommended.

INTRODUCTION

Longitudinal joint deterioration of Hot Mix Asphalt (HMA) pavement has been observed as a problem throughout Illinois. The problem at the longitudinal joint is the low density that allows the infiltration of water and air into the pavement. The infiltration of water may affect the durability of the pavement by causing stripping, which can lead to cracking and raveling. Infiltration of air can produce a higher rate of oxidation that causes the asphalt binder to become brittle and increases the potential for cracking. The infiltration of water and air can shorten the life-span of the pavement. Joints are especially susceptible to low density for several reasons: 1) The first lane placed has an unconfined edge that can push outwards when rolling, as shown if Figure 1. Pushing out produces a thinner mat in the joint area and the lack of confinement makes achieving density difficult. 2) When a lane is placed against a previously placed lane that has been allowed to cool, a cold joint with poor adhesion is formed. Cold joints often result in a natural cracking location (Figure 2), since the material does not meld together. 3) Bridging may occur at the joint if the two matching lanes are uneven. If the joint is uneven or if the roller goes too far over onto the previously placed mat, the roller may lose contact with the material at the joint so compaction cannot occur. Figure 3 exaggerates the bridging effect.

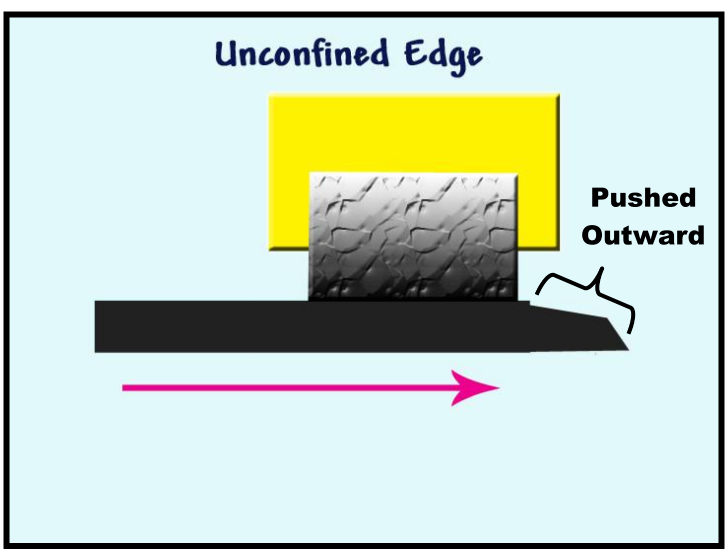


Figure 1: Unconfined Edge

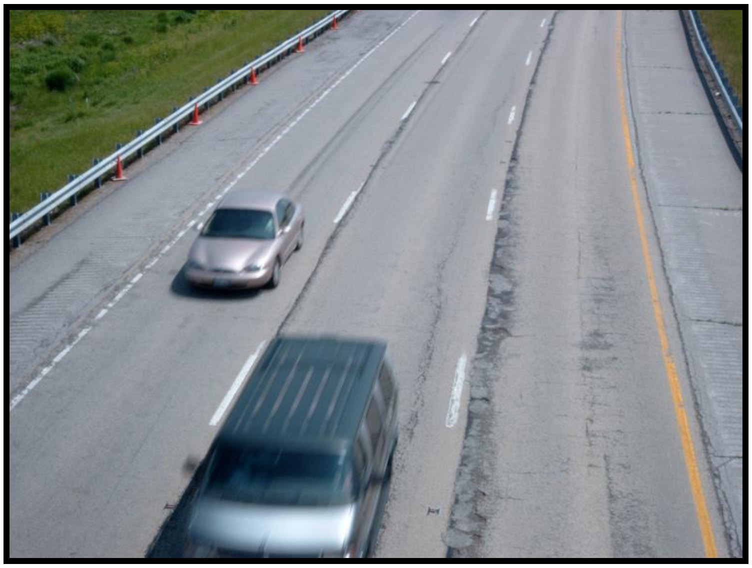


Figure 2: Cold Joint

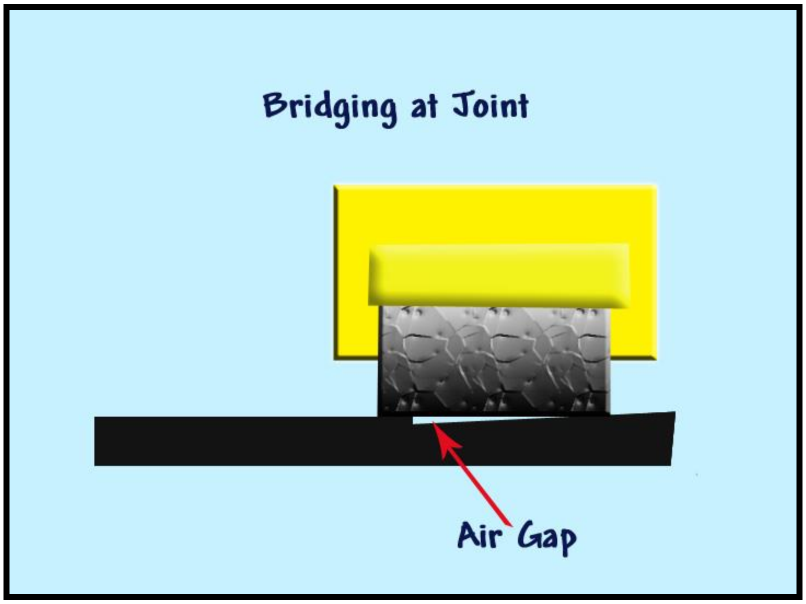


Figure 3: Roller Bridging at Joint

The Illinois Department of Transportation (IDOT) has investigated the potential of using a joint sealant to decrease the permeability of HMA joints. Previously, IDOT looked at a joint tape that was placed at the cold joint interface. The problem was that the low density of the joint is not only concentrated at the joint but also propagates several inches on either side of the joint, as shown in Figures 4 and 5.

Figure 4: Joint Distress with Sealed Joint

Figure 5: Low Joint Density Area

IDOT worked with two suppliers, Quik Pave Products Inc. and Emulsicoat Inc., to produce a joint sealant that extends 6-9 inches on both sides of the joint. The joint sealant is placed over the longitudinal joint prior to paving. The formulations have been designed for their ability to migrate upwards to fill the voids in the HMA while maintaining the ability to allow traffic to drive over the material during construction without excessive tracking. In addition, the joint sealant was that the joint sealant appeared to prevent the unconfined edge from pushing outward as much as it did in the areas without joint sealant. This may also aid in better joint density.

This report documents the various field trials, test procedures, and lab simulations that where used to define and establish acceptable joint sealant formulations.

TESTING

LAB PERMEAMETER

The lab permeameter is a falling head device that measures the drop in water level with time using Equation 1 to determine the pavement permeability. An apparatus designed from the Florida prototype was purchased by IDOT to investigate permeability in Illinois, as shown in Figures 6 – 7. A 6-inch diameter specimen is placed in the device. A rubber membrane between the specimen and cylinder wall is inflated to prevent water from flowing out of the sides of the specimen. The lab permeameter measures vertical flow through a specimen. The lab permeameter was used in earlier trials of joint sealant to demonstrate that the joint sealant would prevent water infiltration of the base material.

$$k = \frac{aL}{At}\ln\left(\frac{h_1}{h_2}\right) \qquad \text{[Equation 1]}$$

where:

- k = coefficient of permeability, cm/sec ($x10^{-5}$)
- a = inside cross section of standpipe, cm^2
- L = lift thickness, cm
- A = cross section of contact area that water can flow into the pavement, cm^2
- t = elapsed time between h_1 and h_2
- h_1 = initial head, cm
- h_2 = final head, cm

Figure 6: Preparing Lab Permeameter for Testing

Figure 7: Timing Drop in Water Height of Lab Permeameter

FIELD PERMEAMETER

The field permeameter is a falling head device that measures the drop in water level with time using equation 1, just like the lab permeameter. A large difference between the field permeameter and the lab permeameter is that the lab permeameter only measures vertical flow through a specimen while the field permeameter allows both vertical and horizontal flow. The Illinois field permeameter was developed using three different diameter standpipes, as per an early National Center for Asphalt Technology (NCAT) prototype. The Illinois permeameter is shown in Figure 8. Silicone is used to seal a neoprene gasket to the pavement as shown in Figure 9. Two 10-pound weights are placed over the base to ensure that no water is able to escape under the apparatus or between the pavement and the neoprene gasket. The three different sized standpipes allow the device to measure low, medium, and high permeability levels. Each standpipe is marked for specific height changes.

Figure 10 illustrates the top standpipe being used to determine permeability of a low permeability pavement. When the drop in height is too quick to measure in the top standpipe, the middle or bottom standpipe is used depending on the level of permeability. It is possible to use a larger standpipe than necessary, but it increases the time to run a test.

Figure 8: Illinois Field Permeameter

Figure 9: Applying Silicone

Figure 10: Measuring Water Fall in Standpipe

DENSITY TESTING

Density testing of the longitudinal joints on the demonstration projects described herein was typically conducted using correlated gauges and cores. The problem with density testing on the areas where the joint sealant was used was that the maximum specific gravity, G_{mm}, to be used was often in question since the G_{mm} was determined based on the material without the joint sealant. The potential of theoretically adjusting the G_{mm} was briefly considered. The problem was that it was impossible to determine how much of the sealant went upwards into the surface and how much went downwards or did not migrate at all. As a result, density testing was used only as a relative comparison between locations. Also, due to the G_{mm} issue, cores from the joint sealant areas were used for visual inspection of migration and not for density.

MIGRATION MEASUREMENT

Migration was measured visually on cores that had been split open using the tensile strength tester, as shown in Figure 11. Immediately after breaking the cores, a distinct line of the joint sealant can be determined, as shown in Figure 12. After a broken core sits for a few hours, the line becomes less and less visually distinct until the joint sealant can no longer be differentiated on the core. In order to distinguish for future reference, the line was marked accordingly as soon as the cores were broken, as shown in Figure 13.

