EVALUATE TxDOT CHIP SEAL BINDER PERFORMANCE USING PAVEMENT MANAGEMENT INFORMATION SYSTEM AND FIELD MEASUREMENT DATA SAN ANTONIO DISTRICT

Interim Research Report
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OU Transportation Research Report

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"Evaluate Texas Department of Transportation Chip Seal Binder Performance Using Pavement Management Information System Data"

Interim Report #1

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EXECUTIVE SUMMARY

Purpose of the Research: This research has two distinct purposes. First, it seeks to determine whether the enhanced skid number performance of emulsion chip seals placed in the Texas Department of Transportation's (TxDOT) Atlanta District found in the 2002 AEMA study was due to binder or aggregate characteristics. Additionally, this project transfer the technology developed in the AEMA project via a series of workshops conducted by the researcher in TxDOT districts. Secondly, it will extend the findings of the AEMA and other recent research to the San Antonio District through a chip seal performance study of both hot applied and emulsion chip seals constructed during the summer of 2005.

Deliverables: Publication of research findings in an annual report that can be used to transfer the knowledge developed in this project to TxDOT construction and maintenance personnel on-site at their district offices in Texas. Additionally the researcher will seek to publish the significant findings of this work in a national peer-reviewed journal. Finally, a chip seal performance workshops have been and will be conducted at districts designated by the sponsor. To date, seminars have been conducted in Austin, Brownwood, Bryan, Lufkin, Paris, Sequin, and Waco. Findings of this study have been presented at regional and national conferences in Nashville, TN, Washington, DC, Austin, TX and at the TxDOT Maintenance Conference in Austin.

Scope of Work: Researchers established test sections on 14 Farm-to-Market roads in the TxDOT San Antonio district and will monitor those sections for a period of three years. Engineering measurement of chip seal surface texture will be made using the New Zealand P-17 Sand Circle test as well as digital imagery to validate those measurements similar to the process being used by the researcher in another project in New Zealand. The analysis will entail processing the PMIS data for each test section on an annual basis and using that to do a comparative analysis of chip seal performance as measured by PMIS and in the field on the actual test sections.

Methodology: The research will be conducted in three phases. Phase 1 is complete and consisted of data collection and reduction. The San Antonio district furnished publicly available contract information from the test section seal coat projects completed using hot asphalt cement binder and the test section seal coat projects that were scheduled to be completed using emulsion binder. The data will be processed in the exact same method as the previously cited research project. Additionally, weighted average metrics will be calculated on a basis of unit area. Finally, cost index number theory will be applied to the problem with specific cost index number metrics being developed for the pavement condition score and the skid number (if skid number data can be obtained). The PMIS data has been received for the preseal condition, but has not yet been analyzed. It will be correlated with the preseal texture measurements and windshield survey to produce a comprehensive picture of the condition of the test section roads prior to the 2005 seal coat. This is the first time that this level of effort has been expended to quantify the condition of the underlying surface for newly sealed roads.

Once the data has been reduced, it will be analyzed. The object of the analysis is to identify performance differences between hot asphalt binder projects and emulsion binder projects on a district-by-district basis. Special attention will be paid to the type of aggregate that is used and whether or not it has been precoated. The PMIS data will be taken before the new seal coat on each test section at the same time as the New Zealand P-17 Sand circle tests and digital imagery will be collected. The PMIS results will be compared with the physical field measurements and trends will be identified.

Phase 2 of the project conducted more workshops for the TxDOT district personnel. The workshops consisted of a formal presentation to a group, a question and answer period, and a follow-on informal discussion period where interested TxDOT personnel can discuss the findings of the researcher directly with the researcher. Additional workshops will be scheduled as requested by the sponsor. This phase is complete

Phase 3 will replicate Phase 1 in that the test sections will be physically sampled once each quarter and the PMIS data will be collected and analyzed each time that it is updated by the district. Two such post-seal samples have been taken and the results are described in detail in the body of this interim report. At each PMIS data update a comparative analysis will be run with the field measurements and trends will be identified and documented. When the three-year observation period is complete, a comprehensive research report will be prepared and submitted to the sponsor.

Emerging Conclusions: The major conclusion found at this early point in the research is that the condition of the substrate will impact the performance of the new seal coat. This is shown by the early flushing of EM road FM 1470 which had a recent reseal before the new emulsion chip seal and the fact that the AC roads that were shot on top of flushed substrate are losing their texture depth at a rate that is faster than those whose substrate was not as highly flushed prior to the new seal. While this is certainly not “new knowledge” to the members of TxDOT and the chip seal industry, this is the first time in Texas and by the author’s knowledge in North America that a quantitative measurement has been use to prove what has been suspected for quite a long time. Thus, the methodology used in this project is proving itself to be very valuable in developing a rationale method using engineering measurements to objectively evaluate the post-seal performance of all types of chips seals.

At this point it is too early in the research to develop any authoritative conclusions with respect to the comparative performance of the two binder types. Nevertheless, several observations of potential trends are possible.

- It appears that both binder types seem to be furnishing satisfactory performance in their early lives. Neither the qualitative nor the quantitative measures indicate poor performance of either binder type.
- At this point it appears that the emulsion binders are performing at least as well as the hot applied asphalt binders when the preseal conditions of the substrate are taken into account.

- The quantitative measures of texture depth appear to show that the emulsion roads are losing their texture depth at a slower rate than the AC roads. This is probably due to the increased amount of flushing that was present on the substrate of the AC roads prior to sealing.
- The importance of having a detailed knowledge of the existing surface prior to the new seal coat is vital to explaining seal coat performance.
- The qualitative rating of the emulsion roads may be more severe than the AC roads because of the great contrast between the uncoated aggregate and the binder. Therefore, both the research team and the reader must be careful to not attach an excessive amount of meaning to the windshield analysis.

At this point, the research methodology has proven itself to furnish useful output data. No change in the research methodology is necessary.

"Evaluate Texas Department of Transportation Chip Seal Binder Performance Using Pavement Management Information System Data"

Interim Report #1

PURPOSE OF THE RESEARCH:

The purpose of this research is to compare the performance of emulsion chip seals placed in the Texas Department of Transportation's (TxDOT) San Antonio District with hot-applied asphalt chip seals place on similar roads in the same area. The project builds on previous work done in the TxDOT Additionally, this project transfers the technology developed in this project via a series of workshops conducted by the researcher in approximately twelve TxDOT districts. This report only speaks to the binder performance comparison completed work to date.

LITERATURE SYNOPSIS AND BACKGROUND

To set the stage and increase the comprehension of potential readers without a background in chip seal design and construction, a short synopsis of the literature is offered. A complete literature review will be included in the final report.

Chip seals, which are also called seal coats or surface treatments, have more than a 50-year recorded history in the United States (Jackson et al, 1990). The first uses were limited to surface treatments as wearing courses in the construction of low-volume roads. Since then, maintenance chip seals have become increasingly popular due to a number of factors including increased maintenance needs of existing pavements and the lack of sufficient funds earmarked for maintenance (Jackson et al, 1990). In 1960, McLeod provided definitions for surface treatments and seal coats (McLeod, 1960). He defined a surface treatment as "a single application of asphalt binder, followed by a single application of cover aggregate, both placed on a prepared gravel or crushed stone base". He defined a seal coat as "a single application of asphalt binder followed by a single application of cover aggregate, both placed on an existing bituminous surface." These definitions are consistent with what is currently being used by TxDOT. A maintenance seal coat is identified as a preventive maintenance (PM) activity. The National Cooperative Highway Research Program (NCHRP) defined preventive maintenance as " a program strategy intended to arrest light deterioration, retard progressive failures, and reduce the need for routine maintenance and service activities" (NCHRP, 1989). On the other hand, routine maintenance was defined as "a program to keep pavements.... in good condition by repairing defects as they occur" (NCHRP, 1989). As a PM activity, chip seals may provide a number of enhancements to the pavement performance including sealing of the pavement to moisture, enrichment of the surface, provide or restore adequate skid resistance, preserve existing structural strength, and improve visibility for night driving (Elmore, et al., 1995, Shuler, 1990). The planned preventive maintenance activities are not expected to enhance the structural capacity of the pavement (Janisch, 1995; MnDOT, 1991). Finally, there is a controversy that rages within the US on whether chip seals can be effectively used on high volume roads. A study done in Texas found that "if rutting is not a concern, chip seal is the best choice for a high traffic area" (Chen et al, 2003). The recently completed National Cooperative Highway Research Program (NCHRP) Synthesis 342:

Chip Seal Best Practices (Gransberg and James, 2005) found that chip seals have been successfully used on interstate highways with traffic volumes that exceed 100,000 vehicles per day. Thus, this pavement preservation technology is both important to the conditions of this nation's highways and has been proven to be effective in a wide variety of applications.

In Texas, hot applied asphalt binders are the dominant type of binders used in chip seals (more commonly called "seal coats" in this state) (Gransberg and Zaman, 2005). A previous study by the author found that these were favored primarily due to the speed at which they cure and with which the newly sealed road can be opened to unrestricted traffic (Gransberg, et al, 1998). A second study done in the Atlanta District (Gransberg and Zaman, 2005) found that there was little difference in the long-term performance of emulsified-asphalt binders when compared to hot applied asphalt binders, except that the emulsion chip seals seemed to retain their skid resistance for a longer time due to the fact that the aggregate does not need to be precoated as is done in hot applied asphalt binder chip seals. It also found that the emulsion chip seals were more cost-effective than the hot applied asphalt chip seals. Since that study a number of TxDOT districts have begun to use more emulsion chip seals generally reserving them for lower volume roads where the need to remove traffic control as fast as possible is much less.

One of the "myths" about chip seal is that it is literally an "art" and cannot be replicated scientifically nor relied on to produce consistently reproducible performance like hot-mix asphaltic concrete (Gransberg and James, 2005). As a result, many US transportation agencies have treated it more like a commodity that is purchased in bulk than an engineered product that is design and constructed in accordance with the designer's specifications and plans. NCHRP Synthesis 342 found that transportation agencies overseas do not share this concept and as a result not only have invested in a continuing research program but also have developed rational engineering design procedures that utilize objective engineering measurements to not only characterize the condition of the existing road's surface for use in design but also are used to monitor the new chip seal's performance across its design life. They also use these measurements to pay their contractors based on the performance. This project will use the Transit New Zealand P/17 sand circle test as an objective engineering measurement for the first time in the US. More information on the details of this procedure is contained in a subsequent section to this report.

As a result, this project will seek to not only compare the performance of two chip seal binder types in the field but it will also demonstrate for the first time in North America the use of an objective engineering measurement to quantify the difference, if any, in performance of each chip seal.

METHODOLOGY

Overall Purpose of the Effort

The objective of the research is to correlate field texture measurements and qualitative ratings taken over a three-year period to the Pavement Management Information System (PMIS) skid and pavement condition data.

General Description of Area

The test sites are located on Farm-to-Market (FM) roads in the South Texas Region. Specifically, they are located in Atascosa, Frio and Wilson counties of the Texas

Figure 1: Location within State—Atascosa, Frio and Wilson Counties

Department of Transportation San Antonio District as shown in Figure 1. Historically, this region is an agricultural area that is made up of mostly prairie interspersed with mesquite, prickly pear, and a variety of other woody vegetation. Most of the woody vegetation was restricted to waterways (rivers, creeks, etc.). Today, due to the overgrazing of livestock and lack of controlled fires, the region's landscape has seen a vast increase in brushy vegetation—dominantly mesquite. Subgrade soils typical of the region are:

- Silty Clay
- Clay Loam
- Clay
- Cherty Clay Loam
- Cherty Clay

- Fine Sandy Loam
- Sandy Clay
- Sandy Clay Loam

The area is characterized by generally light traffic volumes (>600 vehicles per day) though Interstate 35 and a number of the urban roads generally see much higher volumes of traffic. Most of the FM roads are surfaced with a hot-applied asphalt seal coat. These seal coats were done using either a Grade 3 or Grade 4 aggregate. Figure 2 shows the locations of each of the roads that were surveyed and the specific locations of the test sites that were established on each road. The sites were selected on roads that generally receive roughly the same level of traffic and that generally covered the area from east to west. Specific test sites were selected first on a basis of safety primarily picking locations where the researchers would have adequate sight distance to watch for traffic. They were also selected on straight stretches of road to ensure that localized distress due to turning and superelevation did not impact the texture measurements that were taken on the test sites.

