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The results of this task group were originally submitted to Charles W. Heald, P.E., TxDOT Executive Director.

16. Abstract

TxDOT formed a task group late in 1997 to evaluate hot mix construction specifications and practices being used in northeast Texas districts. The objective was to determine if the implemented recommendations from an earlier task group were effective in improving the performance of crushed gravel asphaltic pavements.

The group selected and evaluated 35 pavements constructed during the prior nine years in which a wide variety of materials had beed used. Seven of the pavements had been constructed in 1997. Some of these pavements incorporated the recommendations of the earlier task group.

Evaluations of these pavements confirmed that pavements made with crushed gravel coarse aggregates are significantly more susceptible to moisture damage than either limestone or sandstone coarse aggregate asphaltic pavements. Crushed gravel coarse aggregate pavements treated with lime showed less stripping than those treated with liquid antistripping agents. However, the long-term effectiveness of lime treatment as an antistripping agent could not be determined because lime-treated mixtures of adequate age were not available to the group.

Based on the limited data available in this study, there is no apparent benefit from the use of liquid antistrip agents in limestone asphaltic pavements.

The incorporation of an additional sand equivalent requirement specifically for field sand dramatically improved the quality of the field sands being used.

The task group recommends that all 35 pavements be reevaluated in three years.

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AN EVALUATION OF FACTORS AFFECTING MOISTURE SUSCEPTIBILITY OF PAVEMENTS IN NORTHEAST TEXAS

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EXECUTIVE SUMMARY

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 was to determine if the implemented recommendations from an earlier task group were effective in improving the performance of crushed gravel asphaltic pavements in that area of the state. Details of these recommendations are found in Appendix A.

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 incorporated a number of the earlier task group recommendations.

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

The early age of pavements constructed in 1997 prevented a definitive determination of the long-term effectiveness of changes made that year to improve long-term performance of pavements containing crushed gravel coarse aggregate. However, close evaluation of the collected information revealed performance trends which provide valuable information in this regard. The study focused on factors affecting the moisture susceptibility of pavements.

The evaluation of pavements in this study confirmed that the crushed gravel coarse aggregates are significantly more susceptible to moisture damage than either the limestone or the sandstone coarse aggregates.

Cores from one-to-three-year-old crushed gravel coarse aggregate pavements containing liquid antistripping agents were found to have similar tensile strength ratios (TSRs) to cores from pavements of similar age treated with lime. The visual evaluations of these cores, however, found significantly more evidence of moisture damage in the pavements treated with liquid antistripping agents as compared to lime. Also, from the data collected in this study, there is a question concerning the long-term effectiveness of the liquid antistripping agents used in the past in northeast Texas. There is evidence of moisture damage in these pavements, although the damage has not progressed to the point of affecting the ride or surface appearance of the older roadways. The long-term effectiveness of lime as an antistripping agent could not be determined because lime-treated mixtures of adequate age were not available to be included in this study.

Based on the limited data available in this study, there is no apparent benefit from the use of liquid antistripping agents in limestone asphalt pavements.

The incorporation of an additional sand equivalent requirement specifically for field sand has dramatically improved the quality of field sands being used.

A follow-up evaluation of all 35 pavements in three years is recommended. Moisture damage and other performance indicators collected at that time could be compared to the data presented herein, allowing a considerably more conclusive evaluation of the performance being obtained under current specifications. In the interim, use of lime as an antistripping agent appears to be the most promising treatment.

CHAPTER 1. INTRODUCTION

1.1 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 gravel aggregates in northeast Texas. Solutions were proposed 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. These recommendations are found in Appendix A of Volume II.

The recommended strategies presented in that report were implemented in large measure. About a year later, the Atlanta District requested a follow-up study and results are presented in this report.

1.2 OBJECTIVES

The objective of this task group is to determine if the implemented recommendations from the earlier task group were effective in improving the performance of asphaltic pavements in northeast Texas. Details of these recommendations are presented in Appendix A.

1.3 TASK GROUP COMPOSITION

The group included representatives of the three northeast Texas districts which were involved with the initial study and individuals from the Construction Division - Materials Section and the Design Division - Pavements Section. The task group invited Dr. Tom Scullion, an expert in ground penetrating radar from the Texas Transportation Institute, to assist in evaluating subsurface pavement conditions.

CHAPTER 2. METHODOLOGY

2.1 PLANNING

The task group met in December of 1997 to plan a course of action. The meeting notes are included as Appendix B. It was determined that a series of projects should be selected which represented construction under both the older specification requirements and the new specifications. A variety of aggregate types, mixture types, antistripping agent types, and pavement ages should be included in the series of projects. The projects would then be thoroughly evaluated and the information analyzed in attempts to determine the effectiveness of current specifications. It was recognized that the short period of time under traffic for projects constructed under the new specifications would be a complicating factor in the analysis.

2.2 SELECTION OF PROJECTS

Projects from the Atlanta, Tyler and Lufkin Districts were nominated by each district for inclusion in the study. Each district provided materials, age, traffic and other information about the projects being considered. A total of 35 projects and 38 pavement layers were chosen for evaluation. Both the surface and base courses were included on three of the projects. On two of the projects, only the base course was evaluated.

Selected information about the projects is shown in Table 1. Photographs of the pavements are found in Appendix C. The coarse aggregate was crushed siliceous gravel in 23 of the pavement layers, with the remaining 15 pavement layers being composed of limestone, sandstone, igneous, or quartzite. The majority of the projects used limestone screenings, although crushed siliceous gravel, sandstone and igneous screenings were also represented in the group.

Liquid antistripping agents were used in 18 mixtures while lime was used in 9. No antistripping agent was used in the remaining 11 mixtures.

The ages of the pavement layers range from 1 to 9 years. There were 7 pavement layers that had been placed in 1997.

2.3 TRAFFIC INFORMATION

Traffic levels on these northeast Texas pavements range from very light to high, although none approach the traffic levels of some of the urban expressways in Texas. The lowest traffic levels are about 2,000 ADT and 750 ESALs. The highest are approximately 51,000 ADT and 21,000 ESALs. The traffic information may be found on the Master Data Summary Table 2.

TABLE 1 - PAVEMENTS SELECTED FOR EVALUATION

District - Project ID (Layer)	Highway	Aggregate Mineralogy		Antistripping Agent Type	Age, Years
		Coarse	Screenings		
Atlanta - 1	US 67	Sil. Gravel	Sil. Gravel	Liquid	4
Atlanta - 2	US 67	Sil. Gravel	Sil. Gravel	Lime	3
Atlanta - 3	US 271	Sandstone	Sandstone	Liquid	3
Atlanta - 4	IH 30	Sil. Gravel	Sil. Gravel	Lime	3
Atlanta - 5	FM 881	Limestone	Limestone	Liquid	2
Atlanta - 6	US 59	Sil. Gravel	Sil. Gravel	Liquid	3
Atlanta - 7	IH 20	Sil. Gravel	Sil. Gravel	Liquid	4
Atlanta - 8	IH 30	Sandstone	Sandstone	Liquid	2
Atlanta - 9	IH 20	Limestone	Limestone	Liquid	2
Atlanta - 10	US 79	Quartzite	Quartzite	Lime	2
Atlanta - 11	US 79	Igneous	Igneous	Lime	2
Atlanta - 12	SH 155	Sil. Gravel	Limestone	Lime	1
Atlanta - 13	FM 1397	Sil. Gravel	Sil. Gravel & Donnafill	Lime	1
Atlanta - 14	SH 43	Sil. Gravel	Sil. Gravel	Lime	1
Atlanta - 15	US 271	Sandstone	Sandstone	Liquid	1
Atlanta - 16	SH 11	Sandstone	Sandstone	Lime	1
Atlanta - 17(2)	US 59	Limestone & RAP	Limestone	Liquid	3
Atlanta - 18(2)	US 59	Sil. Gravel & RAP	Sil. Gravel	Liquid	2
Lufkin - 1	US 59	Sil. Gravel	Limestone	None	5
Lufkin - 1(2)	US 59	Sil. Gravel	Limestone	None	6
Lufkin - 2	SH 7	Sil. Gravel	Limestone	None	7
Lufkin - 3	US 59	Limestone	Limestone & Bottom Ash	None	2
Lufkin - 3(2)	US 59	Limestone	Limestone	None	2
Lufkin - 4	US 259	Sil. Gravel	Limestone	Liquid	1
Lufkin - 5	US 59	Sil. Gravel	Limestone	None	7
Lufkin - 6	US 59	Sil. Gravel	Limestone	None	5
Lufkin - 7	US 259	Sil. Gravel	Limestone	None	4
Lufkin - 8	Lp 224	Sil. Gravel	Limestone	Liquid	2
Lufkin - 8(2)	Lp 224	Sil. Gravel	Limestone	Liquid	3
Tyler - 1	US 69	Sil. Gravel	Limestone	Liquid	5
Tyler - 2	US 69	Sil. Gravel	Sil. Gravel	Liquid	5
Tyler - 3	SH 31	Sil. Gravel & RAP	Limestone	Lime	1
Tyler - 4	US 69	Sandstone	Sandstone	None	6
Tyler - 5	SH 31	Limestone	Limestone	None	9
Tyler - 6	US 79	Limestone	Limestone	Liquid	3
Tyler - 7	IH 20	Igneous	Igneous	Liquid	3
Tyler - 8	US 271	Sil. Gravel	Sil. Gravel	Liquid	6
Tyler - 9	US 259	Sil. Gravel	Sil. Gravel	None	6

Air Voids of Cores, %	Indirect Tensile Strength 77 F, psi		TSR	Antistrip Agent (Liquid, % by Wt of Asphalt) (Lime, % by Wt of Mixture)	Age	Coarse Aggr Mineralogy	Screenings Mineralogy	Asphalt and Polymer	18-kip ESALs (Current)	ADT (Current)	Ride Score**	Visual Distress Rating**, Avg	Rutting, %	
	Dry	Wet											Shallow	Deep
NA	206	85	0.41	None	5	Gravel	Limestone	Star AC-20	9,197	8,667	4.1	3.7	0	0
NA	113	No Test	NA	None	6	Gravel	Limestone	Star AC-20						
6.7	151	119	0.79	None	7	Gravel	Limestone	Star AC-20	1,801	3,600	3.6	4.5	0	0
1.7	180	175	0.97	None	2	Limestone	Limestone, B. Ash	Exxon AC-20	10,162	12,045	4	5	0	0
2.3	211	206	0.98	None	2	Limestone	Limestone	Exxon AC-20						
1.9	186	164	0.88	1.0% Permatac Plus	1	Gravel	Limestone	Exxon AC-20	12,000	8,167	4.7	4.6	0	0
NA	111	61	0.55	None	7	Gravel	Limestone	Star AC-20	9,594	11,000	3.9	4.3	0.1	0
NA	176	134	0.76	None	5	Gravel	Limestone	Star AC-20	9,945	10,782	3.8	3.6	0	0
NA	83	46	0.55	None	4	Gravel	Limestone	Asphalt Rubber	15,200	11,618	3.8	4.1	0	0
6.5	198	176	0.89	0.5% Unichem 8161	2	Gravel	Limestone	Lion AC-20	1,436	8,667	4.1	4.6	0	0
9.6	121	82	0.68	0.5% Unichem 8161	3	Gravel	Limestone	Lion AC-20						
NA	142	59	0.42	Liquid	5	Gravel	Limestone	Star AC-10, 3% Latex				4.9		
3.9	148	144	0.97	Probably Liquid	5	Gravel	Gravel	Star AC-10, 3% Latex				3.8		
5.8	163	130	0.80	1.0% Lime	1	Gravel, RAP	Limestone	Lion PG 70-22 (3% Latex)				5		
4.4	200	148	0.74	None	6	Sandstone	Sandstone	Lion AC-20				NA		
NA	226	194	0.86	None	9	Limestone	Limestone	Elf AC-30P				4.8		
4.4	167	157	0.94	0.5% Permatac Plus	3	Limestone	Limestone	Lion AC-20				4.5		
NA	148	53	0.36	0.5% Permatac Plus	3	Igneous	Igneous	Lion AC-10, 3% Latex				4.5		
2.4	159	55	0.35	?% Liquid	6	Gravel	Gravel	Star AC-10, 3% Latex				2.7		
2.4	156	63	0.40	None	6	Gravel	Limestone	Star AC-20				2.9		
1.9	235	124	0.53	1.0% Permatac Plus	4	Gravel	Gravel	Kerr McGee AC-20	8,475	1,657	2.8	3.5	0	0
2.6	120	145	1.21	1.5% Lime	3	Gravel	Gravel	Kerr McGee AC-20	3,283	2,534	3.8	3.6	0.2	0
3.8	276	242	0.88	1.0% Permatac Plus	3	Sandstone	Sandstone	Lion AC-20	3,570	5,800	3.8	4.5	1	0
4.2	87	86	0.99	1.5% Lime	3	Gravel	Gravel	Kerr McGee AC-10, 3% Latex	20,554	19,819	4.4	4.4	0	0
6.5	187	149	0.80	1.0% Unichem 8161	2	Limestone	Limestone	Lion AC-10, 3% Latex	NA	NA	NA	4.6	NA	NA
4.0	108	86	0.80	1.0% Permatac Plus	3	Gravel	Gravel	Exxon AC-10, 3% Latex	2,902	4,038	4	5	0.2	0
0.9	160	106	0.66	0.5% Unichem 8161	4	Gravel	Gravel	Lion AC-20	16,554	11,530	4.4	4.2	1.7	4.2
4.4	135	69	0.51	1.0% Permatac Plus	2	Sandstone	Sandstone	Lion AC-10, 3% Latex	14,666	10,980	4.2	4.2	0	0
6.1	126	139	1.10	1.0% Permatac Plus	2	Limestone	Limestone	Lion AC-10, 3% Latex	16,874	12,238	4.7	4.6	0.7	0
NA	113	94	0.83	1.5% Lime	2	Quartzite	Quartzite	Lion AC-10, 3% Latex	8,316	7,585	3.8	5	0.9	0
2.4	215	185	0.86	1.0% Lime	2	Igneous	Igneous	Lion AC-20	8,242	6,433	2.9	5	9	2
4.9	142	150	1.06	1.0% Lime	1	Gravel	Limestone	Lion AC-20	1,296	2,541	4.4	4.6	3.2	2.3
6.0	130	124	0.95	1.0% Lime	1	Gravel	Gravel, Donnafill	Lion AC-20	499	2,483	4.1	4.7	NA	NA
10.5	118	69	0.58	1.0% Lime	1	Gravel	Gravel	Fina AC-20	NA	NA	NA	4.8	NA	NA
1.7	131	115	0.88	1.0% Permatac Plus	1	Sandstone	Sandstone	Lion AC-10, 3% Latex	4,934	9,480	3.8	5	0	0
8.3	126	118	0.94	1.0% Lime	1	Sandstone	Sandstone	Lion AC-20	754	2,350	4.4	4.6	3.5	2
5.6	167	150	0.90	1.0% Permatac Plus	3	Limestone, RAP	Limestone	Lion AC-10	8,476	11,763	3.9	4.9	0.1	0
4.3	120	143	1.19	1.0% Permatac Plus	2	Gravel, RAP	Gravel	Lion AC-10	11,059	10,700	4.1	5	4.7	2.3
4.8	144	147	1.02		3									
0.4	126	112	0.89		2									

* Core not available for evaluation. Value from the dry core is shown.

**Ride Scores and Visual Distress Ratings are evaluated on a scale to 5, with 5 being the highest possible rating.

2.4 PAVEMENT PERFORMANCE EVALUATIONS

Visual Distress Evaluation

The pavements were visually evaluated by the task group in February of 1998. Four separate distress surveys were completed, one by personnel from each of the districts represented on the task group and one by the division personnel. The survey form used is shown in Appendix D. It is described in SHRP-P-338, *Distress Identification Manual for the Long-Term Pavement Performance Project.* The results of the four surveys for each pavement were averaged and transposed to a scale of 0 to 5.0, with a score of 5.0 meaning that no visual distress of any type was observed.

Seven pavements received a consensus score of 5.0. The lowest scores were averages of 2.7 and 2.9. All results are shown in Table 2.

Pavement Management Information System Data

The projects were all rated in early 1998 and an average ride score was determined for each. In addition, the percentage of each rated section which was found to have rutting from 0.5 to 1.0 inch in depth was reported as "shallow rutting," and the percentage having rutting deeper than 1.0 inch was reported as "deep rutting." Ride scores ranged from a low of 2.8 to a high of 4.8. While there were sections with rutting, rutting was not found to be a major concern at the time of the evaluation on any of the projects. These scores and percentages are included in Table 2.

Ground Penetrating Radar Analysis

The projects were all tested in early 1998 with Ground Penetrating Radar and details of the findings are given in Appendix E. Conclusions from this analysis are:

1. Several of the sections appear to have subsurface defects such as stripping or wet base. This will be useful if long-term monitoring of these sections is to be conducted.

2. Different GPR reflection patterns were obtained from the interface between the existing and the new overlay. It is proposed that GPR can detect the presence of moisture either on top of or beneath the seals placed between layers.

3. Although the data is limited, the variation in amplitude of the GPR reflection from the surface of the pavement appears to correlate with the air void content of the surface layer.

Pavement Coring

The task group selected coring locations on the projects during the visual distress survey. From two to four cores were taken from a single location on each project. They were taken from the outside wheel path of the outside lane. Four-inch diameter cores were taken, and water was used in the coring operation.

Visual Evaluation of Cores for Moisture Damage

The cores were brought to Tyler in April for evaluation by all task group members. The cut sides of the cores were evaluated for evidence of stripping. Evidence of stripping could be in the form of erosion of asphalt and/or fines from around the coarse aggregate on the cut surfaces, or it could be in the form of clean coarse aggregate which had come loose in the coring process. Each core was scored from 1 to 5, with the highest score of 5 meaning that there was absolutely no visual evidence of stripping in the opinion of the evaluator. A rating of 1 would indicate that the layer being evaluated was completely stripped, basically a pile of clean, asphalt-free aggregate. Each task group member individually evaluated each core. The scores were averaged and are shown in Table 3. Photographs of the cores are found in Appendix F.

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 using the same scoring system as used to evaluate the cut sides of the cores. The dry-conditioned and moisture-conditioned cores were evaluated separately. These scores are also shown in Table 3. Photographs of the fractured faces of the tested cores are also found in Appendix F. Figure 1 shows pictures of cores with rating of 1.8 and 4.9 for moisture conditioned specimens.

Ratings for fractured surfaces of the dry-conditioned cores tended to correspond to the earlier ratings for the outside core surface. Little evidence of moisture damage was observed in most dry-conditioned cores. The moisture-conditioned fractured faces, on the other hand, displayed more partially-coated or non-coated aggregate than the dry-conditioned cores had shown. The evaluations of the moisture-conditioned fractured faces were considered much more definitive of the ability of the pavement to resist moisture damage.

TABLE 3 - VISUAL STRIPPING RATINGS OF CORES

District - Project ID (Layer)	Outside Surface of Core Rating	Fractured Surface Ratings	
		Dry	Moisture Conditioned
Atlanta - 1	4.6	4.6	2.9
Atlanta - 2	4.3	4.2	4.1
Atlanta - 3	5.0	4.9	4.7
Atlanta - 4	5.0	4.8	4.8
Atlanta - 5	4.6	4.8	4.7
Atlanta - 6	4.1	3.7	2.8
Atlanta - 7	4.8	3.9	3.1
Atlanta - 8	4.6	4.6	4.5
Atlanta - 9	4.9	4.9	4.9
Atlanta - 10	4.1	4.9	4.8
Atlanta - 11	4.8	4.8	4.6
Atlanta - 12	4.9	4.8	4.6
Atlanta - 13	4.4	4.7	4.6
Atlanta - 14	3.3	4.7	4.2
Atlanta - 15	5.0	5.0	4.6
Atlanta - 16	4.9	4.9	4.9
Atlanta - 17(2)	4.6	4.6	4.3
Atlanta - 18(2)	3.9	4.6	4.4
Lufkin - 1	3.9	3.4	2.5
Lufkin - 1(2)	2.8	3.5	No Test
Lufkin - 2	3.9	3.2	2.7
Lufkin - 3	5.0	4.9	4.8
Lufkin - 3(2)	4.9	4.8	4.7
Lufkin - 4	4.8	4.7	4.4
Lufkin - 5	3.9	3.8	3.0
Lufkin - 6	4.8	4.4	3.4
Lufkin - 7	3.2	2.5	1.8
Lufkin - 8	4.0	4.2	3.1
Lufkin - 8(2)	2.8	4.3	3.2
Tyler - 1	4.8	3.7	2.8
Tyler - 2	4.6	4.5	3.3
Tyler - 3	4.7	4.7	4.4
Tyler - 4	4.6	4.2	4.0
Tyler - 5	5.0	4.7	4.5
Tyler - 6	4.7	4.5	4.5
Tyler - 7	4.0	3.9	3.4
Tyler - 8	2.9	4.1	2.9
Tyler - 9	3.8	3.9	2.6

Figure 1A. Cores from Lufkin-7 Section. Visual stripping ratings are 2.5 and 1.8 for Dry and Moisture Conditioned Specimens, respectively.

Figure 1B. Core from Atlanta-16 Section. Visual stripping ratings is 4.9 for both Dry and Moisture Conditioned Specimens.

Core Testing

The pavement cores were transported to the Materials Section laboratory in Austin for testing. After photographing, the cores were sawed to separate the pavement layers. The cores were then dried to constant weight at 77 F and 0 % relative humidity in an environmental chamber. The drying process continued for four days in most cases. The bulk specific gravity was determined for each layer being evaluated in accordance with Test Method Tex-207-F. One core sample from each layer of interest was selected for moisture conditioning while a second core 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 a period of 3 to 4 hours. They were then tested for indirect tensile strength in accordance with Test Method Tex-226-F. The dry core samples were brought to 77 F in the dry condition by placing them in watertight plastic bags and submerging them in the 77 F water bath. They were likewise tested to failure in indirect tension. The indirect tensile strengths from these single tests are shown in Table 4 along with the calculated tensile strength ratios (TSRs).

Rice specific gravity was determined from the tested core samples in accordance with Test Method Tex-227-F after the fractured surfaces were evaluated for evidence of stripping. Air void percentages were then calculated for each evaluated pavement layer. The average air void results for all pavements are also shown in Table 4.

TABLE 4 - CORE AIR VOIDS AND TENSILE STRENGTH RESULTS

District - Project ID (Layer)	Core Air Voids, %	Indirect Tensile Strength, psi		Tensile Strength Ratio (TSR)
		Dry	Moisture Conditioned	
Atlanta - 1	1.9	235	124	0.53
Atlanta - 2	2.6	120	145	1.21
Atlanta - 3	3.8	276	242	0.88
Atlanta - 4	4.2	87	86	0.99
Atlanta - 5	6.5	187	149	0.80
Atlanta - 6	4.0	108	86	0.80
Atlanta - 7	0.9	160	106	0.66
Atlanta - 8	4.4	135	69	0.51
Atlanta - 9	6.1	126	139	1.10
Atlanta - 10	NA	113	94	0.83
Atlanta - 11	2.4	215	185	0.86
Atlanta - 12	4.9	142	150	1.06
Atlanta - 13	6.0	130	124	0.95
Atlanta - 14	10.5	118	69	0.58
Atlanta - 15	1.7	131	115	0.88
Atlanta - 16	8.3	126	118	0.94
Atlanta - 17(2)	5.6	167	150	0.90
Atlanta - 18(2)	4.3	120	143	1.19
Lufkin - 1	NA	206	85	0.41
Lufkin - 1(2)	NA	113	NA	NA
Lufkin - 2	6.7	151	119	0.79
Lufkin - 3	1.7	180	175	0.97
Lufkin - 3(2)	2.3	211	206	0.98
Lufkin - 4	1.9	186	164	0.88
Lufkin - 5	5.7	111	61	0.55
Lufkin - 6	3.5	176	134	0.76
Lufkin - 7	3.1	83	46	0.55
Lufkin - 8	6.5	198	176	0.89
Lufkin - 8(2)	9.6	121	82	0.68
Tyler - 1	NA	142	59	0.42
Tyler - 2	3.9	148	144	0.97
Tyler - 3	5.8	163	130	0.80
Tyler - 4	4.4	200	148	0.74
Tyler - 5	NA	226	194	0.86
Tyler - 6	4.4	167	157	0.94
Tyler - 7	NA	148	53	0.36
Tyler - 8	2.4	159	55	0.35
Tyler - 9	2.4	156	63	0.40

A question was raised by the group if the vacuuming process itself could have damaged the cores and lowered tensile strengths. In an attempt to answer this question, a second moisture conditioning method was used on remaining cores from four pavements. These cores were placed in the 77 F water bath for seven days. No vacuum was applied. The indirect tensile test was performed at 77 F as was the procedure in the earlier tests. These test results, shown in Table 5, are compared to the vacuum-saturated and the dry test results.

TABLE 5 - COMPARISON OF MOISTURE-CONDITIONING METHODS

District - Project	Core Air Voids, %	Indirect Tensile Strength, 77F, psi		
		Dry	Vacuum Saturated	Water Bath Saturated
Atlanta - 1	1.9	235	124	238
Lufkin - 6	3.5	176	134	114
Lufkin - 8	6.5	198	176	170
Lufkin - 8(2)	9.6	121	82	69

Except for the pavement with very low air voids, the tensile strengths from the seven-day-soak specimens are even lower than the strengths of the vacuum-saturated specimens. Although the data is limited, the results do indicate that the vacuuming process itself does not appear to damage the indirect tensile strength of most pavement cores. This would indicate that it is the simple presence of the water in permeable areas of the cores which significantly reduces the strength of moisture-conditioned cores.

In the case of the pavement core with very low air voids, it is theorized that the vacuuming process damaged the core when the pressures within air voids could not be relieved through inter-connected passages leading to the exterior of the core. It is also possible that the lower test results from the low air void core could have been the result of an existing crack or other abnormality in the single core which represented this test condition.

CHAPTER 3. EVALUATION OF INFORMATION

3.1 Analysis of Factors Affecting Moisture Susceptibility of Pavements

Moisture susceptibility was found to be a predominant cause for unsatisfactory pavement performance in northeast Texas by the 1995 task group. Therefore, factors which could have the affect of causing or preventing this phenomena were closely scrutinized. These analyses would hopefully confirm that the measures being taken over the past year could be expected to improve the overall performance of pavements in this area of Texas.

As the group believed that conclusions should be supported by a consensus of the data to be reliable, the evaluations concentrated on average results from pavements with similar characteristics and comparing these to the averages from other groups of pavements. This task was accomplished by sorting the data presented in Table 2 to group the pavements with respect to various attributes. Tables G1 through G 4 in Appendix G show results of the sorting. Findings are summarized below. The mixture or pavement characteristics which were compared are discussed individually.

Coarse Aggregate Mineralogies

Comparison of pavement layers containing different mineralogies of coarse aggregate revealed several interesting facts. Two methods of comparison were used by the task group. The first is shown in Table 6. (Individual data points are presented in Table G1.)

TABLE 6 - COARSE AGGREGATE MINERALOGY COMPARISON

Coarse Aggregate Mineralogy	Number of Projects	Average Age, Years	Average Core Air Voids, %	Average Dry Tensile Strength, psi	Average Wet Tensile Strength, psi	Average TSR	Average Visual Stripping Rating of Dry Cores	Average Visual Stripping Rating of Wet Cores
Crushed Gravel	23	3.7	4.6	145	107	0.75	4.1	3.4
Limestone	7	3.3	4.4	181	167	0.94	4.7	4.6
Sandstone	5	2.6	4.5	174	138	0.79	4.7	4.5

In addition to the projects represented in Table 6, there were also two projects containing igneous coarse aggregate and one containing quartzite. These are not included because there was not enough representation to adequately evaluate these mineralogies.

The crushed gravel mixtures are noted to possess the least desirable properties in every category of evaluation related to moisture susceptibility. Also, these mixtures as a group are seen to have lower dry tensile strengths. The average visual ratings of the wet cores are a particularly strong indicator of damage that has occurred in these crushed gravel pavements. A review of the individual visual ratings of wet and dry cores shown that none of the limestone and sandstone mixtures showed significant visual moisture damage. The crushed gravel mixtures have been in service about 5 months longer than the limestone mixtures, on the average, so some of the difference in properties may be attributed to this longer time in service.

Comparing the visual evaluation ratings to the TSR values indicates that both properties both rank the three mineralogies in the same sequence. However, the TSR shows the sandstone and crushed gravel as being comparable, while the visual ratings show the sandstone and limestone to be more comparable.

The average air voids in the three groups of cores were virtually identical. This would seem to indicate a great deal of consistency in mixture design and plant job-mix-formula adjustments when these different types of mixtures have been used.

The task group decided to take a second look at the different coarse aggregate mineralogies, attempting to take out the age difference. To do this, only the mixtures which have been in service from one to three years were included in the comparison. Also, to eliminate another source of variability, only mixtures which contained liquid antistripping agent were included. Table 7 shows the resulting information and averaged test results. (Individual data points are presented in Table G2.)

TABLE 7 - COARSE AGGREGATE MINERALOGY COMPARISON (PAVEMENT AGE OF ONE TO THREE YEARS)

Number of Projects	Coarse Aggregate Mineralogy	Average Age, Years	Average Core Air Voids, %	Average Dry Tensile Strength, psi	Average Wet Tensile Strength, psi	Average TSR	Average Visual Stripping Rating of Dry Cores	Average Visual Stripping Rating of Wet Cores
5	Gravel	2.2	5.3	147	130	0.89	4.3	3.6
4	Limestone	2.5	5.7	162	149	0.93	4.7	4.6
3	Sandstone	2.0	3.3	181	142	0.76	4.8	4.6

In the above comparison the crushed gravel mixtures have been in service less than the limestone mixtures, the reverse situation of the information in Table 6. The limestone mixtures, however, still have superior moisture susceptibility properties compared to the crushed gravel mixtures, although the difference is not as great as in Table 6. Interestingly, the sandstone mixture TSR values are lower than those of the crushed gravel while their visual ratings of wet cores indicate very little sign of water damage. As all of the data sets in Table 7 are composed of test results from only three to five cores per test condition, a core with an existing micro-crack in the plane of failure could considerably affect the average result for the group. The average TSR could be increased or decreased, depending on if the flawed core represented the dry or wet condition. Strong conclusions should only be considered from Table 7 when the visual and TSR evaluations are in agreement.

The consensus of both comparison approaches is that mixtures which contain crushed gravel coarse aggregates are more prone to moisture damage than mixtures containing limestone coarse aggregates. This has been shown to be the case even in pavements placed in service within the last three years and which contained liquid antistripping agents. Based on the amount of stripped aggregate which could be observed without magnification, the difference in moisture susceptibility is quite significant. Sandstone coarse aggregate appears to have a moisture susceptibility between those of limestone and crushed gravel.

Screenings Mineralogies

Available data was analyzed to determine if mineralogy of screenings had a significant effect on stripping susceptibility of mixtures. Table 8A shows the comparison of visual stripping rating of gravel mixtures containing gravel and limestone screenings. Projects presented in Table 8A contained liquid antistripping additives. Table 8B contains the same information for projects containing lime additive. (Individual data points are presented in Table G3.)

TABLE 8A - SCREENINGS MINERALOGY COMPARISON - LIQUID ADDITIVE
(ALL PAVEMENTS CONTAIN GRAVEL COARSE AGGREGATE)

Number of Projects	Screenings	Average Age, Years	Average Core Air Voids, %	Average Dry Tensile Strength, psi	Average Wet Tensile Strength, psi	Average TSR	Average Visual Stripping Rating of Dry Cores	Average Visual Stripping Rating of Wet Cores
6	Gravel	4.0	2.9	155	110	0.75	4.2	3.3
4	Limestone	2.8	6.0	162	120	0.72	4.2	3.4

TABLE 8B - SCREENINGS MINERALOGY COMPARISON - LIME ADDITIVE
(ALL PAVEMENTS CONTAIN GRAVEL COARSE AGGREGATE)

Number of Projects	Screenings	Average Age, Years	Average Core Air Voids, %	Average Dry Tensile Strength, psi	Average Wet Tensile Strength, psi	Average TSR	Average Visual Stripping Rating of Dry Cores	Average Visual Stripping Rating of Wet Cores
2	Limestone	1.0	5.4	153	140	0.93	4.7	4.5
4	Gravel	2.0	5.8	114	106	0.93	4.6	4.4

As shown in Table 8A, for projects using liquid additives, six projects contained gravel screenings and four contained limestone screenings. Although projects using gravel screenings are about one year older, there is no appreciable differences between wet or dry tensile strength, TSR or visual stripping rating of these projects. Table 8B shows that for lime treated mixtures, TSR and visual stripping ratings were comparable between gravel and limestone screenings. Mixtures containing limestone screenings showed higher dry and wet tensile strengths. However, these mixtures were one year younger than those containing gravel screenings.

No definite conclusion can be made regarding effects of screenings mineralogy on stripping potential based on available data.