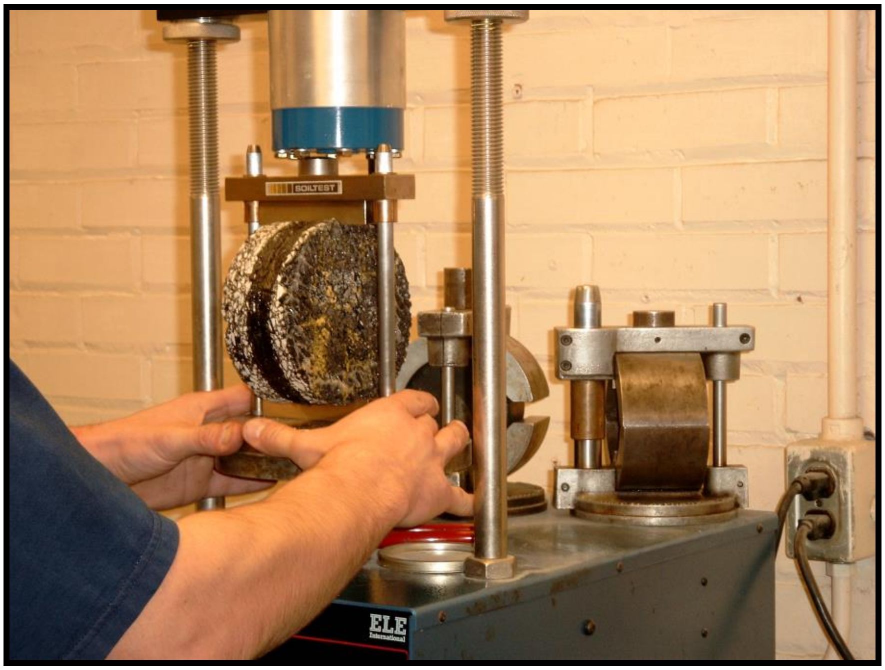


Figure 11: Breaking Cores

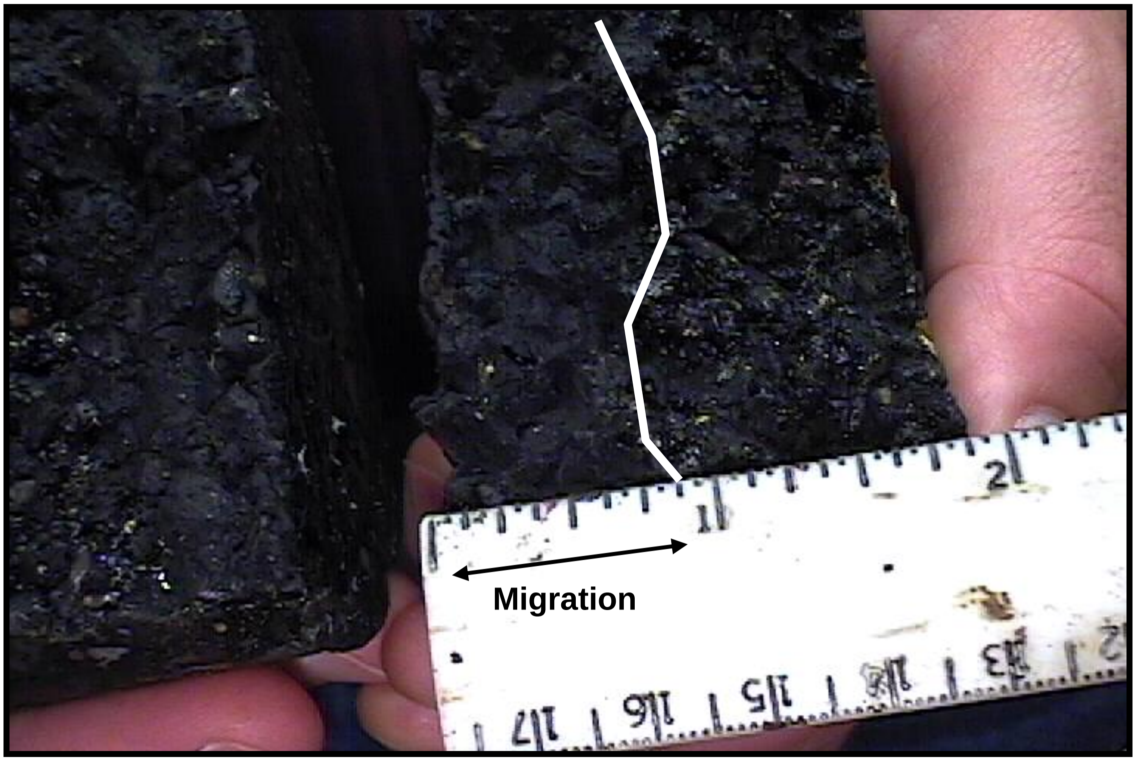


Figure 12: Joint Sealant Migration

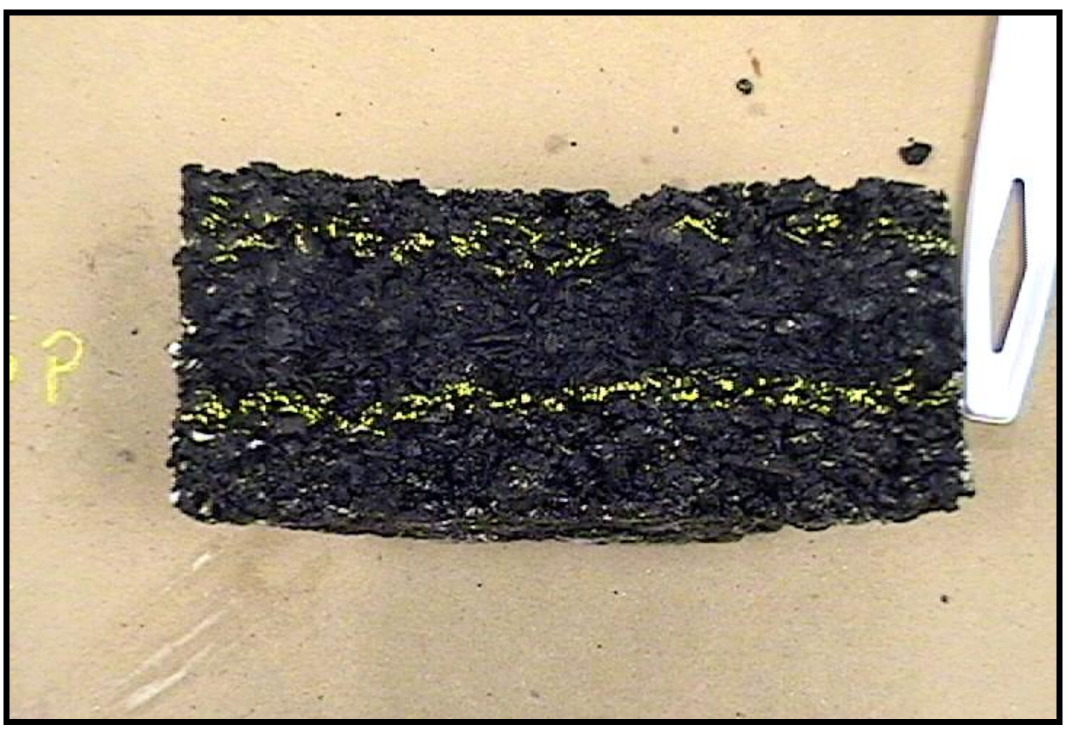


Figure 13: Migration is Marked

It was a concern that the actual migration may be greater than what the visual appearance indicated. Infra-red (IR) spectra scans were used to verify that the actual migration could be determined visually. The resultant spectra, or graphical representation, is unique for each substance and is based on specific functional groups in its molecular structure. It is considered as the substance's fingerprint.

Three cores containing different joint sealant formulations and a control core sample without joint sealer were used for the IR scan. Core samples that contain joint sealer were broken open and marked at the level of visual migration. For each core, a six-gram sample was taken from the top section, middle section, and between the visual lines of migration, as shown in Figure 14. Each sample was dissolved in 10 ml of TCE (trichloroethylene). The solution was mixed and centrifuged at high speed for 10 minutes to completely separate out the aggregates and other fines. Two to three drops of clear supernatant liquid were placed on a KBr plate, dried in the oven at 75°C for 10 minutes, and then analyzed using a Fourier Transform Infra-Red (FTIR) spectrometer. Neat samples of the joint sealant were also analyzed in the same manner.

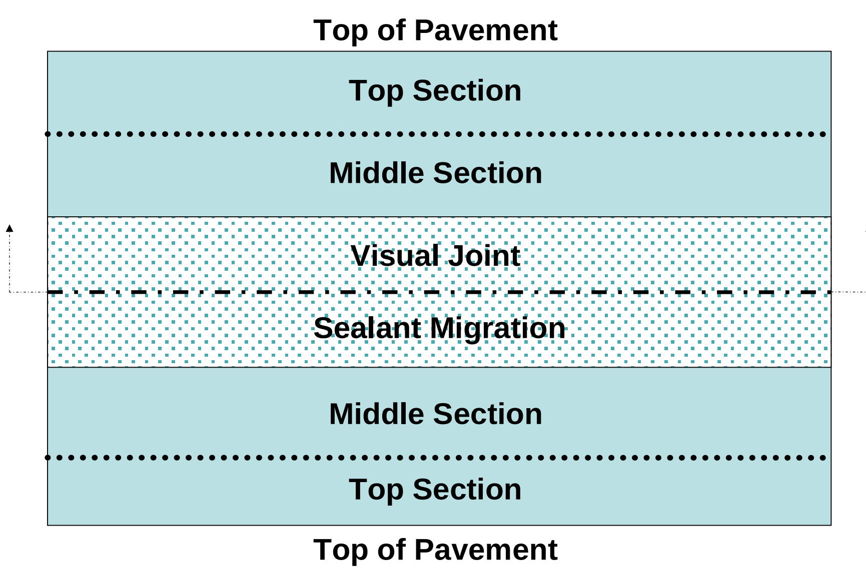


Figure 14: Core Sectioning (Core Folded in Half)

IR scans of the neat joint sealant were compared with those of the core samples. Figure 15 is an output from the analysis. For this formulation, the unique identifying peak is at wave number 966. This identifying mark can be seen in the joint sealant control test and the area between the visual lines. However, it is not present in the two areas above the visual lines or in the control core that did not contain joint sealant.

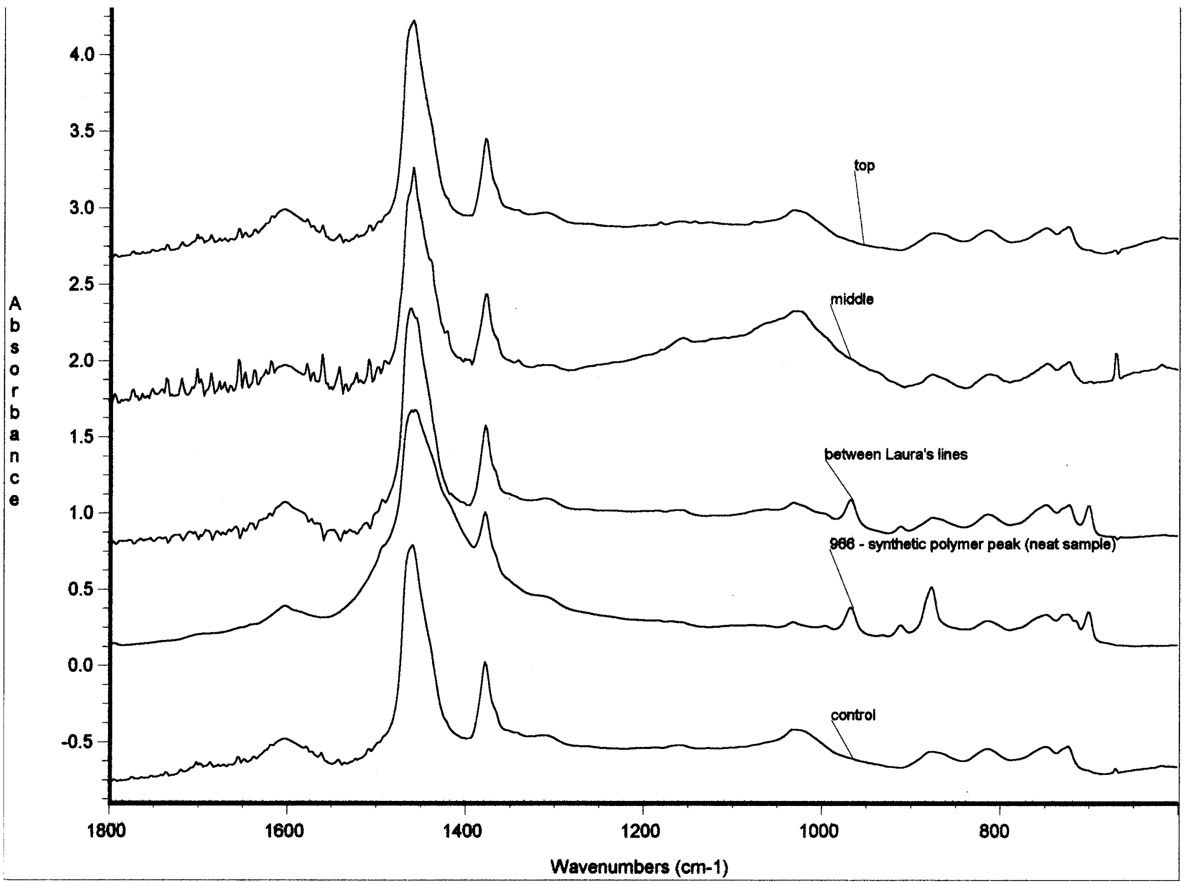


Figure 15: IR Analysis

The results of the IR scan confirmed that a visual evaluation can be used to determine the height of migration.

FIELD TRIALS

ILLINOIS STATE ROUTE 10/121 LINCOLN, ILLINOIS

The first field trial occurred on June 21, 2001 on Route 10/121 in Lincoln, Illinois. The joint sealant used was supplied by Quik Pave Products Inc. The trial consisted of looking at three joint sealant strips that measured 12 inches wide, 24 inches long, and 3/16 inch thick. The purpose of the trial was to determine if the material would melt and migrate as intended and to determine if the plastic backing placed on the material for packaging could be left in place.

Each of the three samples consisted of the same material formulation. Samples 1 and 2 left the plastic backing in place on one side. Sample 1 was placed with the plastic backing facing up so the joint sealant was in contact with the pavement surface. Sample 2 was placed with the plastic backing facing down so the backing was in contact with the pavement surface. The plastic backing was removed from Sample 3. The three samples were placed across the joint area, as shown in Figure 16.

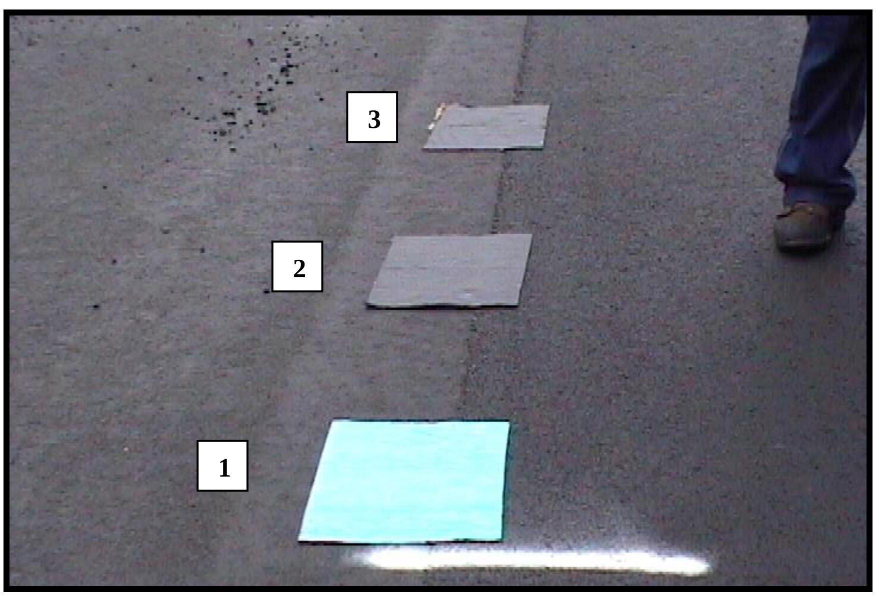


Figure 16: Sample Placement

Half of the joint sealant was paved over as the first lane was placed. Figure 17 illustrates the affect of the unconfined mat pushing out under the weight of the roller. Sample 2 (plastic backing side down) acted as a slip plane between lifts and allowed the mat to push out. Sample 1 (plastic backing side up) had a small effect in preventing the mat from pushing out. While, sample 3 (no plastic backing) had the largest effect in preventing the typical push out resulting from an unconfined edge.

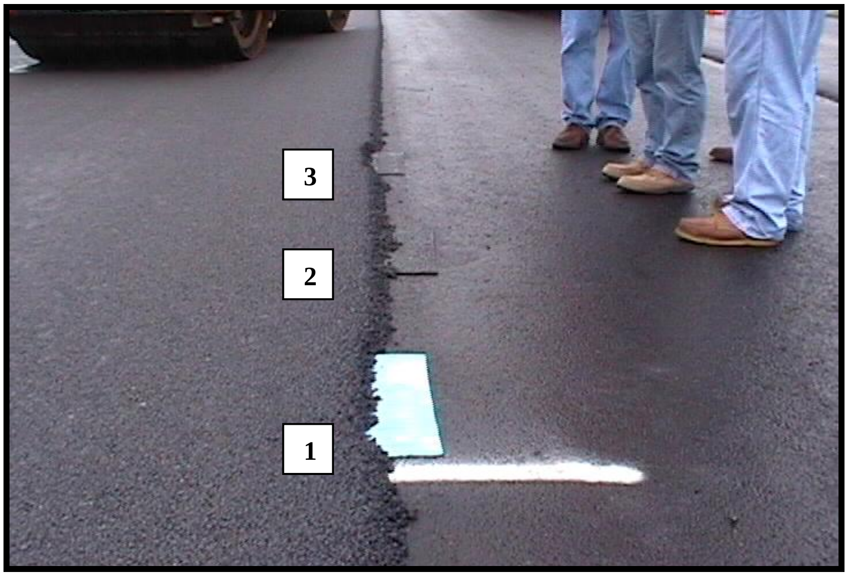


Figure 17: Samples after Paving First Lane

The material did become softer from the heat of the HMA. The elasticity of the material indicates the presence of polymers, as shown in Figure 18.

