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16. Abstract

A task group was formed in late 1997 to evaluate the specifications and practices being used in northeast Texas districts in the construction of hot-mix asphaltic concrete pavements. Specifically, the objective of that task group was to determine if the implemented recommendations from a 1995 task group were effective in improving the performance of crushed gravel asphaltic pavements in that area of the state.

The task group selected and evaluated the performance of 35 pavements constructed using a wide variety of materials over the prior nine years. Seven of the pavements had been constructed in 1997, some of which had incorporated a number of the earlier task group recommendations.

Pavement performance evaluations in early 1998 included a visual distress survey, ground-penetrating radar analysis, pavement management information system data, and testing and visual evaluation of pavement cores.

The early age of pavements evaluated in the spring of 1998 prevented a definitive determination of the long-term performance of northeast Texas asphalt pavements. Therefore, the task force recommended evaluation of the performance of these sections in three years.

In the spring of 2001 the task force was reconvened to conduct the follow-up study on the 35 pavements evaluated in 1998. The task force was composed of personnel from Atlanta, Tyler, and Lufkin districts as well as representatives from Design and Construction Divisions, the Research and Technology Implementation Office, Texas Transportation Institute, and two consultants.

The study presented in this report indicates that many of the recommendations implemented in 1997 by the Atlanta District have resulted in improved pavement performance. Utilization of hydrated lime as an antistripping additive appears to have a positive influence on performance of the mixtures containing crushed siliceous river gravel. It is recommended that the findings of the 1995 task group be considered for implementation by all districts that use crushed siliceous river gravel in hot mix.

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A FOLLOW-UP EVALUATION OF HOT-MIX PAVEMENT PERFORMANCE IN NORTHEAST TEXAS

by

Maghsoud Tahmoressi, P.E.
President
PaveTex Engineering and Testing, Inc.
Dripping Springs, Texas

and

Tom Scullion
Research Engineer
Texas Transportation Institute

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. The engineers in charge were Magshoud Tahmoressi and Tom Scullion, P.E., (Texas, # 62683).

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Members of the task force were:

Paul Krugler, P.E., Chair, Research and Technology Implementation Office
James Joslin, P.E., Atlanta District
Miles Garrison, P.E., Atlanta District
Mike Anderson, P.E., Atlanta District
Chester Still, P.E., Lufkin District
Bill Willeford, P.E., Tyler District
Tracy Monds, P.E., Tyler District
Walter Smith, P.E., Tyler District
Kenneth W. Fults, P.E., Construction Division (Materials & Pavements)
Dale Rand, P.E., Construction Division (Materials & Pavements)
Tom Scullion, P.E., Texas Transportation Institute
Weldon E. Rudd, P.E., Consultant
Maghoud Tahmoressi, P.E., PaveTex Engineering and Testing, Inc.

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CHAPTER 1
INTRODUCTION

BACKGROUND

A joint industry-TxDOT task group was formed in late 1995 to identify issues associated with the unsatisfactory performance of hot-mix asphaltic concrete pavements made with crushed siliceous gravel aggregates in northeast Texas. The task force proposed solutions that would enable the use of these aggregates in highway construction. The findings of the task group are documented in "Recommendations for Improving Performance of Northeast Texas Asphaltic Concrete Pavements," dated September 1996. Table 1 provides a summary of those recommendations.

Table 1. Recommendation Prioritization.

Recommendations	Implementation
Develop tougher stripping test	Implemented by Atlanta District
Toughen field sand specification	Implemented by Atlanta District
Apply superpave PG binder specification	Implemented by Atlanta District
Require use of limestone screenings in lieu of crushed gravel screenings	Not implemented
Require use of asphalt polymers/modifiers	Implemented by Atlanta District
Incorporate edge drains in design of the pavement	Implemented by Atlanta District
Require antistrip agent use in all mixtures until tougher stripping test can be implemented	Implemented by Atlanta District
Insure compatibility of all components of hot mix	Not implemented
Properly pre-engineer rehabilitation and reconstruction projects to avoid stripping caused by trapped moisture in inlays	Implemented by Atlanta District
Adjust specification limits for retained on No. 10 sieve	Not implemented
Use Type D surface course gradations	Not implemented
Try mixture with no field sand and unwashed crushed gravel screenings	Not implemented

About a year later, the Atlanta District requested a follow-up study. The study was conducted by a TxDOT task force, and results were reported in a 1998 TxDOT departmental Research Report Number DHT-46 "An Evaluation of Factors Affecting Moisture Susceptibility of Pavements in Northeast Texas."(*1*) This study involved evaluating 35 roadway sections in northeast Texas for their moisture damage potential. Many of the roadway sections evaluated in 1998 were relatively young. Therefore, one of the recommendations of the 1998 study was to evaluate and core the roadway sections in three years in order to evaluate long-term performance. This recommendation was implemented, and the roadway sections were evaluated and cored in spring of 2001. This report contains the results of this evaluation.

The roadway sections evaluated in this study are the same sections evaluated in the 1998 project. Pictures and other records from the 1998 study were utilized to find exact core locations as in 1998. Cores were obtained from the outside of the wheel path of the outside lane from the same location as in 1998. Selected information about the pavement sections is shown in Table 2.

OBJECTIVES

The objective of this study was to determine if the trends in performance, particularly regarding the effectiveness of liquid antistripping agents and lime, were consistent over time for the pavements that were studied in 1998.

Table 2. Pavement Sections Evaluated in 2001.

District Project ID (Layer)	Highway	Aggregate Mineralogy		Antistripping Agent Type	Asphalt and Polymer	Age, Years
		Coarse	Screenings			
Atlanta - 1	US 67	Sil. Gravel	Sil. Gravel	Liquid	Kerr McGee AC-20	7
Atlanta - 2	US 67	Sil. Gravel	Sil. Gravel	Lime	Kerr McGee AC-20	6
Atlanta - 3	US 271	Sandstone	Sandstone	Liquid	Lion AC-20	6
Atlanta - 4	IH 30	Sil. Gravel	Sil. Gravel	Lime	Kerr McGee AC-10, 3% Latex	6
Atlanta - 5	FM 881	Limestone	Limestone	Liquid	Lion AC-10, 3% Latex	5
Atlanta - 6	US 59	Sil. Gravel	Sil. Gravel	Liquid	Exxon AC-10, 3% Latex	6
Atlanta - 7	IH 20	Sil. Gravel	Sil. Gravel	Liquid	Lion AC-20	7
Atlanta - 8	IH 30	Sandstone	Sandstone	Liquid	Lion AC-10, 3% Latex	5
Atlanta - 9	IH 20	Limestone	Limestone	Liquid	Lion AC-10, 3% Latex	5
Atlanta - 10	US 79	Quartzite	Quartzite	Lime	Lion AC-10, 3% Latex	5
Atlanta - 11	US 79	Igneous	Igneous	Lime	Lion AC-20	5
Atlanta - 12	SH 155	Sil. Gravel	Limestone	Lime	Lion AC-20	4
Atlanta - 13	FM 1397	Sil. Gravel	Sil. Gravel & Donnafill *	Lime	Lion AC-20	4
Atlanta - 14	SH 43	Sil. Gravel	Sil. Gravel	Lime	Fina AC-20	4
Atlanta - 15	US 271	Sandstone	Sandstone	Liquid	Lion AC-10, 3% Latex	4
Atlanta - 16	SH 11	Sandstone	Sandstone	Lime	Lion AC-20	4
Atlanta - 17(2)	US 59	Limestone & RAP	Limestone	Liquid	Lion AC-10	6
Atlanta - 18(2)	US 59	Sil. Gravel & RAP	Sil. Gravel	Liquid	Lion AC-10	5
Lufkin - 1	US 59	Sil. Gravel	Limestone	None	Star AC-20	Milled
Lufkin - 1(2)	US 59	Sil. Gravel	Limestone	None	Star AC-20	Milled
Lufkin - 2	SH 7	Sil. Gravel	Limestone	None	Star AC-20	10
Lufkin - 3	US 59	Limestone	Limestone & Bottom Ash	None	Exxon AC-20	5
Lufkin - 3(2)	US 59	Limestone	Limestone	None	Exxon AC-20	5
Lufkin - 4	US 259	Sil. Gravel	Limestone	Liquid	Exxon AC-20	Milled
Lufkin - 5	US 59	Sil. Gravel	Limestone	None	Star AC-20	10
Lufkin - 6	US 59	Sil. Gravel	Limestone	None	Star AC-20	8
Lufkin - 7	US 259	Sil. Gravel	Limestone	None	Asphalt Rubber	Milled
Lufkin - 8	Lp 224	Sil. Gravel	Limestone	Liquid	Lion AC-20	5
Lufkin - 8(2)	Lp 224	Sil. Gravel	Limestone	Liquid	Lion AC-20	6
Tyler - 1	US 69	Sil. Gravel	Limestone	Liquid	Star AC-10, 3% Latex	8
Tyler - 2	US 69	Sil. Gravel	Sil. Gravel	Liquid	Star AC-10, 3% Latex	8
Tyler - 3	SH 31	Sil. Gravel & RAP	Limestone	Lime	Lion PG 70-22, 3% Latex	4
Tyler - 4	US 69	Sandstone	Sandstone	None	Lion AC-20	9
Tyler - 5	SH 31	Limestone	Limestone	None	Elf AC-30P	12
Tyler - 6	US 79	Limestone	Limestone	Liquid	Lion AC-20	6
Tyler - 7	IH 20	Igneous	Igneous	Liquid	Lion AC-10, 3% Latex	6
Tyler - 8	US 271	Sil. Gravel	Sil. Gravel	Liquid	Star AC-10, 3% Latex	9
Tyler - 9	US 259	Sil. Gravel	Sil. Gravel	None	Star AC-20	9