Antistripping Agents - Lime Versus Liquid Versus Non-Treatment

Tables 9A, 9B and 9C show effects of anti-stripping additive type on moisture damage. (Individual data points are shown in Table G2.) Most of the data, although somewhat limited, indicates that liquid antistrip agents and lime perform fairly similarly in the early years of the pavement life as shown in Table 9A. The visual stripping rating of wet cores shown in Table 9A indicate the lime performing better, but the lime mixtures were also about six months younger on the average.

Mixtures containing liquid antistripping agents, which have been in service an average of 4.8 years (shown in Table 9B) can be compared to those with an average age of 2.2 years (shown in Table 9A). The comparison indicated that moisture damage may increase with age when liquid antistripping agents are used. To reach this conclusion, it must be assumed that other factors are constant between the two groups of projects. Therefore, this finding is not conclusive in itself. Both the visual ratings and TSR values indicate this trend, although reduction in TSR is more significant. No lime-treated mixtures have been in service long enough to adequately determine if this is true for lime or not. The data that is available on lime-treated mixtures indicates that moisture damage does not show an increasing trend between ages one and three. For crushed gravel mixtures treated with liquid antistripping agents, most three-year-old pavements show more moisture damage than one-year-old pavements. (Data presented in Table G2.)

A comparison can be made of the crushed gravel coarse aggregate mixtures which contained liquid antistripping agent and which were from four to six years old to similarly aged crushed gravel coarse aggregate mixtures which contained no liquid antistripping agent or lime. This comparison is provided in Table 9B. The visual evaluations of moisture damage are found to be similar for the wet cores. The average TSR values are identical. Only the visual evaluations of the cores tested dry show a significant improvement when liquid antistripping agents were used. This also raises questions concerning long-term effect of liquid antistripping agents.

From the data collected during this study, the long-term effectiveness of the liquid antistripping agents used in the past in northeast Texas can not be substantiated. The data tends to indicate increasing moisture damage with age.

The best comparison of lime and liquid additives would include pavements with similar age and coarse aggregate mineralogy. This comparison is presented in Table 9C for three-year-old pavements containing liquid and lime. As shown in this table, mixture containing lime showed better results in terms of wet tensile strength, TSR, Dry and Wet Visual Ratings. Projects containing lime also showed lower air voids content than those containing liquid.

Overall analysis of data indicates mixtures containing lime appear less susceptible to moisture damage than those containing liquid antistripping additives.

TABLE 9A - EFFECTS OF ANTI-STRIPPING ADDITIVE TYPE ON STRIPPING SUSCEPTIBILITY - LIQUID VERSUS LIME (1 to 3 year old projects) (ALL PAVEMENTS CONTAIN GRAVEL COARSE AGGREGATE)

Additive Types	Number of Projects	Average Age, Years	Average Core Air Voids, %	Average Dry Tensile Strength, psi	Average Wet Tensile Strength, psi	Average TSR	Average Visual Stripping Rating of Dry Cores	Average Visual Stripping Rating of Wet Cores
Liquid	5	2.2	5.3	147	130	0.89	4.3	3.6
Lime	6	1.7	5.7	127	117	0.93	4.7	4.5

TABLE 9B - EFFECTS OF ANTI-STRIPPING ADDITIVE TYPE ON STRIPPING SUSCEPTIBILITY - LIQUID VERSUS NO ADDITIVE (ALL PAVEMENTS CONTAIN GRAVEL COARSE AGGREGATE)

Additive Types	Number of Projects	Average Age, Years	Average Core Air Voids, %	Average Dry Tensile Strength, psi	Average Wet Tensile Strength, psi	Average TSR	Average Visual Stripping Rating of Dry Cores	Average Visual Stripping Rating of Wet Cores
No Additive	7	5.7	4.6	142	85	0.58	3.5	2.7
Liquid	5	4.8	2.3	169	98	0.58	4.2	3.0

TABLE 9C - EFFECTS OF ANTI-STRIPPING ADDITIVE TYPE ON STRIPPING SUSCEPTIBILITY - LIQUID VERSUS LIME (3 year old projects) (ALL PAVEMENTS CONTAIN GRAVEL COARSE AGGREGATE)

Additive Types	Number of Projects	Average Age, Years	Average Core Air Voids, %	Average Dry Tensile Strength, psi	Average Wet Tensile Strength, psi	Average TSR	Average Visual Stripping Rating of Dry Cores	Average Visual Stripping Rating of Wet Cores
Liquid	2	3	6.8	115	84	0.74	4.0	3.0
Lime	2	3	3.4	103	115	1.1	4.6	4.5

Asphalts: Unmodified Versus Polymer Modification

Table 10 shows a comparison of gravel mixtures containing unmodified and polymer modified asphalts. (Individual data points are shown in Table G4.) SBR Latex was the predominant type of modifier used. As shown in this table, latex-modified asphalt mixtures using crushed gravel performed slightly worse than unmodified asphalt mixtures in the area of moisture susceptibility. Latex modification of the asphalt is not an effective means of preventing moisture damage to the pavement. Somewhat surprisingly, for the crushed gravel coarse aggregate mixtures, even the dry tensile strengths of the latex-modified asphalt mixtures were lower than the dry tensile strengths of unmodified asphalt mixtures. For the limestone mixtures, there was no significant difference between dry indirect tensile strengths of mixtures with and without latex modification of the asphalt.

TABLE 10 - EFFECTS OF LATEX MODIFICATION ON MOISTURE DAMAGE RESISTANCE

Additive Types	Coarse Aggregate Type	Number of Projects	Average Age, Years	Average Core Air Voids, %	Average Dry Tensile Strength, psi	Average Wet Tensile Strength, psi	Average TSR	Average Visual Stripping Rating of Dry Cores	Average Visual Stripping Rating of Wet Cores
None	Gravel	16	3.6	4.9	153	116	0.77	3.5	4.2
Latex	Gravel	7	3.9	4.1	127	87	0.70	4.2	3.3
None	Limestone	4	2.5	3.5	181	172	0.95	4.7	4.6
Latex	Limestone	3	4.3	6.3	180	161	0.92	4.8	4.7

3.2 Analysis of Other Factors Affecting Pavement Performance

There were several other recommendations made in the earlier study of northeast Texas pavement performance that warrant discussion. Also, this close observation of pavement performances and the core testing which followed allowed the discovery or confirmation of other factors which are important to pavement performance.

Use of Sand Equivalent as a Quality Measure of Field Sands

The 1995 task group recommended that a new requirement be placed in Atlanta District projects to eliminate field sands which were found to be abnormally fine. The introduction of the sand equivalent test for evaluating field sands on an individual basis was effective in eliminating the worst field sand source identified in the earlier study. It is recommended that this criteria remain in the specifications used in this area of the state.

Segregation - With and Without Use of a Material Transfer Device

It became obvious to the task group as they evaluated each of the pavements selected for study that the projects where the contractor had used a material transfer device were almost always free of segregation. Segregation was noted to be significant on a number of the other projects.

Importance of Impermeability of Pavement Layers.

The majority of the pavement evaluated in this study had achieved acceptable in-place densities during construction. Table 11 shows average air void content of cores.

TABLE 11. AIR VOID CONTENT OF CORES FROM ALL PROJECTS SEPARATED BY PAVEMENT AGE

Average Age, Years	Number of Projects	Average Core Air Voids, %
1	7	5.6
2	10	3.8
3	9	4.9
4	14	3.2
All Pavements over 2 years	33	3.8

As shown in Table 11, average air void content of pavements one year or newer was 5.6 percent. The air voids content generally reduces as pavements age, but it is apparent that after the second year, air voids content become somewhat more stable. It is interesting to note that for all pavements which are 2 years or older, the average core air void content is 3.8%. All these mixtures were designed with a Texas gyratory compactor with the target lab density of 96.0% (4.0% air void). Therefore, these data strongly support the theory that the Texas gyratory compactor will simulate the in-place air voids content of mixtures after they have been subjected to traffic densification. Further, it is apparent that after only two years of traffic, the majority of the pavement will reach the in-place density predicted by the Texas gyratory compactor.

The importance of achieving adequate in-place density and therefore constructing a water impermeable pavement is demonstrated by this study. As discussed previously, some of the cores which were left soaking in a water bath for 7 days showed significant loss in strength. This loss in strength is directly proportional to the degree of permeability of pavements. A well-constructed pavement which has low in-place air voids while maintaining lab density of 96.0% will be a stable pavement and more resistant to water damage.

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The early age of pavements constructed in 1997 prevented a definitive determination of the long-term effectiveness of changes made that year to improve long-term performance of pavements containing crushed gravel coarse aggregate. However, early results from the Atlanta District indicate hot mix pavements which are being constructed in the Atlanta District will perform adequately.

Based on the conditions of this study and the particular pavements evaluated, the following conclusions are warranted:

1. In general, mixtures containing crushed limestone or sandstone coarse aggregates resisted moisture damage better than crushed gravel coarse aggregate mixtures in northeast Texas. (See Table 6.)
2. Mixtures using crushed gravel coarse aggregate require effective treatment to reduce moisture-induced damage.
3. No significant moisture damage was found in any mixture composed of either limestone or sandstone coarse aggregate. (See Tables 6 and 7.)
4. No apparent advantage was found in treating limestone mixtures with liquid antistrip agents.
5. No definitive conclusion regarding differences between gravel and limestone screenings can be made. (See Tables 8A and 8B.)
6. Pavements composed of crushed gravel hot mix that have been in service for more than three years and that were treated with liquid antistrip agents show moderate to severe moisture damage as indicated by visual evaluation of the cores. No crushed gravel pavements treated with lime older than three years were in service in northeast Texas. Therefore, direct comparison of pavements with lime and liquid antistrip agents can not be made for these older pavements. (See Table 9B.)
7. Of the pavements evaluated, those using crushed gravel coarse aggregate that used liquid antistrip agents resisted moisture damage somewhat better than mixtures with no antistrip agent. Trends in the data consistently indicate that mixtures containing lime were less susceptible to moisture damage than mixtures containing liquid anti-strip agent. (See Tables 9A and 9B.)
8. Long-term effectiveness of liquid antistrip agents used in the past in northeast Texas could not be substantiated. There is evidence that liquid antistripping agents may tend to lose effectiveness with age. (See Tables 9A and 9B.)
9. Latex modification of mixtures in northeast Texas does not appear to affect resistance to moisture damage. (See Table 10.)
10. Observations of the 35 pavement sections found that proper use of a material transfer device to load material into the paver resulted in significantly reduced segregation.

11. The addition of a sand equivalent test requirement on field sand was effective in improving the quality of field sands used in the Atlanta District.

4.2 Recommendations

It is recommended that the pavements included in this study be re-visited and cored in three years. The results should be compared to current results to determine the rate of deterioration and further verify findings established herein. In the meantime, to reduce the risk of premature failure due to moisture damage, the following actions are recommended:

1. Action is recommended to preclude future placement of silicious river gravel mixtures in Northeast Texas that rely on currently used liquid antistripping agents for moisture damage resistance. Based on the mixtures and pavements evaluated, lime treatment offers the best potential for improving moisture damage resistance. The most effective method of introducing hydrated lime is the method described in the Standard Specification Item 301.
2. Use of sand equivalent criteria for field sand.
3. Districts should be allowed to require MTV (Materials Transfer Vehicle) to reduce segregation.

APPENDIX A

EXCERPTS FROM TXDOT REPORT "RECOMMENDATIONS FOR IMPROVING PERFORMANCE OF NORTHEAST TEXAS ASPHALTIC CONCRETE PAVEMENTS", SEPTEMBER 1996

Table 2 - Recommendation Prioritization

Recommendation	Implementation Category	Activity Recommended or Planned
Develop tougher stripping test	All future jobs	Support TxDOT and Akzo Nobel work.
Toughen field sand specification	All future jobs	Atlanta district, supported by Materials and Tests Division, to select new criteria
Apply Superpave PG binder specifications	Implement in conjunction with the rest of TxDOT	Support development of the QC/QA binder specification by Materials and Tests Division
Require use of limestone screenings in lieu of crushed gravel screenings	Trial use on one or more jobs	Atlanta district plans to put requirement on at least one future project
Require use of asphalt polymers/modifiers	All future surface course mixtures	Atlanta district required 3% latex/polymer in all surface courses last year. District plans to continue this year. PG grades should be determined for modified asphalts used.
Incorporate edge drains in design of the pavement	Trial use on one or more jobs	Atlanta district is planning edge drains in two future Interstate projects and is considering field changing another project to include them.
Require antistrip agent use in all mixtures until tougher stripping test can be implemented	All future jobs	Atlanta district is currently requiring 1.5% lime in crushed gravel mixtures
Insure compatibility of all component hot mix materials	Research	Develop additional compatibility test methods.
Properly pre-engineer rehabilitation and reconstruction projects Avoid stripping caused by trapped moisture in inlays	All future jobs	Atlanta and other districts to continue coring to determine presence of stripping and other analysis for consideration of project design.
Adjust specification limits for retained on No. 10 sieve	No action	Atlanta district has adjusted the range back to that required in the 1982 Standard Specifications
Use Type D surface course gradations	Trial use on one or more jobs	Atlanta district is planning several projects with Type D this year and is considering field changing a portion of another.
Try mixture with no field sand and unwashed crushed gravel screenings	Trial use on one or more jobs	Gifford-Hill and a contractor on the team may elect to try a mix of this type.

APPENDIX B

INITIAL MEETING NOTES

Meeting Notes
Northeast Texas ACP Team
December 11, 1997 - Tyler District Office

Review of Recommendations by Earlier Team

The recommendations were reviewed and the districts offered a number of comments on those that had been tried.

Reports from Districts

Each district presented information concerning projects constructed in 1997. The majority of projects using crushed gravel were in the Atlanta District. Of the crushed gravel projects put down in 1997, none were mentioned to be showing signs of serious deterioration at this early stage. The group agreed that at this point there is no assurance that the pavements will perform satisfactorily for their expected service lives.

Testing Plan

1. Ground Penetrating Radar - Ken Fults will request that TTI run GPR on our selected project pavements. This work will be completed by February 20, 1998 if possible. He will have the work funded through a research project. The GPR charts will be analyzed with TTI indicating locations where they recommend coring to determine if stripping is occurring.
2. Rutting and Roughness - The Atlanta and Lufkin Districts will complete PMIS testing on the selected project pavements by February 20, 1998, if possible. They will coordinate with the Tyler District to test their selected pavements as well.
3. Visual Pavement Evaluation for Raveling and Flushing - The entire team plans to visit all of the selected pavements during the week of February 23, 1998. The team will mark coring locations and photograph the locations on each pavement.
4. Pavement Coring - The team believes that from one to three cores per project may be satisfactory to establish current pavement condition below the surface. Coring may be done by the districts and MAT, or may be done by contract. The feeling was to do it in-house if at all possible because much can be learned by observing the coring operations, and cores can be damaged during coring if adequate care is not taken. Cores will be taken with dry ice so that no water will be used.

Project Selection

Six projects were identified in Tyler and six in Lufkin. Atlanta had so many projects that they will study them early next week and select about 12 - 15 for including in this evaluation. In addition, each district will attempt to locate a project which is stripping, or that has been sealed or overlayed and may be stripping, to establish the base line for performance evaluation. If possible, stripping in pavements which had been treated with lime or liquid anti-stripping agents should be found for this purpose. Pavements identified include:

Tyler -
US 69, Type D, Crushed Gravel, Limestone Screenings, Liquid Agent, 1993
US 69, Type C, Crushed Gravel, Gravel Screenings, None or Unknown Agent, 1993
SH 31, Tyler to Kilgore, Current Job
US 69, Type C, Apple Sandstone, N. of Mineola, 1992?
SH 31, Type C, Limestone, AC-30P, W. of Athens, 1989?
SH 19, Limestone, N. of Palestine, Current Job

Lufkin -
US 59, Type C, Crushed Gravel and Lmst Screenings, N. of Nacogdoches, Liquid Agent, 1993
US 59, Type D, Crushed Gravel, N. of Lufkin, May not have an antistrip agent, Rutted this year, 1991
SH 7, Type C, Crushed Gravel, SW, of Center, 1992
US 259, Type D, N. of Nacogdoches, Crushed Gravel and Perch Hill Lmst Screenings, 1997
US 59, Type C, Angelina River, Limestone, 1993?
US 59, Type C, N. of Angelina River, Limestone and Bottom Ash, 1996?

Atlanta -
To be selected. In addition to a number of 1997 projects, they will try to include the oldest possible projects which include crushed gravel and lime and crushed gravel and liquid agent.

Each district will finalize their projects and send the information to other team members. Information should include County, Highway Number, CSJ and Project Limits.

Each district should prepare a summary of information similar to those prepared for this meeting which has information on each of the selected projects. This information will be useful during the visual evaluation scheduled for late February. On several projects, an attempt will be made to determine if the contractor put in a liquid agent on their own initiative.

APPENDIX C

PAVEMENT PHOTOGRAPHS

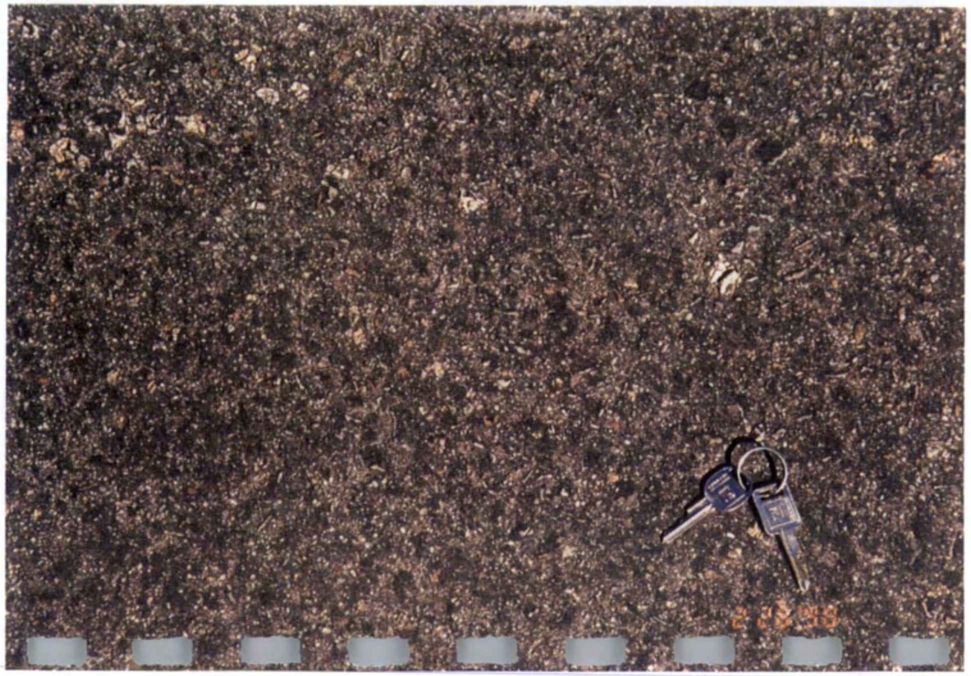
ATLANTA - 1

ATLANTA - 2

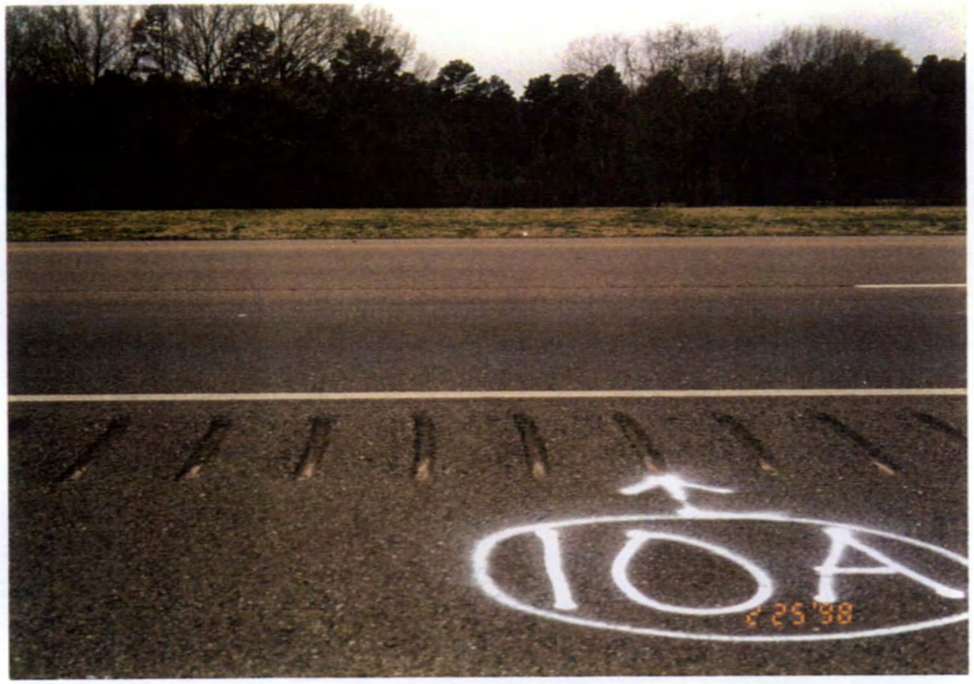
ATLANTA - 2

ATLANTA - 3



ATLANTA - 4

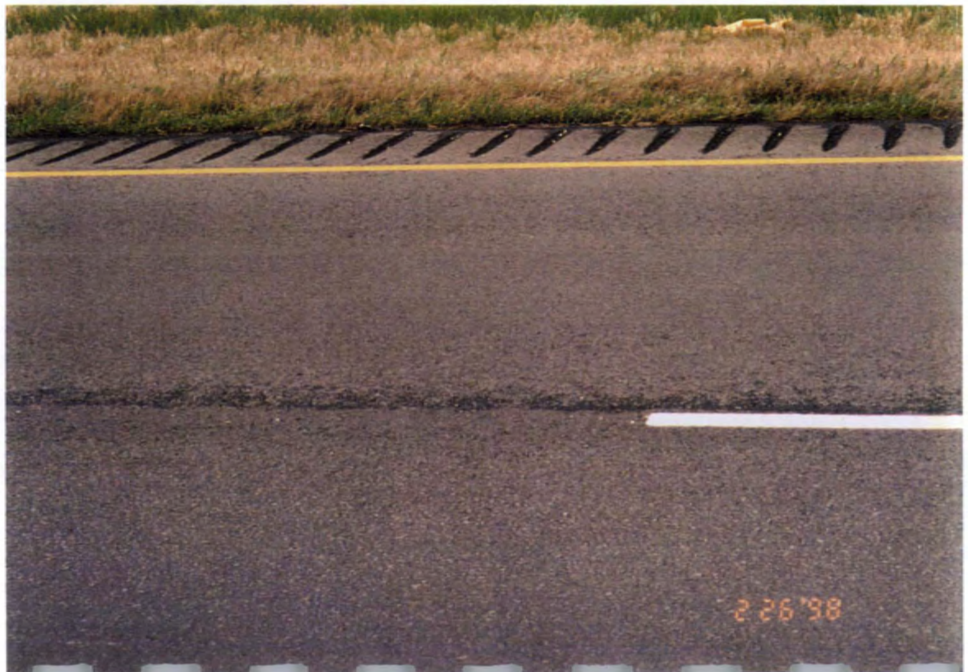
ATLANTA - 5



ATLANTA - 6

ATLANTA - 7


ATLANTA - 8



ATLANTA - 9

ATLANTA -10

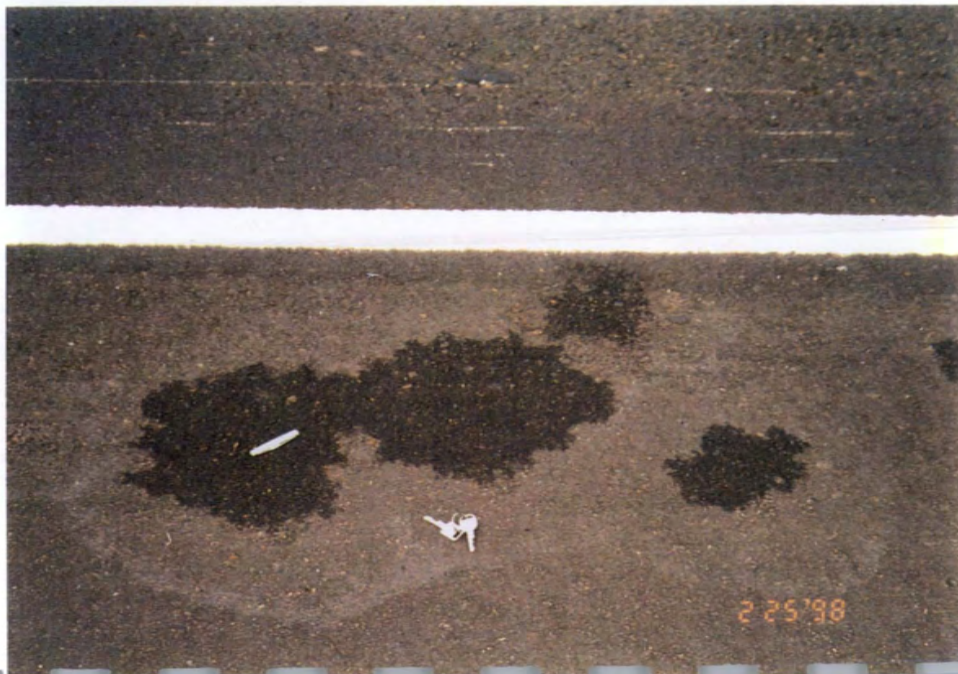
ATLANTA - 11

ATLANTA - 12


29
27 CA

ATLANTA - 13

ATLANTA - 14



ATLANTA - 15

ATLANTA - 16

ATLANTA - 17(2)

ATLANTA - 18(2)

LUFKIN - 1

LUFKIN - 2

LUFKIN - 4

No Photos Taken at
Lufkin Locations
#3, #5

LUFKIN - 6

LUFKIN - 7

LUFKIN - 8

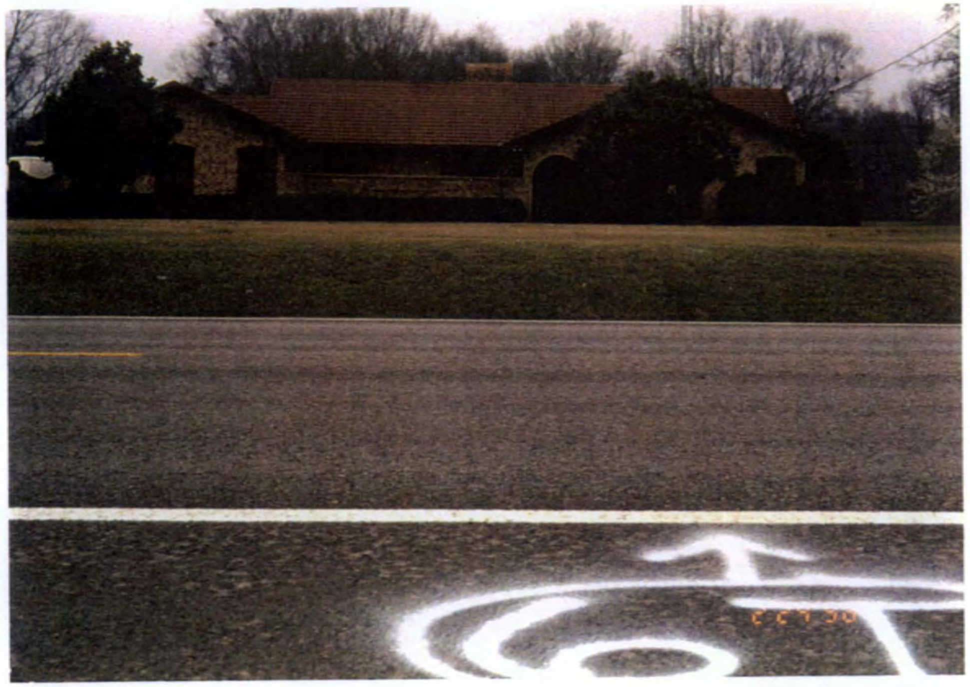
TYLER - 1

TYLER - 2

TYLER - 5

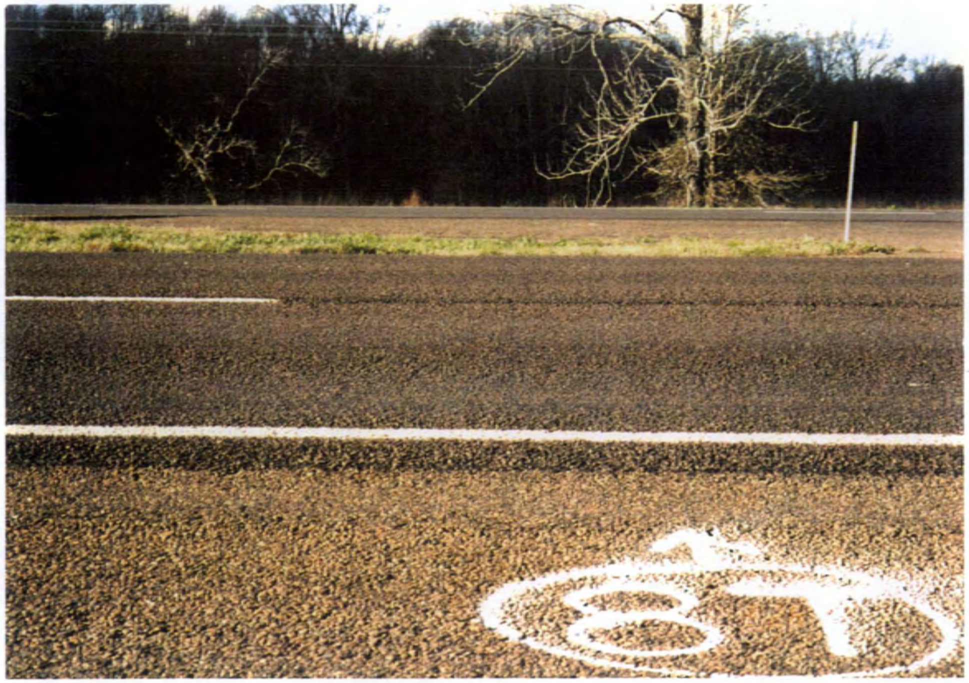
No Photos Taken at
Tyler Location #4

TYLER - 3



TYLER - 6

TYLER - 7



TYLER - 8

TYLER - 8

TYLER - 9

APPENDIX D

DISTRESS SURVEY FORM

Revised December 1, 1992

SHEET 1

DISTRESS SURVEY

LTPP PROGRAM

STATE ASSIGNED ID __ __ __ __

STATE CODE __ __

SHRP SECTION ID __ __ __ __

DISTRESS SURVEY FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES

DATE OF DISTRESS SURVEY (MONTH/DAY/YEAR) __ __/__ __/__ __

SURVEYORS: __ __ __, __ __ __ PHOTOS, VIDEO, OR BOTH WITH SURVEY (P, V, B) __
PAVEMENT SURFACE TEMP - BEFORE __ __ __ __°C; AFTER __ __ __ __°C

DISTRESS TYPE	SEVERITY LEVEL LOW	MODERATE	HIGH
CRACKING			
1. FATIGUE CRACKING (Square Meters)	__ __ __.__	__ __ __.__	__ __ __.__
2. BLOCK CRACKING (Square Meters)	__ __ __.__	__ __ __.__	__ __ __.__
3. EDGE CRACKING (Meters)	__ __ __.__	__ __ __.__	__ __ __.__
4. LONGITUDINAL CRACKING (Meters)			
4a. Wheel Path	__ __ __.__	__ __ __.__	__ __ __.__
Length Sealed (Meters)	__ __ __.__	__ __ __.__	__ __ __.__
4b. Non-Wheel Path	__ __ __.__	__ __ __.__	__ __ __.__
Length Sealed (Meters)	__ __ __.__	__ __ __.__	__ __ __.__
5. REFLECTION CRACKING AT JOINTS Number of Transverse Cracks	__ __ __	__ __ __	__ __ __
Transverse Cracking (Meters)	__ __ __.__	__ __ __.__	__ __ __.__
Length Sealed (Meters)	__ __ __.__	__ __ __.__	__ __ __.__
Longitudinal Cracking (Meters)	__ __ __.__	__ __ __.__	__ __ __.__
Length Sealed (Meters)	__ __ __.__	__ __ __.__	__ __ __.__
6. TRANSVERSE CRACKING Number of Cracks	__ __ __	__ __ __	__ __ __
Length (Meters)	__ __ __.__	__ __ __.__	__ __ __.__
Length Sealed (Meters)	__ __ __.__	__ __ __.__	__ __ __.__
PATCHING AND POTHOLES			
7. PATCH/PATCH DETERIORATION (Number)	__ __ __	__ __ __	__ __ __
(Square Meters)	__ __ __.__	__ __ __.__	__ __ __.__
8. Potholes (Number)	__ __ __	__ __ __	__ __ __
(Square Meters)	__ __ __.__	__ __ __.__	__ __ __.__

Revised December 1, 1992

SHEET 2

DISTRESS SURVEY

LTPP PROGRAM

STATE ASSIGNED ID __ __ __ __

STATE CODE __ __

SHRP SECTION ID __ __ __ __

DATE OF DISTRESS SURVEY (MONTH/DAY/YEAR) __ __/__ __/__ __

SURVEYORS: __ __ __, __ __ __

DISTRESS SURVEY FOR PAVEMENTS WITH ASPHALT CONCRETE SURFACES (CONTINUED)

DISTRESS TYPE	SEVERITY LEVEL LOW	MODERATE	HIGH
SURFACE DEFORMATION			
9. RUTTING - REFER TO SHEET 3 FOR SPS-3 OR Form S1 from Dipstick Manual			
10. SHOVING			
(Number)			__ __ __
(Square Meters)			__ __ __.__
SURFACE DEFECTS			
11. BLEEDING (Square Meters)	__ __ __.__	__ __ __.__	__ __ __.__
12. POLISHED AGGREGATE (Square Meters)			__ __ __.__
13. RAVELING (Square Meters)	__ __ __.__	__ __ __.__	__ __ __.__
MISCELLANEOUS DISTRESSES			
14. LANE-TO-SHOULDER DROPOFF - REFER TO SHEET 3			
15. WATER BLEEDING AND PUMPING			
(Number)			__ __ __
Length of Affected Pavement (Meters)			__ __ __.__
16. OTHER (Describe) ____________________			

____

____

____

APPENDIX E

GROUND PENETRATING RADAR RESULTS

APPENDIX E

EVALUATING THIN HMA OVERLAYS WITH GROUND PENETRATING RADAR (GPR)

Summary

GPR data was collected as part of the evaluation of relatively new gravel overlays in North-East Texas. Many of these overlays were placed over new chip seals and several of the projects were tested shortly after significant rainfall. GPR was able to identify mixes that are holding moisture above the seal. It was also able to identify locations of moisture build up and deterioration in the old HMA layer, this will be useful in predicting the performance of these pavements and in diagnosing the cause of future surface distress. It is proposed that the quality of the mat can also be monitored by the variation is GPR surface reflection but this is complicated by the time since last rainfall, and the age of the surfacing.