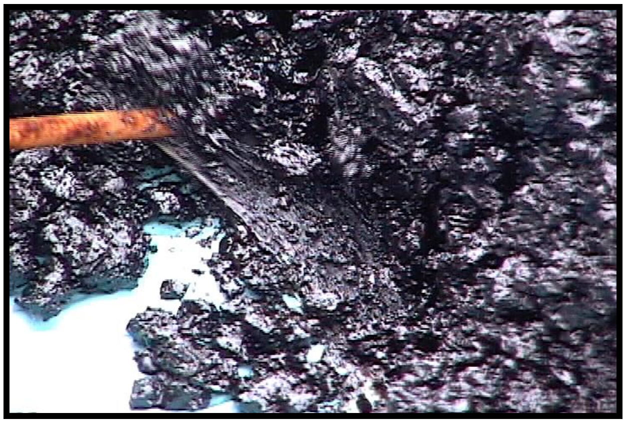


Figure 18: Joint Sealant Elasticity

The locations of the joint tape were marked on the pavement prior to paving the matching lane to ensure that the joint sealant samples could be located for testing and observations. After the second lane was placed, the area was marked for testing, as shown in Figure 19.

Figure 19: Final Mat Showing Sample Locations

Permeability testing was performed over the joint sealant, over joint areas without joint sealant, and on the mainline. Testing layout with permeability results are shown in Figure 20.

The mainline permeability testing ranged from $33x10^{-5}$ cm/sec to $101x10^{-5}$ cm/sec, which is at the desired range of 100×10^{-5} cm/sec or less[1,2]. However, the joint permeability with and without joint sealant was significantly higher. Both control sections tested at $5884x10^{-5}$ cm/sec. The joint sealant sections ranged from $1608x10^{-5}$ cm/sec to $5161x10^{-5}$ cm/sec.

When testing the joints, the water used for permeability testing was observed to disappear into the pavement, to flow rapidly from the pavement around the device, or to resurface at various distances from the test site. Figure 21 demonstrates how the water can flow from the test site, as well as travel further out and resurface.

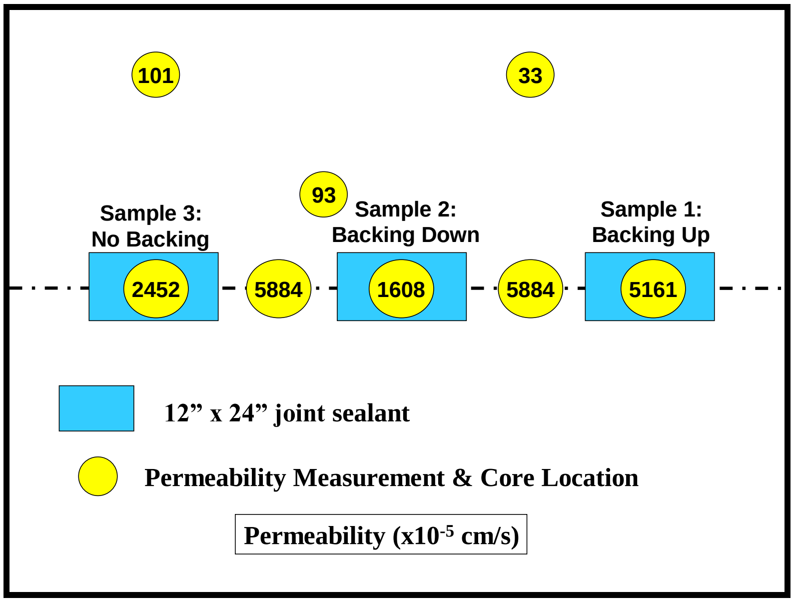


Figure 20: Testing Layout and Permeability Results

Figure 21: Field Permeameter Water Resurfaces along the Joint

The permeability of Sample 1 (plastic backing facing up) was similar to that of the control sections. Based on visual inspection of the cores, it was determined that the plastic backing did not melt as anticipated, as shown in Figure 22. Thus, in the case of

Sample 1, the backing prevented the joint sealant from migrating into the surface. The slight drop in permeability between Sample 1 and the control section is likely due to the fact that Sample 1 prevented the flow of water into the level binder lift below the surface, minimizing some vertical water flow through the pavement.

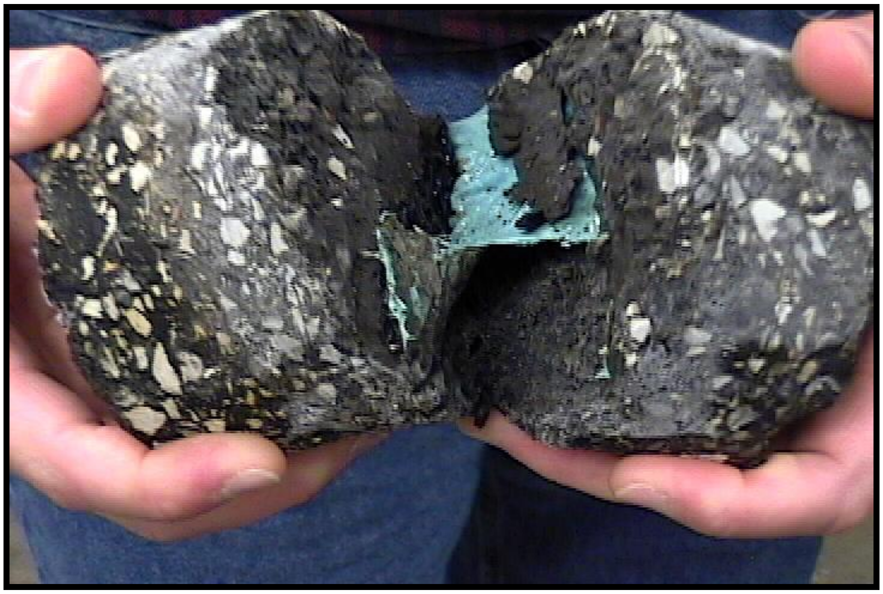


Figure 22: Plastic Backing Did Not Melt

The permeability of Sample 2 was 1608×10^{-5} cm/sec. Although the backing left on Sample 2 provided a slip plane, it also prevented the material from migrating downward into the lower binder lift. Thus, all the material was forced upward and more voids were filled in the surface lift.

The permeability of Sample 3 was 2452×10^{-5} cm/sec, which is less than half of the permeability of the control sections. No backing allowed migration to occur both upward into the surface lift and downward into the level binder lift.

Despite the significant decrease in permeability, as shown in Figure 23, the joint sealant did not migrate as high into the surface lift as desired. If the level of migration could be increased, then permeability may be obtained closer to the desired level. Although placing the plastic backing down did result in the least permeability, the amount of sliding that occurred and the bond breaker effect between lifts were of concern. Therefore, the placement procedure of choice was Sample 3, with no backing. If the migration level could be increased, this would decrease permeability while preventing the slip plane and bond breaking potential problems.

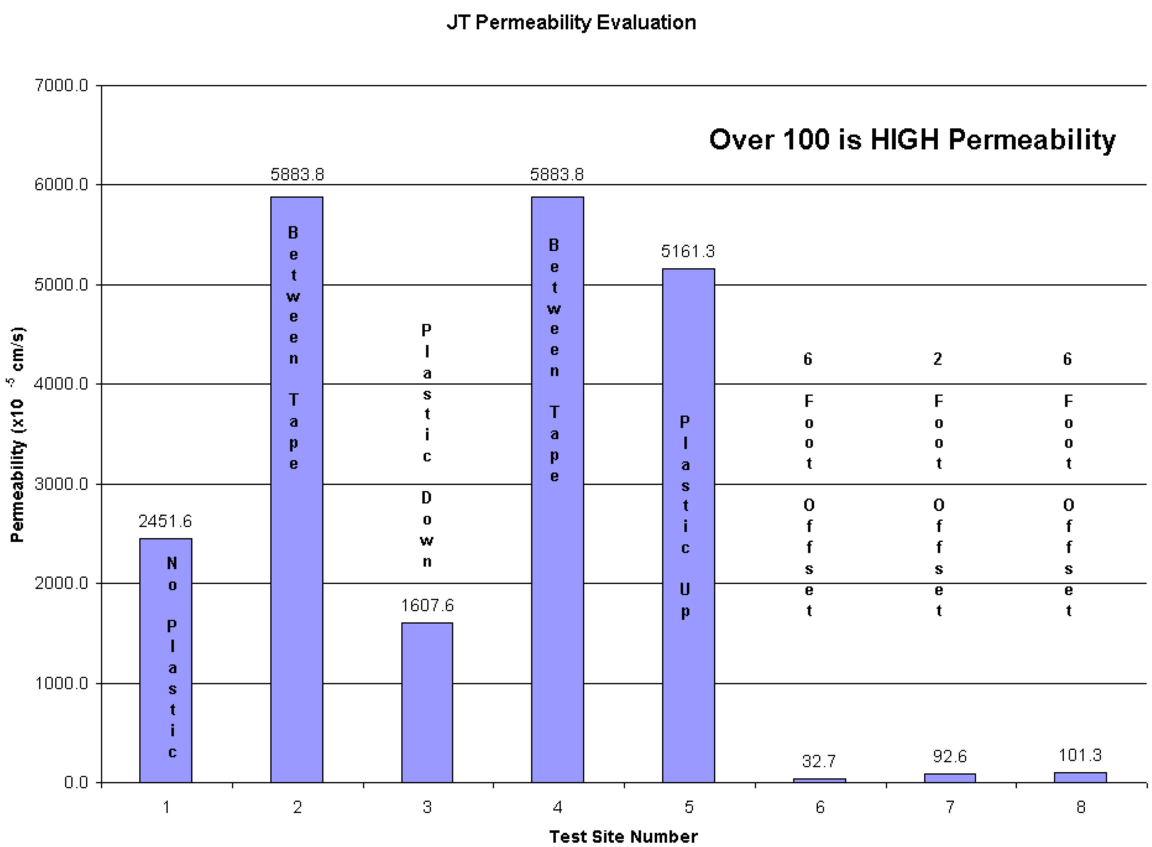


Figure 23: IL 10/121 Permeability Results

Overall, the trial on IL 10/121 did indicate that joint sealant could decrease permeability by half and future usage may be promising.

Illinois State Route 40

The second field trial occurred on September 4th and 5th, 2001 on IL 40 by the Indiana border in District 5. The joint sealant formulation from trial 1 on IL 10/121 in Lincoln was altered with the intent to improve the migration up into the surface. The trial on IL 40 involved looking at the migration of three different formulations fabricated by Quik Pave Products Inc. The joint sealant strips measure 12 inches wide, 30 inches long, and 3/16 inch thick. The three formulations were evenly spaced at the test location and are shown being paved over in Figure 24.

Figure 24: IL 40 Paving over Joint Sealant Formulations

Field permeability, nuclear density, cores, and lab permeability were tested, as well as observing the height of joint sealant migration within the cores. To minimize the effect on traffic, two coring set-ups were used to obtain the cores. The test site after coring is shown in Figure 25. Figure 26 represents the testing layout detail at the joint. Table 1 contains the corresponding test results.

Figure 25: IL 40 after Coring Test Locations

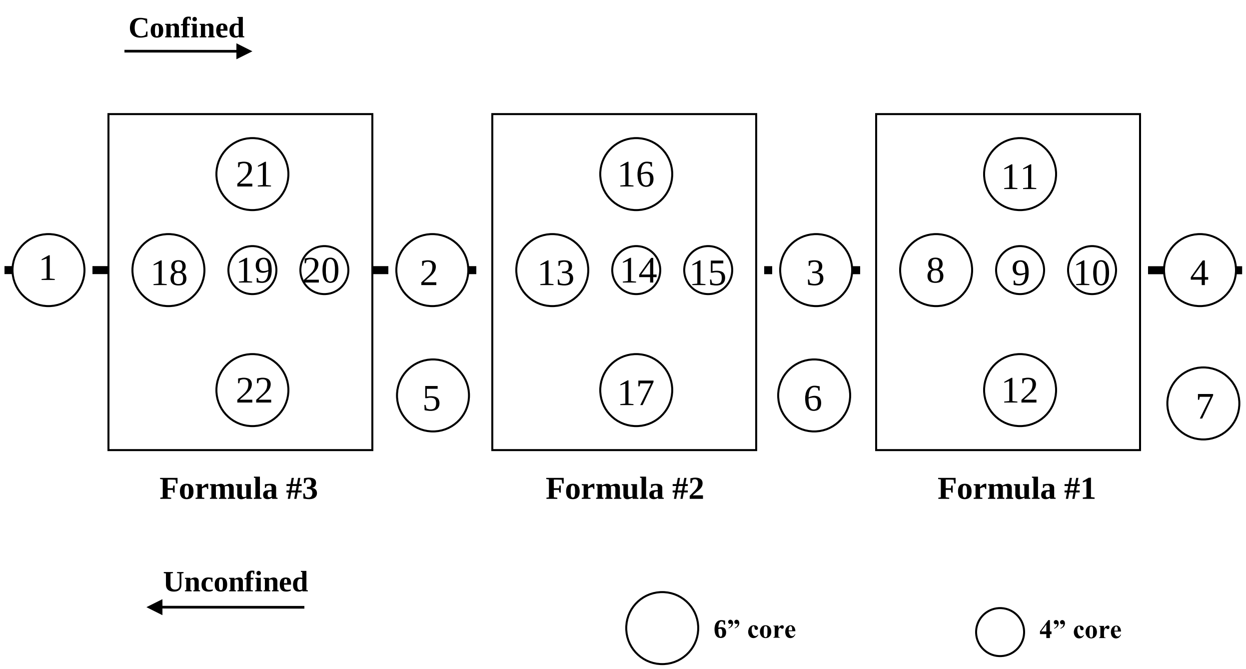


Figure 26: IL 40 Joint Testing Detail

IL 40 Test Results						
Desc		ID #	Field Perm	Lab Perm	Nuclear Density	Core Density
No Joint Sealant	Joint	1	8285	4722	84.6	
	Joint	2	7318		84.2	83.4
	Joint	3	9343		84.2	83.9
	Joint	4	7772	4178	83.9	
	6" Unconfined	5				84.7
	6" Unconfined	6				87.1
	6" Unconfined	7				86.5
Formula #1	Joint	8	4085	0		
	Joint	9	4696		82.2	
	Joint	10	4435		82.2	
	6" Confined	11	974		89.9	
	6" Unconfined	12			88.0	
Formula #2	Joint	13	4123	0		
	Joint	14	4028		84.4	
	Joint	15	3974			
	6" Confined	16	712		90.5	
	6" Unconfined	17			86.5	
Formula #3	Joint	18	4852	0		
	Joint	19	4799		83.4	
	Joint	20	4504			
	6" Confined	21	783		90.5	
	6" Unconfined	22	3956		87.3	

Table 1: IL 40 Test Results

The control section had an average density of 84.2% based on nuclear readings and 83.6% based on cores. IDOT specifies a mainline density of 92.5 – 97.4% of Gmm for 50 and 70 gyration mixtures and 92.0 – 96.0% of Gmm for 90 and 105 gyration mixtures. Currently, IDOT has no joint density specification.