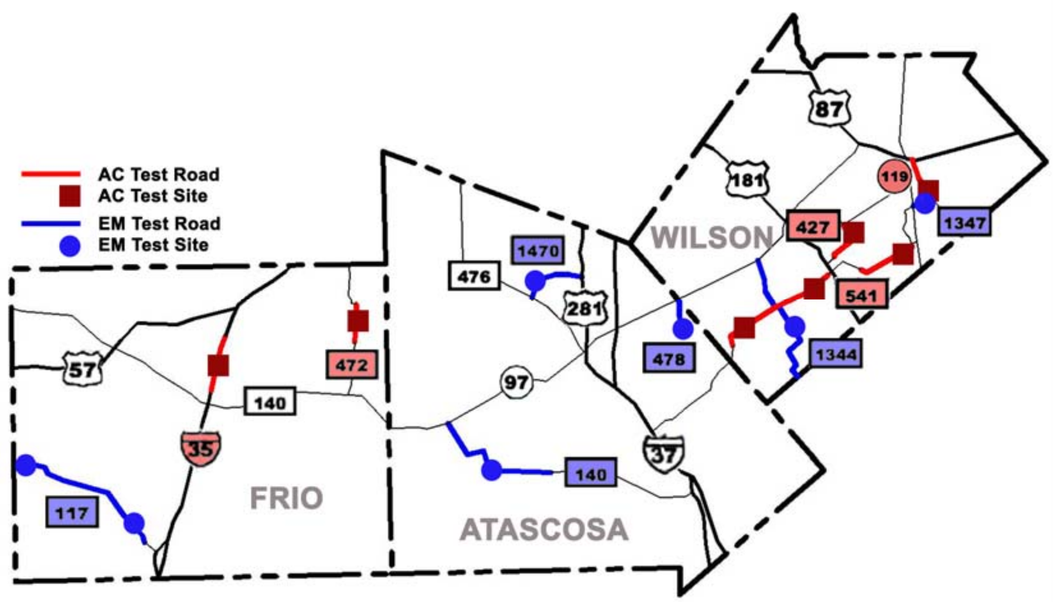

Figure 2: Location of Test Roads and Sites within Counties

Field Research Methods

The three-year research period is a compilation of three (3) major data collection processes:

- Qualitative "windshield" analysis of chip seal visual condition along the entire test road,
- Chip seal imaging of given locations at each test site, and
- Transit New Zealand Specification P/17 - Sand circle testing of given locations at each test site.

The processes occur at each test road, and follow consistent procedures each time they are performed to ensure the most accurate data possible. There will be a total of thirteen (13) test site data collection visits performed over the three-year period—four (4) each year after the new seals are constructed, and one (1) pre-condition test performed at the project's start to provide a means of correlating the roads' pre-existing condition to its condition over the test observation period.

Locating Test Roads and Sites

Before the testing could begin, the actual test roads and test sites had to be selected during the pre-condition stage of the project. Data collection roads were chosen based on regional location (San Antonio, Texas), chip seal type (six (6) emulsion roads, six (6) AC roads), and traffic count (all test roads have similar traffic volumes—approximately 100-600 vehicles per day). The first data collection occurred before new seals were placed to study the affect of previous conditions on the future character of the road. The Texas Department of Transportation (TxDOT) road markers (RM) provide fixed markers for locating purposes, and can be found every two (2) miles. Figure 3 is a typical TxDOT road reference marker. These markers allow the researchers to specifically return to each test site and also furnish a means of locational reference for the qualitative windshield condition surveys.

Figure 3: TxDOT Road Reference Marker

Test sites were marked using green and pink surveyors flagging attached to a nail that was driven in the edge of the pavement at the location where the sand circle tests and corresponding digital images were taken. The pink flag was placed on the side of the road that the corresponding road reference marker was located and the green was placed on the opposite side of the road. As much as possible, these flags were located in line with a road reference marker. In those instances where this was not possible due to safety sight distance

Figure 4: Green Flagging

requirements, they were placed in a measured correlation with some other off-road landmark such as a mailbox, a power pole, or a fence post. Figures 4 and 5 show the results of this marking system.

Figure 5: Pink Flagging

These test site markers were originally emplaced before the 2005 seal coat projects were shot. The research team returned in late June 2005 after the chip seals were complete and re-established the markers as required. About 80% of the original markers had been covered by the new seal coats. Nevertheless, the locational protocol that established them in relationship to a road reference marker or other landmark allowed the team to easily and confidently re-establish this test site control measure. In a number of cases, the team was able to discover the original flagging after measuring the recorded distances from the road reference markers or other landmarks, thus confirming the integrity of the test site set-up procedures. Once the test sites and test roads have been marked, the data collection on each of those roads can be completed.

Field Data Collection

Field data collection consisted of both qualitative (windshield analysis) and quantitative (TNZP/17 Sand Circle texture depth measurements and digital imaging). The qualitative sampling occurred along the entire length of each test road whereas; the quantitative samples were restricted to a single location on each test road. The data collection protocol was established and followed as described in the following sections to this report.

Qualitative Windshield Analysis Procedure

The purpose of the qualitative windshield analysis procedure was to furnish a record of pavement surface condition before the seals were installed and then to follow the progress of pavement surface condition over time. This was done to test the hypothesis that the performance of the new seal is closely related to the condition of the substrate surface upon which it is installed. The protocol is as follows:

1. Two person procedure: Starting at the road first road reference marker, person A shall drive, watch the odometer and call out every 1/2 mile point; person B shall analyze and record the road condition for each half mile.

2. Each test road exists on a section of road that will be analyzed along the road section that has been continuously sealed—the length of the seal determines the length of the windshield analysis.

3. Each time the road data is collected, the road shall be analyzed travelling the same direction.

4. When the first designated RM is located on the road the vehicle shall be stopped and the odometer shall be set to zero. Person B shall record the road condition at that point and person A shall inform person B every 1/2 mile and at every RM, so person B will know when to make the recording.

5. Figure 5 is an example of the windshield analysis form for the 18 August 2005 evaluation. There are ten road condition classifications:

    a. Satisfactory: road texture appears to be uniform across the lane width.
    b. Flushing evident: some localized flushing can be observed but it has not generalized itself along a specific wheel path.
    c. One wheel path flushed: flushing is evident in one wheel path but not the other.
    d. Two wheel paths flushed: flushing is evident in both wheel paths but has not spread between them.
    e. General flushing: flushing is evident across the lane and is no longer confined to the wheel paths.
    f. Reseal: a strip seal or other repair has been made and is obviously newer than the remaining seal along the test road.
    g. Localized shelling evident: some small loss of aggregate in random patches is observed.
    h. Localized shelling ½ lane: some loss of aggregate is observed across only ½ of the lane.
    i. Localized shelling full lane: some loss of aggregate is observed across the full lane.
    j. General shelling: loss of aggregate in large patches along the general length of the rated section.

6. When necessary, person B may wish to step out of the vehicle to confirm if he/she is analyzing the road condition accurately.

7. The windshield analysis shall be recorded continuously. When the analysis is complete, the researchers will then return to the designated data collection point to complete the data collection.

8. Figure 6 graphs the road conditions as they appeared during each research date and is for FM 478 during the 18 August 2005 evaluation. The goal is to determine how the pre-existing road conditions affect the integrity of the new seal over time. The graph will extend to display the road condition observed in each quarter throughout the three (3) year study period.

AEMA RESEARCH **SAN ANTONIO DISTRICT**

Seal Coat Research Data Sheet					Road Condition									
Date	Test Section #	Location	Reference Points	Binder	Satisfactory	Flushing Evident	One Wheel Path	Two Wheel Paths	General Flushing	Reseal	Localized Shelling Evident	Localized Shelling 1/2 Lane	Localized Shelling Full Lane	General Shelling
18-Aug-05	FM 478	Atascosa/ Wilson	**RM 0528**	EM										
		County Line	mile 0.5											
		East of Jourdanton	mile 1.0											
			mile 1.5											
			RM 0526											
			mile 2.5											
			RM 0524											

Figure 5: Example, Windshield Analysis Data Collection Chart for FM 478

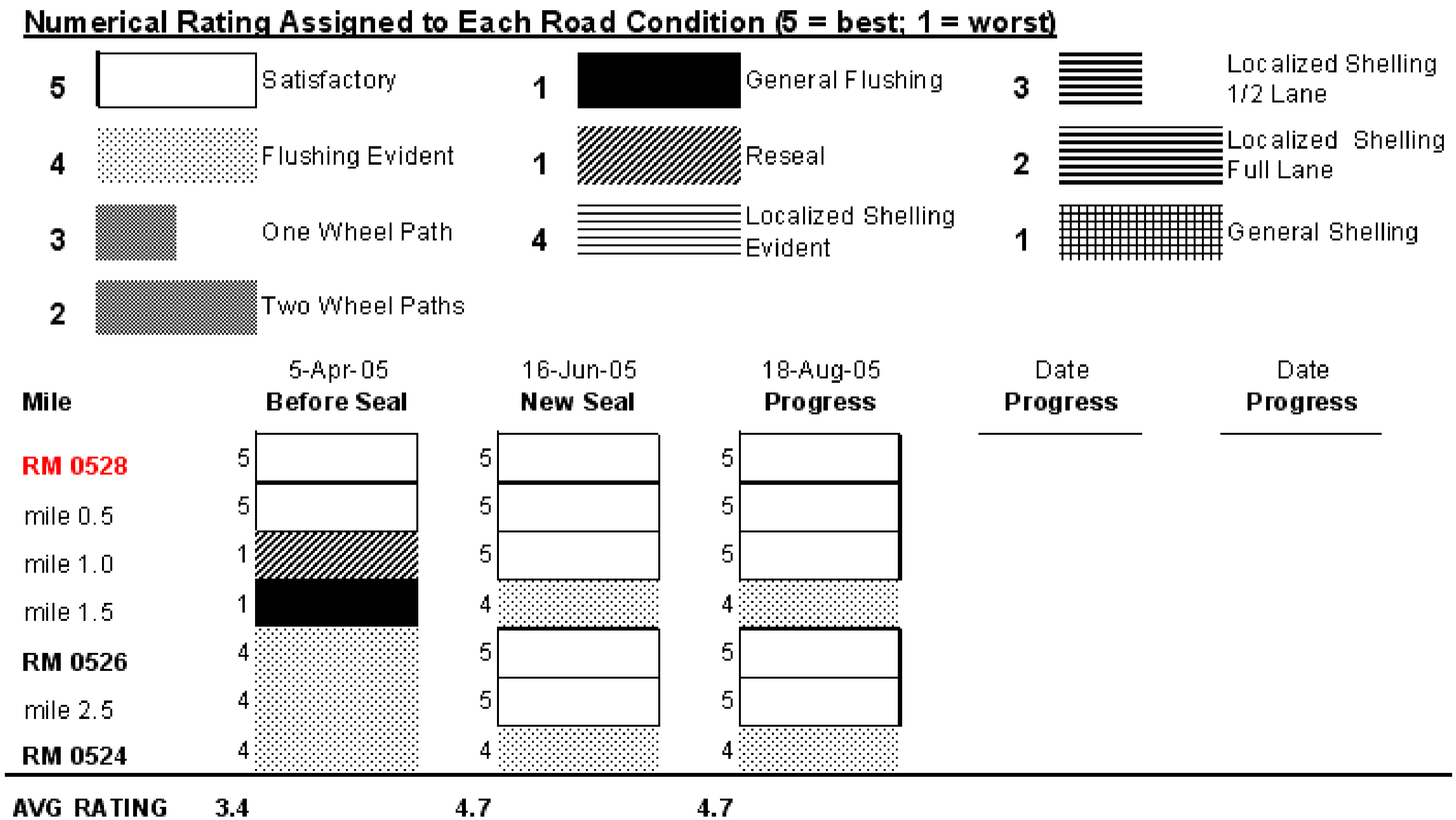

Figure 6: Example, Windshield Analysis Comparison Chart for FM 478

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Figure 6 shows a utility theory-based rating system for tracking the change in overall road condition with respect to time. The 0 to 4 point system was established using safety as the main factor against which to establish the rating. Thus, “general flushing” is the most dangerous condition and a chip seal failure due to “shelling” is not nearly as dangerous as is a failed area that has had a strip or spot seal (called “reseal”). This was selected to track with the pavement texture measurements that are a metric that can best describe surface friction or skid resistance.

Once the qualitative data collection for a given test road was complete, the quantitative sampling could begin. This essentially consisted of three steps. First, the test site was located utilizing the system described above. Next, three digital images were taken in each lane: one in each wheel path and one between the wheel paths. Finally, TNZP/17 sand circle tests were taken at the same exact location as the digital image. The protocols are described below.

Locating Test Sites

The test site location—where images are taken, and sand circle tests are performed—are chosen based on safety and proximity on the test road. When choosing the data collection point, a location near the middle of the test road at a designated RM was first considered. If safety at that location was not satisfactory, then a point was chosen as closes to the central location as could be had providing a safe location and preferably at a RM. Though not all test sites are located at a RM, all sites are referenced to a RM for future locating purposes. Safe locations were determined by visibility of oncoming traffic, and shoulder widths and driveways that give researchers the ability to safely step off the road.

Digital Imaging Background

The imaging technique used in this research project was discovered on a seal coat research project funded by the Texas Department of Transportation (TxDOT): Statewide Seal Coat Constructability Review; TxDOT research project 0-1787. In that project, the researchers conducted site surveys of representative chip seal sections in each of the twenty-five TxDOT Districts in conjunction with a state-wide chip seal constructability review (Gransberg et al, 1998). District personnel were asked to pick site survey sections that typified the overall quality of the chip seals in their districts. During each of these site surveys, the condition of the roadway was recorded by taking digital camera images to document the quality of pavement condition on each section. These images not only showed the overall condition of the roadway but also showed close-up views of the shoulder, wheel path and the area between the wheel-paths. A standardized camera setup was used where the camera angle, zoom and height were kept constant in each of the images. Three of these images – shoulder, wheel path and between wheel-paths were used to find an objective parameter that would quantify the quality level of the chip seal surface.