1. Introduction to GPR

1.1 Basics

The Texas Transportation Institute's Ground Penetrating Radar (GPR) unit is shown in Figure 1. This systems sends discrete pulses of radar energy into the pavement system and captures the reflections from each layer interface within the structure. This particular GPR unit transmits and receives 50 pulses per second and can effectively penetrate to a depth of 0.6 m (2 ft). A typical plot of captured reflected energy versus arrival time for one pulse is shown at the bottom of Figure 1, as a graph of volts versus time in nanoseconds. The automated software, developed by TTI to process this data measures the amplitudes of reflection and time delays between peaks to compute both layer dielectrics and thicknesses.

With reference to Figure 1 the reflection A_1 is the energy reflected from the surface of the pavement, A_2 and A_3 are from the top of the base and subgrade respectively. These amplitudes of reflection are used to calculate individual layer dielectrics. These are electrical properties of the pavement materials. The engineering properties which most influences these dielectrics is the moisture content and density of the individual layers. If the moisture content for a layer increases, then the amount of energy reflected from the top of the layer would increase resulting in an increase in calculated layer dielectric. An increase in air voids would have the opposite effect, if the amount of air in a layer increases the energy reflected and resulting dielectric would decrease. TTI has established a range of typical dielectrics for most paving materials, for example HMA layers normally have a dielectric value between 4.5 and 6.5, depending on the coarse aggregate type. Measured values significantly higher than this would indicate the presence of excessive moisture, lower values could indicate a density problem or indicate that an unusual aggregate, such as lightweight, has been used.

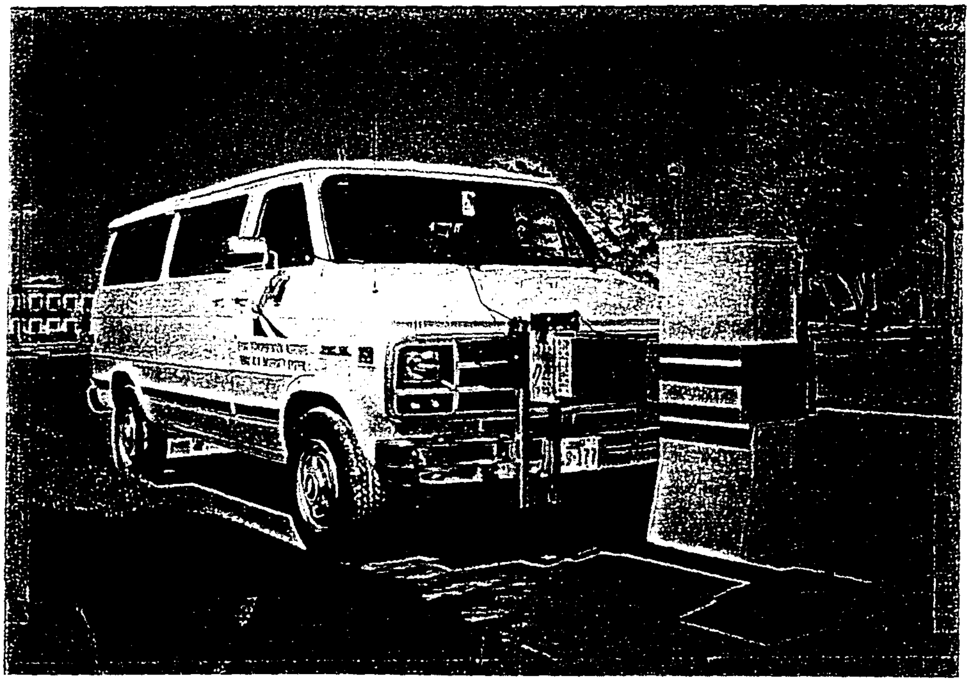
The examples below illustrate how changes in materials properties and structure would influence the typical GPR trace shown in Figure 1,

1) If the thickness of the surface layer increases then the time interval between A_1 and A_2 would increase,
2) If the base layer becomes wetter then the amplitude of reflection from the top of the base A_2 would increase, and
3) If there is a significant defect within the surface layer then a reflection will be observed between A_1 and A_2. This could be either a positive reflection for trapped moisture or a negative reflection for stripping, and
4) As the unit travels along the highway it collects traces at regular intervals, therefore GPR has the potential to monitor the uniformity of the surfacing layer. Large changes in the surface reflection A_1 would indicate changes in either the density (decrease in amplitude) or moisture content (increase in amplitude) along the section.

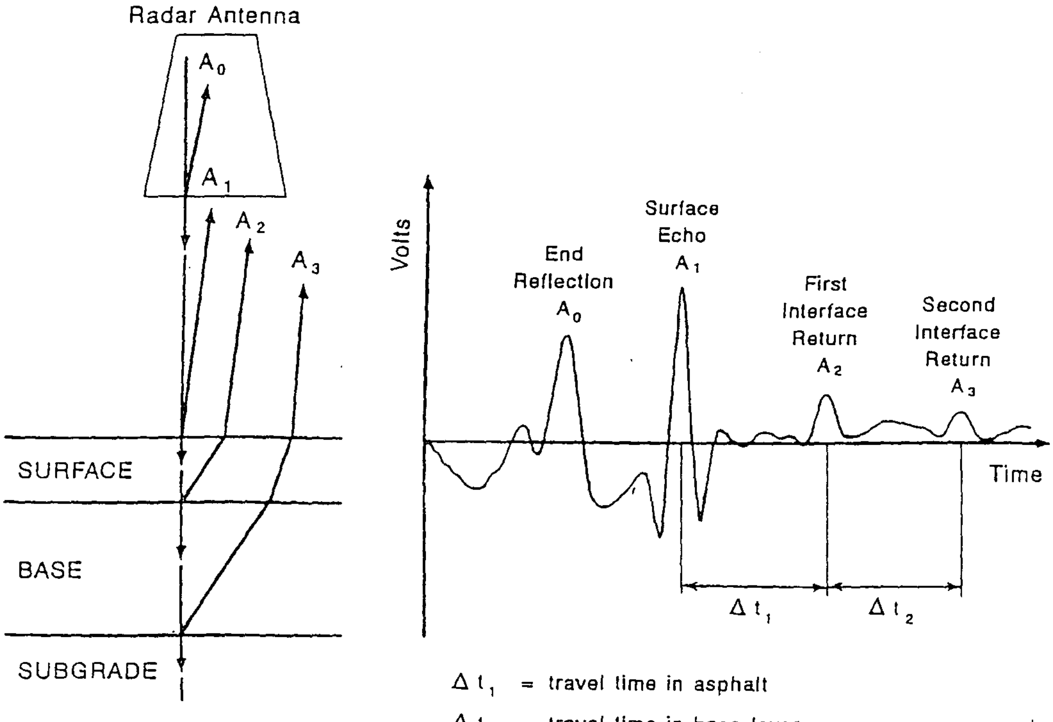
1.2 GPR Reflections from Thin Surfacings

Figure 2 contains a single GPR reflection from one location on a flexible pavement containing a thin 40 mm (1.5 inch) overlay. The blue line in Figure 2 is the raw data, as before A_1 and A_2 are reflections from the top of the HMA and top of the base layer. With GPR systems operating at a frequency of 1 GHz one complicating issue is that reflection from layers less than 75 mm thick will overlap and be impossible to detect the layer interface without additional signal processing. The pavement in Figure 2 had a recent 40 mm overlay and the reflection from the surface will be merged with that from the top of the old HMA layer. To handle this situation a surface subtraction technique has been built into TTI's data processing software. This technique has been applied to the reflection in Figure 2 (blue line) and after surface removal the result is the red line. The reflection from the top of the old HMA layer is shown as reflection B_1. One point which must be emphasized is that GPR only works if there is an electrical contrast between pavement layers, if two layer have exactly the same electrical properties and they are bonded together, then there will be little energy reflected from that interface and it will be impossible to detect it in the reflected trace. This is often the case with thick ASB's consisting of many thin lifts. With these pavements a significant interface reflection would be a cause for concern. However, with a new thin HMA overlay placed over an existing flexible pavement there is often sufficient contrast between the old and new layers to provide a small reflection from the interface.

The trace shown in Figure 2 is classified as an ideal trace for a recent thin HMA overlay over an existing flexible pavement. The small reflection at the interface (B_1), which is found after surface removal, indicates that there is only a small contrast between the old and new layers. As shown on Figure 2 the dielectrics for the upper and lower layers were computed to be 4.8 and 5.6 respectively which are considered to be normal. The thickness of the overlay was computed to be 2.1 ins and the old HMA layer at 6.7 ins. As there are no strong reflections in the lower HMA layer between B_1 and A_2 therefore this layer is judged to be homogeneous and defect free, it should be possible to extracted a solid core from this pavement. The dielectric from the top of the flexible base was calculated to be 12.4 which is classified as marginal for granular material. Top quality flexible base material have been found to have a calculated dielectric of below 10, saturated layers have a value greater than 16.

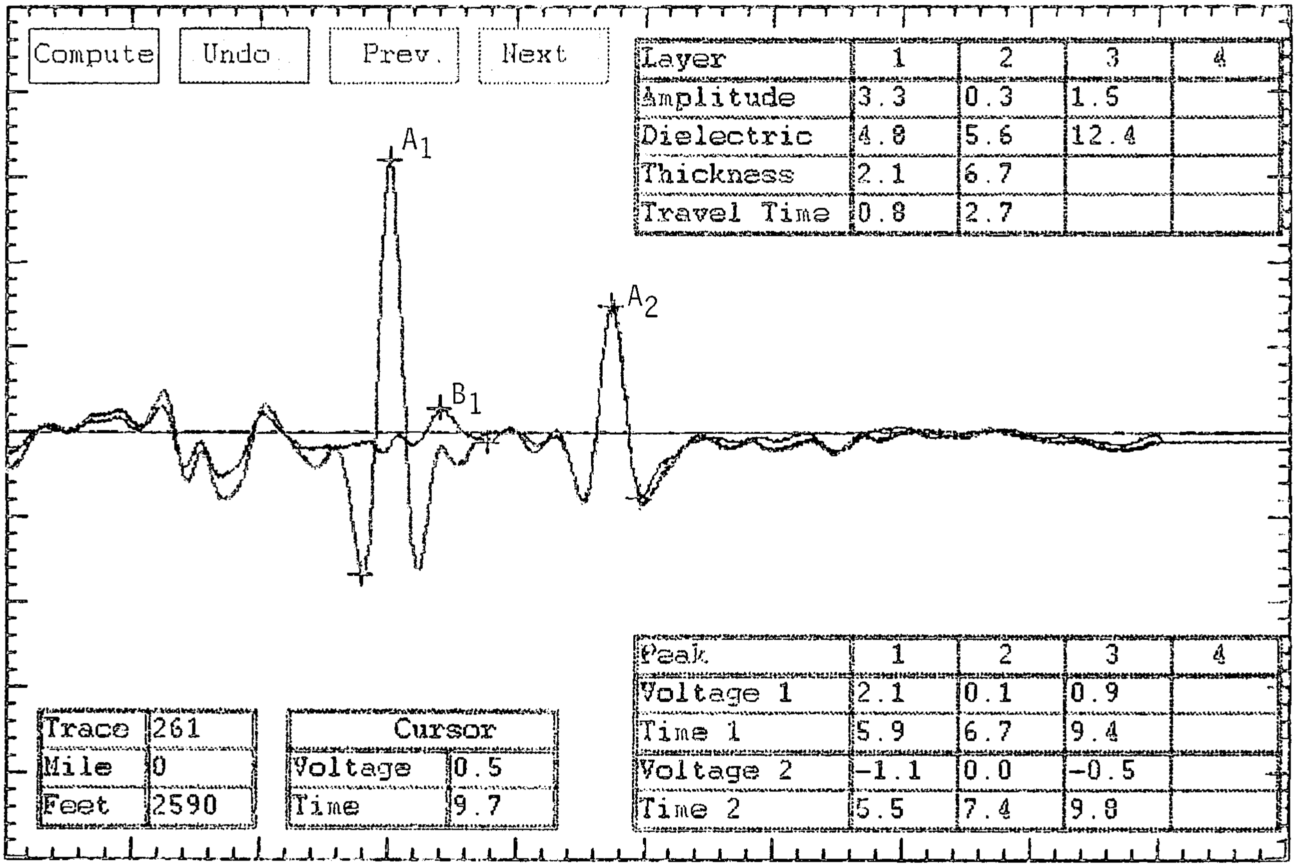


a. TTI GPR Equipment.



b. Principles of Ground Penetrating Radar. The Incident Wave is Reflected at Each Layer Interface and Plotted as Return Voltage Against Time of Arrival in Nanoseconds.

Figure 1. GPR Equipment and Principles of Operation.



Layer	1	2	3	4
Amplitude	3.3	0.3	1.5	
Dielectric	4.8	5.6	12.4	
Thickness	2.1	6.7		
Travel Time	0.8	2.7		

Peak	1	2	3	4
Voltage 1	2.1	0.1	0.9	
Time 1	5.9	6.7	9.4	
Voltage 2	-1.1	0.0	-0.5	
Time 2	5.5	7.4	9.8	

Figure 2. Typical GPR return signal from a flexible pavement with a thin overlay. Reflections A_1, B_1, A_2 from surface, bottom of overlay, top of flexible base, respectively. This is viewed as the "Ideal" Case 1, well bonded overlay no deflects in lower HMA. The blue line is raw GPR return signal, the red line is obtained after surface removal.

1.3 Color-Coded Display of GPR Data

Figure 2 shows an individual GPR reflections from a single location on a highway. When GPR data is collected for any project similar reflections are collected at regular intervals along the highway, typically at 5 or 10 foot spacings. Therefore for any project several thousand GPR traces could be collected. To conveniently display the information from numerous traces a color coding scheme is used. In this scheme the plot of voltage versus arrival time is transformed into a single vertical line scan of different colors. In the current scheme the high positive voltages are colored red and the high negatives are colored blue. The color coded GPR traces are then stacked side by side to generate a subsurface picture of the pavement. A typical color coded display is shown in Figure 3, the bottom axis is distance along the highway, the axis on the right of the figure is a depth scale in inches and on the left is the color-coding scheme used. Normally when providing these color-coded printouts to TxDOT Districts annotation are applied to the figure to identify important features, such as bridges, strong reflections from interfaces and potential defects. For example the section of pavement shown in Figure 3 consists of a thick HMA layer over a granular base. This pavement has recently received a thin overlay. Significant features of this figure are a) the large change in HMA thickness on the approach to the bridge, b) away from the bridges there is no significant reflection from the bottom of the last overlay which indicates similar materials bonded together, and c) a clear old/new HMA interface between the bridges, this as will be described later, indicates moisture trapped at a depth of 3 - 4 inches below the surface.

TYPICAL COLORMAP DISPLAY (10A) WITH ANNOTATION

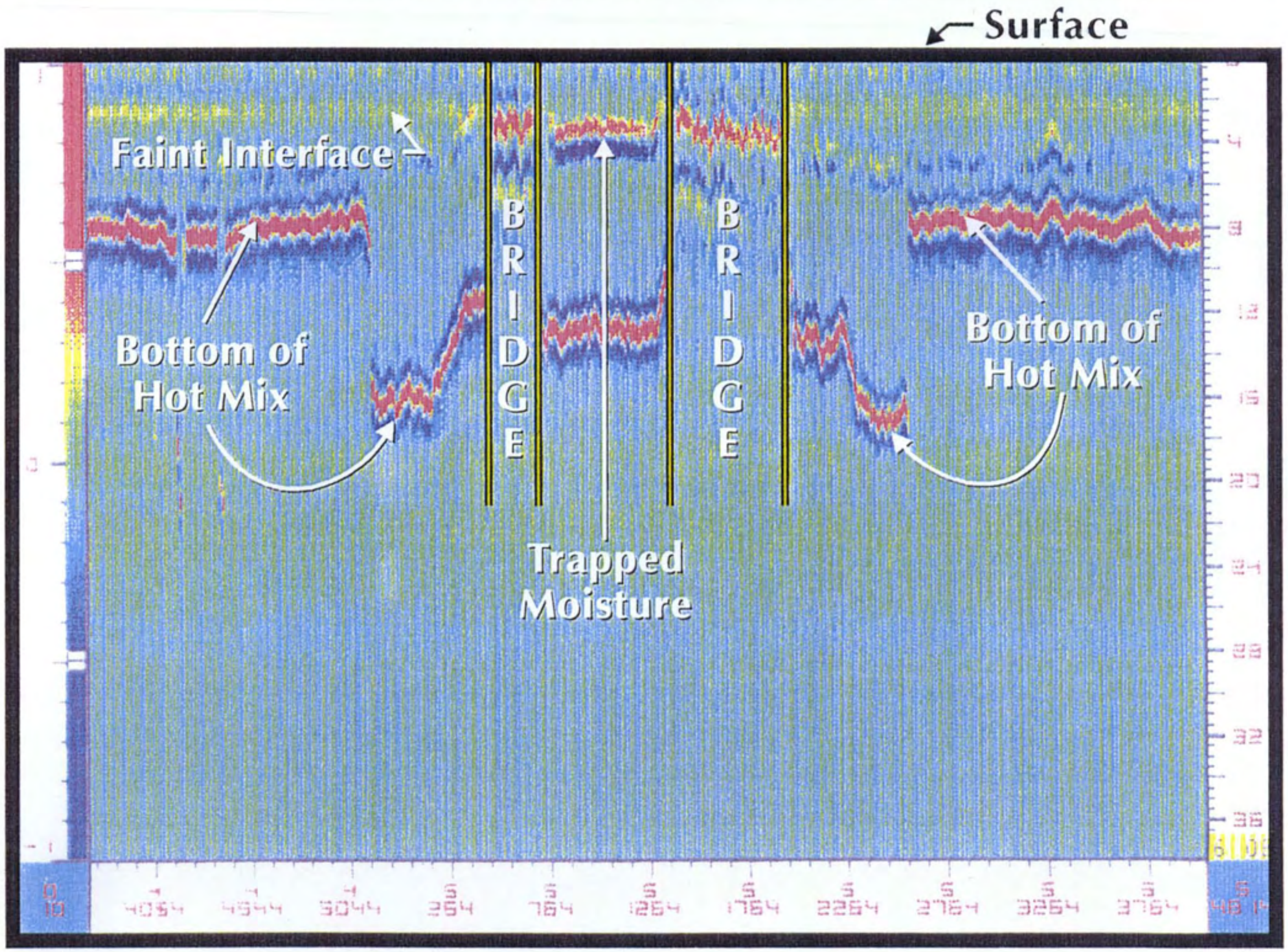


Figure 3. COLORMAP Printout from US59 (Section 6). Depth Scale on Right, Distance Scale at Bottom.

2. Collection and Processing of GPR Data from the Atlanta District's Pavements

2.1 Data Collection

GPR data was collected on the Atlanta pavements in early February 1998. The data collection speed was the posted speed limit which ranged from 35 mph in town to 70 mph on the Interstate. The outside lane outside wheel path was tested on each highway. The GPR "footprint" is approximately 9 ins * 9 ins and each captured trace is an average over this area. On 4 lane highways both directions were tested. Two factors which influence the data analysis are a) the data collection interval and b) the weather conditions at the time of data collection. Most of the projects are several miles long therefore the data collection interval was set at one trace per 10 foot of pavement. The weather at the time of data collection was very variable, considerable rain fell during data collection. GPR data was not collected immediately after heavy rain but many of the sections were tested either 1 or 2 days after significant rain. This rainfall had a substantial impact on the GPR traces particularly the reflection from the interface between HMA layers, this will be described in section 2.2. The operators noted whether the data was collected 1, 2 or 3+ days after heavy rain.

2.2 Types of Reflections From the Interfaces Between Layers

As described above the time since rainfall has a big impact on the GPR signals. The 5 types of reflections found in this study are shown schematically in Figure 4. The "ideal" trace with little contrast between the new and old HMA layers is shown in Figure 2. This is defined as a Case 1 reflection in Figure 4, the other four cases are discussed below;

Case 2 If the lower HMA layer was trapping moisture (for example below a seal placed between layers) then the shape of reflection B_1 would stay the same but its amplitude would increase. The computed dielectric for the lower HMA layer would also increase significantly above 7.

Case 3 If a thin layer moisture was trapped on top of a seal coat placed between HMA layers then both the shape and amplitude of reflection B_1 would change. Overlapping signals would be generated with a positive reflection from the top of the moist layer overlapping with a negative reflection as the wave travels from the wet HMA to dry HMA (high dielectric to low dielectric). In this instance the computed dielectric for the lower HMA layer would not increase. (This was encountered frequently in this study particularly with the pavements from the Atlanta District which mostly had a chip seal placed between the old and new HMA layers and the GPR testing was mostly conducted one or two days after significant rainfall. In some instances the seal was made with lightweight (absorptive) aggregates and in these cases the moisture may have been in the seal itself)

Case 4 If the lower HMA layer contains some deterioration in the form of stripping then a negative reflection would be observed between reflections B_1 and A_2. Similar negative reflections can also be generated by non defects such as buried lightweight aggregate layers or drainage layers. The key to distinguishing between stripping and unusual aggregates is that with stripping the negative reflection would be intermittent, as the severity of the deterioration varies substantially along the highway.

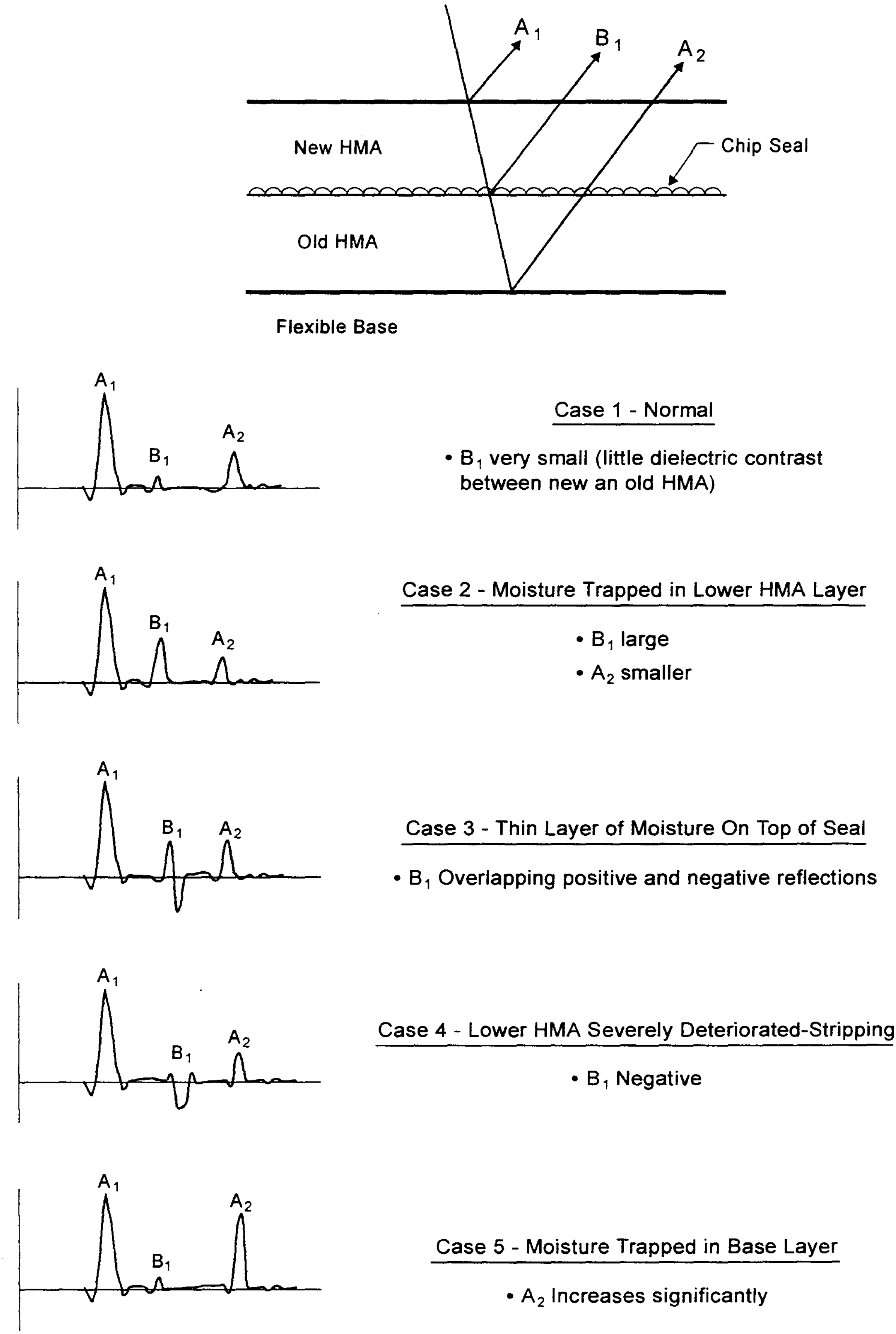


Figure 4. Classification and Interpretation of the Different Subsurface Reflections Found in this Study.

Case 5 If the base layer became excessively wet then amplitude A_2 would increase and from earlier TTI studies the computed dielectric of the base would be greater than 16. For top quality dry granular base material the dielectric values should be less than 10.

Examples of these cases will be presented in the next section.

2.3 Comparing GPR Traces with Field Cores

The GPR data was collected prior to visual inspection of the sections by the Task Force. The data was reviewed and used to select core locations. Figures 5 through 10 show examples of comparing the GPR traces with the corresponding drilling logs. The computed layer thicknesses and dielectrics are shown in the box in the upper right hand corner of each figure. As all of the overlays were thin the surface removal technique described earlier was applied to clearly define the interface reflection. On each figure the raw GPR data is the blue trace and the red trace shows the subsurface reflections after surface removal;

Figure 5 FM 1397, new construction thin HMA layer over flexible base (Section 13 from Table 1 in main body of report). This is an ideal trace. Even though the data was collected one day after rain fall the base dielectric is low at 6.3 indicating a dry base. Little moisture appears to be entering the base from either surface penetration or capillary rise.

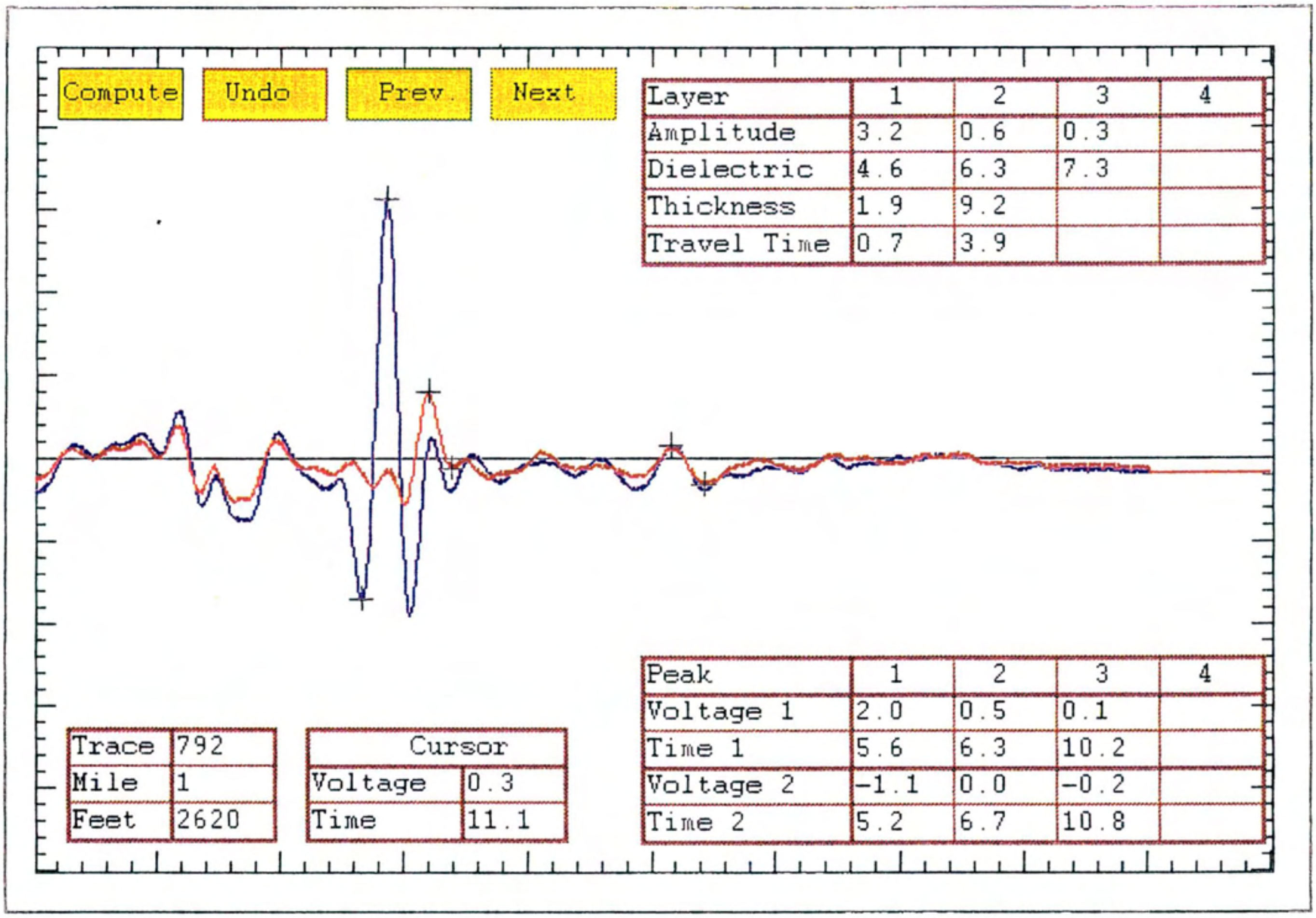
Figure 6 SH 11, new construction thin HMA over lightly stabilized Iron ore base (Section 16). Significantly different trace from Figure 5. Large reflection from the top of base. This indicates that either the base consists of a very unusual aggregate or more probably that the base is holding a lot of moisture. The ground water table is high and there are numerous spring in this area. The performance of this section should be monitored to determine if the base condition leads to poor pavement performance.

Figure 7 US 59, thin overlay over existing HMA (Section 6), data collected 2 days after rain. Ideal Case 1, little reflection from the interface in HMA indicating no problem. No stripping in lower HMA layer.

Figure 8 US 59, thin overlay over thick gravel ASB (section 18), data collected one day after rainfall. There is a lightweight seal coat between layers. The GPR data indicates that there is a slight build up of moisture in a thin 0.8 inch thick layer at this interface, this is a typical Case 3 type interface reflection. This is not judged to be a major concern, although clearly the surface layer is leaking. At this location there does not appear to be any major moisture problems with the lower ASB layer.

Figure 9 US 271, thin overlay over existing HMA layer (Section 15), data collected one day after rainfall. Major moisture trapped within upper pavement layers (Case 3). If these lower layers are susceptible then anticipate rapid stripping of these layers. As the saturated layer was calculated to be 3 inches below the surface it is possible that the GPR trace and core were not from same location. Note with large reflections like this within layers it is impossible to make accurate layer thickness estimates.