The field permeability on the control sections averaged 8180×10^{-5} cm/sec. The extremely low density and high permeability indicates why joint failure occurs. The three formulations produced similar permeability and density test results and all had little (~1/8 inch) to no migration of the joint sealant into the surface. The joint sealant permeability results were approximately half the permeability of the control tests, which was similar to the trial on IL 10/121 in Lincoln. The lab permeameter was used to test both control and joint sealant cores. A permeability of 0 cm/sec was anticipated for the joint seal cores, since the lab permeameter measures vertical flow through a sample and the joint sealant prevents vertical flow through the bottom of the core, regardless of migration level. At the very least, the joint sealant does prevent water from infiltrating lower levels of the pavement. The lab permeability results on the control sections were a little more than half of the field permeability results. This demonstrates that both vertical and horizontal flow contribute significantly to a pavement's permeability.

The data between tests taken 6 inches off the centerline supports that there are differences between the unconfined and confined edges. The data also supports the concerns of low density and high permeability not only located at the joint interface, but at several inches on each side of the joint as well. The average density of the unconfined test sites over the joint sealant was 87.3%, while the average density on the confined test sites over the joint sealant was 90.3%. Due to safety issues, only one permeability test was taken on the unconfined 6-inch offset. The average field permeability of the unconfined 6-inch offset was 3956×10^{-5} cm/sec while the average confined 6-inch offset field permeability was 823×10^{-5} cm/sec. Just as with the Lincoln trial, the ability to determine density of the joint sealant areas is a concern. The joint sealant affects the maximum specific gravity so that the density may be somewhat higher than what was determined using the maximum specific gravity of the mix. The density may help with relative locations, but the permeability data is considered to be more indicative of variations.

Mainline testing was also performed, as shown in Figure 27. The tests were taken at 2, 4, 6, 8, and 10 feet from the centerline, as specified in Figure 27. The core density ranged from 92.4% to 94.7% with an average of 93.7%. The permeability ranged from 0 to 117×10^{-5} cm/sec with an average of 42×10^{-5} cm/sec. With the exception of the 117×10^{-5} cm/sec test result, the permeability results were below the 100×10^{-5} cm/sec desired limit. Even the 117×10^{-5} cm/sec test result was not too far from the desired limit.

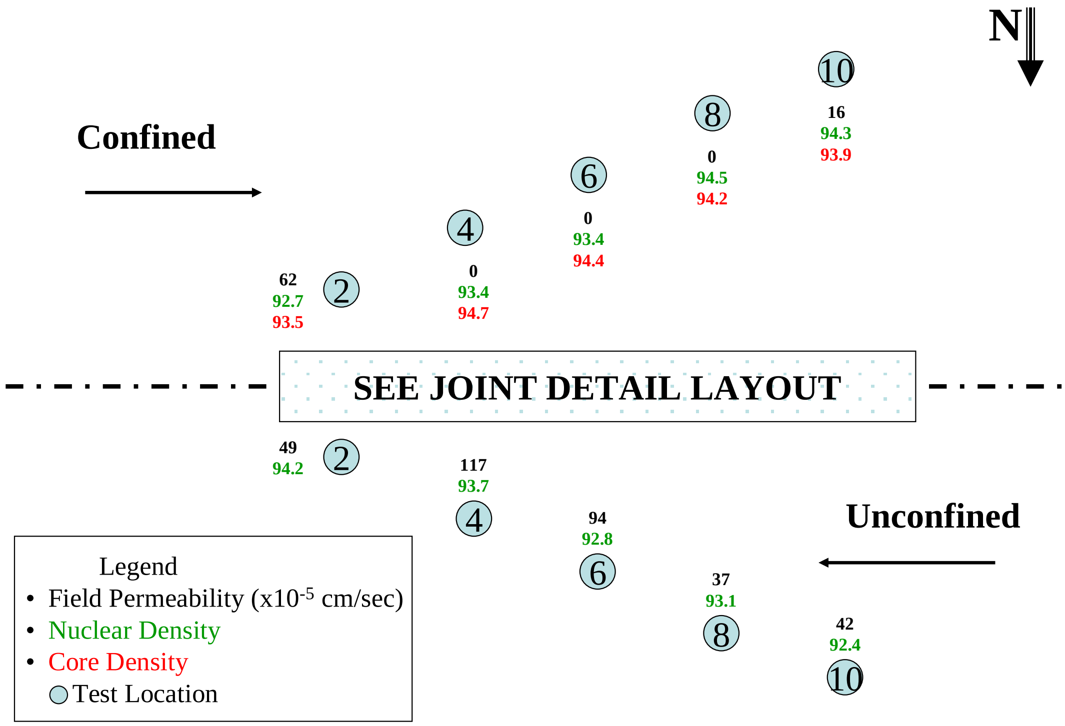


Figure 27: IL 40 Mainline Testing

The migration of the joint sealant within the cores is shown in Figure 28. The joint sealant had little (~1/8 inch) to no migration into the surface. The joint sealant material migrated less in this trial than on IL10/121 in Lincoln. In fact, the material was more of a distinct thick elastic layer on the bottom of the core which made it difficult to completely split into separate halves. It appeared that the modifications made to the formulations were in the wrong direction.

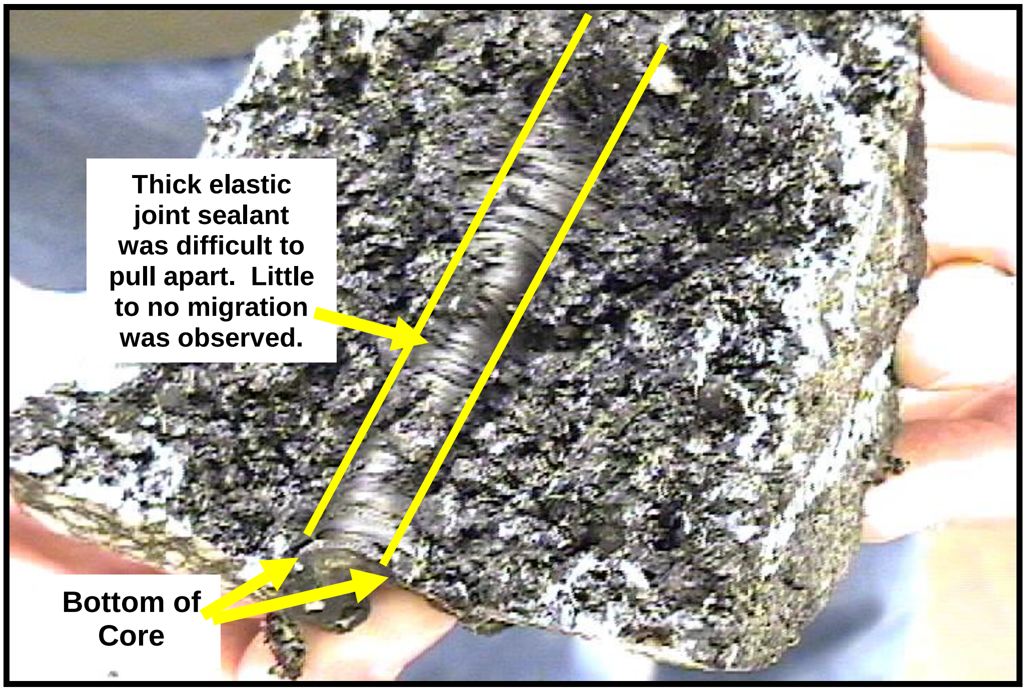


Figure 28: IL 40 Joint Sealant Migration (Thick Layer – No Migration)

Based on visual migration and the permeability results, the joint sealant formulation required further modifications. Although the joint sealant formulations appeared to be slightly softer on IL 40, especially as the temperature increased from the morning to afternoon, the migration level was less. The level of migration may have also been a function of surface mixture, paving equipment, or mix temperature.

Changes made to the joint sealant formulations are the sole responsibility of the Supplier. IDOT specified the desired result of the product but was not involved in determining what changes to make to the formulations. The goal is to create a product that will soften and melt upwards into the HMA surface course, but must also remain stiff enough to allow traffic to pass over the material without tracking prior to placement of the HMA surface course. It is that desired balance that makes determining the ideal formulation difficult. Whatever change was made in this instance by the supplier did help to make a softer material but also appeared to prevent migration.

RETENTION POND BASE

The first field evaluation of the Emulsicoat Jband occurred on October 4th, 2001 at a retention pond in Indiana, as shown in Figure 29.

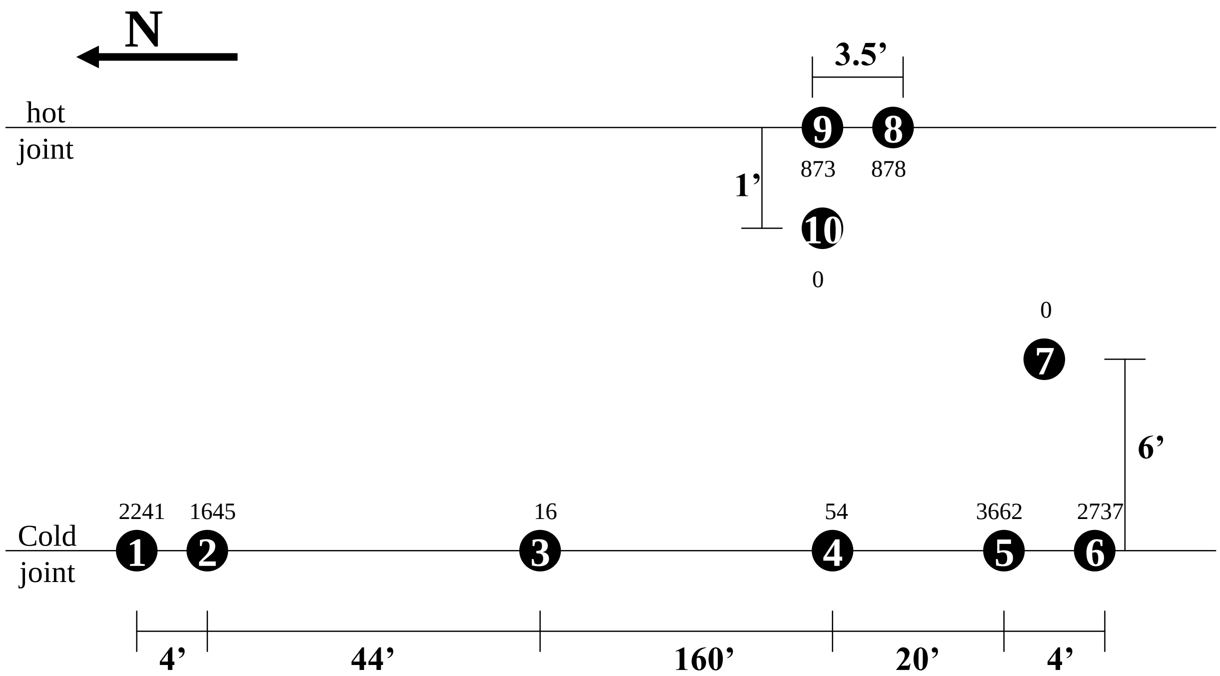
Figure 29: Retention Pond Paving

The Jband differs from the Quik Pave Product not only in formulation but also in application. The Jband material is applied as a viscous fluid. The Jband is heated and the material is placed by a variable thickness strike-off plate, as shown in Figure 30. This application process allows the freedom to make adjustments in thickness and width during placement.   For example, if flushing occurs because of too much migration, then the amount of material placed can easily be decreased. After the material is placed, it cools to a solid so that traffic can pass over the material without causing damage to the JBand, as shown in Figure 31.

Figure 30: Jband Placement

Figure 31: Jband after Placement

Permeability tests were taken on cold joints, hot joints, and mainline locations, as shown in Figure 32. No cores were taken.



* Numbers represent permeability values in units x10^{-5} cm/sec

Figure 32: Retention Pond Test Layout

Since the bituminous mixture was designed with low voids and higher asphalt content (7%) than typical dense-graded mixes used for roadways, the permeability and apparent effect of the joint sealant may not be typical to that of IDOT's typical mixes. The mainline permeability on this project was 0 cm/sec and several areas of flushing occurred.

The joint permeability ranged from 16x10^{-5} cm/sec to 3662x10^{-5} cm/sec. All joints had an application of the Jband material. It was observed that the joints varied significantly in visual appearance. The areas that appeared to be segregated also had high permeability, as expected. Other areas appeared to have more fines, thus making a less permeable joint. The joint variation is demonstrated in Figure 33.

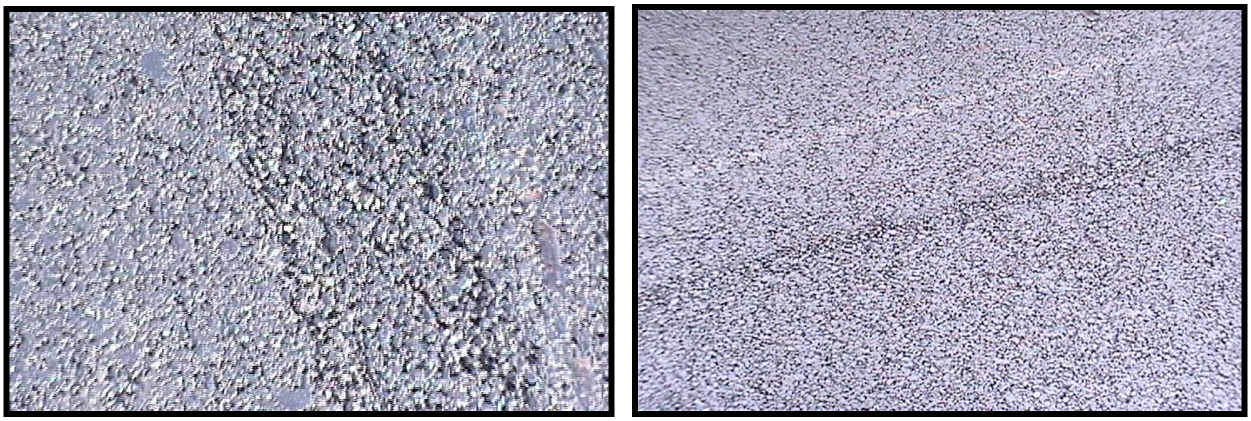


Figure 33: Retention Pond Joint Variability

Since the Retention Pond mixture was different than IDOT's typical mixture, a more applicable mix needed to be used to evaluate the Jband.