The parameter selected was the information content of each image as calculated by a mathematical transform to be discussed later in this report. In essence, each image was a finite amount of information contained within its boundaries. This information can be measured by determining the relative change in luminance intensity between adjoining pixels in the image. This relative difference in luminance is called the spatial frequency. For example, if the luminance intensity of one pixel is high and the intensity of the next pixel is low, the difference between the pixels is a large number, and the two pixels would be said to have a high contrast and a correspondingly high spatial frequency. On the other hand, if two adjoining pixels have luminance intensities that are nearly equal, they would have low contrast and low spatial frequencies. High contrast occurs at the boundaries between two different objects in an image (Ellis, 1976). The relative visibility of an object against its background is a function of the amount of contrast (Cuvalci, et al, 1999). Figure 7 illustrates this concept graphically. Thus, in the chip seal image, the contrast is formed by the amount of light reflected off the exposed aggregate against the amount of light reflected off the background formed by the asphaltic binder (Christie, 1954). The Texas study found that TxDOT maintenance personnel could easily discern between a satisfactory chip seal surface and an unsatisfactory one by merely looking at it (Gransberg, et al, 1999). It was also obvious to the naked eye that the difference between chip seal performance success and failure had to do with the relationship between the aggregate and the surrounding binder. Therefore, it was postulated that one could measure the surface condition by correlating the information content of a digital image and the qualitative rating of the human expert. Such an objective metric would significantly facilitate the decision-making process of allocating funds among several chip seal candidate sections on a basis of a quantitative comparison rather than qualitative comparison.

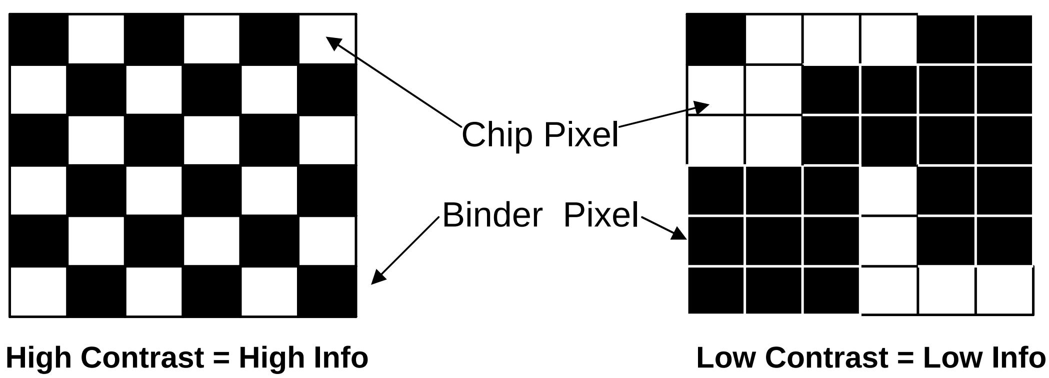

Figure 7: Information Content Measured as a Function of Contrast

The Image Processing Toolbox of MATLAB ® software (MATLAB, 2000, Tang, 1999) was utilized to process the digital images of chip seal test sections in Texas. The processing of the chip seal images consisted of filtering the information content found in the images and quantifying this filtered information. One way to filter information in such an image is detecting the edges of the aggregate particles (i.e. focusing on the boundary between the aggregate and the surrounding binder). As will be seen later, the edge patterns of flushed, shelled and satisfactory pavement surfaces exhibit a significant difference. This difference in edge patterns constituted the main analysis tool to differentiate a flushed or stripped surface from a satisfactory pavement. When a sufficiently large population is imaged and its qualitative performance rating is associated with the product of the FFT image processing output, a distinct difference can be seen between chip seal surfaces with satisfactory texture and those that have failed either by flushing or shelling. Figure 8 comes from the previously mentioned article that reported the proof of this concept (Gransberg et al, 2002). One can easily see the potential for associating a quantitative rather than qualitative texture rating and being able to regress the relationship between the physical texture measurement and its associated image processing output to derive a formula that would allow the engineer to compute the texture measurement from the image output.

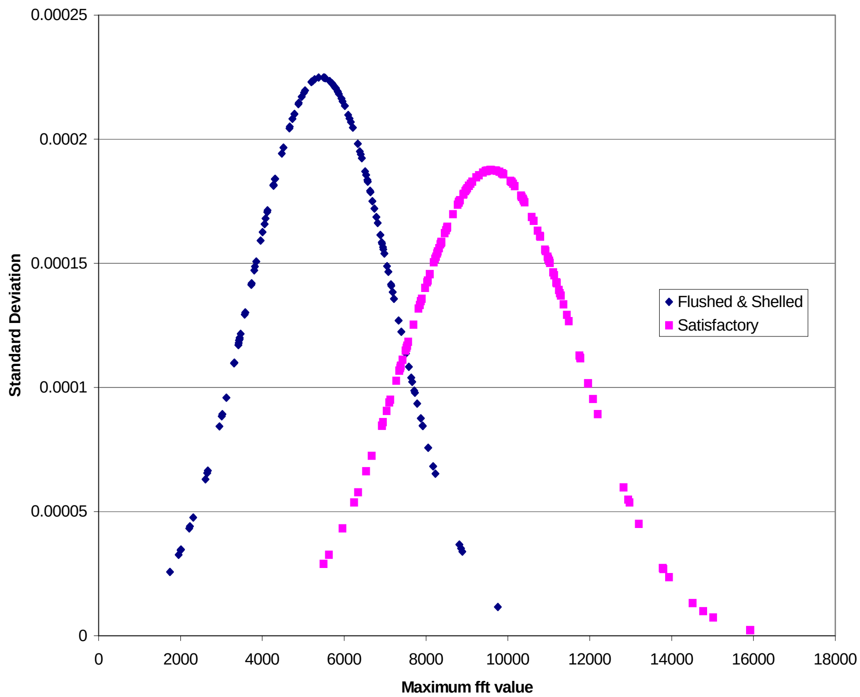

Figure 8: Normal Distribution of Maximum FFT Values for Different Textures. (Gransberg, et al, 2002)

It should be noted at this time that work on developing the regression equations suggested above is progressing in a research project funded by the New Zealand government and the data gathered on this project will be processed when x that work is complete and the equations will be validated for Texas.

Digital Imaging Procedure

The protocol for collecting the digital image data is as follows:

1. Two (2) person procedure: person A moves the camera with tripod and records images; person B watches for traffic and places washers that mark the site of the image for later sand circle testing.

2. Use a new 3-½ floppy disk to record the images for each test site.

3. Label 3-½ floppy disk by the road name and current date before inserting it into the camera to record images.

4. Mark the Northbound or Westbound lane with a nail and green flagging (Figure 4).

5. Mark the Southbound or Eastbound lane with a nail and pink flagging (Figure 5).

6. There are two adjustments per leg on the camera tripod. Adjust the tripod so that one (1) adjustment per leg is fully extended (Figure 9). Position the camera with respect to the sun so that the back leg lines up exactly with its shadow.

Figure 9: Tripod with legs properly adjusted

7. Attach the digital camera to the tripod so that it sits at a ninety-degree angle.

8. Zoom the camera to its maximum.

9. Starting at the wheel path nearest the pink flag, place the digital camera (attached to the tripod) ensuring that no shadows cross the area to be recorded.

10. Place a ¼" washer, painted fluorescent orange for visibility, under the center point of the tripod on the road's surface to mark the location of the recorded image ensuring that the washer will not be recorded in the digital image.

11. Record the image.

12. Pick up the camera and tripod, and proceed to the location of the next image.

13. Working towards the green flag, the digital imaging process and washer placement is performed a total of 6 times. Progressively working from the pink flag to the green flag (see Figure 10 for the image sequence).

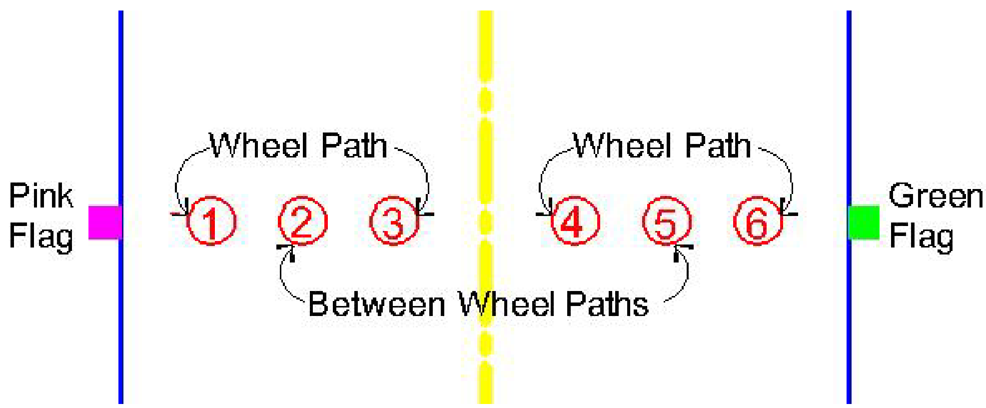

Figure 10: Image & Sand Circle Locations and Sequence relative to the Road

14. If forced to temporarily discontinue imaging due to traffic, leave the travelled way leaving the washers that have been placed on the road. Carefully observe the locations of the washers as the cars pass over them. If they are substantially dislodged, reimage those locations that were disturbed by the traffic. It should be noted that unless the tire of a car actually strikes a washer, the passage of traffic did not appreciably disturb the washers in the field.

15. Upon completion of the six images, input the correlating image number with its location on the road in the field data logbook (Figure 11).

SAN ANTONIO DISTRICT

WP = Wheel Path | N = North | E = East

BWP = Between Wheel Path | S = South | W = West

Seal Coat Research Data Sheet

					Field Sand Circle Measurments TNZP17					
					(NB) Northbound or (WB) Westbound			(SB) Southbound or (EB) Eastbound		
Date	**Test Section #**	**Location**	**Reference Points**	**Binder**	**Photo #**	**Wheel Path Location**	**SC (mm)**	**Photo #**	**Wheel Path Location**	**SC (mm)**
18-Aug-05	FM 117	West Dilley	0.5 miles West of RM 0562	EM	4	WB SWP	132	1	EB SWP	122
	West		At gate		5	BWP	125	2	BWP	110
			painted metal post		6	NWP	137	3	NWP	130
18-Aug-05	FM 117	West Dilley	At RM 0570	EM	4	WB SWP	120	1	EB SWP	250
	East				5	BWP	127	2	BWP	140
					6	NWP	170	3	NWP	150

Figure 11: Example, Sand Circle Test Form for FM 117 West & FM 117 East

Sand Circle Procedure Background

The sand circle test is used to measure the texture of the chip seal road surface. Surface texture refers to the macrotexture of the pavement surface (Austroads, 2004). Surface texture is a measurement which influences the nominal size of aggregate used for the chip seal and thus, ultimately determines material application rates, skid resistance, and road noise. Characterization of the pavement's surface texture is a critical step in the design process because non-uniform surface textures in both the transverse and longitudinal directions make it difficult to design a binder application rate.

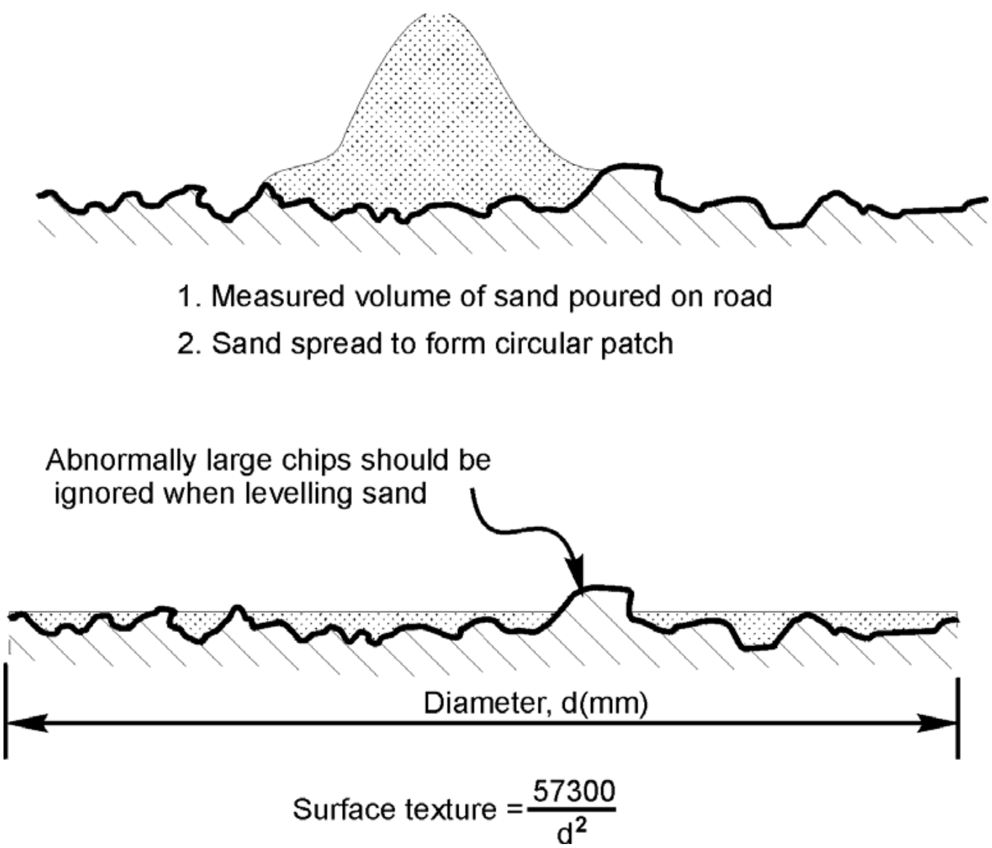

Figure 12: Sand Circle Test for Texture Measurement (TNZ T3, 1981)

Historically, the macrotexture has been measured using volumetric techniques, and the most common test procedure is the Sand Circle Method. This method involves spreading 45 ml of sand (particle size of 300 μm to 600 μm) by revolving a straight-edge until the sand is level with the tops of the cover aggregate (TNZ T3, 1981) (Figure 12). The volume of material that fills the surface voids determines the surface texture. The greater the average texture depth, the greater the quantity of material lost in the surface voids and the smaller the diameter of the sand circle. The average texture depth is calculated by dividing the volume of sand by the area of the sand circle (TNZ T3, 1981).

