Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-09/0-5833-1		

4. Title and Subtitle	5. Report Date
SYNTHESIS STUDY ON TRANSVERSE VARIABLE ASPHALT APPLICATION RATES FOR SEAL COATS	Published: July 2009
	6. Performing Organization Code
7. Author(s) Paul E. Krugler, Cindy K. Estakhri, Carlos M. Chang-Albitres, and Christopher H. Sasser	8. Performing Organization Report No. Report 0-5833-1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS) 11. Contract or Grant No. Project 0-5833
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080	13. Type of Report and Period Covered Technical Report: September 2007- November 2008 14. Sponsoring Agency Code

15. Supplementary Notes
Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Synthesis Study on Variable Asphalt Shot Rates for Seal Coats
URL: http://tti.tamu.edu/documents/0-5833-01.pdf

16. Abstract
This report documents a cooperative effort to collect, process, and make available information about successful methods of varying seal coat asphalt application rates across treated roadways to optimize aggregate retention and avoid wheel path flushing. This topic is of critical importance to maximizing value obtained from TxDOT's multi-million dollar preventive maintenance program. The primary source of the information was highly experienced TxDOT personnel. Researchers used a field interview process to capture knowledge that had been gained through years of roadway practice. Construction specifications and a field guidebook entitled Guide for Transversely Varying Asphalt Rates were developed. Captured field experience and knowledge was prepared for placement into TxDOT's knowledge management system and seal coat inspector training course.

17. Key Words	18. Distribution Statement
Flexible Pavement, Seal Coat, Surface Treatment, Transverse Variable Asphalt Application Rate, TVAR, Seal Coat Design, Flushing, Bleeding, Shelling, Aggregate Loss, Knowledge Management	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	140	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SYNTHESIS STUDY ON TRANSVERSE VARIABLE ASPHALT APPLICATION RATES FOR SEAL COATS

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DISCLAIMER

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. The authors thank the members of TxDOT's Project Monitoring Committee: Tracy Cumby (Lubbock District), Randy King (Brownwood District), Steve Littlefield (Tyler District), and Gerald Peterson (Construction Division). Special thanks go to the project director, Paul Montgomery (Lufkin District), and the program coordinator, Dennis Cooley (Lufkin District). This project would not have been possible without the generous support, feedback, guidance, and assistance from all of these individuals. Special appreciation is also extended to the many individuals in the districts who shared their wealth of seal coating experience and provided traffic control for the numerous pavement test locations.

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CHAPTER 1: INTRODUCTION

This report documents the capture and analysis of information concerning the practice of transversely varying asphalt application rates to diminish existing wheel path flushing while retaining chip seal aggregate outside of the wheel paths. The research team first gathered and analyzed information available from the literature and then utilized a structured interview process to gather institutional knowledge from some of the most experienced TxDOT seal coat project managers and inspectors. The scope of the project also included texture testing pavements prior to the application of selected seal coats during the summer of 2008 to attempt to develop a correlation between the difference in wheel path and outside of wheel path texture depths and the transverse variations in asphalt application rates being used by TxDOT. The research team prepared a field guidebook entitled Guide for Transversely Varying Asphalt Rates based on all gathered information. A recommended construction specification plan note was also developed. Legacy Knowledge documents were written based on information obtained from the structured interview process.

ORGANIZATION OF THE REPORT

This introductory chapter includes a discussion of the significance of properly varying asphalt application rates and documents the current use of this practice in the 25 TxDOT districts.

Chapter 2 documents the findings of a literature review performed at the outset of the project.

Chapter 3 describes the process of identifying and interviewing experienced TxDOT seal coat project managers and inspectors to capture institutional knowledge about transversely varied asphalt rate (TVAR) practices. The methods used to process and distribute this information are also discussed.

Chapter 4 describes current TVAR practices in Texas based on information gathered during district visits.

Chapter 5 describes the pavement texture depth testing that was performed and the comparison of texture depth test results to variations in observed pavement conditions used by TxDOT inspectors to determine when use of TVAR is appropriate.

Chapter 6 includes discussion of currently used TVAR specifications and proposes a plan note suitable for statewide use.

Chapter 7 summarizes the findings and recommendations derived from this research study.

SIGNIFICANCE OF PROPERLY VARYING ASPHALT APPLICATION RATES

The Texas Department of Transportation relies heavily on seal coats for preventive maintenance of flexible pavements. Over the decades, this treatment method has proven to be quite cost effective when applied correctly and in a timely manner *(1)*. Maintaining the knowledge and skills necessary to best use this treatment method is, therefore, of great importance to the department and has been the focus of the research program and the Texas Pavement Preservation Center (TPPC).

In more recent years, TxDOT research efforts have included the successful seal coat constructability review by Senadheera, Gransberg and Kologlu in research project 0-1787 *(2)*, which was followed by the updating of TxDOT's Seal Coat and Surface Treatment Manual in 2004 by Estakhri and Senadheera under implementation project 5-1787 *(1)*. The interview process they performed found that 12 districts had experience varying asphalt application rates transversely at that time. Little detail about that experience was reported. In 2005, Gransberg and James completed a nationwide synthesis on best practices in chip seals *(3)*, finding a variety of design methods being used, but few considering varying the asphalt application rate transversely. Table 1 shows the distribution of methods being used by agencies responding to a survey in 2005.

The Texas Pavement Preservation Center is currently developing an updated seal coat inspector course. The TPPC is asking those who are contributing information to describe the process of setting asphalt rates and is inquiring whether or not they include transverse variation in those determinations. However, a detailed exploration of varying asphalt application rates is beyond the scope of that project.

Table 1. Chip Seal Design Methods in North America (after Gransberg and James).

Chip Seal Design Method	United States (%)	Canada (%)
Kearby/Modified Kearby	7	0
McLeod/Asphalt Institute	11	45
Empirical/Past Experience	37	33
Own formal method	19	0
No formal method	26	22

Optimizing seal coat performance requires that an adequate amount of asphalt is applied to the roadway surface to properly embed and hold the seal coat aggregate, to seal over minor pavement cracks, and to seal surface pores in asphalt surface mixtures. While the optimal asphalt application rate for a given asphalt material and a given seal coat aggregate on a given roadway can be difficult to determine without years of experience, the task is made more challenging when the optimal asphalt amount varies across the width of the pavement. However, asphalt distributor technology has advanced over recent years, making the task easier to accomplish once the desired amount of variability has been determined.

Many factors can contribute to a variable need for asphalt across a pavement width. These include but are not limited to loss of aggregate from a prior seal coat, increased embedment and reorientation of wheel path aggregate by summertime traffic, wearing down of aggregate in the wheel paths, and wheel path flushing of existing asphalt concrete pavement (ACP) mixtures. Regardless of the reason it occurs, when the need for asphalt varies across a roadway, failure to properly adjust the application rate across the roadway will result in shorter service life of the seal coat than would otherwise have been possible. Too much asphalt applied to wheel paths will result in loss of pavement friction and reduced roadway safety as the excess asphalt soon wells up around and possibly even over the freshly placed seal coat aggregate. Less than optimal asphalt application causes increased likelihood of loss of seal coat aggregate, again reducing pavement friction and roadway safety. Figure 1 shows an old seal coat with wheel path flushing. The close-up photos reveal the difference in surface voids found outside of the wheel paths and in the wheel paths. Clearly, optimal asphalt rates to hold the new seal coat aggregate differ across this roadway.

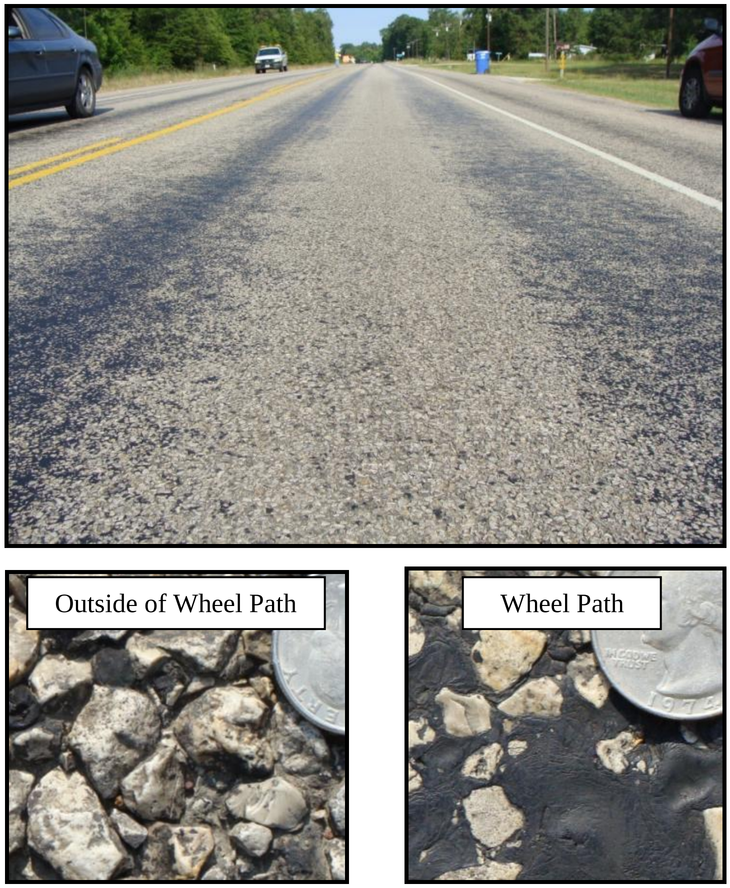

Figure 1. Flushed Pavement and Transverse Texture Differences.

CURRENT EXTENT OF TVAR PRACTICE IN TXDOT

While all TxDOT districts rely heavily on seal coats for preventive maintenance, the districts are currently split concerning use of transversely varied asphalt rates. The TxDOT research project director distributed a questionnaire to each TxDOT district to determine the extent of current TVAR practice. The questionnaires were provided to the district maintenance engineers so that they could either respond or forward to a more appropriate responder. Appendix A includes the questionnaire.

All 25 TxDOT district offices responded to the questionnaire. A summary of all responses is provided in Table 2 and is shown geographically in Figure 2. A majority of districts have either tried or are currently using this technique. Thirteen districts consider it standard practice. However, nine districts reported no use over the last five years other than for experimentation. It is apparent that guidance for use of TVAR would be beneficial to assist districts with limited or no experience.

Table 2. Questionnaire Response Summary.

District	Current Use	Number of Locations Used in Last 5 Years	Comments with Survey Response
Abilene	Standard Practice	Over 30	
Amarillo	Standard Practice	Over 30	Our biggest problem with this practice is keeping up with what nozzles are where and getting the distributor operators to change the arrangement when necessary.
Atlanta	Standard Practice	Over 30	
Austin	Standard Practice	16 to 30	
Beaumont	None	—	
Brownwood	Standard Practice	Over 30	
Bryan	Standard Practice	Over 30	We typically use variable nozzle when ADT > 1000.
Childress	Standard Practice	Over 30	Have been using for probably more than 10 years.
Corpus Christi	Standard Practice in Past but Not Currently Used	—	Stopped use about five years ago.
Dallas	Standard Practice	Over 30	
El Paso	None	—	
Fort Worth	Standard Practice	Over 30	
Houston	Occasionally Use	16 to 30	
Laredo	Standard Practice	Over 30	Standard in wheel path is 15% less than nozzles over other areas of the pavement, unless otherwise directed by the engineer.
Lubbock	Experimented and Decided Not to Use	—	Haven't used in the last seven or eight years.
Lufkin	Standard Practice	Over 30	
Odessa	None	--	
Paris	Standard Practice	Over 30	
Pharr	None	—	
San Angelo	Experimented and Decided Not to Use	1 to 5	
San Antonio	Occasionally Use	6 to 15	
Tyler	Standard Practice in Past but Not Currently Used	—	It has been over five years since we have tried this procedure.
Waco	Standard Practice	6 to 15	
Wichita Falls	Standard Practice in Past but Not Currently Used	—	
Yoakum	Currently Experimenting	—	

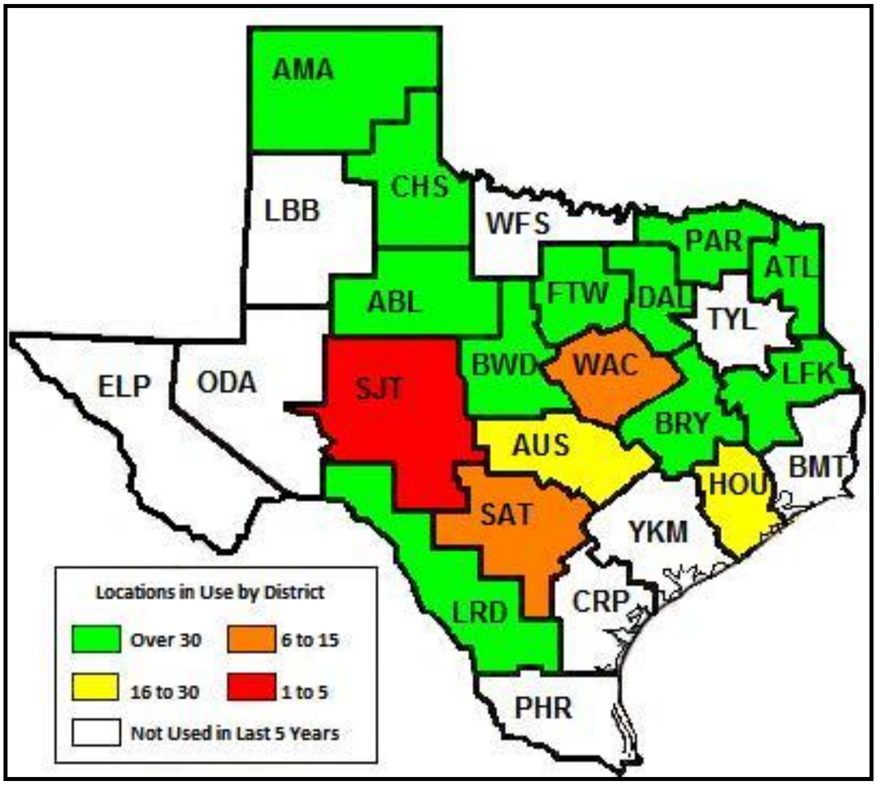

Figure 2. Texas Map − District TVAR Experience over Last Five Years.

CHAPTER 2:
LITERATURE REVIEW

The scope of this project included gathering information about transversely varying asphalt application rates for seal coats from available literature. The most relevant references to this study were identified, and those items are discussed below. The most relevant information was found in literature from New Zealand.

UNITED STATES

Constructability Review of Surface Treatments Constructed on Flexible Base Courses, S. Senadheera, M. Leaverton, and M. Vignarajah, Texas Tech University, 2007 *(4)*. This research project collected best practice information from TxDOT district personnel on the use of surface treatments over flexible base materials. Researchers visited each district, interviewed experienced district personnel, and studied pavements representative of each district's practice. The literature search performed by these researchers revealed that South Africa, New Zealand, and Australia are other countries making extensive use of surface treatments over flexible base material. This practice is less frequent in the US, as only 6 of 28 responding states indicated this use of surface treatments. Unlike during the constructability review by this research team in 2000 regarding all types of seal coats, when wheel path flushing was by far the most frequent performance problem reported, the researchers found it equally frequent for new surface treatments over flexible base to have either wheel path flushing or loss of aggregate.

Statewide Seal Coat Constructability Review, Sanjaya Senadheera, D. Gransberg and T. Kologlu, Texas Tech University, 2000 *(2)*. This research project collected best practice information from TxDOT district personnel on the use of surface treatments over base materials. Each district was visited, experienced district personnel were interviewed, and representative seal coated pavements were studied in each district. The researchers found that the districts were designing their seal coats using either the Modified Kearby Method or an experience-based method. They also found that 12 of the 25 districts had experience transversely varying asphalt application rates. A Brownwood and Abilene district method for adjusting seal coat rates is included in the report. The review conducted during this project did not reveal if variable or constant transverse asphalt application rates were preferable based on resulting performance. One conclusion reached by the researchers was that the percentage of heavy vehicles should be a factor in the design procedure. That conclusion logically, although indirectly, supports the use of transversely varied asphalt application rates.

Seal Coat Inspector's Field Guide, D. Gransberg, S. Senadheera, and T. Kologlu, Texas Tech University, 2000 *(5)*. This field guide covers the contract administration, materials, equipment, and construction aspect of seal coat operations to assist the inspector in performing required duties on these projects.

Information about transversely varying asphalt shot rate is limited to reference to the Seal Coat Field Guide.

NCHRP Synthesis of Highway Practice 342 − Chip Seal Best Practices, D. Gransberg and D. James, Transportation Research Board, 2005 *(3)*. Information about the practices in US state departments of transportations (DOTs), from other US public road authorities, from Canadian road authorities, and from New Zealand, Australia, the United Kingdom, and South Africa is highlighted. This synthesis includes sections on chip seal design, contract administration, materials, equipment, construction practices, and performance measures. Best practice case studies are also included.

The best practices identified include the use of variable rates of asphalt across the roadway. Pre-spraying outside the wheel paths is described as well as using distributors with variable nozzles or spray rate controls. Very little detailed information is provided about any of the methods of obtaining the varied rate of application.

Chip Seal Program Excellence in the United States, D. Gransberg, Transportation Research Board, 2005 *(6)*. The responses from 42 US state DOTs and 12 US cities were analyzed to determine best practices. The most common distress when seal coats are applied by the owner agency is bleeding, particularly in intersections. The most common distress from contractor applied seal coats is early loss of aggregate. These findings emphasize the importance of seal coat design and also indirectly indicate that benefits can be obtained by appropriately matching asphalt rates to variable pavement asphalt needs.

Correlating Chip Seal Performance and Construction Methods, D. Gransberg, Transportation Research Board, 2006 *(7)*. This paper reports correlations between self-reported seal coat success level and the construction methods and equipment used by agencies responding to the NCHRP Synthesis 342 survey. The researcher found a strong trend between the agencies reporting excellent and good seal coat performance and agencies requiring state-of-the-art asphalt distributors. Similarly, agencies with loose asphalt distributor specification requirements were far more likely to report only fair or poor seal coat performance. The tightness of specifications for the aggregate spreaders did not show a correlation with seal coat performance.

INTERNATIONAL

Preventing and Solving Chipseal Problems Using a Transverse Variable Application Sprayer, B. Pidwerbesky and J. Waters, Australian Road Research Board, 2006 *(8)*. This research explored the amount that binder rates could be decreased from traditional application rates without chip loss. On a pavement where no binder rise was visible around the existing chips, no loss of newly placed chips was seen after seven years with approximately 10 percent and 20 percent binder rate decreases. Researchers noted minor chip loss with a 30 percent binder rate decrease. This test used a New Zealand Grade 5 chip, which most closely approximates a TxDOT Grade 5S seal coat aggregate.

Additional seal trials were then placed on pavements having binder flushing in the wheel paths, with 10 percent to 20 percent binder rate decreases in the wheel paths. Performances were reported to be better than seals placed with traditional application rates.

The second aspect of the project was to explore the various methods of calculating the amount to vary the asphalt application rate transversely across the pavement. The New Zealand method of determining texture depth was a part of all of the methods investigated. Traffic level was also a factor in all of the methods. A standard calculation method was not selected during this study. It was decided that for the time being a standard reduction of 10 percent would be used where some degree of binder rise is noted in the wheel paths, and a 20 percent to 30 percent reduction where a significant amount of binder rise is noted in the wheel paths.

Innovative Surfacings: What's New in New Zealand, B. Pidwerbesky and D. Faulkner, Fulton Hogan Ltd., New Zealand, 2005 *(9)*. This paper reports on a variety of innovations being used in New Zealand, including the use of Multispray™ asphalt distributors, which are capable of varying asphalt application rate transversely across the roadway. The nozzle rates are controlled by computer. The early success using these distributors to reduce asphalt application by 10 percent and higher in the wheel paths is reported to have prompted New Zealand to purchase seven distributors of this type for use around the country.

Chipsealing in New Zealand, Transit New Zealand, 2005 *(10)*. Transit New Zealand is the country's primary governmental road authority. This publication serves as their seal coat manual, and it includes chapters on the history, the industry, and the performance of chip sealing in this country.

The 2004 Seal Design Algorithm is introduced in this publication. It is based on traffic, volume of voids, and the average least dimension of the aggregate. The traffic factor considers the percentage of heavy vehicles. An important assumption is that the binder has risen up the aggregate by at least 35 percent before the beginning of winter. A formula is derived to determine asphalt shot rate based on average least dimension of the aggregate, the texture depth from the sand circle test, and the traffic conditions.

This manual does not include a method for determining the amount to transversely vary asphalt shot rate, but it does suggest the following formulas to determine if the difference in texture depth varies enough to take precautionary steps to prevent later flushing.