LAKES AT RIVERBEND SUBDIVISION

The second field trial of the Emulsicoat Jband occurred on November 2, 2001 in the Lakes at Riverbend subdivision in Mahomet, Illinois, as shown in Figure 34.

Figure 34: Subdivision Jband Testing

Two control locations and four joint sealant locations were tested, as shown in Figure 35.

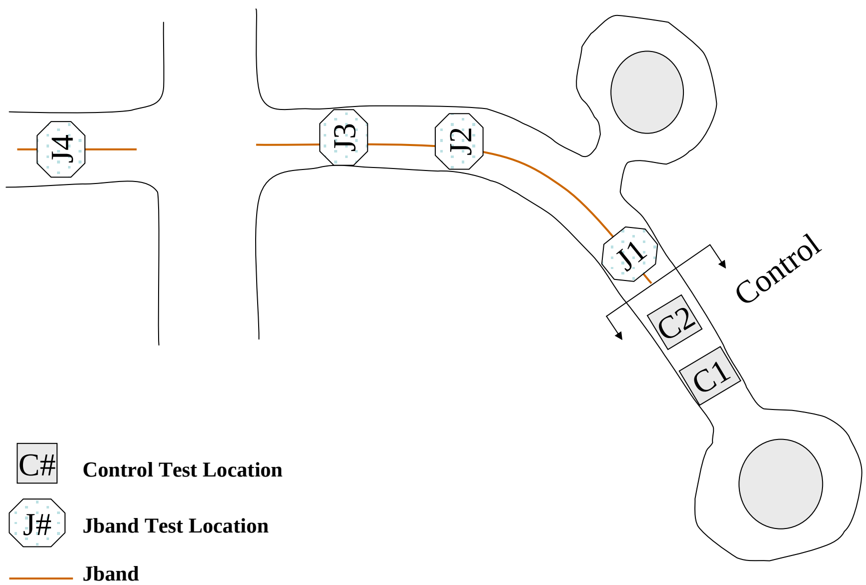


Figure 35: Subdivision Testing Layout

Permeability was tested on the joint and at the 6, 12, and 18 inch offsets from the joint on both the confined and unconfined lanes. Additionally, one control and one joint sealant location were tested for permeability at the 3.5, 5, 6.5, 8, and 10 foot offsets. The cross section was tested to get a better idea of mainline permeability. The permeability results are shown in Table 2.

	Unconfined Edge								**CL**	**Confined Edge**							
offset	**10'**	**8'**	**6.5'**	**5'**	**3.5'**	**18"**	**12"**	**6"**	**0**	**6"**	**12"**	**18"**	**3.5'**	**5'**	**6.5'**	**8'**	**10'**
C1	1088	938	164	149	1326	226	171	232	6364	2114	1512	1529	1413	1361	665	185	1028
C2						298	161	506	4263	1566	1970	1745					
J1						235	238	1926	3250	855	912	1793					
J2						2653	3421	2626	2321	168	229	332					
J3	169	157		925	714	235	831	1733	1595	210	303	409	2261	1024		1512	1198
J4								643	1520	398							

Table 2: Subdivision Permeability Results

The project was located in a subdivision, so IDOT density requirements were not in effect. The mainline density across the mat was likely significantly lower than IDOT requirements, as implied by the high permeability levels. All test data exceeded the desired 100x10^{-5} cm/sec desired limit. The control section contradicts the expectation that the unconfined edge would have lower density than the confined edge. However, it appears that the problem was in the lack of compactive effort in rolling the confined edge and half of the mat, since the low density spans from the joint all the way to the 5 foot offset. The control sections appear to be similar, as shown in Figure 36, which was expected since the two locations were only 40 feet apart.

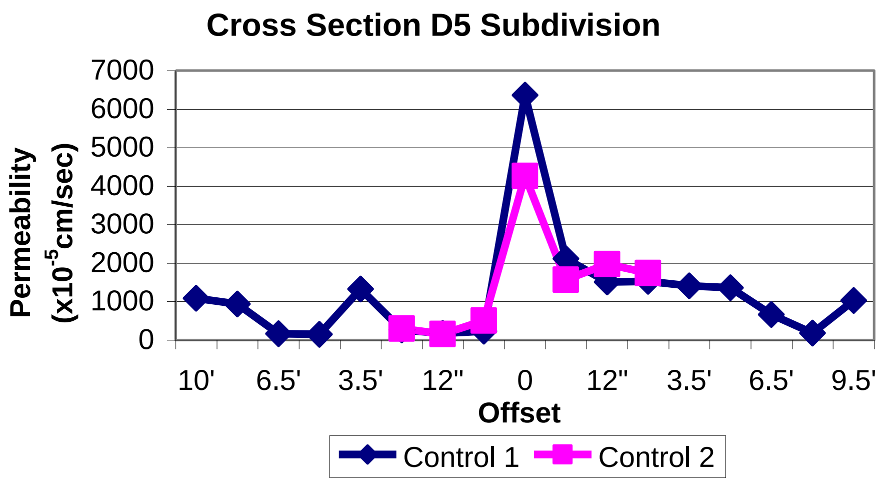


Figure 36: Subdivision Control Permeability

As was expected, the Jband test sites did have higher permeability on the unconfined versus the confined edge. When the J4 test site was paved, the joint was matched almost immediately after placing the first lane, resulting in better test results due to the hot joint.

Overall, the joint permeability was reduced by over half when using the joint sealant. The average joint permeability of the two control sections was 5313x10^{-5} cm/sec. The average joint permeability of the four joint sealant locations was 2172x10^{-5} cm/sec. The test results of the various locations are shown in Figure 37.

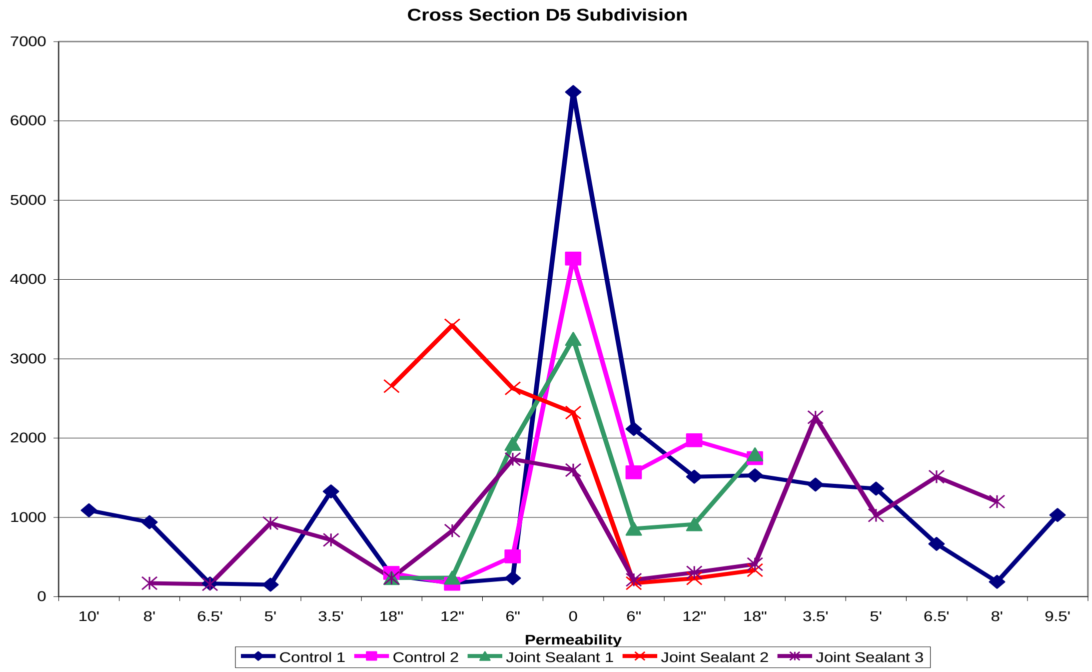


Figure 37: Subdivision Permeability Summary

U.S. Highway 51

The fifth field trial was the first to evaluate the two joint sealant products side by side. The project occurred September 4th and 5th, 2002 on US 51 at the South side of Decatur, Illinois.

The evaluation included one formulation of Emulsicoat's Jband placed at 12 inches wide in one test location and 18 inches wide in another test location. Quik Pave Products Inc. provided two formula variations of their product in two applications of 9 inch wide bands. A double prime test section was also evaluated, as well as several control sections located between the different joint sealant products. Both Emulsicoat and Quik Pave Products Inc. provided their material free of charge. The project test section layout is shown in Figure 38.

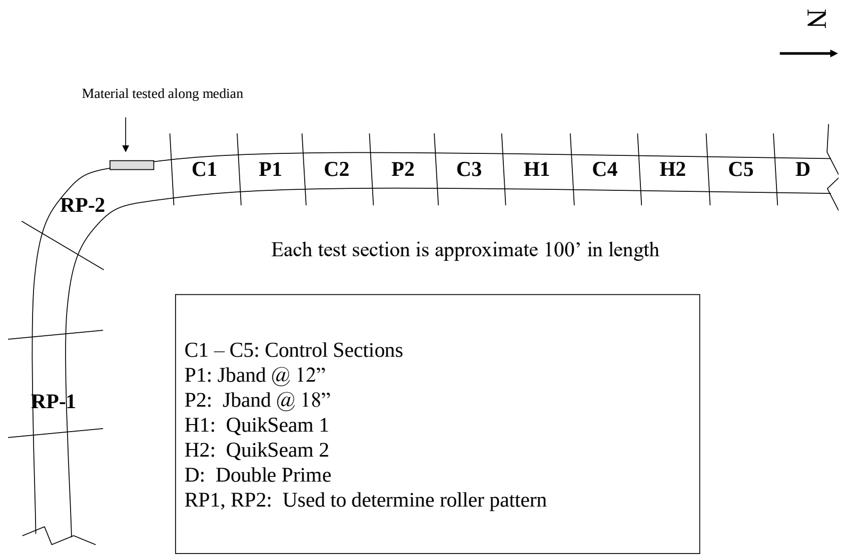


Figure 38: US 51 Test Section Layout

The RP-1 and RP-2 sections contained the Emulsicoat Jband at the centerline and were used to determine the rolling pattern that would be used for all test sections. Each test section was 100 feet in length.

The Jband was placed in one application prior to paving, as shown in Figures 39 and 40. The QuikSeam was placed in two applications. The first QuikSeam application consisted of placing a 9-inch strip so that approximately 2 inches of QuikSeam would remain exposed after the first lane was paved. The second application of QuikSeam was placed after the first lane was paved. The second application was placed adjacent to the first application and lapped up onto the edge of the first lane. The QuikSeam application is shown in Figures 41, 42, and 43.

Figure 39: US 51 Jband Placement

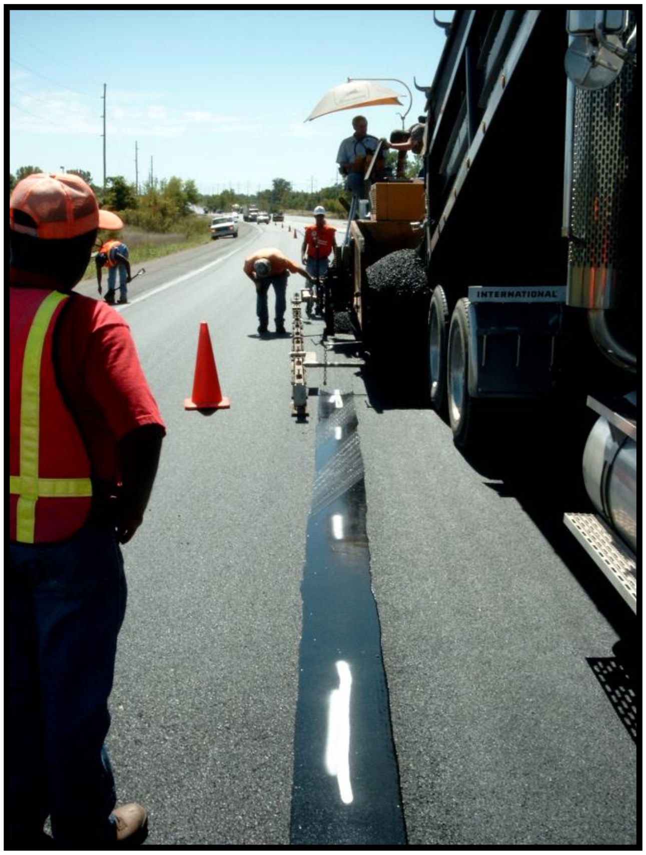


Figure 40: Paving over Jband

Figure 41: US 51 QuikSeam Placement

Figure 42: US 51 Second Application of QuikSeam

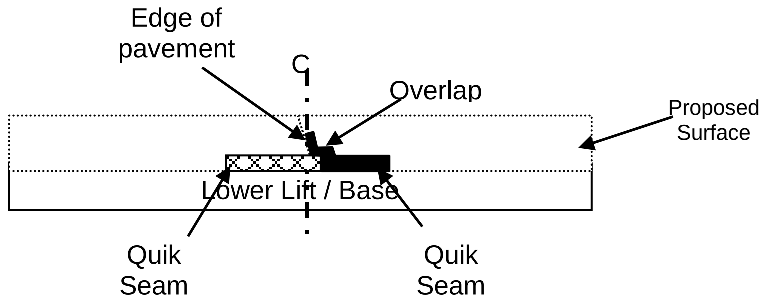


Figure 43: QuikSeam Typical Layout

Figures 44 and 45 show the Jband being applied to the median in the RP-2 test section. It was observed that very little density was being obtained in this area. The vibratory rollers tended to stay far enough away to ensure that the concrete median would not be damaged.

Figure 44: US 51 Jband Applied at Median

Figure 45: US 51 Jband Median Placement

A main concern with the joint sealant material is that traffic should be able to drive over the material without picking up the joint sealant. For the US 51 project, the joint sealant was paved over with the bituminous surface the same day as it was applied. Since the test sections were only 100 feet in length, with control section between, there was little need for construction vehicles to pass over the joint sealant. However, as the temperature increased during the day, the material did become softer and tracking was observed, as shown in Figure 45.

Figure 46: Joint Sealant Tracking

The joint sealants did soften more than what was observed in the past. Figure 46 demonstrates how the joint sealant softened after the first lane was paved. The softening of the material can also be seen by the glossy sheen along the joint sealant and HMA surface. The material is very elastic and contains polymers. The intent is that the polymers will help to prevent cracking. It was also noted when looking at the edge of the surface on the first lane paved that the material was migrating up into the surface. The intent is that the polymers will help to prevent cracking.

