

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

**Interim Research Report #3  
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**“Evaluate Texas Department of Transportation Chip Seal Binder Performance  
Using Pavement Management Information System Data”**

**Interim Report #3**

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## **“Evaluate Texas Department of Transportation Chip Seal Binder Performance Using Pavement Management Information System Data”**

### **Interim Report #3**

#### **EXECUTIVE SUMMARY**

**Purpose of the Research:** This research has two distinct purposes. First, it seeks for the first time in the US to measure the change in chip seal performance over time using quantitative means and comparing it with the current methods used by the Texas Department of Transportation (TxDOT) in its Pavement Management Information System (PMIS). Secondly, it will extend the findings of the previous AEMA study regarding chip seal binder differences in the Atlanta District 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, the TxDOT 2005 Maintenance Conference and at the AEMA 2006 National meeting in Palm Springs, CA. Additionally, a peer-reviewed journal article entitled “Using a New Zealand Performance Specification to Evaluate US Chip Seal Performance” was published in the American Society of Civil Engineers *Journal of Transportation Engineering*, in December 2007 detailing the findings of this study.

**Scope of Work:** Researchers initially established test sections on 12 Farm-to-Market roads in the TxDOT San Antonio district. Premature failure of one test section and the dropping of another planned test section from the 2005 seal coat program forced the sample population to be reduced to 10 FM roads. The researchers have monitored those sections throughout 2 ½ years (ten quarters) of service life and will continue through the end of third year. Engineering measurements of chip seal surface texture were made using the Transit New Zealand P17 Sand Circle test to validate those measurements similar to the process being used by the researcher in another project in New Zealand. The analysis entails 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 was 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. The PMIS data for the preseal condition was correlated with the preseal texture measurements and a qualitative 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. The PMIS results were compared with the physical field measurements and trends have been identified. Phase 1 is complete.

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 is ongoing and replicates Phase 1 in that the test sections are physically sampled once each quarter. Their PMIS data is collected annually and analyzed each time that it is updated by the district. Ten 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 is run with the field measurements and trends are identified and documented. At this report, sufficient data has been collected to permit the conduct of a cost index number analysis that furnishes information on the relative cost effectiveness of each binder with regard to the quantitative and qualitative measurements. 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 at this point in the research remains that the existing condition of the substrate significantly impacts the performance of a new seal coat. This is shown by the early flushing of AC road FM 427, which had very poor texture due to flushing and emulsion road FM 1470 which had a recent reseal before the new emulsion chip seal. Additionally, 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 writing, several trends are observed with respect to the comparative performance of the two binder types.

- 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.
- 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.
- When the quantitative measures of texture depth are compared to the 1-year texture depth performance criteria in use in New Zealand for new chip seals, two of the five AC roads would have failed the test. All emulsion roads passed the criterion.
- 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 ratings of the emulsion roads may indicate more flushing 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.

- The emulsion roads were found to be more cost effective in all five cost index number metrics that were used in the analysis. Two of the metrics were qualitative, springing from the PMIS and windshield survey output and the other three were quantitative, being developed from the texture measurements taken using the TNZ T/3 sand circle tests.

## **“Evaluate Texas Department of Transportation Chip Seal Binder Performance Using Pavement Management Information System Data”**

### **Interim Report #3**

#### **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 placed 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**

Interim Report #1 detailed the significant findings from the literature review. Therefore, no additional review is necessary for this report. A complete literature review will be included in the final report.

#### **METHODOLOGY**

The methodology was described in detail in Interim Report #1. It has not changed.

#### **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 engineering and an economic basis. The requisite information is now available to be able to conduct a similar analysis for the San Antonio roads. Those analyses are found in the final section of this report.

Figure 1 shows the 2-year post-seal conditions of the roads in this study along with the change from the pre-seal PMIS ratings over the second year of service life. Figure 2 is a histogram that shows the change in PMIS Pavement Condition Score and Distress Score for the two types of binders. As can be seen, on average the roads that received a hot AC chip seal (AC roads) were in somewhat better overall condition based on the PC rating one year after the new seal, but that trend reversed itself in 2007. This is a switch from the pre-seal PMIS ratings which had the following major differences:

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

PAVEMENT MANAGEMENT INFORMATION						
TEXAS DEPARTMENT OF TRANSPORTATION						
Numerical Rating Assigned to Each Road Condition						
2007 Fiscal Year; Responsible District = 15 San Antonio						
Rating			Rating			
<b>RAV:</b> Raveling (Shelling)			<b>RD:</b> Rut Depth			
<b>FLU:</b> Flushing			<b>PAV CON:</b> Pavement Condition			
<b>DIS:</b> Distress Score						
EM RDs	County	RAV	FLU	DIS	RD	PAV CON
FM 117	Frio	0.6	2.2	99.5	3.1	98.3
FM 140	Atacosa	1.0	0.2	94.1	2.4	87.2
FM 478	Atacosa	1.0	0.0	80.8	2.6	79.5
FM 1344	Wilson	0.5	0.2	93.4	2.9	93.3
FM 1347	Wilson	0.0	2.5	81.5	2.6	80.5
<b>AVERAGE</b>		<b>0.6</b>	<b>1.0</b>	<b>89.8</b>	<b>2.7</b>	<b>87.8</b>
Change from FY2006		0.5	0.4	-5.7	-0.2	-7.3
AC RDs	County	RAV	FLU	DIS	RD	PAV CON
FM 541 W	Wilson	0.0	0.4	87.1	2.9	87.0
FM 541 C	Wilson	0.0	1.3	89.5	2.6	79.3
FM 541 E	Wilson	0.0	1.3	89.8	2.7	84.9
FM 427	Wilson	0.0	1.8	92.5	2.3	90.4
Hwy 119	Wilson	0.0	0.0	89.6	2.8	87.8
<b>AVERAGE</b>		<b>0.0</b>	<b>0.9</b>	<b>89.7</b>	<b>2.6</b>	<b>85.9</b>
Change from FY2006		0.0	0.5	-9.0	-0.2	-11.9

Figure 1: 2007 PMIS Data Analysis for the Post-Seal Pavement Condition After 24 months and the Change from the FY2006 Condition.

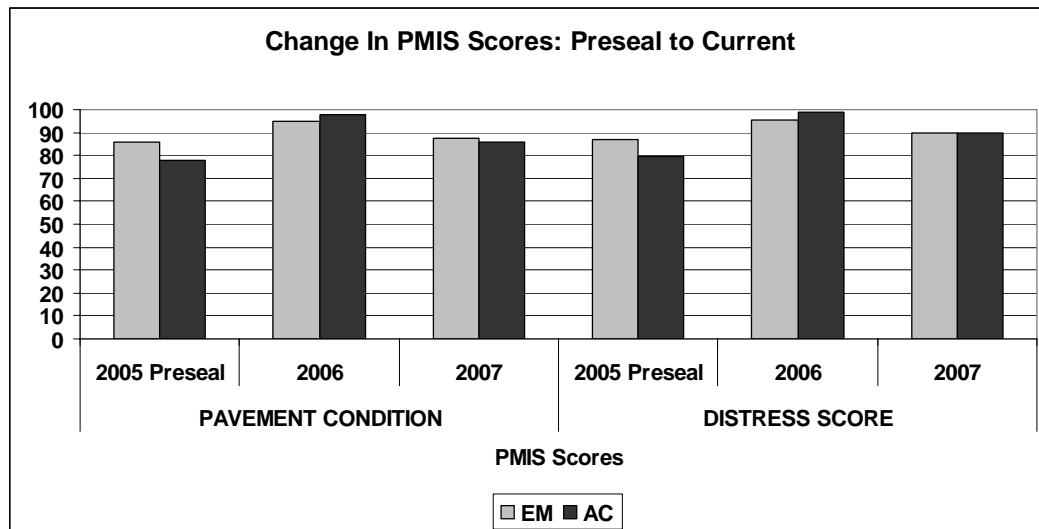


Figure 2: Change in PMIS Data from Pre-Seal to Current.

One can see that the pavement condition difference is minor: 85.9 for AC roads versus 87.8 for EM roads. However, Figure one shows that the drop over the second year of service in both average pavement condition and distress scores to be greater for the AC roads than for the EM roads. One can see in Figure 2 that the AC roads were in poorer condition than the

EM roads prior to the new seal. They then had better 2006 PMIS scores than the EM roads. However, in 2007 those scores had slipped below those of the EM roads. The pre-seal condition of the substrate may account for this trend reversal. Interim Report #2 on this project showed that those roads found to have failed using the New Zealand TNZ P/17 performance specification prior to the reseal flushed prematurely. Thus, there are now two confirmed data points that show the importance of characterizing the road's surface prior to deciding to reseal.