*Note: Donnafill = Igneous Screening

CHAPTER 2
PERFORMANCE EVALUATION

FIELD PERFORMANCE EVALUATION

Team members visually evaluated the pavements in the spring of 2001. Prior to the visual evaluation by team members, districts located and marked the core locations from 1998. Pavement sections were evaluated for evidence of distresses such as rutting, cracking, raveling, or flushing. Table 3 gives a summary of these visual evaluations. A numeric score was determined to allow analysis of field performance information. Table 4 shows the deduct points associated with the various types and extents of distress. The field performance rating score was obtained by subtracting the sum of all distress deduct points from 100.

Appendix A contains the photographs taken at each site.

Table 3. Visual Condition Survey Results.

Project	Visual Condition Survey Results	Field Performance Rating
Lufkin - 1	Applied seal coat due to raveling and cracking- cores not taken	50
Lufkin - 2	Crack sealed	85
Lufkin - 3	Applied seal coat due to excessive cracking- cores not taken	70
Lufkin - 4	Outside lane milled and inlayed, has reflective cracking	40
Lufkin - 5	Severe cracking	70
Lufkin - 6	Recently overlaid, reflective cracking in overlay	55
Lufkin - 7	Outside lane milled and inlayed- cores not taken	40
Lufkin - 8	Segregation is visible in some areas	85
Tyler - 1	Good condition	100
Tyler - 2	Longitudinal cracking near joint	90
Tyler - 3	Cracks beginning to appear	95
Tyler - 4	Applied seal coat, slight rutting	65
Tyler - 5	Strip seal in wheel path	70
Tyler - 6	Slight rutting, otherwise in good condition	95
Tyler - 7	Many potholes, severe rutting and cracking	40
Tyler - 8	Applied seal coat	70
Tyler - 9	Applied seal coat, alligator cracks in some areas	55
Atlanta - 1	Block cracking, microsurfaced	70
Atlanta - 2	Applied seal coat, slight cracking	70
Atlanta - 3	Applied seal coat due to raveling, slight rutting	65
Atlanta - 4	No distresses, excellent condition	100
Atlanta - 5	No distresses, excellent condition	100
Atlanta - 6	Outside lane microsurfaced due to rutting, some cracks	80
Atlanta - 7	Microsurfaced, slight rutting, transverse cracks	70
Atlanta - 8	No distresses, excellent condition	100
Atlanta - 9	Microsurfaced due to loss of skid, no distresses	100
Atlanta - 10	Cracking and moderate rutting	70
Atlanta - 11	No distresses, loss of fines	95
Atlanta - 12	Slight reflective cracking, no rutting with many logging trucks	95
Atlanta - 13	Microsurfaced due to rutting, moderate rutting	85
Atlanta - 14	Longitudinal cracks, no rutting	95
Atlanta - 15	No distresses, excellent condition	100
Atlanta - 16	Severe cracking in segregated areas, no rutting	55
Atlanta - 17	Applied seal coat, slight rutting	65
Atlanta - 18	Microsurfaced due to rutting, has slight rutting	70

Table 4. Deduct Points for Visual Performance Ratings.

Type of Distress	Extent of Distress			
	None	Slight	Moderate	Severe
Cracking	0	5	15	30
Rutting	0	5	15	30
Flushing	0	5	15	30

PAVEMENT CORING

Cores were obtained from the outside of the wheel path of the outside lane at the same location as 1998 cores. Two 4-inch diameter cores and two 6-inch diameter cores were taken at each location. Four-inch diameter cores were taken for tensile strength testing, and 6-inch cores were taken for Hamburg testing.

VISUAL EVALUATION OF FRACTURED CORE FACES FOR MOISTURE DAMAGE

After conditioning and indirect tensile strength testing, as described in the next section, the freshly fractured surfaces of the cores were evaluated for evidence of stripping. Each core was scored from 1 to 5, with the highest score of 5 meaning that the core had no visual evidence of stripping, in the opinion of the evaluator. A rating of 1 indicates that the layer being evaluated was completely stripped, basically a pile of clean, asphalt-free aggregate. Each team member individually evaluated each core using this scoring system. The dry-conditioned and moisture-conditioned cores were evaluated separately.

Averages of the individual core ratings are presented in Table 5, which includes ratings for both 2001 and 1998 cores. As shown in this table, the ratings for 2001 are lower than from those 1998. The reduction in rating indicates deterioration in pavement condition caused by stripping.

CORE TESTING

The cores were sawed to separate the test layers from the remainder of the pavement sections. The sawed core layers were dried to a constant weight, and bulk specific gravity was determined for each layer, in accordance with Test Method Tex-207-F.

One 4-inch diameter core sample from each layer of interest was selected for moisture conditioning, while a second 4-inch core diameter sample was selected to be the unconditioned sample. The cores selected for conditioning were submerged in water at 77 °F, and a vacuum of 27.9 inches of Hg was pulled for a period of 30 minutes. After the vacuuming period, the samples were left submerged for 3 to 4 hours. They were then tested for indirect tensile strength in accordance with Test Method Tex-226-F. The dry cores were dried at ambient laboratory temperature for an extended period of time before testing. The dry core samples were brought to 77 °F by placing them in water-tight plastic bags and submerging them in the 77 °F water bath.

Table 5. Visual Stripping Rating of Core Fracture Surface of TSR Cores.

Project	Layer	Antistripping Agent Type	1998 Core Ratings		2001 Core Ratings	
			Dry	Wet	Dry	Wet
Lufkin – 1	1	None	3.4	2.5	Milled	Milled
Lufkin – 1	2	None	3.5	NA	Milled	Milled
Lufkin – 2	1	None	3.2	2.7	3.1	2.5
Lufkin – 3	1	None	4.9	4.8	4.7	4.5
Lufkin – 3	2	None	4.8	4.7	4.8	4.7
Lufkin – 4	1	Liquid	4.7	4.4	2.6	2.0
Lufkin – 5	1	None	3.8	3.0	3.1	2.2
Lufkin – 6	1	None	4.4	3.4	3.6	3.5
Lufkin – 7	1	None	2.5	1.8	Milled	Milled
Lufkin – 8	1	Liquid	4.2	3.1	2.8	2.5
Lufkin – 8	2	Liquid	4.3	3.2	3.6	3.3
Tyler – 1	1	Liquid	3.7	2.8	2.5	2.1
Tyler – 2	1	Liquid	4.5	3.3	3.7	2.7
Tyler – 3	1	Lime	4.7	4.4	3.7	3.6
Tyler – 4	1	None	4.2	4.0	3.8	3.7
Tyler – 5	1	None	4.7	4.5	3.7	3.5
Tyler – 6	1	Liquid	4.5	4.5	3.2	3.1
Tyler – 7	1	Liquid	3.9	3.4	3.3	2.8
Tyler – 8	1	Liquid	4.1	2.9	1.1	1.1
Tyler – 9	1	None	3.9	2.6	1.1	1.1
Atlanta – 1	1	Liquid	4.6	2.9	4.2	4.1
Atlanta – 2	1	Lime	4.2	4.1	4.0	4.0
Atlanta – 3	1	Liquid	4.9	4.7	4.2	4.2
Atlanta – 4	1	Lime	4.8	4.8	4.0	3.7
Atlanta – 5	1	Liquid	4.8	4.7	3.6	3.5
Atlanta – 6	1	Liquid	3.7	2.8	3.1	2.8
Atlanta – 7	1	Liquid	3.9	3.1	3.2	2.9
Atlanta – 8	1	Liquid	4.6	4.5	3.5	3.7
Atlanta – 9	1	Liquid	4.9	4.9	4.1	4.0
Atlanta – 10	1	Lime	4.9	4.8	3.7	3.5
Atlanta – 11	1	Lime	4.8	4.6	4.2	4.0
Atlanta – 12	1	Lime	4.8	4.6	3.7	3.5
Atlanta – 13	1	Lime	4.7	4.6	3.9	3.8
Atlanta – 14	1	Lime	4.7	4.2	3.9	3.6
Atlanta – 15	1	Liquid	5.0	4.6	4.0	3.9
Atlanta – 16	1	Lime	4.9	4.9	4.1	3.7
Atlanta – 17	2	Liquid	4.6	4.3	3.6	3.2
Atlanta – 18	2	Liquid	4.6	4.4	4.1	3.9

Note: Core ratings:
5 - no evidence of stripping observed.
1 - completely stripped (only clean aggregate obtained from coring).