Figure 47: Joint Sealant Softens under HMA Surface

The joint sealant test section layout is shown in Figure 47. The 100 foot test length was split into thirds. Within each third, the test location was randomly determined by multiplying the 33 foot test length by a random number between 0 and 1.0. Permeability and nuclear density was tested at the joint in two locations, as well as at the 4, 7, 11, and 14 inch offsets on the unconfined first lane paved and the 4, 7, and 11 inch offsets on the second and matching lane. Six inch cores were taken at each centerline test site to be used for visual migration.

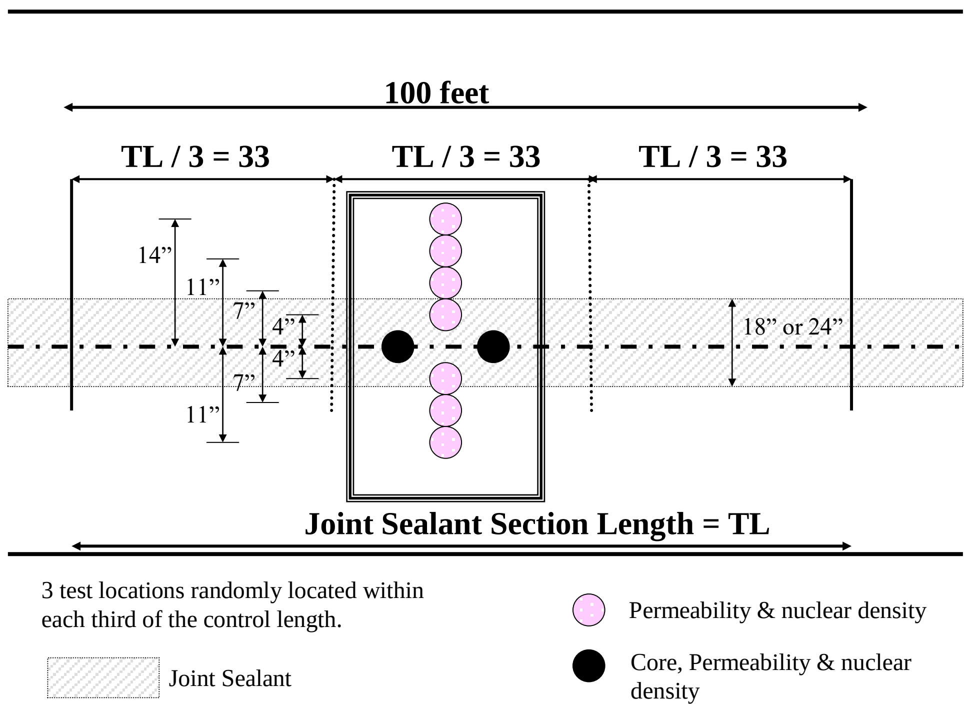


Figure 48: US 51 Joint Sealant Testing Layout

Due to time constraints, the number of control locations was less than that of the joint sealant locations. The control section layout was similar to that of the joint sealant except that, instead of having three test locations within a test section, there was only one. It was determined that it was more important to have control tests between each joint sealant test location to monitor the potential change that may be due to location than to have one of three control test locations. Five control sections were tested. The test sites were determined randomly by multiplying a random number between 0 and 1.0 to the 100 foot sections.

A summary of the permeability, density, and migration levels of each material is shown in Table 3. The Emulsicoat Jband data contains both the 12 and 18 inch width results since little difference was observed between the two. For all test site data, see Appendix A. The “Distance from Top” column represents how close to the surface the material migrated. The lower the value, the more migration occurred. The unconfined first lane was tested at 14, 11, 7, and 4 inch offsets. The confined matching joint lane was tested at 11, 7, and 4 inch offsets. The 14 inch offset was not tested on the confined lane due to time constraints. When testing the confined lane, not only were density and permeability locations tested, but the cores were also obtained at the centerline joint.

Description	Distance from Top (inches)	PULL 1 - UNCONFINED								CENTERLINE		PULL 2 - CONFINED					
		14"		11"		7"		4"		CL		4"		7"		11"	
		P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D
Emulsicoat Jband																	
Average	**1/2 - 3/4**	1291		3084		5039	93.5	9261	89.5	7400	87.2	3596	91.9	2816	92.9	897	
Std dev		628.4		625.9		1611	0.73	2940	0.59	2081	1.39	2917	0.7	1234	0.45	754	
Quik Pave Products Inc. Formulation 1																	
Average	**3/4 - 1**	502		1360		3072	94.7	5600	91	8010	87.2	2405	92.2	1958	92.7	522	
Std dev		502.9		339.9		799.7	0.21	1125	0.21	2896.2	1.00	455.3	0.36	272.7	0.17	101.9	
Quik Pave Products Inc. Formulation 2																	
Average	**5/8 - 3/4**	1250		2025		4093	92.2	6485	90.6	5610	86.6	4128	91.1	3811	91.7	2485	
Std dev		1421		1427		1455	0.25	1392	0.45	1116.5	0.57	687.4	0.3	391.1	0.21	248.1	
Double Prime																	
Average		320		1512		3355	92.7	7159	91.2	10721	86.8	4333	91.7	1585	92.4	607	
Std dev		88.5		410.1		728.2	0.85	884.5	0.44	2088.1	1.00		0.59		0.32		
Control																	
Average		1372		3197		5693	92.9	13467	89.2	15466	86.8	4741	92.2	1881	92.8	733	
Std dev		748.9		31097		1863	1.13	4775	0.73	5391.1	1.00	1177	0.26	468.3	0.31	421.9	

Note: P = permeability (x10^{-5} cm/sec) D = density (% maximum specific gravity)

Table 3: US 51 Average Test Results

In all sections, the 4-inch unconfined permeability is significantly higher than the 4-inch confined permeability, as expected. The permeability of all the joint sealant sections on the unconfined 4-inch offset was significantly less than that of the control sections. The average 4-inch unconfined control permeability was 13467x10^{-5} cm/sec, while the various joint sealant applications ranged from 5600x10^{-5} to 9261x10^{-5} cm/sec. There was less improvement between the average of the control sections (4741x10^{-5} cm/sec) and the joint sealant sections (ranged: 2405x10^{-5} to 4333x10^{-5} cm/sec) in the 4-inch confined lane test locations. The density in the control sections averaged 89.2% in the unconfined lane 4-inch offset and 92.2% in the confined lane 4-inch offset. The permeability and density data confirms that the problem does extend beyond the joint interface.

As before, the density reported in the joint sealant testing locations were calculated using the maximum specific gravity of the mix without joint sealant. Therefore, density results in the joint sealant areas should not be considered as absolutes but better used to indicate differences. All permeability tests were greater than the 100x10^{-5} cm/sec maximum desired level.

Figure 48 shows the normal distribution plots of each joint sealant application and control section. The permeability in the control sections were considerably higher and more variable than the joint sealant applications. The double prime application did help with permeability, but was not as effective as the other joint sealant materials. The QuikSeam formulation #2 had better joint permeability results than formulation #1. The Emulsicoat Jband joint permeability was between the two QuikSeam formulations. As the joint sealant formulations are improved upon, they should further distance themselves from the double prime application.

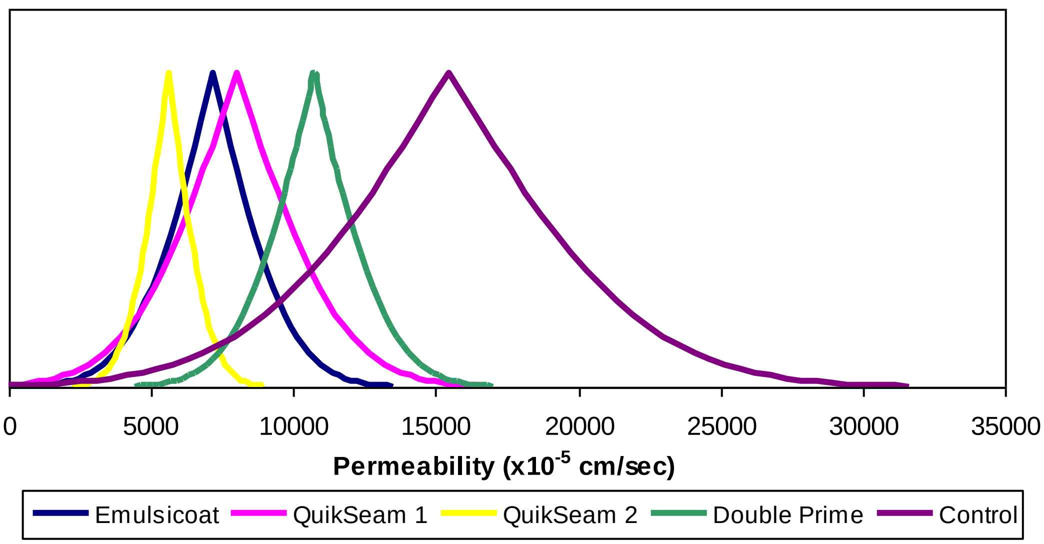


Figure 49: Joint Sealant Normal Distributions

The 6 inch joint cores were broken open to determine the amount of migration. Visual migration was similar between the Emulsicoat Jband and the QuikSeam formulation #2. Since the QuikSeam formulation #2 was better in both permeability and visual migration, it was determined to be the better choice for future QuikSeam usage. Visual migration is shown in Figures 49-51.

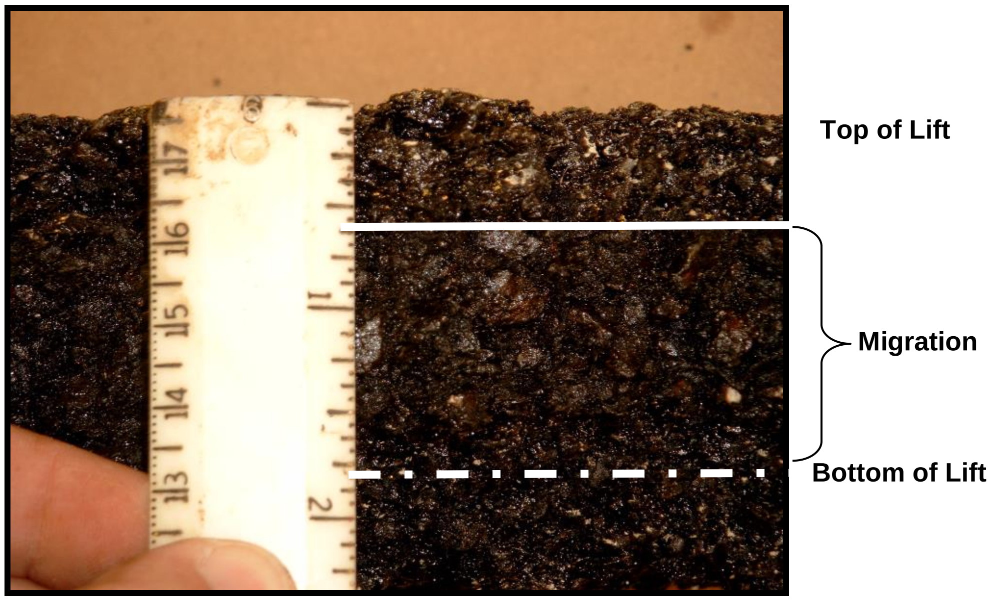


Figure 50: Jband Migration

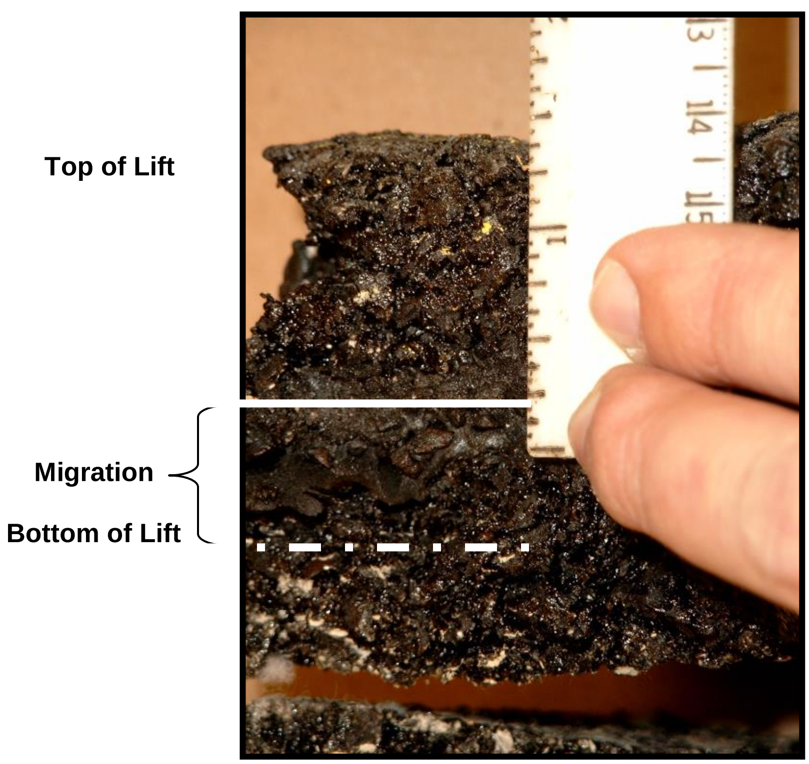


Figure 51: QuikSeam Formula 1 Migration

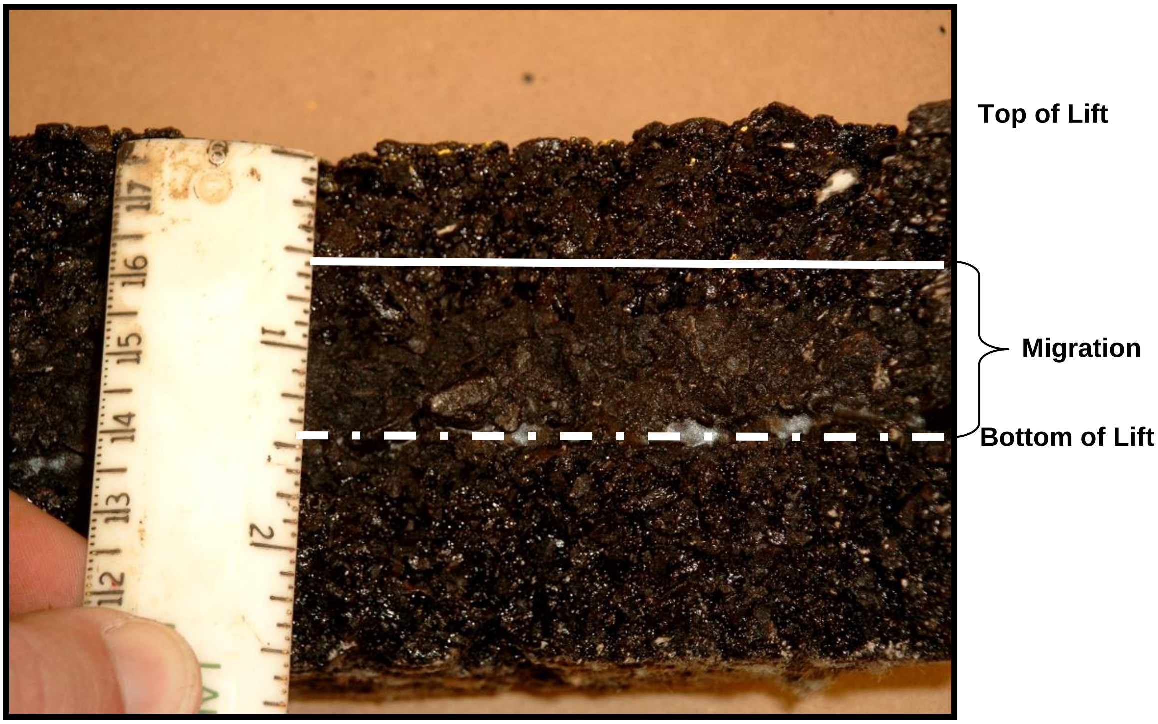


Figure 52: QuikSeam Formula 2 Migration

Overall, the joint sealant applications did show improvement over that of the control section. Based on the collected test data, double prime did help with the joint, but not as effectively as the other joint sealant applications appeared to help. The Jband and QuikSeam formula #2 appeared similar. The QuikSeam formula #2 would be the formulation of choice over that of the QuikSeam formula #1. More migration was observed on US 51 than has been observed on past trials. Although more migration is desired, using the products on a larger scale to evaluate constructability should be included in further investigations.

