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16. Abstract Limestone Rock Asphalt (LRA) mixtures have been produced and placed for several decades using specification requirements currently listed under DMS 9210. Several Districts have had placement issues and premature failures at the beginning of 2010. These issues and failures have been attributed to material properties. Requirements for DMS 9210 have not changed for several years and need to be evaluated to possibly produce a higher quality material to reduce the occurrence of premature failures and to minimize placement issues. The objectives of the study are to (1) Evaluate specification requirements of Item 330 and DMS 9210, (2) Conduct field evaluations and lab testing to determine workability and acceptability as stockpile material for use as needed in pavement maintenance, and (3) Consider improvements to the specification requirements to ensure an acceptable and workable stockpile material for up to 6 months.  Twenty eight test patches were constructed around the state but none of the performance problems seen in 2010 were observed in the test sections. A review of production data indicates that one of the suppliers made some significant changes to the flux oil content during the time when the 2010 performance problems were noted. Tests have been identified in this Year One study which may be better indicators of LRA field performance. These tests are being fully explored in Year Two to determine their sensitivity to flux oil content and type.					
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**IMPROVING DMS 9210 REQUIREMENTS FOR LIMESTONE ROCK  
ASPHALT – YEAR ONE INTERIM REPORT**

by

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## **DISCLAIMER**

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The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objectives of this report.

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  - Ms. Darlene Goehl, Bryan District and Mr. Carl Schroeder, Navasota Maintenance.
  - Mr. Darwin Lankford, Childress District.
  - Mr. Lance Simmons and Mr. Doug Reiter, Atlanta District.

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# CHAPTER 1

## INTRODUCTION

### BACKGROUND

Limestone rock asphalt (LRA) is a relatively porous stone permeated with a very hard natural asphalt. The material is found in very large deposits in the southwest corner of Uvalde County and extending into Kinney County. LRA is quarried with the aid of explosives, which create tremendous piles of rubble, including very large boulders. The boulders are passed through a series of primary and secondary crushers, and screened to standard grading requirements.

For Type I LRA mixtures, the limestone rock asphalt aggregate is blended with varying amounts of flux oil, water, and additives to produce a series of cold-mix, cold-laid paving materials. Type II LRA mixtures consist of a blend of native LRA aggregate, virgin aggregates, fluxing material, additives, and water. Since the aggregate contains natural bitumen, the amount of additional asphaltic binder required to produce a quality paving mixture is significantly reduced.

Flux oils are used to soften the hard native asphalt contained in the pores of the limestone. These softened native asphalts together with the asphalt cement contained in the flux oils act as the binder and impart the engineering properties required for the limestone rock asphalts to perform as roadway surfacing and base materials.

Limestone Rock Asphalt (LRA) mixtures have been produced and placed for several decades using specification requirements currently listed under DMS 9210, and Standard Specification Item 330. Several districts had placement issues and premature failures at the beginning of 2010. Causes of these failures are unknown but could be attributed to material properties.

Some of the complaints from districts are listed as follows:

- District A – Material is sometimes too “dry.” When complaints are voiced to the supplier, the response is “it meets specs, you just need to add some asphalt to it.”
- District B – Shipment of material in 2010 was “unworkable.” It contained large chunks that did not break up in the placement process. In prior years, they had problems with the material not “curing”. When used for base repairs, the material never “set up” and remained unstable. But generally, the material is too dry.
- District C – Shipment of material in 2010 was “unworkable” in the stockpile. Specifications allow for the rejection of “unworkable” material in the first 6 months but once the material has been received and paid for, it’s difficult to “undo.”
- District D – Similar report to District C above.

Poor stockpile workability did not mean that the mix set up in one big immovable mass but that it had smaller chunks of material (particularly chunks of fines) within the stockpile that did not break up when working and blading the material.

## CURRENT MATERIAL REQUIREMENTS

Some of pertinent material specification requirements for Item 330 are summarized from DMS 9210 in [Tables 1.1, 1.2, and 1.3](#). These specification properties and their ranges should be investigated in the research as described in the work plan. Production testing is performed by the material supplier and TxDOT according to [Table 1.4](#).

**Table 1.1. Item 330 Fluxing Material Properties.**  
Fluxing Material Properties

Property	Material	Flux Oil		Aromatic Oil	
	Test Procedure	Min	Max	Min	Max
Kinematic viscosity, 140°F, cSt	T 201	60	200	–	150
Loss on heating, % by wt.	T 47	–	10	–	12
Water, %	T 55	–	0.2	–	0.2
Flash point, C.O.C., °F	T 48	200	–	135	–

**Table 1.2. Item 330 Mixture Components Percent by Weight.**  
Mixture Components % by Weight

Mixture Component							Type I		Type II	
							Grade		Grade	
	AA Coarse Base	A Medium Base	B Fine Base	C Coarse Surface	CC Medium Surface	D Fine Surface	BS Surface	CS Medium Surface	DS Fine Surface	FS Thin Surface
White rock <sup>1</sup>	N/A	15–35	15–35	15–35	15–35	15–35	15–35	15–35	15–35	N/A
LRA	96–98	96–98	96–98	96–98	96–98	96–98	72–80.5	72–80.5	72–80.5	36.5–63.5
Virgin aggregate	N/A	N/A	N/A	N/A	N/A	N/A	18–25	18–25	18–25	35–60
Flux material	2.0–4.0	2.0–4.0	2.0–4.0	2.0–4.0	2.0–4.0	2.0–4.0	1.5–3.0	1.5–3.0	1.5–3.0	1.5–3.5

1. White rock values are given as a percentage of total LRA aggregate.

**Table 1.3. Item 330 Mixture Properties.**  
Mixture Properties

Property	Test Method	Requirement
Hveem stability, min	Tex-208-F	35 <sup>1</sup>
Laboratory-molded density, %	Tex-207-F	89.0 ±2
Theoretical maximum specific gravity of bituminous mixtures	Tex-227-F	N/A
Bitumen content, % by wt.	Tex-236-F	6.5 to 11.0
Water and light hydrocarbon volatiles, %, max	Tex-212-F, Part II	6.0
Boil test, %	Tex-530-C	10 <sup>2</sup>

1. Cease operations if two consecutive tests fail. CST/M&P may waive this requirement if other information indicates that the next material to be produced will meet the minimum value specified.
2. May be increased or eliminated when directed by CST/M&P.

**Table 1.4. Production Testing Frequency for LRA Used in Mixtures (Item 330).**

**Production Testing Frequency for LRA used in Mixtures (Item 330)**

Description	Test Method	Minimum Producer Testing Frequency	Minimum CST/M&P Testing Frequency <sup>1</sup>
Cumulative % Retained (Combined Aggregate Sample <sup>2</sup> )	Tex-200-F, Part I	1 per 300 tons	1 per 3,000 tons
Laboratory-molded density	Tex-207-F	1 per week, per mix type <sup>3</sup>	1 per week, per randomly selected mix type <sup>4</sup>
Hveem Stability	Tex-208-F	1 per week, per mix type <sup>3, 5</sup>	1 per week, per randomly selected mix type <sup>4</sup>
Moisture content	Tex-212-F, Part II	1 per week, per mix type	1 per week, per selected mix type <sup>4</sup>
Deleterious material	Tex-217-F, Part I	1 per month, per aggregate (per grade)	1 per month, per aggregate (per grade)
Decantation	Tex-406-A	1 per month, per aggregate <sup>6</sup> (per grade)	1 per month, per aggregate <sup>6</sup> (per grade)
White rock count	Tex-220-F	1 per day, per mix type	1 per week, per mix type
Flakiness index	Tex-224-F	1 per month, per aggregate (per grade)	1 per month, per aggregate (per grade)
Theoretical maximum specific (Rice) gravity	Tex-227-F	1 per week, per mix type <sup>3</sup>	1 per week, per randomly selected mix type <sup>4</sup>
Naturally impregnated bitumen content, % by wt. for LRA material passing the #10 sieve	Tex-236-F	1 per day	1 per week
Naturally impregnated bitumen content, % by wt. for LRA combined aggregate	Tex-236-F	1 per 600 tons	1 per 5,000 tons
Micro-Deval abrasion	Tex-461-A	1 per week, per mix type <sup>3</sup>	1 per month
Unit weight	Tex-404-A	1 per 20,000	1 per 20,000
Kinematic viscosity, 1400F, cSt	T 201	1 per month	1 per month
Heat Loss Test	T 47	1 per month	1 per month

1. CST/M&P may reduce or waive the sampling and testing requirements based on a satisfactory test history.
2. Combined aggregate sample may contain LRA, white rock, and/or virgin aggregate depending on the mixture type.
3. Minimum production of 100 tons required prior to performing test.
4. Mix type randomly selected by CST/M&P at the plant.
5. Deliver molds used to determine laboratory-molded density to CST/M&P for Hveem Stability testing.
6. Decantation is performed on virgin aggregate only that is added to LRA mixtures.

## **OBJECTIVES**

TxDOT initiated a study with Texas A&M Transportation Institute (TTI) in 2011 with the following objectives:

- Evaluate specification requirements of Item 330 and DMS 9210.
- Conduct field evaluations and lab testing to determine workability and acceptability as stockpile material for use as needed in pavement maintenance.
- Consider improvements to the specification requirements to ensure an acceptable and workable stockpile material for up to 6 months.

To accomplish these objectives, a 2-year work plan was initiated. This report covers the first year of the study and summarizes the results of the first four tasks as described below.

### **Task 1. Meetings with TxDOT and Material Suppliers**

The objective of the meetings in this task is to understand the scope of the problem, gain insight from experienced TxDOT personnel on pertinent issues, and review current production methods.

### **Task 2. Review Production Test Reports from Both Suppliers**

The objective of this task was to evaluate the reports from production testing of the different types of Item 330 from both suppliers to determine how the material properties vary. There is a wide range in the specification limits for some of the test parameters. Data will be reviewed to determine if some of the materials are only barely meeting the minimum requirements or are varying significantly within the specification range.

### **Task 3. Evaluate Field Performance of LRA**

The objective of this task is to evaluate the stockpile and in-service performance of LRA mixtures originating from both suppliers. Four districts were identified, and the project director worked with the districts and the General Services Division such that material from each supplier (Martin Marietta and Vulcan) were purchased and shipped to each of the four districts. Two types of LRA–D and DS–were selected and placed in each district at two different times within the stockpile life.

### **Task 4. Evaluation of Performance Tests as Potential Specification Requirement**

The objective of this task was to perform laboratory tests on all of the mixtures sampled from the four districts in Task 3. Aside from standard tests, some performance tests were also included for their potential at correlating better to some of the workability issues and performance issues that the districts noted.



## CHAPTER 2 EVALUATION OF LRA PRODUCTION DATA

Early in the study, TTI researchers met with TxDOT Construction Division personnel and material supplier personnel at the Uvalde field offices. TxDOT provided TTI with the production test reports covering about a 3-year time span which would bracket the field problems experienced in 2010. Figure 2.1 shows these test reports are handwritten on 3-inch × 5-inch index cards.

TxDOT Form 5.34 9-FIR (Rev. 6/2005)		Car Number	Order No.	Type	Plant	Date	Sample
1	MP 641202		632313	AA	410	4/25/10	5
2	MP 641090						
		Sieve Analysis		Lab Report No.			
3	600K 320067		0-0		2153		
DW	CW	R-1 1/2"	70.1 - 7.0	Bin Analysis			
Tars		R-7/8"	261.6 - 26.2	Bin No.	Size	% by Wt.	
Wt./Sample		R-3/4"	- -	1	P-No. 10		
		R-5/8"	- -	2	3/8"-No. 10		
		R-1/2"	- -	3	1/2"-1/4"		
		R-3/8"	345.6 - 34.6	Flux, Gals.	22.9		
Total Loss		R-1/4"	- -	Nuso Gals.	5.0		
Bitumen, %	60	R-No. 4	518.3 - 51.8	Polymer			
Flux%	2.2	R-No. 8	- -	Diesel-Gals.			
Water %	1.3	R-No. 10	620.5 - 62.1	HFO Gals.	16.0		
-No. 10 Bit %	5.9	R-No. 20		Weight	10000		
White Rock %		P-No. 10		Checked By	SM 4/25		
Bit W.R. %							
Ave. Stab %	40						

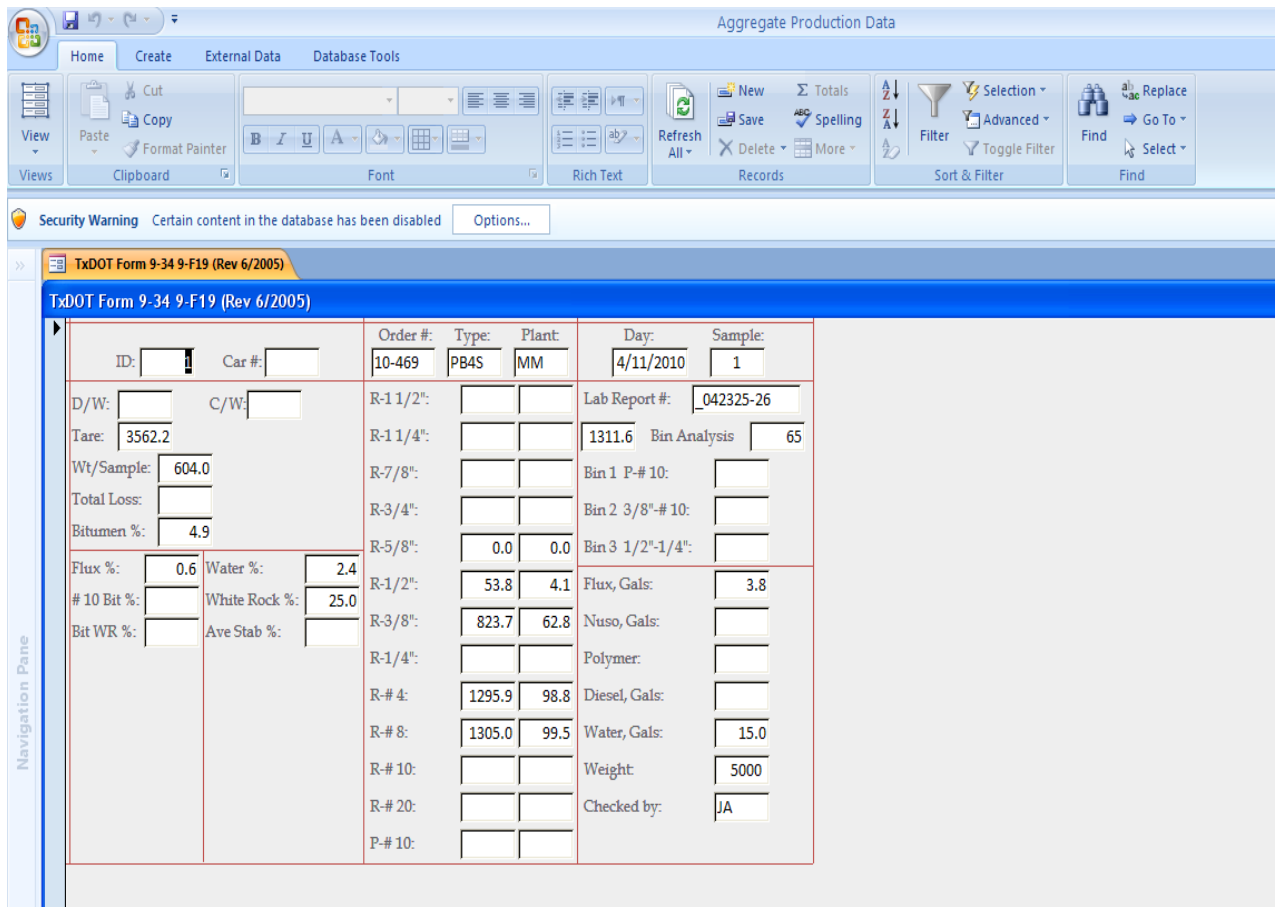
**Figure 2.1. Typical Production Test Report Card for Uvalde Field Labs.**

To process the 4001 cards, TTI researchers wrote a program in Microsoft Access® to enter the data from each card exactly as shown on the data cards (see Figure 2.2).

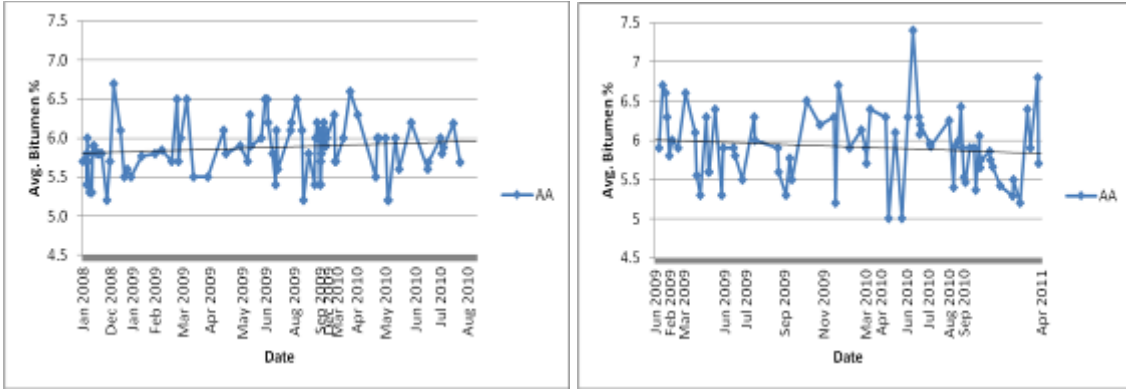
Charts showing side-by-side comparisons of each of the two suppliers were generated for each parameter and are summarized as follows:

- Average Bitumen Content, Figures 2.3 through 2.8.
- Average Hveem Stability, Figures 2.9 through 2.11.
- Average Flux Oil Content, Figures 2.12 through 2.17.
- Average Bitumen Content in Aggregate Passing No. 10 Sieve, Figures 2.18 through 2.23.
- Average Percent Water Added, Figures 2.24 through 2.29.
- Average White Rock Content, Figures 2.30 through 2.34.
- Average Bitumen Content of White Rock, Figures 2.35 through 2.39.
- Average Percent Retained on the Various Sieve Sizes, Figures 2.40 through 2.50.

The significant findings from these data are shown in Figures 2.12 through 2.17. These charts indicate that some major changes occurred with the amount of flux oil being used by Supplier B during a time when field performance problems were noted with this supplier.