There was a good range of pre-seal conditions amongst for types of roads. Thus, the comparison will allow the researcher to watch the trend in each binder 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 pre-seal 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 TNZ T/3 sand circle. Thus, having not only a pre-seal rating for each road but also a representative range of pre-seal pavement conditions will make the outcome of this study authoritative for most conditions.

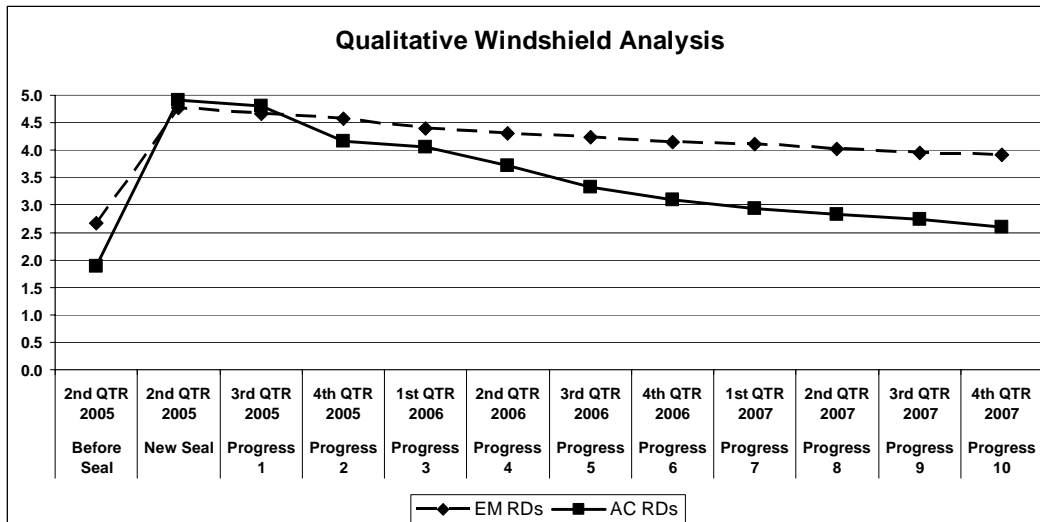
## **RESULTS TO DATE**

The reader must 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 pre-seal condition for each binder rather than the differences between the two binders. The texture depth is measured in millimeters. For instance, the difference in average texture depth between the two binders two months after the new seal is 0.55 millimeters which is 0.02 inches, an extremely small difference.

### *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 synopsisized in Figure 3. One can see that the qualitative condition of the AC roads has dropped off somewhat more quickly than that of the EM roads. This confirms the change found in the 2007 PMIS survey of these roads. It should be noted that the PMIS scores were collected independently from this research project.





**Figure 3: Results of Qualitative Windshield Analysis after 1 Year**

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 researcher 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 3, 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 and the AC roads had each deteriorated by the same amount (0.1 point). At the one-year mark the AC roads had suffered a deterioration of 1.5 points compared to a change for the EM roads of 0.7 points over the same period as shown in Figure 3. By the tenth observation, the AC roads had lost 2.4 points compared to the EM roads loss of 1.1 points. Again, this speaks to the poorer condition of the substrate found on the AC roads prior to the new seal. Again, this argues for the careful characterization of the existing surface prior to making the decision to reseal a chip sealed road that has flushing problems. Figure 3 also furnishes a great example of what happens when one violates the golden rule of pavement preservation: “put the right treatment on the right road at the right time” (Galehouse et al 2003). This leads to the use of quantitative measurements to verify the results the found in the two qualitative procedures (i.e. PMIS ratings and the windshield survey).

#### *Sand Circle Procedure*

The previous interim report reported on the efficacy of using the Transit New Zealand TNZ P/17 chip seal performance specification based on the TNZ T/3 sand circle test procedure. It

utilizes this test to measure performance at the one-year mark after a new chip seal. Hence it is possible to compare the performance of the test roads in Texas to this benchmark and use this as another objective analysis of binder performance. This analysis is repeated in this report because it sets the foundation against which the current set of measurements can be compared. In other words, it is important to identify those roads that are considered to have failed the TNZ P/17 performance specification when looking at the long-term performance of each binder.