LAB PROCEDURE

Field trials took a large amount of time and effort to coordinate and perform testing. The trials on IL 10/121, IL 40, the Indiana retention pond, and at the Lakes at the Riverbend subdivision were all performed to try to evaluate joint sealant formula changes. The conclusion of each of the trials was that further formulation changes were required and additional field trials would be needed. A lab procedure that could better predict which formulations should be taken to the field was desired.

The lab procedure utilizes the gyratory compactor to simulate field conditions. A filler specimen compacted to a height of 3 ½ inches (88.9mm) at 4% air voids is used to simulate a binder base. The filler specimen is then saw cut to a height of 3 inches (76.2mm) to ensure a flat, uniform surface. The filler specimen is placed into a room temperature gyratory mold with the sawed face up. Two paper discs are placed on the 3 inch filler face to prevent the material from migrating down. This is done so that the surface and sealant material can be easily removed for observation and allows the filler specimen to be used on multiple trials. A 6 inch diameter of joint seal at the desired thickness (typically 3/16 inch) is placed on the paper discs. Since the Emulsicoat Jband was sent in pint and quart cans, the joint sealant was heated, poured into a 6-inch mold, and cooled to room temperature (Figure 52).

Figure 53: Joint Sealant Mold and Sample

The predetermined amount of surface mix that will produce a 1 ½ inch (38.1mm) lift at 14% air voids is added on top of the joint sealant. It was determined to target 14% air voids because the average joint density previously observed was approximately 86%. The temperature of the surface mixture is 150˚F. Earlier trials were heated as high as 300°F, but the results produced much more migration than was observed in the field. (The reason for this may be that the heat and pressure may be more concentrated in the gyratory mold than what was experienced in the field.) Various temperatures were tested until the 150°F temperature was concluded upon. The mold is then placed in the gyratory compactor for 10 gyrations. The number of gyrations was also determined based on past migration. The specimens are then removed from the mold and allowed to cool. Once cooled, the surface lift is broken open and the visual height of migration is recorded.

The procedure was developed by using material sampled on the Lake at Riverbend subdivision and the visual height of migration measured in the cores as a base line. In other words, the procedure was set when the height of the migration in the lab compacted specimen matched that of the field core migration. This procedure is not a guarantee since the amount of field compaction and environmental conditions can vary project to project and the procedure was based on only one project. However, it did prove to be a useful tool in determining if formula changes were an improvement over previous formulas and in minimizing the number of unsuccessful field trials necessary to achieve the desired product. The lab procedure is detailed in Appendix B.

The lab procedure helped rule out several intermediate formulations before those that were finally used on US 51. Two such formulations were designated 5005 and 4004. The lab trials showed that the 5005 material did not soften much, thus not migrating up into the sample, as shown in Figures 53 - 55.

Figure 54: 5005 Bottom View

Figure 55: 5005 Side View

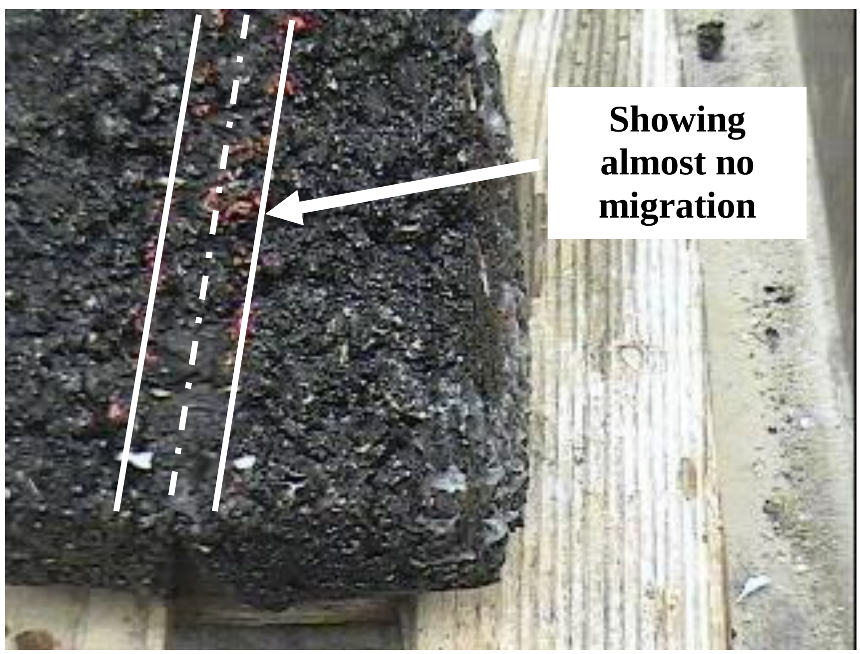


Figure 56: 5005 after Splitting

The 4004 softened more than the 5005 material, but was still not satisfactory, as shown in Figures 56-58. The picture showing both 4004 and 5005 shows that the 5005 material remained as a thick coating while the 4004 material is less detectable, since it did migrate more and had less build up at the interface.

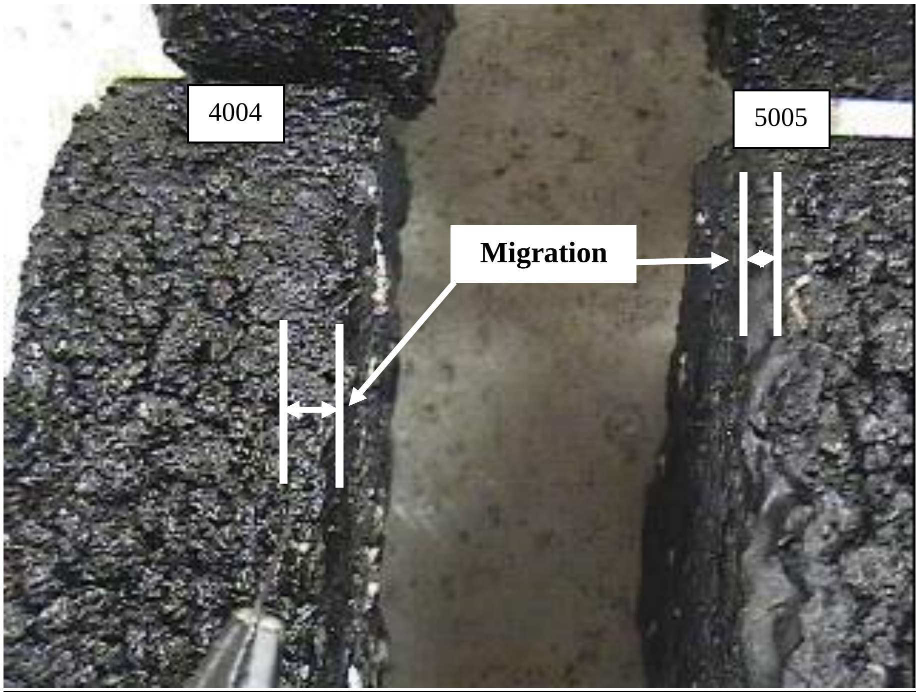


Figure 57: 4004 vs. 5005

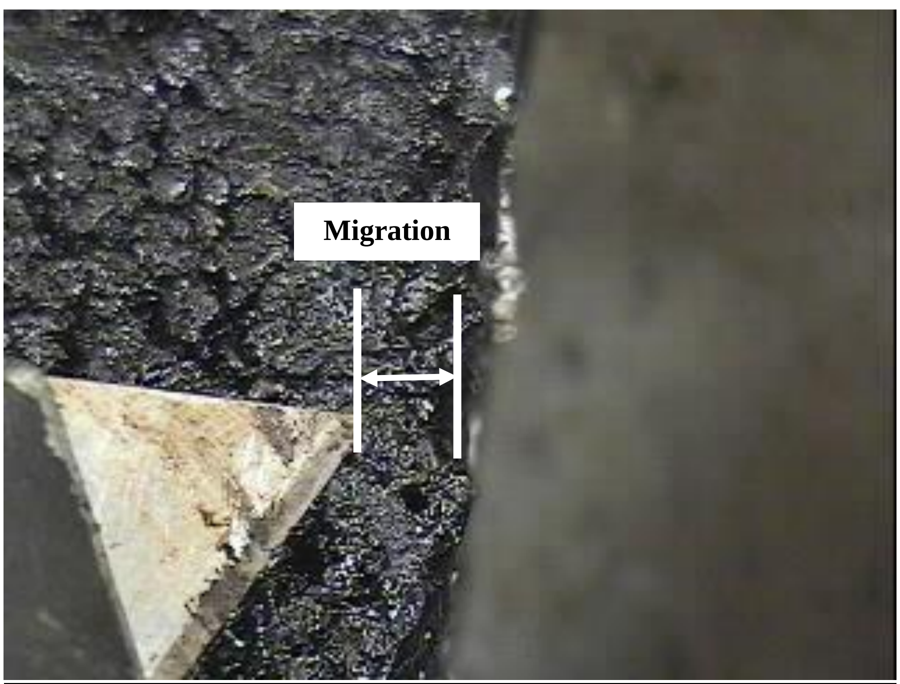


Figure 58: 4004 Side View

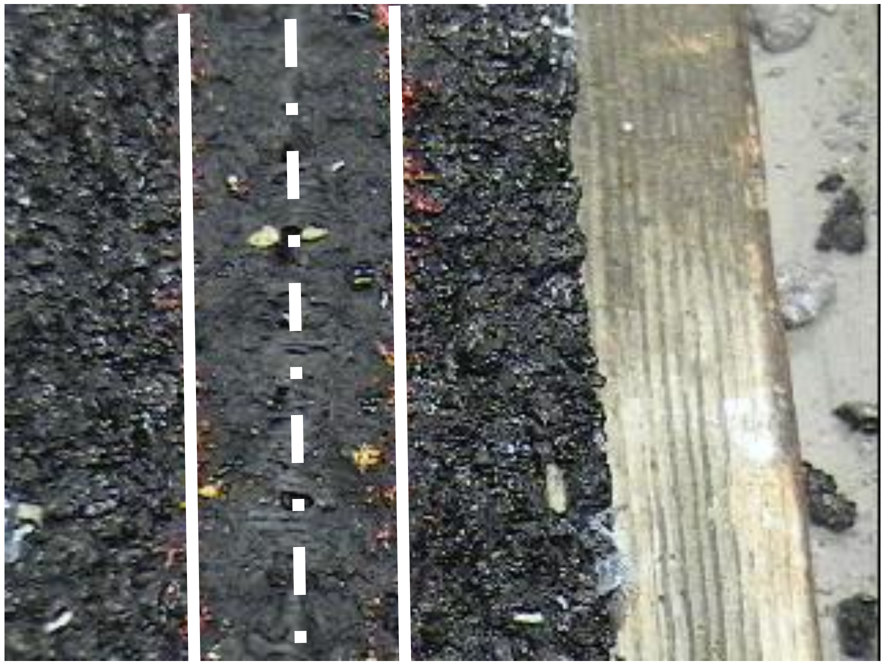


Figure 59: 4004 after Splitting

The lab procedure proved to be a helpful tool in that it helped determine if a joint sealant is worth field testing. However, the procedure is just a tool. If the conditions vary from the project used to determine the procedure, then the lab procedure will be less representative of what is observed in the field. The lab procedure did show how heat and pressure are critical in maximizing migration. The difference in 50°F and 10 gyrations was the difference between the gyratory sample flushing and the gyratory sample producing very little migration. Thus, field practice to apply compactive effort as soon as possible is critical in maximizing joint sealant migration.

CONCLUSIONS

The various projects tested confirmed that joint density is typically less than 90% of the maximum specific gravity of the HMA surface mixture. The low density allows the infiltration of water and air, which accounts for the premature distresses commonly observed in bituminous joints. The problem is not confined to the joint interface. Low density was typically found 4 to 6 inches out on both sides of the joint. The unconfined side of the joint typically had lower density than the confined side, as would be expected. Although the density of the confined edge was higher than that of the unconfined edge, the density and permeability were still at undesirable levels.

The two joint sealant products chosen for testing, Emulsicoat's Jband and Quik Pave Product's QuikSeam, were placed on the pavement prior to placing the HMA surface. Both products extended between 6 to 9 inches on both sides of the joint in order to address the entire low density joint area. Both products are a solid prior to covering with the HMA surface. The heat of the HMA surface softens the joint sealant. The pressure from compacting with a vibratory roller causes the joint sealant to migrate upward into the high voided HMA surface course. The result is a joint area that prevents water and air infiltration into the lower pavement lifts and that significantly decreases permeability in the HMA surface course.