Figure 10 US 271, thin overlay over existing HMA layer (Section 3), data collected over three days since significant rainfall. Case 1 reflection at bottom of thin overlay. Intermediate reflections at mid depth in lower HMA layer and non standard reflection at base interface indicating possible subsurface deterioration.



CORING REPORT AND LOG

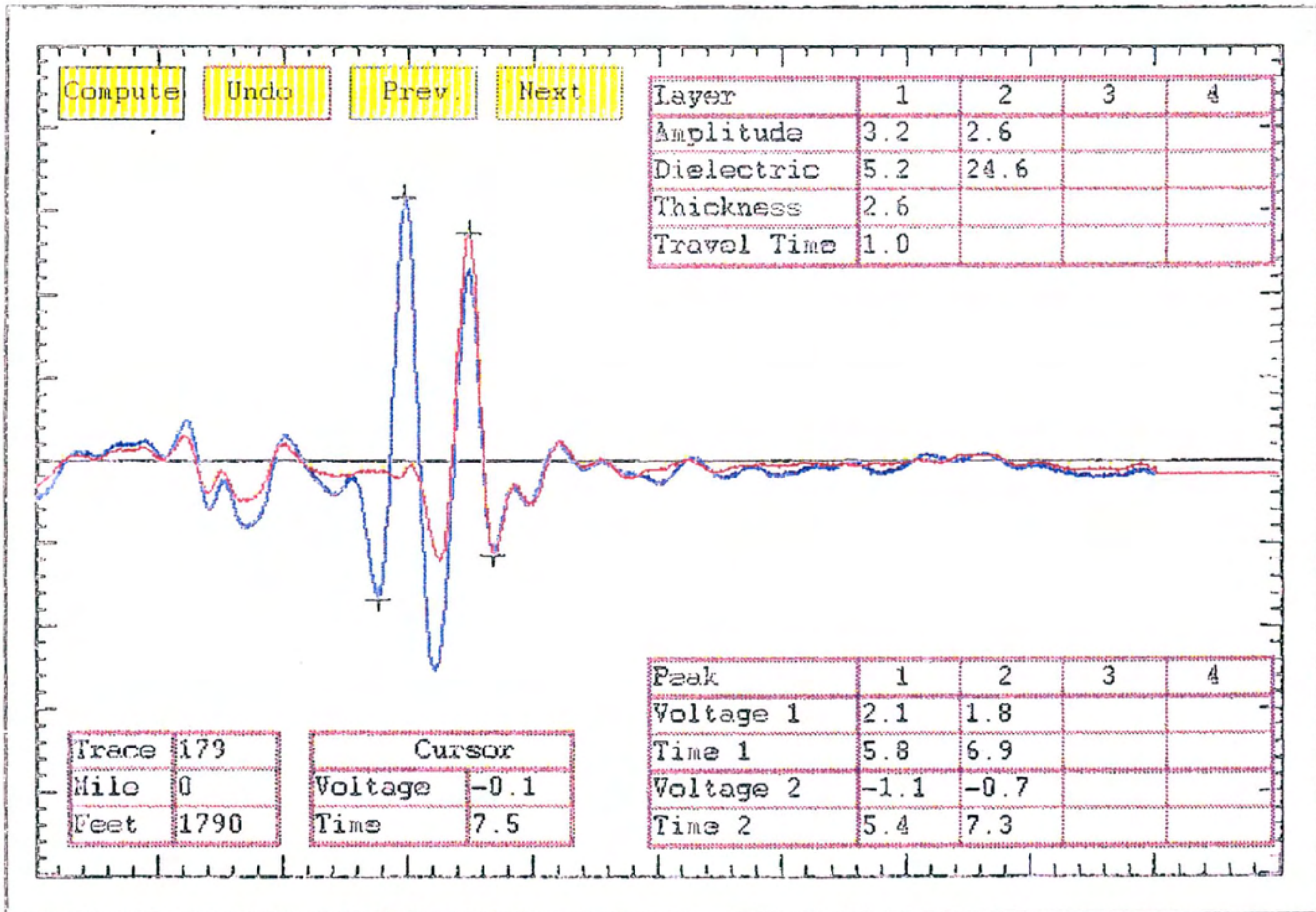
[illegible] BOWIE PROJECT 28A DATE 03-26-98 PAGE 1 /

[illegible] HWY FM 1397 AREA ENGINEER DAVID WILLIAMS

[illegible] 100' S. OF CO. RD. 2319 ~~TO~~ (SHILLING ROAD) CORING TECHNICIAN CHAPPY SHELTON

(1) CORE #	(2) STA OR DIST FROM REFERENCE	(3) DIRECTION AND LANE	(4) LOCATION IN LANE	(5) CORE DIA (IN.)	(6) DEPTH BELOW SURF FROM (IN.)	(6) DEPTH BELOW SURF TO	(7) LAYER THICKNESS (IN.)	(8) DIST. BETWEEN CORES CUMUL.	(9) H.I. ABOVE SURFACE (FT.)	(10) DISCRIPTION OF LAYER INCLUDING KIND, TYPE, CONDITION
		NBL	OWP	4	0	1 5/8				TY C GHLR GRAVEL *
					1 5/8	1 7/8				LT WT GR 4 SEAL
									*	SOME PITTING ON CORE, BUT INSIDE WALLS OF CORE HOLE NONE

Figure 5. GPR Trace and Coring Data from FM 1397 (Section 13). Ideal Trace for New Pavement.



CORING REPORT AND LOG

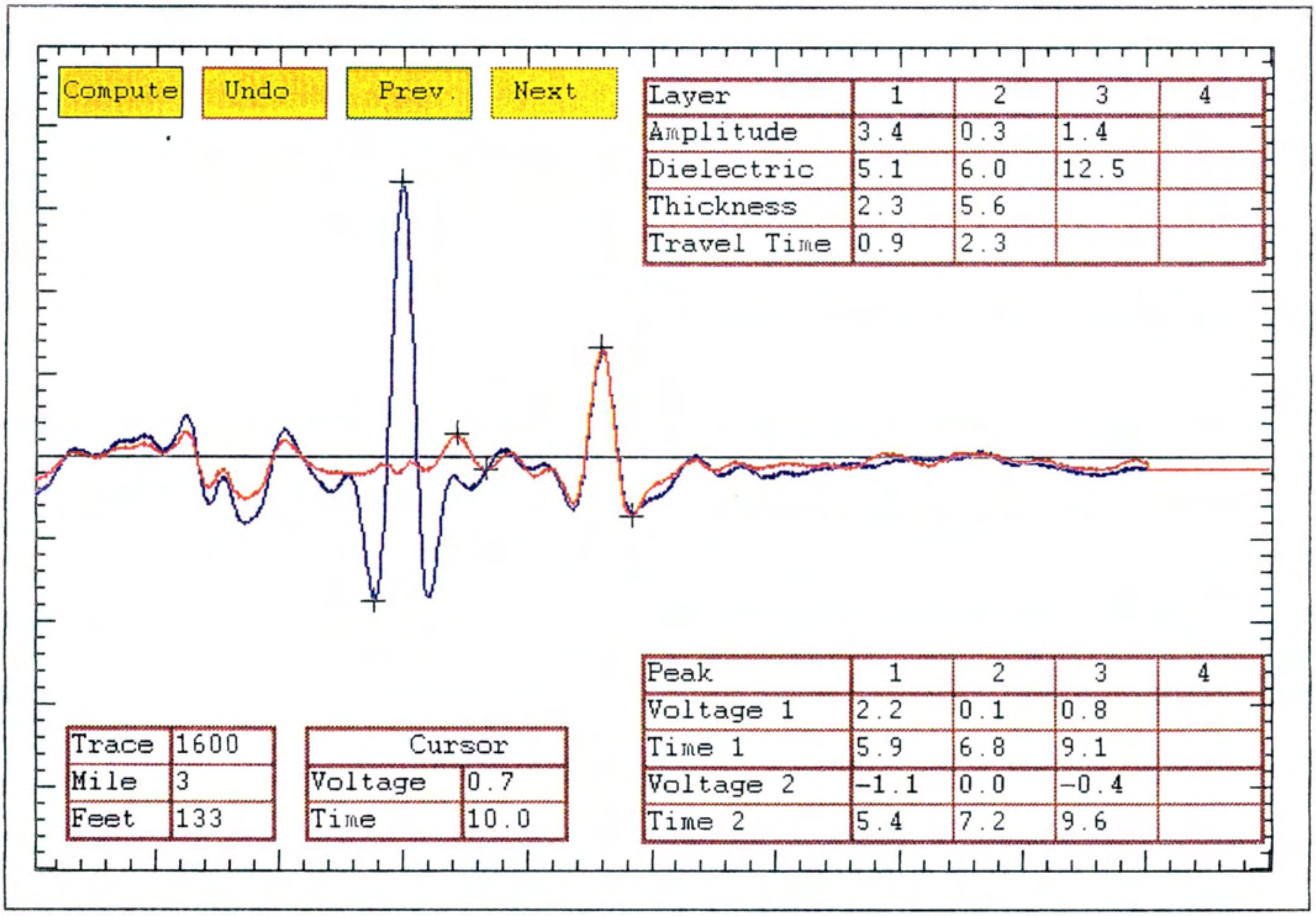
CTY CASS PROJECT 30 CA DATE 03-20-98 PAGE 1 /

RCL HWY SH 11 / SH 49 AREA ENGINEER E. JOHN BAKER

TS 200' N. OF RM 742 TO: CORING TECHNICIAN CHAPPY SHELTON

(1) CORE #	(2) STA. OR DIST FROM REFERENCE	(3) DIRECTION AND LANE	(4) LOCATION IN LANE	(5) CORE DIA (IN.)	(6) DEPTH BELOW SURF FROM (IN.)	TO	(7) LAYER THICK NESS (IN.)	(8) DIST. BETWEEN CORES CUMUL.	(9) H.I. ABOVE SURFACE (FT.)	(10) DISCRIPTION OF LAYER INCLUDING KIND, TYPE, CONDITION
30CA		SBOL	OWP	4	0	2 3/8				TY C MERIDIAN SANDSTONE
					2 3/8	2 3/4				LT WT. SEAL

Figure 6. GPR Trace and Coring Data from SH 11 (Section 16). Thin HMAC Over Wet Base.



CORING REPORT AND LOG

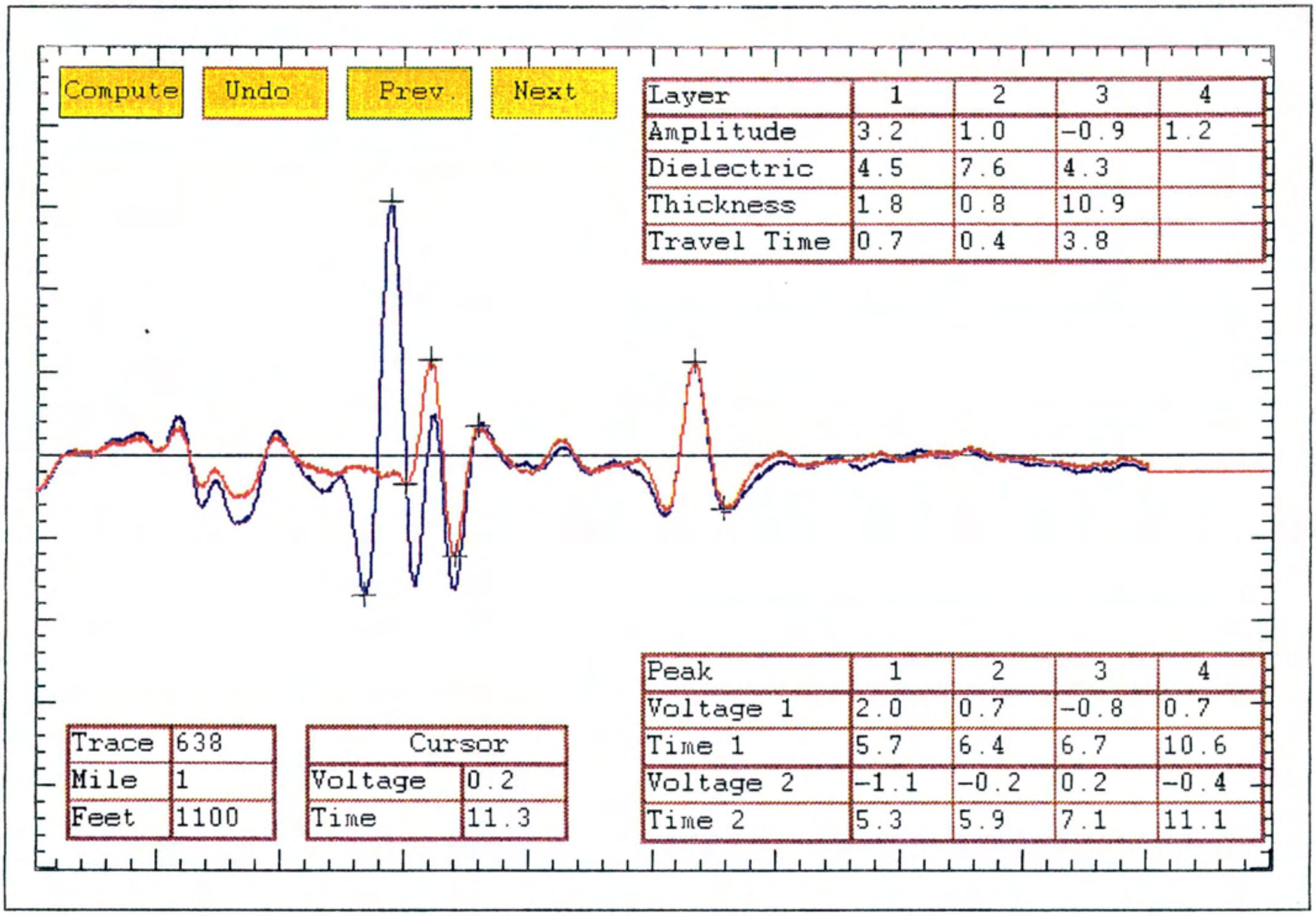
NTY PANOLA PROJECT 10A DATE 03-11-98 PAGE 1 /

ROL HWY US59 AREA ENGINEER MIKE ANDERSON

TS: 0.5 MI. N. RM 308 TO: WHITE FENCE CORING TECHNICIAN CHAPPY SHELTON

(1) CORE #	(2) STA. OR DIST FROM REFERENCE	(3) DIRECTION AND LANE	(4) LOCATION IN LANE	(5) CORE DIA (IN.)	(6) DEPTH BELOW SURF FROM (IN.)	TO	(7) LAYER THICKNESS (IN.)	(8) DIST. BETWEEN CORES CUMUL.	(9) H.I. ABOVE SURFACE (FT.)	(10) DISCRIPTION OF LAYER INCLUDING KIND, TYPE, CONDITION
10A		NBOL	OWP	4	0	2 3/8				GHLR TY C SOME LOSS OF FINES @ CA.
					2 3/8	8'				GHLR TY B LOWER LIFT SPECIMEN #4 CRACKED.

Figure 7. GPR Trace and Coring Data from US 59 (Section 6). Ideal Trace, No Moisture Damage in Either HMA Layers Good Bond Between Layers.



Layer	1	2	3	4
Amplitude	3.2	1.0	-0.9	1.2
Dielectric	4.5	7.6	4.3	
Thickness	1.8	0.8	10.9	
Travel Time	0.7	0.4	3.8	

Trace	638
Mile	1
Feet	1100

Cursor	
Voltage	0.2
Time	11.3

Peak	1	2	3	4
Voltage 1	2.0	0.7	-0.8	0.7
Time 1	5.7	6.4	6.7	10.6
Voltage 2	-1.1	-0.2	0.2	-0.4
Time 2	5.3	5.9	7.1	11.1

CORING REPORT AND LOG

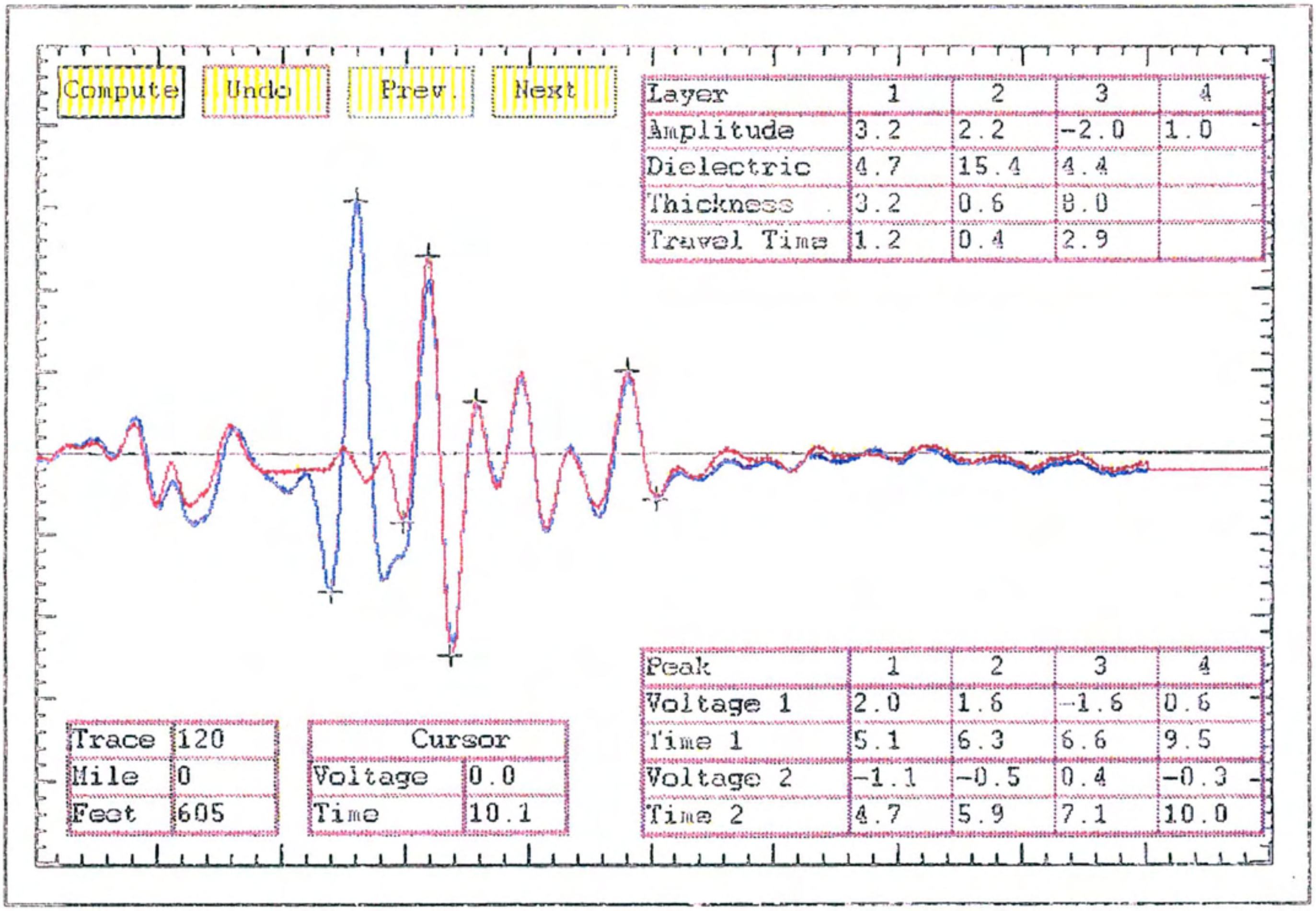
TY CASS — PROJECT 41A — DATE 03-20-98 PAGE 1 /

ROL — HWY US 59 — AREA ENGINEER E. JOHN BAKER

TS 0.5 MI. S. — TO: JOHNS CREEK — CORING TECHNICIAN CHAPPY SHELTON

(1) CORE #	(2) STA. OR DIST FROM REFERENCE	(3) DIRECTION AND LANE	(4) LOCATION IN LANE	(5) CORE DIA (IN.)	(6) DEPTH BELOW SURF FROM (IN.)	TO	(7) LAYER THICKNESS (IN.)	(8) DIST. BETWEEN CORES CUMUL.	(9) H.I. ABOVE SURFACE (FT.)	(10) DISCRIPTION OF LAYER INCLUDING KIND, TYPE, CONDITION
41A		SBOL	OWP	4	0	2				TY C GHLR GRAVEL
"		"	"	"	2	2 1/8				LT WT GR 4 SEAL
"		"	"	"	2 1/8	12 1/4				TY A ACP GHLR 4 LIFTS - 3ND LIFT FROM BOTTOM LOST FINES AROUND C.A.
										3/8" RUT OWP & IWP

Figure 8. GPR and Coring Data from US 59 (Section 18). Example of a Case 3 Reflection, Moisture Build Up at Layer Interface.



CORING REPORT AND LOG

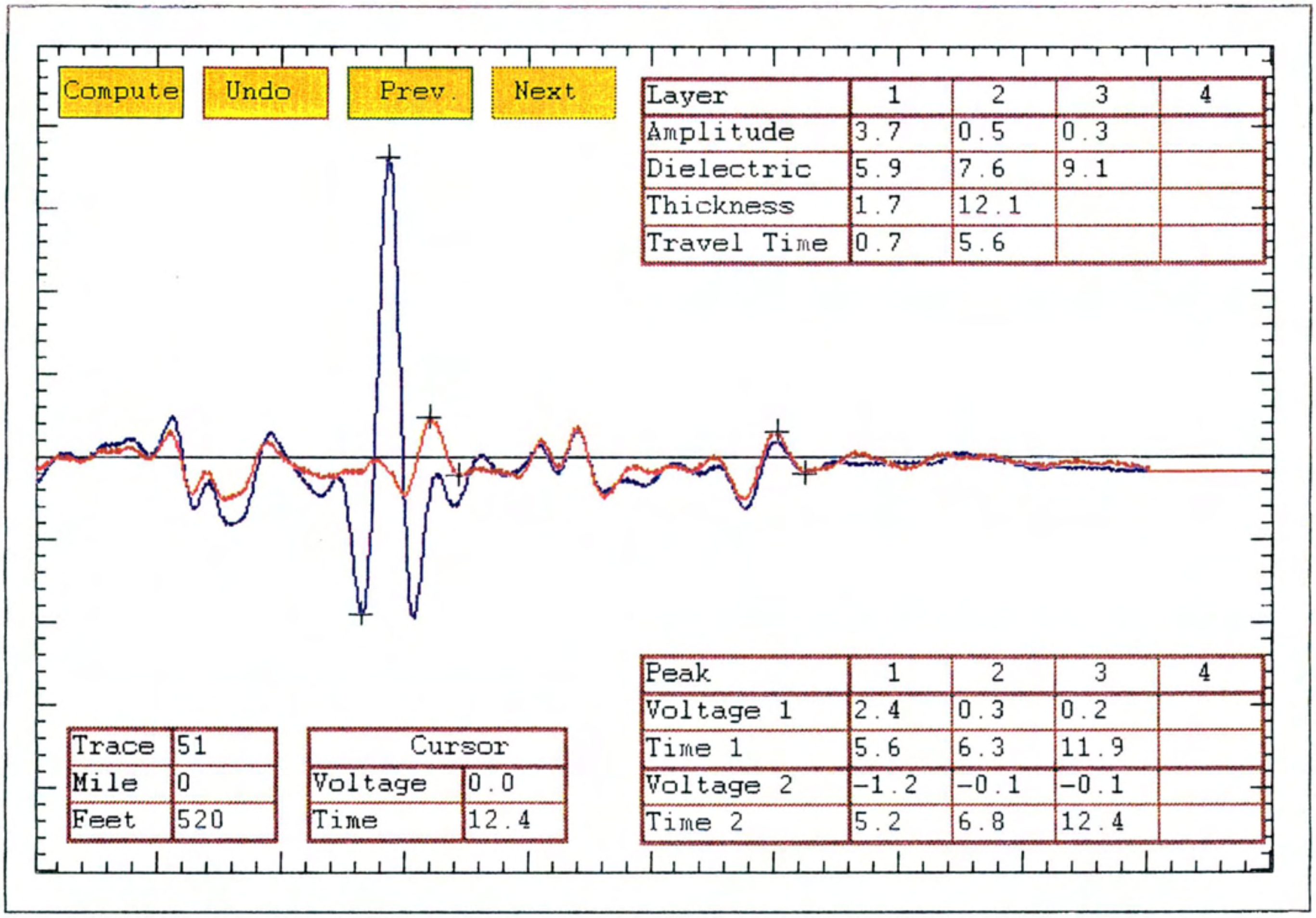
TY: Titus PROJECT 30BA DATE 03-20-98 PAGE 1 / ____

RD ________ ________ HWY US 271 AREA ENGINEER Roger Ledbetter

TS: Autozoné TO: ________ CORING TECHNICIAN Chappy Shelton

(1) CORE #	(2) STA. OR DIST FROM REFERENCE	(3) DIRECTION AND LANE	(4) LOCATION IN LANE	(5) CORE DIA (IN.)	(6) DEPTH BELOW SURF FROM (IN.)	(6) DEPTH BELOW SURF TO	(7) LAYER THICK NESS (IN.)	(8) DIST. BETWEEN CORES CUMUL.	(9) H.I. ABOVE SURFACE (FT.)	(10) DISCRIPTION OF LAYER INCLUDING KIND, TYPE, CONDITION
30BA		SBOL	OWP	4	0	1½				TY C SANDSTONE
					1½	1¾				LT WT GR 4 SEAL
					1¾	9¼				TY B ACP SANDSTONE

Figure 9. GPR Trace and Coring Data from US 271 (Section 15). Large Amount of Moisture Trapped About 3 Inches Below Surface.



Layer	1	2	3	4
Amplitude	3.7	0.5	0.3	
Dielectric	5.9	7.6	9.1	
Thickness	1.7	12.1		
Travel Time	0.7	5.6		

Trace	51
Mile	0
Feet	520

Cursor	
Voltage	0.0
Time	12.4

Peak	1	2	3	4
Voltage 1	2.4	0.3	0.2	
Time 1	5.6	6.3	11.9	
Voltage 2	-1.2	-0.1	-0.1	
Time 2	5.2	6.8	12.4	

CORING REPORT AND LOG

CTY TITUS PROJECT 7A DATE 03-20-98 PAGE 1 /

ROL HWY US 271 AREA ENGINEER ROGER LEDBETTER

TS HOUSE ON N. END % OF PROJECT CORING TECHNICIAN CHAPPY SHELTON

(1) CORE #	(2) STA. OR DIST FROM REFERENCE	(3) DIRECTION AND LANE	(4) LOCATION IN LANE	(5) CORE DIA (IN.)	(6) DEPTH BELOW SURF FROM (IN.)	TO	(7) LAYER THICK NESS (IN.)	(8) DIST. BETWEEN CORES CUMUL.	(9) H.I. ABOVE SURFACE (FT.)	(10) DISCRIPTION OF LAYER INCLUDING KIND, TYPE, CONDITION
		SBL			0	1 3/4				TY C SANDSTONE
					1 3/4	13 1/16				TY A SANDSTONE LOSS OF FINE AROUND C.A. APPROXIMATELY @ MID BASE

Figure 10. GPR Trace and Coring Data from US 271 (Section 3). Thick Lower HMA Layer with Possible Deterioration at Middepth and Bottom.

2.4 GPR Evaluation Criteria for Atlanta Sections

As discussed earlier numerous GPR traces were collected for each of the test sections. In order to evaluate the overall condition of each section criteria had to be developed specifically for this project. No such criteria exist for interpreting GPR signals from thin overlays. Below are listed the three sets of criteria proposed;

A) Quality of Surface Layer. Tentative criteria were developed to relate the measured surface dielectric and its variation along the highway to quality of the surface layer. The dielectric being calculated directly from the amplitude of the surface reflection A_1. Examples of the variation in surface dielectric are shown in Figure 11 as a plot of surface dielectric against distance. The upper plot being for a "good" homogeneous pavement .

As the surface dielectric is related to both air voids and moisture content, the upper plot would represent a pavement with little variation in density along the section. The lower plot is from a highly variable surface with a clear change in surface type at 0 + 3685 feet. The spikes in this lower plot indicate changes in both density and moisture content.

The normal range for the surface dielectric of HMA is 4.5 to 6.5. Values less than 4.5 are attributed to density problems or to porous aggregates. Values greater than 6.5 are attributed to trapped moisture or unusual aggregates. For this study the variation in surface dielectric were classified in terms of;

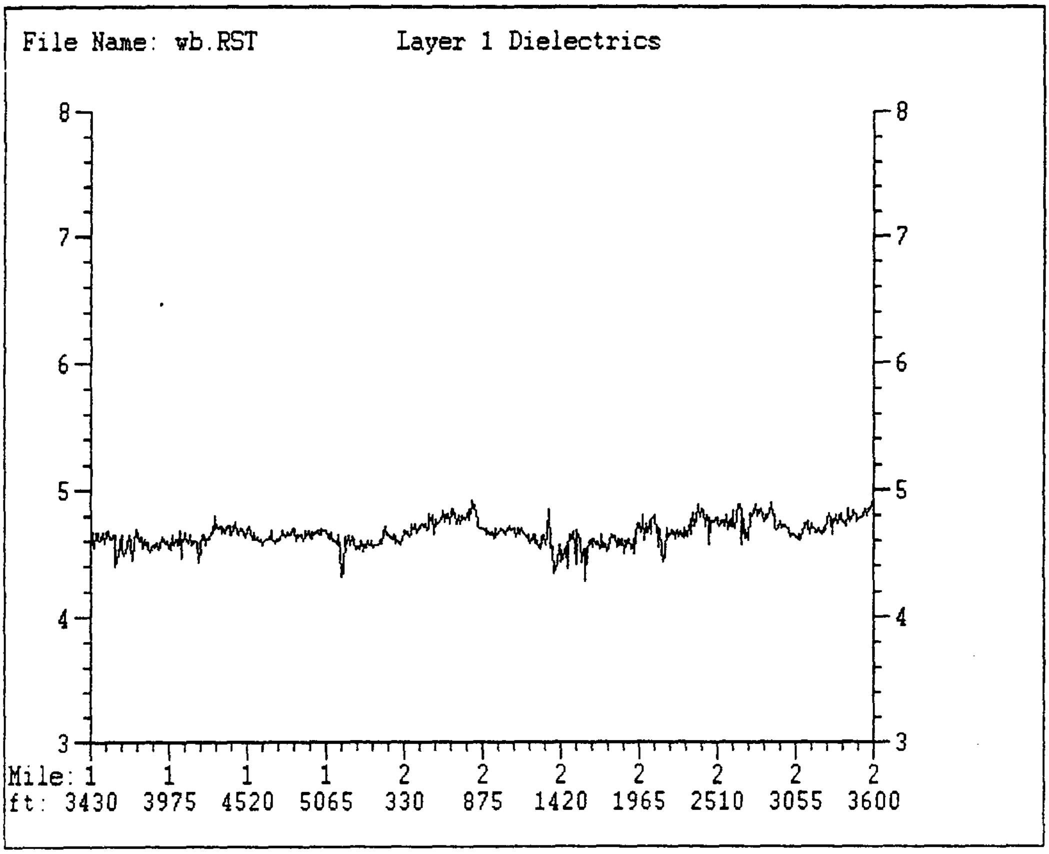
i) Noise

Variations in Surface Dielectric of > 0.4 would be classified as high variability. For new pavements the surface dielectric should be relatively constant. Interpretation becomes more difficult with older weathered and cracked surfaces or if the data was collected shortly after rainfall.