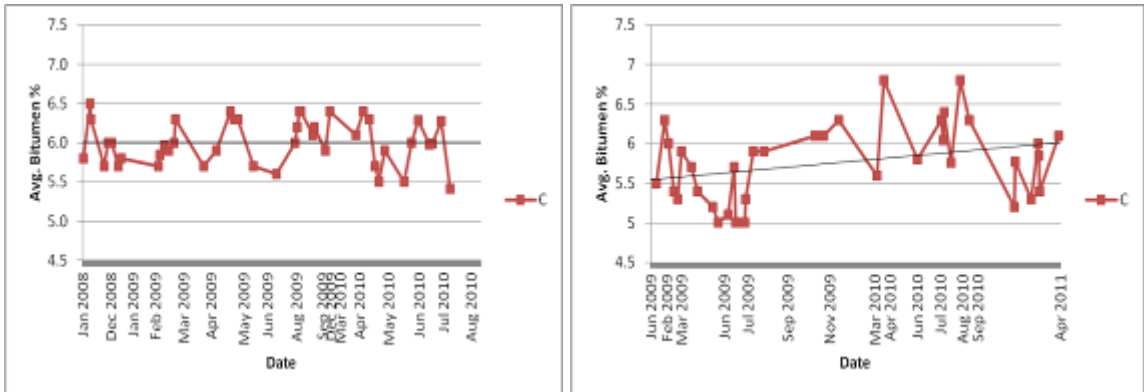


**Figure 2.2. Screen Display of Microsoft Access Program Developed to Process LRA Card Data.**



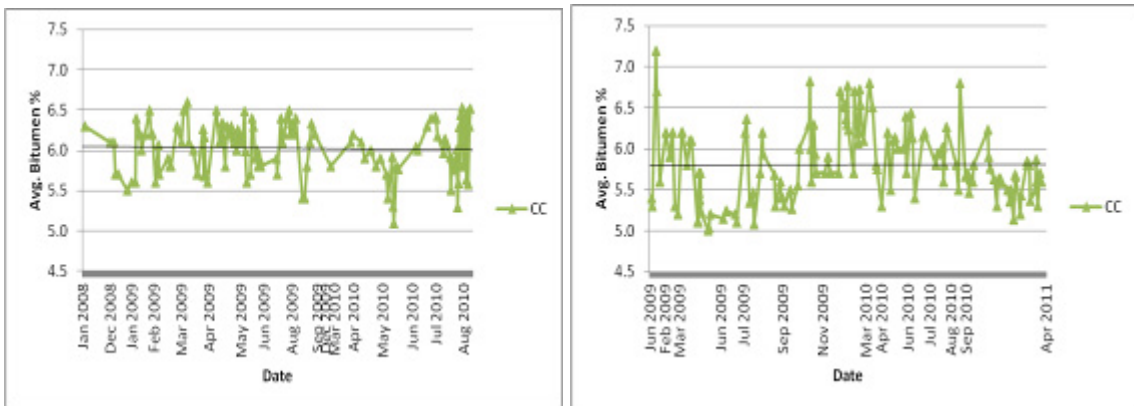
a) Supplier A      b) Supplier B

**Figure 2.3. Item 330, Type AA Mixture Production Data, Average Bitumen Content, % by Wt.**



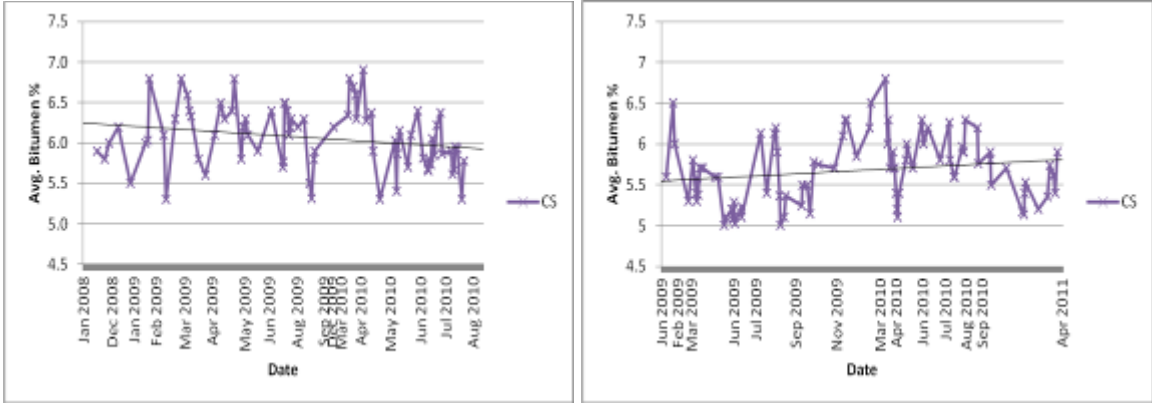
a) Supplier A      b) Supplier B

**Figure 2.4. Item 330, Type C Mixture Production Data, Average Bitumen Content, % by Wt.**



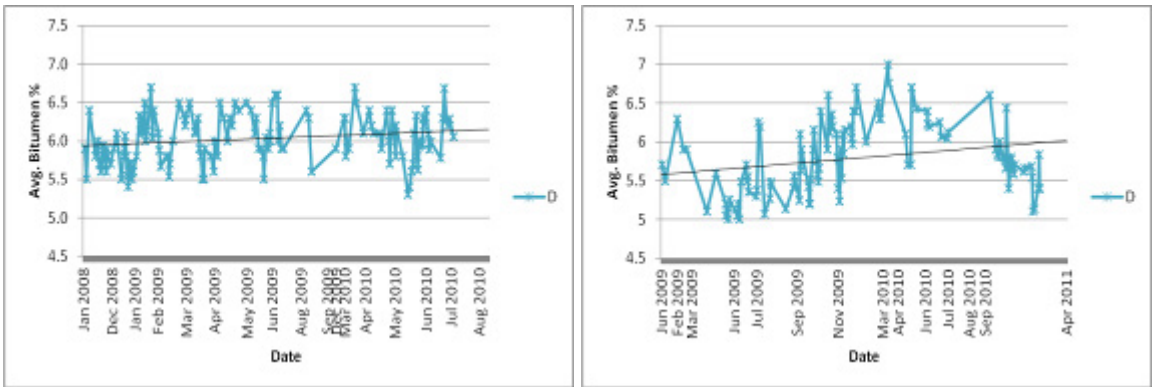
a) Supplier A      b) Supplier B

**Figure 2.5. Item 330, Type CC Mixture Production Data, Average Bitumen Content, % by Wt.**



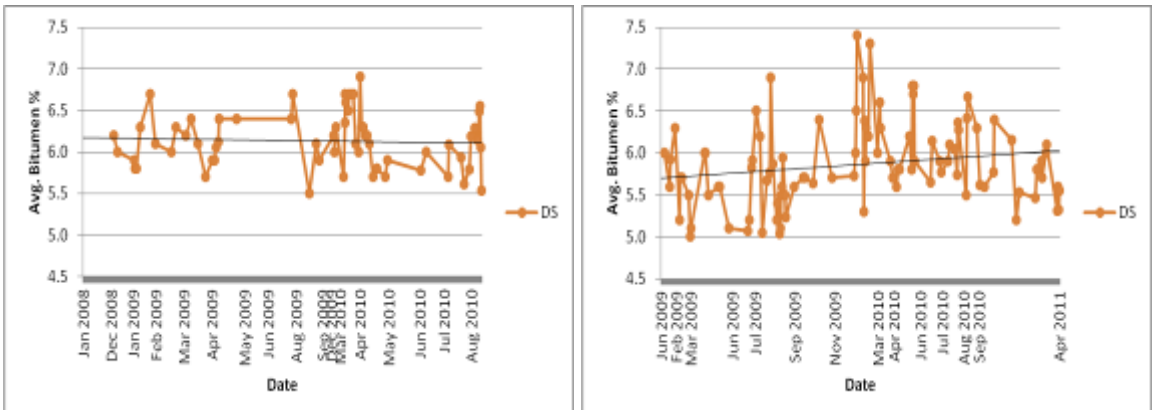
a) Supplier A      b) Supplier B

**Figure 2.6. Item 330, Type CS Mixture Production Data, Average Bitumen Content, % by Wt.**



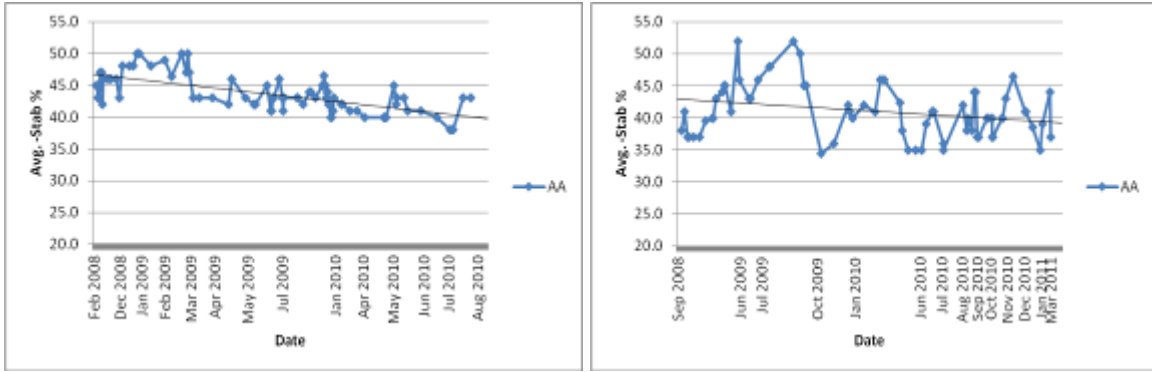
a) Supplier A      b) Supplier B

**Figure 2.7. Item 330, Type D Mixture Production Data, Average Bitumen Content, % by Wt.**



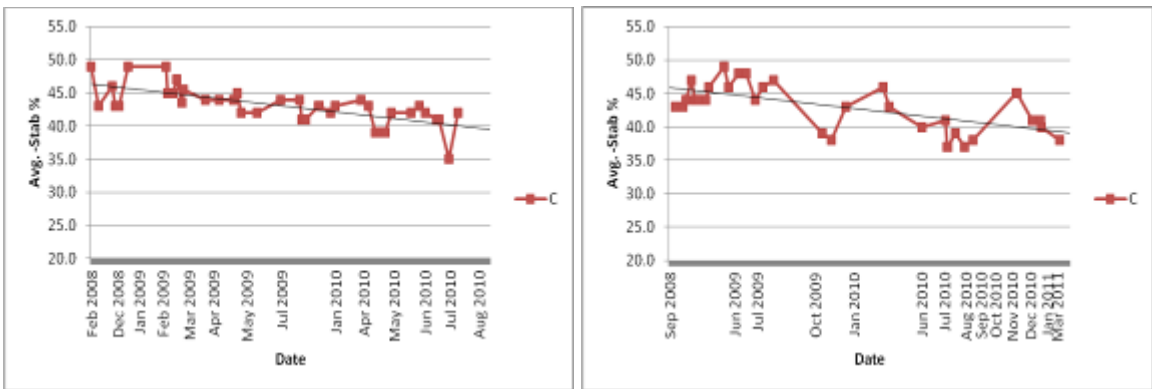
a) Supplier A      b) Supplier B

**Figure 2.8. Item 330, Type DS Mixture Production Data, Average Bitumen Content, % by Wt.**



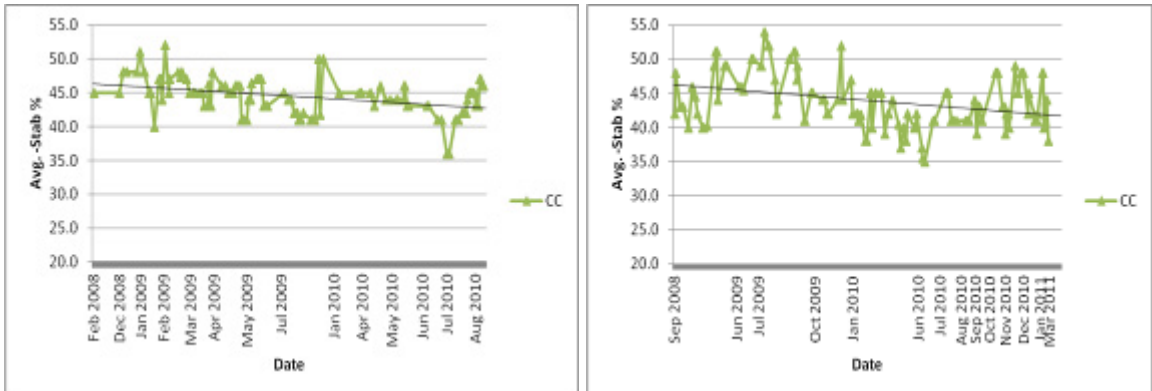
a) Supplier A      b) Supplier B

**Figure 2.9. Item 330, Type AA Mixture Production Data, Average Hveem Stability.**



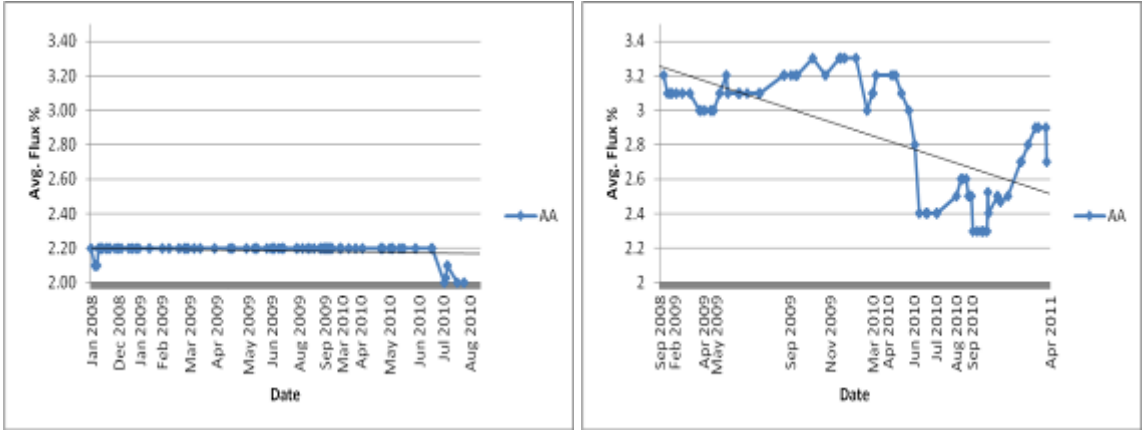
a) Supplier A      b) Supplier B

**Figure 2.10. Item 330, Type C Mixture Production Data, Average Hveem Stability.**



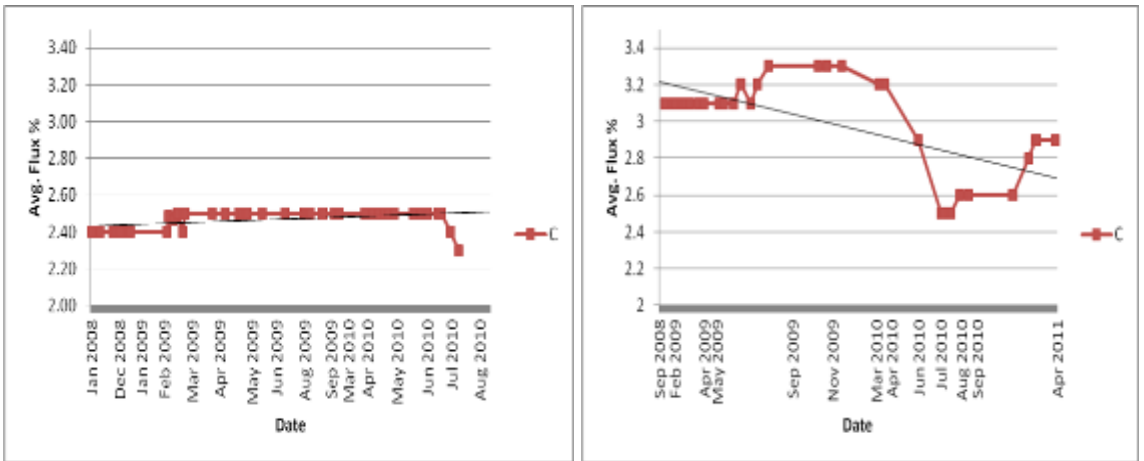
a) Supplier A      b) Supplier B

**Figure 2.11. Item 330, Type CC Mixture Production Data, Average Hveem Stability.**



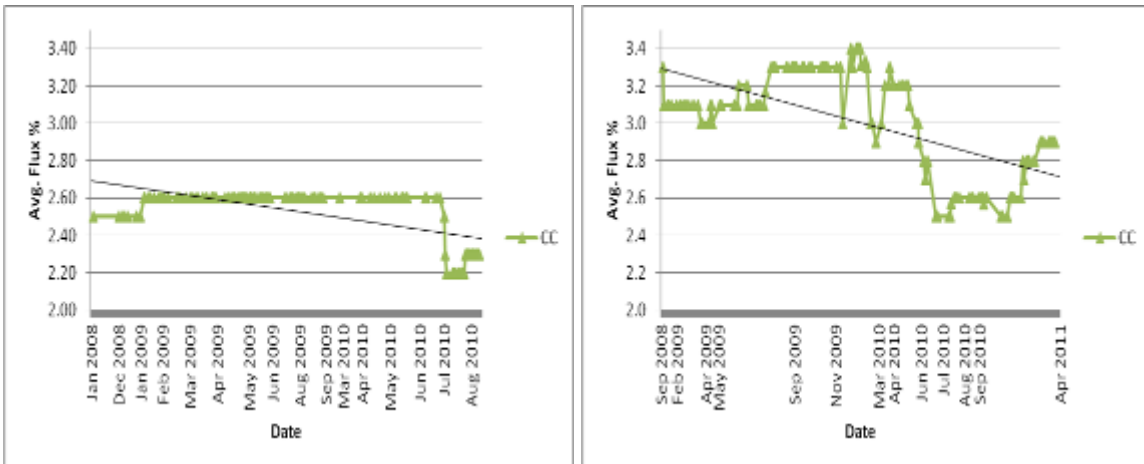
a) Supplier A      b) Supplier B

Figure 2.12. Item 330, Type AA Mixture Production Data, Average Flux Oil Content, % by Wt.



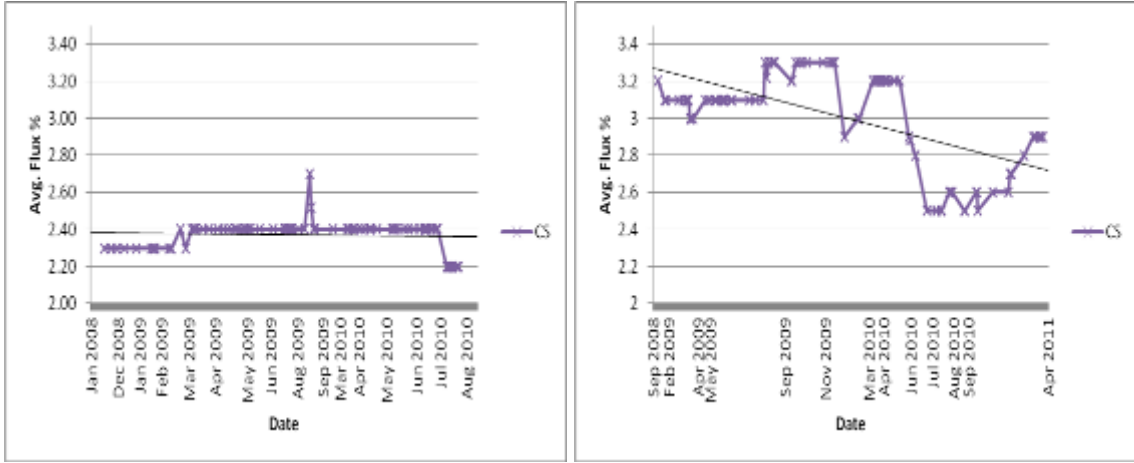
a) Supplier A      b) Supplier B

Figure 2.13. Item 330, Type C Mixture Production Data, Average Flux Oil Content, % by Wt.



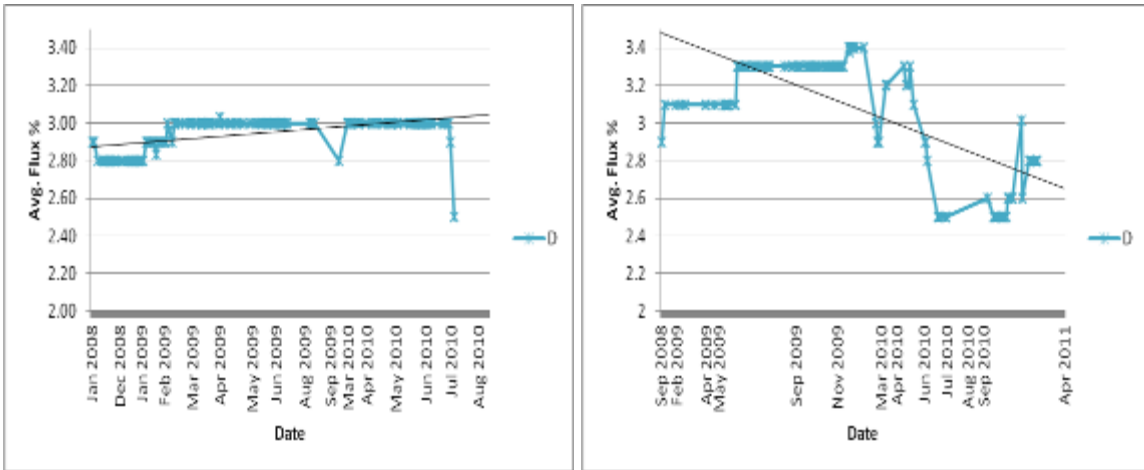
a) Supplier A      b) Supplier B

Figure 2.14. Item 330, Type CC Mixture Production Data, Average Flux Oil Content, % by Wt.