Td(coarse) – Td(average) > ALD/16

and

Td(average) – Td(fine) > ALD/16

Where:

Td(average) = average texture depth (mm) from all sand circle tests

Td(coarse) = largest texture depth (mm) from sand circle tests

Td(fine) = smallest texture depth (mm) from sand circle tests

ALD = average least dimension of the aggregate (mm)

Guidelines for Rural Road Design and Construction Technical Specification, Shire of Wyndham East Kimberley, Australia, 2006 *(11)*. These technical specifications include a requirement for asphalt distributor transverse application uniformity. In this western area of Australia, every test tile that is fully coated may not have a variation in asphalt greater than plus or minus 10 percent of the average application rate.

Innovative Surfacing Treatments for Flexible Pavements in New Zealand, J. Waters and B. Pidwerbesky, Fulton Hogan Ltd., New Zealand *(12)*. This paper reports successful trial and routine uses of several new methods to improve surfacing of New Zealand pavements. The predominant pavement structure in New Zealand is a chip seal surface placed on unbound aggregate base. Two-coat sandwich seals are most frequently used over flushed pavement surfaces. These use rather large stone nominal sizes, reported by the authors to be 20 mm and 12 mm. Use of these aggregates and transverse variable asphalt application rates are reported to be performing very well.

Road Surface Texture Measurement Using Digital Image Processing and Information Theory, B. Pidwerbesky, J. Waters, D. Gransberg, and R. Stemprok, Land Transport New Zealand, 2007 *(13)*. Researchers performed this study to further knowledge in the use of digital image processing with fast Fourier transform (FFT) analysis for the purpose of replacing the sand circle test method for determining pavement texture depth. The study showed that a relationship does exist between seal coat pavement texture and the output from an FFT analysis of a digital image of the pavement. A major limitation to the application of this technology is that chips of variable size are currently not correctly analyzed, so these data points must be removed from the analysis to obtain a desirably accurate characterization. This problem increases as a chip seal aggregate moves further away from being a single-sized aggregate.

CHAPTER 3:
KNOWLEDGE GATHERING AND PROCESSING

DISTRICT VISITS AND INTERVIEWS

The research team contacted those districts who reported on the questionnaire that they have used the TVAR technique in more than 30 locations over the past five years in order to determine the most appropriate individual to interview regarding details about their methods. Of the 11 districts with this level of experience, the research team was successful in interviewing 12 individuals from 9 districts. The individuals interviewed are shown in Table 3.

Table 3. List of Personnel Interviewed.

Name	Primary Duty	District
Joe Higgins	Area Engineer	Abilene
John Baker	Area Engineer	Atlanta
Randy King	Chief Inspector	Brownwood
Richard Walker	District Laboratory Engineer	Brownwood
Darlene Goehl	District Pavement Engineer	Bryan
Sheldon Clagg	Chief Inspector	Dallas
Russell Emerson	Chief Inspector	Dallas
Alan Easterling	Assistant Director of Maintenance	Fort Worth
Albert Quintanilla	Director of Maintenance	Laredo
Paul Montgomery	Director of Maintenance	Lufkin
Jimmy Parham	Chief Inspector	Lufkin
Ernest Teague	Area Engineer	Paris

Interviews were obtained during visits to the districts with two exceptions. Information from Albert Quintanilla and Joe Higgins was obtained by telephone and email. The usual interview process included both audio-taped discussions and observation of TVAR practices by contractors during the summer's seal coat project.

In addition to the TxDOT personnel selected for interview, the project monitoring committee requested that an asphalt distributor supplier be contacted. Kelly Durham with E. D. Etnyre and Co. was specifically suggested. Mr. Durham was interviewed by telephone.

A series of questions was developed to capture desired information during interviews. The list of questions targeted the following areas of information:

- experience level,
- when to transversely vary asphalt rate,
- how to transversely vary asphalt rate,
- distributor calibration and inspection,
- construction inspection,
- seal coat performance, and
- general closing questions.

The question list was modified somewhat for specific interviews to more thoroughly capture the expertise of each individual. An example of an interview question list is included in Appendix B. The question list formed the outline and provided structure for the informal interviews, thereby expediting the process. Most interviews lasted between one hour and two hours. Researchers believe that providing interviewees with the question list in advance helped expedite the interview process and improved the depth of information that they obtained.

PROCESSING INTERVIEW INFORMATION

Researchers audio-recorded interviews with the exception of the interviews with Dallas and Laredo district personnel and the equipment supplier. Recorded interviews were transcribed to facilitate analysis and processing of the information. This analysis resulted in the development of a series of documents for capturing and retaining this knowledge within TxDOT's formal Knowledge Management System (KMS). TxDOT's KMS is accessible by all TxDOT employees on the agency's intranet, i-Way. The Training Section of the Human Resources Division manages the KMS. The prepared documents are in identical format to over 200 Legacy Knowledge documents already available within the KMS. Each document contains a list of key words, as the KMS database is searchable in order to facilitate locating desired information.

Each Legacy Knowledge document was provided to the individual interviewed for review, revision suggestions, and approval. These documents communicate using a conversational writing style, thereby giving the reader the feeling of having had the opportunity to listen to the experienced individual over a cup of coffee. An example of a Legacy Knowledge document is shown in Figure 3.

Texas Department of Transportation

Legacy Knowledge

Joe Higgins: September - 2008

Joe Higgins' Thoughts on ....

TVAR Seal Coat Design
TVAR Seal Coat Inspection

I've been involved with transversely varying asphalt shots as far back as fifteen years ago. I don't know for sure which year Thomas Bohuslav came to the Abilene District from Brownwood, but I remember we talked about asphalt rates and variable nozzles at that time, and we were already using some transverse rates in those years. I had done district seal projects for years, but then I got away from them for awhile. When I started doing the seal coats in my area three or four years ago, we went back to using variable nozzles.

In the early days I would use variable asphalt rates on all the roads in the district seal coat program, whether or not they showed any flushing in the wheel paths. Even on fairly decent looking pavements; I didn't think it was right to wait until you had flushed up asphalt in the wheel paths to start using variable nozzles. I still think that's the way to go because if you use straight nozzles where there's traffic, eventually, those wheel paths are going to show up. It will either be flushing in the wheel paths or you will be losing rock outside the wheel paths. While I would use variable rates on all of the main lanes, we would use straight nozzles on the shoulders.

When Thomas Bohuslav came, he brought a lot of good ideas from the Brownwood District. One thing Brownwood did was they made their own nozzles. We had two or three sets of nozzles made up and we would require the contractors to use them. However, there were some problems with that. We would have to use adapters to make them fit different contractor's spray bars. I really didn't like that, but that's what we did. I think those nozzles were made to give a variation of about 25%.

About two years ago I wanted to go with standard manufacture's nozzles. I picked two nozzles, trying to get as close as possible to 25% variation. Those two nozzles gave about 42% variation when we did the bucket test. Or maybe the 42% was based on the manufacture's literature. We went with them and it seemed to work pretty well. I imagine if we were to vary that much two or three times in a row we might start seeing something. I would say that as far as the amount of variation to use, there is a wide range there. I don't know if anybody really has a good handle on exactly how much variation you should use.

It's my understanding that at least one distributor manufacturer can now make nozzle sets to give the percent variation you want. That's good. Before, I let the

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Figure 3. Example Legacy Knowledge Document.

contractor get by with something outside of the range I was looking for in order to use standard nozzles. Now, I would be a little bit more demanding that we get the variation requested because I know they can get those nozzles.

Recently we have been requiring a variation in the range of 20% to 30%. We need to give the contractor a range because even with good nozzle manufacturing equipment, it's hard to hit a specific rate very closely. I would say 25% plus or minus 5% is about right.

Dealing with traffic and pavement condition adjustment factors, I have a sheet for the inspector that provides the recommended variations (Figure 1). I have another sheet to document the locations where you plan to change the average asphalt rate or the percent variation (Figure 2). That sheet also shows the numbers involved. The average asphalt rate depends on the lane width, because the width determines how many large nozzles you will have to have. So the worksheet guides the inspector through to come up with the average rate being obtained from the nozzles.

Nozzle Configuration

road width	nozzle configuration left to right (L-large, sm-small)	# small nozzles	# large nozzles	total # nozzles	25% variance av. rate* multiplier	30% variance av. rate* multiplier
8	1L 9sm 6L 9sm 3L	18	10	28	1.089	1.107
10	3L 9sm 6L 9sm 4L	18	13	31	1.105	1.126
11	5L 9sm 6L 9sm 5L	18	16	34	1.118	1.141
12	6L 9sm 8L 9sm 5L	18	19	37	1.128	1.154
13	7L 9sm 8L 9sm 7L	18	22	40	1.138	1.165
14	7L 9sm 8L 9sm 10L	18	25	43	1.145	1.174
15	7L 9sm 8L 9sm 13L	18	25	43	1.145	1.174
16	7L 9sm 8L 9sm 16L	18	28	46	1.152	1.183

* wheel path rate = base rate + traffic adj. + truck adj. + surface adj.
outside wheel path rate = wheel path rate X (1+%variance). Example: for variance of 25% then (1+%variance) = 1.25
average rate = wheel path rate X variance multiplier above. Example: for 12' width & 25% variance, multiplier=1.128
above factor = (#small + #largeX(1+variance))/total # of nozzles

Base Rate

Aggr. Grade	Asph base rate gal/sy	Aggr. rate cy/sy
3	0.40	105
4	0.34	115
5	0.25	130

Table base rates are not to be used for emulsions.

Truck Adjustment

% trucks	aggr grade 3	aggr grade 4	aggr grade 5
average	0	0	0
heavy	-0.03	-0.02	-0.01

Surface Condition Adjustment

surface	description	gr3	gr4	gr5
Seal	very dry seal with many cracks	0.06	0.05	0.04
	dry seal with few cracks	0.03	0.03	0.02
	good seal with no cracking	0.00	0.00	0.00
	flushed seal	-0.02	-0.02	-0.01
	bleeding seal	-0.04	-0.04	-0.02
ACP	ACP	0.12	0.10	0.05
Cold Mix Patch	dry, well aged	0.12	0.10	0.04
	fresh (less than 3 months)'	0.00	0.00	0.00
Prime	prime - dry surface, light rate	0.05	0.04	0.02
	prime - average codition	0.02	0.02	0.01
	prime - free asphalt on surface	0.00	0.00	0.00

'recommend cold mix patches have adequate cure time (plus 6 months minimum)

Traffic Adjustment

vol/lane	gr 3	gr 4	gr 5
0	0.07	0.05	0.04
50	0.06	0.04	0.02
100	0.04	0.03	0
300	0.01	0.02	NA
500	0	0	NA
700	-0.01	-0.01	NA
1000	-0.02	-0.02	NA
1500	-0.03	-0.03	NA
2000	-0.04	-0.04	NA

2 lane = ADT/2
4 lane urban = ADT/4
4 lane rural = ADT *.35 outside lanes
4 lane rural = ADT *.15 inside lanes
Shoulder ADT = zero

NOTE: Surface & traffic adjustment factors are subject to change based on experience.
If you experience problems using these rates, please contact Joe Higgins, Hamlin TxDOT.

Figure 1

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Figure 3. Example Legacy Knowledge Document (continued).

Asphalt Design Rate Worksheet

Highway ____________ County ____________

Asphalt type ____________ CSJ ____________

Nozzle var. (20% or 30%)---> ____________ aggregate rate (cy/sy)--> ______

Aggregate Size (3 or 4 or 5---> ____________ asphalt base rate (gal/sy)--> ______

width feet	ADT veh/day	Veh per Lane	truck %	Location (normally Texas ref. mark (or station) and direction)	traffic adjust gal/sy	truck adjust gal/sy	surface adjust gal/sy	wheel path rate* gal/sy	outside wheel path rate** gal/sy	average rate*** gal/sy

Comments:

Vehicles per lane
2 lane = ADT/2
4 lane urban = ADT/4
4 lane rural = ADT *.35 outside lanes
4 lane rural = ADT *.15 inside lanes

*wheel path rate = base rate + traffic adj. + truck adj. + surface adj.
**outside wheel path rate = wheel path rate X 1.25 (for 25% variance)
***average rate = wheel path rate X variance multiplier from nozzle conf. table

Figure 2

Now, with seal coats, my experience is everybody is an expert. You can have a summer hand who has been out there two weeks and knows exactly what to do, what kind of rates to use, and everything else. Regardless of how much or little experience, people think they have it figured out. The recommended rates and adjustments in the worksheet are based on what has worked in the past. I continue to adjust them. There's a note at the bottom of the worksheet that says, "If you use these rates and they don't work for you, let me know and we can adjust them." In fact, I have recently made some adjustments based on the last couple of years of experience. One thing that often throws people off is shooting on top of hot mix. It seems people never add enough asphalt to the base rate when shooting on hot mix. That's a number I have increased in my recommendations. The recommendations are a continuing process, tweaking them as we go.

The biggest thing for the inspector to monitor is that the right nozzles are in the right places. That can be hard once you get the nozzles and spray bar covered with asphalt. An inspector has to be able to look at the spray bar and tell if the nozzles are oversized or too small. Contractors can get a little lazy and put standard nozzles on and not change them when they go back to the main lanes, or vice versa. What we did last year was have the contractor put washers on the bigger or smaller nozzles. We could then check them without getting some diesel and a rag and trying to see the numbers on the nozzles.

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Figure 3. Example Legacy Knowledge Document (continued).

A method some people use to check if the varied asphalt shot rate is proper is to look at the rock embedment behind the rollers. I have never thought that was a good method because there is no way you can really tell when varying shot rates. You have to wait and go through a winter and summer to see if it's going to bleed or lose rocks. So I trust what I have learned from experience about adjusting rates for traffic and road conditions instead of spending a lot of time on my knees looking at embedment. We wait twelve months before checking to see if we had a successful seal coat. When we check it we see if it lost rock, if it bled, we look at when we shot it, and what the rates were that we used. Our district is doing much better with keeping up with the rate we placed and evaluating the condition of the road afterwards. Those evaluations can lead to tweaking the adjustment factors.

When it comes to the process of varying asphalt rates, we have always designed the asphalt rate for the wheel paths first because the wheel paths tell you more. We pick a rate for the wheel paths, and then we increase asphalt outside the wheel paths. If you use variable nozzles, you put down more asphalt than you would otherwise, and you get a better finished product.

The additional asphalt outside the wheel paths helps you hold the rock better and you get a better job of sealing the pavement. It's the same on the shoulders. My instruction to the inspectors on shooting shoulders is to shoot as much asphalt as your construction equipment can get through. If the seal starts picking up on construction equipment, you've shot too much and back off. We always put down a lot of asphalt on the shoulders since they don't carry traffic. I have developed a theory on that. If you want to save money, shoot the shoulder only every other cycle. The cycle that you do shoot it, put down such a heavy rate that that the seal should hold better through the cycle when it's not shot.

The seal contractors that have worked in my district are pretty neutral on transversely varying asphalt rates. Now I do suspect the hands that have to change those nozzles out probably have an opinion on it. But the contractor, the owner of the company, they just go with it. I don't know if they add anything to the bid price or not, but I suspect they get their money back without an increase because they will be putting down a little more asphalt for the same amount of work.

One thing I would tell districts that haven't tried transversely varying asphalt rates is to just look at your roads. On the roads that have been sealed two or three times over the years, you can see it's either flushed in the wheel paths, or you've probably lost some rock between the wheel paths and outside the wheel paths. To me, that is the biggest thing I see that should convince everybody we need to be doing something a little different. I think varying nozzle sizes makes obvious

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Figure 3. Example Legacy Knowledge Document (continued).

sense. The more traffic you have, the more that traffic is going to beat the rock down into the asphalt, and the traffic runs in the wheel paths.

For me, the biggest unanswered question would be how much variation you need. How much variation is enough and not too much? If I can vary from 20% to 40%, that's a wide range. What I have liked to do in the past is base the amount of variation on experience. And then when I go back in twelve months and see that it is working fine, then maybe that was a good rate variation. But the number I pick for a percent variation is just a guess. I don't use a calculation or anything for the amount of variation.

While I haven't tried it, I think using the sand patch test is a very good concept. But I can tell you where it's not going to work if you are testing only the wheel paths. It won't work on hot mix and hot mix-cold laid pavement surfaces. If you do the sand patch test in the wheel path it's going to indicate that you need to back off on the asphalt because the hot mix surface is closed up, similar to a partially flushed seal coat. But you really need to go the other way. My discovery on hot mix is that I have had to bump up the asphalt rate one-tenth above base rate. I increase asphalt at one-tenth for a grade 4 now and twelve-hundredths for a grade 3 aggregate. I have never seen hot mix to bleed up after someone sealed on top of it. I do see a lot of rock loss though. So I keep bumping the rate up for hot mix surfaces. I have a theory on hot mix. Hot mix is just a flush surface and the seal coat rock can't nestle down into it, it just sits on top.

I have one more thing that hasn't been mentioned, and that is you can't totally judge the seal coat based on whether you lose rock or get some flushing. The time of year you shoot is so critical. If you shoot a seal coat in the spring, you have the summer ahead of you before the winter, and you can be good. If you shoot it late, sometimes the pavement doesn't get hot enough for the rock to properly seat. That's when you can lose rock. But in that case it wasn't because the asphalt rate was wrong. It was because of the time of year that you shot it.

One thing I tell my inspector is, "Don't change your rock rate. Keep your rock rate the same." We have so many contractors and inspectors to start increasing rock rather than holding it the same and decreasing the asphalt if they start seeing a little picking up on the dump truck or chip spreader. I try not to vary my asphalt rate based on the time of season, but if we are doing a rehab job and we want to finish it, I might shoot a little more asphalt. But I try to hold my asphalt rate based on the traffic and the pavement conditions, those two factors only. If it's too late in the season, we probably just shouldn't be shooting.

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Figure 3. Example Legacy Knowledge Document (continued).

Key Words, by Category:

Geographic Area - Abilene district, west Texas

Information Type - Legacy knowledge

Legacy Knowledge Source – Joe Higgins, September 2008 interview

Analyses Involved – Test Method Tex-436-A, Sand Patch Test

Flexible Pavement Distresses Involved – Flushing, shelling

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, texture, grade 3, grade 4, grade 5, work sheet, asphalt adjustment factors, nozzle size identification, shoulders, rock rate, picking up, hot mix, hot mix cold laid, traffic, embedment, Thomas Bohuslav

Search Acronyms: Legacy Knowledge – Flexible Pavement – Maintenance, lkfpm, Legacy Knowledge – Flexible Pavement – Inspection, lkfpi, Legacy Knowledge – Flexible Pavement – Construction, lkfpc, Legacy Knowledge – Flexible Pavement – Specifications, lkfps, Legacy Knowledge – Flexible Pavement – Unique Application & Innovation, lkfpu

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Figure 3. Example Legacy Knowledge Document (continued).

The example Legacy Knowledge document in Figure 3 is one of the lengthier in the KMS, as the majority are one to three pages. It is an excellent example, however, of the obvious and long-term value of legacy information when captured and placed in a KMS prior to the retirement of individuals who learned from many decades of experience.

All Legacy Knowledge documents derived from interview transcripts are included as Appendix C.

CHAPTER 4:
CURRENT TXDOT TVAR PRACTICES

PRACTICES OVERVIEW

The interviews in districts routinely using TVAR found universal agreement in the opinion that use of this technique was benefiting performance of their district's seal coats. Most individuals cited reduced occurrence of wheel path flushing as the primary benefit. TVAR has been used on selected pavements for many years in a number of districts. One district reported using this practice for over thirty years.

There was not complete agreement among districts on which pavements should be sealed using the TVAR method. While all of those interviewed viewed seal-coated pavements with flushed wheel paths as excellent candidates, there was difference of opinion on whether hot mix asphalt (HMA) pavements, microsurfaced pavements, and hot mix-cold laid (HMCL) locations were appropriate for TVAR. Concerns with use of TVAR on pavements with asphalt mixes on the surface included the fact that the macrotextures of these surfaces are by nature more closed and, therefore, do not vary considerably across the pavement as they do on seal-coated pavements, even if some degree of wheel path flushing is present. Some of those interviewed noted that HMA surface mixtures will absorb a portion of the seal coat asphalt being shot, making under-asphalting the wheel paths more likely than placing too much asphalt there. Another concern was that hot mix pavements with wheel path flushing may have asphalt stripping occurring below the surface, or there may be an over-asphalted layer in the pavement structure. If either of these is the situation, TVAR will not rectify the problem.

The majority of districts use TVAR on selected pavement sections, opting to stay with uniform transverse asphalt applications on pavements not showing wheel path flushing. The exception to this was an area office where a moderate TVAR percentage was required, about 15 percent additional asphalt being placed outside of the wheel paths, and this TVAR was being used on all pavements in their summer seal coat program. This was done during the 2008 seal coat season, with no negative construction or seal coat performance issues identified to date of this report.