Chip seal contractors in New Zealand are paid on a basis of 1-year chip seal performance. Average texture depth measurements are taken after one year, and those are compared to a 1-year texture depth calculated from an empirical deterioration model. The entire specification is based on the assumption that chip seals fail as a result of flushing (Transit New Zealand 2002). The final acceptance is based on the achievement of the required texture depth, without any significant chip loss. The New Zealand deterioration models from which the P17 specification is derived require the following minimum texture depth one year after the chip seal is completed, using Equation 1 below.

$$Td_1 = 0.07 ALD \log Y_d + 0.9 \quad (\text{Equation 1})$$

where

- $Td_1$  = texture depth in 1 year (mm),
- $Y_d$  = design life in years, and
- $ALD$  = average least dimension of the aggregate.

To put this into a life cycle 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) (Transit New Zealand 2002).

Table 1 recapitulates the results of the one-year measurement of texture depth in the wheel path (WP) and between the wheel paths (BWP) as well as the average texture depth across the test section. The Table 1 results for the 7-year design life track well with the comparison of pre-seal macrotexture shown in Figure 1 with the solitary exception of FM 427. It should be noted that a previous study of the TxDOT chip seal program found that TxDOT expects a service life (not a design life) of roughly seven years from new chip seals (Gransberg et al, 1999). So, discounting the subtle difference between a design and a service life, the 7-year design life performance criterion is probably the best benchmark against which to measure chip seal performance in Texas.

**Table 1: Comparison of Measured 1-Year Macrotexture to TNZ P/17 Performance Criterion Over Three Possible Design Lives by Binder Type**

Test Section	5 Year Design Life minus 1-year Measurement			6 Year Design Life minus 1-year Measurement			7 Year Design Life minus 1-year Measurement		
	Ave Texture Depth	Ave WP Texture Depth	Ave BWP Texture Depth	Ave Texture Depth	Ave WP Texture Depth	Ave BWP Texture Depth	Ave Texture Depth	Ave WP Texture Depth	Ave BWP Texture Depth
FM 117	0.71	0.46	1.36	0.64	0.39	1.29	0.58	0.33	1.23
FM 140	1.14	0.93	1.62	1.07	0.86	1.55	1.01	0.80	1.49
FM 478	1.15	0.97	1.58	1.08	0.90	1.51	1.02	0.84	1.45
FM 1344	0.62	0.46	1.03	0.55	0.39	0.95	0.49	0.33	0.90
FM 1347	0.85	0.72	1.17	0.78	0.65	1.10	0.72	0.59	1.04
<b>EM AVE</b>	<b>0.89</b>	<b>0.71</b>	<b>1.35</b>	<b>0.82</b>	<b>0.64</b>	<b>1.28</b>	<b>0.76</b>	<b>0.58</b>	<b>1.22</b>
FM 541 West	0.53	0.39	0.86	0.46	0.32	0.79	0.40	0.26	0.73
FM 541 Central	0.23	0.09	0.56	0.16	0.02	0.49	0.10	<b>-0.04</b>	0.43
FM 541 East	<b>-0.49</b>	<b>-0.65</b>	<b>-0.01</b>	<b>-0.56</b>	<b>-0.72</b>	<b>-0.08</b>	<b>-0.62</b>	<b>-0.78</b>	<b>-0.14</b>
FM 427	0.21	<b>-0.04</b>	0.94	0.13	<b>-0.12</b>	0.87	0.08	<b>-0.17</b>	0.81
State 119	0.39	0.24	0.76	0.32	0.17	0.69	0.26	0.11	0.63
<b>AC AVE</b>	<b>0.17</b>	<b>0.00</b>	<b>0.62</b>	<b>0.10</b>	<b>-0.07</b>	<b>0.55</b>	<b>0.04</b>	<b>-0.13</b>	<b>0.49</b>

When one compares the results in Table 1 with the current PMIS qualitative ratings in Figure 2, a very different picture of the new chip seals' performance is found. The PMIS results after one year show FM 541 East's flushing score to have improved by 2.1 out of a possible 5 points and its pavement condition to be nearly perfect with a score of 97 out of 100. A similar picture is given for FM 427 whose pavement condition improved from 38 to 97 and whose flushing score remained unchanged. This should not be read as an indictment of the TxDOT PMIS program. One must remember that the PMIS scores shown in Table 1 are an average of the qualitative scores taken at half-mile increment along the entire test section length. This study's texture depth measurements were taken at a single point on each road, and a check of the PMIS section data for FM 427 showed a flushing score of 2 out of 5 in the section where the sand circle test was conducted indicating that flushing was observed by the PMIS surveyors in that particular section. Interestingly, that section had a 2005 flushing score of zero indicating no flushing. Whereas, the pre-seal windshield survey by the researchers observed flushing in both wheel paths in that section and the pre-seal measured texture depth was only 0.28 mm (0.01 inches) greater than the TNZ P/17 failure criteria of 0.9 mm (0.035 inches). This discrepancy highlights the major benefit of using a quantitative metric over a qualitative one. With observational methods, it becomes very difficult to obtain consistent ratings between two different observers. Notwithstanding the previously discussed marginal measurement accuracy problems inherent to the TNZ T/3 sand circle test, as a quantitative measure it virtually eliminates the discrepancy found with the PMIS qualitative rating on FM

427 for no other reason than the test mandates that the test taker stop and make the measurement rather than derive a qualitative judgment from a moving vehicle.