They were likewise tested to failure under indirect tension. Table 5 shows the indirect tensile strengths from these single tests along with the calculated tensile strength ratios (TSRs). The TSR values determined in this study are not the same as the TSR values measured by Test Method Tex-531-C. This is due to differences in the conditioning method and core air voids.

The pavements had already densified under traffic when the pavements were cored in 1998; therefore, the cores from 2001 do not necessarily show any more densification than what had already taken place.

Two 6-inch diameter cores from each section were subjected to the Hamburg wheel tracking test in accordance with Test Method Tex-242-F. In this test, the specimen is subjected to repeated wheel tracking for 20,000 cycles or until the sample experiences 12.5 mm of rutting. The Hamburg wheel track test was conducted at 122 ^{o}F test temperature.

Table 7 shows the results of the Hamburg wheel tracking test. The test is stopped when either of the two end points is reached. Photographs of each core at the end of the Hamburg test are shown in Appendix B. As shown in Table 6, in some cases the rut depth reached 12.5 mm before 20,000 cycles. In those cases, the rut depth was estimated at 20,000 cycles using a straight-line approximation. Hamburg cores were visually evaluated after testing, and a stripping rating was assigned to each tested sample. The stripping rating of the Hamburg samples was conducted in the same manner as for the TSR samples and by the same group of individuals.

Table 6. Comparison of TSR and Core Air Voids.

Project	Layer	Antistripping Agent Type	1998 Cores: Air Voids of Cores, %	1998 Cores: TSR, %	2001 Cores: Air Voids of Cores, %	2001 Cores: Indirect Tensile Strength 77 °F, psi: Dry	2001 Cores: Indirect Tensile Strength 77 °F, psi: Wet	2001 Cores: TSR, %
Lufkin - 1	1	None		0.41				
Lufkin - 1	2	None						
Lufkin - 2	1	None	6.7	0.79	6.7	220	198	0.90
Lufkin - 3	1	None	1.7	0.97	1.0	300	304	1.00
Lufkin - 3	2	None	2.3	0.98	4.6	183	179	0.98
Lufkin - 4	1	Liquid	1.9	0.88	2.3	238	191	0.80
Lufkin - 5	1	None	5.7	0.55	4.6	223	207	0.93
Lufkin - 6	1	None	3.5	0.76	1.4	165	189	1.15
Lufkin - 7	1	None	3.1	0.55				
Lufkin - 8	1	Liquid	6.5	0.89	4.7	164	152	0.93
Lufkin - 8	2	Liquid	9.6	0.68	6.0	210	167	0.80
Tyler - 1	1	Liquid		0.42		160	108	0.68
Tyler - 2	1	Liquid	3.9	0.97	3.9	182	158	0.87
Tyler - 3	1	Lime	5.8	0.80	7.2	183	162	0.89
Tyler - 4	1	None	4.4	0.74	6.2	213	208	0.98
Tyler - 5	1	None		0.86		167	157	0.94
Tyler - 6	1	Liquid	4.4	0.94	5.3	225	188	0.84
Tyler - 7	1	Liquid		0.36		233	127	0.55
Tyler - 8	1	Liquid	2.4	0.35		*	*	
Tyler - 9	1	None	2.4	0.40		*	*	
Atlanta - 1	1	Liquid	1.9	0.53	3.8	226	221	0.98
Atlanta - 2	1	Lime	2.6	1.21	5.2	177	147	0.83
Atlanta - 3	1	Liquid	3.8	0.88	3.4	253	302	1.19
Atlanta - 4	1	Lime	4.2	0.99	4.4	111	95	0.86
Atlanta - 5	1	Liquid	6.5	0.80	7.3	190	170	0.89
Atlanta - 6	1	Liquid	4.0	0.80	1.4	189	155	0.82
Atlanta - 7	1	Liquid	0.9	0.66	2.0	250	186	0.74
Atlanta - 8	1	Liquid	4.4	0.51	3.9	267	198	0.74
Atlanta - 9	1	Liquid	6.1	1.10	6.4	190	150	0.79
Atlanta - 10	1	Lime		0.83		143	127	0.89
Atlanta - 11	1	Lime	2.4	0.86	1.6	248	231	0.93
Atlanta - 12	1	Lime	4.9	1.06	3.0	194	244	1.26
Atlanta - 13	1	Lime	6.0	0.95	4.2	198	177	0.89
Atlanta - 14	1	Lime	10.5	0.58	7.9	238	178	0.75
Atlanta - 15	1	Liquid	1.7	0.88	0.6	154	139	0.90
Atlanta - 16	1	Lime	8.3	0.94	7.0	191	188	0.98
Atlanta - 17	2	Liquid	5.6	0.90	8.0	169	157	0.93
Atlanta - 18	2	Liquid	4.3	1.19	4.2	172	143	0.83

* Cores were not taken.

Table 7. Hamburg Results.

Project	Layer	Antistripping Agent Type	Hamburg Results mm Rut Depth or No. of Cycles to Reach 12.5 mm	Estimated Hamburg Rut Depth at 20,000 Cycles	Hamburg Visual Rating
Lufkin - 1	1	None	Milled	Milled	NA
Lufkin - 1	2	None	None	Milled	NA
Lufkin – 2	1	None	12200	20.5	1.8
Lufkin –3	1	None	4200	59.5	NA
Lufkin - 3	2	None	10.5	10.5	NA
Lufkin – 4	1	Liquid	5700	43.9	1.6
Lufkin – 5	1	None	13700	18.2	1.6
Lufkin – 6	1	None	15800	15.8	2.0
Lufkin – 7	1	None	Milled	Milled	NA
Lufkin – 8	1	Liquid	6.2	6.2	NA
Lufkin –8	2	Liquid	3000	83.3	NA
Tyler – 1	1	Liquid	13000	19.2	1.8
Tyler – 2	1	Liquid	4400	56.8	1.8
Tyler – 3	1	Lime	6.1	6.1	3.5
Tyler – 4	1	None	10.3	10.3	3.9
Tyler – 5	1	None	19200	13.0	3.1
Tyler – 6	1	Liquid	8.0	80	3.4
Tyler – 7	1	Liquid	6900.0	36.2	2.4
Tyler – 8	1	Liquid	No Cores*	No Cores*	NA
Tyler – 9	1	None	No Cores*	No Cores*	NA
Atlanta – 1	1	Liquid	8.1	8.1	3.8
Atlanta – 2	1	Lime	2.1	2.1	4.3
Atlanta – 3	1	Liquid	4.7	4.7	3.9
Atlanta – 4	1	Lime	0.6	0.6	4.3
Atlanta – 5	1	Liquid	8.9	8.9	3.3
Atlanta – 6	1	Liquid	15100	16.6	1.7
Atlanta – 7	1	Liquid	13500	18.5	2.0
Atlanta – 8	1	Liquid	1.0	1.0	4.3
Atlanta – 9	1	Liquid	0.6	0.6	4.2
Atlanta – 10	1	Lime	8.0	8.0	3.0
Atlanta – 11	1	Lime	1.8	1.8	4.2
Atlanta – 12	1	Lime	2.5	2.5	3.9
Atlanta – 13	1	Lime	4.8	4.8	NA
Atlanta – 14	1	Lime	1.3	1.3	3.5
Atlanta – 15	1	Liquid	3.0	3.0	4.2
Atlanta – 16	1	Lime	1.3	1.3	4.2
Atlanta – 17	2	Liquid	18000	13.9	2.5
Atlanta – 18	2	Liquid	11.2	11.2	3.5

Note *: 6-inch cores disintegrated upon retrieval
* 25.4 mm = 1 inch

CHAPTER 3
EVALUATION OF INFORMATION

ANALYSIS OF FACTORS AFFECTING MOISTURE SUSCEPTIBILITY OF PAVEMENTS

The data collected during this follow-up study were analyzed by grouping the pavement sections with similar characteristics and evaluating the visual stripping ratings, dry and wet strength, TSR and Hamburg results. As mentioned previously in Chapter 2 of this report, the moisture conditioning technique used in this study is not the same as the one used in Test Method Tex-531-C, and the results are not comparable.