METHODS OF DETERMINING WHEN TO USE TVAR

All districts currently using TVAR rely on visual appearance of the roadway surface as the primary method for determining if a given roadway is a good candidate for a TVAR seal coat. The extent to which the wheel path condition differs from conditions outside of the wheel paths is the determinant. Differences in macrotexture and free asphalt at or near the surface are the factors of most importance. Difference of pavement color across the lane is another indicator, but at times color will not vary to the extent that macrotexture conditions vary. The researchers found that districts vary in the amount of visual difference that triggers their decisions to use TVAR. In the Bryan District, TVAR is used broadly, generally whenever the wheel path locations can be visually identified and the traffic level is at least 1000 AADT. The Bryan District reports success using this application approach. Most other districts require more difference in appearance than just being able to visually identify wheel path locations. Figure 4 shows a roadway appearance and difference in texture conditions where most districts would use TVAR. The insets show close-up photographs of wheel path (WP) and between wheel path (BWP) locations.

Figure 4. Roadway Condition Generally Considered Appropriate for TVAR.

An area engineer in the Atlanta District, John Baker, uses a pseudo sand patch test method that he developed to help make the decision on occasional roadways where appearance alone doesn't provide him enough information. He performs this test between the wheel paths and measures the diameter of the sand circle created. The diameter provides him information about the openness of texture outside of the wheel paths, and based on this diameter he decides if the design shot rate for the wheel paths should be adequate outside of the wheel paths.

SEAL COAT MATERIALS CONSIDERATIONS

The districts reported that TVAR has been frequently and successfully used with virtually all commonly used seal coat asphalts and aggregate materials. TVAR is an appropriate consideration when shooting either emulsified asphalt or hot asphalt cement. It may be used with both Grade 3 and Grade 4 aggregate, with lightweight and natural aggregates, and with precoated and plain aggregates. One area engineer reported successful use of TVAR with rubber-asphalt. Grade 5 aggregate was the only material-related limitation mentioned by the districts, as the small dimensions of this aggregate allow little room for variation in asphalt application rate.

NON-CONDUCIVE PAVEMENT SURFACE TYPES AND CONDITIONS

Frequent TVAR users consider several other factors in addition to the degree of flushing apparent in the wheel paths when determining appropriateness of use of this technique on a roadway. Principal among these are the level of traffic on the roadway and the likelihood of traffic tracking in a consistent manner. TVAR is not recommended on shoulders, continuous left-hand turn lanes, and other locations where traffic patterns are random. Roadways through towns and cities are less likely to benefit from TVAR because of the randomness of traffic tracking.

Another situation where current TVAR users usually elect not to use this technique is for new construction. While the technique has been tried occasionally as a preventive measure on new construction, the consensus of users is that potential benefit from using TVAR in new construction is small compared to potential for loss of performance life resulting from using less asphalt to seal the portion of the pavement carrying the majority of traffic loads.

Roadway profile is another factor to be considered, particularly when emulsified asphalts are being used. Significantly rutted pavements and full super-elevated sections are locations where higher asphalt rates outside of the wheel paths may foster migration of that asphalt into the wheel paths.

ASPHALT DISTRIBUTOR CALIBRATION

Distributor calibration when TVAR is specified is generally handled in the same manner as for standard seal coats. The exception is that districts also have the contractor verify the required TVAR capability of the distributor(s).

For single spray bar distributors, after the normal calibration test to assure that nozzle outputs do not vary by more than 10 percent, the contractor sets up the spray bar for TVAR and then runs the test again to verify TVAR percentage capability. Figure 5 shows a distributor being prepared for the bucket test under Texas Test Method Tex-922-K, Part III. The nozzles used for the TVAR verification should be identified on the calibration report. Some districts require the contractor to place plastic ties or spot weld a washer on the larger nozzles to be used when TVAR is required to facilitate spray bar inspection during construction.

Figure 5. Distributor Calibration (photo provided by R. Walker).

Dual spray bar distributors should be similarly calibrated. A standard approach to assuring calibration of dual spray bar distributors at TVAR percentages has not been developed. The researchers believe it prudent for inspectors to have the contractor check nozzle output at 0 percent, 15 percent and 30 percent asphalt variations to verify that the nozzles and asphalt pumps will allow proper flow of asphalt material across the entire range of probable TVAR percentages to be requested on the project.

ROADWAY INSPECTION PROCEDURES

Spray Bar(s) and Nozzles

When TVAR is required, the TxDOT inspector must define for the contractor the transverse dimensions for application of the variable asphalt rates. These dimensions are controlled by the locations of nozzles providing the differing amounts of asphalt. Table 4 shows recommended nozzle arrangements for various lane widths. This table was prepared by consolidating information gathered from several districts frequently requiring TVAR. These districts also stated that they will occasionally vary from their standard nozzle arrangements when traffic patterns on a given roadway locate the wheel paths consistently closer or farther from the center line stripe. All of the districts generally stipulate a 3-ft wheel path width, which is provided by 9 nozzles at a separation of 4 inches on the spray bar.

Table 4. Recommended TVAR Nozzle Arrangements for Various Lane Widths.

Lane Width, Feet	Center Line to Wheel Path (Larger Nozzles)	Inside Wheel Path (Smaller Nozzles)	Between Wheel Paths (Larger Nozzles)	Outside Wheel Path (Smaller Nozzles)	Wheel Path to Pavement Edge (Larger Nozzles)
9	1	9	6	9	2
10	2	9	6	9	4
11	4	9	7	9	4
12	5	9	8	9	5
12 (with edge line)	6	9	8	9	4
13	7	9	8	9	6

Some distributors now feature dual spray bars controlled by separate computers, thereby facilitating TVAR use by allowing the equipment to change TVAR percentages without changing nozzles on the spray bar. Figure 6 shows a dual spray bar system.

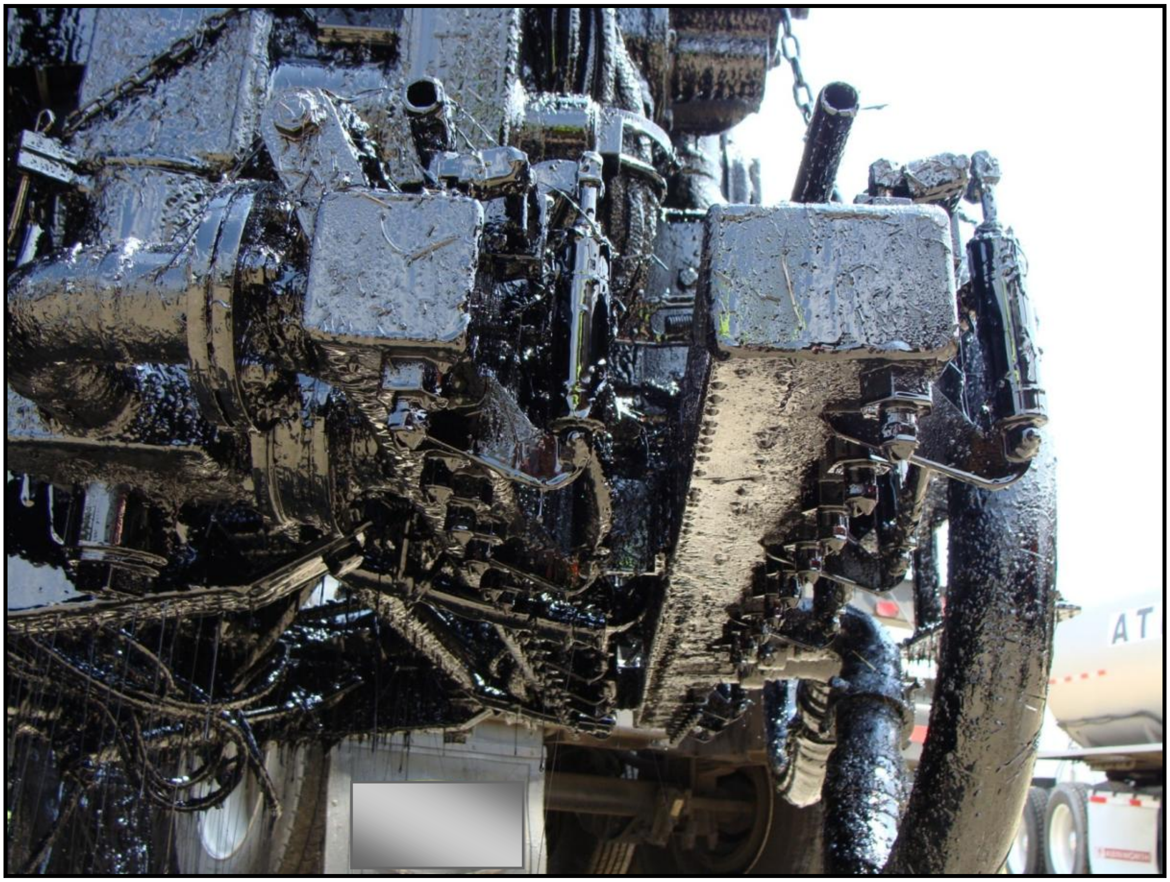


Figure 6. Dual Spray Bars on Asphalt Distributor.

Distributor Computer Controls

Modern asphalt distributors use computerized controls for applying the asphalt rates. It's important for the inspector to understand the meaning of the asphalt rate entered into the distributor's computerized controller, or both rates if there are two computers.

When a distributor with a single spray bar is being used, unless otherwise indicated in the distributor's operation manual, the computer setting establishes the total amount of asphalt to be applied. Therefore, one of the most important inspection items when transversely varying asphalt rate with a single spray bar distributor is to assure that the average asphalt rate is set on the distributor's computer controller. The average asphalt application rate is determined from the two rates being applied by a formula. The average rate is not the simple average of the two rates in most cases because there are usually more nozzles spraying one rate than the other rate. The formula below should be used to determine the average asphalt rate.

Average Asphalt Rate = [(L/100) x (V/100) x R] + R

where:

L = percent of nozzles of the larger size = the number of larger nozzles across the spray bar divided by the total number of nozzles and then multiplied by 100,

V = percent increase in asphalt rate selected for outside of the wheel paths (TVAR %), and

R = design rate of asphalt application for the wheel paths in gallons per square yard.

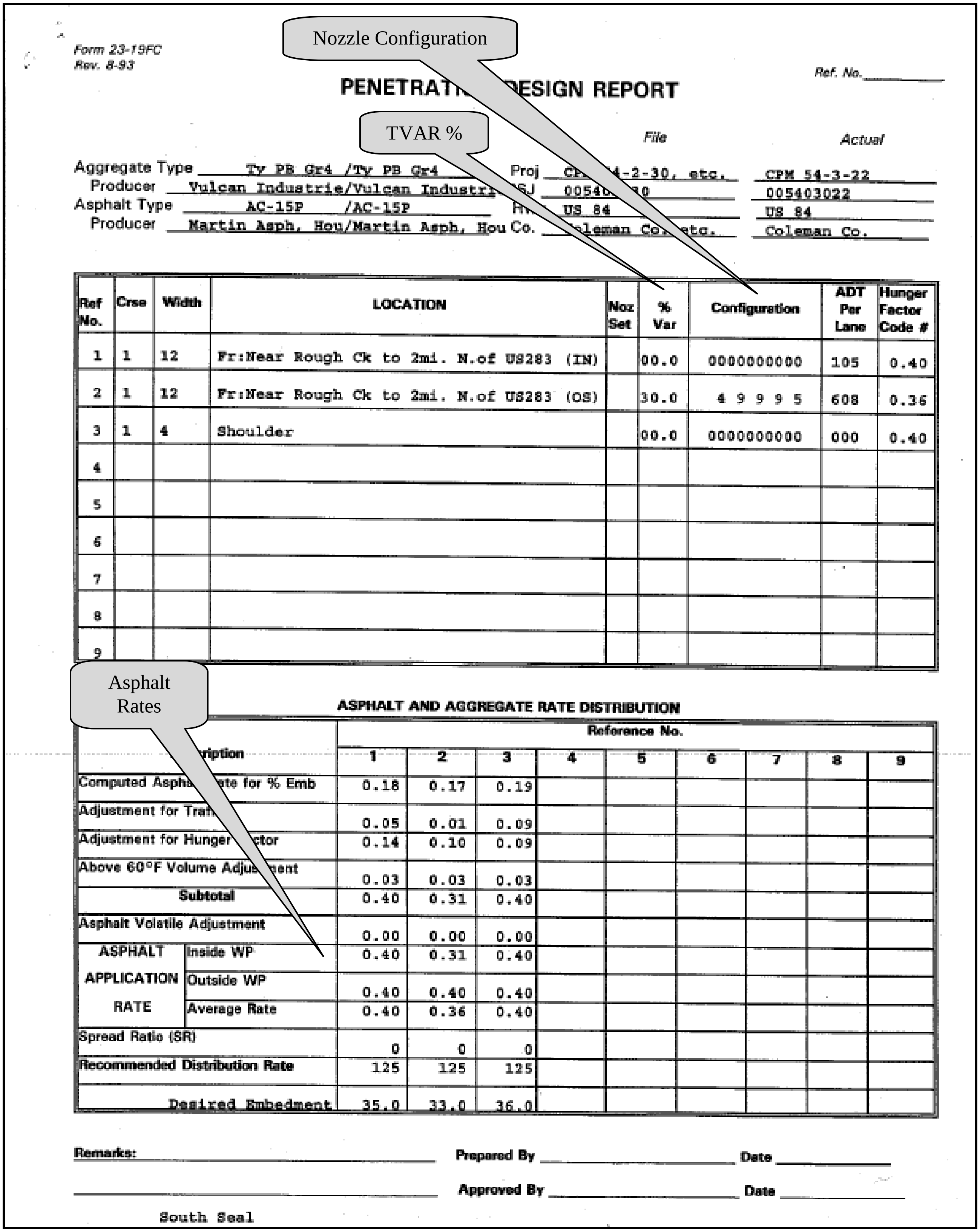
When the distributor has two spray bars and a computer controlling each one separately the inspector need only assure that the correct asphalt rate has been entered into the correct spray bar controller.

Contractor Communications

A number of districts using TVAR have developed written methods of communicating TVAR information to the contractor in advance of the contractor arriving on the roadways where this technique is to be used. This is usually in the form of a design report or worksheet. Information being communicated usually includes:

- the roadway width,
- the desired configuration of larger and smaller nozzles,
- the asphalt application rates for the wheel paths and outside the wheel paths,
- the average asphalt application rate,
- the desired aggregate distribution rate, and
- the limits of the sections where these asphalt and aggregate rates are to be applied.

Figure 7 is an example of the form used by the Brownwood District to communicate this information to contractors. This example requests a TVAR of 30 percent in the outside lane and stipulates a nozzle configuration of 49995 when shooting that lane. This series of numbers indicates the numbers of different sized nozzles used across the spray bar, as similarly indicated in Table 4. A single nozzle size is to be used in the inside lane and on the shoulder where TVAR is not desired, as indicated by the 0000000000 entry in the configuration column of the design sheet.



Form 23-19FC
Rev. 8-93

Ref. No.

PENETRAT[illegible]ESIGN REPORT

			File	Actual
Aggregate Type	Ty PB Gr4 /Ty PB Gr4	Proj	CP[illegible]4-2-30, etc.	CPM 54-3-22
Producer	Vulcan Industrie/Vulcan Industri	[illegible]SJ	0054[illegible]0	005403022
Asphalt Type	AC-15P /AC-15P	H[illegible]	US 84	US 84
Producer	Martin Asph, Hou/Martin Asph, Hou	Co.	[illegible]leman Co[illegible]etc.	Coleman Co.

Ref No.	Crse	Width	LOCATION	Noz Set	% Var	Configuration	ADT Per Lane	Hunger Factor Code #
1	1	12	Fr:Near Rough Ck to 2mi. N.of US283 (IN)		00.0	0000000000	105	0.40
2	1	12	Fr:Near Rough Ck to 2mi. N.of US283 (OS)		30.0	4 9 9 9 5	608	0.36
3	1	4	Shoulder		00.0	0000000000	000	0.40
4								
5								
6								
7								
8								
9								

ASPHALT AND AGGREGATE RATE DISTRIBUTION

[illegible]ription		Reference No. 1	2	3	4	5	6	7	8	9
Computed Aspha[illegible]ate for % Emb		0.18	0.17	0.19						
Adjustment for Traf[illegible]		0.05	0.01	0.09						
Adjustment for Hunger [illegible]ctor		0.14	0.10	0.09						
Above 60°F Volume Adju[illegible]ent		0.03	0.03	0.03						
Subtotal		0.40	0.31	0.40						
Asphalt Volatile Adjustment		0.00	0.00	0.00						
ASPHALT APPLICATION RATE	Inside WP	0.40	0.31	0.40						
	Outside WP	0.40	0.40	0.40						
	Average Rate	0.40	0.36	0.40						
Spread Ratio (SR)		0	0	0						
Recommended Distribution Rate		125	125	125						
Desired Embedment		35.0	33.0	36.0						

Remarks: ______ Prepared By ______ Date ______

______ Approved By ______ Date ______

South Seal

Figure 7. Brownwood District Penetration Design Report.

The desired asphalt and aggregate application rates shown on this form are determined by Brownwood's chief inspector on the district seal project several weeks before the project start date. The chief inspector drives all of the seal locations to select these rates. The contractor is advised, however, that the rates shown on the design sheets are only for his material estimation purposes and his planning for nozzle configuration changes. The rates themselves may be adjusted somewhat by the inspector on the day each roadway is sealed, depending on weather conditions that day and on the performance of earlier sealed roadways with similar rates.

Determining Adjustments in TVAR Asphalt Rates

Determining if the selected TVAR percentages are proper or should be adjusted as the seal coat operation moves down the roadway is done in the same manner as when shooting a uniform asphalt application across the roadway. Most inspectors look at the aggregate embedment depth, both immediately after rolling and then again after a day or two of traffic. An embedment depth of 35 to 40 percent is desired. Figure 8 shows embedment in this range after several days of traffic.

Figure 8. Proper Aggregate Embedment After Several Days of Traffic.

CHAPTER 5:
PAVEMENT TEXTURE DEPTH TESTING AND DATA ANALYSIS

PAVEMENT TEXTURE TEST PROCEDURES

This project included pavement texture testing of selected pavements prior to placement of seal coats during the summer of 2008. Texture testing was limited to pavements located in three districts. The Brownwood, Bryan, and Lufkin districts were contacted, and individual pavements to be sealed during their district seal coat programs were selected for testing. Factors considered when selecting pavements included the conditions of the wheel paths, the traffic levels, the types of existing seal coats, the contractor's seal coat schedule, and the ease with which the district could provide effective traffic control for the testing operation. Many of the selected pavements were to receive a TVAR seal coat. In some cases, however, the TVAR use decision was changed by the inspector on the day that the seal coat was placed. The locations and descriptions of the selected pavement sections are included in Appendix D.

Three methods of determining pavement texture were used. These methods included:

- ❖ Circular Track Meter (CTMeter) testing, ASTM E 2157,
- ❖ Outflow Meter testing, ASTM E 2380, and
- ❖ Sand Patch Volumetric Method testing, ASTM E 965 and Texas Test Method Tex-436-A.

Each pavement to be tested was observed from one end to the other to identify potential testing locations. Generally, as is common on pavements, conditions of the pavement varied up and down the roadway. In some cases, a single testing location was selected to represent the general roadway condition. In most cases, several testing locations were chosen to include distinctly different pavement conditions in the tested group.

Each selected testing location was marked every 5 feet for 20 feet, giving 5 specific longitudinal locations for testing. These locations were marked in both the outside wheel path and between the wheel paths. See Figure 9 for the standard testing layout. A metal pin with rope flagging as shown in Figure 10 was then driven into the ground just outside of the paved surface. The distances to the wheel path and between wheel paths' testing locations were measured and noted (Figure 11). The GPS location of the metal pin was also noted while in the field.