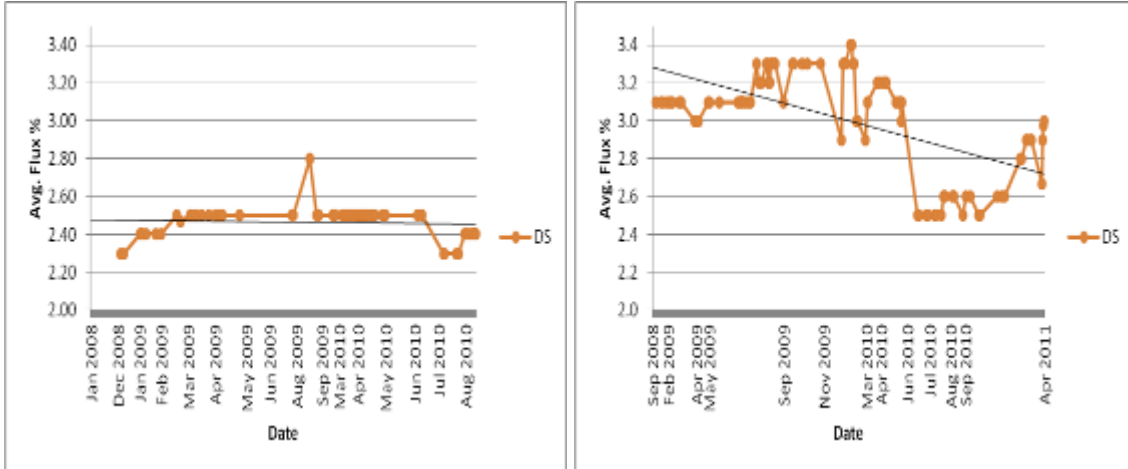
a) Supplier A      b) Supplier B

Figure 2.15. Item 330, Type CS Mixture Production Data, Average Flux Oil Content, % by Wt.



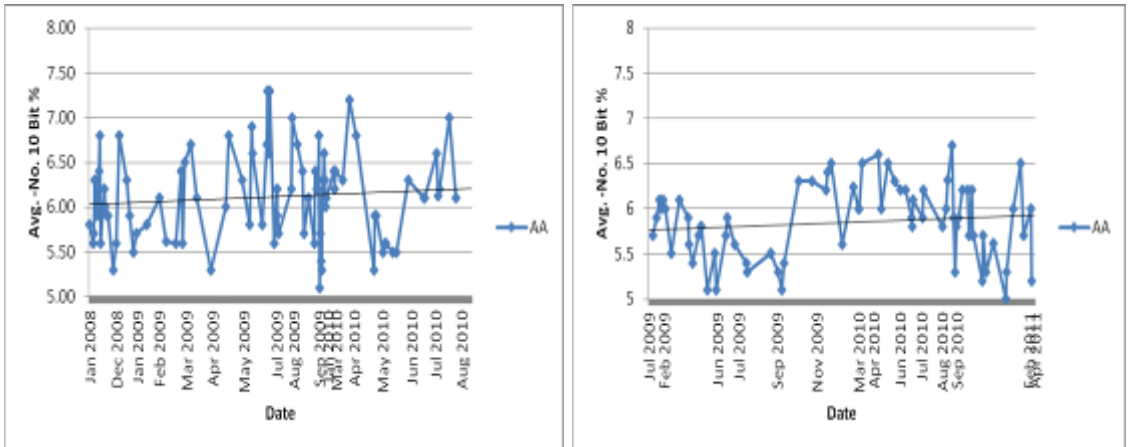
a) Supplier A      b) Supplier B

Figure 2.16. Item 330, Type D Mixture Production Data, Average Flux Oil Content, % by Wt.



a) Supplier A      b) Supplier B

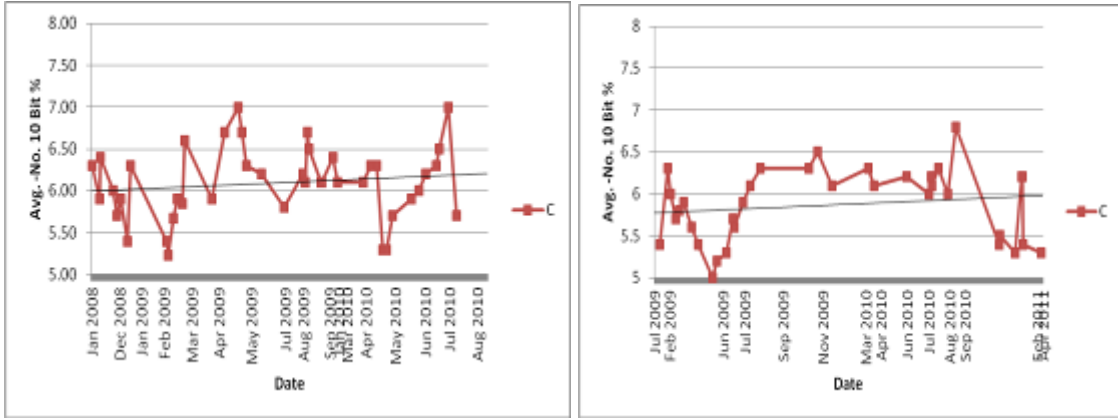
Figure 2.17. Item 330, Type DS Mixture Production Data, Average Flux Oil Content, % by Wt.



a) Supplier A      b) Supplier B

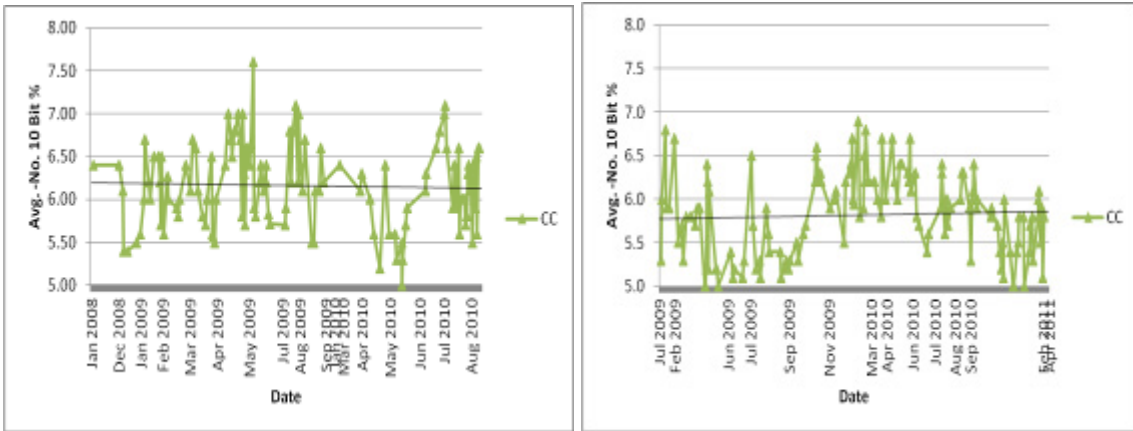
Figure 2.18. Item 330, Type AA Mixture Production Data, Average Bitumen Content in Aggregate Passing No. 10 Sieve.





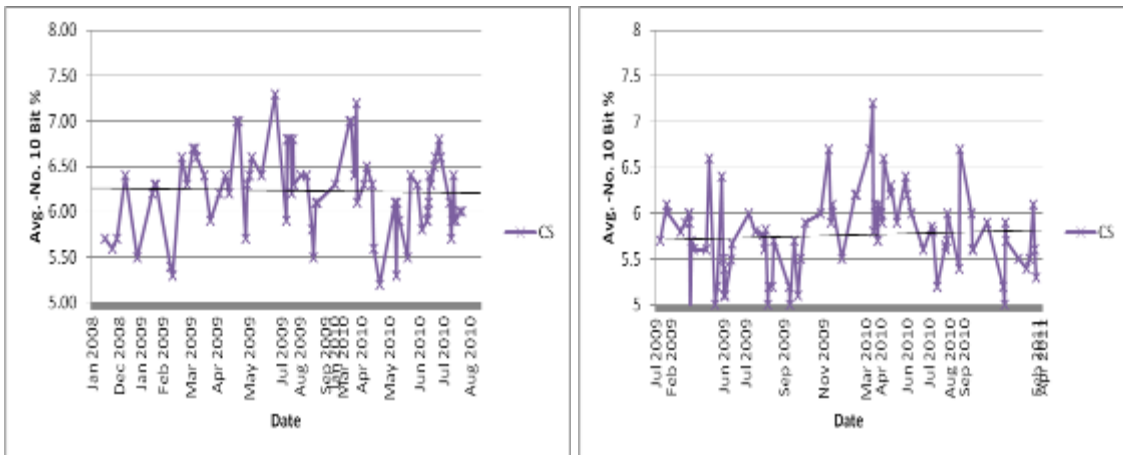
a) Supplier A      b) Supplier B

**Figure 2.19. Item 330, Type C Mixture Production Data, Average Bitumen Content in Aggregate Passing No. 10 Sieve.**



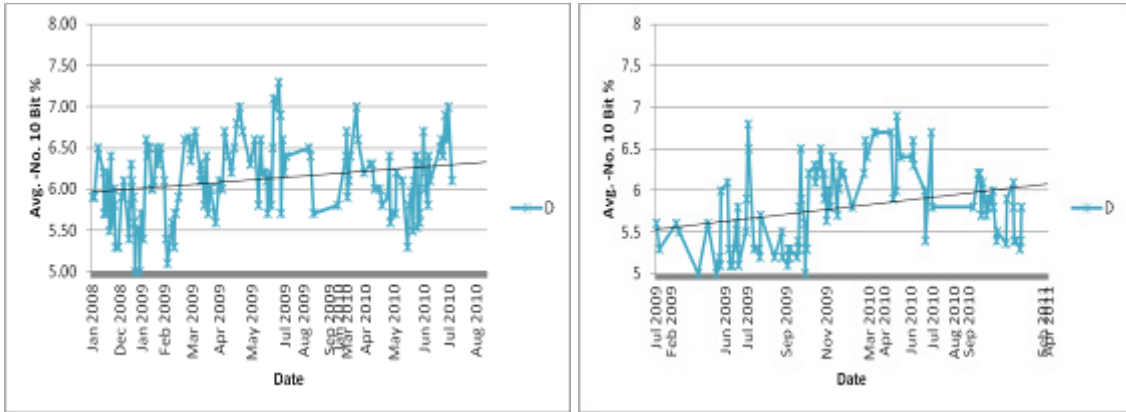
a) Supplier A      b) Supplier B

**Figure 2.20. Item 330, Type CC Mixture Production Data, Average Bitumen Content in Aggregate Passing No. 10 Sieve.**



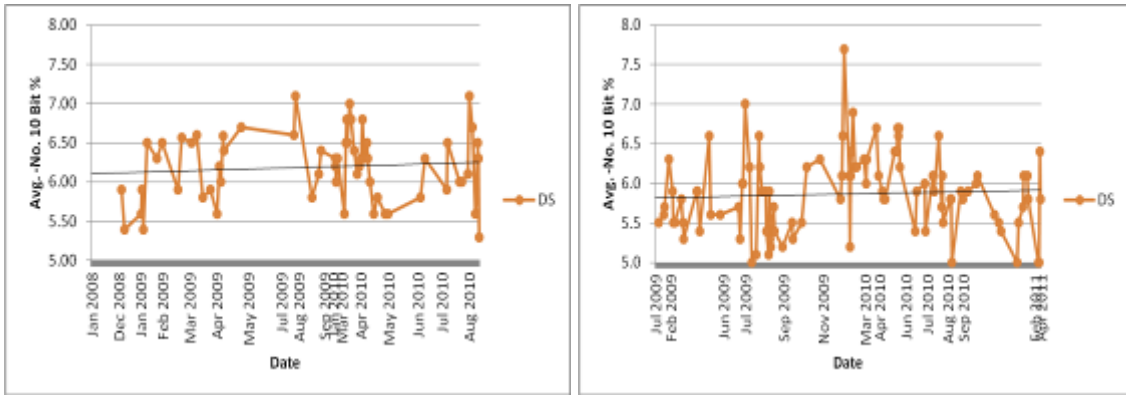
a) Supplier A      b) Supplier B

**Figure 2.21. Item 330, Type CS Mixture Production Data, Average Bitumen Content in Aggregate Passing No. 10 Sieve.**



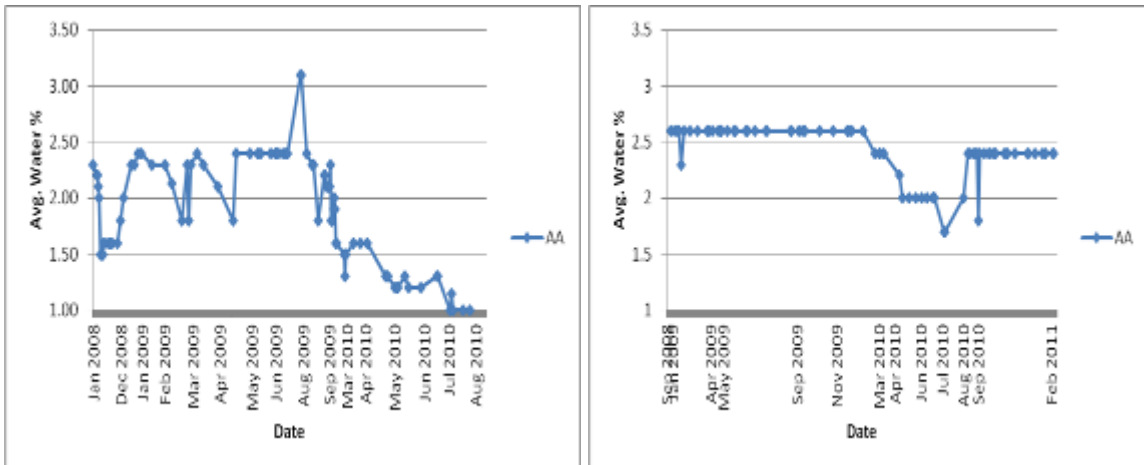
a) Supplier A      b) Supplier B

**Figure 2.22. Item 330, Type D Mixture Production Data, Average Bitumen Content in Aggregate Passing No. 10 Sieve.**



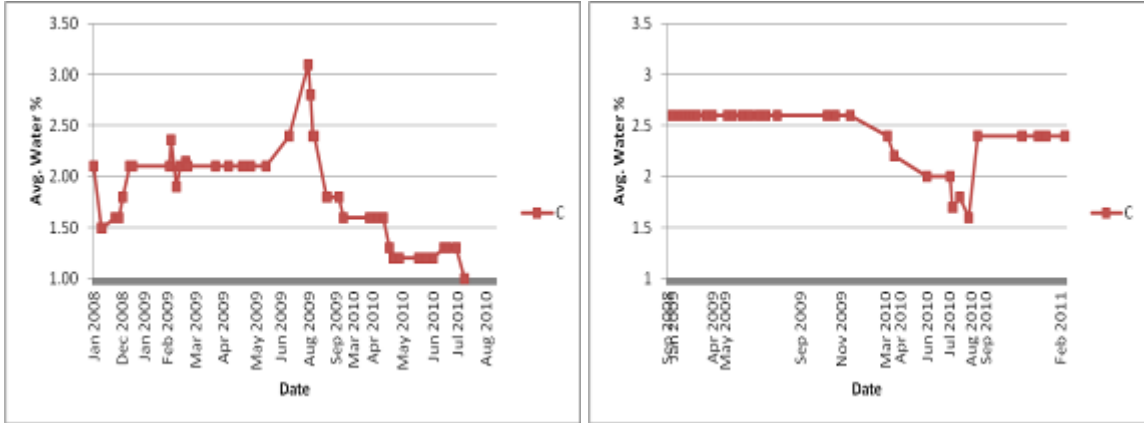
a) Supplier A      b) Supplier B

**Figure 2.23. Item 330, Type DS Mixture Production Data, Average Bitumen Content in Aggregate Passing No. 10 Sieve.**



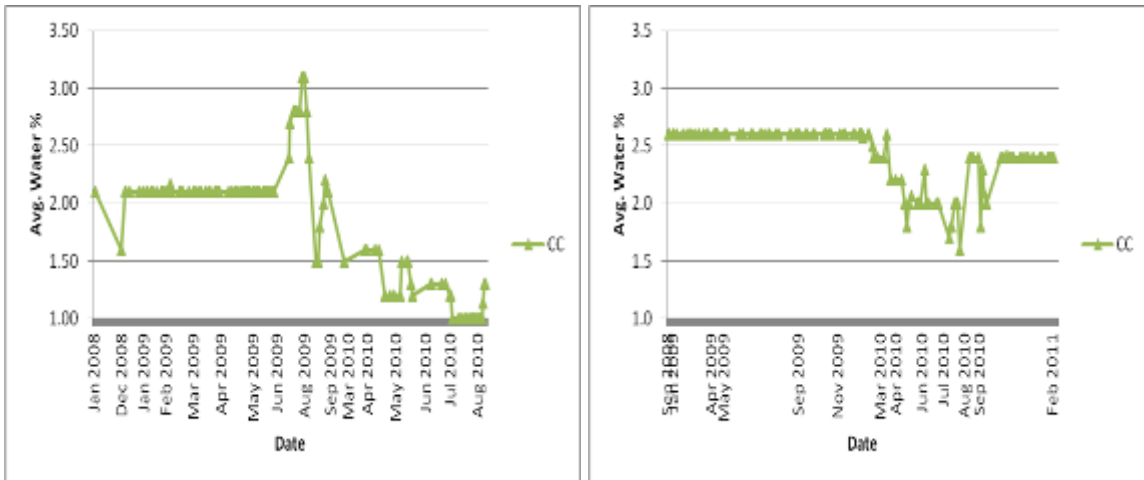
a) Supplier A      b) Supplier B

**Figure 2.24. Item 330, Type AA Mixture Production Data, Average Percent Water Added.**



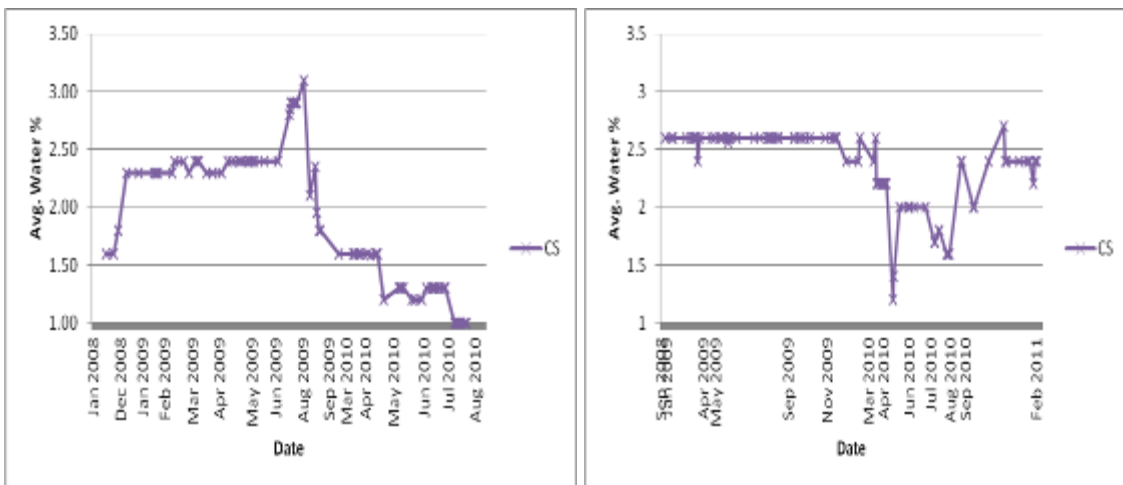
a) Supplier A      b) Supplier B

Figure 2.25. Item 330, Type C Mixture Production Data, Average Percent Water Added.