At the start of this project, the researchers planned to use the ASTM E965 sand patch test as well as the Transit New Zealand sand circle test. The ASTM test differs from the TNZ test in that the sand is finer (pass the #60, retained on the #80 versus TNZ gradation of pass the #40, retained on the #80) and it requires about half the TNZ volume of sand. Both tests worked well in the laboratory. However, when the researchers went to the field, they had great difficulty achieving a reasonable level of reproducibility with the ASTM test. There was a steady breeze in the field and it served to blow some of the testing sand away from the site of the test and as the volume of sand was small, the loss to wind was significant in degrading the ability of the test taker to consistently reproduce roughly the same circle diameter. The coarser sand and greater volume of the New Zealand test eliminated this problem in the field. Thus, it was decided to only measure texture using the TNZ test as it was functionally impossible to ensure that there was no wind during the filed trials.

Sand Circle Procedure

Once the washers for the digital images are in place and digital imaging is complete, sand circle tests can be taken at those locations in accordance with the following test protocol.

1. The sand circles shall be completed in the same order that the images were recorded.

2. One person shall perform all sand circle tests to maintain consistency and reduce error caused by subtle human differences.

3. Both persons shall wear hard hats, safety vests, long pants, and work boots (Figure 13).

Figure 13: Proper Attire includes a hard hat, safety vest, long pants, and work boots

4. While the data recorder watches for traffic, tester shall perform the sand circle test at each of the locations designated by the six washers, while the other person records the data read out by the sand circle tester in the field data book.

5. Fill three PVC cups with sieved sand. The PVC cups are 2” PVC plugs precisely cut to hold 45 milliliters of sand. The sand was passed through a #40 sieve and retained on a #80 sieve to achieve near-uniform particle size. See 3.1.1 Texture Measurement in the Literature Review for additional information on the sand circle process. Figure 14 shows the test equipment.

Figure 14: Testing Equipment (hockey puck, washer, sieved sand, PVC cup)

6. Top off cup with straight edge (i.e. ruler) to ensure a precise quantity of sand.

7. Setting your body up to block any wind that may be in evidence on the day of the test, carefully dump one cup of sand at the location where the first image was taken.

8. Using the spreading tool (hockey puck pictured in Figure 15), spread the sand using a circular motion until the voids in the pavement have been filled and the sand is even with the top of the pavement. The circle of sand should be as uniform as possible.

Figure 15: Researcher performing Sand Circle Test

9. Use a clear plastic metric ruler to measure the longest and shortest diameters of the sand circle—record the average of the two, in millimeters, as the circle's diameter.

10. Perform the next two sand circles to complete one traffic lane, refill the three cups with sand, and proceed to perform the test on the next lane.

11. Record all data, and travel to the next road site. Figure 16 shows a typical test site after the sand circle tests have been completed.

Figure 16: Southbound Lane Sand Circles on Highway 119

PAVEMENT MANAGEMENT INFORMATION SYSTEM DATA ANALYSIS

The analysis TxDOT Pavement Management Information System (PMIS) data will track the analysis done in a previous study complete under the auspices of the Asphalt Emulsion Manufacturers Association (AEMA) entitled: *Comparing the Performance of Emulsion Versus Hot Asphalt Chip Seal Projects in the Texas Department of Transportation's Atlanta District*. In that study, a series of cost indices were developed to compare the performance of various roads on both an engineering and an economic basis. At this writing, the only PMIS data available are the preseal road conditions. Therefore it is not possible to conduct those calculations in this report. Those calculations and analyses will be included in future reports as the updated data becomes available to the researchers.

PAVEMENT MANAGEMENT INFORMATION SYSTEM (PMIS)

TEXAS DEPARTMENT OF TRANSPORTATION

Numerical Rating Assigned to Each Road Condition

2005 Fiscal Year; Responsible District = 15 San Antonio

Rating		Rating	
RAV:	Raveling (Shelling)	**RD:**	Rut Depth
FLU:	Flushing	**PAV CON:**	Pavement Condition
DIS:	Distress Score		

EM RDs	**RAV**	**FLU**	**DIS**	**RD**	**PAV CON**
FM 117	0.0	2.2	80.3	3.4	80.3
FM 140	0.0	0.1	48.3	2.4	88.0
FM 1470	0.0	.9	54.3	2.8	53.3
FM 478	0.3	0.0	85.5	3.1	85.5
FM 1344	0.0	0.5	84.5	3.3	84.5
FM 1347	0.0	0.5	91.0	2.8	90.8
AVERAGE	**0.1**	**0.7**	**74.0**	**3.0**	**80.4**

AC RDs	**RAV**	**FLU**	**DIS**	**RD**	**PAV CON**
I-35 Front	No Data	No Data	No Data	No Data	No Data
FM 541 W	0.8	1.6	91.4	3.1	91.4
FM 541 C	0.0	2.5	82.4	2.9	78.9
FM 541 E	0.0	2.6	85.7	2.8	81.5
FM 427	0.0	0.5	38.3	2.4	38.0
Hwy 119	0.0	1.1	100	2.8	99.1
AVERAGE	**0.2**	**1.7**	**79.6**	**2.8**	**77.8**

Figure 17: 2005 PMIS Data Analysis for the Preseal Pavement Condition.

Figure 17 shows the preseal conditions of the roads in this study. Due to TxDOT policy, skid numbers were not released to the researchers. Therefore, only the pavement condition ratings can be compared. The researchers will make an effort to gain permission to get access to those numbers for future reports. As can be seen, on average the roads that received an emulsion chip seal (EM roads) were in somewhat better condition overall. The major differences were as follows:

- The roads that received the hot applied asphalt binder (AC roads) had more flushing.
- The EM roads had more slightly distress.
- The EM roads had more slightly rutting.

Additionally, one can see that there is a good range of preseal conditions amongst for types of roads. The EM roads range form a low pavement condition rating of 53.3 on FM 1470 to a high of 90.8 on FM 1347. The AC roads range from a low of 38.0 on FM 427 to a high of 99.1 on SH 119. Thus, the comparison will allow the researchers to watch the trend in each binders on roads that were in poor conditions at the time of the seal as well as on roads that were in excellent condition at the time of the seal. Additionally, the amount of preseal flushing is also across a nice range for both binder types as each has at least one road with no flushing and another that has a flushing rating above 2.0. This is particularly important to the methodology being used in this project. The New Zealand chip seal design method takes great care to characterize the road's existing surface using engineering measurements including the TNZP/17 sand circle. Thus, having not only a preseal rating for each road but also a representative range of preseal pavement conditions will make the outcome of this study authoritative for most conditions.

EMERGING RESULTS

The reader must remember that this project is literally in its infancy, and therefore, not attach too much significance to the results that are reported in the following sections. The reader must also be careful to put the graphical results in context. For example, the texture measurements should be viewed in a relative fashion looking at the change from the preseal condition for each binder rather than the differences between the two binders. The texture depth is measured in millimetres. For instance, the difference in average texture depth between the two binders two months after the new seal is 0.1 millimeters which is 0.004 inches, an extremely small difference.

Specific details for each road in the study are contained in the Appendix to this report. The overall results are synopsized below.

Qualitative Windshield Analysis Procedure

Data collected before the placement of the new seals displayed significant flushing in every road that was tested. The AC roads, on average, had a little less texture than the EM roads. Though the AC roads' pre-conditions were inferior to the EM roads, the two post-data collections indicate that the textures of the AC roads are slightly better than the EM roads. On average, both sets of roads are considered to be satisfactory at this juncture. The windshield analysis results to date are synopsized in Figure 18. It should be noted that originally the team surveyed FM 472 in Frio County which was scheduled to get a hot applied asphalt seal coat (see Figure 2). However, changes occurred during execution of the seal coat contract and that road was not sealed. Therefore, the team surveyed the Interstate 35 Frontage road north of FM 140 in Frio county instead to ensure that equal numbers of EM and AC roads would be followed. As a result, there is no recorded preseal condition for this road. However, in the initial reconnaissance looking for suitable test sections, the team did visit this road. It was in relatively decent condition with no major distress before the 2005 seal.

AVERAGE ROAD CONDITION RATING

(Determined through Windshield Analysis)

Numerical Rating Assigned to Each Road Condition
(5 = best; 1 = worst)

5	Satisfactory	**1**	Reseal
4	Flushing Evident	**4**	Localized Shelling Evident
3	One Wheel Path	**3**	Localized Shelling 1/2 Lane
2	Two Wheel Paths	**2**	Localized Shelling Full Lane
1	General Flushing	**1**	General Shelling

EM RDs	5-Apr-05 **Before Seal**	16-Jun-05 **New Seal**	18-Aug-05 **Progress**	EM RDs **w/o FM 1470**
FM 117	**2.1**	**4.5**	**4.2**	**4.2**
FM 140	**1.4**	**4.8**	**4.8**	**4.8**
FM 1470	**1.0**	**4.8**	**3.3**	
FM 478	**3.4**	**4.7**	**4.7**	**4.7**
FM 1344	**2.3**	**4.8**	**4.8**	**4.8**
FM 1347	**4.2**	**5.0**	**4.8**	**4.8**
AVERAGE	**2.4**	**4.8**	**4.4**	**4.7**
AC RDs				
I-35 Front	**No Data**	**5.0**	**5.0**	
FM 541 W	**2.6**	**4.9**	**4.8**	
FM 541 C	**1.3**	**5.0**	**5.0**	
FM 541 E	**1.0**	**4.8**	**4.5**	
FM 427	**1.9**	**4.8**	**4.7**	
Hwy 119	**2.7**	**5.0**	**5.0**	
AVERAGE	**1.9**	**4.9**	**4.8**	

Figure 18: Results of Qualitative Windshield Analysis

Visual analysis (windshield analysis) of both road types present unique challenges for each chip seal type. AC roads utilize a precoated stone that is dark in color, while EM roads use an uncoated stone that is very light. The difference requires the analyst to calibrate his/her eyes to each chip seal type. Some common issues that the analyst must be aware of include:

- AC roads may appear to be satisfactory when flushing or shelling is actually evident—the darker appearance of this road type masks possible imperfections.

- EM roads may appear to be poor when they are actually satisfactory, because vehicle tires can spread fresh oil down the road giving the appearance of flushing or shelling on a newly placed chip seal. The light color of the road accentuates this condition. It also makes distinguishing flushing from shelling difficult from a moving vehicle, forcing the research to stop frequently to be able to differentiate between a dark spot that is flushing and a similar dark spot that is actually shelling.

Looking at Figure 18, one can see that roads with both binder types were improved to nearly perfect condition. After the first progress sample (two months), it appeared that the EM roads had started to deteriorate faster than the AC roads. However, when looking back into the preseal data (Figure 19), it was found that FM 1470 had apparently failed due to flushing at some point in its recent past and had a reseal applied. This would tend to make it have a higher binder content than a road with a 5 to 7 year old seal in it. The August 18th survey showed that the road was starting to flush prematurely and that can be attributed to the reseal.

Figure 19: FM 1470 Windshield Analysis

When FM 1470 was removed form the sample, the average change in the EM roads was the same as the AC roads. Given the inherent difficulties discussed above with the inherent visual differences between the "black rock-black binder" AC roads and the "white rock-black binder" EM roads, the research team will focus not on the discreet average condition number but rather the differences between the changes in the qualitative condition numbers over time.

The results to date show the integrity of the research protocol and more importantly the importance of characterizing the existing surface prior to chip sealing to assist the observer in understanding the actual performance of the new seal. The issue that arose with FM 1470 as described above, graphically pointed out both the value of having a record of preseal surface condition and the value of post-seal monitoring of seal coat performance to gain knowledge on means and method that can be used to improve the overall performance of a public agencies pavement preservation program.

Digital Imaging Procedure

At this juncture, the algorithm for texture measurement using digital imagery is still under development and therefore, not available. Thus, no analysis of the images taken so far can be done. Nevertheless, the archive of chip seal images will furnish a valuable resource for future use in Texas as the technology is refined and fielded in New Zealand. It will also serve as a visual record of chip seal performance over time for both of the binder types being studied in this project.