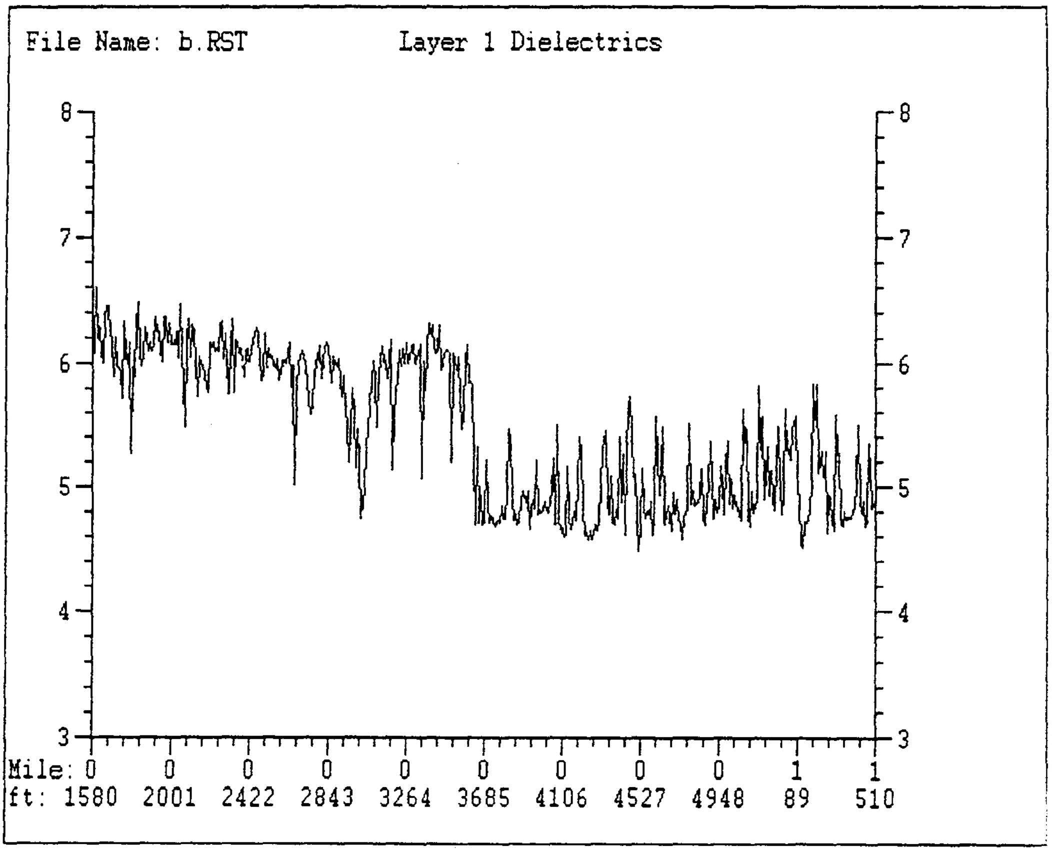
ii) Range

Range (R) Values less than 0.5 are viewed as Normal
Values 0.5 to 1.0 are viewed as Moderate
Values more than 1 are judged as High.

This variable checks for major changes in surface condition along a project.



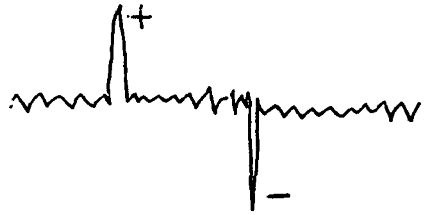
a. "Good" Pavement - Little Change in Density Along Section.



b. "Poor" Pavement - Change in Surface Type and Density.

Figure 11. Surface Dielectric Versus Distance Along Project.

iii) Presence of Spikes



Spikes are defined as discrete changes in dielectric of more than 0.5
Positive spikes would indicate surface moisture
Negative spikes would indicate density problems

The "spike" test for localized major changes in surface reflection. The effectiveness of this variable is limited by the data collection interval of one trace every 10 ft. It would have been preferred to take one trace per foot, this parameter may be more useful in future use of GPR for quality control of new HMA surfaces.

For this study it is proposed that good quality surfacing would have low noise, low range and not contain any positive or negative spikes.

B) Interface reflections from the bottom of the most recent overlay. As shown in Figure 4, Cases 1, 2 and 3 illustrate the three types of interface reflection found in this study. The case 3 reflection (thin layer of trapped moisture) was also a function of how long since last significant rainfall.

C) Defects in lower layers Both Case 4 (stripping in lower HMA layer) and Case 5 (saturated base) were observed in this study.

The results of applying these criteria to the Atlanta sections is shown in Table 1, the column descriptors are as follows;

Section — Section Number

MTV — Usage of a Material Transfer Vehicle
1 = MTP - Screed Transfer Paver
2 = MTV - Shuttle
3 = Wind-row with shuttle buggy

Seal — Y = Yes, N = No, application of a chip seal beneath overlay

Rain — Days since significant rain (1, 2 or 3+)

DIR — Direction of GPR data collection

Table 1. Summary Results from Atlanta.

ATLANTA SECTIONS

Section (MTV) (SEAL)	*Rain (days since)*	*DIR*	*A. Surface Dielectrics*			*B. Layer 1 Interface*	*C. Lower Layers Evaluation*
			Mean	*Range*	*Comment*		
1 3 N					Not Tested with GPR		
2 None N	3+	NB	4.6	4.2-4.8	Noise - Low Range - Mod. Spikes - High (M-)	Variable, some trapped moisture, some wet lower HMA (Cases 2 and 3)	4-5" HMA (total), check lower 2" for stripping
3 3 Y	3+	SB	5.0	4.0 - 5.4 (high)	Noise - High Range - High Spikes - High (M+, M-)	Small reflection, little contrast (Case 1)	2 Sections a) 8-9" HMA on bridge approaches, wet base, b) 11 - 14" HMA with localized stripping 7" down.
4 3 Y	1	EB	5.0	4.6-5.4	Noise - Low Range - Moderate Spikes - Low	Moisture on top of seal. (Case 3)	2" over 4" old HMA over PCC. Lower HMA looks good.
5 2 Y	1	SB	6.8 (High)	6.4-7.4	Noise - High Range - Moderate Spikes - High (F+)	Strong reflection from second HMA layer - High Dielectric 9-10. (Case 2)	Lower HMA layer has moisture, Base holding moisture
6 1 N	2	NB	5.0	4.6-5.2	Noise - High Range - Low Spikes - Low	Small reflection (Case 1)	2" over 6" old HMA (good condition). Base holding moisture
7 2 Y	2	EB	4.6	4.4 - 4.9	Noise - Low Range - Low Spikes - Low	Clear positive reflection, Case 1. No Problem	2" new HMA, 3" old HMA, over concrete. No obvious problems

Table 1. Summary Results from Atlanta. (Continued)

Section (MTV) (SEAL)	*Rain (days since)*	*DIR*	*A. Surface Dielectrics*			*B. Layer 1 Interface*	*C. Lower Layers Evaluation*
			Mean	*Range*	*Comment*		
8 2 Y	3+	WB	4.5	4.2-4.8	Noise - High Range - Moderate Spikes - Low	Strong reflection, moisture (3+ days after rain) (Case 3)	2" + 2" HMA over PCC
8A 3 N	1	SB	4.0 (low)	3.8-4.2	Noise - Low Range - Low Spikes - Low	Single HMA layer over flex base (Not Cored by TxDOT)	Base layer looks good
9 2 Y	2	WB	8.2 (High)	7.8-9.0	Noise - High Range - High Spikes - High (M+, F-)	Case 2, lower HMA layer higher dielectric, high values for both layers.	High dielectrics for all layers. 2" over 3" Old HMA over PCC
10 2 Y	2	NB	5.4	5.1-6.0	Noise - High Range - Moderate Spikes - Low	Moisture on top of seal. (Case 3)	<u>Problem Pavement</u>. Vary variable lower layers. Lower HMA layer (6-10" thick), looks like stripping.
11 3 Y	2	SB			Not Tested with GPR		
12 2 Y	1	SB	4.7	4.6-4.9	Noise - Low Range - Low Spikes - Low	Strong Reflection, moist in lower HMA layer (Case 2)	<u>Problem Pavement</u>. 2" over 2 - 3" old HMA check for stripping at bottom of HMA, wet base expect problems. .

Table 1. Summary Results from Atlanta. (Continued)

Section (MTV) (SEAL)	*Rain (days since)*	*DIR*	*A. Surface Dielectrics*			*B. Layer 1 Interface*	*C. Lower Layers Evaluation*
			Mean	*Range*	*Comment*		
13 2 Y	1	NB	4.5	4.2-4.6	Noise - Low Range - Low Spikes - High (+) (standing water)	Only one thin HMA layer over Base	Base looks good - Few localized wet spots.
14 2 Y	1	EB	4.8	4.4-5.4	Noise - High Range - mod. Spike - High (M+)	Variable, mostly Case 1 (small) or Case 2 reflection.	Possible problem with lower HMA layer. Highly variable, check for trapped moisture and stripping or unusual aggregates
15 2 Y	1	SB	4.6	3.8 - 4.8 (high)	Noise - Low Range - High Spikes - Low	Very strong reflections. Clear indication of trapped water on top of seal (Case 3)	8-10" HMA, good condition, Moisture in Base
16 2 Y	1	EB	5.2	5.0-5.4	Noise - High Range - Low Spikes-High (M+, M-) (problem)	One HMA Layer over Base	Problem Pavement. Very Wet Base, (high Dielectrics 20+)
17 2 Y	2	NB	4.5	4.2 - 4.7	Noise - Low Range- Low Spikes - Low	Cases 1 and 3 small reflections, no problem (CMHB surface + seal over gravel layer)	2" HMA over 3" HMA. No obvious problems with lower HMA layer or base.
18 2 Y	1	SB	5.0	4.8 - 5.4	Noise - Low Range - Low Spikes - Low	Case 1 and Case 3 reflections moisture in Lwt seal. No problems.	2" over 10" of gravel ASB. No moisture problems in ASB.

3. Discussion of Atlanta Results

3.1 Importance of Surface Dielectric Measurements

As described earlier the time since significant rainfall had a major impact on the results obtained from these sections. Figure 11 illustrated the types of surface dielectric plots generated in this study. Good quality surfacing were defined as those having low noise, low range and no major spikes. Poor quality surfacings were defined as those having high noise, high range and a large numbers of spikes. The major question is what physical property of the mat does this classification describe? This is difficult to define because of our limited experience in testing new overlays with different aggregates, etc. Also in this study only one core per section was tested to correlate to the surface dielectric criteria. As shown in Table 2 the indication is that the ranking is possibly related to % air voids. The projects with high air voids are those with the "bad ranking". This could be explained by the more open surfacing being those that permit more moisture into the layer and these appear more variable to GPR. Clearly with so few data points more validation is required.

Table 2. Comparing Sections Classified as "Good" and "Bad" Based on Variations in Surface Dielectric.

Good			**Bad**		
Section ID	Day Since Rain	% Voids	Section ID	Days Since Rain	% Voids
7-IH20	2	0.9	14-SH43	1	10.5
17-US59	2	5.6	16-SH11	1	8.3
18-US59	1	4.3	5-FM881	1	6.5
12-SH155	1	4.9	9-IH20	2	6.1

3.2 Sections with Subsurface Defects

As the current intention is to monitor the performance of the surfacings for several years it is important to identify any possible subsurface problems which may negatively impact long term pavement performance. As shown in Table 1 five sections were identified as having potential problems with either the lower HMA layer or with the flexible base. These are described in Table 3.

Table 3. Sections with Possible Subsurface Defects.

Section ID	Potential Defect
12 - SH 155	Stripping in Old HMA, Wet Base
14 - SH 43	Variable Old HMA, Could be Stripping (or Unusual Aggregates)
16 - SH 11	Wet Base
3 - US 271	Stripping About 7 inches down in Thick HMA section. Wet Base on Bridge Approaches
10 - US 79	Variable Lower HMA Layer Could be Stripping

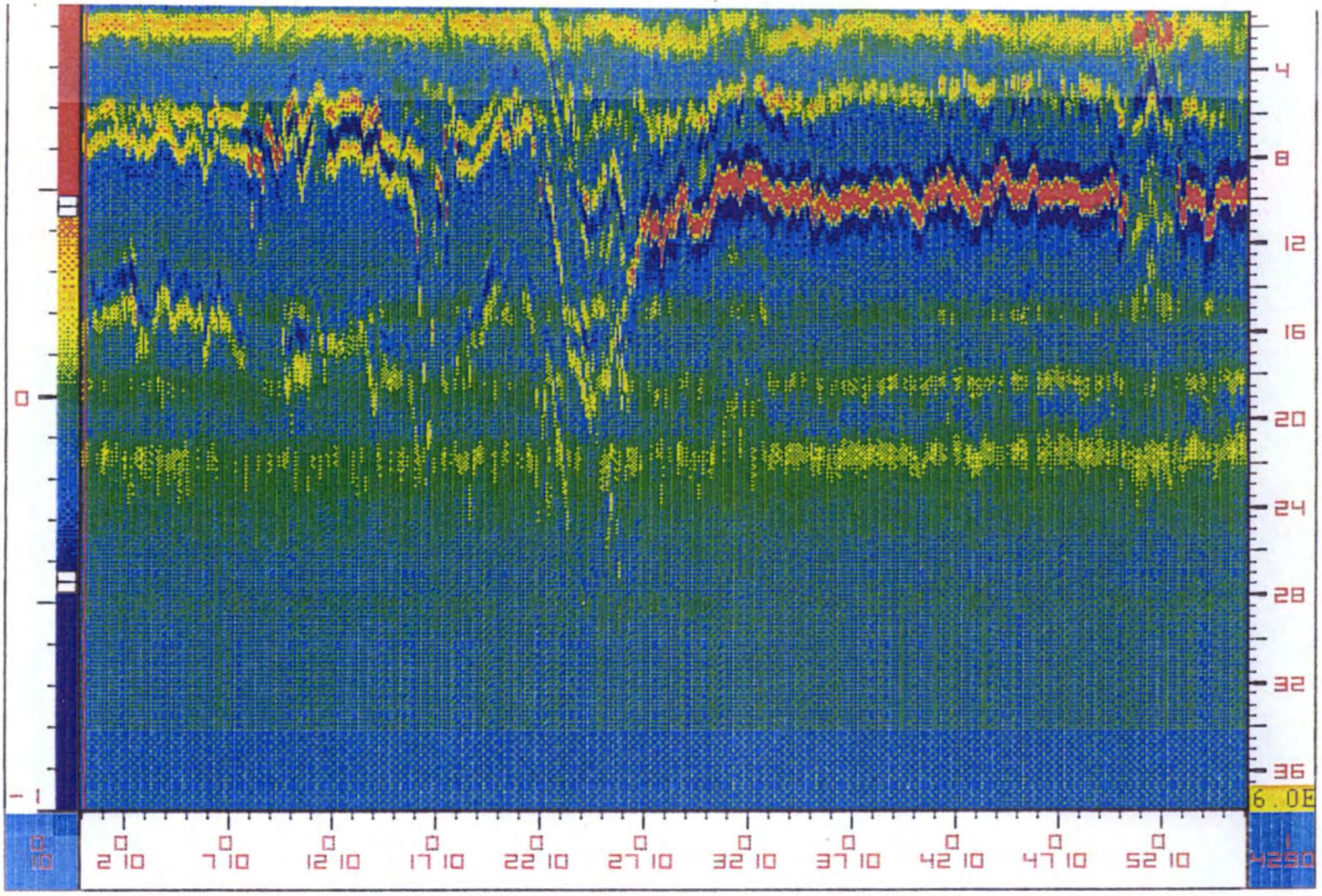
The GPR color printouts of subsurface condition are useful at rapidly identifying problems within the lower pavement layers. Figure 3 shown earlier in this Appendix, illustrates the data collected in this study on US 59. This is from a pavement with no major subsurface defects. That color printout should be compared with Figure 12 from two of the potential problem sections.

The upper figure is from Section 3 on US 271, southbound direction. The section has a clear structure break around 0 + 2700 feet, this being the beginning of an approach to a bridge. The bridge deck is at approximately 0 + 5000 ft. In the first half of the project the HMA layer is substantially thicker with a faint reflection around 16 inches deep. The blue patterns at mid depth around 0 + 1210 ft are typical of stripping. The bright red reflection at a depth of 10 inches on the bridge approaches signifies that the base moisture content is significantly higher in this area.

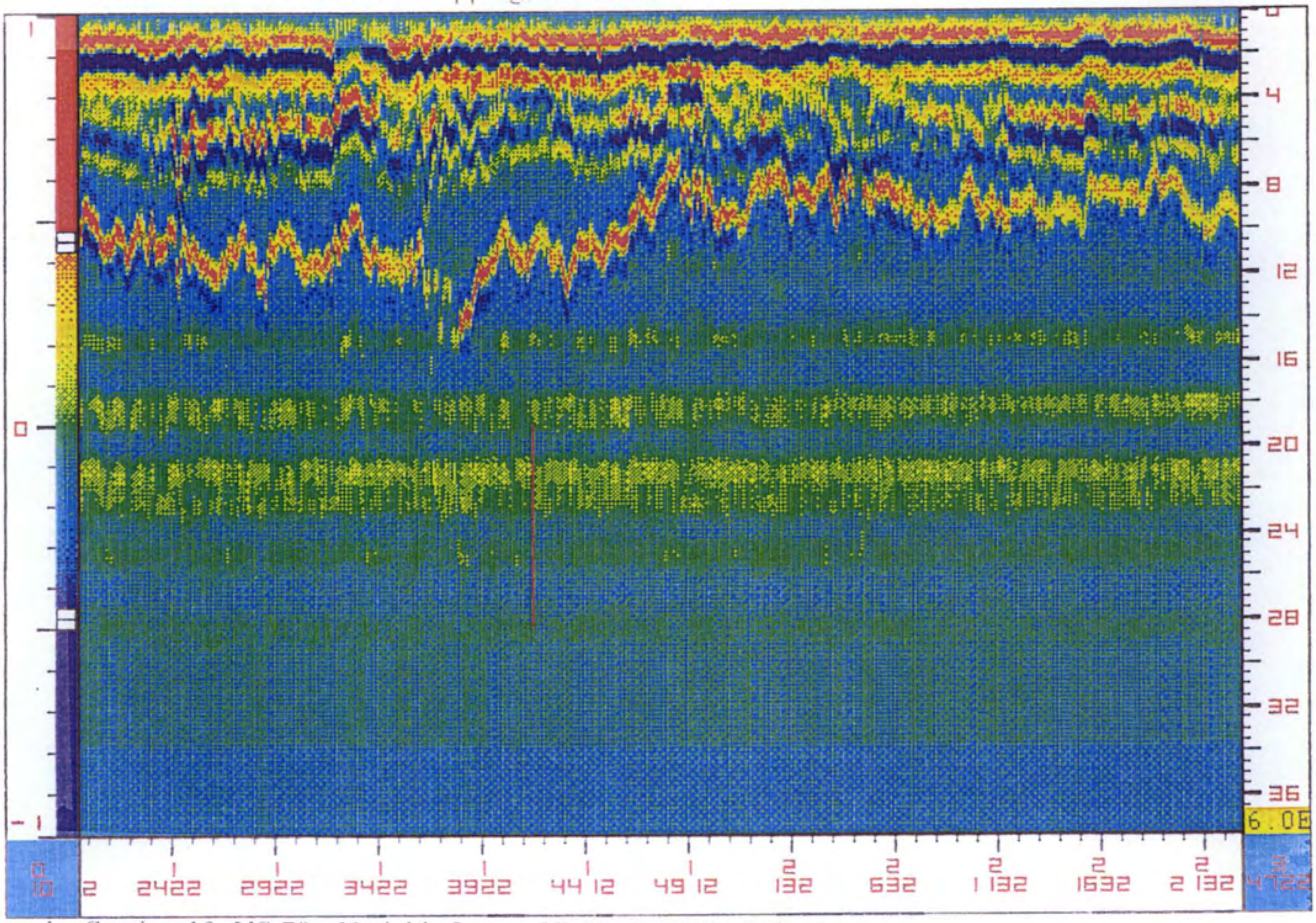
The lower figure is from Section 10 on US 79. The parallel red/blue line at a depth of 2 inches are typical of Case 3 reflections with moisture trapped on top of the seal coat. The bottom of the HMA layer is the lower red line at a depth ranging from 8 to 12 inches. The intermittent blue areas within the lower HMA are areas of possible moisture damage (stripping).

3.3 Influence of Subsurface Seals

The benefit of placing a seal coat beneath the last overlay is of substantial interest to the Atlanta district engineers. The rationale was that the seal would protect the lower HMA layer from moisture entering from the surface. Any surface moisture would be held in the upper asphalt layer and hopefully evaporate quickly. The concern is that the application of a seal may also trap moisture beneath the seal this being moisture that is trying to evaporate from an area of wet base or wet subgrade. GPR does appear to have the capability of defining which if any of these is occurring. These were proposed earlier as Case 1, 2 and 3 interface reflection in Figure 4. Examples of a Case 1 “ideal” reflection is shown in Figure 7, there are no moisture problems at this interface. The Case 3 “moisture on top of the seal” was shown in Figure 8 as an overlapping positive and negative reflection. An example of a Case 2 “moisture under seal” is shown in Figure 13, this being from section 12 on SH 155. The positive reflection at the top of the old



a. US 271 - Section Break - Stripping; Wet Base.



b. Section 10, US 79 - Variable Lower HMA, Possible Stripping.

Figure 12. COLORMAP Printout from Section with Potential Subsurface Problems.

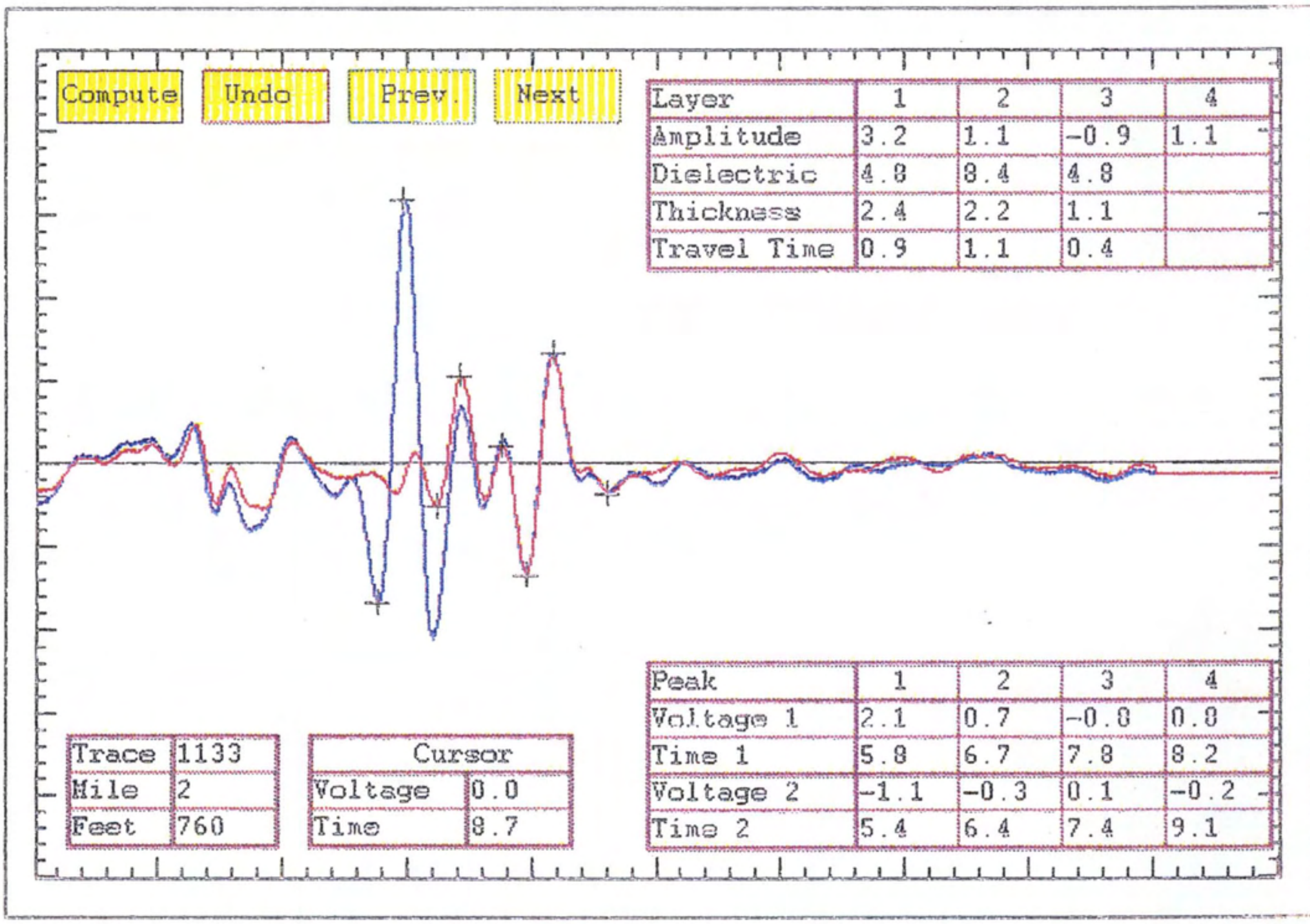


Figure 13. Large Positive Reflection from Interface Between New Overlay and Old HMA (Section 12 on SH155).

HMA produced a lower HMA dielectric of 8.4. This pavement has approximately 2 inches of new material over 3 inches of old. There appears to be some problems with the lower HMA layer.

Table 4 illustrates the predominant interface condition from sections which had a seal placed beneath the overlay, which also have a lower HMA layer and which were tested one day after heavy rainfall.

Table 4. Interface Condition One Day After Heavy Rainfall.

Section ID	Interface Condition
4 - IH30	Case 3 - Moisture on Top of Seal
5 - FM 881	Case 2 - Moisture Under Seal
12 - SH 155	Case 2 - Moisture Under Seal
14 - SH 43	Case 2 - Moisture Under Seal
15 - US 271	Case 3 - Moisture on Top of Seal
18 - US 59	Case 3 - Moisture on Top of Seal

4. Conclusions and Recommendations

This data collection and analysis were performed to demonstrate the capabilities of using Ground Penetrating Radar technology for evaluating thin HMA overlays on flexible pavements. The main conclusions are;

1) Although the data is limited the amplitude of the GPR reflection from the surface appears to correlate with the air void content of the HMA overlay,
2) GPR identified several different reflection patterns from the interface between the new overlay and the existing old HMA layer. It was proposed that these indicate the presence of moisture either on top of or beneath the seal placed between the layers, and
3) Several of the section appear to have subsurface defects either excessive moisture in the flexible base or stripping in the lower HMA layer. This should be taken into consideration when evaluating the long term performance of these sections.

As all of the Atlanta projects were relatively new with little or no distress at the time of testing it is proposed that periodic monitoring be considered for these sections.

APPENDIX F

PHOTOGRAPH OF PAVEMENT CORES

Table 1. Pavements Selected For Evaluation.

District – Project ID (Layer)	Project ID	Highway	Direction	Location
Atlanta – 1	4A	US 67 7th St	EB	Between Ambusher Deer Stands Inc and Nettie Drive
Atlanta – 2	5A	US 67	NB	New Boston, at SH 8 Turnoff Sign
Atlanta – 3	7A	US 271	SB	House on N. End of Project
Atlanta – 4	8A	IH 30	WB	100' E. of New St. Michael's Str. Overpass
Atlanta – 5	9A	FM 881	SB	Near Middle of Job
Atlanta – 6	10A	US 59	NB	0.5 Mile N. of RM 308 (White Fence)
Atlanta – 7	11A	IH 20	WB	1.5 Miles E. of FM 3251 (Between 2 Structures @ Potters Creek)
Atlanta – 8	12A	IH 30	WB	Exit 199 Sign
Atlanta – 9	13A	IH 20	WB	Mile Post 631 + 800'
Atlanta – 10	14A	US 79	NB	RM 288, 100' South
Atlanta – 11	22A	US 79	SB	100' N of Entrance to Carthage Gas Unit 6
Atlanta – 12	27A	SH 155	SB	1.0 Miles S. of RM 244
Atlanta – 13	28A	FM 1397	NB	100' S. of Co. Rd. 2319 (Shilling Road)
Atlanta – 14	30A	SH 43	NB	150' N. of Leslie Street
Atlanta – 15	30BA	US 271	SB	At Autozone
Atlanta – 16	30CA	SH 11	SB	200' N. of RM 742
Atlanta – 17	40A	US 59	SB	500' N. of FM 1186 (RAP stockpile)
Atlanta – 18	41A	US 59	SB	0.5 Miles S. of Johns Creek
Lufkin – 1	1L	US 59	NB	RM 358
Lufkin – 2	2L	SH 7	EB	RM 758 + 1.25 Miles
Lufkin – 3	3L	US 59		
Lufkin – 4	4L	US 259	SB	RM 342
Lufkin – 5	5L	US 59		
Lufkin – 6	6L	US 59	SB	Lake Nacogdoches Sign
Lufkin – 7	7L	US 259	NB	Travis Baker Rd Sign
Lufkin – 8	8L	Lp 224	WB	Across from Fire Dept.
Tyler – 1	1T	US 69	SB	200' S. of FM 2493 Intersection
Tyler – 2	2T	US 69	SB	Foot of Hill N. of Loves Lookout. Reference Marker (RM) 354
Tyler – 3	3T	SH 31	SB	300' N. of Bridge Over Slough on N. End of Project
Tyler – 4	4T	US 69		
Tyler – 5	5T	SH 31	EB	Across from Co. Rd. 1436 (Outside Crescent Heights)
Tyler – 6	6T	US 79	EB	200' W. of Co. Rd. 444D
Tyler – 7	7T	IH 20	WB	Exit 589 Sign
Tyler – 8	8T	US 271	NB	1.7 Miles N. of RM 320 (Between 2 Structures)
Tyler – 9	9T	US 259	NB	1 Mile S. of SHRP 481113 Sign

APPENDIX G

INDIVIDUAL DATA SHEETS

Project	Layer	Stripping Ratings of Cores Fractured Surface - Dry	Stripping Ratings of Cores Fractured Surface - Wet	Air Voids of Cores, %	Indirect Tensile Strength 77 F, psi Dry	Indirect Tensile Strength 77 F, psi Wet	TSR	Antistrip Agent (Liquid, % by Wt of Asphalt) (Lime, % by Wt of Mixture)	Age	Coarse Aggr Mineralogy	Screenings Mineralogy	Asphalt and Polymer	18-kip ESALs (Current)	ADT (Current)	Ride Score **	Visual Distress Rating, ** Avg	Rutting, % Shallow	Rutting, % Deep
Atlanta-12	1	4.8	4.6	4.9	142	150	1.06	1.0% Lime	1	**Gravel**	Limestone	Lion AC-20	1,296	2,541	4.4	4.6	3.2	2.3
Atlanta-13	1	4.7	4.6	6.0	130	124	0.95	1.0% Lime	1	**Gravel**	Gravel, Donnafill	Lion AC-20	499	2,483	4.1	4.7	NA	NA
Lufkin-4	1	4.7	4.4	1.9	186	164	0.88	1.0% Permatac Plus	1	**Gravel**	Limestone	Exxon AC-20	12,000	8,167	4.7	4.6	0	0
Atlanta-14	1	4.7	4.2	10.5	118	69	0.58	1.0% Lime	1	**Gravel**	Gravel	Fina AC-20	NA	NA	NA	4.8	NA	NA
Lufkin-8	1	4.2	3.2	6.5	198	176	0.89	0.5% Unichem 8161	2	**Gravel**	Limestone	Lion AC-20	1,436	8,667	4.1	4.6	0	0
Atlanta-4	1	4.9	4.8	4.2	87	86	0.99	1.5% Lime	3	**Gravel**	Gravel	Kerr McGee AC-10, 3% Latex	20,554	19,819	4.4	4.4	0	0
Atlanta-2	1	4.2	4.1	2.6	120	145	1.21	1.5% Lime	3	**Gravel**	Gravel	Kerr McGee AC-20	3,283	2,534	3.8	3.6	0.2	0
Lufkin-8	2	4.3	3.2	9.6	121	82	0.68	0.5% Unichem 8161	3	**Gravel**	Limestone	Lion AC-20						
Atlanta-6	1	3.7	2.8	4.0	108	86	0.80	1.0% Permatac Plus	3	**Gravel**	Gravel	Exxon AC-10, 3% Latex	2,902	4,038	4	5	0.2	0
Atlanta-7	1	3.9	3.2	0.9	160	106	0.66	0.5% Unichem 8161	4	**Gravel**	Gravel	Lion AC-20	16,554	11,530	4.4	4.2	1.7	4.2
Atlanta-1	1	4.6	3.0	1.9	235	124	0.53	1.0% Permatac Plus	4	**Gravel**	Gravel	Kerr McGee AC-20	8,475	1,657	2.8	3.5	0	0
Lufkin-7	1	2.5	1.8	NA	83	46	0.55	None	4	**Gravel**	Limestone	*Asphalt Rubber*	15,200	11,618	3.8	4.1	0	0
Lufkin-6	1	4.4	3.4	NA	176	134	0.76	None	5	**Gravel**	Limestone	Star AC-20	9,945	10,782	3.8	3.6	0	0
Tyler-2	1	4.5	3.3	3.9	148	144	0.97	Probably Liquid	5	**Gravel**	Gravel	Star AC-10, 3% Latex				3.8		
Tyler-1	1	3.7	2.8	NA	142	59	0.42	Liquid	5	**Gravel**	Limestone	Star AC-10, 3% Latex				4.9		
Lufkin-1	1	3.4	2.5	NA	206	85	0.41	None	5	**Gravel**	Limestone	Star AC-20	9,197	8,667	4.1	3.7	0	0
Tyler-8	1	4.1	2.9	2.4	159	55	0.35	?% Liquid	6	**Gravel**	Gravel	Star AC-10, 3% Latex				2.7		
Tyler-9	1	3.9	2.6	2.4	156	63	0.40	None	6	**Gravel**	Limestone	Star AC-20				2.9		
Lufkin-1	2	3.5	3.5*	NA	113	No Test	NA	None	6	**Gravel**	Limestone	Star AC-20						
Lufkin-5	1	3.8	3.0	NA	111	61	0.55	None	7	**Gravel**	Limestone	Star AC-20	9,594	11,000	3.9	4.3	0.1	0
Lufkin-2	1	3.2	2.7	6.7	151	119	0.79	None	7	**Gravel**	Limestone	Star AC-20	1,801	3,600	3.6	4.5	0	0
Tyler-3	1	4.7	4.4	5.8	163	130	0.80	1.0% Lime	1	**Gravel, RAP**	Limestone	Lion PG 70-22 (3% Latex)				5		
Atlanta-18	2	4.6	4.4	4.3	120	143	1.19	1.0% Permatac Plus	2	**Gravel, RAP**	Gravel	Lion AC-10	11,059	10,700	4.1	5	4.7	2.3
		4.1	3.4	4.6	145	107	0.75		3.7				8,253	7,854	4.0	4.2		
Atlanta-11	1	4.8	4.7	2.4	215	185	0.86	1.0% Lime	2	**Igneous**	Igneous	Lion AC-20	8,242	6,433	2.9	5	9	2
Tyler-7	1	3.9	3.4	NA	148	53	0.36	0.5% Permatac Plus	3	**Igneous**	Igneous	Lion AC-10, 3% Latex				4.5		
Atlanta-9	1	4.9	4.9	6.1	126	139	1.10	1.0% Permatac Plus	2	**Limestone**	Limestone	Lion AC-10, 3% Latex	16,874	12,238	4.7	4.6	0.7	0
Lufkin-3	1	4.9	4.8	1.7	180	175	0.97	None	2	**Limestone**	Limestone, B. Ash	Exxon AC-20	10,162	12,045	4	5	0	0
Lufkin-3	2	4.8	4.7	2.3	211	206	0.98	None	2	**Limestone**	Limestone	Exxon AC-20						
Atlanta-5	1	4.8	4.7	6.5	187	149	0.80	1.0% Unichem 8161	2	**Limestone**	Limestone	Lion AC-10, 3% Latex	NA	NA	NA	4.6	NA	NA
Tyler-6	1	4.5	4.5	4.4	167	157	0.94	0.5% Permatac Plus	3	**Limestone**	Limestone	Lion AC-20				4.5		
Tyler-5	1	4.7	4.5	NA	226	194	0.86	None	9	**Limestone**	Limestone	Elf AC-30P				4.8		
Atlanta-17	2	4.6	4.3	5.6	167	150	0.90	1.0% Permatac Plus	3	**Limestone, RAP**	Limestone	Lion AC-10	8,476	11,763	3.9	4.9	0.1	0
		4.7	4.6	4.4	181	167	0.94		3.3				11,837	12,015	4.2	4.7		
Atlanta-10	1	4.9	4.8	NA	113	94	0.83	1.5% Lime	2	**Quartzite**	Quartzite	Lion AC-10, 3% Latex	8,316	7,585	3.8	5	0.9	0
Atlanta-16	1	4.9	4.9	8.3	126	118	0.94	1.0% Lime	1	**Sandstone**	Sandstone	Lion AC-20	754	2,350	4.4	4.6	3.5	2
Atlanta-15	1	5.0	4.6	1.7	131	115	0.88	1.0% Permatac Plus	1	**Sandstone**	Sandstone	Lion AC-10, 3% Latex	4,934	9,480	3.8	5	0	0
Atlanta-8	1	4.6	4.6	4.4	135	69	0.51	1.0% Permatac Plus	2	**Sandstone**	Sandstone	Lion AC-10, 3% Latex	14,666	10,980	4.2	4.2	0	0
Atlanta-3	1	4.9	4.7	3.8	276	242	0.88	1.0% Permatac Plus	3	**Sandstone**	Sandstone	Lion AC-20	3,570	5,800	3.8	4.5	1	0
Tyler-4	1	4.2	4.0	4.4	200	148	0.74	None	6	**Sandstone**	Sandstone	Lion AC-20				NA		
		4.7	4.5	4.5	174	138	0.79		2.6				5,981	7,153	4.1	4.6		
Atlanta-18	1	4.5	4.2	0.4	126	112	0.89		2									
Atlanta-17	1	4.4	4.0	4.8	144	147	1.02		3									