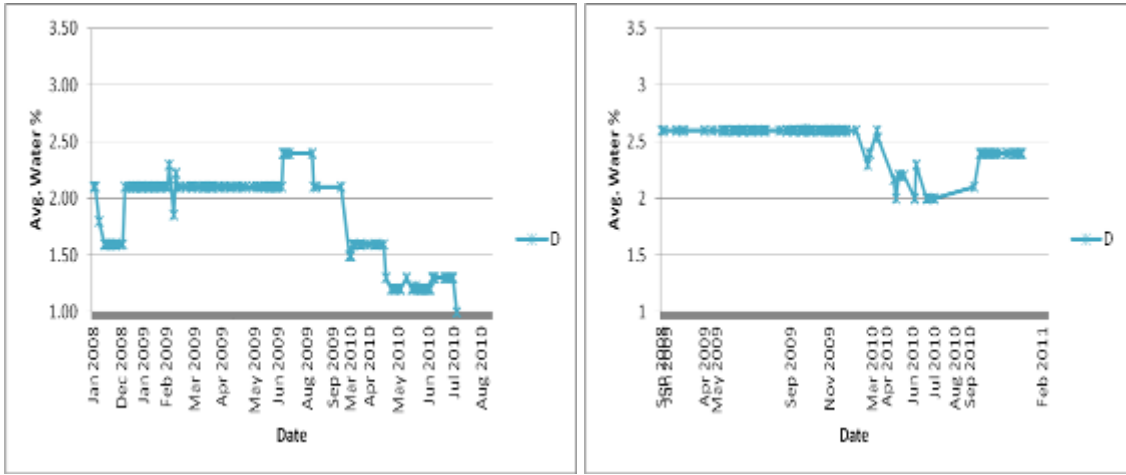
a) Supplier A      b) Supplier B

Figure 2.26. Item 330, Type CC Mixture Production Data, Average Percent Water Added.



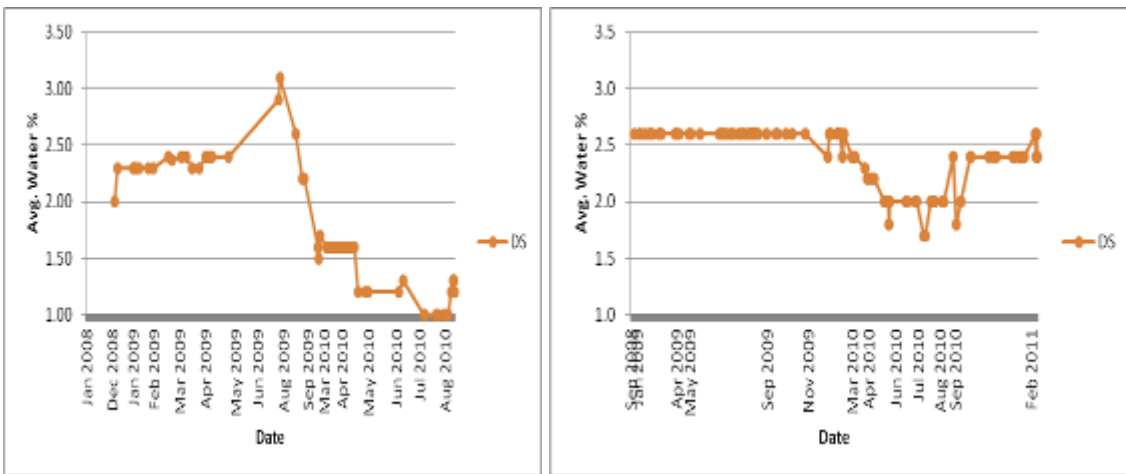
a) Supplier A      b) Supplier B

Figure 2.27. Item 330, Type CS Mixture Production Data, Average Percent Water Added.



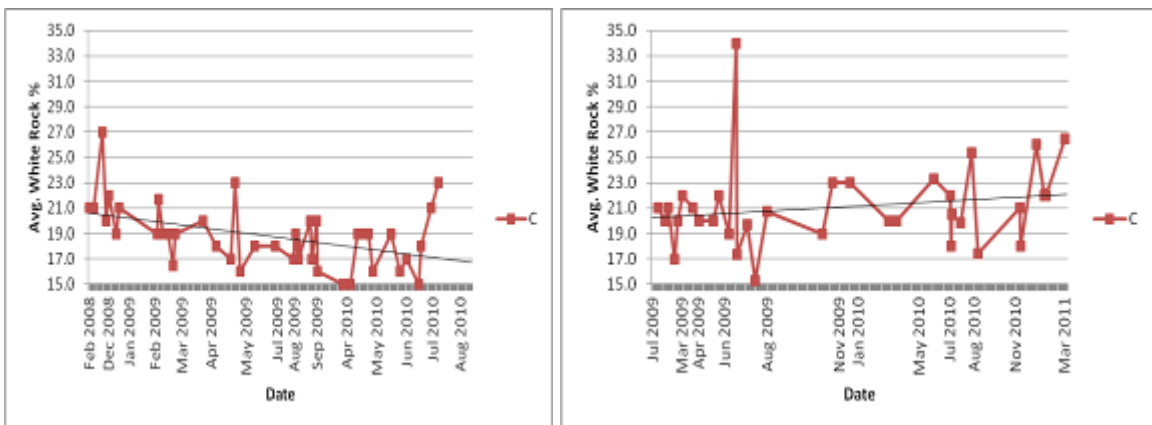
a) Supplier A      b) Supplier B

Figure 2.28. Item 330, Type DD Mixture Production Data, Average Percent Water Added.



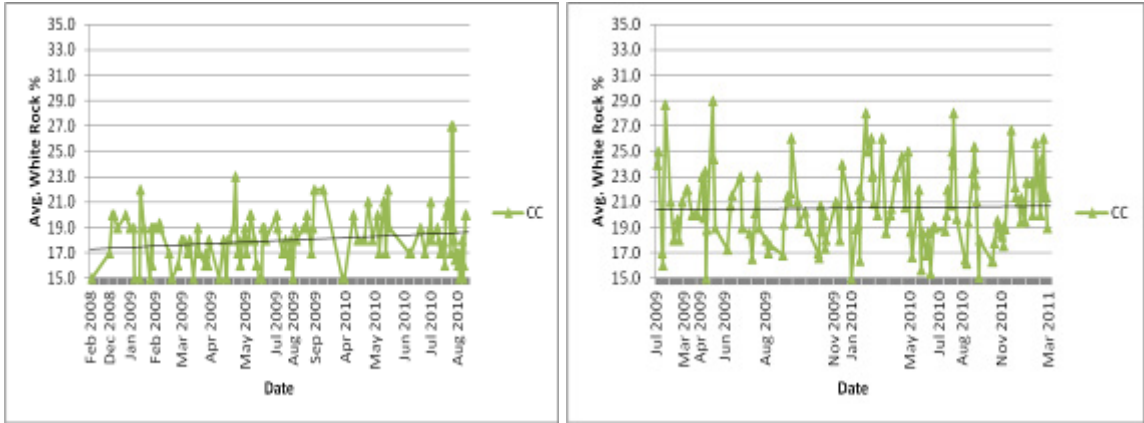
a) Supplier A      b) Supplier B

Figure 2.29. Item 330, Type DS Mixture Production Data, Average Percent Water Added.



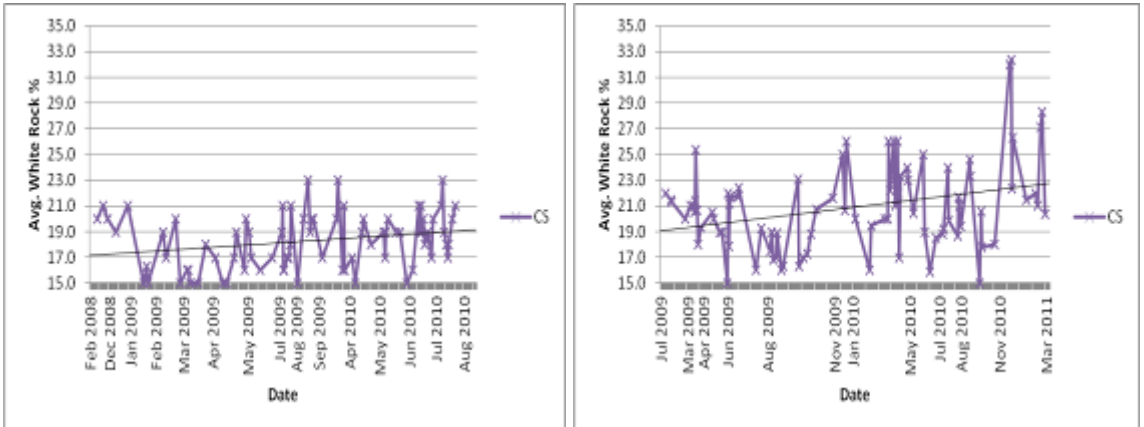
a) Supplier A      b) Supplier B

Figure 2.30. Item 330, Type C Mixture Production Data, Average White Rock Content as a Percent of LRA Aggregate.



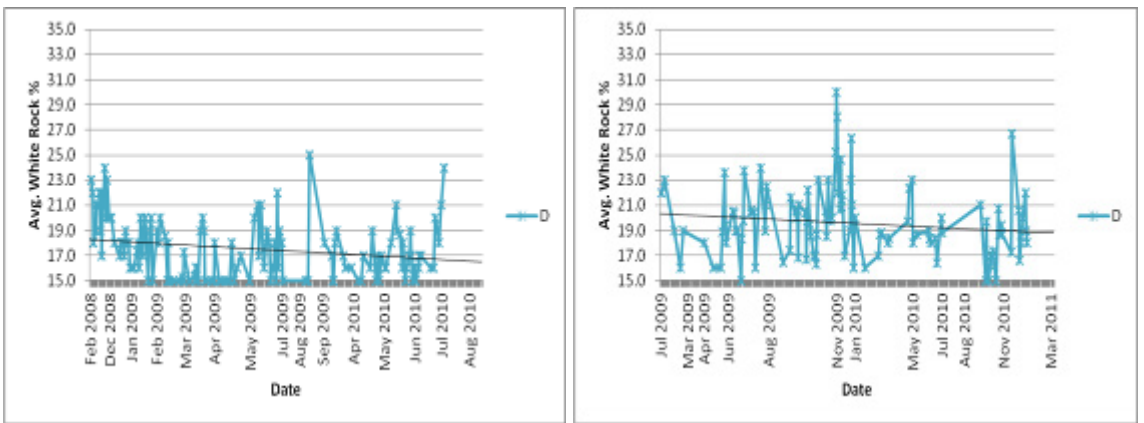
a) Supplier A      b) Supplier B

**Figure 2.31. Item 330, Type CC Mixture Production Data, Average White Rock Content as a Percent of LRA Aggregate.**



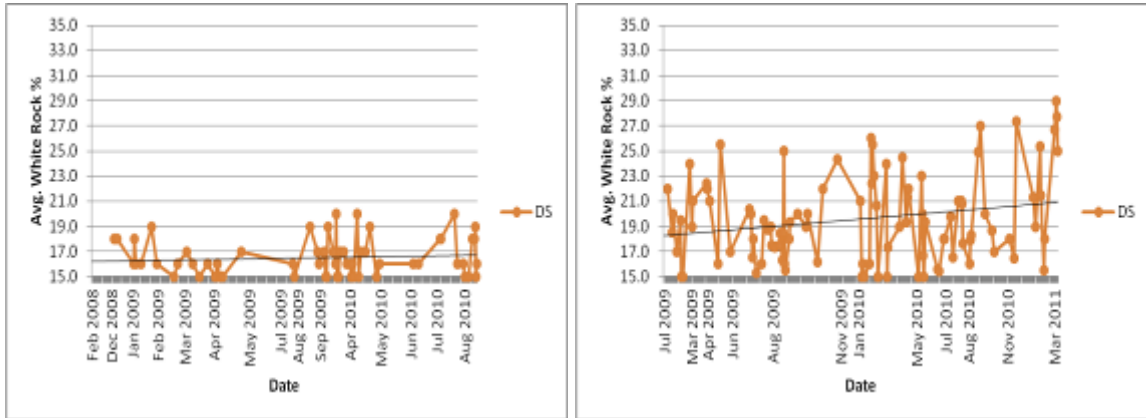
a) Supplier A      b) Supplier B

**Figure 2.32. Item 330, Type CS Mixture Production Data, Average White Rock Content as a Percent of LRA Aggregate.**



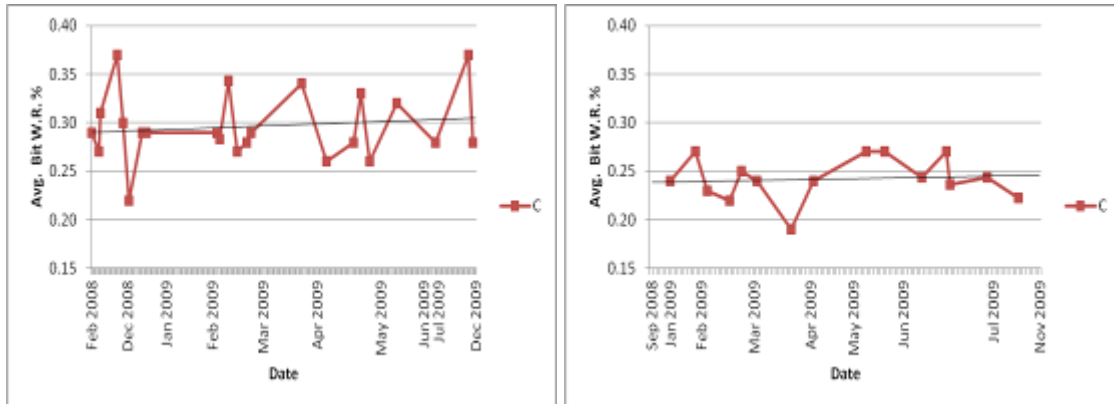
a) Supplier A      b) Supplier B

**Figure 2.33. Item 330, Type D Mixture Production Data, Average White Rock Content as a Percent of LRA Aggregate.**



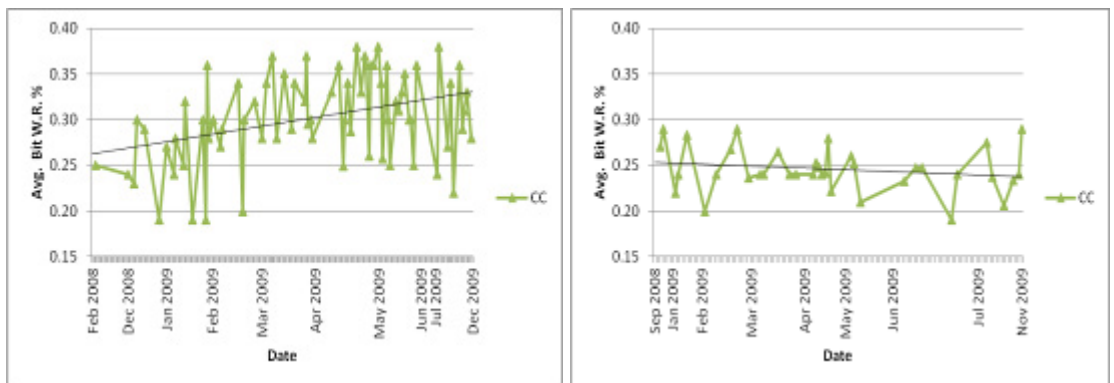
a) Supplier A      b) Supplier B

**Figure 2.34. Item 330, Type DS Mixture Production Data, Average White Rock Content as a Percent of LRA Aggregate.**



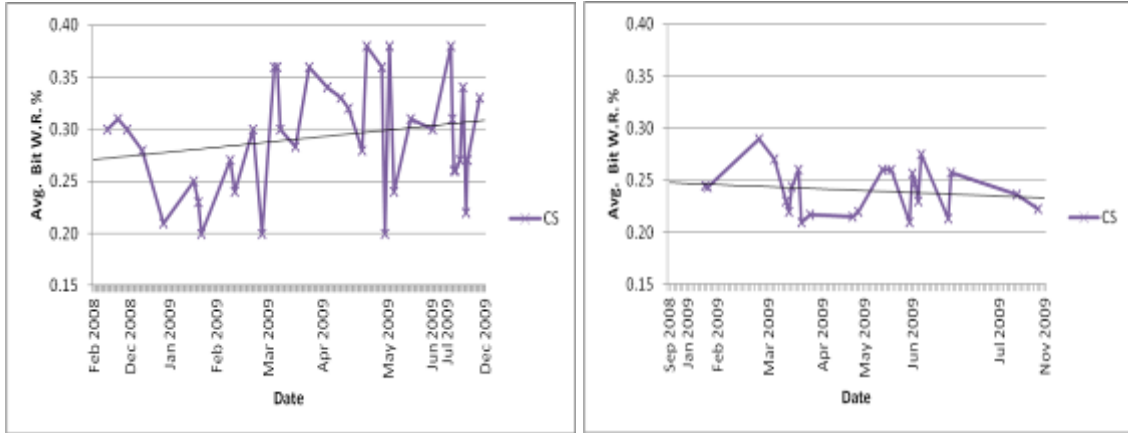
a) Supplier A      b) Supplier B

**Figure 2.35. Item 330, Type C Mixture Production Data, Average Bitumen Content of White Rock.**



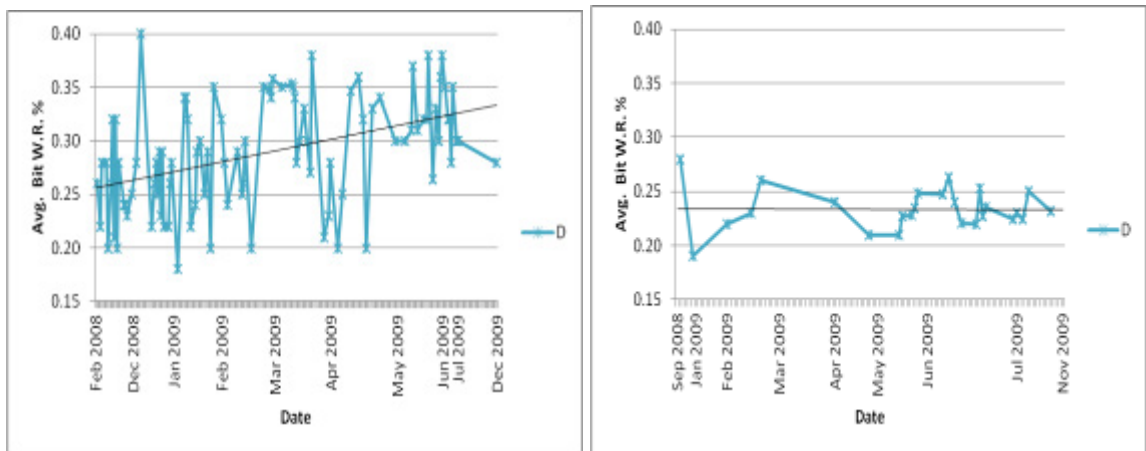
a) Supplier A      b) Supplier B

**Figure 2.36. Item 330, Type CC Mixture Production Data, Average Bitumen Content of White Rock.**



a) Supplier A      b) Supplier B

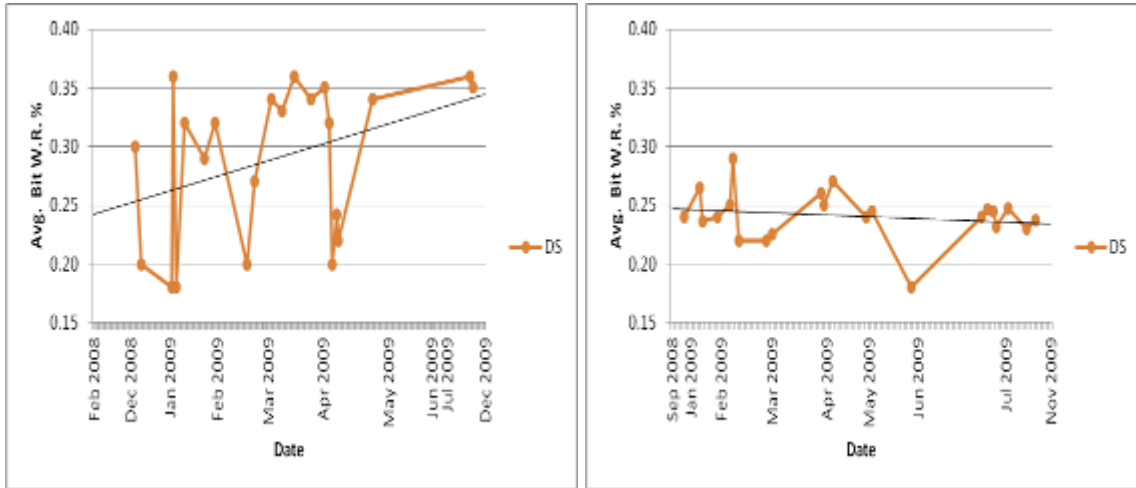
Figure 2.37. Item 330, Type CS Mixture Production Data, Average Bitumen Content of White Rock.