Sand Circle Procedure

Figure 19 shows the overall results for the average texture comparisons in the wheel paths of the EM and AC roads (the greater the depth, the higher the texture rating). Figure 20 shows the results between the wheel paths and Figure 21 is the average texture depth calculated using a mathematical average of the data shown in the two previous figures. The texture depth in the wheel paths is probably the measurement of greatest interest. Transit New Zealand states that traffic can be used to enhance aggregate embedment by "traffic control to direct slowly moving vehicles over the fresh seal and to move the traffic stream gradually across the entire width of the seal to aid in compaction…" (TNZ, 2005). Thus, they depend on the additional embedment that is achieved by traffic on a new seal. In Texas, this will only happen in the wheel paths as policy is to open a newly sealed road to traffic as soon as feasible.

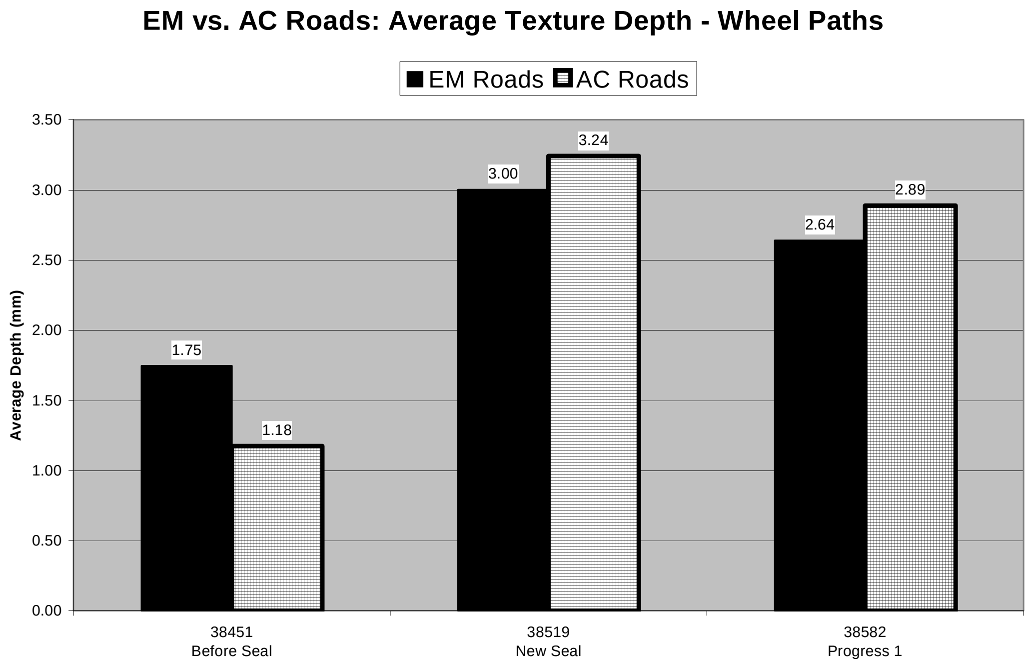

Figure 19: Overall Comparison of Texture Depth Change in the Wheel Paths to Date.

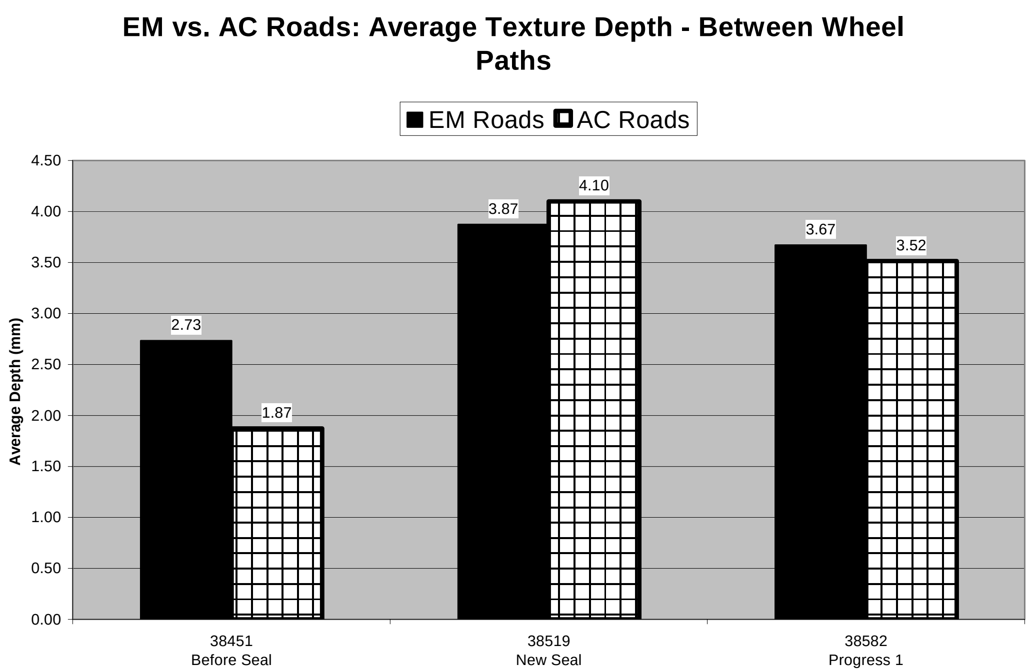

Figure 20: Overall Comparison of Texture Depth Change Between the Wheel Paths to Date.

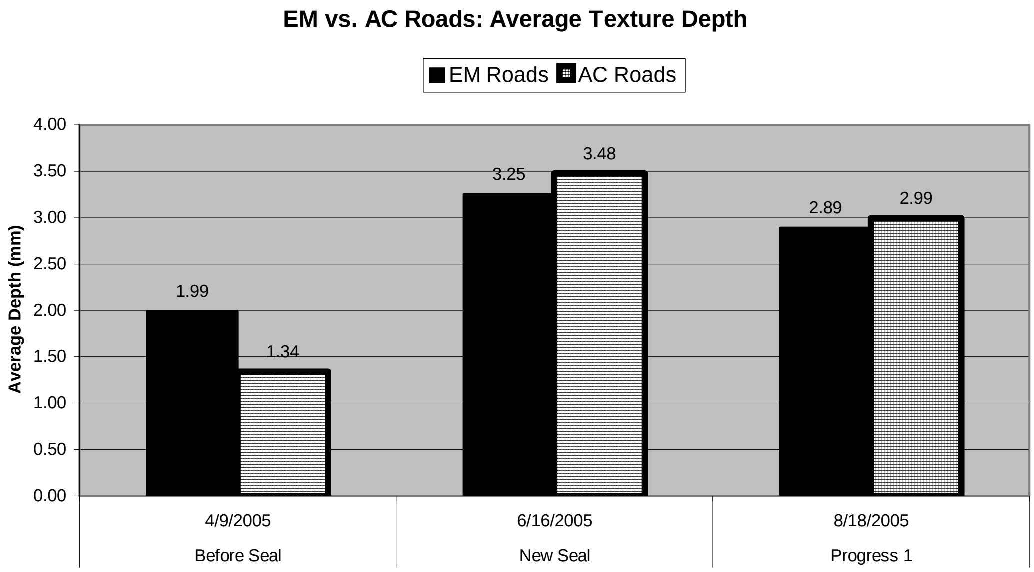

Figure 21: Overall Comparison of Texture Depth Change to Date.

When looking at the three figures, the reader must remember that the texture depth shortly after a new seal is primarily a function of the size of the aggregate and the amount of rolling that was completed during chip seal construction. Therefore, the discreet measurements of texture between the two binders are not nearly as informative as the change in texture over time. In Figure 19, one can see that both the AC and the EM roads lost approximately 0.35 millimeters of texture between the new seal reading and the first progress measurement. Between the wheel paths, Figure 20 shows that the EM roads lost only 0.2 millimeters whereas the AC roads changed by 0.58 millimeters. Thus, the AC roads apparently either gained embedment between the wheel paths because the construction rolling was inadequate or more likely, the embedment due to traffic was greater because the substrate was softer. As the AC roads had more flushing prior to the seal, this second explanation seems more logical. Finally, when the average change in texture depth is considered in Figure 21, The EM roads lost 0.36 millimeters of depth while the AC roads lost 0.49 millimeters.

To put this into perspective, Transit New Zealand defines a chip seal failure due to flushing as:

- "When the chip seal's texture depth is less than 0.7 mm in areas where the posed speed is less than 70 kilometers per hour (43.5 mph)
- "When the chip seal's texture depth is less than 0.9 mm in areas where the posed speed is greater than 70 kilometers per hour (43.5 mph)

In the appendix, one will find that only FM 541 Central and FM 541 East (both AC roads) would have been considered as failed due to flushing before the new seal was applied. Table 1 shows the change in texture depth for these two test sections. It can be seen that FM 541 Central was only failed in the wheel paths; whereas, FM 541 East was failed across the entire section. On FM 541 East, the wheel paths gained better than a full millimeter of texture with the new seal, but at the next measurement, the wheel paths are already nearing the failure level of 0.9mm. This may be due to traffic embedding the aggregate into the soft flushed substrate, or it is also possible that there was rutting in the wheel paths that cause them to be flood with binder during the new seal creating excessive binder in the wheel paths that will lead to premature flushing.

Table 1: Change in Texture Depth on Two Roads That Were Failed Due to Flushing Prior to the New Seal.

Road	Before Seal			New Seal			Progress 1 8-18-05		
	Ave Text Depth	Ave WP Text Depth	Ave BWP Text Depth	Ave Text Depth	Ave WP Text Depth	Ave BWP Text Depth	Ave Text Depth	Ave WP Text Depth	Ave BWP Text Depth
FM 541 Central	0.99	0.78	1.80	3.86	3.54	4.65	3.75	3.27	3.91
FM 541 East	0.77	0.72	0.89	2.12	1.74	3.34	1.33	0.99	2.92

One issue that must continually be brought to the front is the idea that a “deep” texture represents a satisfactory condition. There is a point where high texture depth signifies shelling. This is usually the case near four millimeters. Also, while is it intuitive that the texture depth should decline over time at each site, it is impossible to take the texture measurement in exactly the precise location each time. Therefore, due to the inherent variation in the pavement in the roughly one foot radius in which the test is actually taken, it would be expected that some of the individual test site measurements might get seemingly deeper instead of shallower because of the fact that the sand circle was taken in slightly different locations over time. Additionally, the amount of wind that is present at the time of the test could also cause the sand circles to be artificially smaller in diameter than ones taken on calm days. This test has its limitations and the other countries that use it account for that by taking 3 to 5 tests in each location and using the average of those tests. This project does not have the luxury of setting up the traffic control that is necessary to take that many tests in a single location. Therefore, the research team will have to live with the occasional counterintuitive outcome created by the constraints of the tests and the weather conditions.

EMERGING CONCLUSIONS

At this point it is too early in the research to develop any authoritative conclusions with respect to the comparative performance of the two binder types. Nevertheless, several observations of potential trends are possible. First, it appears that both binder types seem to be furnishing satisfactory performance in their early lives. Neither the qualitative nor the quantitative measures indicate poor performance of either binder type. Thus, at this point it appears that the emulsion binders are performing at least as well as the hot applied asphalt binders when the preseal conditions of the substrate are taken into account. Next, the quantitative measures of texture depth appear to show that the emulsion roads are losing their texture depth at a slower rate than the AC roads. This is probably due to the increased amount of flushing that was present on the substrate of the AC roads prior to sealing. Once again the importance of having a detailed knowledge of the existing surface prior to the new seal coat is vital to explaining seal coat performance. Finally, the qualitative rating of the emulsion roads may be more severe than the AC roads because of the great contrast between the uncoated aggregate and the binder. Therefore, both the research team and the reader must be careful to not attach an excessive amount of meaning to the windshield analysis.

At this point, the research methodology has proven itself to furnish useful output data. Even at this early point in the research, it has proven authoritatively the hypothesis that the condition of the substrate will impact the performance of the new seal coat. This is shown by the early flushing of EM road FM 1470 and the fact that the AC roads that were shot on top of flushed substrate are losing their texture depth at a rate that is faster than those whose substrate was not as highly flushed prior to the new seal. While this is certainly not "new knowledge" to the members of TxDOT and the chip seal industry, this is the first time in Texas and by the author's knowledge in North America that a quantitative measurement has been use to prove what has been suspected for quite a long time. Thus, the methodology used in this project is proving itself to be very valuable in developing a rationale method using engineering measurements to objectively evaluate the post-seal performance of chips seals.

The only recommended change at this point is to remove FM 1470 and I-35 Frontage road from the data sample. The condition on which the new seal for FM 1470 was applied is atypical. Because the data sample is small, it will unnecessarily skew the numerical results. To keep the AC and EM samples the same size (i.e. 5 roads), the I-35 Frontage road can be removed as the team did not get to conduct a preseal survey of its condition and as a result there is not "before" data against which to compare its performance. The team believes that this can be done without sacrificing the integrity of the research outcome.

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APPENDIX

The following pages contain the individual details of each road that has been surveyed to date. Both the qualitative windshield survey and the quantitative texture depth changes are provided for every road in this project.