Various methods were used to determine the effectiveness of the joint sealants. The lab permeameter did not detect changes based on migration levels into the surface. However, the lab permeameter did confirm that the joint sealant did prevent water form migrating into the pavement below the HMA surface. Field permeability testing was used to determine the amount of water flow in the HMA surface. Field permeability results on control sections were much greater than the $100x10^{-5}$ cm/sec desired values. The joint sealant significantly decreased the field permeability by typically showing at least a 50% reduction in permeability versus the results in the control sections. Although the permeability was significantly decreased, it was still above the $100x10^{-5}$ cm/sec desired value. Nuclear density readings were also taken at and around the joint. Since the presence of joint sealant would affect the maximum specific gravity, the density could only be used to look at potential differences between sites at best. Thus, field permeability tests were more representative of changes resulting from the joint sealant than density tests. The best test for the migration level of the joint sealant was to break open cores and visually determine how much migration had occurred. The ability to determine migration visually was validated by infra-red (IR) scans.

QuikSeam

Quik Pave Product's QuikSeam joint sealant was used on three trials. On IL 10/121 it was determined that the use of this joint sealant was promising but the migration was not as much as desired. The backing on the sealant that was used for packaging was initially assumed to be left in place so it would melt with the joint sealant. It was determined that the backing did not melt and would need to be removed prior to placing the HMAC surface. The project on IL 40 was used to evaluate changes that had been made to the original formulation to increase migration levels. The three formulations did not migrate as much as that on IL 10/121 and further formulation changes were needed. Both the IL 10/121 and IL 40 trials consisted of small joint sealant samples less than 3 feet in length. The third trial on US 51 consisted of 100 foot test sections and two different formulations were evaluated. The material on the US 51 project was applied in two 9-inch wide applications. The first application was placed so approximately 2 inches of joint sealant would be left uncovered after placing the first lane of HMA surface course. The second application was placed adjacent to the first application and lapped up onto the edge of the first lane's unconfined edge to allow for more joint sealant at the joint interface. The downside of two applications was the additional labor. The upside to two applications was the additional material at the joint. The best migration of the QuikSeam occurred on US 51 with one of the formulations migrating to within 5/8 inch of the top of the HMA surface. The surface was 1 ½ inches thick so the original 3/16 inch of material migrated to a height of approximately 7/8 inch.

Jband

Emulsicoat's Jband was used on three trials. The initial trial was on a retention pond base in Indiana. The Jband material did migrate high enough in some areas to cause flushing. Since the HMA surface material used on the retention pond had lower voids and higher asphalt content than typical IDOT HMA surface mixtures, the results of the Jband on this project were inconclusive. The project at Lakes at Riverbend subdivision in Mahomet, Illinois was used to evaluate Jband when using a conventional IDOT HMA surface. Approximately 525 feet of Jband was applied at the centerline joint. The Jband did decrease permeability. The migration height into the surface was not as high as desired; however, with increased migration the permeability could be further decreased. The Jband did not appear to have tracking problems but the project was also done in the cool weather of November, which could contribute to the lack of tracking. The third project on US 51 consisted of two 100 foot test sections. One test section consisted of placing Jband 12 inches wide while the other placed Jband 18 inches wide. The best migration of the Jband was observed on the US 51 project, as the Jband migrated to within ½ inch of the top of the HMA surface. The surface was 1 ½ inches thick so the original 3/16 inch of material migrated to a height of approximately 1 inch.

Lab Procedure

Field trials were very time and labor intensive. A lab procedure was developed based on the material and migration levels of the Jband at the Lakes at Riverbend subdivision. The lab procedure was a good tool to determine if formulation changes were worth taking to the field. Several joint sealant formulations were never tested in the field because the lab procedure indicated there would be little, if any, additional migration from what had been observed with previous formulations. Since the joint sealant migration is sensitive to construction practices, the lab procedure is only a relative measurement of change and not directly related to field migration. The lab procedure helped to determine the formulations that were used on US 51. The migrations of both the QuikSeam and the Jband were better than experienced on previous trials, as both came to within ½ inch of the top of the HMA surface.

Overall, it was determined that the joint sealant was more effective in decreasing permeability than applying an extra bituminous prime coat or applying nothing at all. Construction practices as well as environmental and climatic condition may affect migration. Heating the joint sealant and applying pressure are very important to the amount of joint sealant migration that occurs. The heat provides the ability for the joint sealant to melt and the pressure provides the necessary force to promote migration. The ability of the various joint sealants to withstand traffic without tracking still remains a concern. An evaluation of tracking would be more effective with larger test sections. Further formulation changes may be needed for both products. Based on the previous trials, a larger scale test section would help to better evaluate placement and construction issues.

RECOMMENDATIONS

1. Additional formulation changes to maximize migration while minimizing tracking is recommended.

2. A demonstration project utilizing a longer test section to fully evaluate constructability issues is recommended.

3. Investigating how heat and pressure affect sealant migration through various rolling patterns is recommended.

4. Further verification of the lab procedure to better predict the performance of other potential joint sealants is recommended.

5. A cost analysis for the benefits of joint sealant versus the cost of the joint sealant is recommended.

6. Performing yearly follow-up visits to the various field trials to monitor and document performance observations is recommended.

7. Implementing widespread use of joint sealant prior to evaluating constructability issues is not recommended.

REFERENCES

1. R.B. Mallick, L.A. Cooley, Jr., M.R. Teto, R.L. Bradbury, and D. Peabody. “An Evaluation of Factors Affecting Permeability of Superpave Designed Pavements.” Prepared for Presentation and Publication at the 80th Annual Meeting of the Transportation Research Board. January 2001.

2. L.A. Cooley, Jr., E.R. Brown, and S. Maghsoodloo. “Development of Critical Field Permeability and Pavement Density Values for Coarse Graded Superpave Pavements.” Journal of the Transportation Research Board. No. 1761,2001.

APPENDIX A

Description	Distance from Top (inches)	PULL 1 - UNCONFINED								CENTERLINE				PULL 2 - CONFINED					
		14"		11"		7"		4"		CL 1		CL 2		4"		7"		11"	
		P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D
RP1-A	1/2	205		729		3706		5692		6057	86.1	7637	85.5	6704	91.1	4934	93.1	2342	
RP1-B	1/2 - 3/4	227		1252		3864		6260		6273	87.5	6273	86.1	3939	91.5	2500	92.2	1955	
RP1-C	1/2	196		965		2817		6172		4647	88.2	6057	88.9	2203	92.5	1831	93.2	1688	
Ave PR1	1/2 - 3/4	209		982		3462		6041		5659	87.3	6656	86.8	4282	91.7	3088	92.8	1995	
Std dev		15.95		261.91		564.43		305.71		883.05	1.07	856.69	1.81	2270.02	0.72	1633.02	0.55	328.83	
C1		2177		4384		8231	92.4	17706	88	16263	86.9	13108	86.2	3880	91.8	1699	93.3	1421	
P1-A	5/8 - 3/4	1050		3041		7779	92.6	12214	88.6	8057	87.8	8527	86.8	3823	92.1	2826	92.9	568	
P1-B	1/2 - 3/4	2251		3030		5181	92.6	7380	89.3	8445	85.5	12031	85	9245	90.6	5098	93.4	2131	
P1-C	1/2 - 3/4	383		1934		3295	93.9	4850	90.2	6554	86.5	5666	86.1	3250	92.4	2680	92.9	1538	
Ave P1	1/2 - 3/4	1228		2668		5418	93	8148	89.4	7685	86.6	8741	86	5439	91.7	3535	93.1	1412	
Std dev		946.64		635.98		2251.4	0.75	3741.59	0.8	998.79	1.15	3187.91	0.91	3308.23	0.96	1355.85	0.29	789.04	
C2		1781		3656		6598	92.9	11757	89.6	13306	91.9	12031	86.8	3291	92.4	1198	92.9	359	
P2-A	1/2 - 3/4	1673		3421		4193	94	8844	89.2	7319	88	6756	87.1	1667	92.6	1512	93.2	345	
P2-B	1/2 - 3/4	1250		3308		5803	94.3	12600	89.9	8208	87	7772	87.9	2167	91.8	1985	92.7	400	
P2-C	1/2 - 3/4	1140		3768		3987	93.4	9683	89.9	3277	88.9	6190	89.9	1429	91.9	2796	92.1	400	
Ave P2	1/2 - 3/4	1354		3499		4661	93.9	10376	89.7	6268	88	6906	88.3	1754	92.1	2098	92.7	382	
Std dev		281.4		239.71		994.35	0.46	1971.48	0.4	2628.14	0.95	801.6	1.44	376.67	0.44	649.37	0.55	31.75	
C3		177		1416		3381	94.6	17996	89.4	23736	85.3	23736	86.3	6015	92.4	2261	92.6	419	
H1-A	1	217		1436		3527	94.5	6015	91.1	12915	88.3	8695	86.4	2342	91.9	2149	92.6	409	
H1-B	3/4 - 1	1083		1656		3541	94.8	6458	90.8	5558	87.5	9245	88.1	1985	92.6	1646	92.6	607	
H1-C	3/4 - 1	207		989		2149		4326		6229	87	5421	85.7	2889	92.1	2080	92.9	550	
Ave H1	3/4 - 1	502		1360		3072	94.7	5600	91	8234	87.6	7787	86.7	2405	92.2	1958	92.7	522	
Std dev		502.9		339.88		799.66	0.21	1125.05	0.21	4067.72	0.66	2067.39	1.23	455.32	0.36	272.68	0.17	101.93	
C4		1354		3333		4561		6410		10710	86.5	10842	86.7	5777	92	2364	92.5	733	
H2-A	3/4	2889		3376		5666	92.2	7258	90.6	5855	86.3	5259	87	3599	90.8	3611	91.5	2241	
H2-B	3/4	503		2167		3818	91.9	7319	90.2	5388	86.5	7199	85.7	4905	91.1	3561	91.9	2476	
H2-C	5/8 - 3/4	359		533		2796	92.4	4879	91.1	6141	86.8	3823	87.3	3880	91.4	4262	91.8	2737	
Ave H2	5/8 - 3/4	1250		2025		4093	92.2	6485	90.6	5795	86.5	5427	86.7	4128	91.1	3811	91.7	2485	
Std dev		1420.95		1426.78		1454.68	0.25	1391.46	0.45	380.11	0.25	1694.26	0.85	687.41	0.3	391.09	0.21	248.11	
C5							91.5		89.9										
D-A		409		1926		3662	91.8	7912	90.7	9245	85.4	12198	86.4	4333	92.4	1585	92.6	607	
D-B		232		1106		2524	93.5	6185	91.4		86.1		87.5		91.5		92		
D-C		320		1503		3880	92.7	7380	91.5		88		87.5		91.3		92.5		
Ave D		320		1512		3355	92.7	7159	91.2	9245	86.5	12198	87.1	4333	91.7	1585	92.4	607	
Std dev		88.5		410.07		728.16	0.85	884.46	0.44		1.35		0.64		0.59		0.32		
Ave Control		1372		3197		5693	92.9	13467	89.2	16004	87.7	14929	86.5	4741	92.2	1881	92.8	733	
Std dev		748.94		1096.6		1863.28	1.13	4775.1	0.73	4877.41	2.52	5147.36	0.25	1176.88	0.26	468.32	0.31	421.85	

APPENDIX B

Evaluation of Longitudinal Joint Seals

Lab Work for
Establishing a Test Procedure

The purpose of this procedure will be to measure a joint seals ability to melt and be drawn up into a 1½ inch lift of mix at 150° F compacted to 14% voids. The temperature and void level represents the lowest allowable field mix temperature and field density at a longitudinal joint.

Practice Procedure:

1. Compact filler specimens 3½ inches (88.9 mm) in height at 4% air voids, extrude and allow to cool to room temperature.
2. Saw the 3½ inch specimen to 3 inches (76.2 mm) in height
3. Prepare a surface mixture heated to 150° F.
4. Determine the weight of mixture needed to provide a specimen 1½ inches (38.1mm) in height at 14 ± 0.5% voids.
5. Place the 3 inch room temperature specimen in a room temperature gyratory mold sawed face up. If the 3 inch specimen will not fit into the mold, place the mold in a 200°F oven for 5 minutes. Repeat the process of heating the mold until the 3 inch specimen will fit into the mold. Allow the mold to reach room temperature before proceeding.
6. Place two paper disks in the mold on top of the room temperature specimen.
7. Place the 150° F mixture in the mold on top of the paper disks.
8. Set the gyratory to compact the composite sample to a height of 114.3mm.
9. Extrude sample and allow sample to cool for 15 minutes. If the sample will not extrude, place the mold and sample in a 200°F oven in 5 minute intervals until the specimen will extrude.
10. Separate the top 1½ inches from the bottom sample.
11. Determine the air voids of the 1½ inch specimen voids using AASHTO T166.
12. Adjust the sample weight and repeat *Practice Procedure* until 14 ± 0.5% voids is achieved in top 1½ inches.

Procedure using Joint seal:

1. Compact filler specimens 3½ inches (88.9 mm) in height at 4% voids, extrude and allow to cool to room temperature.
2. Saw the 3½ inch filler specimen to 3 inches (76.2 mm) in height.
3. Prepare the polymer surface mixture and heat to 150° F.
4. Use predetermined weight of mixture to provide a specimen 1½ inches (38.1mm) in height at 14 $\pm$ 0.5% voids.
5. Weigh and record the sample weight of sealant to be used to obtain desired thickness. (Typically 3/16 inch = ~ 100g) Note: Have samples prepared before next step.
6. Place the 3 inch room temperature specimen in a room temperature gyratory mold with the sawed face up. If the 3 inch specimen will not fit into the mold, place the mold in a 200°F oven for 5 minutes. Repeat the process of heating the mold until the 3 inch specimen will fit into the mold. Allow the mold to reach room temperature before proceeding.
7. Place two paper disks on top of the 3 inch specimen.
8. Place a 6 inch diameter sample of joint seal in the mold on top of the paper disks.
9. Place the 150° F mixture in the mold on top of the joint seal.
10. Set the gyratory to compact the composite sample to 10 gyrations and compact.
11. Extrude sample and allow sample to cool for 15 minutes.
12. Separate the top 1½ inch specimen from the bottom 3 inch specimen.
13. Split the 1½ inch specimen using the indirect tensile compression head.
14. Visually observe and record the distance the joint seal migrated upward.