a) Supplier A      b) Supplier B

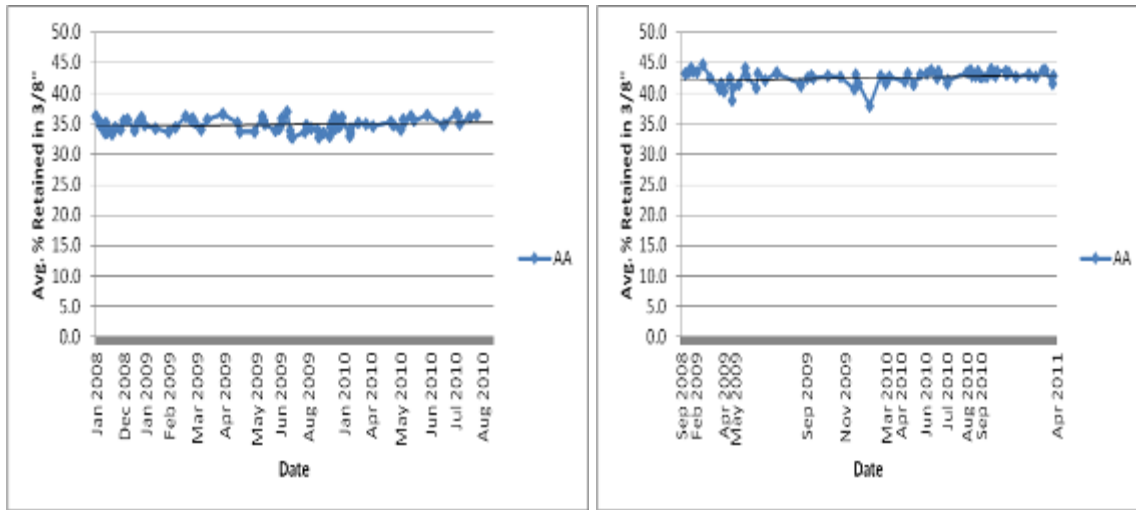
Figure 2.38. Item 330, Type D Mixture Production Data, Average Bitumen Content of White Rock.





a) Supplier A      b) Supplier B

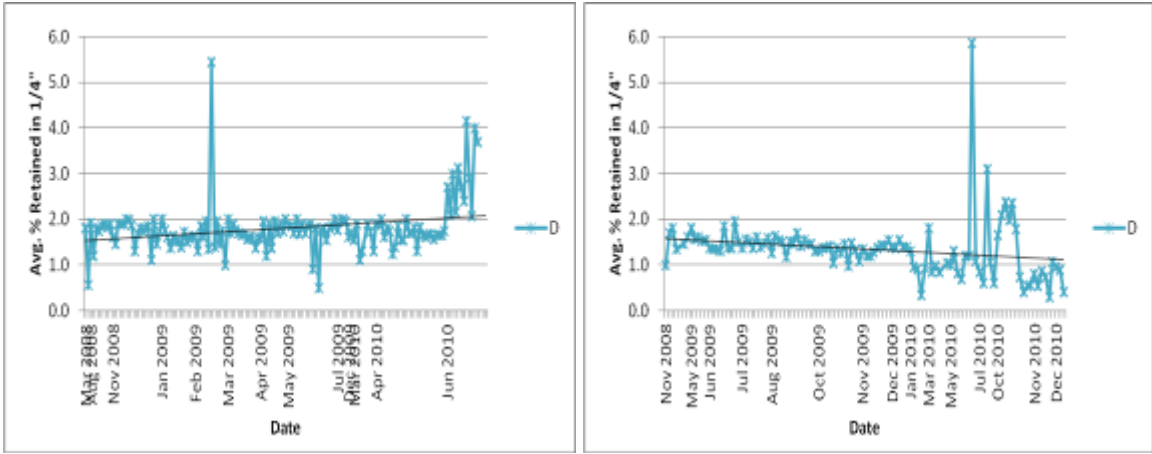
Figure 2.39. Item 330, Type DS Mixture Production Data, Average Bitumen Content of White Rock.



a) Supplier A      b) Supplier B

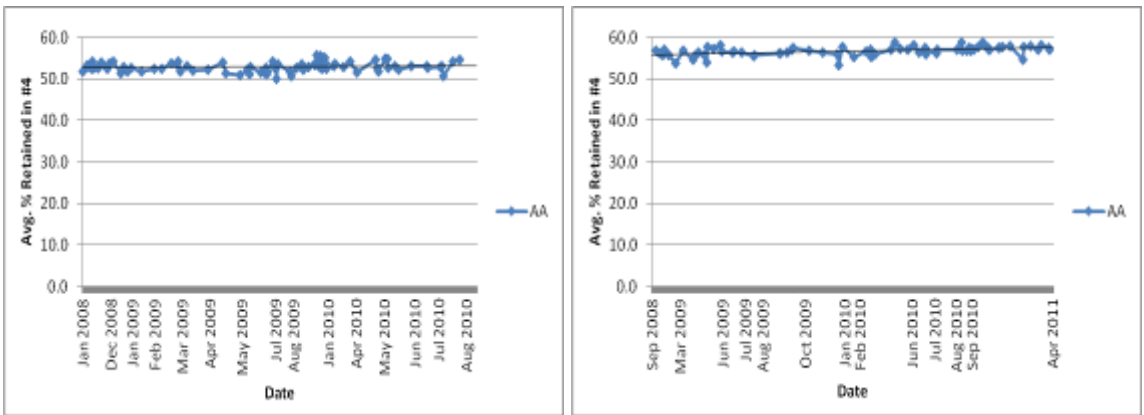
Figure 2.40. Item 330, Type AA Mixture Production Data, Average Percent Retained on 3/8-in Sieve.





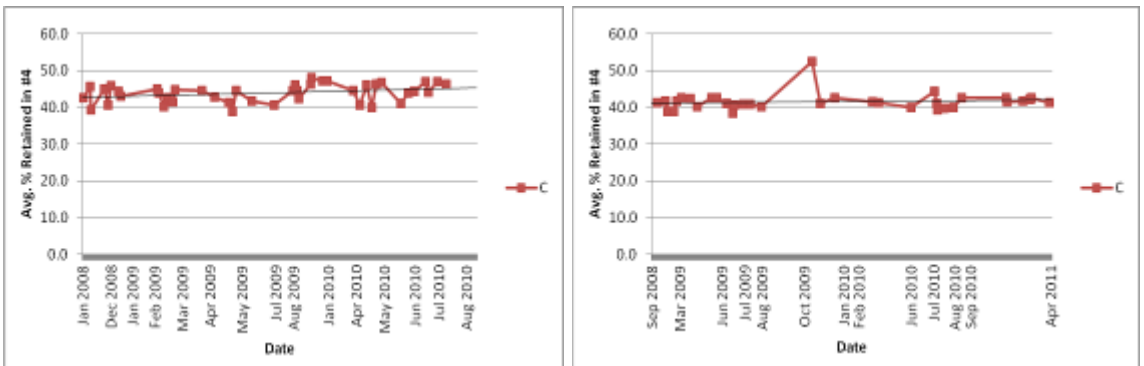
a) Supplier A      b) Supplier B

Figure 2.41. Item 330, Type D Mixture Production Data, Average Percent Retained on 1/4-in. Sieve.



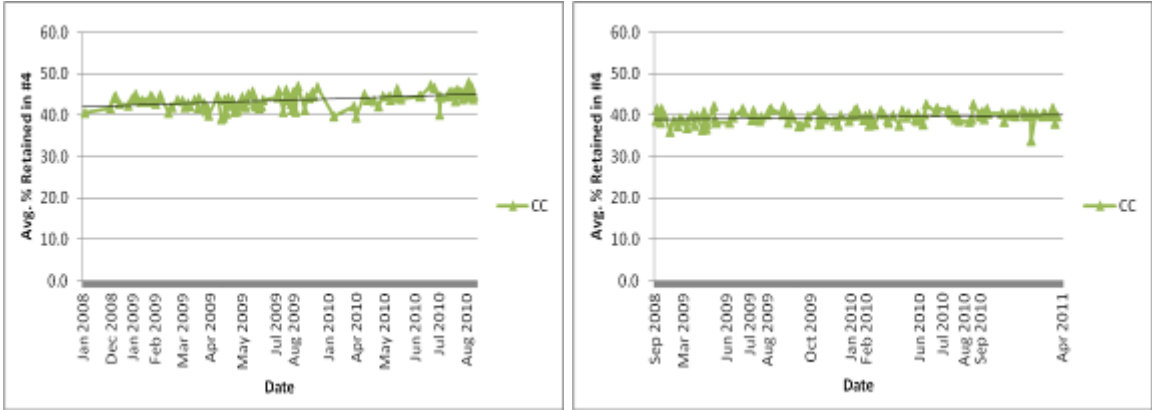
a) Supplier A      b) Supplier B

Figure 2.42. Item 330, Type AA Mixture Production Data, Average Percent Retained on No. 4 Sieve.



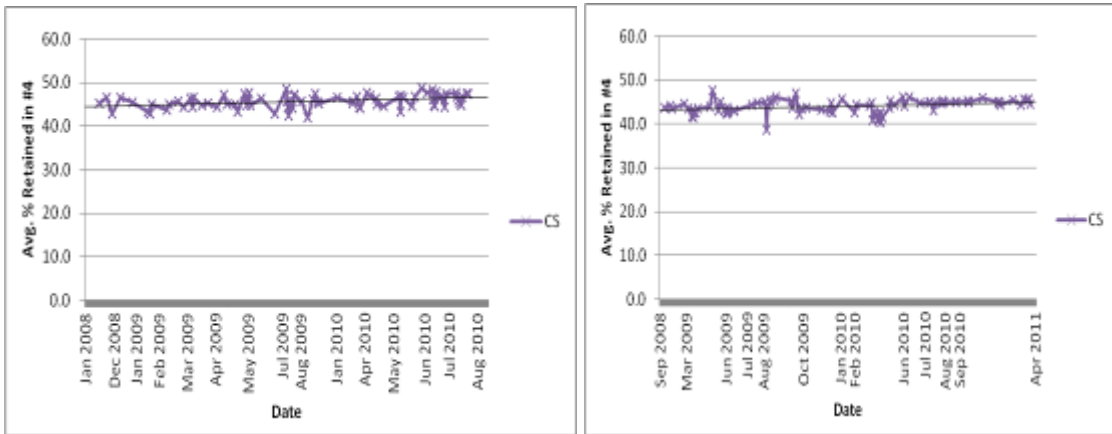
a) Supplier A      b) Supplier B

Figure 2.43. Item 330, Type C Mixture Production Data, Average Percent Retained on No. 4 Sieve.



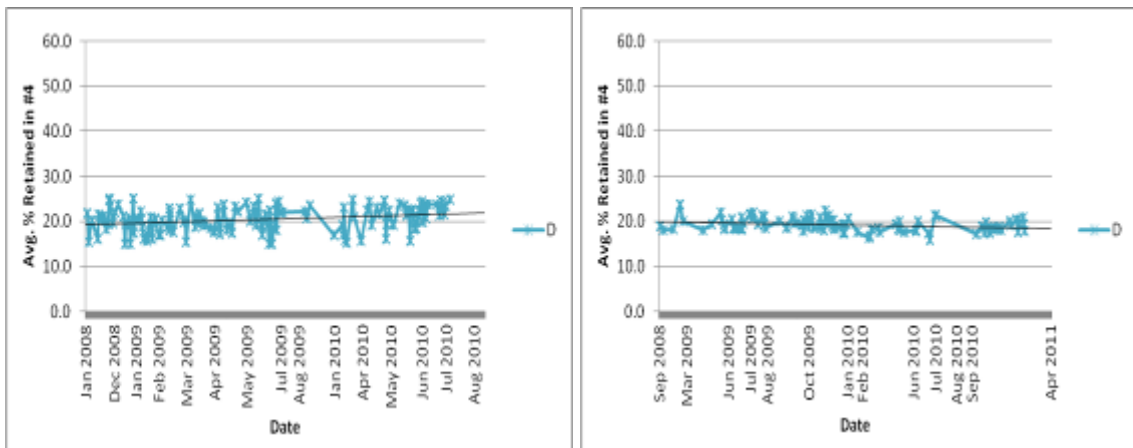
a) Supplier A      b) Supplier B

**Figure 2.44. Item 330, Type CC Mixture Production Data, Average Percent Retained on No. 4 Sieve.**



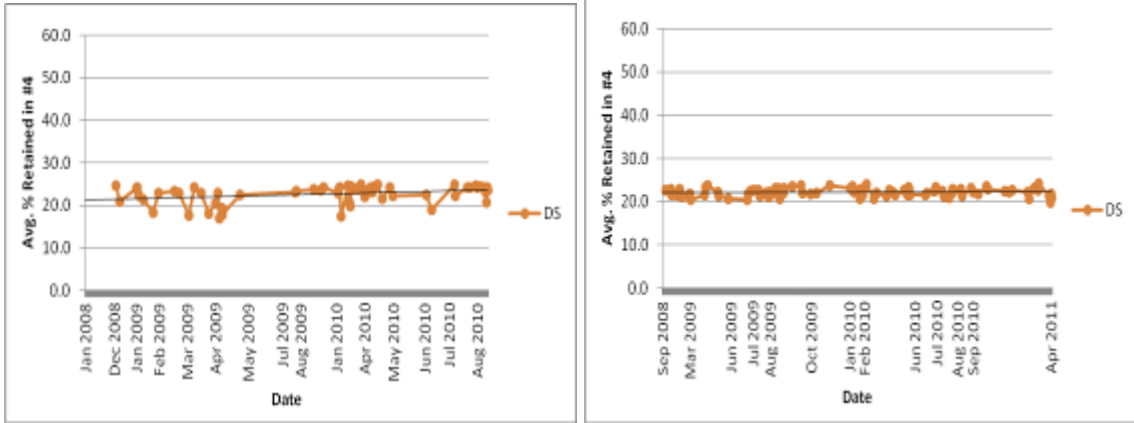
a) Supplier A      b) Supplier B

**Figure 2.45. Item 330, Type CS Mixture Production Data, Average Percent Retained on No. 4 Sieve.**



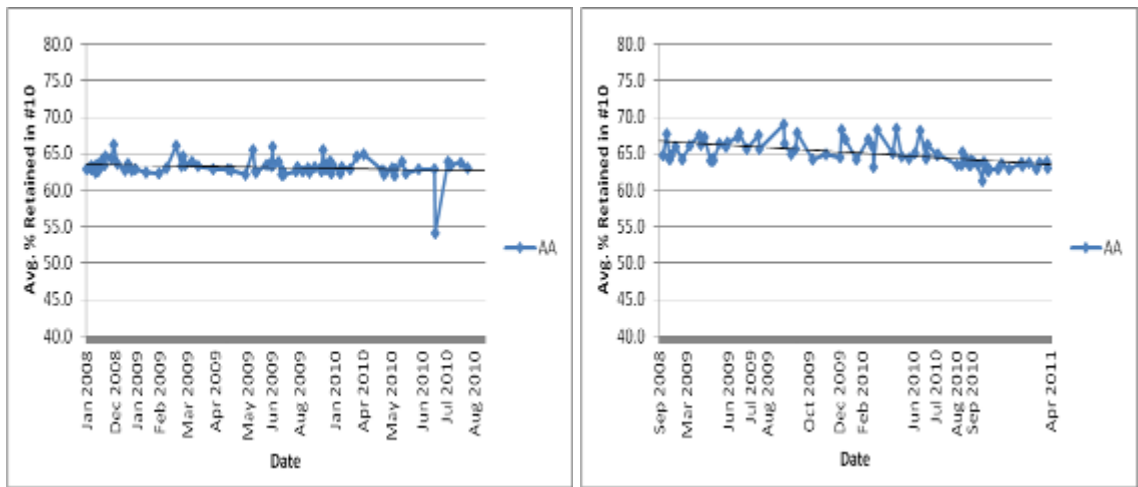
a) Supplier A      b) Supplier B

**Figure 2.46. Item 330, Type D Mixture Production Data, Average Percent Retained on No. 4 Sieve.**



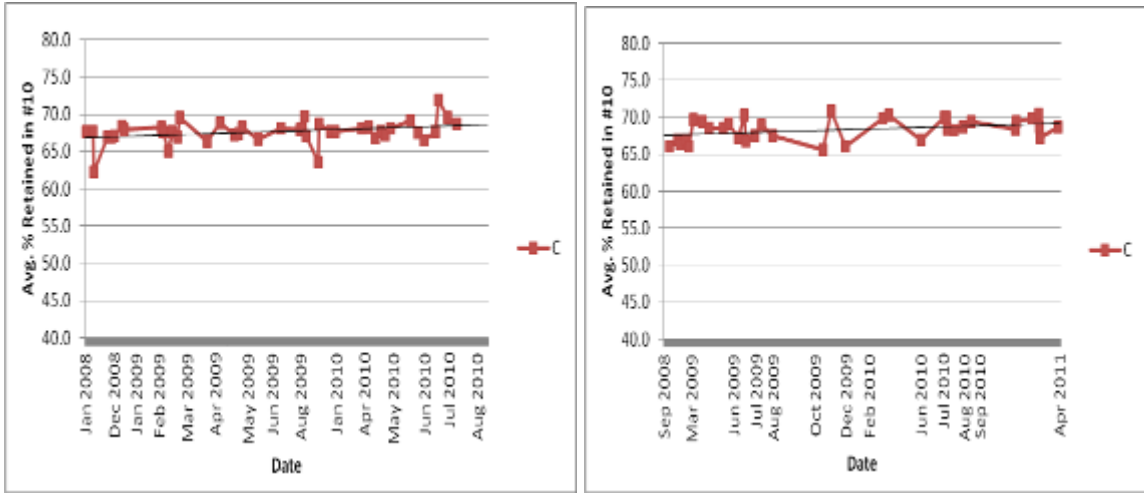
a) Supplier A                      b) Supplier B

**Figure 2.47. Item 330, Type DS Mixture Production Data, Average Percent Retained on No. 4 Sieve.**



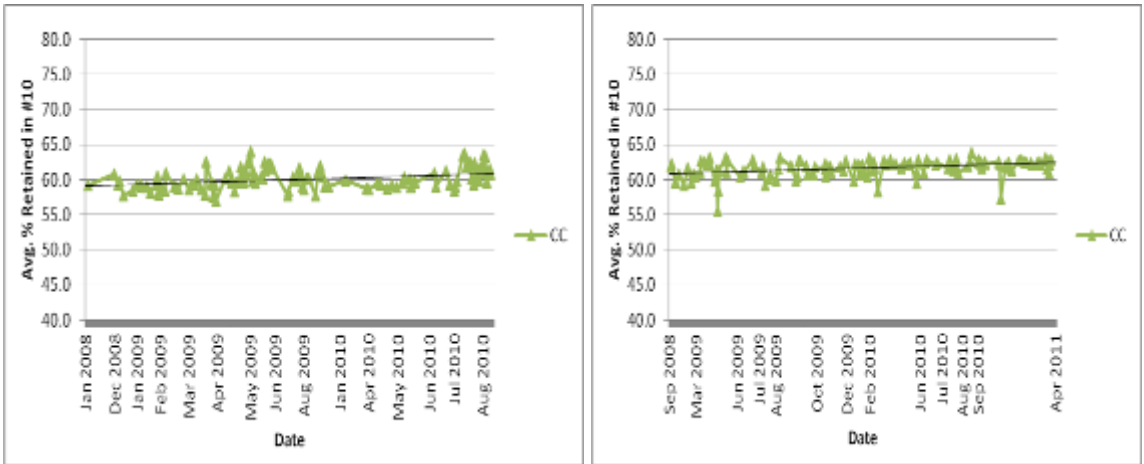
a) Supplier A                      b) Supplier B

**Figure 2.48. Item 330, Type AA Mixture Production Data, Average Percent Retained on No. 10 Sieve.**



a) Supplier A      b) Supplier B

**Figure 2.49. Item 330, Type C Mixture Production Data, Average Percent Retained on No. 10 Sieve.**



a) Supplier A      b) Supplier B

**Figure 2.50. Item 330, Type CC Mixture Production Data, Average Percent Retained on No. 10 Sieve.**

## CHAPTER 3 FIELD EVALUATION

### GENERAL

The objective of the field evaluation task in this study was to evaluate the stockpile and in-service performance of LRA mixtures originating from both suppliers. Four districts were identified around the state and the project director worked with those districts and the General Services Division such that material from each supplier (Martin Marietta and Vulcan) could be purchased and shipped to each of the four districts. Two types of LRA were the target of the field study: Type D and Type DS. Two districts were selected from a wet climatic area (Bryan and Atlanta) and two from a dry area (San Antonio and Childress).