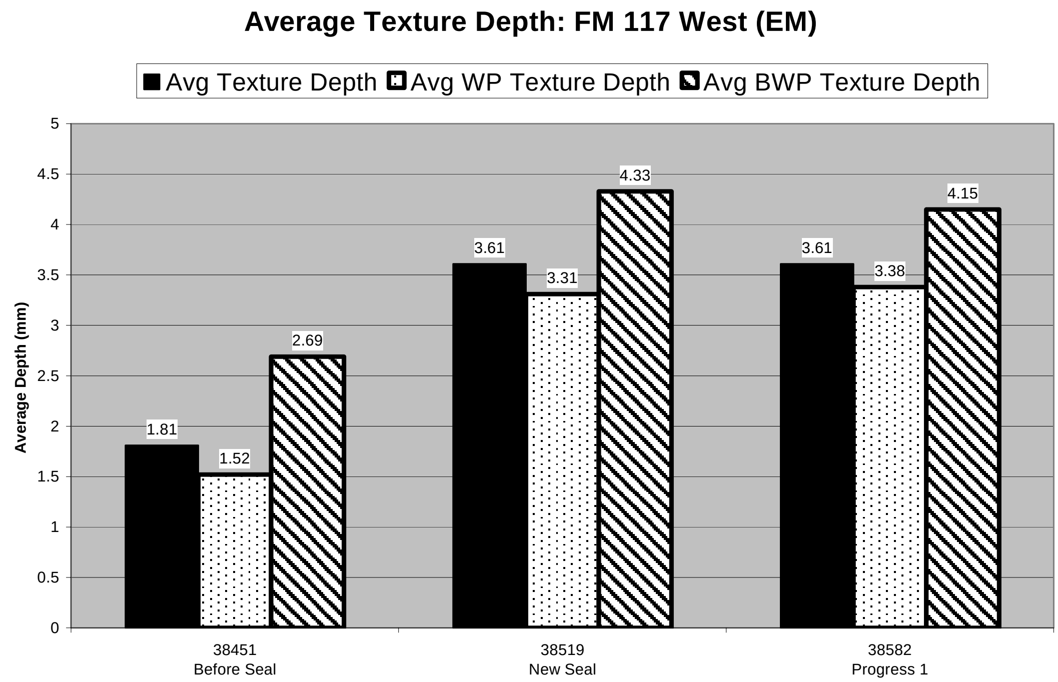
The reader must remember that due to the impossibility of taking the TNZP/17 sand circle test in EXACTLY the same spot, it is possible for a reading to show a momentary increase over time. Nevertheless, by the end of the 3-year project period the trend will correct itself.

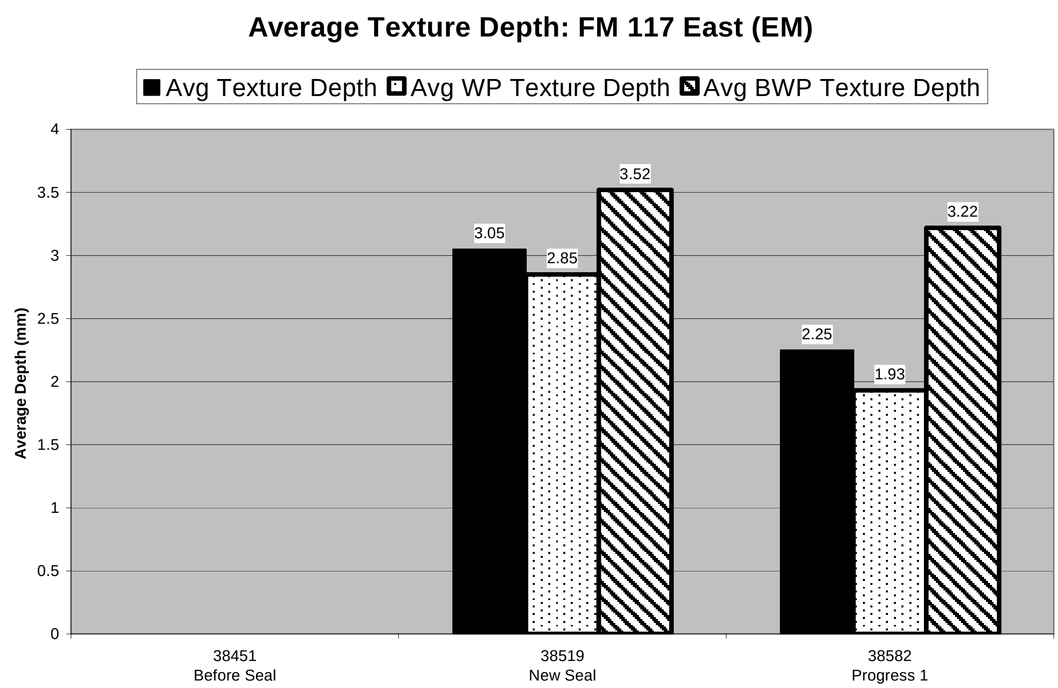
Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

5	Satisfactory	**1**	General Flushing	**3**	Localized Shelling 1/2 Lane
4	Flushing Evident	**1**	Reseal	**2**	Localized Shelling Full Lane
3	One Wheel Path	**4**	Localized Shelling Evident	**1**	General Shelling
2	Two Wheel Paths				

FM 117 **Mile**	**EM**	5-Apr-05 **Before Seal**	16-Jun-05 **New Seal**	18-Aug-05 **Progress**	Date **Progress**	Date **Progress**
RM 0562		2	5	5		
mile 0.5		1	5	4		
mile 1.0		1	5	4		
mile 1.5		1	5	5		
RM 0564		1	5	5		
mile 2.5		4	5	5		
mile 3.0		4	4	4		
mile 3.5		1	4	4		
RM 0566		1	5	5		
mile 4.5		5	5	5		
mile 5.0		4	5	5		
mile 5.5		4	5	5		
RM 0568		1	5	5		
mile 6.5		4	5	5		
mile 7.0		1	5	5		
mile 7.5		1	5	4		
RM 0570		1	5	3		
mile 8.5		5	4	3		
mile 9.0		1	2	2		
mile 9.5		1	2	2		
RM 0572		1	4	4		
AVG RATING	**2.1**		**4.5**	**4.2**		

FM 117


Average Texture Depth: FM 117 West (EM)
Avg Texture Depth
Avg WP Texture Depth
Avg BWP Texture Depth
Average Depth (mm)
1.81
1.52
2.69
3.61
3.31
4.33
3.61
3.38
4.15
38451
Before Seal
38519
New Seal
38582
Progress 1

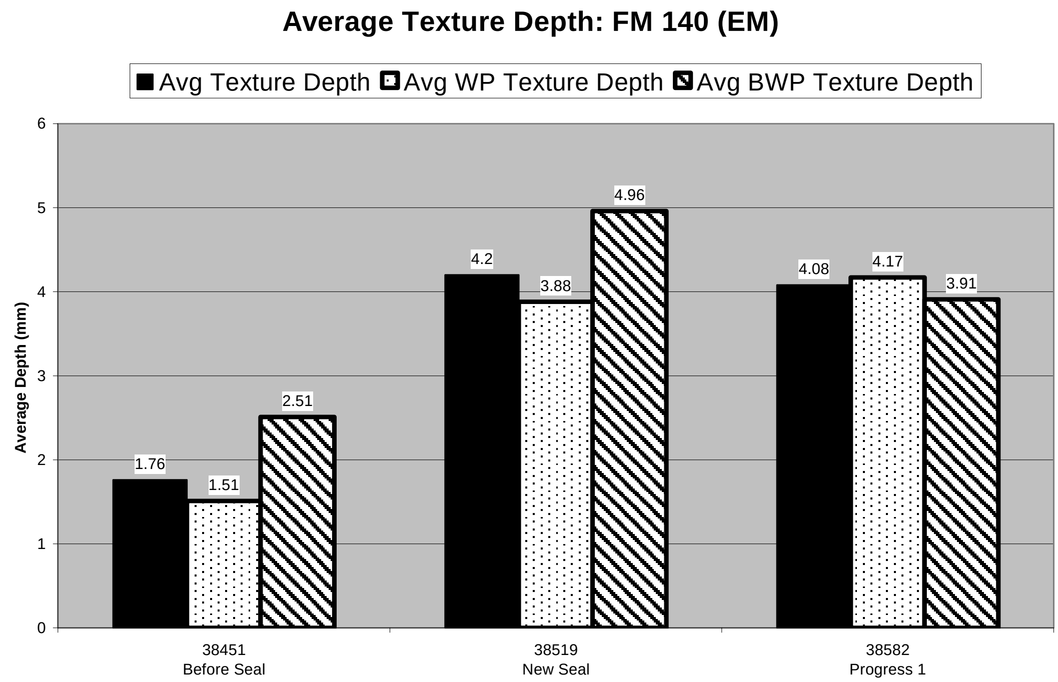

Average Texture Depth: FM 117 East (EM)
Avg Texture Depth
Avg WP Texture Depth
Avg BWP Texture Depth
Average Depth (mm)
3.05
2.85
3.52
2.25
1.93
3.22
38451
Before Seal
38519
New Seal
38582
Progress 1

Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

5	Satisfactory	**1**	General Flushing	**3**	Localized Shelling 1/2 Lane
4	Flushing Evident	**1**	Reseal	**2**	Localized Shelling Full Lane
3	One Wheel Path	**4**	Localized Shelling Evident	**1**	General Shelling
2	Two Wheel Paths				

FM 140 EM **Mile**	5-Apr-05 **Before Seal**	16-Jun-05 **New Seal**	18-Aug-05 **Progress**	Date **Progress**	Date **Progress**
RM 0492	4	5	5		
mile 0.5	1	5	5		
mile 1.0	1	4	4		
mile 1.5	1	5	5		
RM 0494	1	5	5		
mile 2.5	1	5	4		
mile 3.0	1	5	5		
mile 3.5	1	5	5		
RM 0496	1	5	4		
mile 4.5	5	5	5		
mile 5.0	4	5	5		
mile 5.5	1	5	5		
RM 0498	1	5	5		
mile 6.5	1	5	5		
mile 7.0	1	5	5		
mile 7.5	1	5	5		
RM 0500	1	5	5		
mile 8.5	1	5	5		
mile 9.0	1	5	5		
mile 9.5	1	4	4		
RM 0502	1	5	5		
mile 10.5	1	5	5		
mile 11.0	1	5	5		
mile 11.5	1	4	4		
RM 0504	1	4	4		
AVG RATING	**1.4**	**4.8**	**4.8**		

FM 140

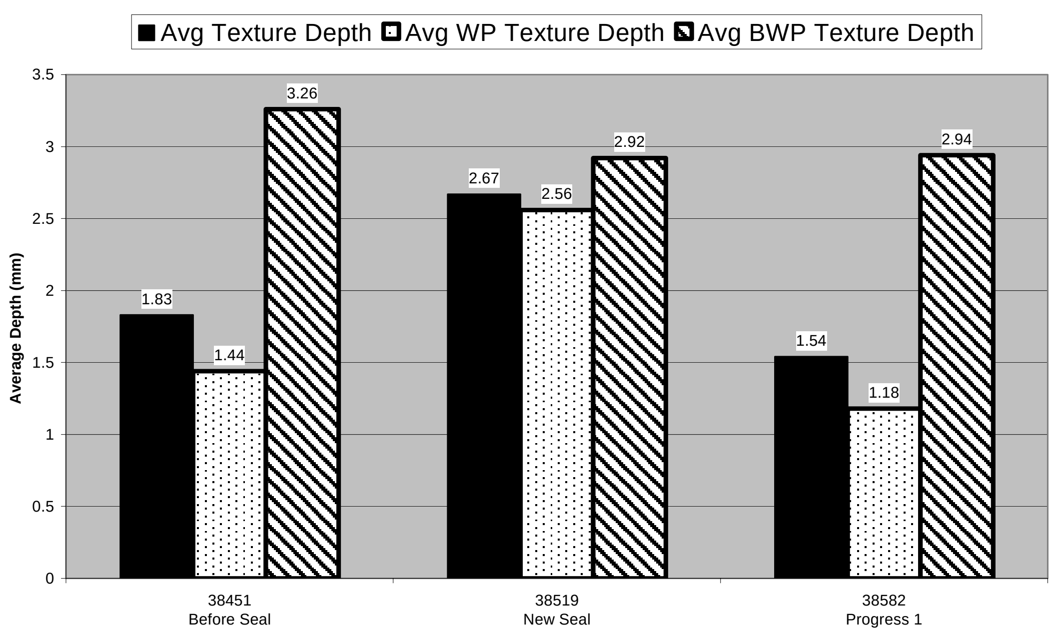

Average Texture Depth: FM 140 (EM)
Avg Texture Depth
Avg WP Texture Depth
Avg BWP Texture Depth
Average Depth (mm)
0
1
2
3
4
5
6
1.76
1.51
2.51
4.2
3.88
4.96
4.08
4.17
3.91
38451
Before Seal
38519
New Seal
38582
Progress 1

Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

5	Satisfactory	1	General Flushing	3	Localized Shelling 1/2 Lane
4	Flushing Evident	1	Reseal	2	Localized Shelling Full Lane
3	One Wheel Path	4	Localized Shelling Evident	1	General Shelling
2	Two Wheel Paths				

FM 1470 EM Mile	5-Apr-05 Before Seal	16-Jun-05 New Seal	18-Aug-05 Progress	Date Progress	Date Progress
RM 0488	1	5	3		
mile 0.5	1	5	3		
mile 1.0	1	5	3		
mile 1.5	1	5	4		
RM 0490	1	4	4		
mile 2.5	1	4	4		
mile 3.0	1	5	3		
mile 3.5	1	5	3		
RM 0492	1	5	3		
AVE RATING FM 1470	**1.0**	**4.8**	**3.3**		

Average Texture Depth: FM 1470 (EM)