COARSE AGGREGATE MINERALOGY

Table 8 shows comparisons of pavement layers containing different mineralogies of coarse aggregate.

Table 8. Coarse Aggregate Mineralogy Comparison.

Coarse Aggregate Mineralogy	No. of Projects	Stripping Ratings of Cores		Air Voids of Cores, %	Indirect Tensile Str. 77 °F, psi		TSR	Hamburg Rut Depth @ 20,000 Cycles	Average Age, Years	Visual Performance Rating
		Dry	Wet		Dry	Wet				
Gravel	23	3.3	2.9	4.3	194	171	0.88	18.7	6.7	74
Limestone	7	4.0	3.8	5.4	203	186	0.91	16.4	6.3	81
Sandstone	5	3.9	3.8	4.2	216	207	0.96	4.0	5.6	77

There were also two mixtures containing igneous coarse aggregate and one containing quartzite. These are not included because there was not enough representation to adequately evaluate these aggregate types. As shown in Table 7, there are far more mixtures containing siliceous gravel coarse aggregates in this study than any other aggregate type. Mixtures containing gravel coarse aggregates showed lower performance properties, as indicated by the stripping rating of the cores, TSR, Hamburg rut depth, and visual pavement rating, than limestone or sandstone mixtures.

Table 8 shows the influence of antistripping additives on performance indicators for siliceous gravel and limestone mixtures. As shown in this table, gravel mixtures containing lime had better performance in terms of the stripping rating of cores, TSR, Hamburg rut depth, and visual pavement rating than those that contained liquid antistripping additives or no additives. The only exception is for gravel mixtures without any additives, which show an average TSR of

0.99, as shown in Table 9. However, gravel mixes without any additive showed a high failure rate, four projects out of seven. The TSR values shown in Table 9 are the average values for pavements that did not fail. Therefore, the average TSR of 0.99 is not an accurate representation of performance of gravel mixtures without any additives.

Table 9. Coarse Aggregate Mineralogy and Additive Type Comparison.

Coarse Aggregate Mineralogy	Additive	No. of Projects	Stripping Ratings of Cores		Air Voids of Cores, %	Indirect Tensile Str. 77 °F, psi		TSR	Hamburg Rut Depth @ 20,000 Cycles	Average Age, Years	Performance Visual Rating
			Dry	Wet		Dry	Wet				
Gravel	Lime	6	3.9	3.7	5.3	184	167	0.91	2.9	4.7	90
Gravel	Liquid	10	3.1	2.7	3.5	199	165	0.82	29.3	6.5	76
Gravel	None	7	2.7	2.3	4.2	203	198	0.99	18.2	8.7	58
Limestone	Liquid	4	3.6	3.5	6.8	194	166	0.86	7.9	5.5	90
Limestone	None	3	4.4	4.2	2.8	217	213	0.98	27.7	7.3	70

Note: four of the seven projects using gravel without any antistripping additives exhibited failures, which required major rehabilitation, including milling. These TSR values reflect data only from the remaining pavement sections.

Gravel mixtures with liquid antistripping additives performed better than those mixtures without any additive.

Limestone mixtures with liquid antistripping additives performed better than limestone mixtures without any additives in terms of Hamburg test results and field evaluation. However, in terms of stripping rating of the cores and TSR, limestone mixtures without liquid antistripping additives performed better. The field condition survey indicated that the three projects containing limestone mixture without any additives exhibited severe cracking, and they all required application of seal coat. The four projects with liquid additives did not show any signs of cracking. Two of these four projects exhibited slight rutting. In summary, limestone mixtures with liquid antistripping additive showed less cracking but more rutting than limestone mixtures without any liquid additive.

There were no limestone mixtures with lime in this data set. Therefore, a direct comparison of lime and liquid antistripping additives with limestone mixtures could not be made.

Table 10 contains a summary of performance indicators for 4 to 6 year old projects. As shown in this table, there are no gravel with no additive or limestone coarse aggregate pavements with lime in this age group. For mixtures containing gravel coarse aggregate, those containing lime had better performance indicators than those containing liquid additives. For mixtures containing limestone coarse aggregates, liquid antistripping additives improved performance indicators compared to mixtures without any additive.

Table 10. Comparison of Coarse Aggregate Mineralogy and Additive Type for 4-6 Year Old Projects.

Coarse Aggregate Minerology	Additive	No. of Projects	Stripping Rating of Cores		Air Voids of Cores, %	Indirect Tensile Str. 77 °F, psi		TSR	Hamburg Rut Depth @ 20,000 Cycles	Age, Years	Visual Performance Rating
			Dry	Wet		Dry	Wet				
Gravel	Lime	6	3.87	3.70	5.3	185	167	0.91	2.90	4.7	90
Gravel	Liquid	5	3.24	2.90	3.7	195	162	0.84	32.23	5.2	72
Gravel	None	0									
Limestone	Lime	0									
Limestone	Liquid	4	3.63	3.45	6.8	194	166	0.86	7.85	5.5	90
Limestone	None	2	4.75	4.6	2.8	242	24	1.00	35.01	5.0	70

A direct comparison of the effects of lime and liquid additives on performance indicators is shown in Table 11 for 4 to 6 year old gravel projects. As shown in this table, mixtures containing lime performed better than mixtures containing liquid additives for all performance indicators.

Table 11. Comparison of 4-6 Year Old Projects with Lime To 4-6 Year Old Projects with Liquid.

Coarse Aggregate Minerology	Additive	No. of Projects	Stripping Ratings of Cores		Air Voids of Cores, %	Indirect Tensile Str. 77 °F, psi		TSR	Hamburg Rut Depth @ 20,000 Cycles	Age, Years
			Dry	Wet		Dry	Wet			
Gravel	Lime	6	3.87	3.70	5.32	183	167	0.91	2.90	4.67
Gravel	Liquid	5	4.2	3	2.3	169	98	0.58	NA	4.8

Note: data for 4-6 year old liquid projects were obtained from the DHT-46 report.

SCREENING MINERALOGY

Available data were analyzed to determine if mineralogy of screenings had a significant effect on stripping susceptibility of mixtures containing gravel coarse aggregates. Table 12 shows the comparison of properties of gravel mixtures containing gravel and limestone screenings.

Within each screening type, the influence of antistripping additive is shown in Table 12. In general, mixtures containing gravel screenings performed better when lime was used as an antistripping additive as opposed to liquid additives. Mixtures containing limestone screenings also performed better with lime additive than with liquid additives.

Table 12. Influence of Antistripping Additives on Mixtures Containing Gravel Coarse Aggregates.

Screening Mineralogy	Additives	No. of Projects	Stripping rating of Cores		Air Voids of Cores, %	Indirect Tensile Str. 77°F, psi		TSR	Hamburg Rut Depth @ 20,000 Cycles	Age, Years	Visual
			Dry	Wet		Dry	Wet				
Gravel	Lime	4	4.0	3.8	5.4	181	149	0.83	2.2	5.0	88
Gravel	Liquid	6	3.2	2.9	3.1	204	173	0.85	22.2	7.0	75
Limestone	Lime	2	3.7	3.6	5.1	189	203	1.07	4.3	4.0	595
Limestone	Liquid	4	2.9	2.5	4.3	193	155	0.80	38.2	5.8	78
Limestone	none	7	2.7	2.3	4.2	203	198	0.99	18.2	8.7	58

Based on evaluation of data presented in Table 12, mixtures containing gravel and limestone screenings appear to have comparable properties.