The following materials were shipped to each district:

- ~100 tons of Item 330, LRA, Type I, Grade D, SAC Class B from Martin Marietta.
- ~100 tons of Item 330, LRA, Type I, Grade D, SAC Class B from Vulcan.
- ~100 tons of Item 330, LRA, Type II, Grade DS, SAC Class B from Martin Marietta.
- ~100 tons of Item 330, LRA, Type II, Grade DS, SAC Class B from Vulcan.

Districts placed blade-on, level-up patches with each of the four materials at two different stockpile ages according to the protocol described in [Appendix A](#).

**Table 3.1. Test Section Descriptions.**

<b>District</b>	<b>Test Sections with Fresh, Newly Stockpiled Material (Stockpile Age 1 month or less)</b>	<b>Test Section Placed at Stockpile Age of 4+ Months</b>
San Antonio – Uvalde Maint.	US 83, Approx. 8 miles North of SH 55 intersection. Work to be between County Road 429 and Reference Marker 572	FM 55 approximately 200 ft before RM 536
Bryan – Grimes County Maint.	FM 1227 near RM 434	FM 1774 near RM 424
Childress – Childress Maint.	US 70 near RM 448	US 70 near RM 448
Atlanta – Jefferson Maint.	None	SH 49, 2 miles east of Jefferson.

Researchers provided sampling buckets for TxDOT personnel to sample materials soon after delivery. Signs were provided to the district to designate the four separate stockpiles at each maintenance yard ([Figure 3.1](#)). [Figure 3.2](#) shows the typical stockpiles.



(a) Five Buckets Per Material Were Sampled.  
(b)



(c) Signs Provided to Maintenance Yards.

Figure 3.1. Sample Containers and Stockpile Designation Signs.



**(a) Fresh Stockpiles.**



**(b) Stockpiles After Four Months Age.**

**Figure 3.2. Research Stockpiles at Uvalde Maintenance Yard.**



## CONSTRUCTION

Test section construction in each of the four districts is shown in [Figures 3.3](#) through [3.6](#).



a) Application of Tack



b) Box Spreader



c) Spreading Material



d) Blading Material



e) Pneumatic Roller



e) Small Steel Wheel Roller

**Figure 3.3 Construction Sequence of Uvalde Test Sections.**





a) Application of Tack



b) Placement of Material



c) Placement of Material



d) Spreading Material



e) Pneumatic Rolling



f) Small Steel Wheel Roller

**Figure 3.4. Construction Sequence of Navasota Test Sections.**



a) Application of Tack



b) Placing Material



c) Spreading Material



d) Compacting in Multiple Lifts



e) Steel Wheel Roller

**Figure 3.5. Construction Sequence of Childress Test Sections.**



**a) Application of Tack**



**b) Placing Material**



**c) Spreading Material**



**d) Pneumatic Rolling**



**e) Steel Wheel Roller**

**Figure 3.6. Construction Sequence of Jefferson Test Sections.**

## Performance

Most of the performance problems which have been experienced by TxDOT with Item 330 occurs soon after the mix is placed in service. Maintenance personnel in each of the four districts assisted with the research by closely monitoring the performance of all the test sections during the first few days after placement. They reported a few minor performance issues; however, after further long-term evaluations, no significant difference was noted between the performance of the materials in terms of LRA type (D or DS) or LRA supplier. Performance information is summarized below:

- Early raveling in the first 24 hours. TTI researchers noted that in almost all of the test sections around the state, some raveling occurred within the first 24 hours of patch placement as shown in [Figure 3.7](#). In this photo, shoulders were present on the roadway where the loose material collected, and all four materials performed similarly in terms of raveling. In every test section, this type of raveling did not progress any further after the first day or two of trafficking.
- Development of a few small potholes after a rain within the first week. This happened on one of the test sections for the Jefferson test patches ([Figure 3.8](#)). Note that the photo was taken soon after the rain occurred and the moisture in the pavement indicates areas of low density and in the wheel path which was attributed to the loss of material after the rain. Maintenance patched these few small potholes and no further loss of material was observed as shown in the photo in [Figure](#) taken 6 months later.
- Fatigue cracking on test patch in Uvalde. This occurred within the first few days of placement in one of the materials; however, it was in an area where alligator cracking was observed in the surface prior to placement ([Figure 3.9](#)).
- OVERALL, NO DIFFERENCE IN MATERIAL PERFORMANCE BETWEEN ITEM 330 TYPE (D vs DS) or SUPPLIER. None of the performance problems noted above are attributed to the type or supplier of LRA. Overall performance of the test patches placed around the state indicate no significant difference among any of the materials or between the suppliers and no significant performance problems were noted with any of the materials ([Figures 3.10](#) through [3.13](#)).





**(a) Ravelling Observed 24 Hours After Construction.**



**(b) No Sign of Ravelling at Four Months of Age.**

**Figure 3.7. Typical Example of Ravelling Seen on All Test Sections but Only in the First 24 hours of Trafficking (Uvalde, US 83).**



**(a) Areas of Low Density Holding Water (Small Potholes Developed in Wheelpath (Martin Marietta DS).**



**(b) Close up of Pothole (2 days After Rain) (c) Patched Potholes 3 months later.**  
**Figure 3.8. Jefferson Test Section Developed Pothole in Wheelpath in Area Holding Water (After a Rain in First Week).**



**Figure 3.9 FM 55 Uvalde Isolated Location of Alligator Cracking in Surface Prior to LRA Application (of Martin Marietta Type D).**



**Figure 3.10. Alligator Cracking Reappeared Two Days after Placement of LRA Level-up.**





**Vulcan D**

**Martin D**

**(a) Type D Mixes**



**Martin DS**

**Vulcan DS**

**(b) Type DS Mixes**

**Figure 3.11. Uvalde Test Sections After 6 Months in Service.**





**(a) Martin DS**



**(b) Vulcan DS**



**(c) Martin D**



**(d) Vulcan D**

**Figure 3.12. Bryan Test Sections After 6 Months in Service.**



**(a) Martin DS**



**(b) Vulcan D**



**(c) Martin D**



**(d) Vulcan DS**

**Figure 3.13. Childress Test Sections After 6 Months in Service.**



**Vulcan DS**

**Martin D**



**Vulcan D**

**Martin DS**

**Figure 3.14. Jefferson Test Sections After 3 Months in Service**



## CHAPTER 4 LABORATORY TEST RESULTS

### OVERVIEW OF LAB TESTING PROGRAM

The laboratory testing program was aimed at achieving two goals:

- Characterize material properties according to specification requirements.
- Identify potential tests that are better indicators of LRA performance.

Five 5-gallon buckets of mix were sampled from each of the four stockpiles delivered to each of the four districts for a total of 80 buckets. Maintenance personnel conducted sampling according to the sampling protocol described in [Appendix A](#).

The following laboratory tests were conducted to characterize material properties including specification requirements:

- Tex-212-F, Part II Determining Water and Light Hydrocarbon Volatiles.
- Tex-236-F, Determining Asphalt Content from Asphalt Paving Mixtures by Ignition Method.
- Tex-200-F, Part I. Sieve Analysis of Fine and Coarse Aggregates.
- Aggregate Imaging System (AIMS).
- Maximum Theoretical Specific Gravity.
- Lab-Molded Density.
- Tex-208-F, Hveem Stability.

Other tests that were evaluated are listed below and were selected in response to the following complaints:

- *LRA material that sets up in the stockpile and cannot be easily broken up for use.* (Workability problem not meeting the minimum 6-month requirement).
  - Workability Test.
- *LRA material which is excessively dry and cannot be adequately compacted in the field, this material ravels very badly.* (Problem associated with low asphalt content or bad flux oil).
  - Tex-245-F, Cantabro Loss.
- *Instability of LRA patches.* (Rutting problem).
  - Tex-242-F, Hamburg Wheel Tracking Test.
  - Modified Hamburg (dry).

Additional tests include the Tex-226-F, Indirect Tensile Strength (before and after moisture conditioning).

## **DISCUSSION OF RESULTS**

### **Tex-212-F, Part II. Determining Water and Light Hydrocarbon Volatiles.**

In this test, a 200 gram sample of material is allowed to dry in an oven set at a temperature between 200° and 300°F. The weight of the sample is determined at 30-minute intervals until a constant weight is reached. The specification allows a maximum of 6 percent; however, some of our samples may have been exposed to the weather in the stockpile prior to sampling.

### **Tex-236-F, Determining Asphalt Content from Asphalt Paving Mixtures by Ignition Method.**

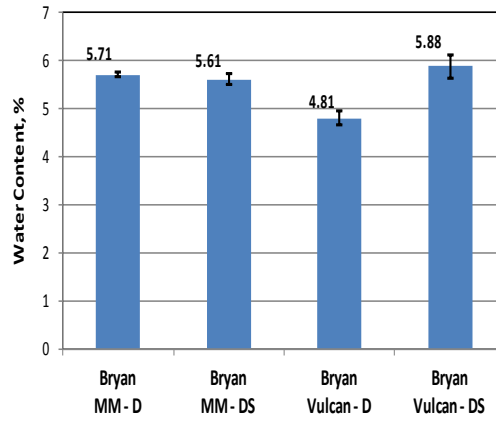
This method will determine the amount of bitumen added in the mixture as well as the naturally impregnated bitumen content of the native LRA. These results are shown in [Figure 3.2](#). The Vulcan mixes tended to have a slightly higher total bitumen content than the Martin Marietta materials. The specification allows between 6.5 and 11.0 percent.

### **Tex-200-F, Part I. Sieve Analysis of Fine and Coarse Aggregates.**

A sieve analysis was performed on each of four mixtures from each of the four districts. These results are shown in [Table 3.1](#), and [Figures 3.3](#) and [3.4](#). Some of the data indicated that the material did not meet the specification requirement. However, the ignition oven can sometimes cause the aggregates to break down during the burning process, which probably accounts for the materials not meeting the minimum percent retained in some cases.

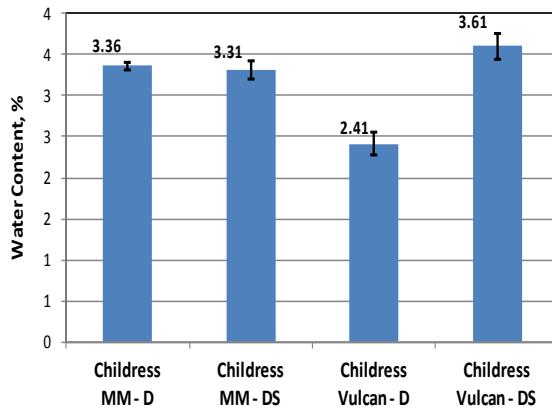
### **Aggregate Imaging System (AIMS).**

TTI's AIMS equipment was used to evaluate the aggregate angularity after ignition oven testing. These results are shown in [Figures 3.5](#) and [3.6](#). AIMS uses one video camera and a microscope to capture different types of images. The system measures the three dimensions of the aggregate particles.

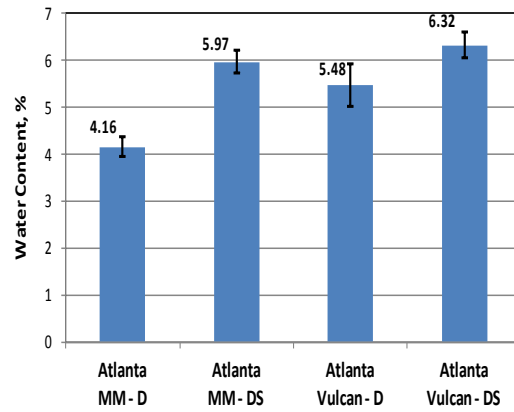


**(a) Uvalde**

**(b) Bryan**



**(c) Childress**



**(d) Atlanta**

**Figure 4.1. Water and Light Hydrocarbon Volatiles Content, Tex-212-F.**



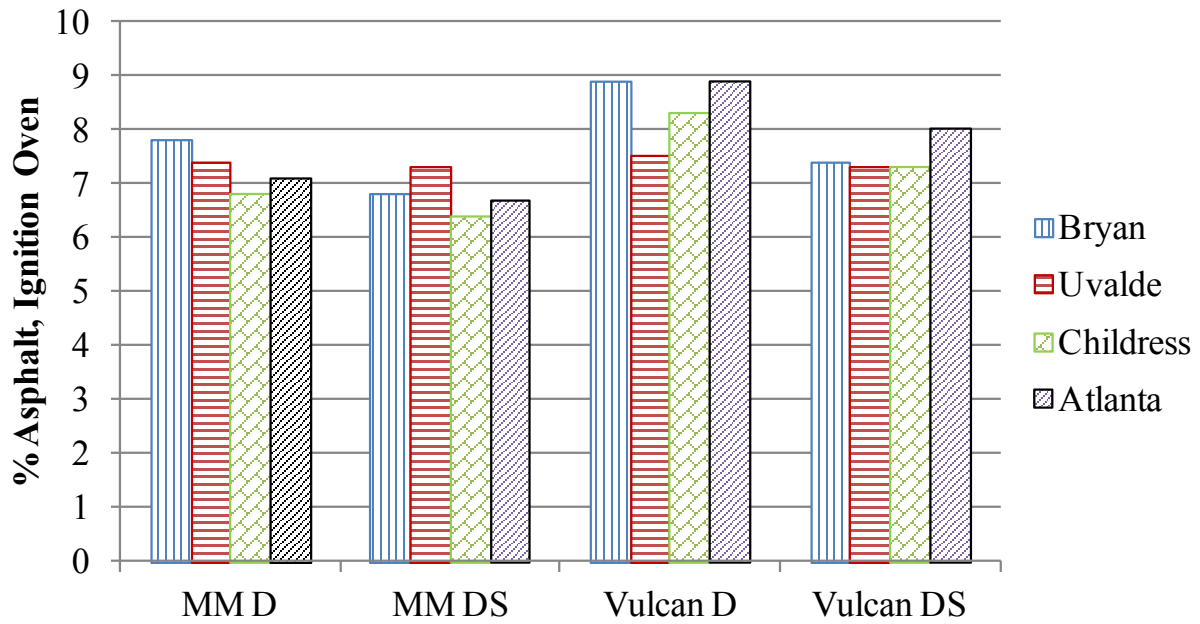


Figure 4.2. Total Bitumen Content of All Field Mixes.

Table 4.1. Sieve Analysis Results (after Ignition Oven).

Material	% Retained				
	3/8"	1/4"	#4	#10	PAN
Childress Vulcan D	0	2.9	9.9	31.3	55.8
Childress Vulcan DS	0	1.9	9.1	32.7	56.3
Childress MM D	0	1.8	12.1	41.0	45.0
Childress MM DS	0	1.6	12.4	37.8	48.2
Bryan Vulcan D	0	4.6	12.5	31.6	51.2
Bryan Vulcan DS	0	0.9	7.3	33.4	58.3
Bryan MM D	0	1.2	9.3	33.3	56.1
Bryan MM DS	0	3.0	19.1	36.2	41.7
Uvalde Vulcan D	0	0.9	7.7	33.7	57.7
Uvalde Vulcan DS	0	2.8	11.5	31.4	54.2
Uvalde MM D	0	2.4	17.3	36.1	43.8
Uvalde MM DS	0	2.0	15.1	37.2	45.6
Atlanta Vulcan D	0	1.9	10.2	32.2	55.4
Atlanta Vulcan DS	0	0.6	6.7	30.7	62.1
Atlanta MM D	0.2	1.0	9.0	33.5	56.2
Atlanta MM DS	0	1.4	13.3	35.6	49.7



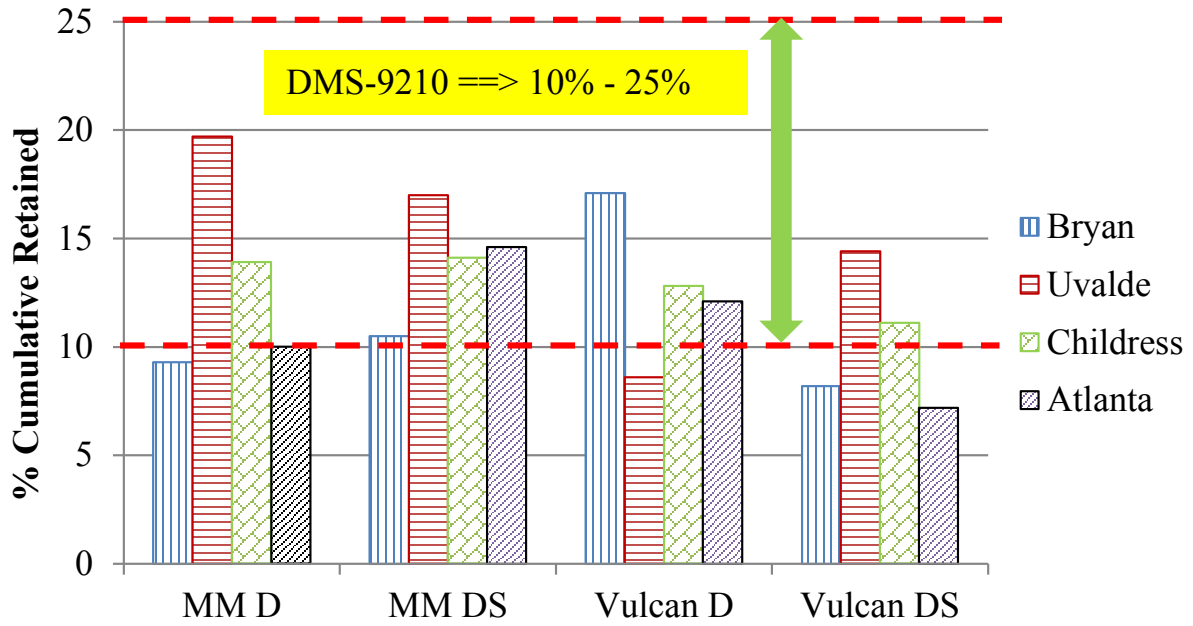


Figure 4.3. Percent Material Retained on the No. 4 Sieve (after Ignition Oven).

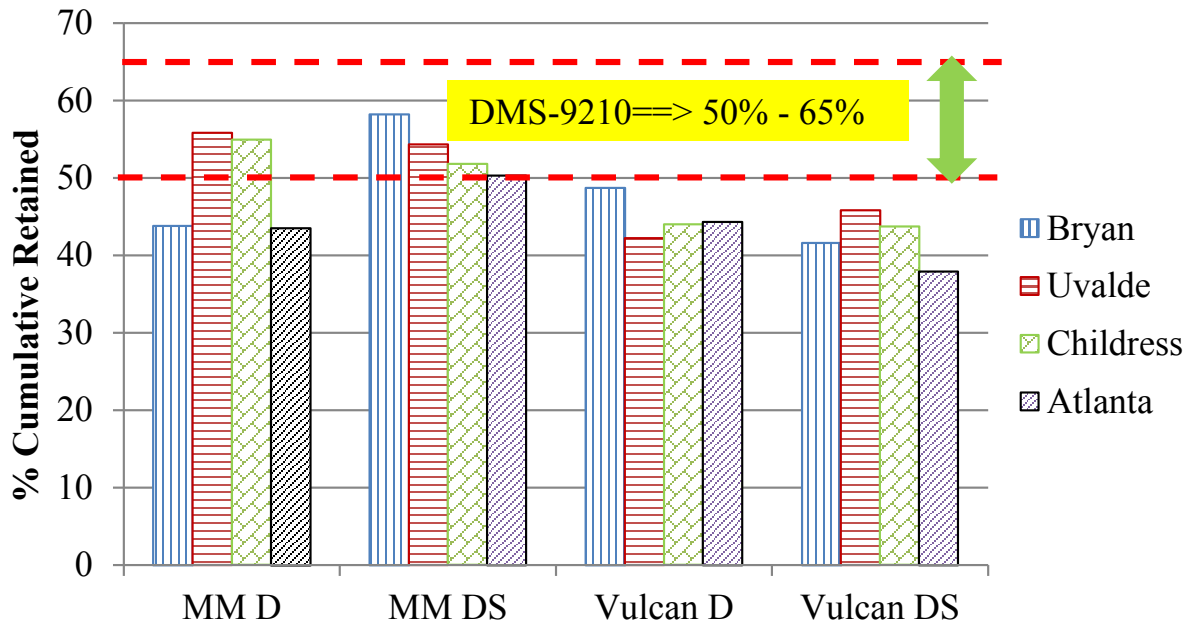


Figure 4.4. Percent Material Retained on the No. 10 Sieve (after Ignition Oven).