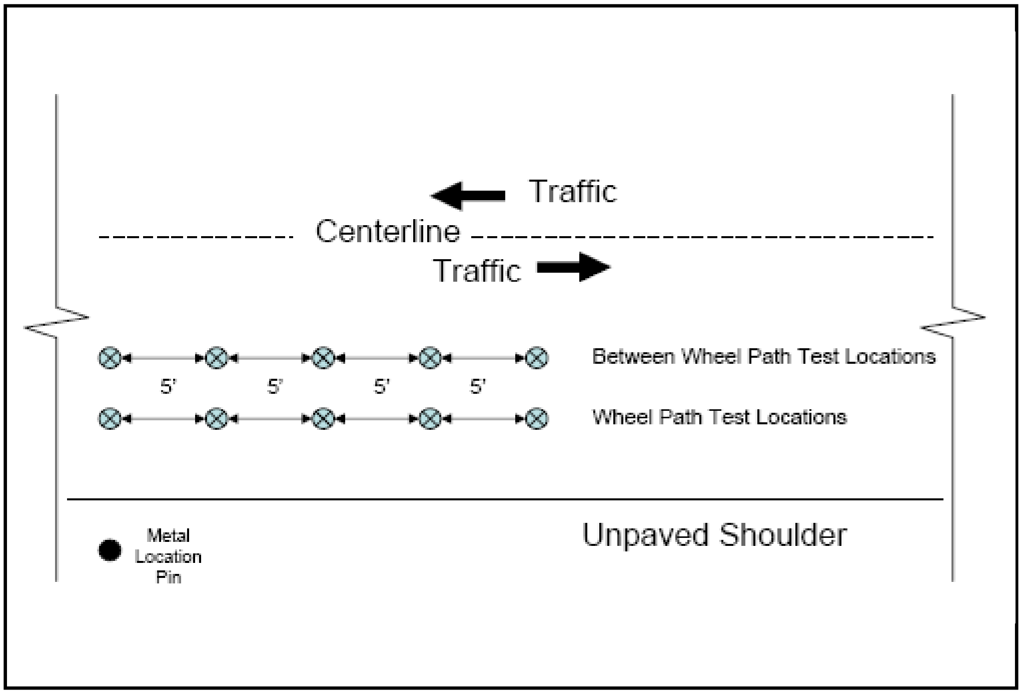


Figure 9. Standard Pavement Texture Test Layout.

Figure 10. Metal Pin Test Location Marker.

Figure 11. Measurement from Location Pin to Test Locations.

Photographs were taken of each pavement to be tested prior to placement of the new seal coat. Photography included close-ups of both wheel path and outside wheel path locations. These photographs are included in Appendix E.

The CTMeter and the Outflow Meter tests were performed at all 10 locations marked on the pavement. The Sand Patch Test was performed only at the first, middle, and last locations, both in the wheel path and between the wheel paths. Test results were then averaged to represent the wheel path and between wheel paths conditions as determined by each of the three methods of test. The same operator performed all Sand Patch Tests at all test locations in all three districts. This was done to improve comparability between test results.

In addition to the texture test results, the asphalt rates that the contractor later applied in the wheel paths and outside of the wheel paths were noted during the visit or were obtained from the district at a later date.

Circular Track Meter

The CTMeter uses laser technology to measure mean profile depth (MPD) of pavement macrotexture. Testing followed ASTM E 2157 procedures. The laser component of the test equipment moves in a circular path 11.2 inches in diameter. The meter's automated analysis of test data includes division of the circular path into eight segments with mean texture depth results determined for each segment. The individual segment data along with the overall mean texture depth is then stored in the laptop computer being used to control the test. Figure 12 shows the CTMeter in operation. Each test requires only a few seconds. Speed and accuracy are the strengths of this equipment. High equipment cost limits practicality for routine field use by TxDOT.

Figure 12. Circular Track Meter Test Equipment.

Outflow Meter

The Outflow Meter estimates mean texture depth by measuring the length of time required for a standard volume of water to escape from the meter's cylindrical water chamber through the macrotexture openings in the underlying pavement. The research team followed ASTM E 2380 testing procedures, including use of the recommended formula for estimating mean texture depth.

The meter is placed on the pavement location to be tested. If the meter is found to rock when gently pushed from any angle, the meter is moved slightly until a stable setting is found. The water chamber is then filled with water, and an electronic timer on top of the meter is zeroed by the operator. The operator releases the water to escape from the bottom of the water chamber by pulling up on a plunger-rod assembly running vertically through the meter. The timer is automatically activated and then stopped by a pair of floating switches inside the water chamber. These switches are located inside of the water chamber so that the length of time for the standard water volume to escape is measured on the electronic timer. As pavement mean texture depth increases, the time required for the standard volume of water to escape decreases. The Outflow Meter is shown in operation in Figure 13. Strengths of this test procedure are simplicity of operation and no requirement of supplies except water. However, frequent testing requires operators to transport large volumes of water to the field.

During this project, the research team found that an electronic timer measuring in increments of 1 second, as was the case with the meter used for this project, did not provide a desirable level of precision when testing seal-coated pavements. Measurements taken from locations outside of the wheel paths often were less than 3 seconds.

Figure 13. Outflow Meter Test Equipment.

Sand Patch Volumetric Method

The Sand Patch Volumetric Method is found in ASTM E 965. It is also designated as the Sand Patch Test in Texas Test Method Tex-436-A. This procedure has been sporadically used in Texas for many decades. A standard volume of test sand is spread on the pavement surface until the tops of aggregate particles on the pavement surface have been reached. The diameter of the circle of sand is then measured at four points and averaged. Figure 14 shows this test being performed. A formula is used to calculate the average pavement macrotexture depth from the average diameter of the circle and the known volume of test sand. Strengths of this test are high correlation to CTMeter mean profile depths, test procedure simplicity, test performance speed, and inexpensive test equipment cost. As noted by the research team, a wind shield is often required to protect the testing area in Texas. The test also requires the use of standard test sand or glass spheres of a specific gradation.

Figure 14. Sand Patch Test Equipment.

PAVEMENT TEXTURE DATA ANALYSIS

Comparison of Results from Testing Methods

Texture test results obtained from all three test methods are included in Appendix E, along with corresponding photography from each tested pavement location. Texture test results are also included in Table 5 below.

Table 5. Texture Depth Data from All Testing Methods.

Roadway Designation	Location Number	Wheel Path Mean Texture Depth Test Results, mm			Outside of Wheel Paths Mean Texture Depth Test Results, mm		
		CTMeter	Sand Patch	Outflow Meter	CTMeter	Sand Patch	Outflow Meter
FM 696	1	1.83	2.16	2.58	2.18	2.50	3.23
FM 696	2	1.02	0.93	1.50	1.84	2.14	3.23
FM 908	1	0.73	0.79	0.98	1.95	2.14	2.19
FM 908	2	1.99	2.15	2.58	2.88	3.22	4.53
FM 819	1	0.90	1.19	1.09	1.79	1.97	2.58
FM 819	2	1.24	1.49	1.38	2.10	2.51	3.23
FM 2457	1	0.65	0.79	0.93	2.09	2.29	2.19
FM 2457	2	0.40	0.41	0.75	1.46	1.42	1.67
SH 147	1	1.85	1.93	2.58	2.83	2.91	5.83
SH 147	2	1.37	1.34	1.61	1.44	1.39	1.67
SH 147	3	0.50	0.62	0.87	1.98	2.40	3.23
SH 147	4	1.36	1.45	1.75	1.63	1.79	3.23
SH 103	1	0.72	0.79	1.29	2.36	2.53	3.75
SH 103	2	1.29	1.34	1.83	2.73	2.82	3.75
SH 103	3	1.39	1.34	2.19	2.68	2.80	3.75
US 190	1	1.44	1.70	1.55	2.17	2.37	2.19
US 190	2	1.85	2.09	2.37	2.22	2.40	2.58
US 190	3	1.60	1.83	2.86	2.33	2.45	2.05
SH 153	1	0.90	1.02	1.19	1.44	1.88	1.83
FM 3425	1	0.77	1.07	1.04	1.36	1.52	1.26
US 283	1	0.87	0.99	1.31	1.44	1.65	2.05
US 283	2	0.88	1.04	1.31	1.73	1.91	2.05
FM 2134	1	1.99	2.29	2.86	3.06	3.57	3.75
FM 2134	2	2.11	2.39	2.86	2.93	3.03	8.42
SH 6	1	1.19	1.27	1.50	1.67	1.89	2.58
FM 2689	1	1.13	1.35	1.46	2.19	2.57	2.86
FM 2689	2	3.35	3.48	8.42	3.51	3.90	4.53
Average of all Locations		1.31	1.45	1.95	2.15	2.37	3.12

A comparison of all CTMeter mean profile depths to corresponding Sand Patch Test mean texture depths determined during this study is shown in Figure 15. The r-squared correlations are separately shown for wheel path test locations and outside of wheel path test locations. Almost identical correlations were found, and both correlations are considered extremely close for entirely different testing techniques.

A comparison of all CTMeter mean profile depths to corresponding Outflow Meter mean texture depths determined during this study is shown in Figure 16. The r-squared correlations are again separately shown for wheel path test locations and outside of wheel path test locations. The test result correlation is seen to be better for wheel path test results than for the pavement areas with increased texture depths outside of the wheel paths. However, neither correlation approaches the excellent correlation level that was found between the CTMeter and the Sand Patch Test results.

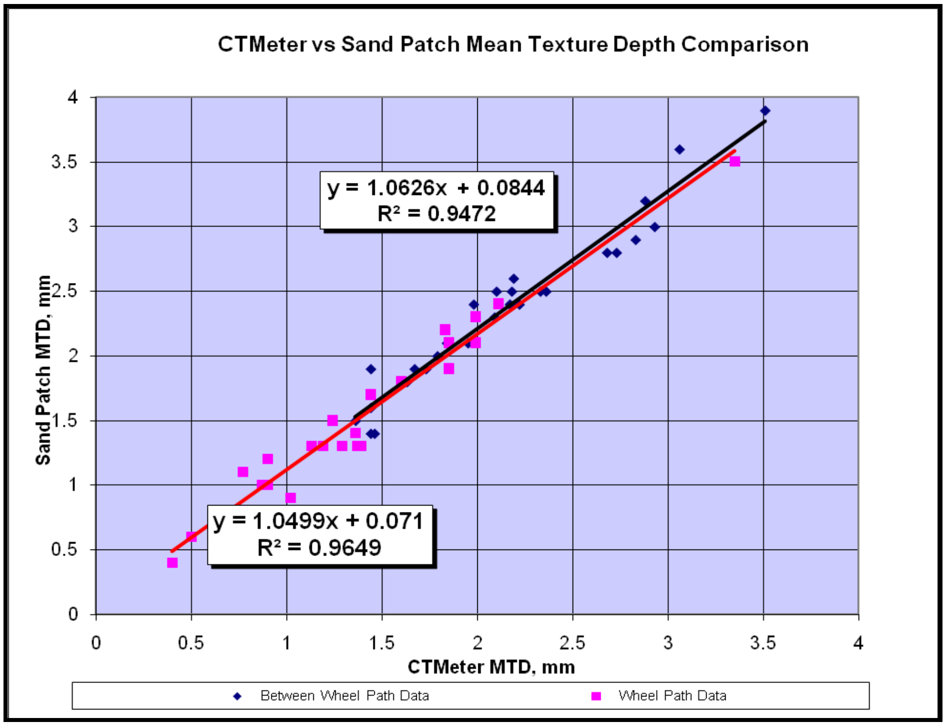


Figure 15. CTMeter Versus Sand Patch Mean Texture Depth.

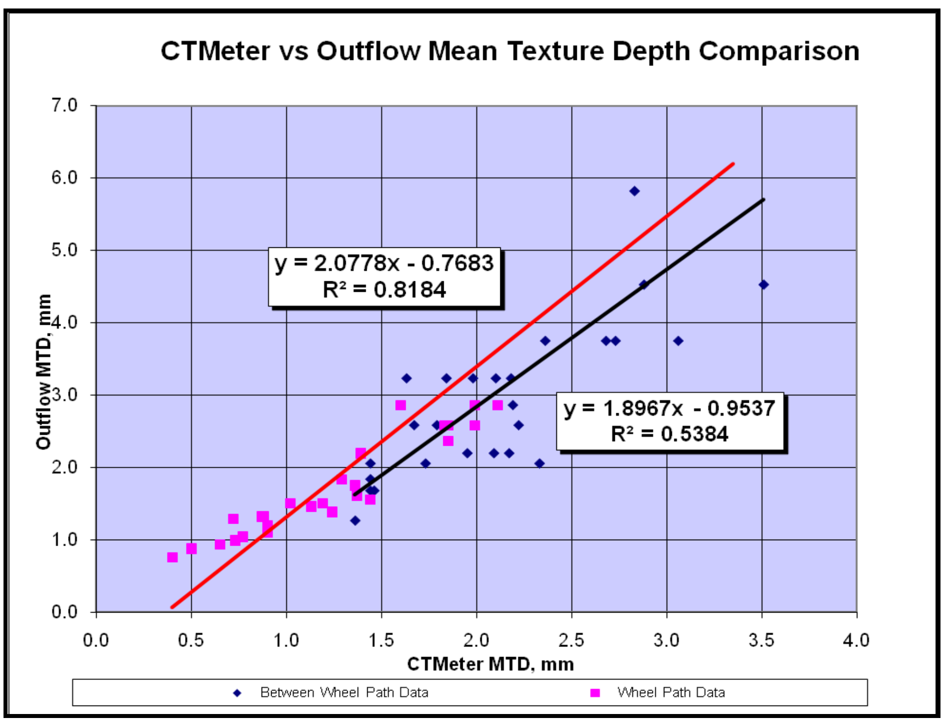


Figure 16. CTMeter Versus Outflow Meter Mean Texture Depth Comparison.

Researchers noted during field testing that obtaining a stable setting for the Outflow Meter often required several adjustments of the meter position on the pavement. As rocking of the meter indicates that it is resting on as few as two or three aggregate particles, it is apparent that the Outflow Meter is less appropriate than the other test methods for use on seal-coated surfaces where occasional individual particles can more easily stand higher than surrounding aggregate since construction compaction is limited to pneumatic tire rollers. Whenever the neoprene gasket on the bottom of the Outflow Meter does not uniformly rest on aggregate tops completely around its circumference, test results will indicate a higher mean texture depth than actually exists because of the bridging effect. This could be a partial explanation for the lack of correlation found between these test results and those from the other two test methods used in this study.

Comparison of Sand Patch Test Results to Visual Roadway Appearance

As transverse variations in asphalt application rates are usually established by TxDOT project inspectors based on visual appearance of the roadway, an attempt was made to compare visual roadway appearance to results from the Sand Patch Test. Photographs of all tested pavement locations were reviewed, and seven roadway locations were selected by the research team to represent the range of wheel path flushing seen on Texas roadways. These pavements are shown in Figures 17 through 23. BWP indicates that the inset close-up photograph was taken between the wheel paths. WP indicates that the close-up photograph was taken in a wheel path.

The Sand Patch Test results obtained from these seven pavements were then compared to the visually observable wheel path conditions. The mean texture depths from the Sand Patch Tests performed in the wheel path and between wheel paths for these pavements are shown in Table 6, along with the differences in these mean texture depths. While the largest mean texture depth differences were found on the most heavily flushed pavements, as would be expected, and the smallest mean texture depth difference was found on the pavement with no visual indication of wheel path texture difference, the pavements between those two extreme conditions were not differentiated by amount of difference in mean texture depths.

The research team then compared differences in Sand Patch Test circle diameters to the visual appearances of the selected roadways. The circle diameter differences are believed to provide a more direct correlation to differences in void volume between the aggregate. Table 7 displays this data.

Figure 17. Severe Flushing of Grade 3 Seal Coat.

Figure 18. Moderate to Severe Flushing of Grade 3 Seal Coat.

Figure 19. Moderate Flushing of Grade 3 Seal Coat.

Figure 20. Mild to Moderate Flushing of Grade 3 Seal Coat.

Figure 21. Mild Flushing of Grade 3 Seal Coat.

Figure 22. Slight Color Difference in Grade 4 Seal Coat.

Figure 23. No Color Difference in Grade 4 Seal Coat.

Table 6. Comparison of Visual Appearance to Sand Patch Mean Texture Depths.

Roadway and Condition	Sand Patch Mean Texture Depths, mm		
	Wheel Path	Outside Wheel Paths	Difference
Severe Flushing of Grade 3 Seal Coat (Figure 17)	0.8	2.5	1.7
Moderate to Severe Flushing of Grade 3 Seal Coat (Figure 18)	0.8	2.3	1.5
Moderate Flushing of Grade 3 Seal Coat (Figure 19)	1.0	1.9	0.9
Mild to Moderate Flushing of Grade 3 Seal Coat (Figure 20)	1.0	1.9	0.9
Mild Flushing of Grade 3 Seal Coat (Figure 21	0.9	2.1	1.2
Slight Color Difference in Wheel Path of Grade 4 Seal Coat (Figure 22)	2.1	3.2	1.1
No Color Difference in Wheel Path of Grade 4 Seal Coat (Figure 23)	2.2	2.5	0.3

Table 7. Comparison of Visual Appearance to Differences in Sand Patch Circle Diameters.

Roadway and Condition	Sand Patch Average Diameters, mm		
	Wheel Path	Outside Wheel Paths	Difference
Severe Flushing of Grade 3 Seal Coat (Figure 17)	199	111	88
Moderate to Severe Flushing of Grade 3 Seal Coat (Figure 18)	200	117	83
Moderate Flushing of Grade 3 Seal Coat (Figure 19)	174	129	45
Mild to Moderate Flushing of Grade 3 Seal Coat (Figure 20)	177	129	48
Mild Flushing of Grade 3 Seal Coat (Figure 21)	184	121	63
Slight Color Difference in Wheel Path of Grade 4 Seal Coat (Figure 22)	121	99	22
No Color Difference in Wheel Path of Grade 4 Seal Coat (Figure 23)	121	112	9

Several noteworthy observations can be made from Table 7. First, increasing difference in circle diameters corresponds better to increases in visually observed wheel path flushing conditions than did the mean texture depths. The pavement shown in Figure 21 is a notable exception to this improved correlation. Upon close observation, however, this pavement was seen to have lost some of the seal coat aggregate outside of the wheel paths. This is a probable cause of the greater difference in macrotexture void volume than was expected based on the level of visually observable wheel path flushing. It appears that the test procedure correctly identified a void volume difference that was not easily observable. Also of interest in Table 7 is that the Sand Patch Test circle diameter difference discerned a very minor macrotexture void volume reduction caused by traffic on the roadway shown in Figure 23, a roadway where no difference in wheel path color was observable.

Because of the improved correlation seen with observable wheel path flushing conditions, and because the differences in circle diameters appear to be sensitive to differences in macrotexture void volume that are not readily visible, and because of the belief that circle diameter differences are inherently more indicative of differences in macrotexture void volume, measurement and comparison of Sand Patch Test circle diameters is recommended as an aide in determining when use of the TVAR technique is appropriate.

Development of Sand Patch Test Criteria

When the contractor's asphalt distributor has a single spray bar, the only decision is whether TVAR is appropriate or not on each roadway or lane. When a dual spray bar asphalt distributor is available, the inspector may select TVAR percentages anywhere between 0 percent and 30 percent, or even somewhat higher in special situations. The criteria shown in Table 8 are initial recommendations when using measurements of Sand Patch Test circle diameters to assist in determining the appropriateness of TVAR for a given roadway. Based on researcher observations in the field and the test data gathered and analyzed, these recommendations were established to be conservative, steering less-experienced districts toward TVAR use in situations clearly justifying a variation in asphalt shot rate across the roadway. The researchers believe that many roadways with test circle diameter differences in the 35 mm to 50 mm range would also benefit from use of 22 percent to 32 percent more asphalt outside of the wheel paths without jeopardizing roadway performance.

Table 8. Recommended TVAR Sand Patch Criteria.

Difference in Sand Patch Test Diameters, mm	Use of TVAR with a Single Spray Bar Asphalt Distributor	Use of TVAR with a Dual Spray Bar Asphalt Distributor
Less than 20	No	No
21 to 50	Optional	15%
Greater than 50	Yes (22% to 32%)	30%

The criteria above are based on researcher observations of existing conditions of pavement to be sealed, discussions with experienced seal coat project managers and inspectors, and analyses of the texture test results from tests performed prior to placement of the new seal coats on these pavements. It is recommended that performance levels, and particularly the reoccurrence of rutting conditions, for the tested pavements be monitored for the lives of the seal coats. In this manner the criteria shown in Table 8 may be validated or possibly revised to better reflect appropriateness of TVAR use as determined using differences in diameters of Sand Patch Test circles.

CHAPTER 6: TVAR SPECIFICATIONS

CURRENT TXDOT SPECIFICATIONS

The 2004 Standard Specification Item 316, Surface Treatments, includes provisions for a plan note to require the contractor to have the capability to transversely vary asphalt application rates. The equipment section of this specification states:

> "When a transverse variance rate is shown on the plans, ensure that the nozzles outside the wheel paths will output a predetermined percentage more of asphalt material by volume than the nozzles over the wheel paths."

Under the distributor calibration section of this specification, the following statements are made:

> "When a transverse variance rate is required, perform the test using the type and grade of asphalt material to be used on the project. The Engineer may verify the transverse rate and distribution at any time. If verification does not meet the requirements, correct deficiencies and furnish a new test report."

These provisions in the standard specifications allow use of a simple general note in the plans to invoke and define requirements for transversely varying asphalt rates on a project. Districts currently using TVAR have developed various plan notes, several of which follow.