Table G1

Project	Layer	Stripping Ratings of Cores: Fractured Surface - Dry	Stripping Ratings of Cores: Fractured Surface - Wet	Air Voids of Cores, %	Indirect Tensile Strength 77 F, psi: Dry	Indirect Tensile Strength 77 F, psi: Wet	TSR	Antistrip Agent (Liquid, % by Wt of Asphalt) (Lime, % by Wt of Mixture)	Age	Coarse Aggr Mineralogy	Screenings Mineralogy	Asphalt and Polymer	18-kip ESALs (Current)	ADT (Current)	Ride Score **	Visual Distress Rating, ** Avg	Rutting, % Shallow	Rutting, % Deep
Lukin-7	1	2.5	1.8	NA	83	46	0.55	None	4	Gravel	Limestone	*Asphalt Rubber*	15,200	11,618	3.8	4.1	0	0
Lukin-6	1	4.4	3.4	NA	176	134	0.76	None	5	Gravel	Limestone	Star AC-20	9,945	10,782	3.8	3.6	0	0
Lukin-1	1	3.4	2.5	NA	206	85	0.41	None	5	Gravel	Limestone	Star AC-20	9,197	8,667	4.1	3.7	0	0
Tyler-9	1	3.9	2.6	2.4	156	63	0.40	None	6	Gravel	Limestone	Star AC-20				2.9		
Lukin-1	2	3.5	2.5*	NA	113	No Test	NA	None	6	Gravel	Limestone	Star AC-20						
Lukin-5	1	3.8	3.0	NA	111	61	0.55	None	7	Gravel	Limestone	Star AC-20	9,594	11,000	3.9	4.3	0.1	0
Lukin-2	1	3.2	2.7	6.7	151	119	0.79	None	7	Gravel	Limestone	Star AC-20	1,801	3,600	3.6	4.5	0	0
		3.5	2.7	4.6	142	85	0.58		5.7				9,147	9,133	3.8	3.9		
Lufkin-4	1	4.7	4.4	1.9	186	164	0.88	1.0% Permatac Plus	1	Gravel	Limestone	Exxon AC-20	12,000	8,167	4.7	4.6	0	0
Atlanta-18	2	4.6	4.4	4.3	120	143	1.19	1.0% Permatac Plus	2	Gravel, RAP	Gravel	Lion AC-10	11,059	10,700	4.1	5	4.7	2.3
Lufkin-8	1	4.2	3.2	6.5	198	176	0.89	0.5% Unichem 8161	2	Gravel	Limestone	Lion AC-20	1,436	8,667	4.1	4.6	0	0
Lufkin-8	2	4.3	3.2	9.6	121	82	0.68	0.5% Unichem 8161	3	Gravel	Limestone	Lion AC-20						
Atlanta-6	1	3.7	2.8	4.0	108	86	0.80	1.0% Permatac Plus	3	Gravel	Gravel	Exxon AC-10, 3% Latex	2,902	4,038	4	5	0.2	0
		4.3	3.6	5.3	147	130	0.89		2.2				6,849	7,893	4.2	4.8		
Atlanta-7	1	3.9	3.2	0.9	160	106	0.66	0.5% Unichem 8161	4	Gravel	Gravel	Lion AC-20	16,554	11,530	4.4	4.2	1.7	4.2
Atlanta-1	1	4.6	3.0	1.9	235	124	0.53	1.0% Permatac Plus	4	Gravel	Gravel	Kerr McGee AC-20	8,475	1,657	2.8	3.5	0	0
Tyler-2	1	4.5	3.3	3.9	148	144	0.97	Probably Liquid	5	Gravel	Gravel	Star AC-10, 3% Latex				3.8		
Tyler-1	1	3.7	2.8	NA	142	59	0.42	Liquid	5	Gravel	Limestone	Star AC-10, 3% Latex				4.9		
Tyler-8	1	4.1	2.9	2.4	159	55	0.35	?% Liquid	6	Gravel	Gravel	Star AC-10, 3% Latex				2.7		
		4.2	3.0	2.3	169	98	0.58		4.8				12,515	6,594	3.6	3.8		
Tyler-3	1	4.7	4.4	5.8	163	130	0.80	1.0% Lime	1	Gravel, RAP	Limestone	Lion PG 70-22 (3% Latex)				5		
Atlanta-12	1	4.8	4.6	4.9	142	150	1.06	1.0% Lime	1	Gravel	Limestone	Lion AC-20	1,296	2,541	4.4	4.6	3.2	2.3
Atlanta-13	1	4.7	4.6	6.0	130	124	0.95	1.0% Lime	1	Gravel	Gravel, Donnafill	Lion AC-20	499	2,483	4.1	4.7	NA	NA
Atlanta-14	1	4.7	4.2	10.5	118	69	0.58	1.0% Lime	1	Gravel	Gravel	Fina AC-20	NA	NA	NA	4.8	NA	NA
Atlanta-4	1	4.9	4.8	4.2	87	86	0.99	1.5% Lime	3	Gravel	Gravel	Kerr McGee AC-10, 3% Latex	20,554	19,819	4.4	4.4	0	0
Atlanta-2	1	4.2	4.1	2.6	120	145	1.21	1.5% Lime	3	Gravel	Gravel	Kerr McGee AC-20	3,283	2,534	3.8	3.6	0.2	0
		4.7	4.5	5.7	127	117	0.93		1.7				6,408	6,844	4.2	4.5		
Atlanta-11	1	4.8	4.7	2.4	215	185	0.86	1.0% Lime	2	Igneous	Igneous	Lion AC-20	8,242	6,433	2.9	5	9	2
Tyler-7	1	3.9	3.4	NA	148	53	0.36	0.5% Permatac Plus	3	Igneous	Igneous	Lion AC-10, 3% Latex				4.5		
Lufkin-3	1	4.9	4.8	1.7	180	175	0.97	None	2	Limestone	Limestone, B. Ash	Exxon AC-20	10,162	12,045	4	5	0	0
Lufkin-4	2	4.8	4.7	2.3	211	206	0.98	None	2	Limestone	Limestone	Exxon AC-20						
Tyler-5	1	4.7	4.5	NA	226	194	0.86	None	9	Limestone	Limestone	Elf AC-30P				4.8		
		4.8	4.7	2.0	206	192	0.94		4.3				10,162	12,045	4	4.9		
Atlanta-9	1	4.9	4.9	6.1	126	139	1.10	1.0% Permatac Plus	2	Limestone	Limestone	Lion AC-10, 3% Latex	16,874	12,238	4.7	4.6	0.7	0
Atlanta-5	1	4.8	4.7	6.5	187	149	0.80	1.0% Unichem 8161	2	Limestone	Limestone	Lion AC-10, 3% Latex	NA	NA	NA	4.6	NA	NA
Tyler-6	1	4.5	4.5	4.4	167	157	0.94	0.5% Permatac Plus	3	Limestone	Limestone	Lion AC-20				4.5		
Atlanta-17	2	4.6	4.3	5.6	167	150	0.90	1.0% Permatac Plus	3	Limestone, RAP	Limestone	Lion AC-10	8,476	11,763	3.9	4.9	0.1	0
		4.7	4.6	5.7	162	149	0.93		2.5				12,675	12,001	4.3	4.7		
Atlanta-10	1	4.9	4.8	NA	113	94	0.83	1.5% Lime	2	Quartzite	Quartzite	Lion AC-10, 3% Latex	8,316	7,585	3.8	5	0.9	0
Tyler-4	1	4.2	4.0	4.4	200	148	0.74	None	6	Sandstone	Sandstone	Lion AC-20				NA		
Atlanta-15	1	5.0	4.6	1.7	131	115	0.88	1.0% Permatac Plus	1	Sandstone	Sandstone	Lion AC-10, 3% Latex	4,934	9,480	3.8	5	0	0
Atlanta-8	1	4.6	4.6	4.4	135	69	0.51	1.0% Permatac Plus	2	Sandstone	Sandstone	Lion AC-10, 3% Latex	14,666	10,980	4.2	4.2	0	0
Atlanta-3	1	4.9	4.7	3.8	276	242	0.88	1.0% Permatac Plus	3	Sandstone	Sandstone	Lion AC-20	3,570	5,800	3.8	4.5	1	0
		4.8	4.6	3.3	181	142	0.76		2				7,723	8,753	3.9	4.6		
Atlanta-16	1	4.9	4.9	8.3	126	118	0.94	1.0% Lime	1	Sandstone	Sandstone	Lion AC-20	754	2,350	4.4	4.6	3.5	2

* Core not available for evaluation. Value from the dry core is shown.
**Ride Scores and Visual Distress Ratings are evaluated on a scale to 5, with 5 being the highest possible rating.

Table G2

Project	Project	Layer	Stripping Ratings of Cores: Fractured Surface - Dry	Stripping Ratings of Cores: Fractured Surface - Wet	Air Voids of Cores, %	Indirect Tensile Stre 77 F, psi: Dry	Indirect Tensile Stre 77 F, psi: Wet	TSR	Antistrip Agent (Liquid, % by Wt of Asphalt) (Lime, % by Wt of Mixture)	Age	Coarse Aggr Mineralogy	Screenings Mineralogy	Asphalt and Polymer	18-kip ESALs (Current)	ADT (Current)	Ride Score **	Visual Distress Rating, ** Avg	Rutting, %: Shallow	Rutting, %: Deep
Lukin-7	7L	1	2.5	1.8	NA	83	46	0.55	None	4	Gravel	Limestone	*Asphalt Rubber*	15,200	11,618	3.8	4.1	0	0
Lukin-6	6L	1	4.4	3.4	NA	176	134	0.76	None	5	Gravel	Limestone	Star AC-20	9,945	10,782	3.8	3.6	0	0
Lukin-1	1L	1	3.4	2.5	NA	206	85	0.41	None	5	Gravel	Limestone	Star AC-20	9,197	8,667	4.1	3.7	0	0
Tyler-9	9T	1	3.9	2.6	2.4	156	63	0.40	None	6	Gravel	Limestone	Star AC-20				2.9		
Lukin-1	1L	2	3.5	2.5*	NA	113	No Test	NA	None	6	Gravel	Limestone	Star AC-20						
Lukin-5	5L	1	3.8	3.0	NA	111	61	0.55	None	7	Gravel	Limestone	Star AC-20	9,594	11,000	3.9	4.3	0.1	0
Lukin-2	2L	1	3.2	2.7	6.7	151	119	0.79	None	7	Gravel	Limestone	Star AC-20	1,801	3,600	3.6	4.5	0	0
	AVERAGES		3.5	2.7	4.6	142	85	0.58		5.7				9,147	9,133	3.8	3.9		
Atlanta-18	41A	2	4.6	4.4	4.3	120	143	1.19	1.0% Permatac Plus	2	Gravel, RAP	Gravel	Lion AC-10	11,059	10,700	4.1	5	4.7	2.3
Atlanta-6	10A	1	3.7	2.8	4.0	108	86	0.80	1.0% Permatac Plus	3	Gravel	Gravel	:xxon AC-10, 3% Late	2,902	4,038	4	5	0.2	0
Atlanta-1	4A	1	4.6	3.0	1.9	235	124	0.53	1.0% Permatac Plus	4	Gravel	Gravel	Kerr McGee AC-20	8,475	1,657	2.8	3.5	0	0
Atlanta-7	11A	1	3.9	3.2	0.9	160	106	0.66	0.5% Unichem 8161	4	Gravel	Gravel	Lion AC-20	16,554	11,530	4.4	4.2	1.7	4.2
Tyler-2	2T	1	4.5	3.3	3.9	148	144	0.97	Probably Liquid	5	Gravel	Gravel	Star AC-10, 3% Latex				3.8		
Tyler-8	8T	1	4.1	2.9	2.4	159	55	0.35	?% Liquid	6	Gravel	Gravel	Star AC-10, 3% Latex				2.7		
	AVERAGES		4.2	3.3	2.9	155	110	0.75		4.0				9,748	6,981	3.8	4.0		
Lufkin-4	4L	1	4.7	4.4	1.9	186	164	0.88	1.0% Permatac Plus	1	Gravel	Limestone	Exxon AC-20	12,000	8,167	4.7	4.6	0	0
Lufkin-8	8L	1	4.2	3.2	6.5	198	176	0.89	0.5% Unichem 8161	2	Gravel	Limestone	Lion AC-20	1,436	8,667	4.1	4.6	0	0
Lufkin-8	8L	2	4.3	3.2	9.6	121	82	0.68	0.5% Unichem 8161	3	Gravel	Limestone	Lion AC-20						
Tyler-1	1T	1	3.7	2.8	NA	142	59	0.42	Liquid	5	Gravel	Limestone	Star AC-10, 3% Latex				4.9		
	AVERAGES		4.2	3.4	6.0	162	120	0.72		2.8				6,718	8,417	4.4	4.7		
Tyler-3	3T	1	4.7	4.4	5.8	163	130	0.80	1.0% Lime	1	Gravel, RAP	Limestone	on PG 70-22 (3% Latex)				5		
Atlanta-12	27A	1	4.8	4.6	4.9	142	150	1.06	1.0% Lime	1	Gravel	Limestone	Lion AC-20	1,296	2,541	4.4	4.6	3.2	2.3
			4.7	4.5	5.4	153	140	0.93		1				1,296	2,541	4.4	4.8		
Atlanta-13	28A	1	4.7	4.6	6.0	130	124	0.95	1.0% Lime	1	Gravel	Gravel, Donnafil	Lion AC-20	499	2,483	4.1	4.7	NA	NA
Atlanta-14	30A	1	4.7	4.2	10.5	118	69	0.58	1.0% Lime	1	Gravel	Gravel	Fina AC-20	NA	NA	NA	4.8	NA	NA
Atlanta-4	8A	1	4.9	4.8	4.2	87	86	0.99	1.5% Lime	3	Gravel	Gravel	r McGee AC-10, 3% L	20,554	19,819	4.4	4.4	0	0
Atlanta-2	5A	1	4.2	4.1	2.6	120	145	1.21	1.5% Lime	3	Gravel	Gravel	Kerr McGee AC-20	3,283	2,534	3.8	3.6	0.2	0
	AVERAGES		4.6	4.4	5.8	114	106	0.93		2.0				8,112	8,279	4.1	4.4		
Atlanta-11	22A	1	4.8	4.7	2.4	215	185	0.86	1.0% Lime	2	Igneous	Igneous	Lion AC-20	8,242	6,433	2.9	5	9	2
Tyler-7	7T	1	3.9	3.4	NA	148	53	0.36	0.5% Permatac Plus	3	Igneous	Igneous	Lion AC-10, 3% Latex				4.5		
Lufkin-3	3L	1	4.9	4.8	1.7	180	175	0.97	None	2	Limestone	.imestone, B. As	Exxon AC-20	10,162	12,045	4	5	0	0
Lufkin-3	3L	2	4.8	4.7	2.3	211	206	0.98	None	2	Limestone	Limestone	Exxon AC-20						
Tyler-5	5T	1	4.7	4.5	NA	226	194	0.86	None	9	Limestone	Limestone	Elf AC-30P				4.8		
	AVERAGES		4.8	4.7	2.0	206	192	0.94		4.3				10,162	12,045	4	4.9		
Atlanta-9	13A	1	4.9	4.9	6.1	126	139	1.10	1.0% Permatac Plus	2	Limestone	Limestone	Lion AC-10, 3% Latex	16,874	12,238	4.7	4.6	0.7	0
Atlanta-5	9A	1	4.8	4.7	6.5	187	149	0.80	1.0% Unichem 8161	2	Limestone	Limestone	Lion AC-10, 3% Latex	NA	NA	NA	4.6	NA	NA
Tyler-6	6T	1	4.5	4.5	4.4	167	157	0.94	0.5% Permatac Plus	3	Limestone	Limestone	Lion AC-20				4.5		
Atlanta-17	40A	2	4.6	4.3	5.6	167	150	0.90	1.0% Permatac Plus	3	.imestone, RAI	Limestone	Lion AC-10	8,476	11,763	3.9	4.9	0.1	0
	AVERAGES		4.7	4.6	5.7	162	149	0.93		2.5				12,675	12,001	4.3	4.7		
Atlanta-10	14A	1	4.9	4.8	NA	113	94	0.83	1.5% Lime	2	Quartzite	Quartzite	Lion AC-10, 3% Latex	8,316	7,585	3.8	5	0.9	0
Tyler-4	4T	1	4.2	4.0	4.4	200	148	0.74	None	6	Sandstone	Sandstone	Lion AC-20				NA		
Atlanta-15	30BA	1	5.0	4.6	1.7	131	115	0.88	1.0% Permatac Plus	1	Sandstone	Sandstone	Lion AC-10, 3% Latex	4,934	9,480	3.8	5	0	0
Atlanta-8	12A	1	4.6	4.6	4.4	135	69	0.51	1.0% Permatac Plus	2	Sandstone	Sandstone	Lion AC-10, 3% Latex	14,666	10,980	4.2	4.2	0	0
Atlanta-3	7A	1	4.9	4.7	3.8	276	242	0.88	1.0% Permatac Plus	3	Sandstone	Sandstone	Lion AC-20	3,570	5,800	3.8	4.5	1	0
	AVERAGES		4.8	4.6	3.3	181	142	0.76		2				7,723	8,753	3.9	4.6		
Atlanta-16	30CA	1	4.9	4.9	8.3	126	118	0.94	1.0% Lime	1	Sandstone	Sandstone	Lion AC-20	754	2,350	4.4	4.6	3.5	2

* Core not available for evaluation. Value from the dry core is shown.

**Ride Scores and Visual Distress Ratings are evaluated on a scale to 5, with 5 being the highest possible rating.

Table G3

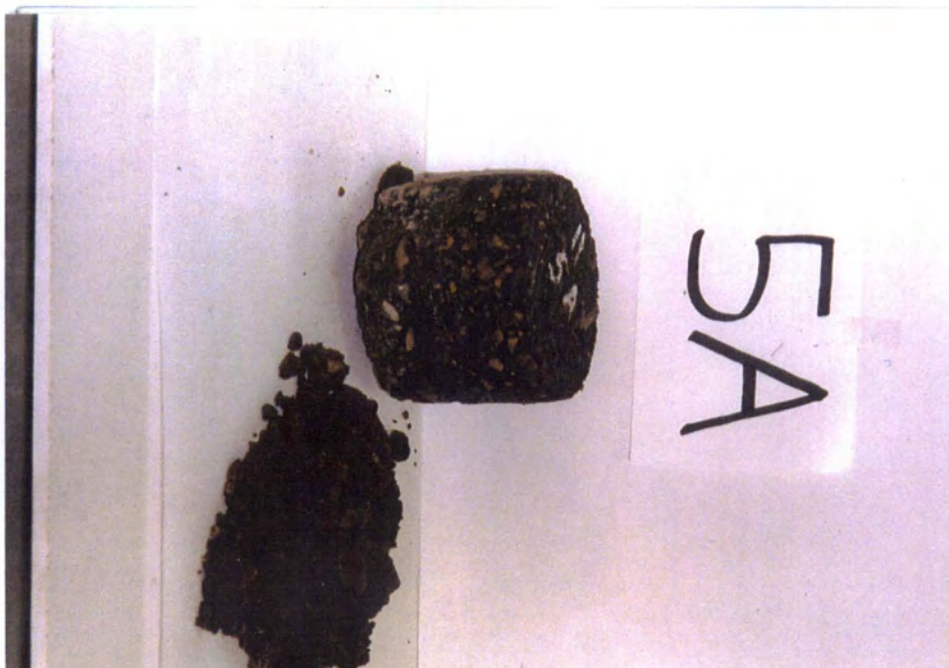
Project	Layer	Fractured Surface - Dry	Fractured Surface - Wet	Air Voids of Cores, %	Indirect Tensile Strength 77 F, psi Dry	Wet	TSR	Antistrip Agent (Liquid, % by Wt of Asphalt) (Lime, % by Wt of Mixture)	Age	Coarse Aggr Mineralogy	Screenings Mineralogy	Asphalt and Polymer	18-kip ESALs (Current)	ADT (Current)	Ride Score **	Visual Distress Rating, ** Avg	Rutting, % Shallow	Rutting, % Deep
7L	1	2.5	1.8	NA	83	46	0.55	None	4	**Gravel**	Limestone	***Asphalt Rubber***	15,200	11,618	3.8	4.1	0	0
10A	1	3.7	2.8	4.0	108	86	0.80	1.0% Permatac Plus	3	**Gravel**	Gravel	**Exxon AC-10, 3% Latex**	2,902	4,038	4	5	0.2	0
8A	1	4.9	4.8	4.2	87	86	0.99	1.5% Lime	3	**Gravel**	Gravel	**Kerr McGee AC-10, 3% Latex**	20,554	19,819	4.4	4.4	0	0
3T	1	4.7	4.4	5.8	163	130	0.80	1.0% Lime	1	**Gravel, RAP**	Limestone	**Lion PG 70-22 (3% Latex)**				5		
2T	1	4.5	3.3	3.9	148	144	0.97	Probably Liquid	5	**Gravel**	Gravel	**Star AC-10, 3% Latex**				3.8		
1T	1	3.7	2.8	NA	142	59	0.42	Liquid	5	**Gravel**	Limestone	**Star AC-10, 3% Latex**				4.9		
8T	1	4.1	2.9	2.4	159	55	0.35	?% Liquid	6	**Gravel**	Gravel	**Star AC-10, 3% Latex**				2.7		
AVERAGES		4.0	3.3	4.1	127	87	0.70		3.9				12885	11825	4.1	4.3		
4L	1	4.7	4.4	1.9	186	164	0.88	1.0% Permatac Plus	1	**Gravel**	Limestone	Exxon AC-20	12,000	8,167	4.7	4.6	0	0
30A	1	4.7	4.2	10.5	118	69	0.58	1.0% Lime	1	**Gravel**	Gravel	Fina AC-20	NA	NA	NA	4.8	NA	NA
5A	1	4.2	4.1	2.6	120	145	1.21	1.5% Lime	3	**Gravel**	Gravel	Kerr McGee AC-20	3,283	2,534	3.8	3.6	0.2	0
4A	1	4.6	3.0	1.9	235	124	0.53	1.0% Permatac Plus	4	**Gravel**	Gravel	Kerr McGee AC-20	8,475	1,657	2.8	3.5	0	0
41A	2	4.6	4.4	4.3	120	143	1.19	1.0% Permatac Plus	2	**Gravel, RAP**	Gravel	Lion AC-10	11,059	10,700	4.1	5	4.7	2.3
27A	1	4.8	4.6	4.9	142	150	1.06	1.0% Lime	1	**Gravel**	Limestone	Lion AC-20	1,296	2,541	4.4	4.6	3.2	2.3
28A	1	4.7	4.6	6.0	130	124	0.95	1.0% Lime	1	**Gravel**	Gravel, Donnafill	Lion AC-20	499	2,483	4.1	4.7	NA	NA
8L	1	4.2	3.2	6.5	198	176	0.89	0.5% Unichem 8161	2	**Gravel**	Limestone	Lion AC-20	1,436	8,667	4.1	4.6	0	0
8L	2	4.3	3.2	9.6	121	82	0.68	0.5% Unichem 8161	3	**Gravel**	Limestone	Lion AC-20						
11A	1	3.9	3.2	0.9	160	106	0.66	0.5% Unichem 8161	4	**Gravel**	Gravel	Lion AC-20	16,554	11,530	4.4	4.2	1.7	4.2
6L	1	4.4	3.4	NA	176	134	0.76	None	5	**Gravel**	Limestone	Star AC-20	9,945	10,782	3.8	3.6	0	0
1L	1	3.4	2.5	NA	206	85	0.41	None	5	**Gravel**	Limestone	Star AC-20	9,197	8,667	4.1	3.7	0	0
9T	1	3.9	2.8	2.4	156	63	0.40	None	6	**Gravel**	Limestone	Star AC-20				2.9		
1L	2	3.5	2.5*	NA	113	No Test	NA	None	6	**Gravel**	Limestone	Star AC-20						
5L	1	3.8	3.0	NA	111	61	0.55	None	7	**Gravel**	Limestone	Star AC-20	9,594	11,000	3.9	4.3	0.1	0
2L	1	3.2	2.7	6.7	151	119	0.79	None	7	**Gravel**	Limestone	Star AC-20	1,801	3,600	3.6	4.5	0	0
AVERAGES		4.2	3.5	4.9	153	116	0.77		3.6				7,095	6,861	4.0	4.2		
7T	1	3.9	3.4	NA	148	53	0.36	0.5% Permatac Plus	3	**Igneous**	Igneous	**Lion AC-10, 3% Latex**				4.5		
22A	1	4.8	4.7	2.4	215	185	0.86	1.0% Lime	2	**Igneous**	Igneous	Lion AC-20	8,242	6,433	2.9	5	9	2
13A	1	4.9	4.9	6.1	126	139	1.10	1.0% Permatac Plus	2	**Limestone**	Limestone	**Lion AC-10, 3% Latex**	16,874	12,238	4.7	4.6	0.7	0
9A	1	4.8	4.7	6.5	187	149	0.80	1.0% Unichem 8161	2	**Limestone**	Limestone	**Lion AC-10, 3% Latex**	NA	NA	NA	4.6	NA	NA
5T	1	4.7	4.5	NA	226	194	0.86	None	9	**Limestone**	Limestone	**Elf AC-30P**				4.8		
AVERAGES		4.8	4.7	6.3	180	161	0.92		4.3				16874	12238	4.7	4.7		
3L	1	4.9	4.8	1.7	180	175	0.97	None	2	**Limestone**	Limestone, B. Ash	Exxon AC-20	10,162	12,045	4	5	0	0
3L	2	4.8	4.7	2.3	211	206	0.98	None	2	**Limestone**	Limestone	Exxon AC-20						
6T	1	4.5	4.5	4.4	167	157	0.94	0.5% Permatac Plus	3	**Limestone**	Limestone	Lion AC-20				4.5		
40A	2	4.6	4.3	5.6	167	150	0.90	1.0% Permatac Plus	3	**Limestone, RAP**	Limestone	Lion AC-10	8,476	11,763	3.9	4.9	0.1	0
AVERAGES		4.7	4.6	3.5	181	172	0.95		2.5				9,319	11,904	4.0	4.8		
14A	1	4.9	4.8	NA	113	94	0.83	1.5% Lime	2	**Quartzite**	Quartzite	**Lion AC-10, 3% Latex**	8,316	7,585	3.8	5	0.9	0
30BA	1	5.0	4.6	1.7	131	115	0.88	1.0% Permatac Plus	1	**Sandstone**	Sandstone	**Lion AC-10, 3% Latex**	4,934	9,480	3.8	5	0	0
12A	1	4.6	4.6	4.4	135	69	0.51	1.0% Permatac Plus	2	**Sandstone**	Sandstone	**Lion AC-10, 3% Latex**	14,666	10,980	4.2	4.2	0	0
AVERAGES		1.5	1.5	3.1	133	92	0.70		1.5				9,800	10,230	4	4.6		
30CA	1	4.9	4.9	8.3	126	118	0.94	1.0% Lime	1	**Sandstone**	Sandstone	Lion AC-20	754	2,350	4.4	4.6	3.5	2
7A	1	4.9	4.7	3.8	276	242	0.88	1.0% Permatac Plus	3	**Sandstone**	Sandstone	Lion AC-20	3,570	5,800	3.8	4.5	1	0
4T	1	4.2	4.0	4.4	200	148	0.74	None	6	**Sandstone**	Sandstone	Lion AC-20				NA		
AVERAGES		4.7	4.5	5.5	201	169	0.85		3.3				2162	4075	4.1	4.6		

e for evaluation. Value from the dry core is shown.