These techniques also serve to reinforce the primary tenet of pavement preservation that public agencies must “place the right treatment, on the right road, at the right time”(Galehouse et al 2003). Looking at the pre-seal conditions of the roads in this study, only FM 541 Central and FM 541 East would have been considered as failed due to flushing using the TNZ P/17 performance specification before the new seal was applied. Table 5 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 two months later, the wheel paths are already nearing the failure level of 0.9 mm (0.035 inches). This may be due to traffic embedding the aggregate into the existing soft flushed substrate, or it is also possible that there was rutting in the wheel paths that cause them to be flooded with binder during construction of the new seal creating excessive binder in the wheel paths that led to premature flushing. In either case, it is obvious that placing a new chip seal on FM 541 East was not the right treatment as the road had become too heavily flushed to permit the new chip seal to restore its surface texture for more than a short period of time, in this case less than two months. This is confirmed by the 1-year measurement in the wheel paths being less than the TNZ P/17 ultimate failure criterion. Thus, using these two roads as an example, one would have to conclude that quantitatively characterizing the pre-seal macrotexture not only aids the engineer on evaluating chip seal performance, but also furnishes a rational methodology for determining the proper pavement preservation treatment to use based on objective measurements rather than qualitative observational condition ratings.

**Table 2 Change in Measured Texture Depth on Two Roads That Were Failed Due to Flushing Prior to the New Seal (Note: bold values are less than the TNZ P/17 Ultimate Failure Criterion).**

Rd	Before Seal			New Seal			2 Months After New Seal			1 Year After New Seal		
	Ave Total Text Depth (mm)	Ave WP Text Depth (mm)	Ave BWP Text Depth (mm)	Ave Total Text Depth (mm)	Ave WP Text Depth (mm)	Ave BWP Text Depth (mm)	Ave Total Text Depth (mm)	Ave WP Text Depth (mm)	Ave BWP Text Depth (mm)	Ave Total Text Depth (mm)	Ave WP Text Depth (mm)	Ave BWP Text Depth (mm)
FM 541 C	0.99	<b>0.78</b>	1.80	3.86	3.54	4.65	3.75	3.27	3.91	1.75	1.61	2.08
FM 541 E	<b>0.77</b>	<b>0.72</b>	<b>0.89</b>	2.12	1.74	3.34	1.33	0.99	2.92	1.03	<b>0.87</b>	1.51

Given the above discussion, the project has now progressed for 2 ½ years and as a result has a large data set for the ten test roads. Figures 4, 5, and 6 show the average change in surface texture over time for both the AC and the EM roads taken as shown in the above tables. These figures allow the direct comparison of the two binder types with regard to one another in maintaining macrotexture as measured by the TNZ t/3 sand circle test.