<u>Brownwood District Plan Note.</u> The contractor shall furnish the distributor nozzles. The nozzles shall be furnished such that the nozzles outside of the wheel paths of the travel way shall place 22 to 32 percent more by volume than the nozzles over the wheel paths or as directed.

<u>Lufkin District Plan Note.</u> Provide a transverse spray bar, capable of applying lighter rates in the wheel paths regardless of the width of the roadway, when directed due to existing surface conditions.

<u>Paris District Plan Note.</u> The use of variable rate nozzles will be required on this project. The asphalt distributor nozzles will be set to apply 10 to 15 percent less asphalt in the wheel paths, unless otherwise directed by the engineer. Upon request, the contractor shall provide a means to demonstrate this application distribution for verification.

Fort Worth District Plan Note. Furnish a distributor that is capable of shooting an asphalt placement rate outside the wheel path 22 percent to 32 percent greater than the rate inside the wheel path, unless otherwise approved.

PROPOSED TVAR PLAN NOTE

The following plan note is recommended for use by all districts desiring to use transversely varied asphalt shot rates.

> "In addition to other asphalt distributor requirements, the asphalt distributor shall be capable of providing a transversely varied asphalt rate. The Contractor shall demonstrate that the distributor can apply an asphalt rate outside of the wheel path locations between 22 and 32 percent higher than the asphalt rate being applied in the wheel paths. The Contractor's calibration of the distributor will include verification of this capability and a description of the spray bar(s) and nozzles to be used. The percentage difference in asphalt rate provided by each tested spray bar and nozzle arrangement shall be provided to the Engineer. The Engineer will select the pavements where the transversely varied asphalt rate is to be provided."

Requiring that contractors be able to provide at least one transversely varied asphalt rate, between 22 and 32 percent, instead of requiring two or more, should allow every contractor an opportunity to meet this requirement. Contractors with single-spray-bar asphalt distributors should be able to use differing standard nozzle sizes to provide the singe variable rate required as a minimum. This percentage range was determined by a study of standard nozzle sizes by the Brownwood District.

Some contractors have distributors with dual spray bars having separate computer controllers. These contractors have the ability to vary asphalt rates over a much broader range than that suggested for the plan note.

CHAPTER 7: FINDINGS AND RECOMMENDATIONS

FINDINGS

This project resulted in the following findings.

- Development of TVAR techniques in New Zealand have been documented in the literature. Use is reported to be successful and expanding in that country.
- At the time of the Texas survey in early 2008, 13 TxDOT districts were currently using TVAR techniques as standard practice, several other districts were experimenting with it, and 8 districts reported having no experience or experimentation with TVAR over the past five years.
- TVAR is being used by districts using emulsified asphalts and districts using hot asphalt cements.
- TVAR is being used with Grade 3 and Grade 4 aggregates, lightweight and natural aggregates, and precoated and plain aggregates.
- TVAR is being successfully placed using standard, single-bar asphalt distributors as well as multi-bar distributors designed to facilitate TVAR applications.
- Comparative texture testing of wheel path and outside of wheel path locations appears to be a viable method for estimating most appropriate transverse asphalt application variations.
- Differences in Sand Patch Test circle diameters appear to correlate better to degree of observable wheel path flushing than do mean texture depths calculated from Sand Patch Testing.
- Texture test results obtained from Circular Track Meter and Sand Patch Test methods correlated with an r-squared value of 0.96 for tests performed in the wheel paths and a value of 0.95 for tests performed between the wheel paths.
- Texture test results obtained from Circular Track Meter and Outflow Test methods correlated with an r-squared value of 0.82 for tests performed in the wheel paths and a value of 0.54 for tests performed between the wheel paths.

RECOMMENDATIONS

The following recommendations are offered.

- TxDOT should expand use of TVAR seal coat techniques to a statewide basis.
- Regional workshops are recommended to expedite training of personnel in use of TVAR techniques.
- Existing TxDOT seal coat design and inspection training courses should be revised to include TVAR-related techniques.
- It is recommended that a simplification of Test Method Tex-436-A, Sand Patch Test, be used to assist field personnel in determining when and how much to transversely vary seal coat asphalt application rates.
- The performance of the seal coated pavements included in this project should be monitored for the lives of the seal coats, particularly concerning reoccurrence of wheel path flushing and loss of aggregate outside of wheel paths.

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APPENDIX A: DISTRICT TVAR EXPERIENCE QUESTIONNAIRE

District Seal Coat Questionnaire

Subject: Seal Coat Information Request

I have a favor to ask that should take only a minute. I'm the project director for research project 0-5833, which is developing TxDOT guidance for transversely varying asphalt seal coat shot rates when surface conditions warrant. The TTI research team is looking at what is done in other parts of the country and world, but we anticipate that the most helpful information will be obtained from in-state experience, as this experience will be with materials we use, contractors we use, and under our climate and traffic conditions.

Please reply to this email with your responses to the two questions below about your district's experience with transversely varying asphalt seal coat shot rates. This experience can be work done by your maintenance forces or during work by your contractors. You may just reply with the number and letter of your response selections.

Your district's experience is best described as:

1. Have not tried it to my knowledge
2. Currently experimenting with it
3. Experimented with it in the past and decided not to use it further
4. Used it as somewhat standard practice in the past, when conditions warranted, but no longer use it
5. Currently use it on occasion
6. Currently use it as standard practice when surface conditions warrant

For those districts in the 4, 5, or 6 categories, on how many highway locations would you guess that this practice has been used in your district over the last 5 years?

A. 1 to 5 locations
B. 6 to 15 locations
C. 16 to 30 locations
D. Over 30 locations

Thanks in advance. This will provide a quick assessment of statewide experience. You may be contacted at a later date to determine if your district has current or recently retired employees with considerable experience that you would recommend we contact about a possible interview. Paul Krugler is the research supervisor and will be the one to make those contacts, describe the interview process, and make any other arrangements that might be required.

Paul D. Montgomery
Director of Maintenance
Lufkin District

APPENDIX B: EXAMPLE LIST OF INTERVIEW QUESTIONS

Interview Questions –
Transverse Variation of Asphalt for Seal Coats

Experience

1. For approximately how long has your district transversely varied asphalt application rates?

2. What would you guess is the percentage of your district's annual seal coat program where this technique is used?

When to Transversely Vary Asphalt Rate

3. Who usually makes the determination in your district that the seal coat asphalt rate should be varied transversely on a particular pavement, and when is this decision usually made? Is this decision made by visual observation only or is some type of test used to assist in making the determination?

4. Are there types/grades of seal coat asphalt where you do not recommend transversely varying the application rate?

5. Are there grades of seal coat aggregate where you would not recommend transversely varying asphalt application rates?

6. Do you sometimes transversely vary asphalt shot rates on more than one course of a multiple-course surface treatment?

How to Transversely Vary Asphalt Rate

7. When the asphalt rate will be varied transversely, does your district vary it by a standard percentage? If a standard percentage variation is not used, how do you determine the amount to vary the asphalt shot rate across the pavement? Is the grade of aggregate being used a factor in determining the percentage variation?

8. If a standard percentage variation is not used, what is the range of asphalt variations that have been used in your district?

9. Do you use a standard wheel path width and location for the lesser asphalt rates, or are measurements made on individual pavements to determine the location and width of the lesser asphalt application?

Distributor Calibration and Inspection

10. Are there unique, additional distributor calibration or inspection procedures used when you will be transversely varying asphalt shot rates? If so, please describe.

Construction Inspection

11. Are there unique or particularly important things for the construction inspector to monitor when asphalt shot rates are transversely varied? If so, please describe.

12. Are there indicators to look for in the freshly completed seal coat that the asphalt shot rate was properly varied? Is it typical for you to adjust the amount of transverse variation in asphalt shot rate as you go down the road on a job?

13. What are common errors that a contractor or inspector might make who do not have prior experience in transversely varying the asphalt application rate?

Seal Coat Performance

14. Based on your own observations, do you think that transversely varying seal coat asphalt shot rates significantly improves rock retention outside of the wheel paths? Has there been an impact on reducing wheel path flushing from reoccurring?

15. Have you seen situations when the asphalt shot rate was increased too much outside of the wheel paths? If so, at what amount of increase did that occur? Do you have a suggestion on how someone can determine the maximum amount to increase the shot rate on a particular pavement?

General Closing Questions

16. Do seal coat contractors in your district generally have an opinion on this technique? (Do they think it gives a better job or not? Do they dislike doing it? etc.)

17. Do all seal coat contractors working in your district have the equipment capability to transversely vary asphalt shot rates?

18. If you had an opportunity to share just one or two things you have learned about transversely varying seal coat asphalt shot rates with districts that haven’t tried it, what would you tell them?

19. Are there some unanswered questions about transversely varying seal coat asphalt shot rates that hopefully will be answered one day?

If your district uses a special provision to the specifications to allow transverse seal coat asphalt shot rates to be varied, or if you have a standard plan note for that purpose, we would appreciate getting a copy of that information.

Thank you for your time and valuable information.

APPENDIX C: LEGACY KNOWLEDGE DOCUMENTS PREPARED FROM INTERVIEWS

Texas Department of Transportation

Richard Walker's Thoughts on ....

History of TVAR Use in Brownwood
Nozzle Manufacture and Precision
Basis for TVAR Specification Range
Double Surface Treatments
Asphalt Distributor Calibration

I've been working in the Brownwood District for 28 years, and they had been transversely varying asphalt about 10 years before that. So the district has been transversely varying asphalt for around 38 to 40 years.

Whenever I am asked to talk about transverse nozzles, I always preach on one thing. You never put less asphalt in the wheel path. Instead, you put exactly what the wheel paths require, and then put more asphalt outside the wheel paths to help hold the rock and keep it from shelling. You will invariably here people say, "We put less asphalt in the wheel paths with variable nozzles." You didn't. You put exactly what the wheel path required. When I tried to explain it to the contractors, some of them thought they were getting cheated. They thought they were shooting less asphalt now. But they're shooting more. In an ideal world if everybody was designing for the wheel paths, the variable nozzles would be letting you hold rock outside of the wheel paths. You aren't shooting less to prevent flushing.

We use a lot of emulsions in our district. Sometimes the asphalt rate was increased too much outside of the wheel paths. What was actually happening was the emulsion was flowing toward the wheel paths and we were getting more asphalt in the wheel paths than we designed. You want to make sure that the viscosity is good whatever asphalt you are using. It will flow if it's too thin. I really like emulsions, but low viscosity can cause more problems than anything else with them.

If you have a standard asphalt distributor, one with a single spray bar, the only way to vary asphalt rates is to use a special set of nozzles. Making the nozzle sets is a tedious process that takes a lot of trial and error. We used to make them in our district shops. It's not something everybody can do, and even when you make a nozzle set, its variance will change depending on the viscosity of the asphalt and the pressure being used. So you can't tell the contractor that "I want a 25.6% variance," because he can't ever obtain something that precise. What we do is give them a 10% variance range that they have to hit, between 22% and 32%. I went up to 32% because, at the time, there were some nozzles you could buy where two different sizes would give you a 32% variation. We were really looking for a 30% variance on most of our seal coat roads, but because that one combination made a 32%, we didn't want to cut them out. If you are going to fine tune and vary less than that, you have to give them a pretty good range for that too. For example, if you want to lower the rate to about half that much, you would need to give them a range something like 12 to 20%. The reality is that the nozzles of just one size, when you buy them, can vary as much as 10%. So, if you are not varying rates by more than 10%, you may not be accomplishing that much. That's why I think you need at least 20% variation to be sure you're accomplishing something. On most roads, a 30% variation works pretty well. If you go very far over 30%, the asphalt viscosity of emulsion allows some flow back. The distributor may be shooting it right, but it doesn't end up right on the highway. Over the years and by trial and error the first people using it in Brownwood determined the maximum amount they could put out there successfully was around 30%.

Now, contractors with distributors with double spray bars can do more adjusting of the rates. Double bar distributors can fine tune the amount of asphalt being put down through each bar and separately control the asphalt rates outside and inside the wheel paths. I haven't seen the double bar asphalt distributor here in our district. If you set up your specs for just the double bar distributor, you eliminate a lot of contractors and cause the cost to go up quite a bit because there aren't many contractors who have them.

One thing that would be easy for the contractor or the inspector to miss when using variable nozzle sizes is making sure the right nozzles are in the right places on the spray bar. It's always good practice to check them at least every morning or when you move. Sometimes at night the operator might decide to clear out his nozzles and throw them all in a bucket. You can never know what happens when you aren't there. I've even seen them put in there backwards. If you put the big nozzles in the middle of the wheel paths you make a terrible mess. That's the worst possible error that can occur. So it's good to verify that you've got the right nozzles in there when you start in the morning.

We had a few area engineers a long time ago who liked to put down a small variance in asphalt rates on new construction. They might want a 12% variation or something like that. We custom made all our nozzles back then, and we tested all our nozzles, so we could really fine tune the nozzle sets contractors used. Things have changed, and we aren't able to do that anymore. Making nozzles is a very time consuming and labor intensive process, and then you needed to keep them in good shape. What would happen was the nozzles would get lost during seal coat jobs. We got to the point where we couldn't keep supplying the nozzles with our limited forces. So that's when we turned it over to requiring the contractors to furnish nozzles. Very few contractors have the expertise or the time and knowledge to make nozzles. That's why we went to the 22 to 32% range, so they could use combinations of purchased nozzles.

The nozzle set I really liked had obviously different nozzle sizes. You could easily see whether the right nozzles were in place or not by looking at the back of the bar (Figure 1).

Figure 1 – Taller Nozzle for Outside Wheel Paths, Shorter Nozzle for Wheel Paths

When you make a nozzle set yourself in the machine shop, sometimes the only way you could tell the difference in sizes was to mark the nozzles. We used to put an "X" on the larger nozzles. But when you got asphalt on them, it was still tough to tell whether the right ones were in the right places. You always have to pay attention because you never know when one of the nozzles will get stopped up. If you're not there, the operator may just take it out and stick another one in without insuring it's the right size.

When we decided to require the contractor to furnish the bucket test, we wanted to ease into it. It's a test that wasn't commonly run in the industry. It doesn't require a special person or a lot of equipment. You just have to have a calibrated set of scales to run the test. I have a series of photos I can send you showing the calibration process (Figures 2 – 6). Now, more and more contractors are getting calibrations run at commercial labs. But there's nothing prohibiting a contractor from doing his own testing right now. We have the option, if we are out there and something doesn't look right, to stop him and call in our own forces or require him to furnish a new calibration.

Figure 2 – Building Calibration Test Pad

Figure 3 – Blowing Out Spray Bar

Figure 4 – Cylinders Placed Under the Nozzles

Figure 5 – Cylinders ¾ Filled with Asphalt

Figure 6 – Weighing Cylinders to Nearest Gram

We use double surface treatments primarily on new construction. We really don't have the need to use variable nozzles much on new construction. What I do suggest, if they're going to shoot the first course then right away back up and shoot the second course, is that they take the design asphalt rate for the bottom course and cut it down some and add that amount to the top course asphalt rate. That lets more asphalt fill in the voids from the top instead of from the bottom. We've done that in the past pretty successfully. Doubles are really tough to design, and it all depends on how the top rock fits into the bottom rock, how it geometrically fits in there. I really like them to shoot one course one year and come back a year later to shoot the second course. You can see how you did on the first course and fix any problems with the second course. We do double seal coats a lot in new construction, but it's not the easiest thing to do.

As I said, we use a lot of emulsions in our district. In dealing with emulsions, the textbook says that your spreader box should follow right behind the distributor. You should just push one of them with the other one. Sometimes in construction that just doesn't work real well. It's an ideal thing to shoot for, but I would say that 95% of the emulsions that are shot are shot after a short wait time so the rock sticks to the asphalt before the spreader box gets on it. You put the rock on as quickly as possible, and it's left up to the inspector to determine how quick and possible that is. Any type of literature you read on this will tell you that with emulsions you put the rock on right behind the distributor. And if you can do that, it is the best way. But in construction if the rock rolls too much or gets asphalt on top of it, the rock starts sticking to your roller tires. This causes a lot of other problems. So it's just not always possible to put the rock on right behind the distributor, but the intent is to get the rock on the asphalt as quickly as you can.

When deciding if the asphalt rate you chose was right, sometimes it takes a year before you can tell. The road has to have gone through a winter and summer before you can tell if it is doing what you wanted it to do or not. You can kind of tell out there after construction. But with most seal coats, it's hard to tell until they've gone for a year.

What we really need for transversely varying seal coat is to have an accurate way to measure the rock embedment. Right now we know how much embedment we think we want, but we don't always know if we're getting that embedment or even if that is the correct embedment. We're going off some theories. The design procedure we've used is based on the embedment and has a long track history of being successful, but we don't know if the embedment is actually 35% or 30%. We calculated it to be 35%, but we aren't positive on how that embedment changes over time. After time the embedment increases, your rock wears down, and you push it down further into the asphalt. If you had an accurate way to actually measure the embedment, you could measure the performance of that road by how its embedment was changed.

Key Words, by Category:

Geographic Area – Brownwood district

Information Type – Legacy knowledge

Legacy Knowledge Source – Richard Walker, June 2008 interview

Analyses Involved – Test Method Tex-922-K, AASHTO T 72

Flexible Pavement Distresses Involved – Flushing

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, emulsion viscosity testing, field sampling, contractor communications, nozzle sizes, nozzle manufacture, double surface treatment, distributor calibration, photos, bucket test, aggregate embedment

Search Acronyms: Legacy Knowledge – Flexible Pavement – Maintenance, lkfpm, Legacy Knowledge – Flexible Pavement – Inspection, lkfpi, Legacy Knowledge – Flexible Pavement – Construction, lkfpc, Legacy Knowledge – Flexible Pavement – Specifications, lkfps, Legacy Knowledge – Flexible Pavement – Unique Application & Innovation, lkfpu

Texas Department of Transportation

Legacy Knowledge

Paul Montgomery: April - 2008

Paul Montgomery's Thoughts on ....

TVAR Seal Coat Objectives
TVAR Seal Coat Specification Approaches

The whole concept behind transverse variable shot rates is to give us the ability to put more oil on the road. We want more oil on the road, but we don't want traffic to track it. Using variable rates let us lessen it up in the wheel paths to prevent the tracking and then to put more oil in the areas where the traffic isn't predominately running. The net result is more oil on the road and a better seal.

Another thing that's desirable is putting a little more asphalt on the shoulders. If you're just shooting the shoulders you can aim for about 50% embedment. You don't have to worry about asphalt tracking as much.

Our plan note about transverse variable shot rates generally says, "Do what Jimmy says to do." Jimmy has come out of the maintenance side in the district and he's gone through his career doing seal coats, actually riding the distributors. We have enough confidence in him to set an approximate rate on the plans for every road and then let Jimmy figure it out from there. You'll find that Brownwood does it differently. I know Randy King goes out and does some calculations on each road to get the shot rates. Randy comes from the design end and has a good method. It all depends on your personnel. Our approach works out well for us and Brownwood has a really strong seal coat program and their approach works out well for them.

Key Words, by Category:

Geographic Area - Lufkin district, east Texas

Information Type - Legacy knowledge

Legacy Knowledge Source – Paul Montgomery, April 2008 interview

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, shoulders, aggregate embedment, Randy King, Jimmy Parham

Search Acronyms: Legacy Knowledge – Flexible Pavement – Maintenance, lkfpm, Legacy Knowledge – Flexible Pavement – Inspection, lkfpi, Legacy Knowledge – Flexible Pavement – Specifications, lkfps, Legacy Knowledge – Flexible Pavement – Unique Application & Innovation, lkfpu

John Baker's Thoughts on ….

TVAR Seal Coat Use
TVAR Distributor Inspection
Sand Patch Testing for TVAR Design

I've been working with the Atlanta District's seal coat program since 1989. We have supervised all of the district's seal coat construction planning and record keeping since some time in the early 1990's. We get recommendations from maintenance supervisors on which roads to seal, and then we go over the pavement scores and look at skid numbers on the different roads to see if we have serious problems somewhere. Then we develop the seal coat plans and go on and build it the next summer. We generally set the seal coat rates and hope the contractors can hit them.

At first, determining when and how to transversely vary asphalt rates was kind of subjective. It was just "I think we need this much asphalt." It's a guess at how many hundredths of a gallon per square yard it will take to fill the voids in the existing pavement. I set out to come up with some way to get a definite number attached to that decision. One thing I tried was something like the old sand patch test we used to measure tine depths on bridge decks. I poured either 100 ML or 200 ML of sand on the pavement between the wheel paths, spread it out down to the top of the rocks, and measured the diameter of the circle. The diameter is an indication of how much asphalt I'll need to fill up the voids between the rocks. After awhile I developed a table showing circle diameters and shot rate adjustments I thought were about right. For instance, if I spread out 100 ML and the diameter is between 15 ½ and 19 ¾ inches, I would increase the asphalt rate 0.02 gal/sy to fill up those voids. Toward the other end of the range, if the diameter was between 7 ½ and 8 inches, I would increase the rate 0.10 gal/sy. These rate adjustments versus diameters were developed for Grade 4 hard rock and lightweight precoat aggregate. I don't need to use the test on every pavement we are going to shoot. I just run it where I'm uncertain on the amount of variation I should ask for.