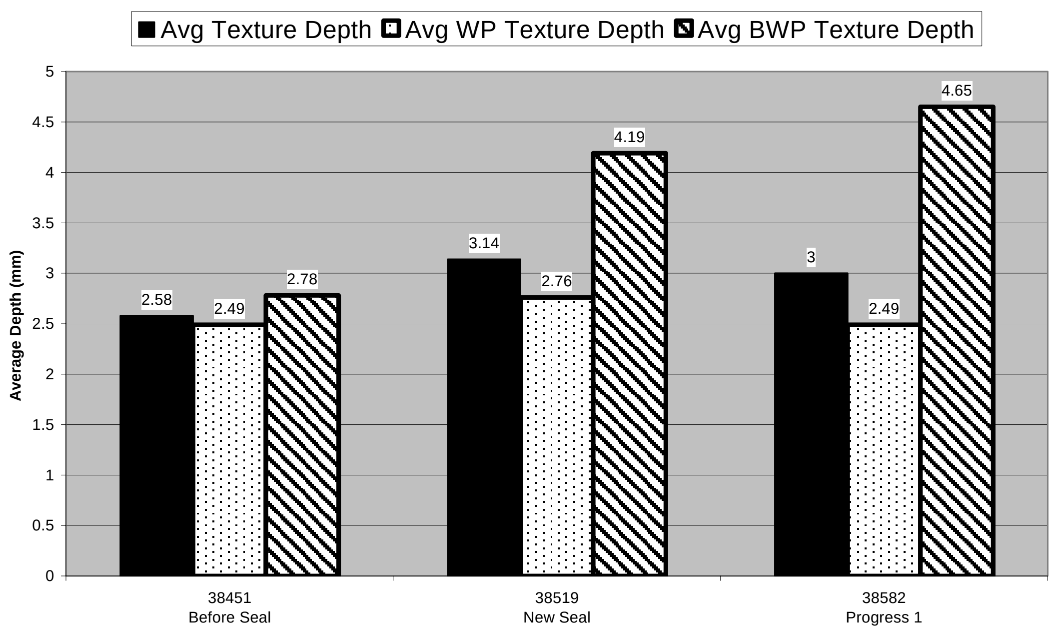
Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

Rating	Condition	Rating	Condition	Rating	Condition
5	Satisfactory	1	General Flushing	3	Localized Shelling 1/2 Lane
4	Flushing Evident	1	Reseal	2	Localized Shelling Full Lane
3	One Wheel Path	4	Localized Shelling Evident	1	General Shelling
2	Two Wheel Paths				

Mile (FM 478 EM)	5-Apr-05 Before Seal	16-Jun-05 New Seal	18-Aug-05 Progress	Date Progress	Date Progress
RM 0528	5	5	5		
mile 0.5	5	5	5		
mile 1.0	1	5	5		
mile 1.5	1	4	4		
RM 0526	4	5	5		
mile 2.5	4	5	5		
RM 0524	4	4	4		
AVG RATING	**3.4**	**4.7**	**4.7**		

FM 478

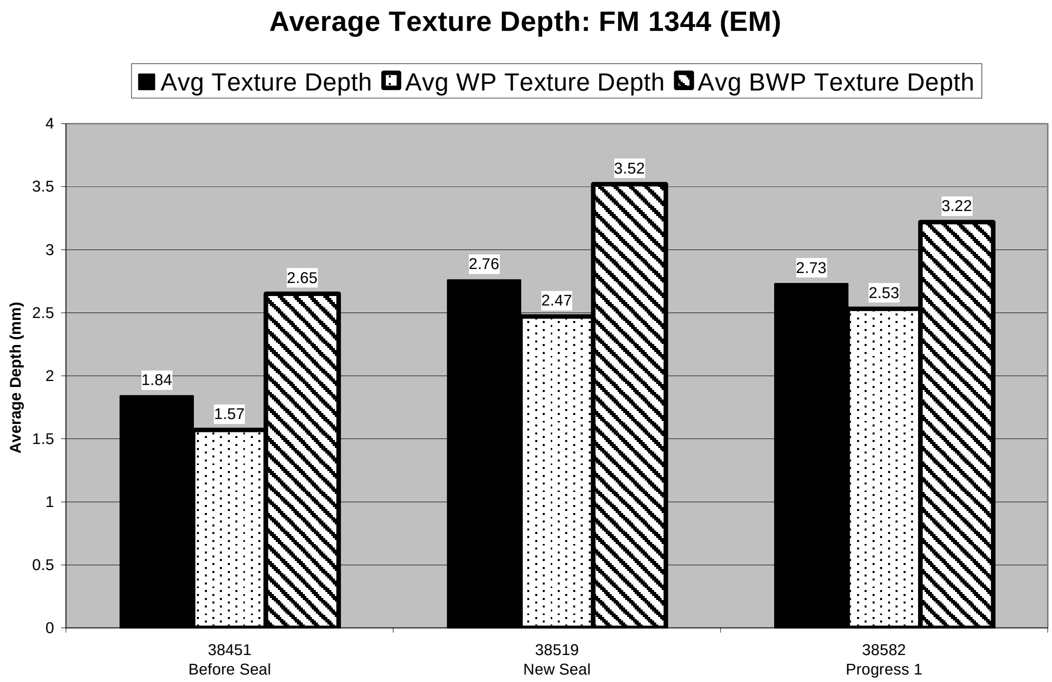
Average Texture Depth: FM 478 (EM)



Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

Rating	Condition	Rating	Condition	Rating	Condition
5	Satisfactory	1	General Flushing	3	Localized Shelling 1/2 Lane
4	Flushing Evident	1	Reseal	2	Localized Shelling Full Lane
3	One Wheel Path	4	Localized Shelling Evident	1	General Shelling
2	Two Wheel Paths				

FM 1344 EM Mile	5-Apr-05 Before Seal	16-Jun-05 New Seal	18-Aug-05 Progress	Date Progress	Date Progress
RM 0522	1	4	4		
mile 0.5	1	5	5		
mile 1.0	1	5	5		
mile 1.5	4	5	5		
RM 0524	1	5	5		
mile 2.5	1	5	5		
mile 3.0	1	4	4		
mile 3.5	1	5	5		
RM 0526	1	5	5		
mile 4.5	1	5	5		
mile 5.0	4	5	5		
mile 5.5	1	4	4		
RM 0528	1	5	5		
mile 6.5	4	5	5		
mile 7.0	1	5	4		
mile 7.5	1	5	5		
RM 0530	1	5	5		
mile 8.5	5	4	4		
mile 9.0	1	5	5		
mile 9.5	4	5	5		
RM 0532	5	4	4		
mile 10.5	1	5	4		
mile 11.0	5	5	5		
mile 11.5	5	5	5		
RM 0534	4	5	5		
mile 12.5	4	5	5		
mile 13.0	1	5	5		
mile 13.5	1	5	5		
RM 0536	4	5	5		
AVG RATING FM 1344	**2.3**	**4.8**	**4.8**		

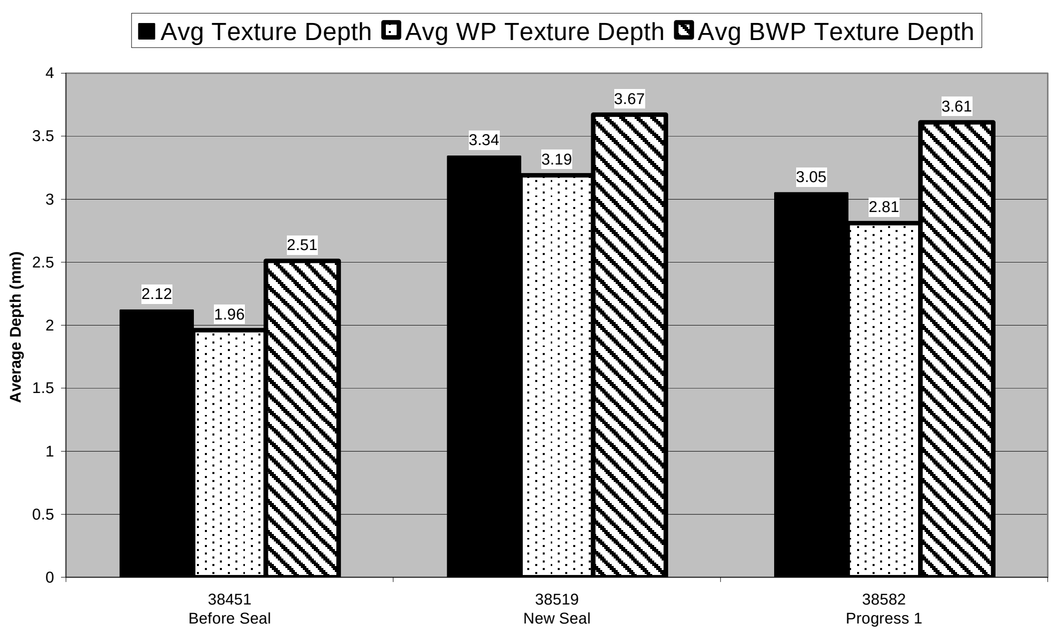

Average Texture Depth: FM 1344 (EM)
Avg Texture Depth
Avg WP Texture Depth
Avg BWP Texture Depth
Average Depth (mm)
4
3.5
3
2.5
2
1.5
1
0.5
0
1.84
1.57
2.65
2.76
2.47
3.52
2.73
2.53
3.22
38451
Before Seal
38519
New Seal
38582
Progress 1

Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

5	Satisfactory	1	General Flushing	3	Localized Shelling 1/2 Lane
4	Flushing Evident	1	Reseal	2	Localized Shelling Full Lane
3	One Wheel Path	4	Localized Shelling Evident	1	General Shelling
2	Two Wheel Paths				

FM 1347 EM Mile	5-Apr-05 **Before Seal**	16-Jun-05 **New Seal**	18-Aug-05 **Progress**	Date **Progress**	Date **Progress**
FM 1347	5	5	5		
mile 0.5	4	5	4		
mile 1.0	4	5	5		
FM 0530	4	5	5		
mile 1.5	4	5	5		
mile 2.0	4	5	5		
AVG RATING FM 1347	**4.2**	**5.0**	**4.8**		

Average Texture Depth: FM 1347 (EM)



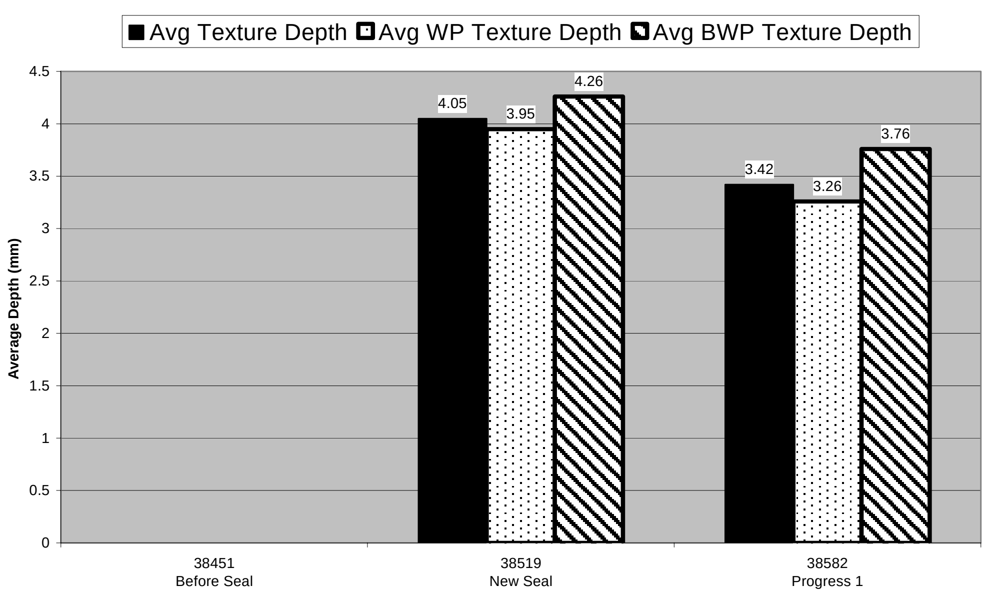
Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

5	Satisfactory	**1**	General Flushing	**3**	Localized Shelling 1/2 Lane
4	Flushing Evident	**1**	Reseal	**2**	Localized Shelling Full Lane
3	One Wheel Path	**4**	Localized Shelling Evident	**1**	General Shelling
2	Two Wheel Paths				

I35 Frontage AC Mile	5-Apr-05 **Before Seal**	16-Jun-05 **New Seal**	18-Aug-05 **Progress**	Date **Progress**	Date **Progress**
Exit 111	NO DATA	5	5		
mile 0.5		5	5		
mile 1.0		5	5		
mile 1.5		5	5		
mile 2.0		5	5		
mile 2.5		5	5		
mile 3.0		5	5		
mile 3.5		5	5		
mile 4.0		5	5		
mile 4.5		5	5		
mile 5.0		5	5		
mile 5.5		5	5		
mile 6.0		5	5		
mile 6.5		5	5		
Exit 104		5	5		
AVG RATING		**5.0**	**5.0**		

I35 Frontage

Average Texture Depth: I-35 Frontage (AC)