**Ride Scores and Visual Distress Ratings are evaluated on a scale to 5, with 5 being the highest possible rating.

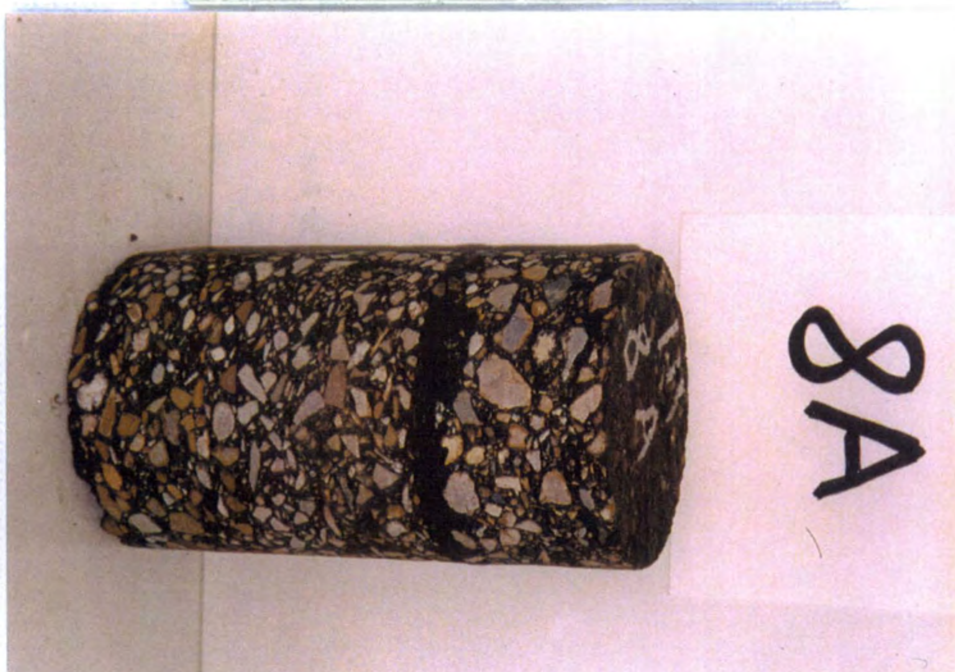
Table G4

ATLANTA - 2



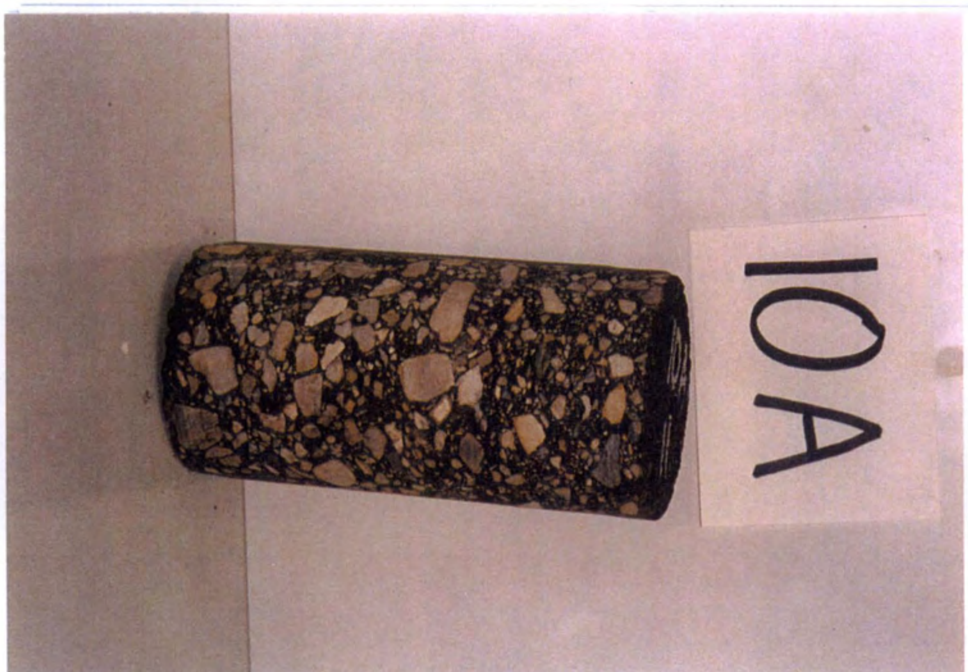
ATLANTA - 1

ATLANTA - 4



ATLANTA - 3

ATLANTA - 6



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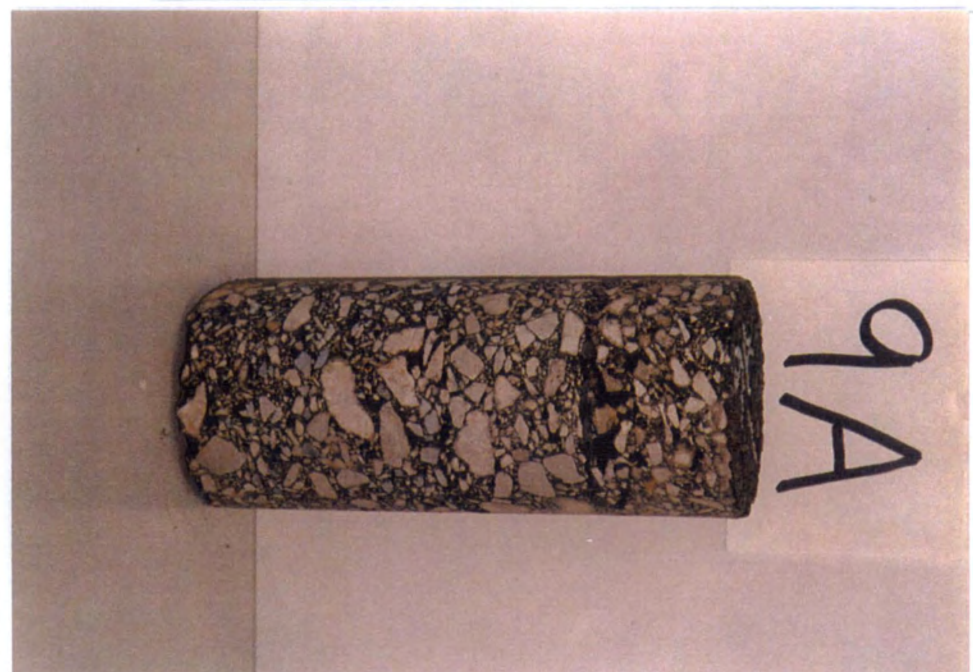

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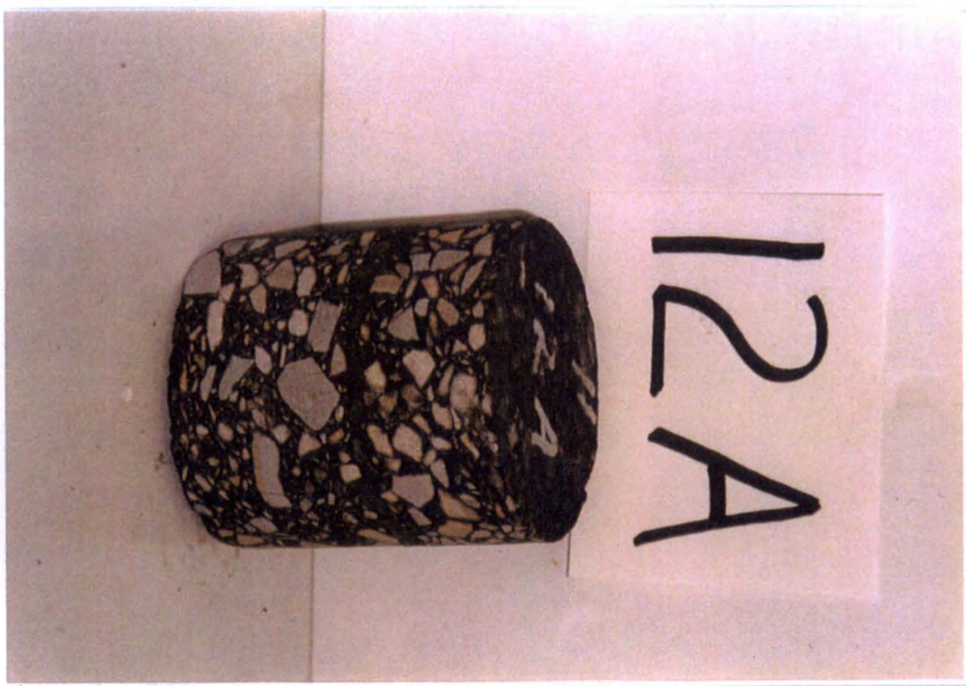
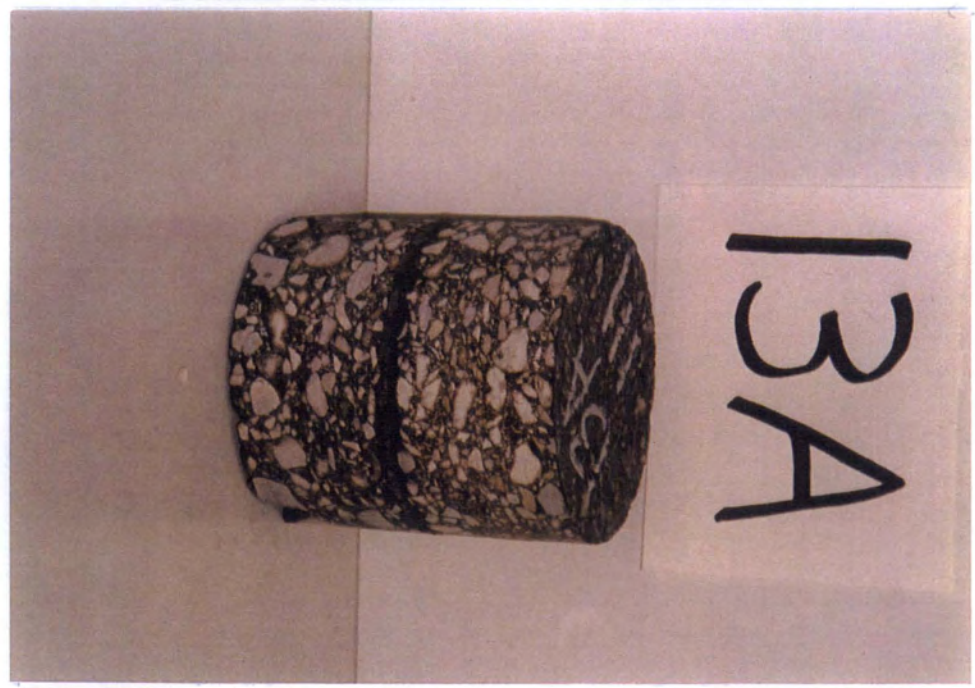


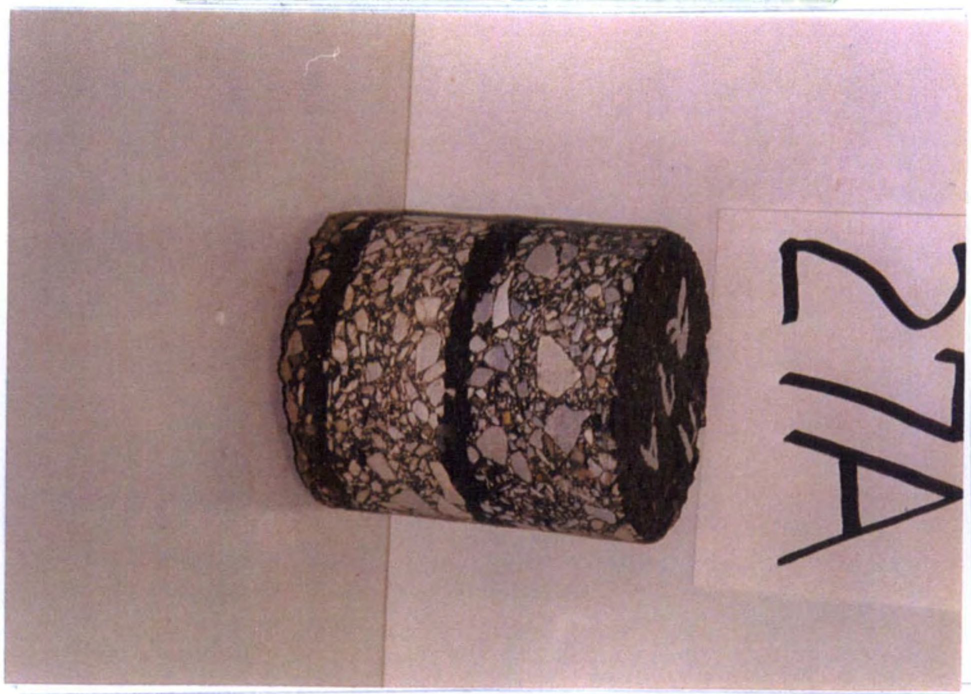
ATLANTA - 7

ATLANTA - 9



ATLANTA - 10

ATLANTA - 12



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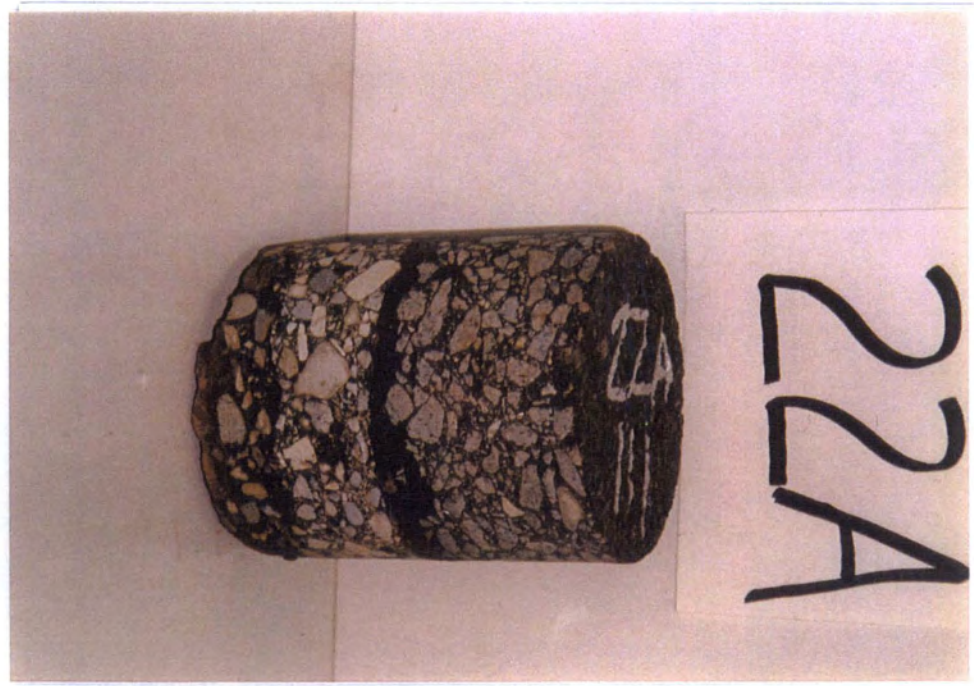

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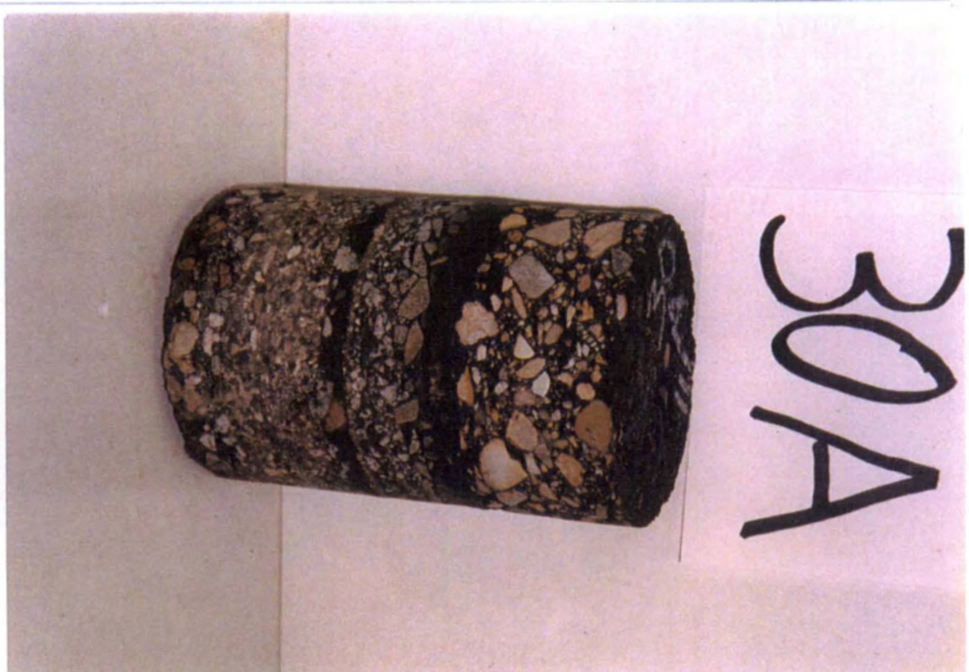
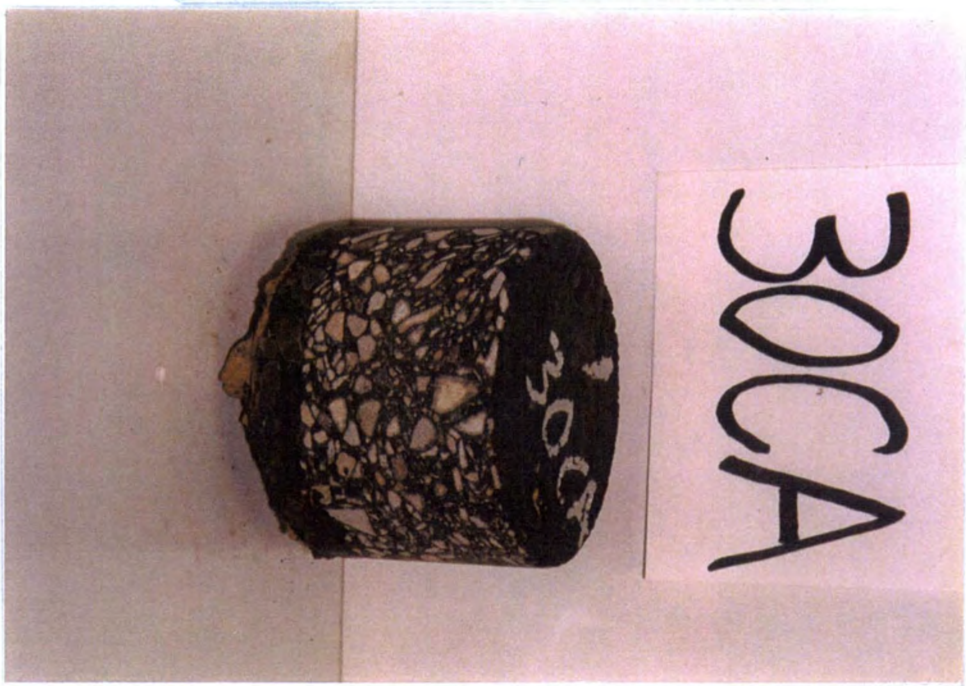
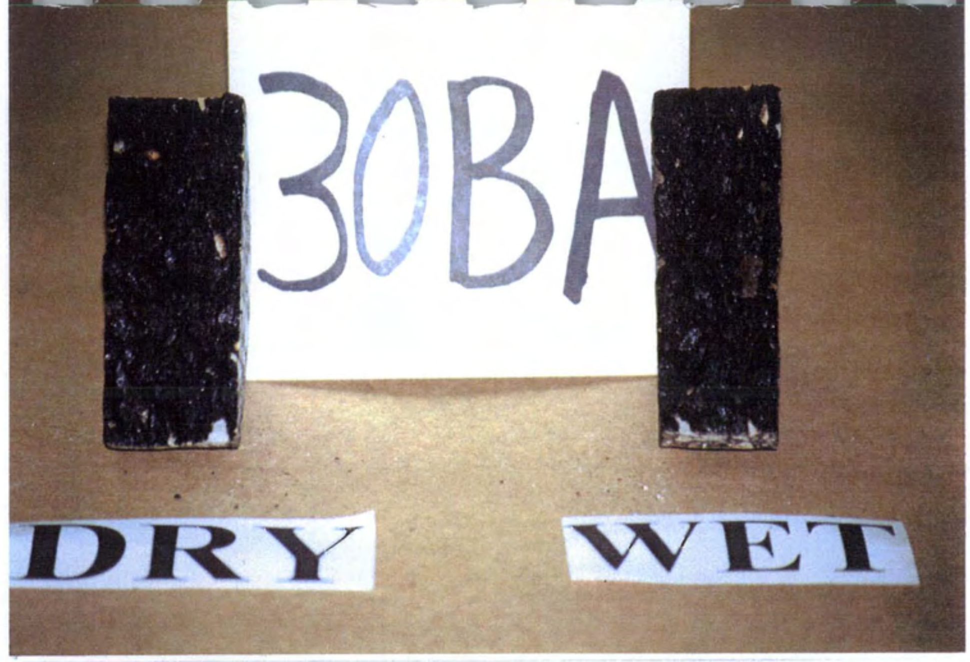


ATLANTA - 13

ATLANTA - 16





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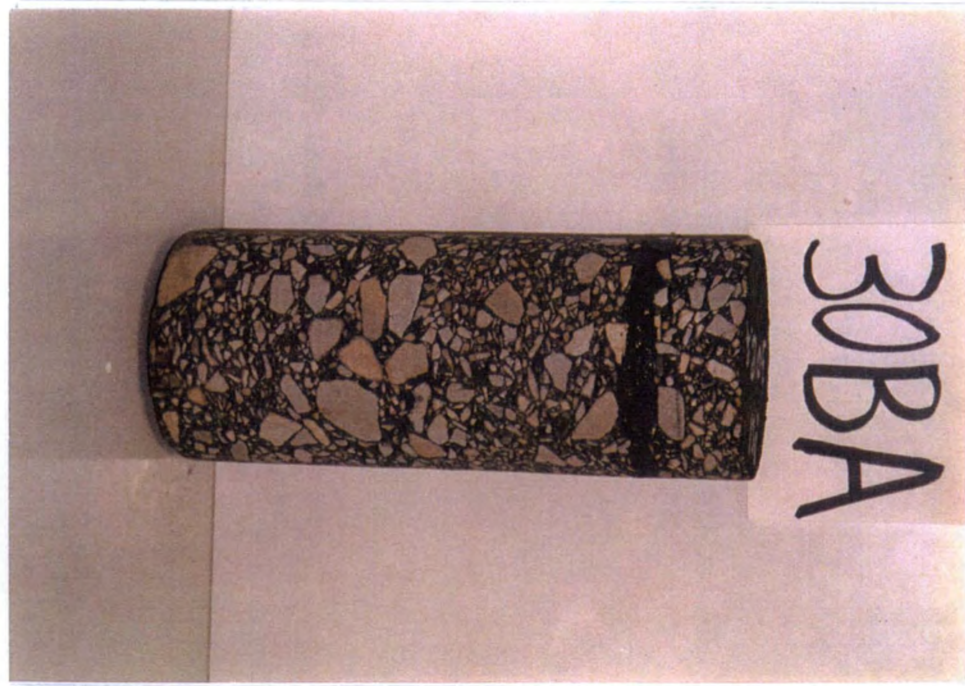

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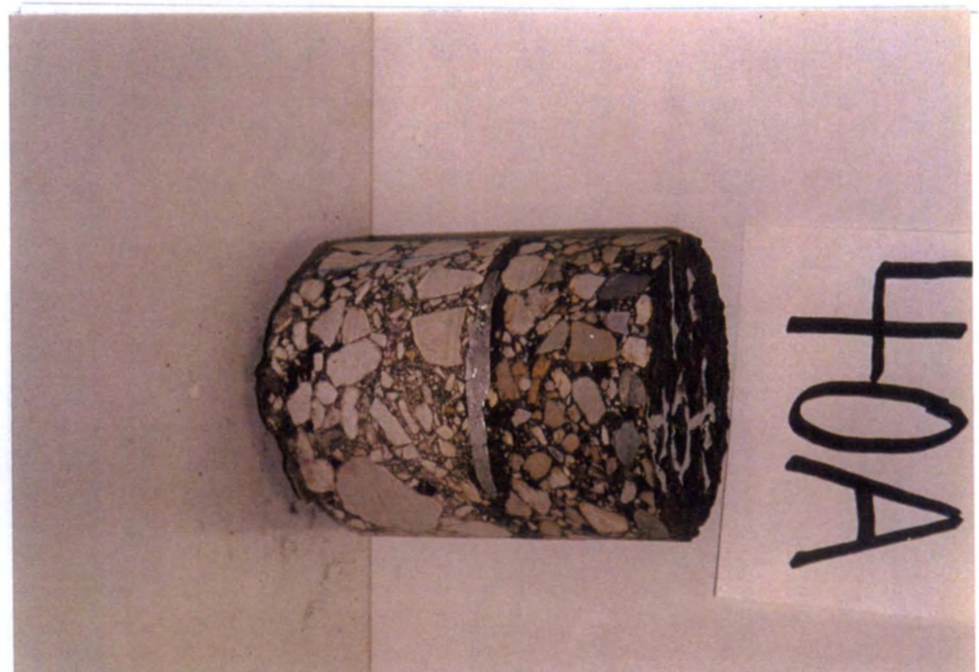

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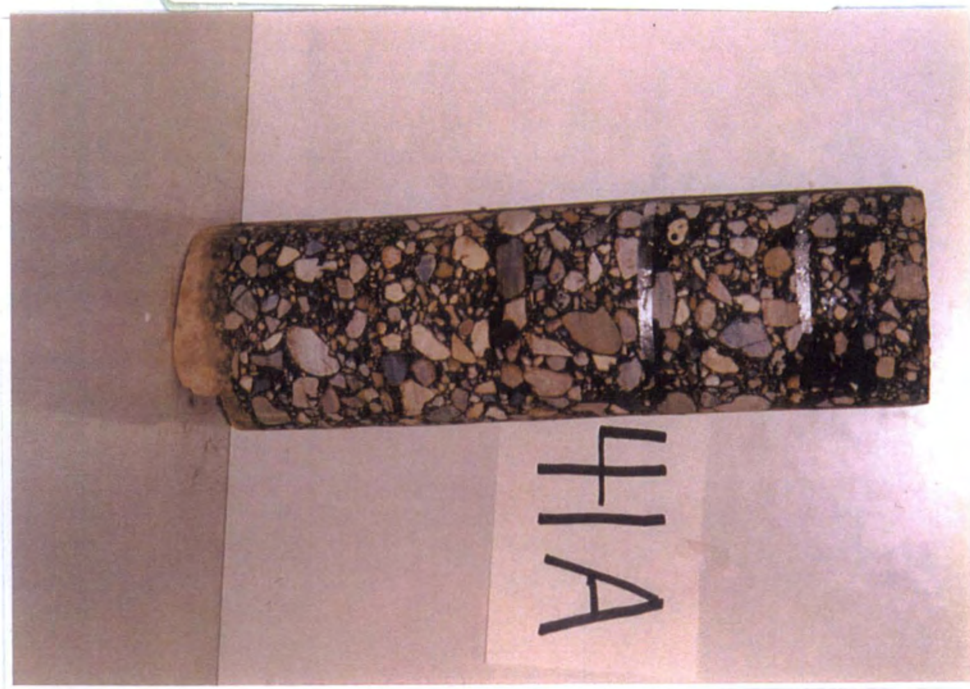

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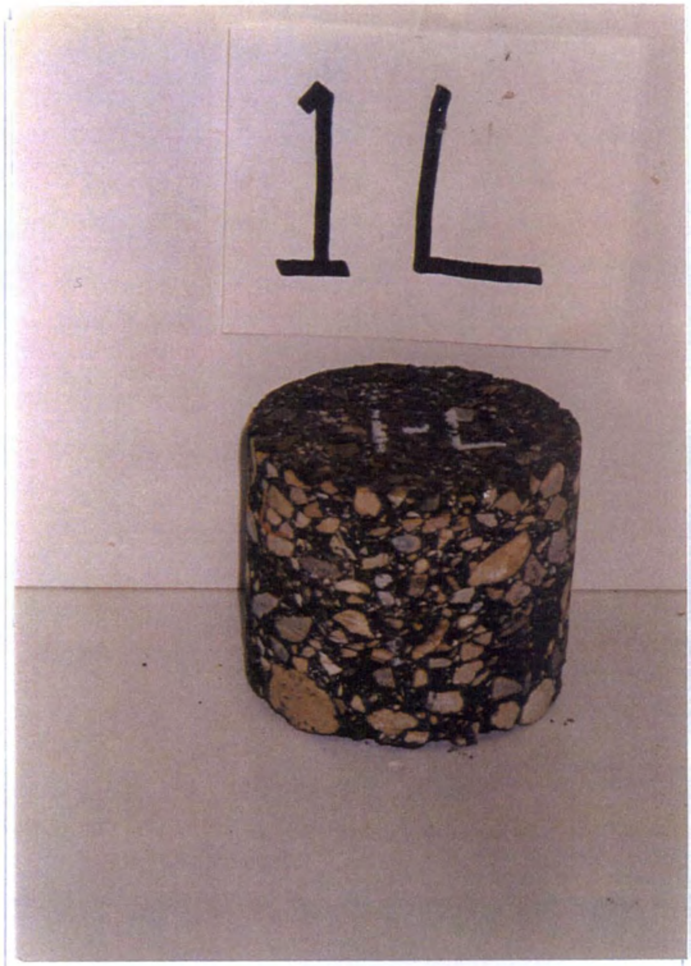

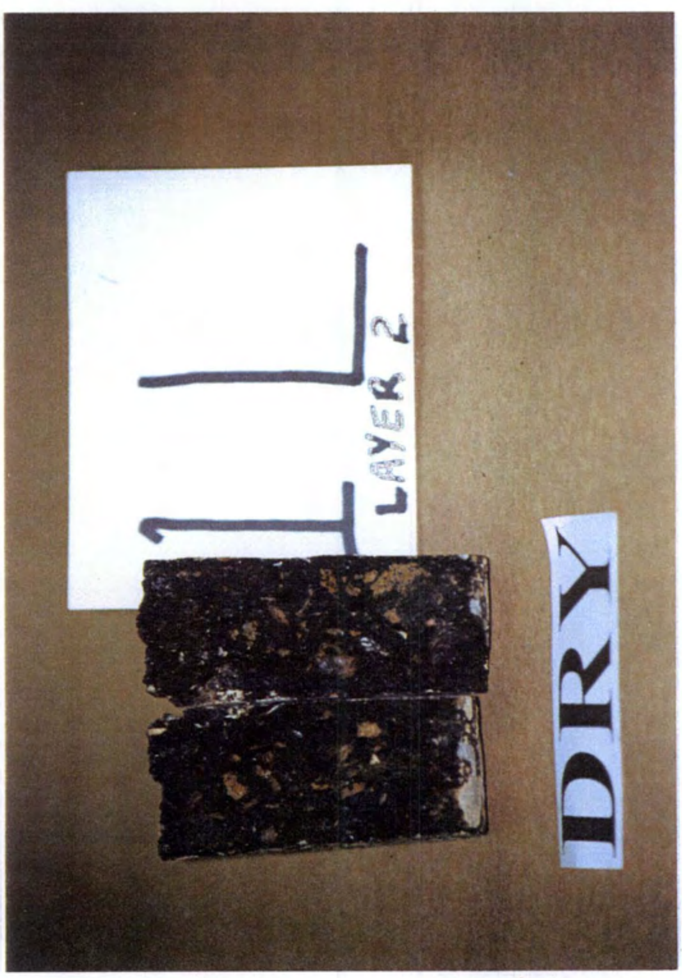

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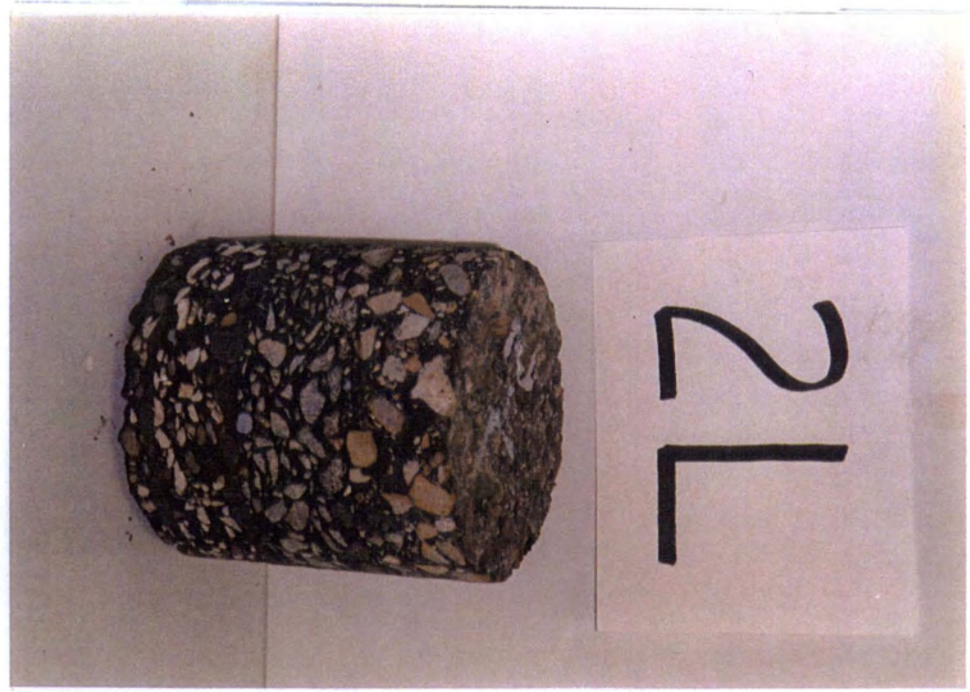