ASPHALTS - UNMODIFIED VERSUS LATEX MODIFICATION OF ASPHALT

Styrene butadiene rubber (SBR) latex was the predominant type of latex used in the projects included in this study. Table 13 shows a comparison of mixtures containing unmodified AC-20 and latex-modified asphalts. As the table shows, latex-modified asphalt mixtures using crushed gravel performed slightly worse than unmodified asphalt mixtures. Somewhat surprisingly, for both limestone and crushed gravel coarse aggregate mixtures, even the dry tensile strengths of the polymer-modified asphalt mixtures were lower than the dry tensile strengths of unmodified asphalt mixtures. Latex modification appears to improve resistance to rutting of limestone mixtures, as indicated by Hamburg test results. The latex-modified mixes also had a substantially better visual condition rating. The average rating for pavements with gravel mixes increased from 71 to 89 and that for pavements with limestone from 78 to 100. From Table 3, six sections in the study had a perfect performance rating of 100. Each one of these used a latex-modified binder.

Table 13. Effects of Latex Modification.

Polymer Additive	Coarse Aggregate	No. of Projects	Stripping rating of Cores		Air Voids of Cores, %	Indirect Tensile Str. 77°F, psi		TSR	Hamburg Rut Depth @ 20,000 Cycles	Age, Years	Visual
			Dry	Wet		Dry	Wet				
None	Gravel	15	3.3	3.0	4.3	209	188	0.91	18.8	6.7	71
None	Limestone	3	4.2	4.1	3.6	236	224	0.94	26.0	5.3	78
Latex	Gravel	6	3.0	2.7	4.2	165	136	0.82	19.9	6.8	89
Latex	Limestone	2	3.9	3.8	6.9	190	160	0.84	4.8	5.0	100

EVALUATION OF HAMBURG DATA

Table 14 shows groupings of Hamburg rut depth in order of increasing rut depth. In this table the data is separated into three groups. The first group contains all of the pavements that had less than 5 mm rut depth. The second group shows pavements with a rut depth of more than 5 mm, but less than 12.5 mm. The third group contains all projects with more than 12.5 mm rut depth. Currently, the maximum allowable rut depth that indicates acceptable performance is 12.5 mm.

The majority of pavements in the first group (less than 5 mm rut depth) contained lime. Only two pavements with lime did not fall in this group. These two pavements had 6.1 and 8.0 mm of rutting, two of the better performers in the second group.

The pavements in the second group (rut depth between 5 and 12.5 mm) displayed more distresses than the first group. The distresses were mostly of a cracking nature.

The pavements in the third group had the lowest average visual performance rating of the three groups. Of the 18 projects in this group, 15 used crushed siliceous gravel coarse aggregates. Half of these pavements used liquid antistripping additives, and the other half did not use any additives. None of the sections that used lime fell into this bottom group.

Table 14. Hamburg Test Results Sorted in Order of Ascending Hamburg Rut Depth.

Project	Layer	Hamburg Rut Depth @ 20,000 Cycles	years	Visual Performance Rating	Antistrip Agent	Coarse Aggregate Mineralogy	Screening Mineralogy
Atlanta - 4	1	0.6	6	100	Lime	Gravel	Gravel
Atlanta - 9	1	0.6	5	100	Liquid	Limestone	Limestone
Atlanta - 8	1	1.0	5	100	Liquid	Sandstone	Sandstone
Atlanta - 14	1	1.3	4	95	Lime	Gravel	Gravel
Atlanta - 16	1	1.3	4	55	Lime	Sandstone	Sandstone
Atlanta - 11	1	1.8	5	95	Lime	Igneous	Igneous
Atlanta - 2	1	2.1	6	70	Lime	Gravel	Gravel
Atlanta - 12	1	2.5	4	95	Lime	Gravel	Limestone
Atlanta - 15	1	3.0	4	100	Liquid	Sandstone	Sandstone
Atlanta - 3	1	4.7	6	65	Liquid	Sandstone	Sandstone
Atlanta - 13	1	4.8	4	85	Lime	Gravel	Gravel
Average		**2.2**	**4.8**	**87.3**			
Tyler - 3	1	6.1	4	95	Lime	Gravel	Limestone
Lufkin - 8	1	6.2	5	85	Liquid	Gravel	Limestone
Atlanta - 10	1	8.0	5	70	Lime	Quartzite	Quartzite
Tyler - 6	1	8.0	6	95	Liquid	Limestone	Limestone
Atlanta - 1	1	8.1	7	70	Liquid	Gravel	Gravel
Atlanta - 5	1	8.9	5	100	Liquid	Limestone	Limestone
Tyler - 4	1	10.3	9	65	None	Sandstone	Sandstone
Lufkin - 3	2	10.5	5	70	None	Limestone	Limestone
Atlanta - 18	2	11.2	5	70	Liquid	Gravel	Gravel
Average		**8.6**	**5.7**	**80.0**			
Tyler - 5	1	13.0	12	70	None	Limestone	Limestone
Atlanta - 17	2	13.9	6	65	Liquid	Limestone	Limestone
Lufkin - 6	1	15.8	8	55	None	Gravel	Limestone
Atlanta - 6	1	16.6	6	80	Liquid	Gravel	Gravel
Lufkin - 5	1	18.2	10	70	None	Gravel	Limestone
Atlanta - 7	1	18.5	7	70	Liquid	Gravel	Gravel
Tyler - 1	1	19.2	8	100	Liquid	Gravel	Limestone
Lufkin - 2	1	20.5	10	85	None	Gravel	Limestone
Tyler - 7	1	36.2	6	40	Liquid	Igneous	Igneous
Lufkin - 4	1	43.9	4	40	Liquid	Gravel	Limestone
Tyler - 2	1	56.8	8	90	Liquid	Gravel	Gravel
Lufkin - 3	1	59.5	5	70	None	Limestone	Limestone
Lufkin - 8	2	83.3	6	85	Liquid	Gravel	Limestone
Tyler - 8	1		9	70	Liquid	Gravel	Gravel
Lufkin - 1	2		9	50	None	Gravel	Limestone
Lufkin - 7	1		7	40	None	Gravel	Limestone
Tyler - 9	1		9	55	None	Gravel	Limestone
Lufkin - 1	1		8	50	None	Gravel	Limestone
Average	**18**	**32.0**	**7.7**	**65.8**			

CHAPTER 4
RECOMMENDATIONS AND CONCLUSIONS

Based on evaluation of laboratory test results, visual stripping ratings of cores, and field performance of the 35 northeast Texas pavements, the following conclusions are made.

CONCLUSIONS

1. Siliceous gravel mixtures containing lime performed very well under a variety of conditions.
2. Mixtures containing siliceous gravel screenings and limestone screenings appeared to have similar performance properties as measured in this study.
3. Limestone mixtures with liquid antistripping additives performed well and better than limestone mixtures without any additive. Limestone mixtures with lime were not evaluated in this study.
4. The use of latex improved pavement performance.
5. Hamburg test results correlated with visual pavement condition ratings.

RECOMMENDATIONS

The findings of this project indicate that many of the recommendations of the 1995 task group, which were implemented in the Atlanta District, resulted in improved pavement performance. Lime additive should be required when siliceous river gravel is used. The researchers recommend that the following findings of the 1995 task group be considered for implementation by districts that use siliceous crushed river gravel:

1. Use lime additive with siliceous river gravel mixtures.
2. Remove the specification requirement prohibiting use of siliceous gravel screenings.
3. Consider establishing Hamburg criteria for all mixture types.

REFERENCES

1. "An Evaluation of Factors Affecting Moisture Susceptibility of Pavements in Northeast Texas," TxDOT departmental Research Report Number DHT-46, Volume 1, 1998.