When we go out to set asphalt rates, generally the first thing we look at is the wheel path. Most of the roads we see will have some degree of flushing or bleeding. Or at least the asphalt has come to the top of the existing surface. Then we set an asphalt rate needed for the wheel paths. After that we select an asphalt rate for outside the wheel paths. If a road is in fairly good shape, and we usually see this on low traffic roads, we haven't varied the rate at all if there's still a good texture across the surface. But probably the majority of roads need the asphalt variation.

Selecting the asphalt rates is usually done about a week to ten days before the contractor gets started. Sometimes it is even as close as three to four days before. Also, it's probably better to go out in the afternoon than first thing in the morning. It's hot and the sun has been out for awhile, so in the afternoon you get a better look at how alive the asphalt gets in the wheel paths.

I would mention a couple of thing to districts that haven't been transversely varying shot rates. Make sure you get the right rate into the right distributor computer if the distributor has two spray bars. Getting that wrong makes a mess in a hurry. If the distributor has only one bar, you've got to watch to be sure they get the different nozzle sizes where they are supposed to be. I would also suggest that they add the variation incrementally until they are comfortable with it, a smaller variation at first and then work up from there.

Key Words, by Category:

Geographic Area - Atlanta district, northeast Texas

Information Type - Legacy knowledge

Legacy Knowledge Source – John Baker, June 2008 interview

Analyses Involved – Tex-436-A, Sand Patch Test

Flexible Pavement Distresses Involved – Flushing, bleeding

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, texture

Search Acronyms: Legacy Knowledge – Flexible Pavement – Maintenance, lkfpm, Legacy Knowledge – Flexible Pavement – Inspection, lkfpi, Legacy Knowledge – Flexible Pavement – Construction, lkfpc, Legacy Knowledge – Flexible Pavement – Specifications, lkfps, Legacy Knowledge – Flexible Pavement – Unique Application & Innovation, lkfpu

Randy King's Thoughts on ….

Seal Coat Asphalt Rate Selection
TVAR Asphalt Distributor Calibration
TVAR Seal Coat Inspection

I would say that the Brownwood District transversely varies asphalt on about 60% to 70% of our seal coats. I make the asphalt rate determinations on each road in our district, including if we will vary rates or not.

We have a seal coat design report program in our laptop. I'll go out on the roadway within a month before our seal coat program starts and drive each of the roads that we have set up. I usually make the asphalt rate decisions based on what I see and using the design method. But sometimes a road looks like a road we shot last year, and I'll go back and find the rate I shot last year. How the road from last year looks helps me set the rate for this year's road.

There are some times I wouldn't recommend transversely varying the asphalt rate. If a district shoots a grade 5 rock, which our district doesn't shoot, I would probably not recommend varying the asphalt rate on it. Also, you really want to look at the roadway to see what type of roadway it is, what seal is there, or if it's a hot mix or a microsurface. You definitely don't want to use variable nozzles on a microsurface or a hot mix project because the roadway is consistent all the way across. You also don't want to do it if you don't see a set traffic pattern and wheel paths. In-town sections are higher volume and the traffic tends to use the whole roadway. So you want to be careful on the hot mix and microsurface projects and places where there's no set traffic pattern.

One thing that really helps to get good seals is to have the same guys out on the seal coat project year after year. They get experience with those variable nozzles and with making rate adjustments. Making rate adjustments out on the roadway is part of using variable nozzles. That's the reason I have one guy that's been with me for 10 to 12 years, and he and I get together make those rate adjustments. When you do decide to lower the rate a little bit where wheel paths are flushed, you have more leeway because of the 22 to 32% higher rate going outside the wheel paths.

There's a requirement in the spec book that the distributor has to be calibrated. The contractor does it now. He has to perform it each year, or whenever the district wants him to do it. There's more to it when you are going to use variable nozzles. He will do a calibration using the same sized nozzles all the way across because there is a spec that says each nozzle has to be within 10%. After that he's got to put in the variable nozzles and do a calibration to show that they will give the 22 to 32% variance that's required in the plan note. We do the bucket test for calibration, usually for a standard 12-foot width set up on the spray bar.

As far as distributor inspection, I just make sure that once we decide on the rates we're going to shoot that we give the contractor all those different rates. Since there are four or five dials on the computer in the distributor cab, he can go ahead and put those rates into his computer. That way, when he sees we want a different rate by what we wrote on the roadway, he's ready to make those adjustments. But as far as an inspection procedure, I just make sure I have a couple of inspectors that know these variable nozzles well enough. When the contractors change nozzles out, we need somebody there watching to see that they get them changed correctly for the type of roadway and the locations of the wheel paths. You can sure mess up a road if they put the nozzles in there wrong.

The location of the wheel paths varies on different roads, but we pretty well always use a three-foot wheel path width when we vary the asphalt rate. For example, if it's an FM road with maybe 9 or10 foot travel lanes, the traffic will normally run to the middle of the center line. So you have to make spray bar adjustments for wheel path locations on those type roadways. But when you get on a US or a state highway with a shoulder and an edge line on the travel lane, the traffic tends to move over towards your shoulder to follow that stripe. But three foot is pretty well the width of your wheel path in all cases.

Something to keep an eye on if you're using emulsion is the viscosity of the emulsion. If your wheel paths are depressed a half inch or so lower than outside the wheel paths, the emulsion will tend to run down into your wheel paths and give you more asphalt there than you want. So you really have to watch the viscosity on emulsions. That's the reason we put a viscosity check in our spec a few years ago, in early 2000. If we saw something changing or something different with the emulsion viscosity out on the roadway, that we could stop, halt the project, and bring a test sample in and check it. Hot oil doesn't have this problem because it cools so quickly and the viscosity is higher.

The complaint that I hear from contractors about transversely varying the asphalt rate is they don't like changing the nozzles, stopping and having to change nozzles. They say it holds them up. There are some that it doesn't bother a bit. But the biggest complaint I have heard is from their guys that run the distributors. They just don't like getting back there and changing them. That's probably the biggest complaint. I would say if you've got a good distributor guy, and he doesn't have a problem changing them, he can have them changed out in 15 to 20 minutes pretty easily. Your inspector should be there with him, helping him by showing him where the smaller nozzles should go. Yeah, I would say on average that you're changed and ready to go in 15 minutes. Normally we try to get the contractor to change them as soon as the distributor gets to that roadway, because they're waiting for the rest of the equipment to get there anyway. So what I do is send my inspector up there to get with the distributor operator right away. There's not really any down time for the contractor if you do it that way.

Last year I tried to use a lower asphalt rate in only one wheel path. We had one wheel path that was slick and the other one that wasn't slick. So I wanted to try using the smaller nozzles in only one wheel path. But we didn't go very far because I could tell right away that something didn't look right. For some reason the distributor pushed too much oil into the other wheel path, so I had to stop and readjust.

Something I would tell districts that don't use variable nozzles is that they work. They definitely work. But I'd also tell them to be sure to look at your roadways and use the variable nozzles on the roadways that really need them. They will save some slick wheel paths, just make sure to use them in the right places.

Key Words, by Category:

Geographic Area – Brownwood district

Information Type – Legacy knowledge

Legacy Knowledge Source – Randy King, June 2008 interview

Analyses Involved – Test Method Tex-922-K

Flexible Pavement Distresses Involved – Flushing

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, emulsion viscosity, field sampling, contractor communications, grade 5, changing nozzles, nozzle sizes, nozzle arrangement, traffic, distributor calibration

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Jimmy Parham's Thoughts on ….

TVAR Seal Coat Inspection
Communicating Asphalt Rate Changes
Sealing over Fresh Hot Mix Patches

We have been transversely varying asphalt rates for about eight to ten years in Lufkin. There have been some years we might not have a road where we use it. In other years, we might have several roads where we use it. It fluctuates every year. I imagine it averages close to 40 to 50% of our roads need it.

I usually ride the roads before we shoot them, look at them, and make some notes about asphalt rates and other things. But the final decision on asphalt rate is made the day we shoot that road. I'll go ahead of the distributor after the shots are marked and communicate back to the distributor operator by CB. I have a CB in my truck and the distributor operators have them in their trucks. When we're going to make a decision on a shot mark, I'll tell them a rate for the wheel paths and then a higher rate for outside the wheel paths. If we want the variable rate just part way through a shot, I'll make a little mark on the road to let him know where he should begin shooting the asphalt rate full width. We can be this flexible because our contractor usually has two spray bars on his distributor. So he doesn't have to change nozzles to go back to shooting straight bar.

The asphalt rates for the wheel paths are set pretty much by their visual appearance. But I do have a little temperature gage to check the roadway temperature. And a lot of times I'll take a rock and push it down into the oil to see how much free asphalt we actually have in the wheel path. Then I'll make my adjustments. I might make a short test shot to see what it does, what kind of embedment we get with the amount of oil that is already on the roadway.

Another factor to consider is what type of oil we are using. If we are shooting hot oil, it's going to liven up the oil on the roadway more than if we are shooting an emulsion. So that's a factor as well. What I'm doing is trying to determine how much asphalt I already have out there by how far I can push that rock in. Then I can cut my asphalt rate back because the contractor is going to shoot oil that's 330 or 340° F, and it's going to liven up that asphalt we already have on the road.

If you shoot too much asphalt considering how much oil is already at the surface, the seal coat rock is going to be pushed down and embedded too deep after traffic gets on it. Before you know it, the rock is gone and your oil is on top again. So I use that rock test to kind of check the depth of the asphalt that I already have out there. Then I can cut my rate down. I might cut it down as low as 0.22 gal/sy in some cases.

Another factor is the type of pavement you are sealing. I had a road that had a lot of fresh milled inlay patches on it. I had to change my rates based on that. I cut my rates down when shooting on fresh hot mix. When I get back on just old seal coat that has been there five or six years, I'm increasing the rate back up.

Your ADT, your traffic count, is another factor. If you have a lot of heavy loads coming through there, you want to try to shoot your wheel paths even a little lighter. Climbing lanes would be another example of a place where you may want to lower the shot rate a little more.

There's nothing too different for an inspector to look at when shooting variable rates. They just need to check to see if the different sizes of nozzles are in the right places and have their angles right. Also, any time you shoot, you have to check the speed of the distributor. Some of them get in a hurry and want to get the tank emptied out, particularly when they're running behind. I always like my distributors to shoot about 350 feet a minute. The height of the bar is another thing to always check.

The way I tell if my variable shot rates are correct is to look at the embedment of my rock. I go back and check it out after my rollers have rolled it and gotten through. I'll get out, walk, look and check the embedment of my rock. When I shoot, I like to try to get about 35% of my rock embedded. When it heats up during the summer and traffic runs on it, the rock is going to push down some more. So you have to allow some room for that.

If the contractor's distributor requires that he change the nozzle sizes every time the rates are varied transversely, you aren't going to have a lot of options on variable rates. If he has number four nozzles across the spray bar, you have him change to number three nozzles in the wheel paths.

I would recommend to anyone that has a lot of flushing in the wheel paths to give a shot to transversely varying the asphalt rate. Over the years I've been doing this I've learned that you aren't going to get every wheel path perfect by varying the asphalt rates, but it will help you on the embedment of your rock. Where you're seeing a little flushing, you can keep it from flushing again. I would recommend everybody to give it a try, at least.

Key Words, by Category:

Geographic Area – Lufkin district, east Texas

Information Type – Legacy knowledge

Legacy Knowledge Source – Jimmy Parham, April 2008 interview

Analyses Involved – Pavement temperature, depth of surface asphalt

Flexible Pavement Distresses Involved – Flushing

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, embedment depth, temperature, distributor speed, hot mix patches, traffic, climbing lanes, asphalt adjustment, nozzle sizes, CB, contractor communications

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Texas Department of Transportation

Ernest Teague's Thoughts on ….

TVAR Seal Coat Use
TVAR with Asphalt Rubber

We started doing transverse variable rates last year. Our experience so far has been with a contractor having a standard, single-spray-bar distributor. What we did for a typical 12-foot lane was consider the outside 2 feet on each side to be outside the wheel path and that there would be 2 feet between the wheel paths. This gives us two 3-foot wheel paths. Typically, if they're putting down a straight shot, they will use all number 5 nozzles when they are shooting AC-20-5TR or AC-20XP. They like to use the bigger nozzles for those asphalts. When we ask for a variation in shot rate, which for us means 10 to15% less in the wheel paths, they alternate the nozzles between number 5's and number 4's in the wheel paths. This works well because the fan spray patterns from the nozzles overlap one another and gives you an average. To get a uniform average, you need to set the spray bar height to get double overlap instead of triple.

I checked with the Brownwood District when we started looking into this. They are probably TxDOT's champions in varying asphalt shot rates. They go from a number 5 nozzle outside the wheel paths to a number 4 nozzle inside the wheel paths. This results in about a 30% difference in asphalt rate. When I first heard about that, I thought 30% was too much of a difference for us to start out with even though they obviously like it. They've been getting good results with that for years. Now I could see where 30% might work, in particular where you have wheel paths that are flushed. But I wanted to use this on all of my seals and wasn't willing to go that far. So we looked for a way to get 10 to15% variation, and alternating nozzle sizes in the wheel paths was the method we came up with.

As we evolve in our thinking and get more experience, I can see a situation where I might have a road that is flushed badly in the wheel paths. I might be inclined to go with a 30% variation there. We would want to shoot a lot less in the wheel path and still try to keep enough oil up between the wheel paths and outside the wheel paths to hold the rock. At the same time we would want to try to keep from re-creating the flushing problem in the wheel paths. I could see asking a contractor to vary 30% if we had that type of situation.

Last year we shot hot asphalt rubber on IH-30 in Hunt, Hopkins and Franklin counties. We were having trouble with some old dry asphalt, and it was starting to shell out on us. We needed to capture that right quick. We opted for the hot rubber product because we felt that we needed something with a lot of elasticity.

We didn't want to use grade 3 rock because of broken windshields, especially with the high speed traffic on the interstate. Also, we knew that grade 4 rock is harder to get the asphalt just right to keep from losing rock and keep it from bleeding. That was when we decided to use variable asphalt rates, which was the first time I tried it. I had pretty good luck with it. There's a stretch in another county done by the same contractor where the asphalt rubber rate wasn't varied. Right now you can drive through there and see that there isn't a whole lot of difference in the wheel path, but you can see a little difference in rock loss outside the wheel path where the rate wasn't varied. It was the same contractor and the same product. That's just an example of the advantages we can gain by transversely varying asphalt. That little difference can sometimes show up in a big way, and that sold me.

Key Words, by Category:

Geographic Area - Paris district, northeast Texas

Information Type - Legacy knowledge

Legacy Knowledge Source – Ernest Teague, June 2008 interview

Flexible Pavement Distresses Involved – Flushing, shelling

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, grade 3, grade 4, alternating nozzle sizes, nozzle arrangement, hot asphalt rubber, broken windshields, double overlap, AC-20-5TR, AC-20XP

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Texas Department of Transportation

Legacy Knowledge

Darlene Goehl: May - 2008

Darlene Goehl's Thoughts on ….

TVAR Location Selection
TVAR Seal Coat Inspection

We have been transversely varying asphalt rates for around eight, maybe ten years in Bryan. So we have been doing it for quite awhile now. I would guess that we average using it on about 50% of our district seal locations.

The director of construction and I ride all the roads in the district seal project a couple of weeks before the project starts. We set up the asphalt rate table to be used, and that is also when we decide where we are going to use transverse variable shot rates.

Deciding on when to use variable rates is a visual determination, but we also consider the traffic and road width. Usually around 1000 ADT and above we are going to go with variable rates. On the other hand, if the road is really narrow, 20 to 22 feet, we may go with a straight bar because the wheel paths are in odd locations. This is typically how we decide. We look and see if the wheel paths are visible. Are they worn down? Is the aggregate worn down or is the asphalt flushed up? If we can see the wheel paths, then we will usually shoot variable asphalt rate because something different is going on in the wheel paths. We also look and see if we have any raveling outside the wheel paths. If there is raveling, it may be an indication that we need more asphalt outside the wheel paths. So that may be another reason to use variable asphalt rates.

The 1000 ADT break point I mentioned is a rule of thumb we came up with. I have the ADT numbers with me when we drive the roads, and I've noticed that somewhere around 1000 ADT we start seeing the wheel paths.

We always design the asphalt rate for the wheel path condition. Then we have to decide if we need more asphalt than that for outside the wheel paths. If we have a low volume road and we are going to shoot asphalt on the higher end of the normal range, we may go with a straight bar because we will have enough asphalt for outside the wheel paths. It is all about embedment and embedment depth. So the lower the ADT, the less embedment benefit you get from traffic and the higher your asphalt rate needs to be in the wheel paths. On the other hand, if we are shooting a low rate in the wheel paths, we will have to have more asphalt outside the wheel paths to hold the aggregate. That is typically the main reason we shoot variable rates, to hold aggregate outside the wheel paths. In our district, we are not lowering the asphalt rate in the wheel path. We are increasing the asphalt rate outside the wheel paths to prevent raveling.

We have transversely varied asphalt using both emulsions and asphalt cements. The type of asphalt doesn't matter. As for the aggregate, we'll do it with grade 3 and grade 4, but usually not with grade 5. We use grade 5 on rehabs, and they are usually being put on top of the base. Grade 5 is also small to begin with, so varying asphalt rate would be more difficult.

Our approach in the specifications has been to have a general note that says we want a minimum of 20% variation possible. However, the flexibility that we can get on a given project is going to fall back to the equipment that the contractor has out there. Some distributors have two spray bars, and you can vary the rate over a wide range. When the equipment has a single spray bar, the contractor has to go to the next size of spray nozzle. This usually gives about a 20% difference in rate.

When you vary the nozzle sizes on a single spray bar you need to be sure that the average shot rate is what is entered into the distributor's computer. If you want 0.35 gal/sy in the wheel paths and you are varying rates by 20%, then you will have to set the computer at something like 0.39 gal/sy. This setting will then give you about 0.42 gal/sy asphalt outside the wheel paths. We've developed a set of tables to help figure out average asphalt rates for each lane width (Example in Figure 1 for 12-foot lanes).

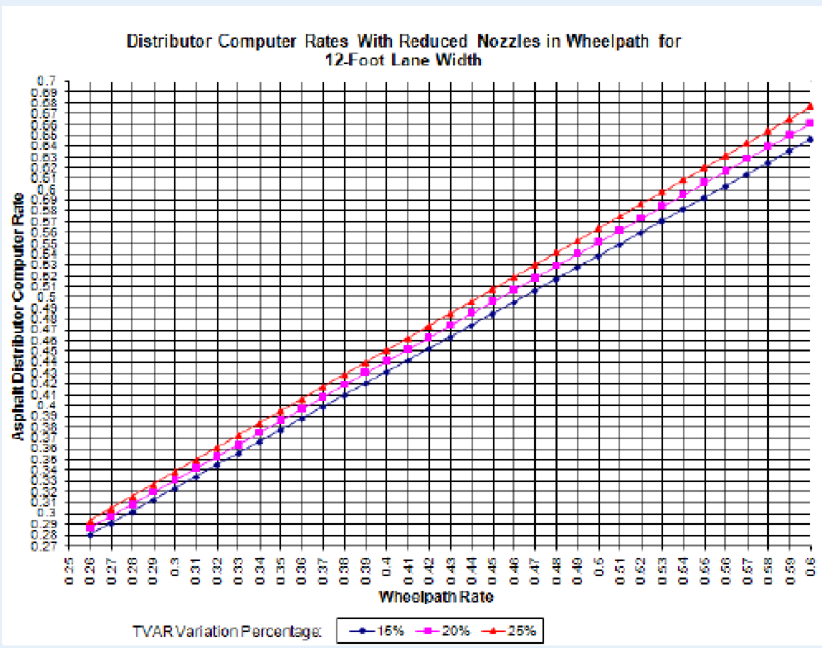

Figure 1

When we vary the asphalt rate, we usually assume the wheel path is 3 feet wide no matter how wide the lane is. But the locations of the wheel paths change with different lane widths. We developed a table to help us place the different sized nozzles correctly on pavements with different lane widths (Figure 2).