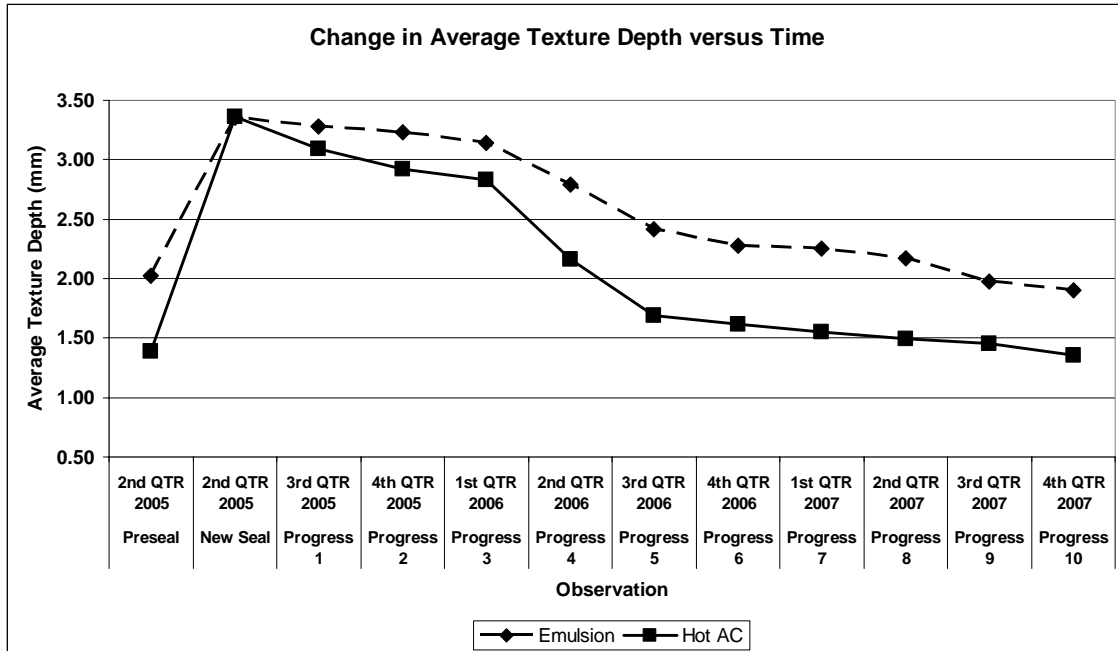


Figure 4: Change in Average Texture Over Time

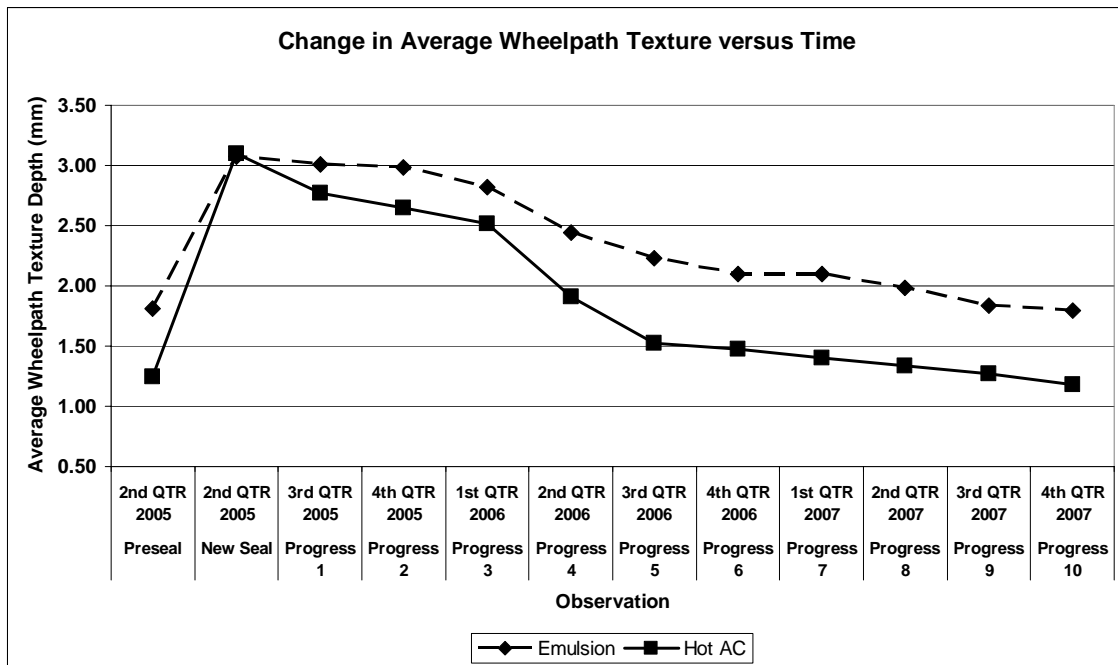


Figure 5: Change in Average Wheelpath Texture Over Time

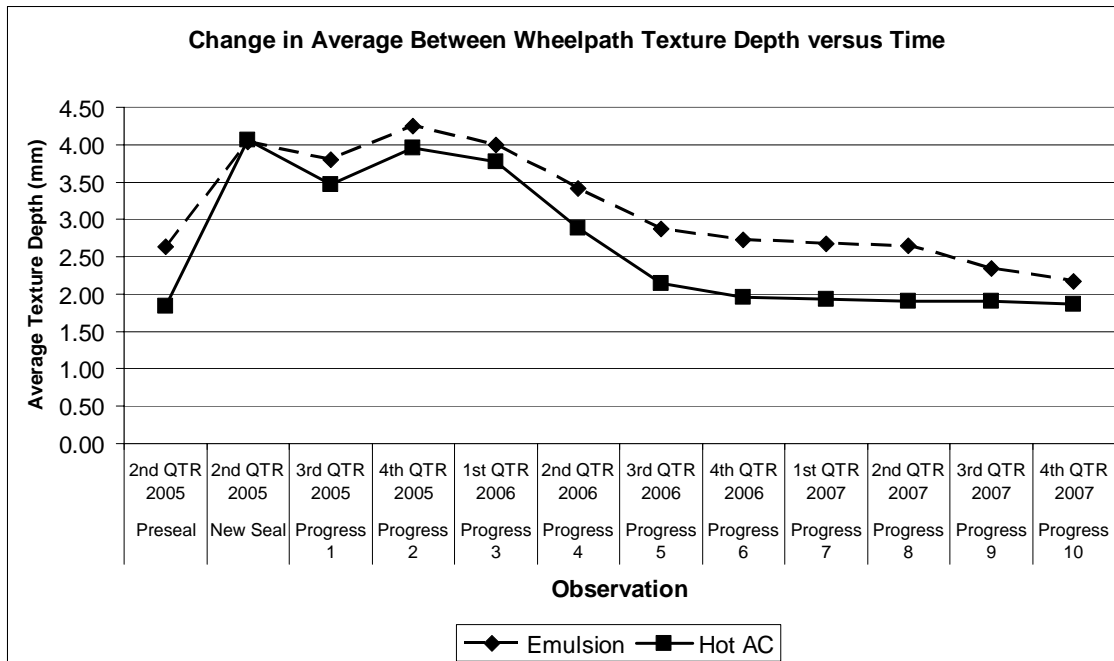


Figure 6: Change in Average Between Wheelpath Texture Over Time

One can see that in all three cases the EM roads have lost their surface texture at a slower rate than the AC roads. The difference is most pronounced in the wheel paths where macrotexture is critical to skid resistance. There is no seemingly logical physical explanation regarding the differences in the binders for this. It is probably due to the fact that the AC roads' substrate was more highly flushed before the new seal as can be seen in each figure. However, the comparison on this quantitative basis certainly supports the conclusion that the EM roads are performing as well if not better than the AC roads.

*Cost Index Number Analysis*

The final category of comparative metrics comes from a variant of Utility Theory called Cost Index Number Theory (West and Riggs, 1986). As PMIS is itself based on Utility Theory (TxDOT, 2001), using Cost Index Number Theory is a logical choice for this type of analysis. The method seeks to combine cost and engineering measurements into a single index that can permit the direct comparison of two or more alternatives simultaneously and thus provide a measure of cost effectiveness on an engineering property basis. This theory allows the research team to compare a more expensive technology with a less expensive technology to determine if the incremental cost difference between the two alternatives is offset by enhanced engineering performance.