APPENDIX A

PHOTOGRAPHS OF PAVEMENT CONDITION

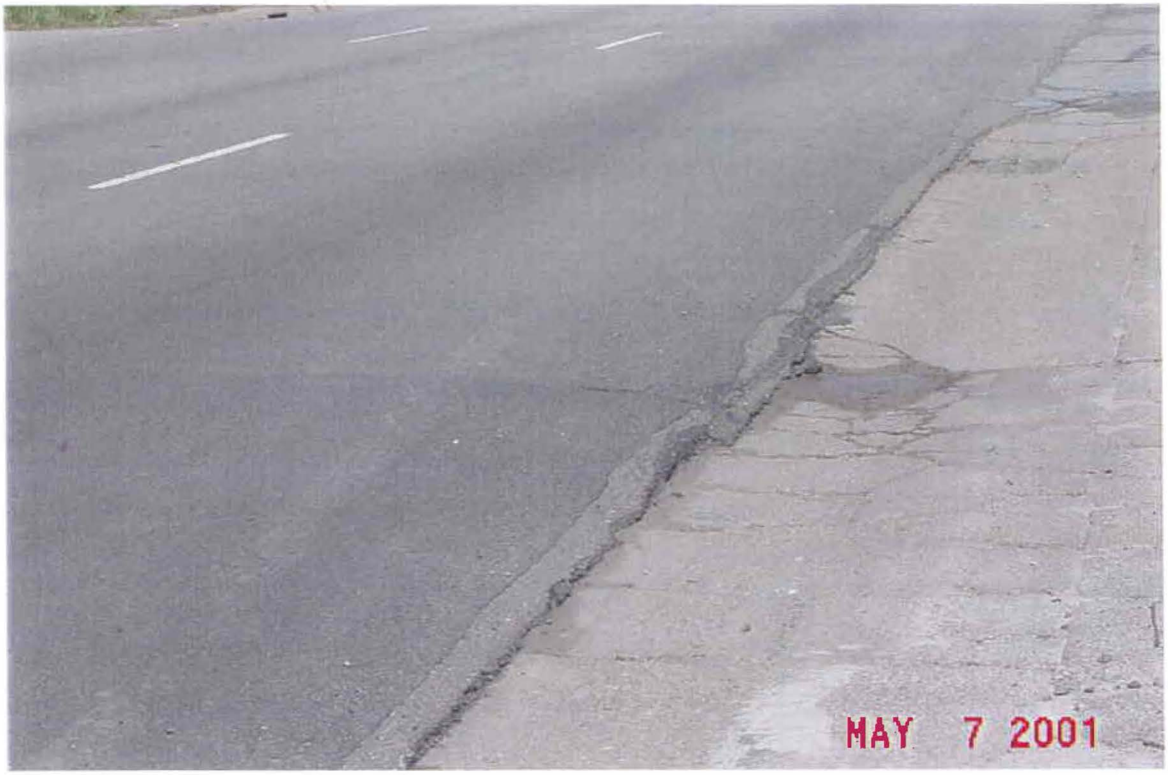


Figure A1. Atlanta Section 1 (US 67).

Figure A2. Atlanta Section 2 (US 67).

Figure A3. Atlanta Section 3 (US 67). No Photographs Taken, Section has been Overlaid. Core Locations Could Not be Found.

Figure A4. Atlanta Section 4 (IH 30).

Figure A5. Atlanta Section 5 (FM 881).

Figure A6. Atlanta Section 6 (US 59).

Figure A7. Atlanta Section 7 (IH 20).

Figure A8. Atlanta Section 8 (IH 30).

Figure A9. Atlanta Section 9 (IH 20).

Figure A10. Atlanta Section 10 (US 79).

Figure A11. Atlanta Section 11 (US 79).

Figure A12. Atlanta Section 12 (SH 155).

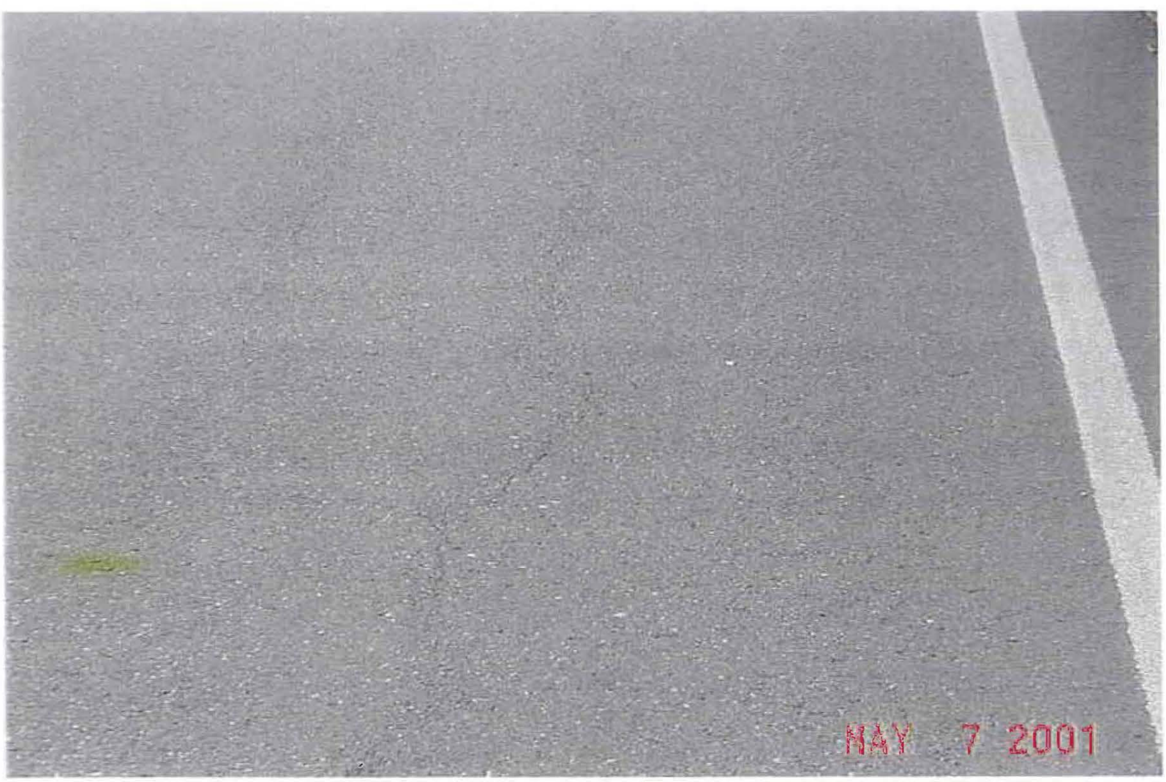


Figure A13. Atlanta Section 13 (FM 1397).

Figure A14. Atlanta Section 14 (SH 43).

Figure A15. Atlanta Section 15 (US 271).

Figure A16. Atlanta Section 16 (SH 11).

Figure A17. Atlanta Section 17(2) (US 59).

Figure A18. Atlanta Section 18(2) (US 59).

Figure A19. Lufkin Section 2 (SH 7).

Figure A20. Lufkin Section 3 (US 59).

Figure A21. Lufkin Section 4 (US 259).

Figure A22. Lufkin Section 5 (US 59).

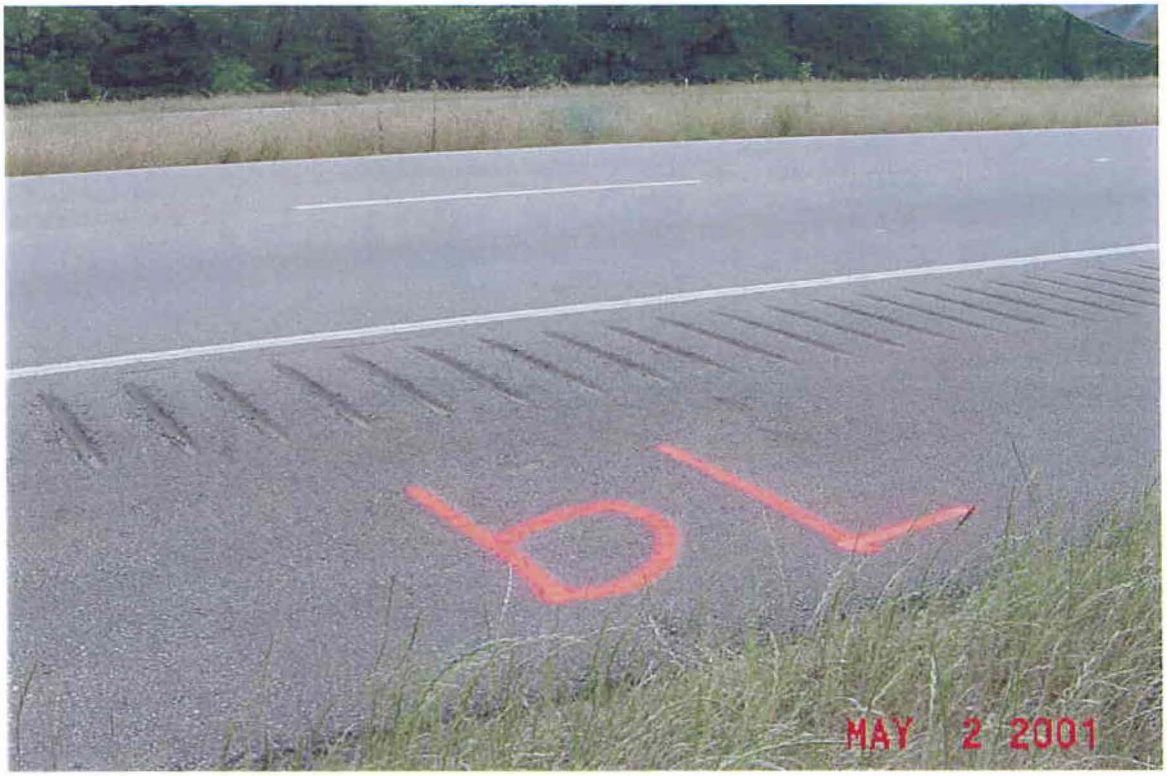


Figure A23. Lufkin Section 6 (US 59).