Lane Width, ft.		ft.	Wheel Path Width, ft.	ft.	Wheel Path Width, ft.	ft.	
9	Center Line	0	3	2	3	1	Edge Line
10		1	3	2	3	1	
11		1.33	3	2	3	1.66	
12		1.66	3	2.7	3	1.7	
13		2.3	3	2.7	3	2	

Figure 2

On the inspection end of things, we need to make sure the right nozzles are in the right places when the contractors change the nozzles out. That is the main thing for the inspector to check. Before you start, the contractor should have a calibration record for those nozzles. That's also important.

Key Words, by Category:

Geographic Area – Bryan district

Information Type – Legacy knowledge

Legacy Knowledge Source – Darlene Goehl, May 2008 interview

Flexible Pavement Distresses Involved – Flushing, raveling

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, grade 3, grade 4, grade 5, nozzle sizes, nozzle configuration, traffic, average asphalt rates, distributor calibration

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Texas Department of Transportation

Legacy Knowledge

Albert Quintanilla: June - 2008

Albert Quintanilla's Thoughts on ….

TVAR Seal Coat Use
TVAR Seal Coat Inspection
Field Adjustments to Asphalt Shot Rates

The Laredo District has used transversely variable asphalt rates off and on for about the last ten years. This past year we didn't use any though. If I had to guess, over the years we have used it on about 10% of the locations in our annual seal coat programs. The determination of the seal coat asphalt rate is made in the field by consensus between the inspector and contractor prior to beginning seal coating on that particular location.

When we decide to transversely vary the asphalt rate, our experience has been to change out distributor nozzles so the areas outside the wheel paths receive about 15% more asphalt than the wheel paths. We change the nozzles on the distributor spray bar which generally follow the wheel paths. This is standard regardless of the aggregate being used.

Concerning construction inspection and decisions made on the roadside, the most important decision is determining if the pavement condition prior to the seal coat warrants having the contractor changing nozzles on his distributor. On projects where this is done, we inspect the nozzles before the contractor installs them to insure they'll give the proper varied rate. The biggest error that can be made would be not changing the nozzles in the wheel paths when it's needed. If they aren't changed, tracking or bleeding issues occur.

We allow the inspector to make limited adjustments to preset shot rates. As far as increasing the shot rates, typically I tell the inspector he can increase the asphalt rate up to 0.05 gal/sy based on the existing pavement conditions and up to 0.05 gal/sy based on traffic. However, he or she isn't allowed to increase the total asphalt rate by more than 0.06 gal/sy without prior approval from the area engineer.

Also, it's important to have good communication with the seal coat contractor. They usually don't complain about changing the nozzles as long as they have enough lead time so they can do it without stopping the seal coat operations. In other words, if you let them know when the distributor first gets to the location, they can change the nozzles while they wait for the sweepers and rollers to show up and for the temporary tabs to be installed.

Transversely varied asphalt shot rates are just another tool that can be used on seal coats. What matters most is having the knowledge to use the right tool for the right job.

Key Words, by Category:

Geographic Area – Laredo district, south Texas

Information Type – Legacy knowledge

Legacy Knowledge Source – Albert Quintanilla, June 2008 interview

Analyses Involved – None

Flexible Pavement Distresses Involved – Flushing

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, field asphalt shot rate adjustments, contractor communications

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Joe Higgins' Thoughts on ….

TVAR Seal Coat Design
TVAR Seal Coat Inspection

I've been involved with transversely varying asphalt shots as far back as fifteen years ago. I don't know for sure which year Thomas Bohuslav came to the Abilene District from Brownwood, but I remember we talked about asphalt rates and variable nozzles at that time, and we were already using some transverse rates in those years. I had done district seal projects for years, but then I got away from them for awhile. When I started doing the seal coats in my area three or four years ago, we went back to using variable nozzles.

In the early days I would use variable asphalt rates on all the roads in the district seal coat program, whether or not they showed any flushing in the wheel paths. Even on fairly decent looking pavements; I didn't think it was right to wait until you had flushed up asphalt in the wheel paths to start using variable nozzles. I still think that's the way to go because if you use straight nozzles where there's traffic, eventually, those wheel paths are going to show up. It will either be flushing in the wheel paths or you will be losing rock outside the wheel paths. While I would use variable rates on all of the main lanes, we would use straight nozzles on the shoulders.

When Thomas Bohuslav came, he brought a lot of good ideas from the Brownwood District. One thing Brownwood did was they made their own nozzles. We had two or three sets of nozzles made up and we would require the contractors to use them. However, there were some problems with that. We would have to use adapters to make them fit different contractor's spray bars. I really didn't like that, but that's what we did. I think those nozzles were made to give a variation of about 25%.

About two years ago I wanted to go with standard manufacture's nozzles. I picked two nozzles, trying to get as close as possible to 25% variation. Those two nozzles gave about 42% variation when we did the bucket test. Or maybe the 42% was based on the manufacture's literature. We went with them and it seemed to work pretty well. I imagine if we were to vary that much two or three times in a row we might start seeing something. I would say that as far as the amount of variation to use, there is a wide range there. I don't know if anybody really has a good handle on exactly how much variation you should use.

It's my understanding that at least one distributor manufacturer can now make nozzle sets to give the percent variation you want. That's good. Before, I let the contractor get by with something outside of the range I was looking for in order to use standard nozzles. Now, I would be a little bit more demanding that we get the variation requested because I know they can get those nozzles.

Recently we have been requiring a variation in the range of 20% to 30%. We need to give the contractor a range because even with good nozzle manufacturing equipment, it's hard to hit a specific rate very closely. I would say 25% plus or minus 5% is about right.

Dealing with traffic and pavement condition adjustment factors, I have a sheet for the inspector that provides the recommended variations (Figure 1). I have another sheet to document the locations where you plan to change the average asphalt rate or the percent variation (Figure 2). That sheet also shows the numbers involved. The average asphalt rate depends on the lane width, because the width determines how many large nozzles you will have to have. So the worksheet guides the inspector through to come up with the average rate being obtained from the nozzles.

Nozzle Configuration

road width	nozzle configuration left to right (L-large, sm-small)	# small nozzles	# large nozzles	total # nozzles	25% variance av. rate* multiplier	30% variance av. rate* multiplier
8	1L 9sm 6L 9sm 3L	18	10	28	1.089	1.107
10	3L 9sm 6L 9sm 4L	18	13	31	1.105	1.126
11	5L 9sm 6L 9sm 5L	18	16	34	1.118	1.141
12	6L 9sm 8L 9sm 5L	18	19	37	1.128	1.164
13	7L 9sm 8L 9sm 7L	18	22	40	1.138	1.165
14	7L 9sm 8L 9sm 10L	18	25	43	1.145	1.174
15	7L 9sm 8L 9sm 13L	18	25	43	1.145	1.174
16	7L 9sm 8L 9sm 16L	18	28	46	1.152	1.183

* wheel path rate = base rate + traffic adj. + truck adj. + surface adj.
outside wheel path rate = wheel path rate X (1+%variance). Example: for variance of 25% then (1+%variance) = 1.25
average rate = wheel path rate X variance multiplier above. Example: for 12' width & 25% variance, multiplier=1.128
above factor = (#small + #largeX(1+variance))/total # of nozzles

Surface Condition Adjustment

surface	description	gr3	gr4	gr5
Seal	very dry seal with many cracks	0.06	0.06	0.04
	dry seal with few cracks	0.03	0.03	0.02
	good seal with no cracking	0.00	0.00	0.00
	flushed seal	-0.02	-0.02	-0.01
	bleeding seal	-0.04	-0.04	-0.02
ACP	ACP	0.12	0.10	0.06
Cold Mix Patch	dry, well aged	0.12	0.10	0.04
	fresh (less than 3 months)'	0.00	0.00	0.00
Prime	prime - dry surface, light rate	0.05	0.04	0.02
	prime - average codition	0.02	0.02	0.01
	prime - free asphalt on surface	0.00	0.00	0.00

'recommend cold mix patches have adequate cure time (plus 6 months minimum)

NOTE: Surface & traffic adjustment factors are subject to change based on experience.
If you experience problems using these rates, please contact Joe Higgins, Hamlin TxDOT.

Base Rate

Aggr. Grade	Asph base rate gal/sy	Aggr. rate cy/sy
3	0.40	105
4	0.34	115
5	0.25	130

Table base rates are not to be used for emulsions.

Truck Adjustment

% trucks	aggr grade 3	aggr grade 4	aggr grade 5
average	0	0	0
heavy	-0.03	-0.02	-0.01

Traffic Adjustment

vol/lane	gr 3	gr 4	gr 5
0	0.07	0.05	0.04
50	0.06	0.04	0.02
100	0.04	0.03	0
300	0.01	0.02	NA
500	0	0	NA
700	-0.01	-0.01	NA
1000	-0.02	-0.02	NA
1500	-0.03	-0.03	NA
2000	-0.04	-0.04	NA

2 lane = ADT/2
4 lane urban = ADT/4
4 lane rural = ADT *.35 outside lanes
4 lane rural = ADT *.15 inside lanes
Shoulder ADT = zero

Figure 1

Asphalt Design Rate Worksheet

Highway ____________ County ____________

Asphalt type ____________ CSJ ____________

Nozzle var. (20% or 30%)----> ________ aggregate rate (cy/sy)--> ________

Aggregate Size (3 or 4 or 5---> ________ asphalt base rate (gal/sy)--> ________

width feet	ADT veh/day	Veh per Lane	truck %	Location (normally Texas ref. mark (or station) and direction)	traffic adjust gal/sy	truck adjust gal/sy	surface adjust gal/sy	wheel path rate* gal/sy	outside wheel path rate** gal/sy	average rate*** gal/sy

Comments:

Vehicles per lane
2 lane = ADT/2
4 lane urban = ADT/4
4 lane rural = ADT *.35 outside lanes
4 lane rural = ADT *.15 inside lanes

*wheel path rate = base rate + traffic adj. + truck adj. + surface adj.
**outside wheel path rate = wheel path rate X 1.25 (for 25% variance)
***average rate = wheel path rate X variance multiplier from nozzle conf. table

Figure 2

Now, with seal coats, my experience is everybody is an expert. You can have a summer hand who has been out there two weeks and knows exactly what to do, what kind of rates to use, and everything else. Regardless of how much or little experience, people think they have it figured out. The recommended rates and adjustments in the worksheet are based on what has worked in the past. I continue to adjust them. There's a note at the bottom of the worksheet that says, "If you use these rates and they don't work for you, let me know and we can adjust them." In fact, I have recently made some adjustments based on the last couple of years of experience. One thing that often throws people off is shooting on top of hot mix. It seems people never add enough asphalt to the base rate when shooting on hot mix. That's a number I have increased in my recommendations. The recommendations are a continuing process, tweaking them as we go.

The biggest thing for the inspector to monitor is that the right nozzles are in the right places. That can be hard once you get the nozzles and spray bar covered with asphalt. An inspector has to be able to look at the spray bar and tell if the nozzles are oversized or too small. Contractors can get a little lazy and put standard nozzles on and not change them when they go back to the main lanes, or vice versa. What we did last year was have the contractor put washers on the bigger or smaller nozzles. We could then check them without getting some diesel and a rag and trying to see the numbers on the nozzles.

A method some people use to check if the varied asphalt shot rate is proper is to look at the rock embedment behind the rollers. I have never thought that was a good method because there is no way you can really tell when varying shot rates. You have to wait and go through a winter and summer to see if it's going to bleed or lose rocks. So I trust what I have learned from experience about adjusting rates for traffic and road conditions instead of spending a lot of time on my knees looking at embedment. We wait twelve months before checking to see if we had a successful seal coat. When we check it we see if it lost rock, if it bled, we look at when we shot it, and what the rates were that we used. Our district is doing much better with keeping up with the rate we placed and evaluating the condition of the road afterwards. Those evaluations can lead to tweaking the adjustment factors.

When it comes to the process of varying asphalt rates, we have always designed the asphalt rate for the wheel paths first because the wheel paths tell you more. We pick a rate for the wheel paths, and then we increase asphalt outside the wheel paths. If you use variable nozzles, you put down more asphalt than you would otherwise, and you get a better finished product.

The additional asphalt outside the wheel paths helps you hold the rock better and you get a better job of sealing the pavement. It's the same on the shoulders. My instruction to the inspectors on shooting shoulders is to shoot as much asphalt as your construction equipment can get through. If the seal starts picking up on construction equipment, you've shot too much and back off. We always put down a lot of asphalt on the shoulders since they don't carry traffic. I have developed a theory on that. If you want to save money, shoot the shoulder only every other cycle. The cycle that you do shoot it, put down such a heavy rate that that the seal should hold better through the cycle when it's not shot.

The seal contractors that have worked in my district are pretty neutral on transversely varying asphalt rates. Now I do suspect the hands that have to change those nozzles out probably have an opinion on it. But the contractor, the owner of the company, they just go with it. I don't know if they add anything to the bid price or not, but I suspect they get their money back without an increase because they will be putting down a little more asphalt for the same amount of work.

One thing I would tell districts that haven't tried transversely varying asphalt rates is to just look at your roads. On the roads that have been sealed two or three times over the years, you can see it's either flushed in the wheel paths, or you've probably lost some rock between the wheel paths and outside the wheel paths. To me, that is the biggest thing I see that should convince everybody we need to be doing something a little different. I think varying nozzle sizes makes obvious sense. The more traffic you have, the more that traffic is going to beat the rock down into the asphalt, and the traffic runs in the wheel paths.

For me, the biggest unanswered question would be how much variation you need. How much variation is enough and not too much? If I can vary from 20% to 40%, that's a wide range. What I have liked to do in the past is base the amount of variation on experience. And then when I go back in twelve months and see that it is working fine, then maybe that was a good rate variation. But the number I pick for a percent variation is just a guess. I don't use a calculation or anything for the amount of variation.

While I haven't tried it, I think using the sand patch test is a very good concept. But I can tell you where it's not going to work if you are testing only the wheel paths. It won't work on hot mix and hot mix-cold laid pavement surfaces. If you do the sand patch test in the wheel path it's going to indicate that you need to back off on the asphalt because the hot mix surface is closed up, similar to a partially flushed seal coat. But you really need to go the other way. My discovery on hot mix is that I have had to bump up the asphalt rate one-tenth above base rate. I increase asphalt at one-tenth for a grade 4 now and twelve-hundredths for a grade 3 aggregate. I have never seen hot mix to bleed up after someone sealed on top of it. I do see a lot of rock loss though. So I keep bumping the rate up for hot mix surfaces. I have a theory on hot mix. Hot mix is just a flush surface and the seal coat rock can't nestle down into it, it just sits on top.

I have one more thing that hasn't been mentioned, and that is you can't totally judge the seal coat based on whether you lose rock or get some flushing. The time of year you shoot is so critical. If you shoot a seal coat in the spring, you have the summer ahead of you before the winter, and you can be good. If you shoot it late, sometimes the pavement doesn't get hot enough for the rock to properly seat. That's when you can lose rock. But in that case it wasn't because the asphalt rate was wrong. It was because of the time of year that you shot it.

One thing I tell my inspector is, "Don't change your rock rate. Keep your rock rate the same." We have so many contractors and inspectors to start increasing rock rather than holding it the same and decreasing the asphalt if they start seeing a little picking up on the dump truck or chip spreader. I try not to vary my asphalt rate based on the time of season, but if we are doing a rehab job and we want to finish it, I might shoot a little more asphalt. But I try to hold my asphalt rate based on the traffic and the pavement conditions, those two factors only. If it's too late in the season, we probably just shouldn't be shooting.

Key Words, by Category:

Geographic Area - Abilene district, west Texas

Information Type - Legacy knowledge

Legacy Knowledge Source – Joe Higgins, September 2008 interview

Analyses Involved – Test Method Tex-436-A, Sand Patch Test

Flexible Pavement Distresses Involved – Flushing, shelling

Other Descriptors – Transversely varied asphalt rate, TVAR, seal coat, texture, grade 3, grade 4, grade 5, work sheet, asphalt adjustment factors, nozzle size identification, shoulders, rock rate, picking up, hot mix, hot mix cold laid, traffic, embedment, Thomas Bohuslav

Search Acronyms: Legacy Knowledge – Flexible Pavement – Maintenance, lkfpm, Legacy Knowledge – Flexible Pavement – Inspection, lkfpi, Legacy Knowledge – Flexible Pavement – Construction, lkfpc, Legacy Knowledge – Flexible Pavement – Specifications, lkfps, Legacy Knowledge – Flexible Pavement – Unique Application & Innovation, lkfpu

APPENDIX D: PAVEMENT TEXTURE TEST LOCATIONS AND NEW SEAL COAT APPLICATION RATES

Brownwood District Information															
District Seal Project Ref. No.	Highway County	Lane	Ref Marker	GPS Coordinates		Additional Location Comment	Existing Seal Coat Being Covered		New Seal Coat - Actual Placement Data						
				Latitude	Longitude		Aggregate Grade	Aggregate Type	Asphalt	Asphalt Rate in WP	Asphalt Rate Outside of WPs	Aggregate Grade	Aggregate Type	Aggregate Spread Rate	
16	US 190 McCullough County	EB	462 +1.6	31° 11.767 N	99° 14.182 W	At County Road 418 sign	Gr 3	Lightweight	AC-20XP	0.45	0.45	Gr 3	Precoated Limestone	90	
16	US 190 McCullough County	WB	470+0.6	31° 14.357 N	99° 08.736 W	Outside lane where roadway expanded to include a climbing lane	Gr 3	Lightweight	AC-20XP	0.48	0.48	Gr 3	Precoated Limestone	90	
16	US 190 McCullough County	WB	470+0.6	31° 14.357 N	99° 08.736 W	Inside lane where roadway expanded to include a climbing lane	Gr 3	Lightweight	AC-20XP	0.50	0.50	Gr 3	Precoated Limestone	90	
23	SH 153 Coleman County	EB	Near 370	31° 49.883 N	99° 28.108 W	At Watch for Ice sign west of bridge	Gr 3	Lightweight	AC-20XP	0.49	0.49	Gr 3	Precoated Limestone	90	
21	FM 3425 Coleman County	SB	332+0.2	31° 51.272 N	99° 24.536 W	-	Gr 3	Lightweight	AC-20XP	0.42	0.42	Gr 3	Precoated Limestone	90	
5	US 283 Coleman County	SB	376+0.5	31° 33.446 N	99° 22.451 W	-	Gr 3	Lightweight	AC-20XP	0.47	0.47	Gr 3	Precoated Limestone	90	
6	US 283 Coleman County	NB	382+1.4	31° 27.370 N	99° 22.491 W	At culvert	Gr 3	Lightweight	AC-20XP	0.47	0.47	Gr 3	Precoated Limestone	90	
30	FM 2134 Coleman County	WB	350	31° 34.987 N	99° 37.869 W	-	Gr 3	Limestone	AC-20XP	0.52	0.52	Gr 3	Precoated Limestone	90	
30	FM 2134 Coleman County	EB	348	31° 34.251 N	99° 39.674 W	In dead-end section past park road entrance.	Gr 3	Limestone	AC-20XP	0.52	0.52	Gr 3	Precoated Limestone	90	
15	SH 6 Eastland County	SB	362	32° 18.999 N	98° 49.758 W	-	Gr 3	Limestone	AC-20XP	0.45	0.45	Gr 3	Precoated Limestone	90	
24	FM 2689 Eastland County	NB	308+ 30 feet	32° 14.581 N	98° 40.250 W	-	Gr 3	Limestone	AC-20XP	0.3*	0.38*	Gr 3	Precoated Limestone	90	
24	FM 2689 Eastland County	NB	308 - 0.1	32° 14.679 N	98° 40.251 W	At No Passing sign	Gr 3	Limestone	AC-20XP	0.3*	0.38*	Gr 3	Precoated Limestone	90	

*Average rates for entire roadway.