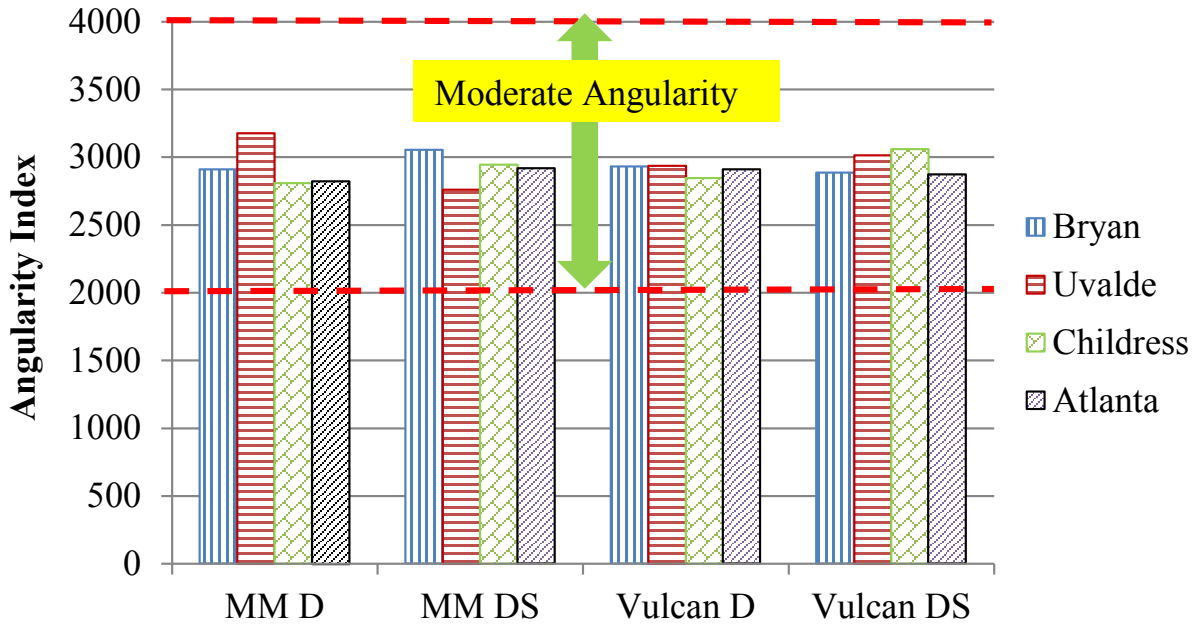


Figure 4.5. Angularity Index from AIMS Testing (after Ignition Oven).

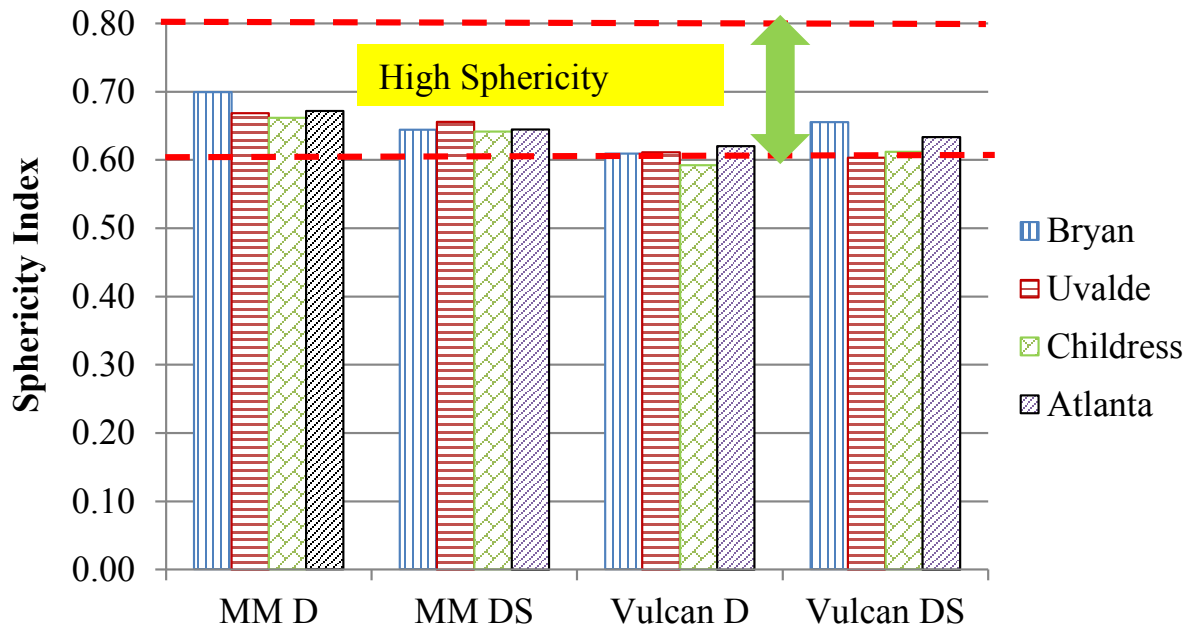


Figure 4.6. Sphericity Index from AIMS Testing (after Ignition Oven).

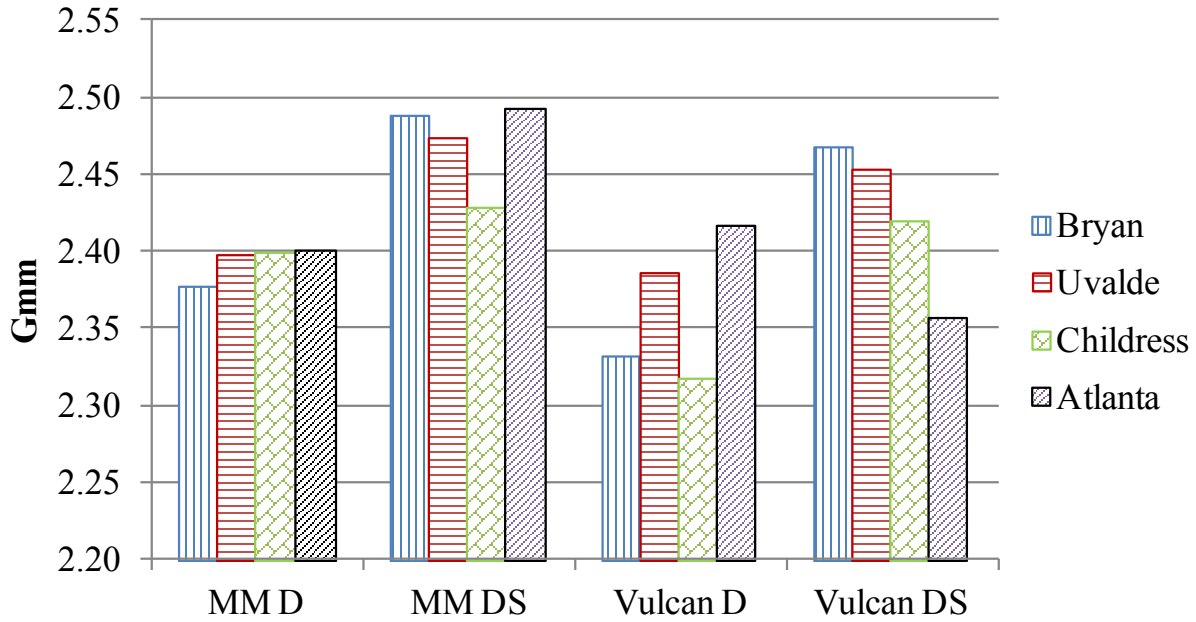


Figure 4.7. Sphericity Index from AIMS Testing (after Ignition Oven).

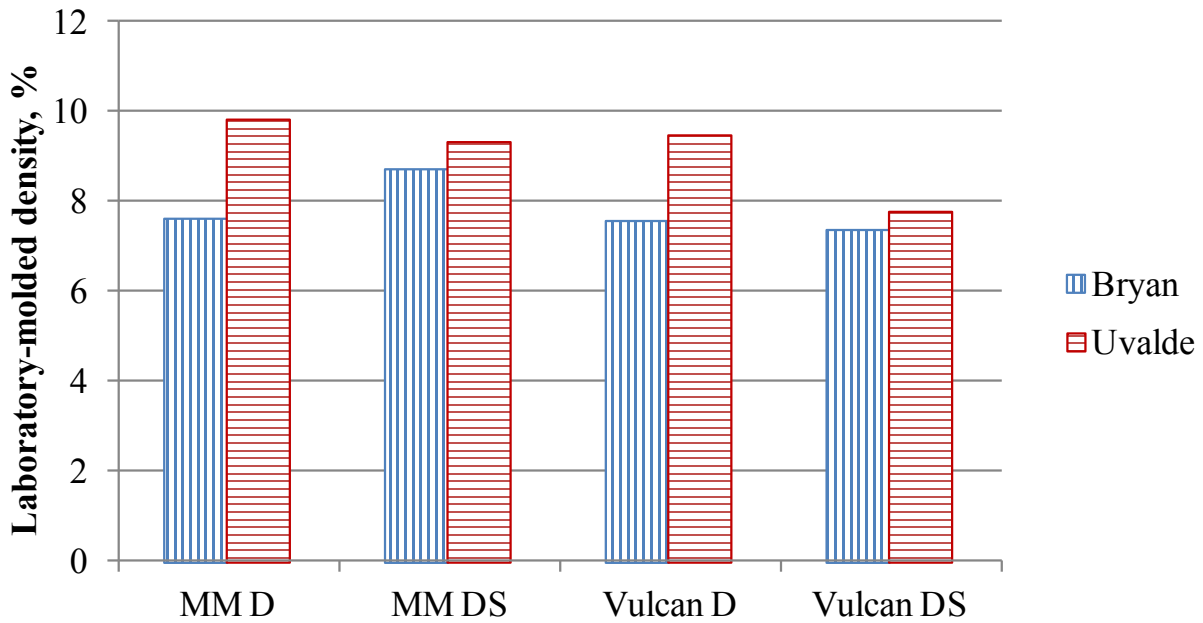


Figure 4.8. Sphericity Index from AIMS Testing (after Ignition Oven).

**Tex 208-F, Hveem Stability Results.** This test method provides a procedure for determining the relative stability (Stabilometer Value) of an asphalt mix by measuring the transmitted horizontal pressure developed in a compacted test specimen under a given vertical pressure. This

value indicates the ability of the pavement to resist plastic deformation under the action of traffic. The stabilometer, a closed system triaxial test, applies an increasing load to the top of the sample at a predetermined rate. As the load increases, the lateral pressure is read at specified intervals. The relative resistance to lateral deformation is determined on a scale ranging from 0 to 90. Zero would represent a condition where lateral pressure is equal to vertical pressure (e.g. liquid). Ninety would represent a condition where there is no lateral pressure no matter what the vertical pressure (e.g. incompressible solid). Hveem stability should decrease with increasing asphalt content. Mixtures designed using the Hveem stability strive to select an asphalt content resulting in the highest durability without falling below a minimum stability. That minimum stability value is 35 in Item 330 specifications. This test should ensure a mixture is not susceptible to rutting but cannot be used to identify a mixture which is “dry”.

**Table 4.2. Hveem Stability Results.**

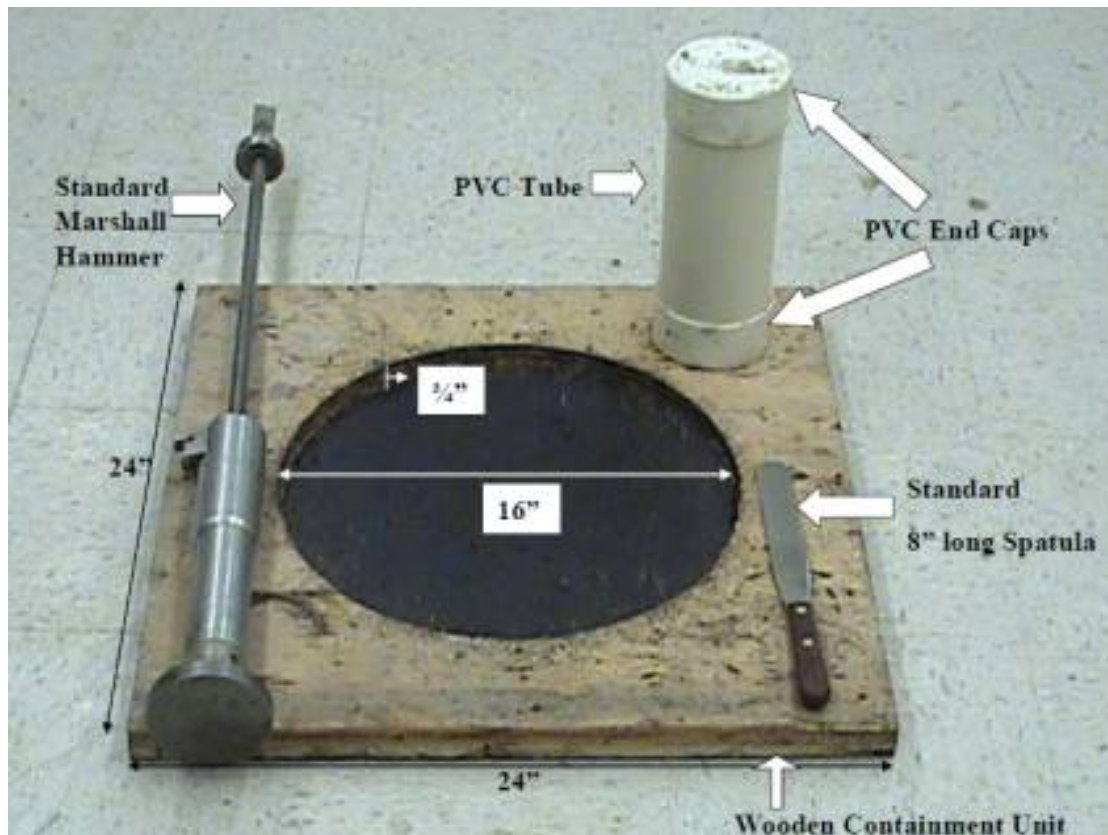
<b>Material Type</b>	<b>Martin Marietta</b>	<b>Vulcan</b>
Type D	40	30
Bryan	37	34
	38	33
Type D	47	37
Uvalde	47	33
	45	36
Type DS	45	35
Bryan	39	35
	40	35
Type DS	38	38
Uvalde	40	43
	44	37

**Workability Test: Cold Patch Slump Test (CPST)**

A Cold Patch Slump Test (CPST) used at the University of Texas in Austin to evaluate the workability of cold patch mixtures was evaluated. Figure 4.9 shows the main components of this test. The cold patch mixtures are poured in a PVC cylinder tube, which is 4 inches in diameter and 8 inches in height, and a standard Marshall Hammer is used to compact the mixtures.

After removing the compacted mixtures, the researchers placed the specimen in a wooden containment unit (see [Figure 2](#)) and put a standard weight above the specimen. The time is noted until the specimen fails under its own weight in addition to the standard weight on top of it. Less time noted indicates better workability for the cold patch mixtures.

Upon failure, the researchers used a standard 8-inch-long spatula to spread the mixture and fill out the cavity of the Wooten containment. This is another subjective rating tool to assess the workability of the mixtures by noting the time required to spread the mixtures. In addition, the rater provides a subjective rating of the materials workability from 1 to 5, where 1 means that this mixture is easy to work while 5 means that is the mixture is hard to work.



**Figure 4.9. The Main Components of the Cold Patch Slump Test (CPST)**

TTI modified the test slightly by compacting mixtures in a steel mold ([Figure 4.10a](#)) which is easy to fix during the specimen extraction ([Figure 4.10b](#)). A standard Marshall Hammer will be used as in the CPST to compact the LRA mixtures. [Figure 4.11](#) illustrates this procedure.

Results are presented in [Figures 4.12](#) through [4.15](#). This test is performed on “uncured” materials so the moisture content in the as-sampled stockpile can certainly affect the workability results. This test definitely identified some notable differences in the materials. However, no clear correlation to field performance was made.



(a) Compaction Mold and Marshall Hammer



(b) TTI Specimen Extraction Process

**Figure 4.10. TTI-Modified Cold Patch Slump Test**

Sample Preparation  
Test specimen (4" by 8")

Sample Compaction  
Two lifts, 4" each  
Marshall hammer;  
four blows on each  
layer

Sample Extraction

2.5 kg on the top  
of the sample  
Record the time to  
collapse

After Slump:  
Record the time to fill out the cavity  
Subjective rating for the material  
workability

**Figure 4.11. Steps in the CPST Workability Test Procedure.**

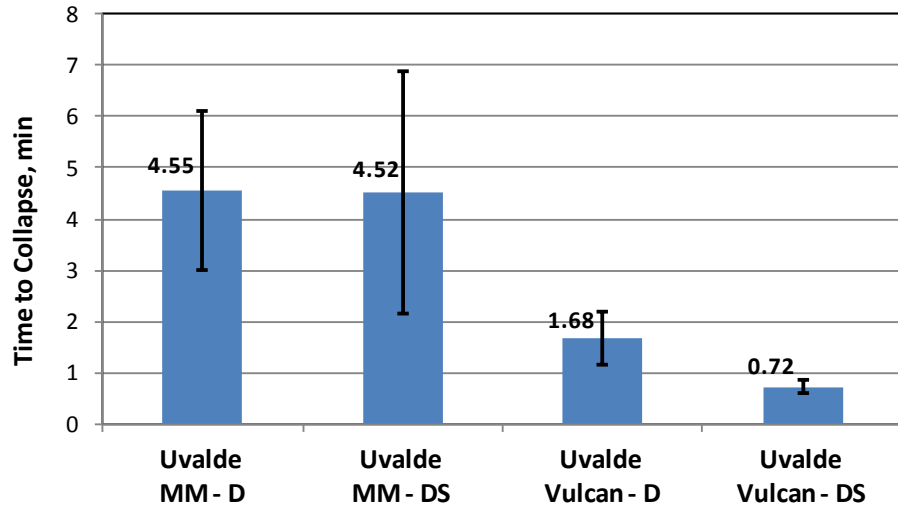


Figure 4.12. Time to Collapse CPST Workability Test for the Uvalde Mixes.

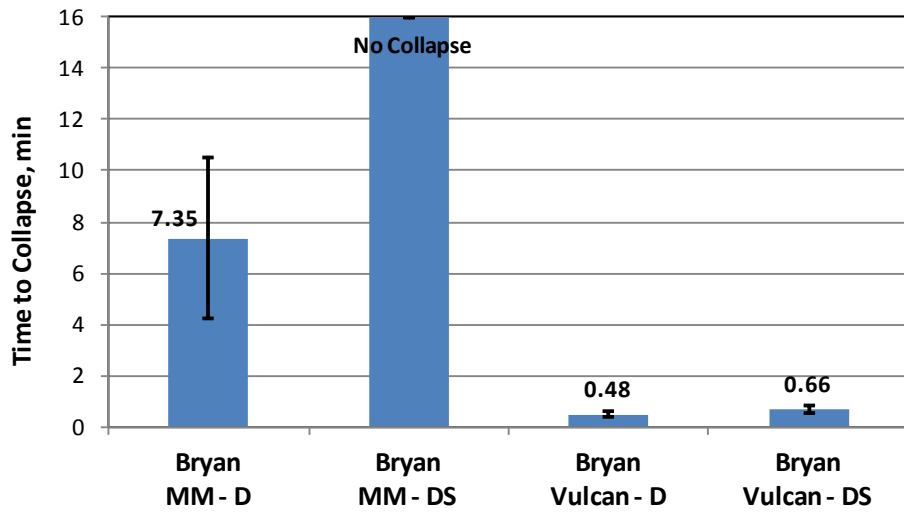


Figure 4.13. Time to Collapse CPST Workability Test for the Bryan Mixes.