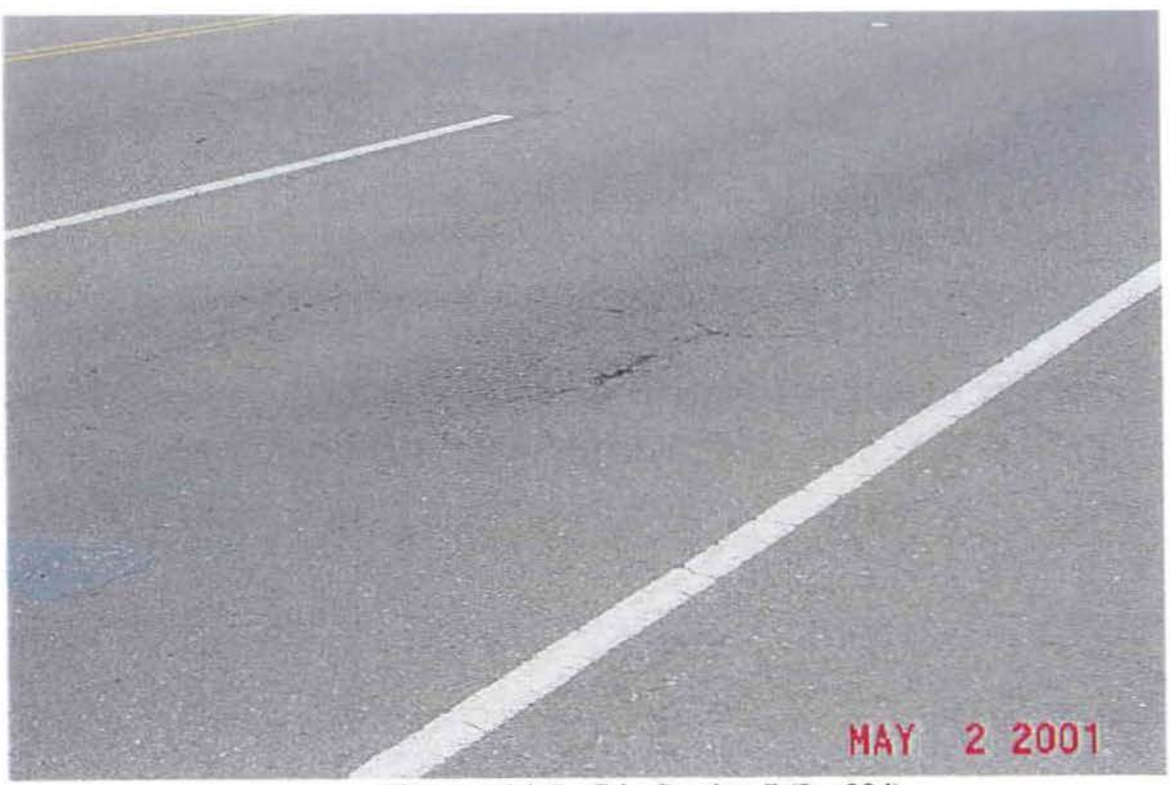


Figure A24. Lufkin Section 7 (Lp 224).

Figure A25. Tyler Section 1 (US 69).

Figure A26. Tyler Section 2 (US 69).

Figure A27. Tyler Section 3 (SH 31).

Figure A28. Tyler Section 4 (US 69).

Figure A29. Tyler Section 5 (SH 31).

Figure A30. Tyler Section 6 (US 79).

Figure A31. Tyler Section 7 (IH 20).

Figure A32. Tyler Section 8 (US 271).

Figure A33. Tyler Section 9 (US 259).

APPENDIX B

PHOTOGRAPHS OF CORES AFTER HAMBURG AND TSR TESTS

Figure B1. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 1 – US 67).

Figure B2. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 2 – US 67).

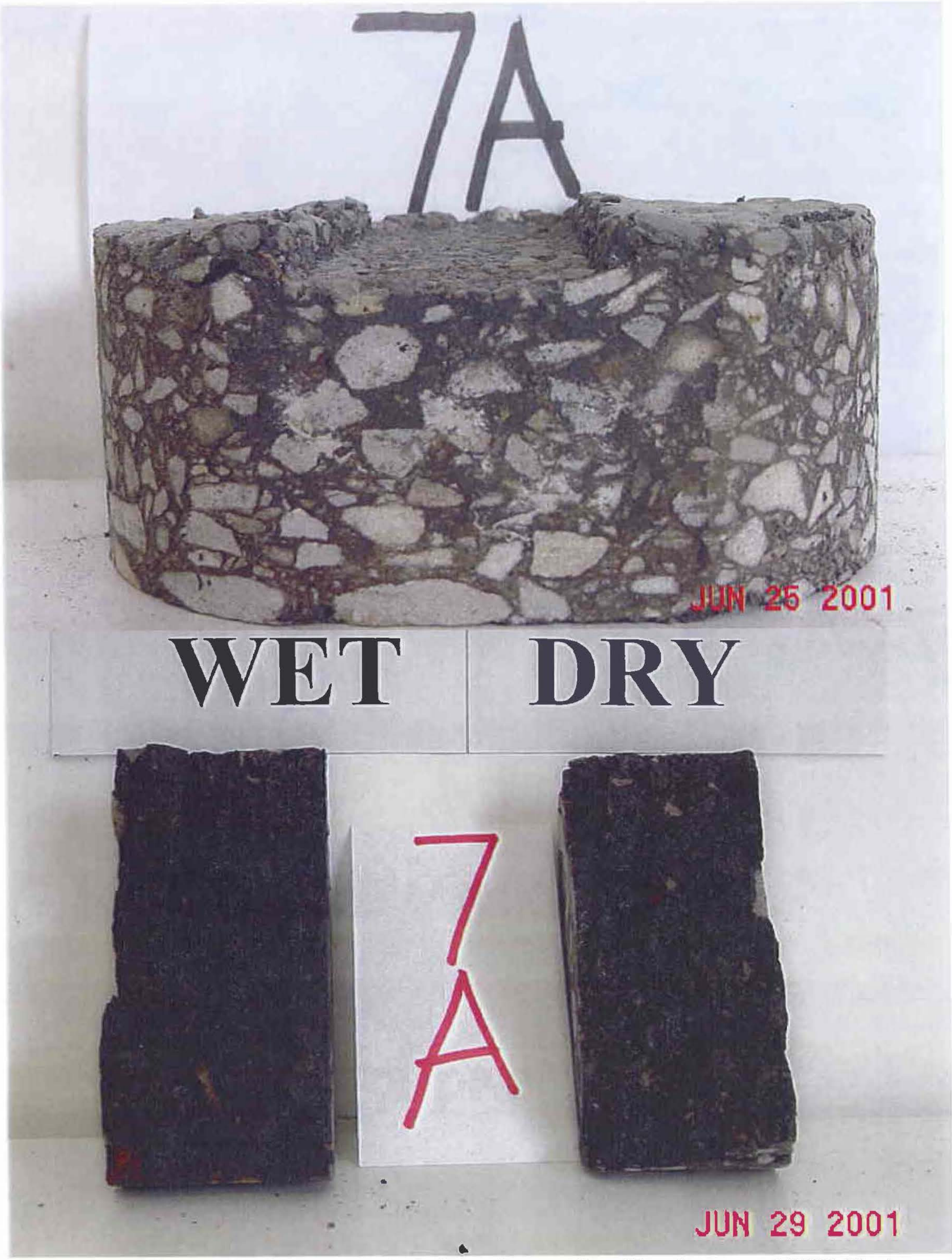


Figure B3. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 3 – US 271).

Figure B4. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 4 – IH 30).

Figure B5. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 5 – FM 881).

Figure B6. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 6 – US 59).

Figure B7. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 7 – IH 20).

Figure B8. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 8 – IH 30).

Figure B9. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 9 – IH 20).

Figure B10. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 10 – US 79).

Figure B11. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 11 – US 79).

Figure B12. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 12 – SH 155).

Figure B13. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 13 – FM 1397).

Figure B14. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 14 – SH 43).

Figure B15. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 15 – US 271).

Figure B16. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 16 – SH 11).

Figure B17. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 17(2) – US 59).

Figure B18. Photographs of the Cores after Hamburg and TSR Tests (Atlanta – Section 18(2) – US 59).