Bryan District Information															
Location No.	Highway County	Lane	Ref Marker	GPS Coordinates		Additional Location Comment	Existing Seal Coat		New Seal Coat						
				Latitude	Longitude		Aggregate Grade	Aggregate Type	Asphalt	Asphalt Rate in WP	Asphalt Rate Outside of WPs	Aggregate Grade	Aggregate Type	Aggregate Spread Rate
1	FM 696 Burleson County	NB	598 – 1.2	30° 27.084 N	96° 51.915 W	First maintenance seal location north of aggregate stockpiles.	Gr 4	Lightweight	AC-20XP	0.36	0.36	Gr 4	Precoated Lightweight	1/127
2	FM 696 Burleson County	NB	598 – 1.1	30° 27.107 N	96° 51.876 W	Approx 200 feet south of the above location.	Gr 4	Lightweight	AC-20XP	0.36	0.36	Gr 4	Precoated Lightweight	1/127
3	FM 908 Burleson County	NB	598 + 1.1	30° 31.254 N	96° 49.377 W	At sign indicating left curve and 45 mph speed limit near Liberty Cemetery.	Gr 4	Lightweight	AC-20XP	0.32	0.38	Gr 4	Precoated Lightweight	1/125
4	FM 908 Burleson County	NB	598 + 1.0	30° 31.294 N	96° 49.405 W	Maintenance seal north of left curve sign. About 30 feet south of culvert.	Gr 4	Lightweight	AC-20XP	0.32	0.38	Gr 4	Precoated Lightweight	1/125
5	FM 908 Burleson County	NB	602 + 1.8	NA	NA	~30 feet into heavily flushed area beginning just north of speed limit sign near intersection with SH 21.	Gr 4	Lightweight	AC-20XP	0.39	0.45	Gr 4	Precoated Lightweight	1/125
6	FM 2027 Milam County	SB	388 + 0.5	31° 02.621 N	96° 49.137 W	~50 feet north of culvert.	Gr 4	Lightweight	AC-20-5TR	0.38	0.38	Gr 4	Precoated Lightweight	1/125
7	FM 2027 Milam County	NB	388 + 1.6	31° 01.862 N	96° 48.491 W	At sign indicating left curve and 55 mph speed limit.	Gr 4	Lightweight	AC-20-5TR	0.38	0.38	Gr 4	Precoated Lightweight	1/125

Lufkin District Information														
Location No.	Highway County	Lane	Ref Marker	GPS Coordinates		Additional Location Comment	Existing Seal Coat		New Seal Coat					
				Latitude	Longitude		Aggregate Grade	Aggregate Type	Asphalt	Asphalt Rate in WP	Asphalt Rate Outside of WPs	Aggregate Grade	Aggregate Type	Aggregate Spread Rate
1	FM 819 Angelina County	SB	360 + 0.636	NA	NA	Trial location tested in April.	Gr 4	Lighweight	AC-20-5TR	NA	NA	Gr 4	Precoated Lightweight	NA
2	FM 819 Angelina County	NB	360 + 0.636	NA	NA	Trial location tested in April.	Gr 4	Lightweight	AC-20-5TR	NA	NA	Gr 4	Precoated Lightweight	NA
3	SH 147 San Augustine County	NB	366 + 1.3	31° 16.489 N	94° 17.478 W	At JCT FM 3185 sign. Light flushing in wheel paths.	Gr 3	Lightweight	AC-15P	0.32	0.38	Gr 4	Precoated Lightweight	1/113
4	SH 147 San Augustine County	Left Turn Lane	364 + 0.9	31° 18.258 N	94° 16.266 W	At driveway into vacant yellow store	Gr 3	Lightweight	AC-15P	0.33	0.33	Gr 4	Precoated Lightweight	1/113
5	SH 147 San Augustine County	SB	364 + 0.1	31° 18.878 N	94° 15.786 W	At 55 mph sign.	Gr 3	Lightweight	AC-15P	0.34	0.34	Gr 4	Precoated Lightweight	1/113
6	SH 147 San Augustine County	Left Turn Lane	364 + 0.1	31° 18.878 N	94° 15.786 W	At 55 mph sign. Not much traffic in median.	Gr 3	Lightweight	AC-15P	0.38	0.38	Gr 4	Precoated Lightweight	1/113
7	SH 103 Sabine County	WB	762 + 0.002	31° 24.694 N	94° 00.608 W	10 feet East of Ref Mrk 762. Inverted seal done in the wheel paths due to bleeding in wheel paths. Put a 1/113 of rock, then oil at 0.28, then roock at 1/113.	Gr 3	Lightweight	AC-15P	0.25	0.32	Gr 4	Precoated Lightweight	1/113
8	SH 103 Sabine County	WB	764 - 1.4	31° 24.750 N	93° 59.937 W	At West SH 103 sign	Gr 3	Lightweight	AC-15P	0.35	0.35	Gr 4	Precoated Lightweight	1/113
9	SH 103 San Augustine County	WB	756 + 0.9	31° 24.210 N	94° 04.638 W	At Do Not Pass sign.	Gr 3	Lightweight	AC-15P	0.3	0.38	Gr 4	Precoated Lightweight	1/113
10	FM 2457 Polk County	WB	698 – 0.4	30° 44.369 N	95° 01.839 W	100' East of Blue XX East Road. Heavy flushing.	Gr 3	Limestone	AC-20-5TR	0.24	0.33	Gr 4	Precoated Lightweight	1/112
11	FM 2457 Polk County	EB	698 – 1.70	30° 44.240 N	95° 03.165 W	300' East of Exxon Store. Heavy flushing.	Gr 3	Limestone	AC-20-5TR	0.26	0.34	Gr 4	Precoated Lightweight	1/113

APPENDIX E: TEXTURE DEPTH TEST RESULTS AND PHOTOGRAPHY

US 190 (Location 1) − McCullough County


Eastbound View


Westbound View


Between Wheel Path Texture


Wheel Path Texture

Location and Texture Data Summary

Highway:	US 190
County:	McCullough
Test Location:	1
Lane:	Eastbound
TRM*:	462+1.6
Latitude:	31°11.767N
Longitude:	99°14.182W

*TRM – Texas Reference Marker

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.70	1.44	1.55	136
Between WP	2.37	2.17	2.19	115
Difference	0.67	0.73	0.64	20

US 190 (Location 2) − McCullough County

Westbound View

Eastbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	US 190
County:	McCullough
Test Location:	2
Lane:	Westbound
TRM:	470+0.6
Latitude:	31° 14.357 N
Longitude:	99° 08.736 W

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	CTMeter	Outflow Test	
Wheel Path	2.09	1.85	2.37	122
Between WP	2.40	2.22	2.58	114
Difference	0.31	0.37	0.21	8

US 190 (Location 3) − McCullough County

Westbound View

Eastbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	US 190
County:	McCullough
Test Location:	3
Lane:	Westbound
TRM:	470+0.6
Latitude:	31° 14.357 N
Longitude:	99° 08.736 W

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.83	1.60	2.86	131
Between WP	2.45	2.33	2.05	113
Difference	0.62	0.73	-0.81	18

SH 153 – Coleman County

Eastbound View

Westbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	SH 153
County:	Coleman
Test Location:	1
Lane:	Eastbound
TRM:	Near 370
Latitude:	31° 49.883 N
Longitude:	99° 28.108 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.02	0.90	1.19	177
Between WP	1.88	1.44	1.83	129
Difference	0.86	0.54	0.64	48

FM 3425 – Coleman County


Southbound View


Northbound View


Between Wheel Path Texture


Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 3425
County:	Coleman
Test Location:	1
Lane:	Southbound
TRM:	332+0.2
Latitude:	31° 51.272 N
Longitude:	99° 24.536 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.07	0.77	1.04	172
Between WP	1.52	1.36	1.26	144
Difference	0.45	0.59	0.22	28

US 283 (Location 1) – Coleman County


Southbound View


Northbound View


Between Wheel Path Texture


Wheel Path Texture

Location and Texture Data Summary

Highway:	US 283
County:	Coleman
Test Location:	1
Lane:	Southbound
TRM:	376+0.5
Latitude:	31° 33.446 N
Longitude:	99° 22.451 W

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	0.99	0.87	1.31	178
Between WP	1.65	1.44	2.05	138
Difference	0.66	0.57	0.74	40

US 283 (Location 2) – Coleman County

Northbound View

Southbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	US 283
County:	Coleman
Test Location:	2
Lane:	Northbound
TRM:	382+1.4
Latitude:	31° 27.370 N
Longitude:	99° 22.491 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.04	0.88	1.31	174
Between WP	1.91	1.73	2.05	129
Difference	0.87	0.85	0.74	45

FM 2134 (Location 1) – Coleman County


Westbound View


Eastbound View


Between Wheel Path Texture


Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 2134
County:	Coleman
Test Location:	1
Lane:	Westbound
TRM:	350
Latitude:	31° 34.987 N
Longitude:	99° 37.869 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	2.29	1.99	2.86	117
Between WP	3.57	3.06	3.75	94
Difference	1.28	1.07	0.89	23

FM 2134 (Location 2) – Coleman County

Eastbound View

Westbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 2134
County:	Coleman
Test Location:	2
Lane:	Eastbound
TRM:	348
Latitude:	31° 34.251 N
Longitude:	99° 39.674 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	2.39	2.11	2.86	115
Between WP	3.03	2.93	8.42	102
Difference	0.64	0.82	5.56	13

SH 6 – Eastland County

Southbound View

Northbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	SH 6
County:	Eastland
Test Location:	1
Lane:	Southbound
TRM:	362
Latitude:	32° 18.999 N
Longitude:	98° 49.758 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.27	1.19	1.50	157
Between WP	1.89	1.67	2.58	129
Difference	0.62	0.48	1.08	28

FM 2689 (Location 1) – Eastland County

Northbound View

Southbound View

Between Wheel Path Texture

Wheel Path Texture

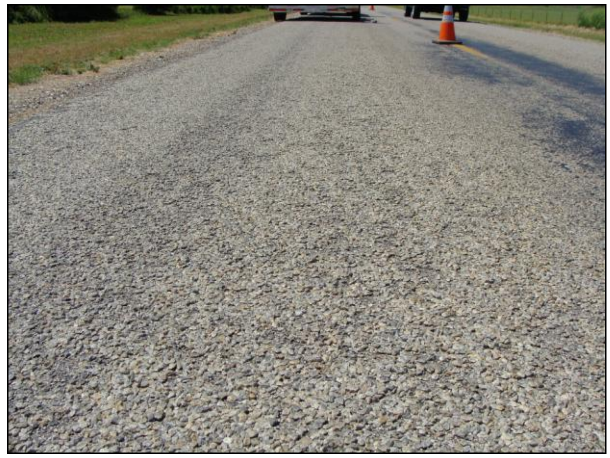
Location and Texture Data Summary

Highway:	FM 2689
County:	Eastland
Test Location:	1
Lane:	Northbound
TRM:	308+30 feet
Latitude:	32° 14.581 N
Longitude:	98° 40.250 W

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	CTMeter	Outflow Test	
Wheel Path	1.35	1.13	1.46	154
Between WP	2.57	2.19	2.86	111
Difference	1.22	1.06	1.40	43

FM 2689 (Location 2) – Eastland County

Northbound View



Southbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 2689
County:	Eastland
Test Location:	2
Lane:	Northbound
TRM:	308-0.1
Latitude:	32° 14.679 N
Longitude:	98° 40.251 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	3.48	3.35	8.42	95
Between WP	3.90	3.51	4.53	90
Difference	0.42	0.16	-3.89	5

FM 696 (Location 1) – Burleson County

Northbound View

Southbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 696
County:	Burleson
Test Location:	1
Lane:	Northbound
TRM:	598-1.2
Latitude:	30° 27.084 N
Longitude:	96° 51.915 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	2.16	1.83	2.58	121
Between WP	2.50	2.18	3.23	112
Difference	0.34	0.35	0.65	9

FM 696 (Location 2) – Burleson County

Northbound View

Southbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 696
County:	Burleson
Test Location:	2
Lane:	Northbound
TRM:	598-1.1
Latitude:	30° 27.107 N
Longitude:	96° 51.876 W

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	0.93	1.02	1.50	184
Between WP	2.14	1.84	3.23	121
Difference	1.21	0.82	1.73	63

FM 908 (Location 1) – Burleson County


Northbound View


Southbound View


Between Wheel Path Texture


Wheel Path Texture

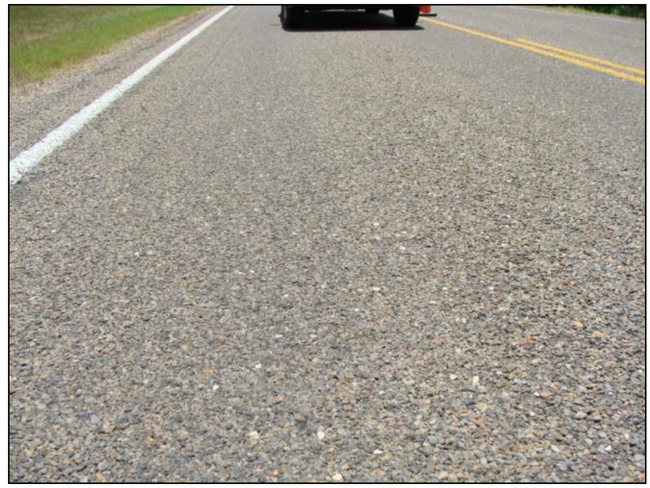
Location and Texture Data Summary

Highway:	FM 908
County:	Burleson
Test Location:	1
Lane:	Northbound
TRM:	598+1.1
Latitude:	30° 31.254 N
Longitude:	96° 49.377 W

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	CTMeter	Outflow Test	
Wheel Path	0.79	0.73	0.98	199
Between WP	2.14	1.95	2.19	121
Difference	1.35	1.22	1.21	78

FM 908 (Location 2) – Burleson County

Northbound View



Southbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 908
County:	Burleson
Test Location:	2
Lane:	Northbound
TRM:	598+1.0
Latitude:	30° 31.294 N
Longitude:	96° 49.405 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	2.15	1.99	2.58	121
Between WP	3.22	2.88	4.53	99
Difference	1.07	0.89	1.95	22

FM 908 (Location 3) – Burleson County

Northbound View

Transverse View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 908
County:	Burleson
Test Location:	3
Lane:	Northbound
TRM:	602+1.8
Latitude:	NA
Longitude:	NA

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	Photographic documentation only at this location.			
Between WP				
Difference				

FM 2027 (Location 1) – Milam County

Southbound View

Northbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 2027
County:	Milam
Test Location:	1
Lane:	Southbound
TRM:	388+0.5
Latitude:	31° 02.621 N
Longitude:	96° 49.137 W

Mean Texture Depth, mm				**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	Photographic documentation only at this location.			
Between WP				
Difference				

FM 2027 (Location 2) – Milam County

Northbound View

Southbound View

Between Wheel Path Texture

Wheel Path Texture

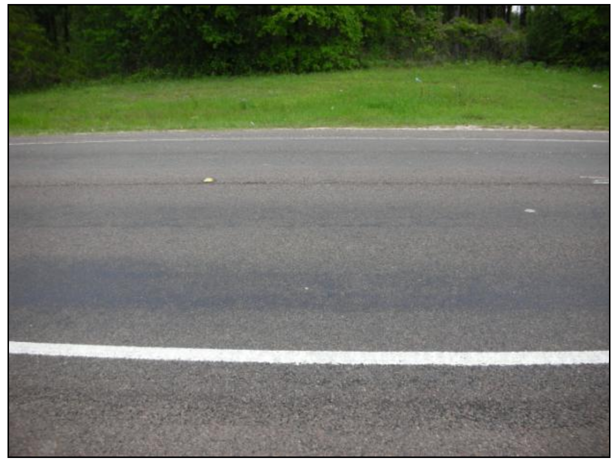
Location and Texture Data Summary

Highway:	FM 2027
County:	Milam
Test Location:	2
Lane:	Northbound
TRM:	388+1.6
Latitude:	31° 01.862 N
Longitude:	96° 48.491 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	Photographic documentation only at this location.			
Between WP				
Difference				

FM 819 (SB) – Angelina County

Southbound View



Transverse View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 819
County:	Angelina
Test Location:	SB
Lane:	Southbound
TRM:	360+0.636
Latitude:	NA
Longitude:	NA

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.19	0.90	1.09	163
Between WP	1.97	1.79	2.58	126
Difference	0.78	0.89	1.49	37

FM 819 (NB) – Angelina County

Northbound View

Transverse View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 819
County:	Angelina
Test Location:	NB
Lane:	Northbound
TRM:	360+0.636
Latitude:	NA
Longitude:	NA

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	CTMeter	Outflow Test	
Wheel Path	1.49	1.24	1.38	145
Between WP	2.51	2.10	3.23	112
Difference	1.02	0.86	1.85	33

SH 147 (Location 1) – San Augustine County


Northbound View


Southbound View


Between Wheel Path Texture


Wheel Path Texture

Location and Texture Data Summary

Highway:	SH 147
County:	San Augustine
Test Location:	1
Lane:	Northbound
TRM:	366+1.3
Latitude:	31° 16.489 N
Longitude:	94° 17.478 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.93	1.85	2.58	128
Between WP	2.91	2.83	5.83	104
Difference	0.98	0.98	3.25	24

SH 147 (Location 2) – San Augustine County


Northbound View


Southbound View


Between Wheel Path Texture


Wheel Path Texture

Location and Texture Data Summary

Highway:	SH 147
County:	San Augustine
Test Location:	2
Lane:	Left turn lane
TRM:	364+0.9
Latitude:	31° 18.258 N
Longitude:	95° 16.266 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.34	1.37	1.61	153
Between WP	1.39	1.44	1.67	151
Difference	0.05	0.07	0.06	2

SH 147 (Location 3) – San Augustine County


Southbound View


Northbound View


Between Wheel Path Texture


Wheel Path Texture

Location and Texture Data Summary

Highway:	SH 147
County:	San Augustine
Test Location:	3
Lane:	Southbound
TRM:	364+0.1
Latitude:	31° 18.878 N
Longitude:	94° 15.786 W

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	0.62	0.50	0.87	226
Between WP	2.40	1.98	3.23	114
Difference	1.78	1.48	2.36	112

SH 147 (Location 4) – San Augustine County

Southbound View

Northbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	SH 147
County:	San Augustine
Test Location:	4
Lane:	Left turn lane
TRM:	364+0.1
Latitude:	31° 18.878 N
Longitude:	94° 15.786 W

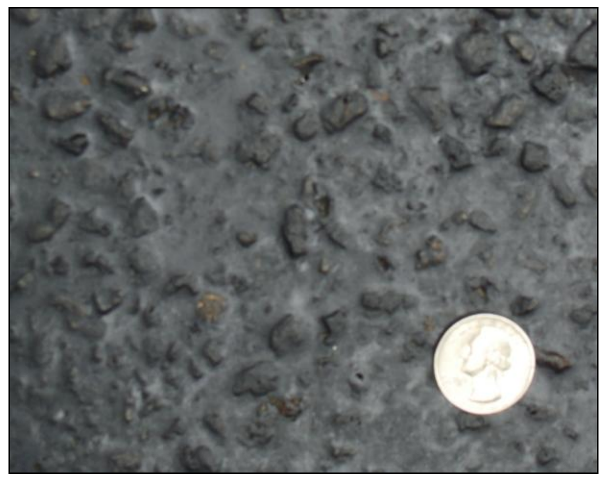
	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.45	1.36	1.75	148
Between WP	1.79	1.63	3.23	132
Difference	0.34	0.27	1.48	16

SH 103 (Location 1) – San Augustine County


Westbound View


Eastbound View


Between Wheel Path Texture


Wheel Path Texture

Location and Texture Data Summary

Highway:	SH 103
County:	Sabine
Test Location:	1
Lane:	Westbound
TRM:	762+0.002
Latitude:	31° 24.694 N
Longitude:	94° 00.608 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	0.79	0.72	1.29	199
Between WP	2.53	2.36	3.75	111
Difference	1.74	1.64	2.46	88

SH 103 (Location 2) – San Augustine County

Westbound View

Eastbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	SH 103
County:	Sabine
Test Location:	2
Lane:	Westbound
TRM:	764-1.4
Latitude:	31° 24.750 N
Longitude:	93° 59.937 W

	Mean Texture Depth, mm			Average Diameter of Sand Patch Circle, mm
	Sand Patch	CTMeter	Outflow Test	
Wheel Path	1.34	1.29	1.83	153
Between WP	2.82	2.73	3.75	106
Difference	1.48	1.44	1.92	47

SH 103 (Location 3) – San Augustine County

Westbound View

Eastbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	SH 103
County:	San Augustine
Test Location:	3
Lane:	Westbound
TRM:	756+0.9
Latitude:	31° 24.210 N
Longitude:	94° 04.638 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	1.34	1.39	2.19	154
Between WP	2.80	2.68	3.75	106
Difference	1.46	1.29	1.56	48

FM 2457 (Location 1) – Polk County

Westbound View

Eastbound View

Between Wheel Path Texture

Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 2457
County:	Polk
Test Location:	1
Lane:	Westbound
TRM:	698-0.4
Latitude:	30° 44.369 N
Longitude:	95° 01.839 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	0.79	0.65	0.93	200
Between WP	2.29	2.09	2.19	117
Difference	1.50	1.44	1.26	83

FM 2457 (Location 2) – Polk County


Eastbound View


Westbound View


Between Wheel Path Texture


Wheel Path Texture

Location and Texture Data Summary

Highway:	FM 2457
County:	Polk
Test Location:	2
Lane:	Eastbound
TRM:	698-1.70
Latitude:	30° 44.240 N
Longitude:	95° 03.165 W

	Mean Texture Depth, mm			**Average Diameter of Sand Patch Circle, mm**
	Sand Patch	**CTMeter**	**Outflow Test**	
Wheel Path	0.41	0.40	0.75	275
Between WP	1.42	1.46	1.67	152
Difference	1.01	1.06	0.92	123