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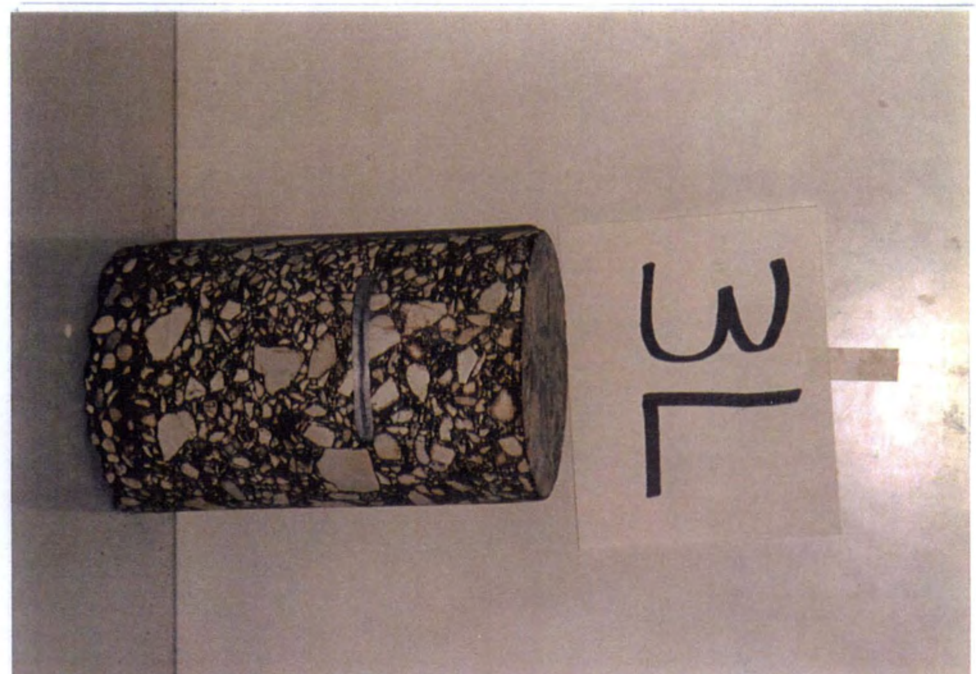

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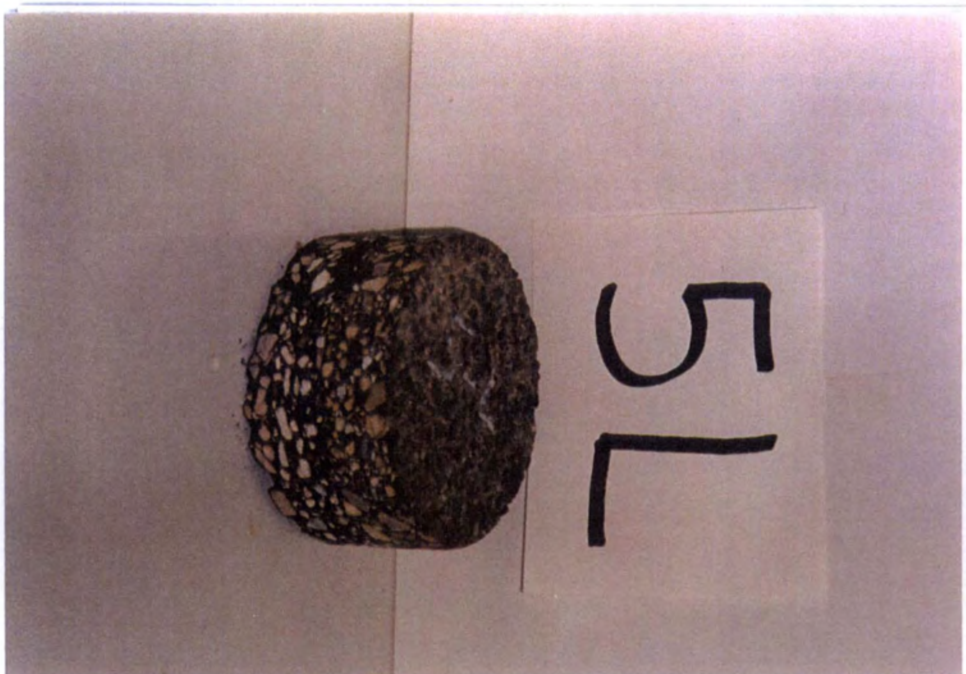

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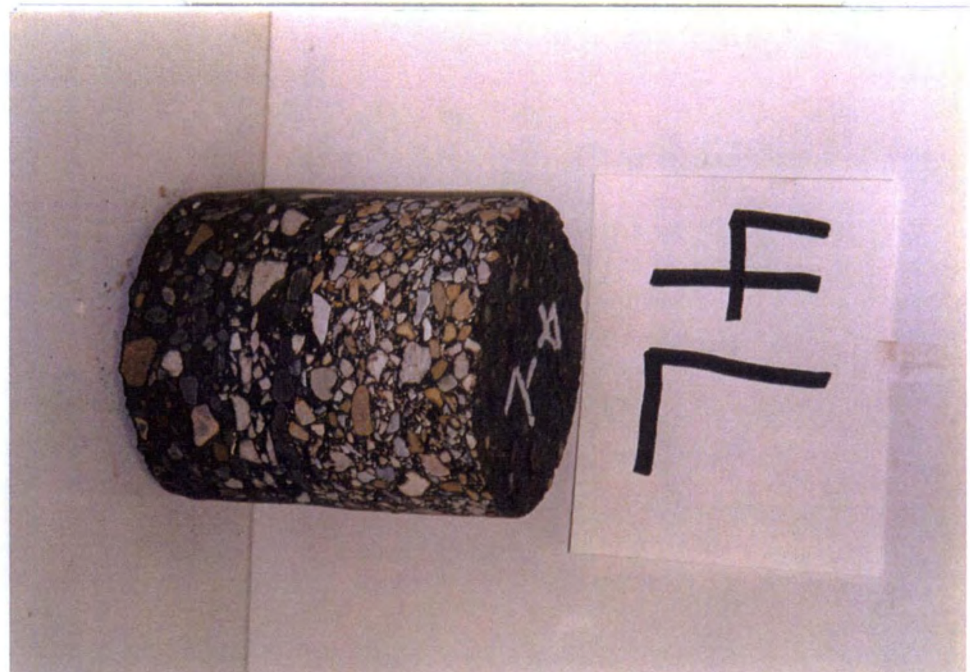

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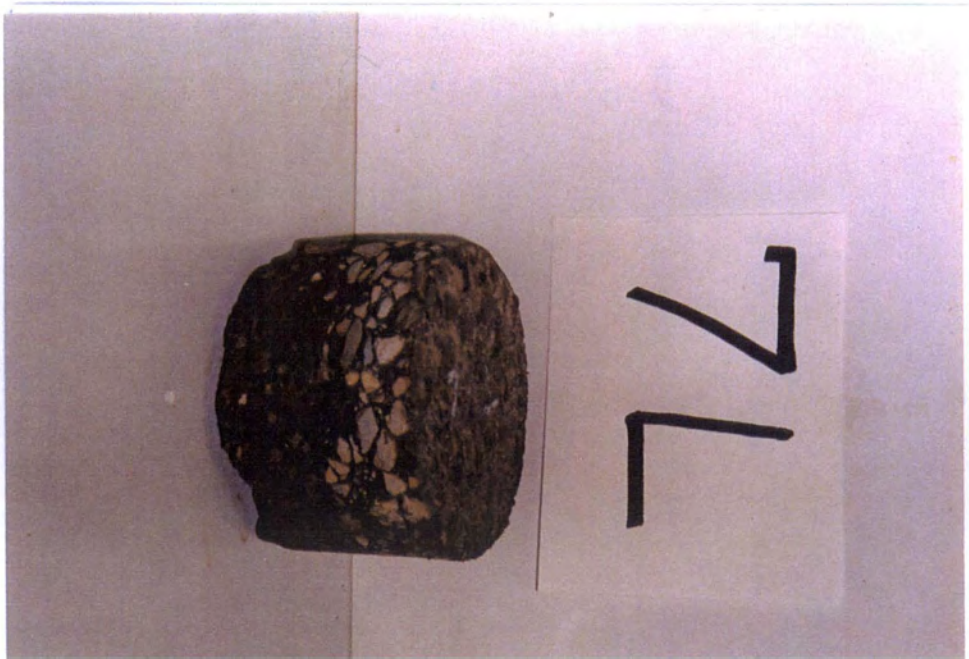

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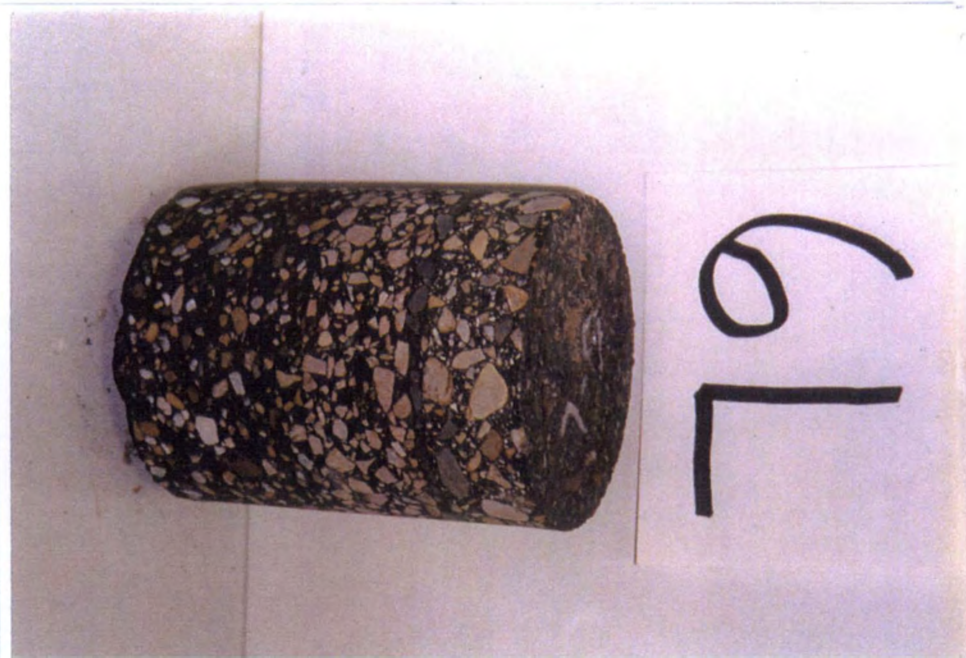

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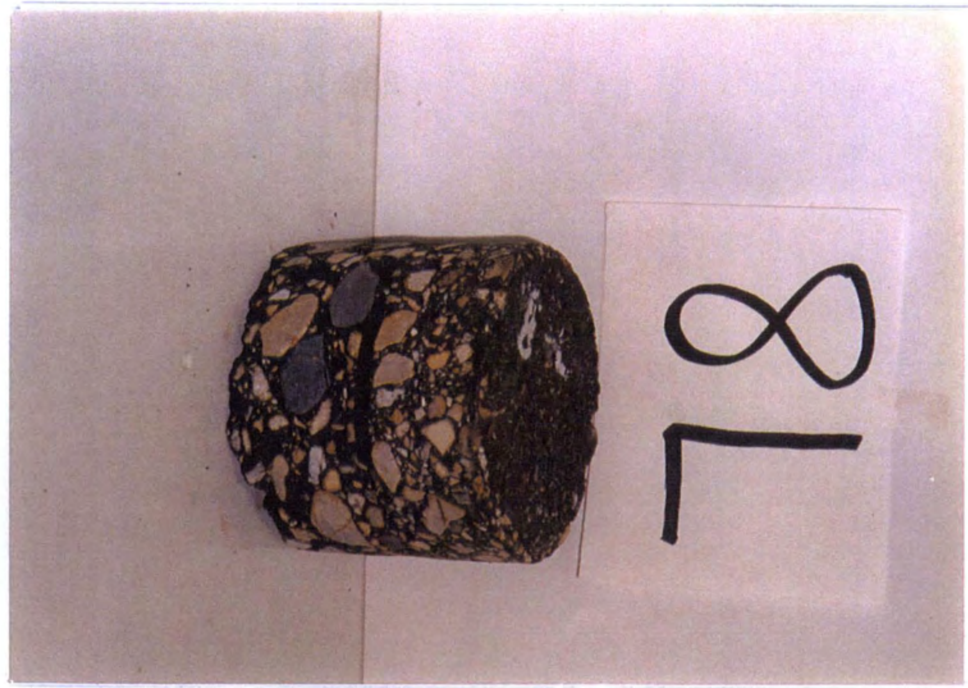

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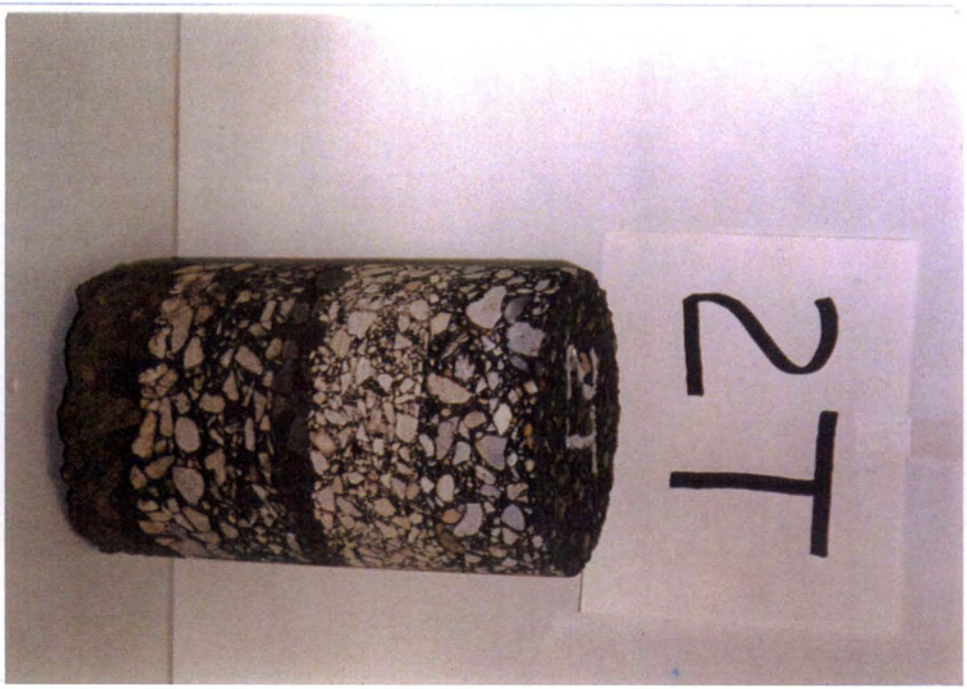

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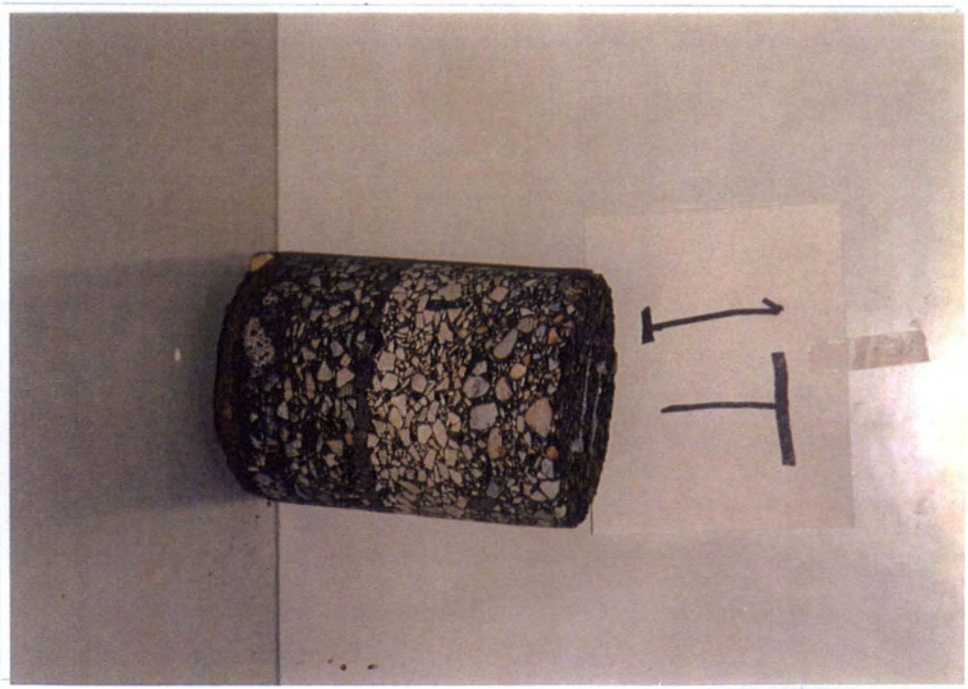

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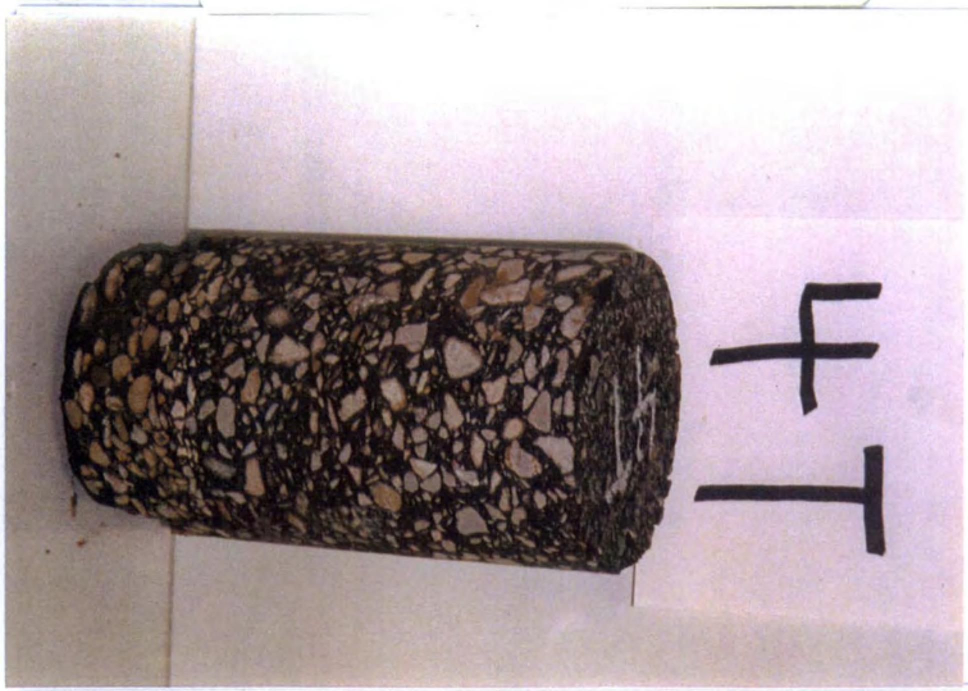

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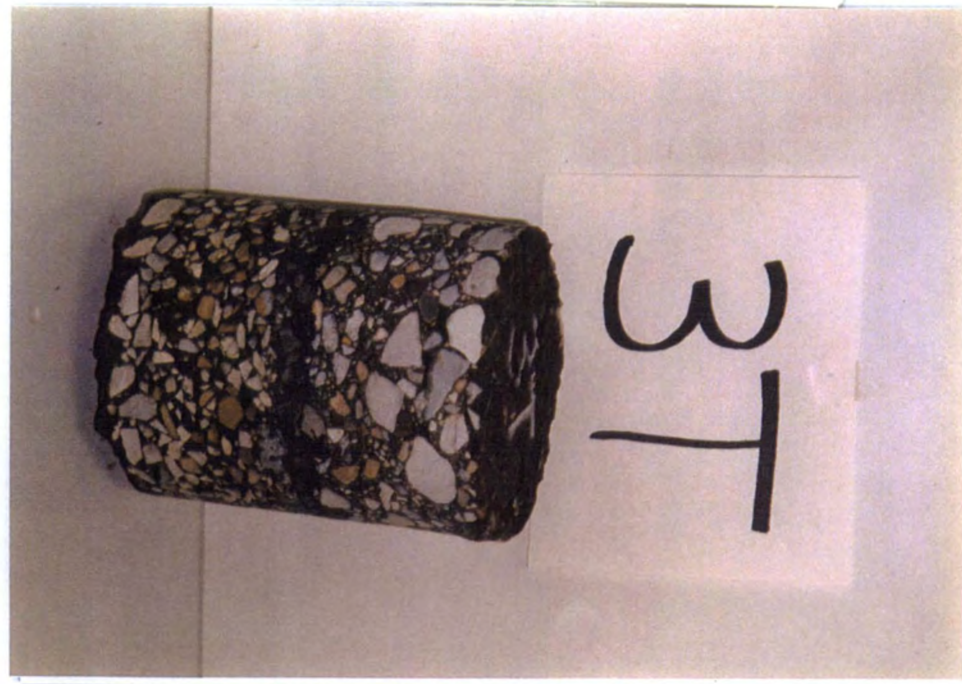

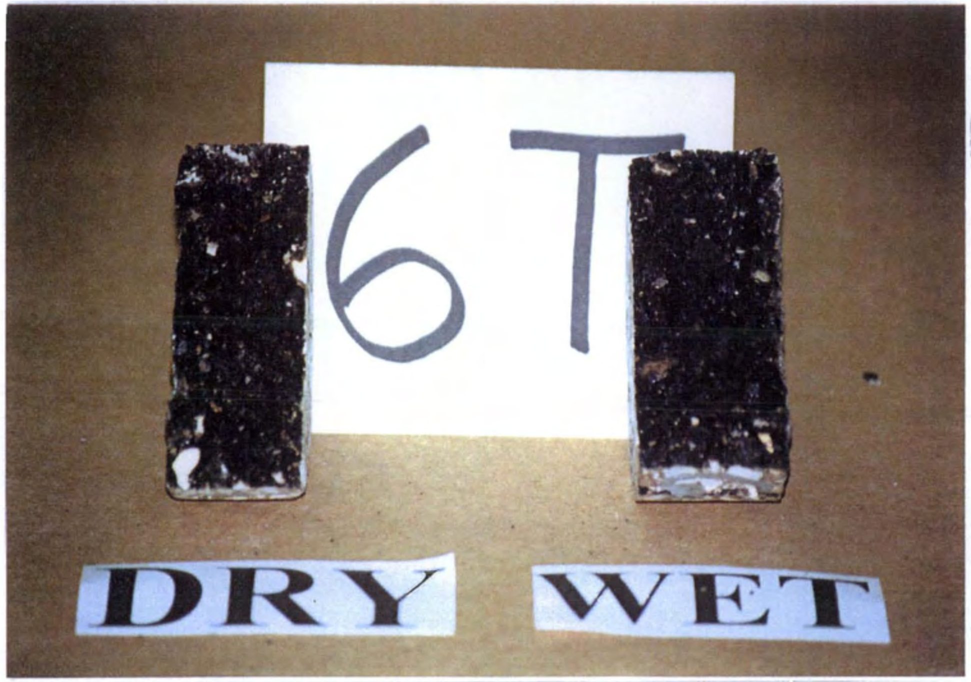

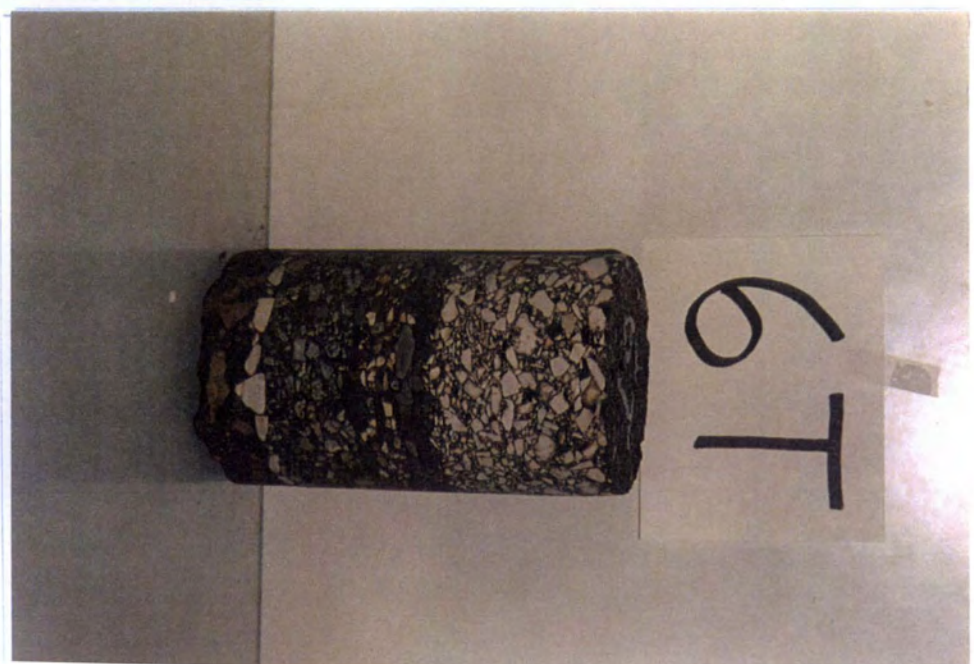

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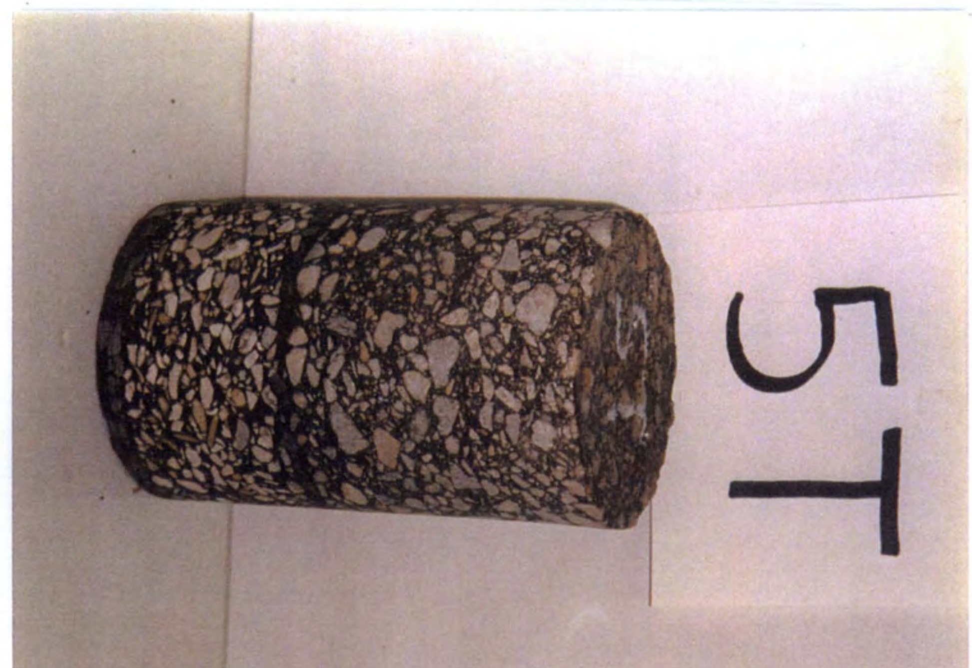

TYLER - 5

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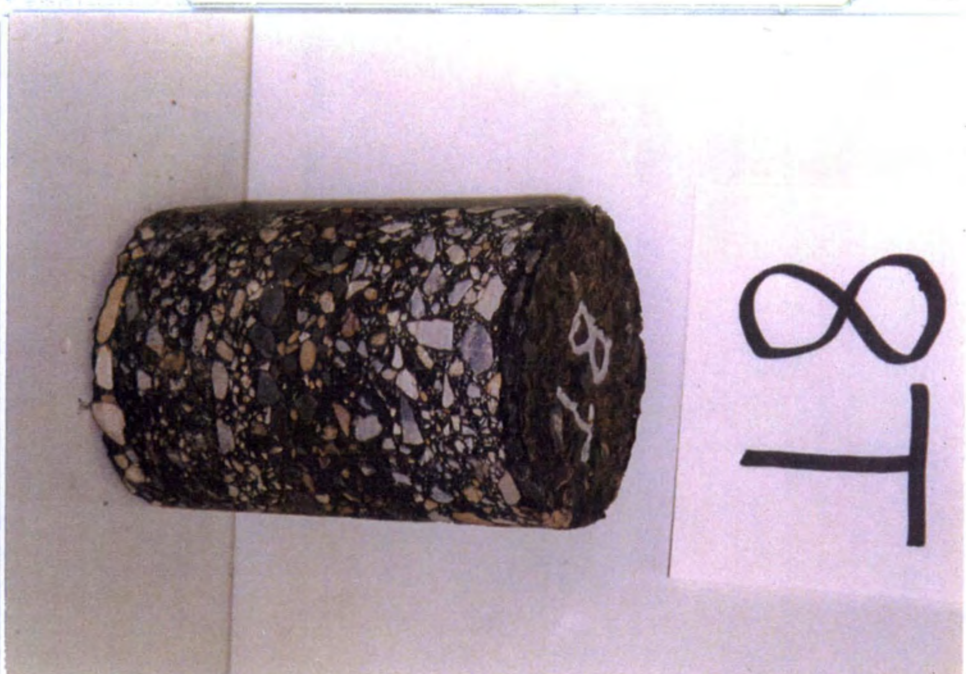

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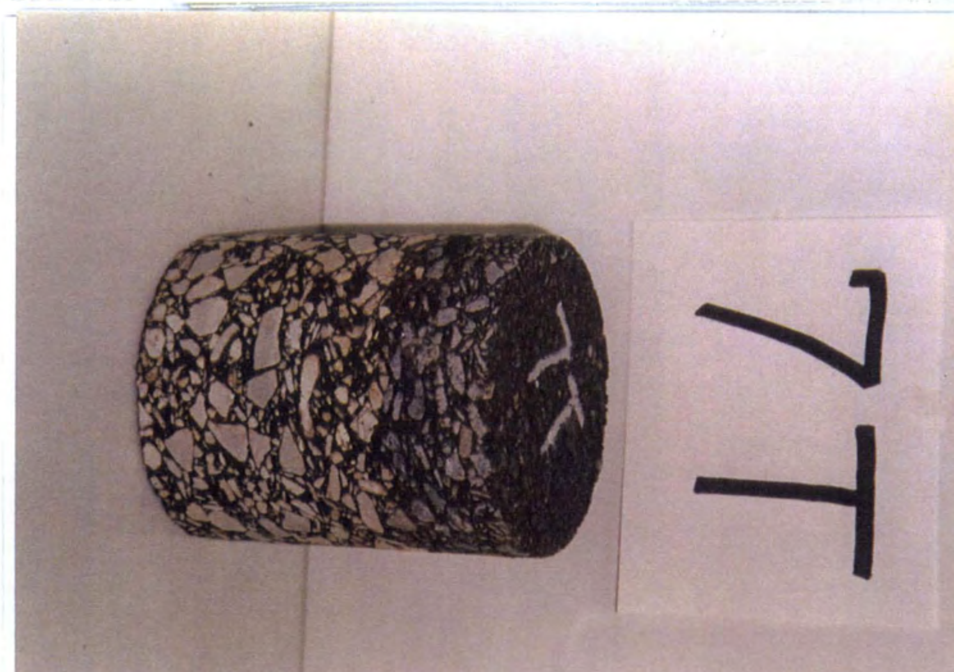

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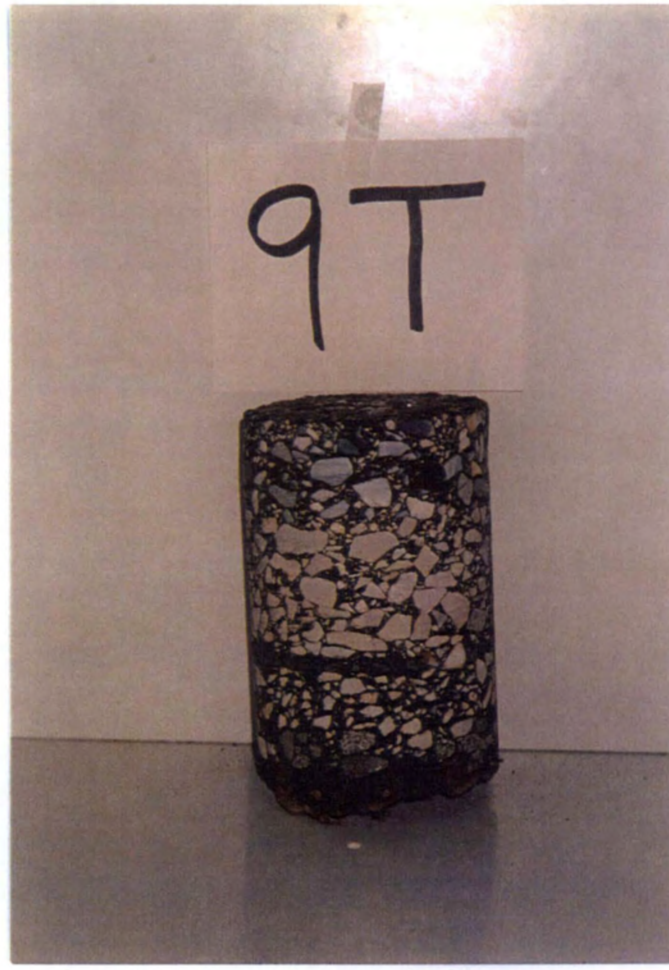

Texas
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of Transportation

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