Figure B19. Photographs of the Cores after Hamburg and TSR Tests (Lufkin – Section 2 – SH 7).

Figure B20. Photographs of the Cores after Hamburg and TSR Tests (Lufkin – Section 3 – US 59).

Figure B21. Photographs of the Cores after Hamburg and TSR Tests (Lufkin – Section 4 – US 259).

Figure B22. Photographs of the Cores after Hamburg and TSR Tests (Lufkin – Section 5 – US 59).

Figure B23. Photographs of the Cores after Hamburg and TSR Tests (Lufkin – Section 6 – US 59).

Figure B24. Photographs of the Cores after Hamburg and TSR Tests (Lufkin – Section 8 – Lp 224).

Figure B25. Photographs of the Cores after Hamburg and TSR Tests (Tyler – Section 1 – US 69).

Figure B26. Photographs of the Cores after Hamburg and TSR Tests (Tyler – Section 2 – US 69).

Figure B27. Photographs of the Cores after Hamburg and TSR Tests (Tyler – Section 3 – SH 31).

Figure C28. Photographs of the Cores after Hamburg and TSR Tests (Tyler – Section 4 – US 69).

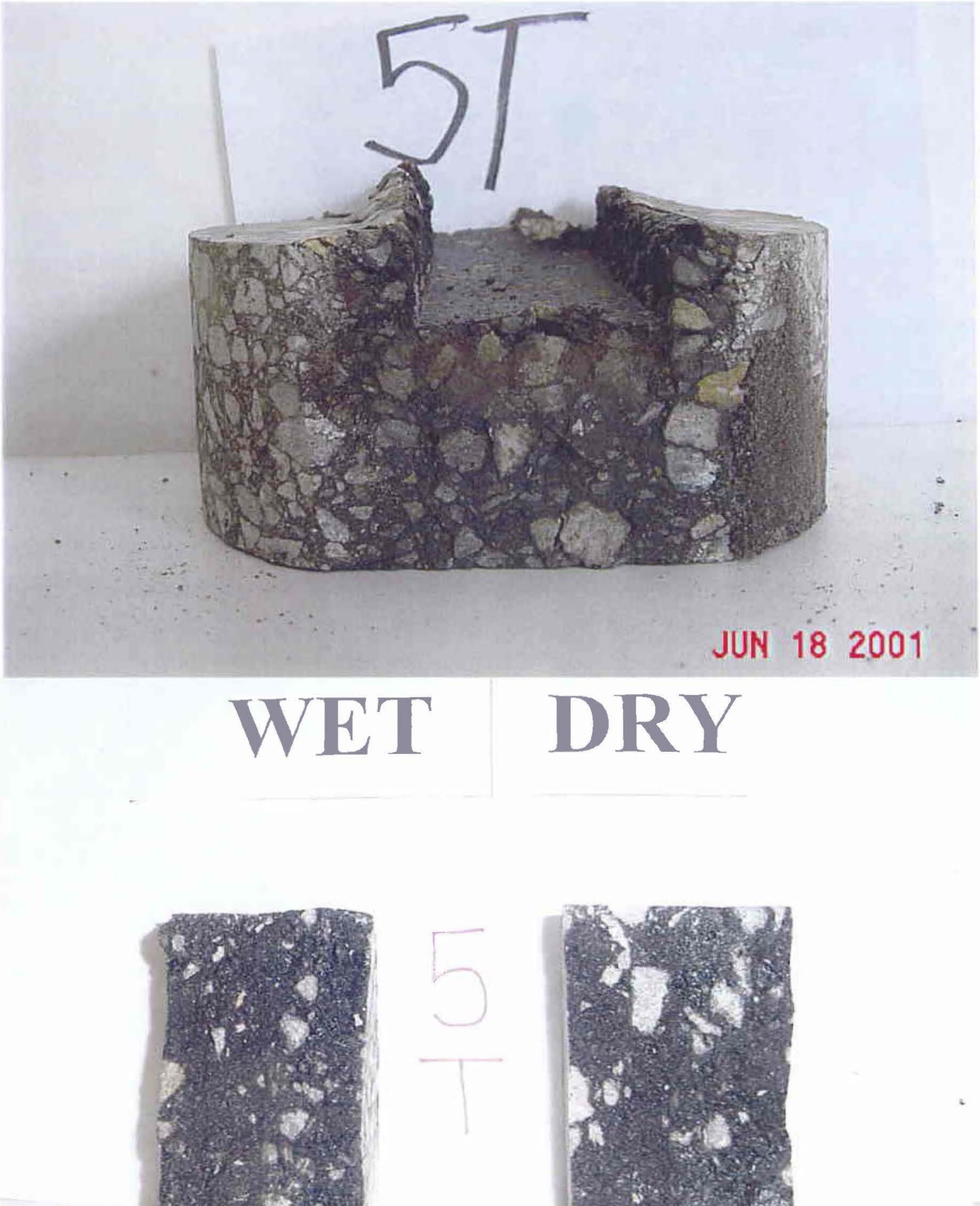
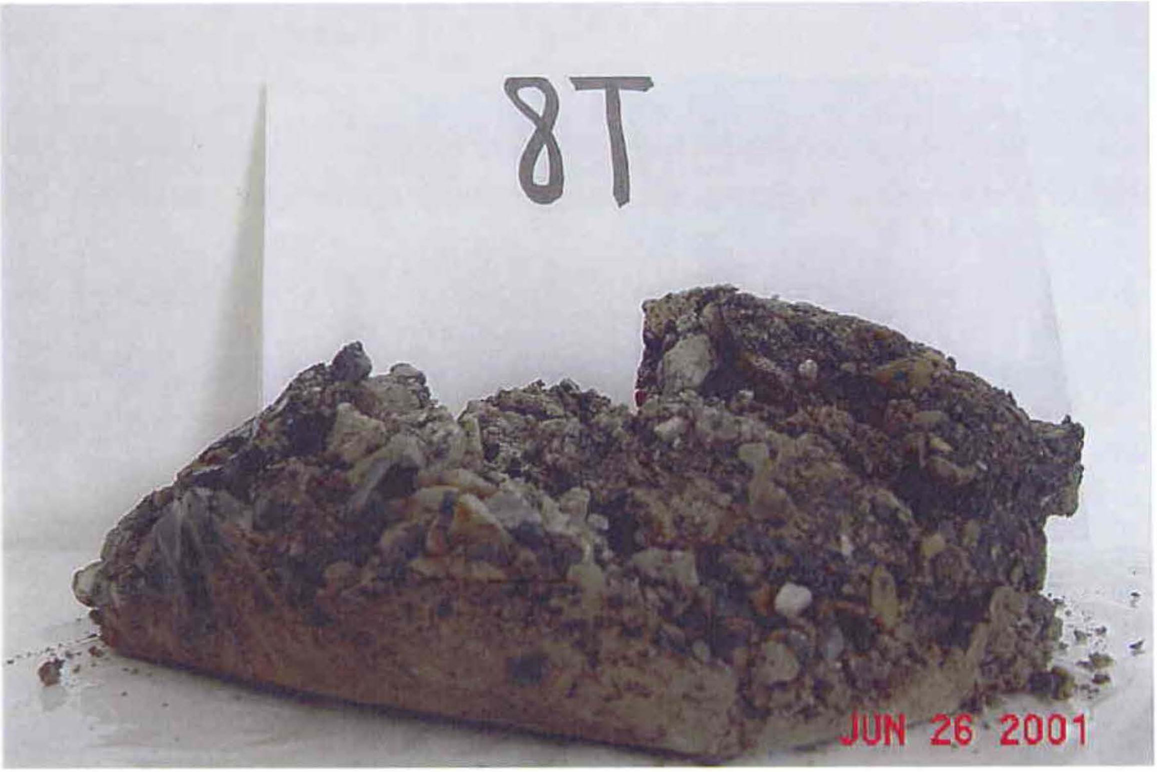


Figure B29. Photographs of the Cores after Hamburg and TSR Tests (Tyler – Section 5 – SH 31).

Figure B30. Photographs of the Cores after Hamburg and TSR Tests (Tyler – Section 6 – US 79).

Figure B31. Photographs of the Cores after Hamburg and TSR Tests (Tyler – Section 7 – IH 20).



Note: No TSR sample available.

Figure B32. Photographs of the Cores after Hamburg and TSR Tests (Tyler – Section 8 – US 271).

Note: No TSR sample available.

Figure B33. Photographs of the Cores after Hamburg and TSR Tests (Tyler – Section 8 – US 250).