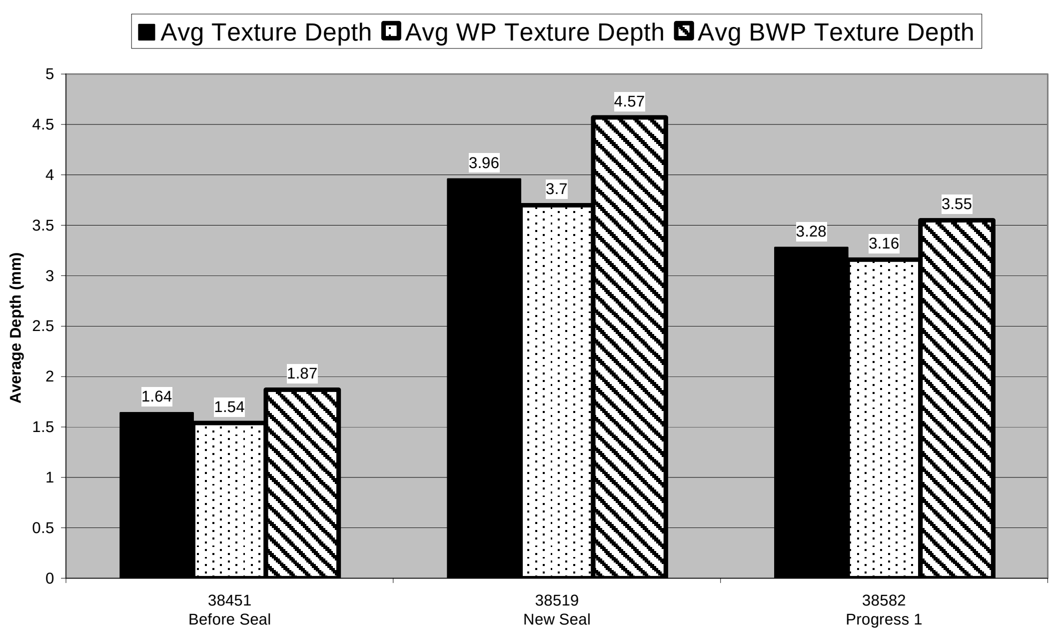
Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

Rating	Condition	Rating	Condition	Rating	Condition
5	Satisfactory	1	General Flushing	3	Localized Shelling 1/2 Lane
4	Flushing Evident	1	Reseal	2	Localized Shelling Full Lane
3	One Wheel Path	4	Localized Shelling Evident	1	General Shelling
2	Two Wheel Paths				

FM 541W AC Mile	5-Apr-05 **Before Seal**	16-Jun-05 **New Seal**	18-Aug-05 **Progress**	Date **Progress**	Date **Progress**
RM 0538	4	5	5		
mile 0.5	3	5	5		
mile 1.0	4	5	5		
mile 1.5	2	4	4		
RM 0540	2	5	5		
mile 2.5	3	5	5		
mile 3.0	2	5	5		
mile 3.5	2	5	5		
RM 0542	1	5	4		
AVG RATING	**2.6**	**4.9**	**4.8**		

FM 541W

Average Texture Depth: FM 541 West (AC)



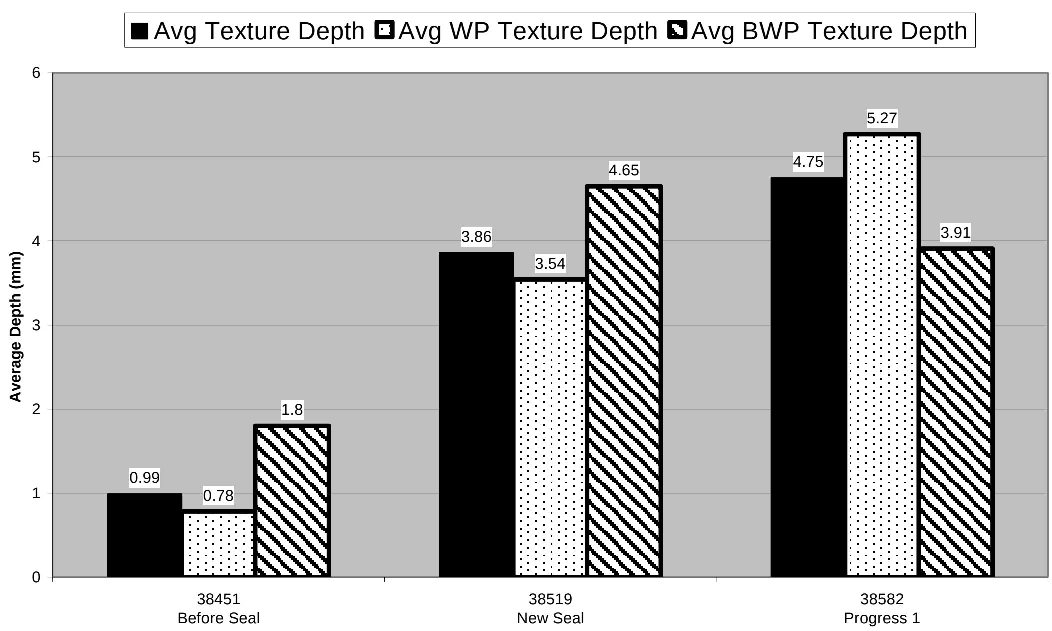
Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

Rating	Condition	Rating	Condition	Rating	Condition
5	Satisfactory	1	General Flushing	3	Localized Shelling 1/2 Lane
4	Flushing Evident	1	Reseal	2	Localized Shelling Full Lane
3	One Wheel Path	4	Localized Shelling Evident	1	General Shelling
2	Two Wheel Paths				

FM 541C AC Mile	5-Apr-05 Before Seal	16-Jun-05 New Seal	18-Aug-05 Progress	Date Progress	Date Progress
RM 0544	1	5	5		
mile 0.5	1	5	5		
mile 1.0	1	5	5		
mile 1.5	1	5	5		
RM 0546	1	5	5		
mile 2.5	4	5	5		
mile 3.0	1	5	5		
mile 3.5	1	5	5		
RM 0548	1	5	5		
AVG RATING	**1.3**	**5.0**	**5.0**		

FM 541C

Average Texture Depth: FM 541 Central (AC)

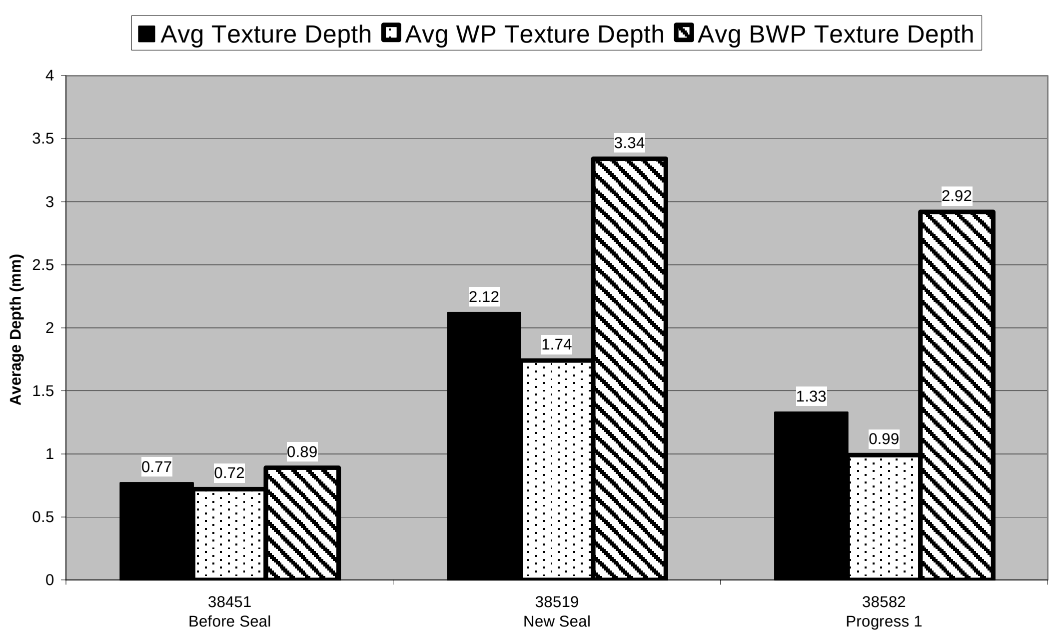


Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

Rating	Condition	Rating	Condition	Rating	Condition
5	Satisfactory	1	General Flushing	3	Localized Shelling 1/2 Lane
4	Flushing Evident	1	Reseal	2	Localized Shelling Full Lane
3	One Wheel Path	4	Localized Shelling Evident	1	General Shelling
2	Two Wheel Paths				

FM 541E AC Mile	5-Apr-05 Before Seal	16-Jun-05 New Seal	18-Aug-05 Progress	Date Progress	Date Progress
RM 0552	1	5	5		
mile 0.5	1	5	5		
mile 1.0	1	5	5		
mile 1.5	1	5	4		
RM 0554	1	5	3		
mile 2.5	1	5	5		
mile 3.0	1	5	5		
mile 3.5	1	5	5		
RM 0556	1	4	3		
mile 4.5	1	5	5		
mile 5.0	1	5	5		
mile 5.5	1	4	4		
RM 0558	1	5	5		
AVG RATING FM 541E	**1.0**	**4.8**	**4.5**		

Average Texture Depth: FM 541 East (AC)



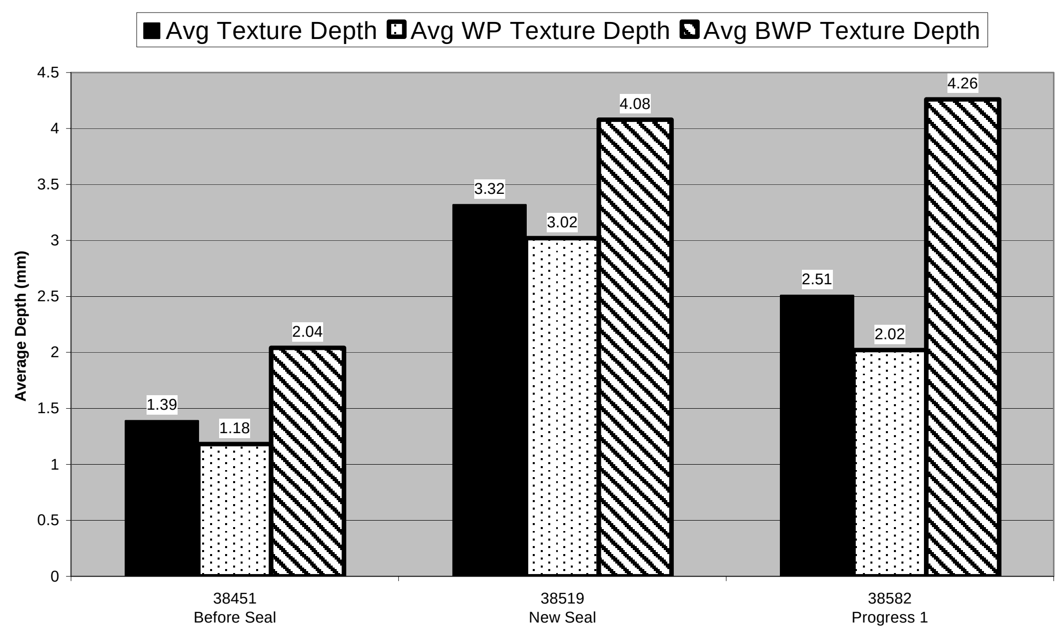
Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

Rating	Condition	Rating	Condition	Rating	Condition
5	Satisfactory	1	General Flushing	3	Localized Shelling 1/2 Lane
4	Flushing Evident	1	Reseal	2	Localized Shelling Full Lane
3	One Wheel Path	4	Localized Shelling Evident	1	General Shelling
2	Two Wheel Paths				

FM 427 AC Mile	5-Apr-05 Before Seal	16-Jun-05 New Seal	18-Aug-05 Progress	Date Progress	Date Progress
RM 0522	1	4	4		
mile 0.5	3	5	5		
mile 1.0	3	5	5		
mile 1.5	2	4	4		
RM 0520	2	5	5		
mile 2.5	3	5	5		
mile 3.0	1	5	5		
mile 3.5	1	5	4		
RM 0518	1	5	5		
AVG RATING	**1.9**	**4.8**	**4.7**		

FM 427

Average Texture Depth: FM 427 (AC)



Numerical Rating Assigned to Each Road Condition (5 = best; 1 = worst)

Rating	Condition	Rating	Condition	Rating	Condition
5	Satisfactory	1	General Flushing	3	Localized Shelling 1/2 Lane
4	Flushing Evident	1	Reseal	2	Localized Shelling Full Lane
3	One Wheel Path	4	Localized Shelling Evident	1	General Shelling
2	Two Wheel Paths				

SH 119 AC Mile	5-Apr-05 Before Seal	16-Jun-05 New Seal	18-Aug-05 Progress	Date Progress	Date Progress
RM 0518	4	5	5		
mile 0.5	4	5	5		
mile 1.0	4	5	5		
mile 1.5	1	5	5		
RM 0516	4	5	5		
mile 2.5	1	5	5		
mile 3.0	1	5	5		
mile 3.5	4	5	5		
RM 0514	1	5	5		
AVG RATING	**2.7**	**5.0**	**5.0**		

SH 119

Average Texture Depth: Highway 119 (AC)