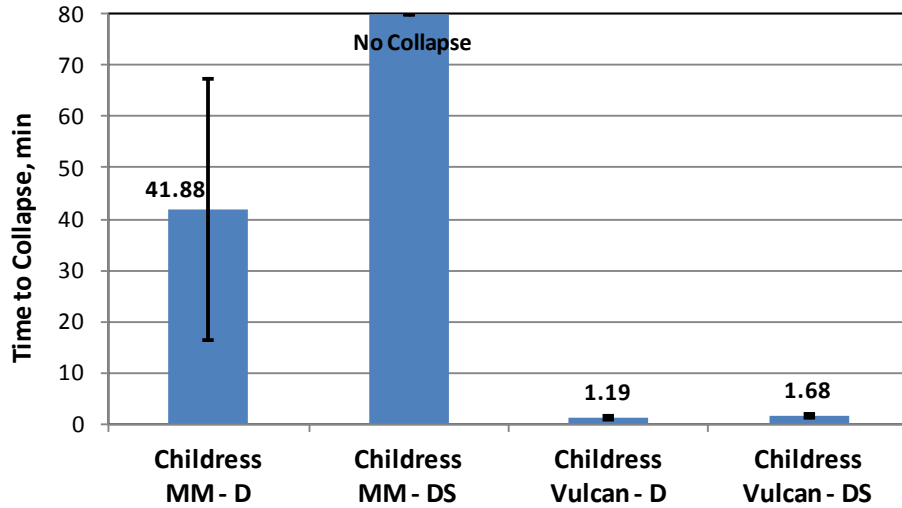


Figure 4.14. Time to Collapse CPST Workability Test for the Childress Mixes.

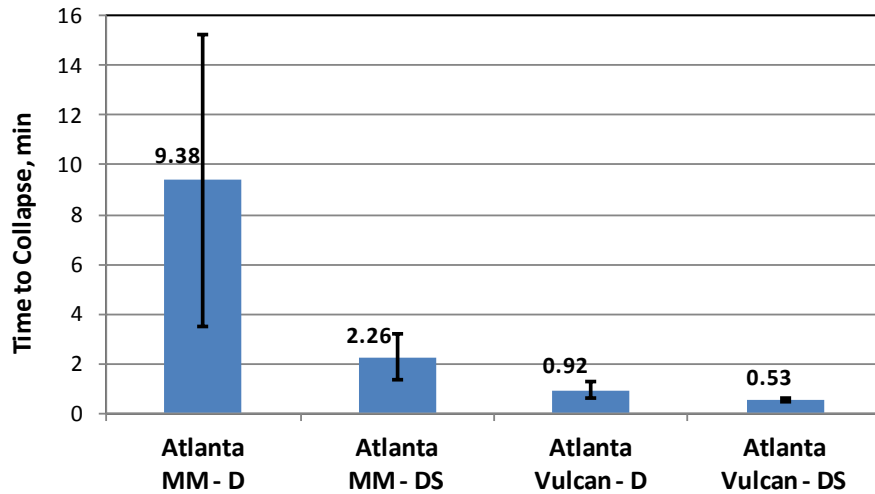


Figure 4.15. Time to Collapse CPST Workability Test for the Atlanta Mixes.

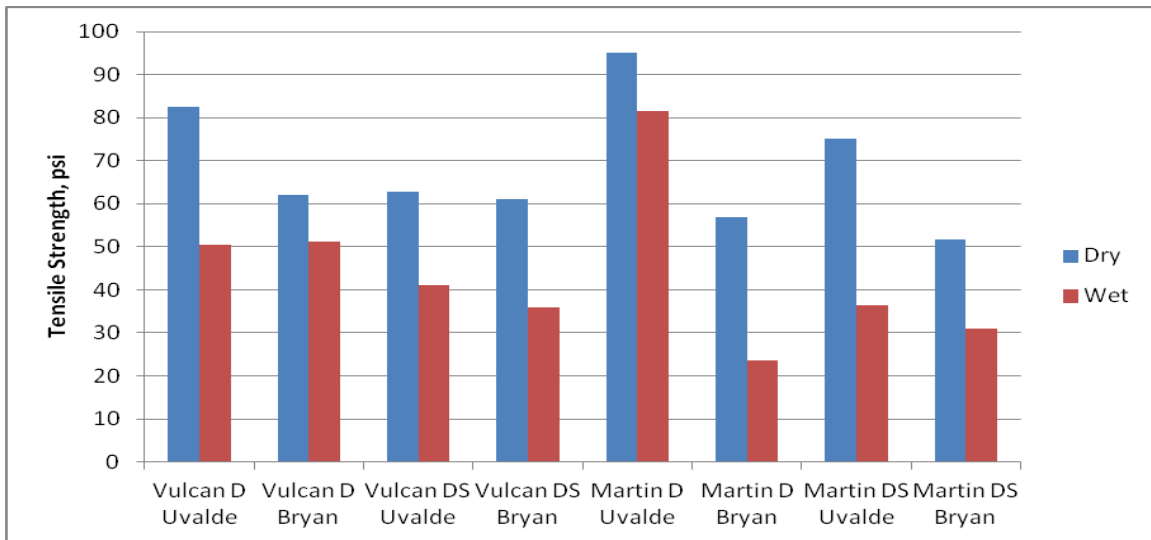
### Tex-226-F, Indirect Tensile Strength (IDT) Test.

Test equipment and sample configuration (see Figure 4.16) were used to conduct indirect tensile strength tests on LRA mixtures compacting in the Texas Gyrotory Compactor according to Tex-206-F. In addition, IDT strength tests were performed on specimens after soaking in a water bath overnight. Results are presented in Tables 4.3 and Figure 4.17. This test measures indicates a significant susceptibility to moisture of the LRA mixtures as is measured by the loss of strength after water conditioning. This test is being explored in more detail in the second year of this research effort.





**Figure 4.16. Tex-226-F, Indirect Tensile Strength (IDT) Test.**



Note: The Uvalde, Martin D was only soaked for 2 hours while the other mixtures were soaked for 24 hours.

**Figure 4.17. Wet and Dry Indirect Tensile Strength Results.**

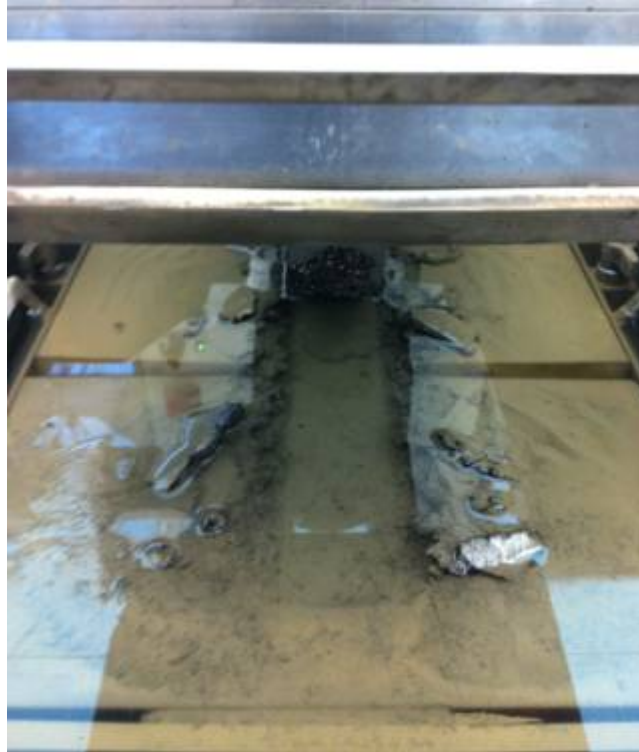
**Table 4.3. Wet and Dry Indirect Tensile Strength Results.**

<b>Supplier</b>	<b>Maintenance Location</b>	<b>Indirect Tensile Strength, psi Dry</b>	<b>Indirect Tensile Strength, psi Wet</b>
Martin Marietta D	Uvalde	90.4	77.9*
		95.1	81.5*
		80.6	81.8*
Martin Marietta DS	Uvalde	80.6	37.1
		75.1	36.5
		76.6	43.2
Vulcan D	Uvalde	84.1	48.0
		82.5	50.4
		88.6	50.2
Vulcan DS	Uvalde	61.9	39.8
		62.7	41.1
		70.1	39.9
Martin Marietta D	Bryan	58.5	29.7
		55.8	23.6
		56.2	24.8
Martin Marietta DS	Bryan	55.4	35.1
		51.7	31.0
		51.3	25.8
Vulcan D	Bryan	63.6	39.8
		61.1	35.9
		60.9	37.1
Vulcan DS	Bryan	63.4	61.0
		60.8	51.1
		62.0	48.5

\*These specimens were soaked for only 2 hours.

**Tex-242-F, Hamburg Wheel Tracking Test**

Hamburg Wheel Tracking Tests were performed on limited samples of LRA. Performed under water, this test is too severe for LRA mixtures (see [Figures 4.18 to 4.19](#)) and all mixtures failed in less than 2500 cycles (see [Table 4.4](#)). Since the test appeared too severe for LRA, the same samples were tested in the Hamburg equipment but without water. Under these conditions, the test is not severe enough. Based on these results, the researchers will not pursue further Hamburg testing on LRA mixtures.



**Figure 4.18. Hamburg Wheel Tracking Tests on LRA Mixture.**



**Figure 4.19. LRA Specimens after 20,000 Passes in a Dry Condition in the Hamburg Wheel Tracking Test.**

**Table 4.4. Hamburg Wheel Tracking Test Results.**

Number of Cycles	MM – DS	MM- D	Vulcan D	Vulcan DS	MM – DS	MM- D	Vulcan D	Vulcan DS
	Rut Depth, mm							
	Dry	Dry	Dry	Dry	Wet	Wet	Wet	Wet
5000	1.97	0.85	1.98	1.27	12.57 mm	12.70mm	12.86 mm	12.64 mm
10000	2.18	0.95	2.21	1.42	@ 1800 cycles*	@ 2150 cycles*	@ 1900 cycles*	@ 1900 cycles*
15000	2.23	1.04	2.27	1.60	13.21 mm	12.48 mm	13.45 mm	12.64mm
20000	2.26	1.10	2.29	1.65	@ 6000 cycles**	@ 6082 cycles**	@ 2350 cycles**	@ 3950 cycles**

\*Tested at the standard test temperature of 50°C

\*\*Tested at a reduced temperature of 30°C

**Tex-245-F, Cantabro Loss.**

The Cantabro involves tumbling a lab-molded specimen in the Los Angeles Abrasion machine for a predetermined time and measuring the percentage of material that is lost from the specimen as shown in Figure 4.20. Historically, this test has been used on permeable friction course mixtures as an indication of the propensity of the mixture for ravelling. Preliminary results performed on LRA mixtures as shown in Table 4.5 indicate that the test may be sensitive to minor differences in material properties and it is anticipated that this test may be used to identify mixtures that are “too dry”. Ongoing work with this test in year 2 of this study involves modifying the sample configuration to use a Texas Gyrotory Compacted specimen and evaluating the sensitivity of the mixture to flux oil content and flux oil type. Other modifications being investigated include adapting the test to use the wet-ball mill equipment as opposed to the LA abrasion equipment.



**Figure 4.20. Lab Molded LRA Specimen Before and After Cantabro Test.**

**Table 4.5. Cantabro Loss Test Results.**

<b>Material Type</b>	<b>Martin Marietta, % Loss</b>	<b>Vulcan, % Loss</b>
Type D	13.7 22.6	3.5 5.0
Type DS	28.9 22.8	7.4 6.0



## CHAPTER 5 CONCLUSIONS AND FUTURE WORK

- Year 1 study is complete and candidate tests have been identified, which may be improved indicators of LRA field performance.
- Twenty-eight test sections have been constructed around the state using Type D and DS LRA from both suppliers. Overall, no difference in material performance between Item 330 type (D vs DS) or supplier (Martin Marietta vs Vulcan). Performance of the test patches placed around the state indicate no significant difference among any of the materials or between the suppliers and no significant performance problems were noted with any of the materials.
- The materials placed in test sections in 2012 and the materials tested in 2012 did not exhibit performance as poor as that reported by the districts for material received in 2010. Researchers are focusing year 2 efforts to determining factors that are causing poor field performance and to recommend tests that can identify those poor-performing materials.
- Large variations in flux oil were identified between suppliers during the time when field performance problems were reported. Lab studies are underway to determine the impact of variations in flux oil type and quantity on mixture performance.

Based on the preliminary results of this study, it appears that the problems identified in the past with LRA field performance have been largely attributed to manufacturers changing the type and quantity of flux oils. Most of the performance problems have been related to the mixes being too dry and raveling. Hveem stability is TxDOT's current performance test for LRA and it did not detect this property. From the work in Year 1 of this study, researchers have identified candidate tests, which may be better predictors of field performance: Cantabro, Indirect Tensile Strength, and Modified Wet Ball Mill (to simulate Cantabro). These tests are current standard TxDOT tests and the equipment is readily available.

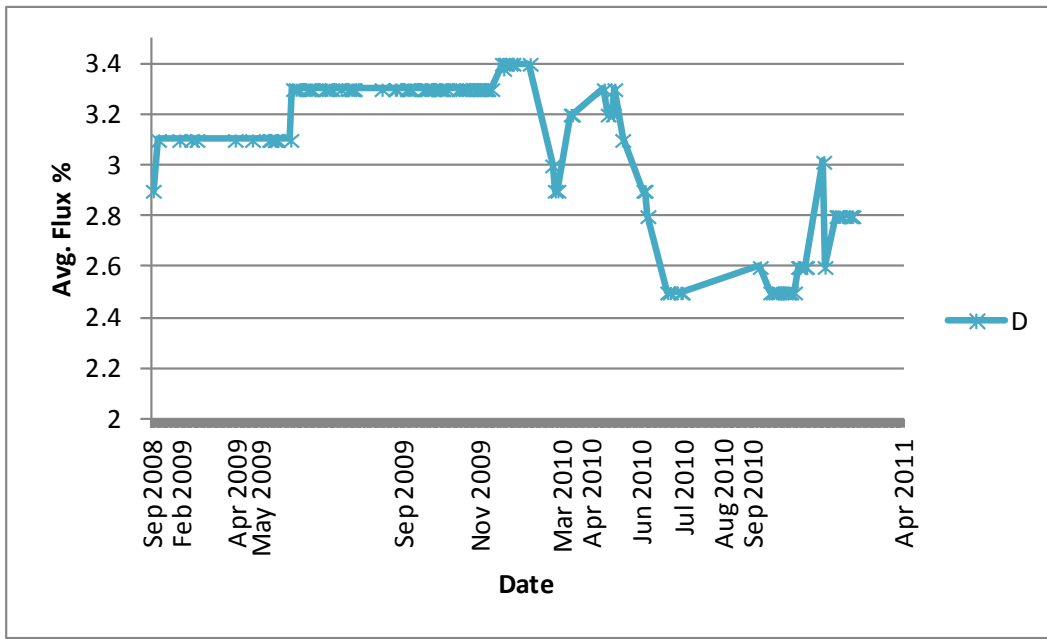
The major objective of the year 2 effort in this study is to conduct a focused lab study to determine the impact of variations in flux oil type and quantity using the proposed potential new tests.

Researchers have obtained current mix designs and the materials needed to fabricate mixtures in the laboratory. This includes samples of the raw aggregates and flux oils. Sufficient samples of the flux oils from each LRA supplier have been obtained and mixture fabrication and testing is underway. In addition to the flux oils that the LRA suppliers currently use, TTI has obtained samples of other types of flux oil materials to determine the impact of type and quantity of different types of flux oils.

Flux oil content will be varied based on production data, which was identified in [Chapter 2](#). [Figure 4](#) presents a sample of these data. The mix design for the Type D mix shown in this figure



from Supplier B called for an optimum flux oil content of 2.8 percent. During the time in which performance problems were noted, flux oil contents ranged from 2.5 to 3.4. These are the flux oil content ranges which will be investigated in TTI's second year lab study.



**Figure 5.1. Variation in Flux Oil Content for Item 330, Type D, Supplier B.**

# APPENDIX A

## LRA SAMPLING AND CONSTRUCTION PROTOCOLS FOR RESEARCH TEST SECTIONS

### Protocol for Placement of LRA Test Section Patches for TxDOT Research Study 0-6686 “Improving DMS 9210 Requirements for LRA” 10/5/2011

Atlanta, Bryan, Childress, and San Antonio Districts have agreed to participate in a field experiment for this research study. During the month of October, each district will be acquiring 90–100 tons of the following materials:

- Item 330, Type I, Grade D from Martin Marietta.
- Item 330, Type I, Grade D from Vulcan.
- Item 330, Type II, Grade DS from Martin Marietta.
- Item 330, Type II, Grade DS from Vulcan.

Prior to placement of each patch, please contact TTI since they will need to be present for construction documentation.

#### **TTI Contact:**

Cindy Estakhri  
Office: 979-845-9551  
Cell: 979-255-7376  
Email: [c-estakhri@tamu.edu](mailto:c-estakhri@tamu.edu)

#### **Type of Roadway:**

- ADT between ~2000 to 5000.
- Existing surface should have no rutting more than ¼ inch, no raveling, no bleeding or flushing.

#### **Time to Place Patch:**

- Place one patch of each material in November/December, 2011.
- Place a second patch of each material during the month of April, 2012.

#### **Patch Configuration:**

The patch should be in a main lane and have the following approximate dimensions:

- Minimum one lane width.
- Approximately 250 to 300 ft.
- Thickness: less than 1.5 inches.

#### **Construction:**

- Apply tack coat.
- Blade on using motor grader.
- Compaction equipment should consist of both pneumatic and flat-wheel if available.  
Please use a steel wheel roller for the final pass to “seal” the surface.

#### **Follow-Up Sealing:**

If patch is to be sealed, wait at least 8 weeks to allow TTI to do performance evaluation.

**Protocol for Sampling LRA Test Stockpiles**  
**TxDOT Research Study 0-6686 “Improving DMS 9210 Requirements for LRA”**  
**10/5/2011**

Atlanta, Bryan, Childress, and San Antonio Districts will receive 90–100 tons of the following materials:

- Item 330, Type I, Grade D from Martin Marietta.
- Item 330, Type I, Grade D from Vulcan.
- Item 330, Type II, Grade DS from Martin Marietta.
- Item 330, Type II, Grade DS from Vulcan.

Each district should now have 20 sample buckets and 4 signs to designate stockpiles.

**Sample Quantities**

Obtain 5 full buckets of each stockpile.

**Sampling Time**

Sample stockpile within 7 days of material delivery.

**Sampling Procedure**

Obtain representative samples of each stockpile as follows:

- Take samples from stockpiles near the top of the pile, near the base of the pile, and at an intermediate point.
- Shove a board into the pile just above the point of sampling to prevent further segregation during sampling.
- Do not use the material on the surface of the stockpile as part of the sample.
- In each instance, dig a small trench or hole into the pile approximately 1 ft deep and take the sample from the innermost part of the hole.
- Sampling tubes, if available, may be used instead of shovels.
- Take samples from these three points at several places around the stockpile.
- TTI will combine all 5 buckets upon receipt to form a composite sample.
- Seal buckets with the lids provided.
- Label buckets.

**Labeling Instructions**

Using a Sharpie marker or paint pen, please include the following on each bucket:

- District.
- Date stockpile arrived.
- Date bucket sample obtained.
- Material source (Martin Marietta or Vulcan).
- Material type.

**Storing Samples**

Please store samples out of the sun (inside a warehouse or lab if space is available) until TTI can pick them up. TTI will plan to pick up all of the samples at the time of the test section patch construction.