The actual contract prices for the 2005 seal coat contract were used for each of the test roads. The actual quantities were multiplied by the contract unit prices to obtain the total cost for the aggregate and binder for each road. The EM roads had an average unit cost of \$0.82 per square yard and the AC roads had an average unit cost of \$0.92 per square yard. The general formula developed for each of the five cost indices was derived by dividing the cost per square yard by a physical parameter as follows:

$$CI = (CSY/PP) \times 10^X \tag{equation 2}$$

Where: CI = Cost index number  
 CSY = Cost per square yard (\$/SY)  
 PP = Physical parameter  
 X = A power of ten that allows the resultant number to be roughly a whole number between 1 and 120

The physical parameters were defined as follows:

PC = Average PMIS pavement condition score for each class of road  
 WR = Average windshield rating score for each class of road  
 AT = Average texture depth for each class of road  
 WP = Average wheelpath texture depth for each class of road  
 BWP = Average between wheelpath texture depth for each class of road

Therefore the PCCI is the pavement condition cost index and is essentially the cost per square yard to attain one point of PMIS pavement condition score. Because the purpose of this analysis is to compare the two binders, the CI numbers for both groups will be reported as dimensionless to reduce confusion and allow the focus on relative rather than absolute values. Table 3 contains the resultant values of the physical parameters used for each road and the average for the two groups in each parameter. One can see that the EM roads have a slightly better PMIS pavement condition score and windshield rating score as a group than the AC roads. As previously reported, they also have a retained an average deeper texture in all three measurements.

Table 3: Physical Parameters Used in the Cost Index Number Analysis for Each Road

EM RDs	Pavement Condition Score	Windshield Rating Score	Avg Texture Depth	Avg WP Texture Depth	Avg BWP Texture Depth
FM 117	98.3	3.6	2.02	1.94	2.20
FM 140	87.2	3.9	2.27	2.23	2.35
FM 478	79.5	3.8	1.97	1.74	2.56
FM 1344	93.3	4.2	1.82	1.69	2.14
FM 1347	80.5	4.0	1.43	1.35	1.60
<b>AVERAGE</b>	87.8	3.9	1.90	1.79	2.17

AC RDs	Pavement Condition Score	Windshield Rating Score	Avg Texture Depth	Avg WP Texture Depth	Avg BWP Texture Depth
FM 541 W	87.0	3.8	1.72	1.57	2.07
FM 541 C	79.3	2.3	1.48	1.27	2.10
FM 541 E	84.9	2.6	0.76	0.60	1.36
FM 427	90.4	1.0	1.16	0.99	1.66
Hwy 119	87.8	3.2	1.66	1.48	2.14
<b>AVERAGE</b>	85.9	2.6	1.36	1.18	1.87

Table 4 is the result of applying the cost index number analysis to each of the roads and then taking an average value for comparison between the two different types of binders. The average index values are lower for the EM than the AC roads in all five categories. Thus, this clearly demonstrates that the EM binder is more cost effective than the AC binder. This

approach demonstrates that the lower cost option actually produces a result that is at least as good if not measurably better in each of the five metrics chosen for this study.

Table 4: Cost Index Numbers for Each Road.

EM RDs	PCCI	WRCI	ATCI	WPCI	BWPCI
FM 117	82	22	40	41	37
FM 140	92	21	35	36	34
FM 478	107	22	43	49	33
FM 1344	86	19	44	48	38
FM 1347	105	21	59	63	53
<b>AVERAGE</b>	94	21	44	47	39
AC RDs	PCCI	WRCI	ATCI	WPCI	BWPCI
FM 541 W	106	24	53	58	44
FM 541 C	116	39	62	72	44
FM 541 E	108	35	121	154	67
FM 427	102	92	79	92	55
Hwy 119	105	29	55	62	43
<b>AVERAGE</b>	107	44	74	88	51

### **EMERGING CONCLUSIONS**

At this writing, the research is third year into a three year project that will compare the performance of the two binder types which should ideally perform within the specified criterion for a minimum of 5 years. The use of the TNZ performance specification allowed the research team to create a benchmark based on a well-established and long-standing practice against which to compare the two binders during their first year of life. A potential trend seems to be emerging in the comparative analysis. Based on the qualitative windshield survey and the PMIS data, both binder types seem to be furnishing satisfactory performance in their 2 ½ years of service. Neither the qualitative nor the quantitative measures indicate poor performance of either binder type. Thus, at this point it appears that both binders are performing satisfactorily when the pre-seal conditions of the substrate are taken into account. Next, the previous interim report found that 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 trend continues with the measurements taken for this report. 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.

Using the TNZ P17 performance criterion as a benchmark against which to measure the one-year texture depth performance, it was found that all the EM roads and three of five AC roads exceeded the performance benchmark based on wheelpath texture depth for both 5 and 6-year design lives. If the 7-year criterion is used, all EM and only two AC roads would pass the test. If a design life is back-calculated using the same equation, the EM roads have an average design life based on averaged measured texture depth and average measured wheelpath texture depth that is double that observed for the AC roads. This second trend should be viewed as indicative rather than predictive as a design life is fundamentally different than a service life, and the TNZ P17 1-year performance criterion equation was not developed to predict service life.



The cost index number analysis permitted the researcher to do a “bang for the buck” comparison. The EM roads were found to be the more cost effective in every single metric. They were particularly cost effective in their ability to retain surface texture, the set of metrics based on physical measurements rather than qualitative ratings. The qualitative metrics also tracked together with the study-specific windshield survey conducted by this research team giving the same outcome as the PMIS pavement condition score that was conducted by the San Antonio District’s PMIS surveyors.

At this point, the research methodology has proven itself to furnish useful output data. It has authoritatively proven the hypothesis that poor substrate condition will adversely impact the performance of a new seal coat. This is shown by the early flushing of AC road FM 541 East and EM road FM 1470. This is further confirmed by 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 rational method using engineering measurements to objectively evaluate the post-seal performance of chips seals.

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