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16. Abstract

This report summarizes the results of a long-term field evaluation of the effectiveness of lime and various antistripping agents. This research study was a continuation of the research carried out between 1986 and 1991 (documented in CTR Research Reports 441-1 and 441-2F).

Core samples were obtained from the field test sections and tested in the laboratory based on Test Methods Tex-531-C and AASHTO T283. Test results did not indicate any consistent pattern with regard to effectiveness of certain antistripping additives versus others.

The field test sections, treated with antistripping agents and built in eight districts of the Texas Department of Transportation (TxDOT), were monitored for signs of distress during the course of the research study. No signs of moisture damage could be found on any of the test sections (with and without antistripping) which had been exposed to traffic and moisture for six to seven years. At this time, the average air void levels for different districts varied between 2 and 5 percent. Other types of distress such as cracking and rutting could be found on some of the sections.

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LONG-TERM EVALUATION OF STRIPPING AND MOISTURE DAMAGE IN ASPHALT PAVEMENTS TREATED WITH LIME AND ANTISTRIPPING AGENTS

by

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Research Report Number 1286-1F

Research Project 0-1286

Long-Term Evaluation of Stripping and Moisture Damage in Asphalt Pavements Treated with Lime and Antistripping Agents

conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH

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THE UNIVERSITY OF TEXAS AT AUSTIN

September 1993

IMPLEMENTATION STATEMENT

One of the objectives of this study was to determine which antistripping agents are more efficient in improving a mixture's resistance to moisture damage. A firm conclusion regarding this matter cannot be drawn based on the field evidence and test results of this study. It is possible that some of the field test sections will manifest some distress of this type in the future. However, the low air void level at this stage restricts ingress of moisture, thereby reducing the rate of moisture damage significantly, and stripping effects may not be observed for years.

Prepared in cooperation with the Texas Department of Transportation and the
U.S. Department of Transportation, Federal Highway Administration

DISCLAIMERS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

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BIDDING, OR PERMIT PURPOSES

Thomas W. Kennedy (Texas No. 29596)
Research Supervisor

PREFACE

This is the final report for Project 0-1286 (3-9-92/3-1986), "Long-Term Evaluation of Stripping and Moisture Damage in Asphalt Pavements Treated with Lime and Antistripping Agents." The report presents the information and findings based upon the performance of the field test sections placed in eight districts of the Texas Department of Transportation (TxDOT) under Research Project 441.

The assistance and close cooperation of the Texas Department of Transportation, especially personnel from those districts directly involved and from the Materials and Tests Division, is acknowledged.

Appreciation is also extended to the Center for Transportation Research staff, especially Mr. Eugene Betts.

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September 1993

ABSTRACT

This report summarizes the results of a long-term field evaluation of the effectiveness of lime and various antistripping agents. This research study was a continuation of the research carried out between 1986 and 1991 (documented in CTR Research Reports 441-1 and 441-2F).

Core samples were obtained from the field test sections and tested in the laboratory based on Test Methods Tex-531-C and AASHTO T283. Test results did not indicate any consistent pattern with regard to effectiveness of certain antistripping additives versus others.

The field test sections, treated with antistripping agents and built in eight districts of the Texas Department of Transportation (TxDOT), were monitored for signs of distress during the course of the research study. No signs of moisture damage could be found on any of the test sections (with and without antistripping) which had been exposed to traffic and moisture for six to seven years. At this time, the average air void levels for different districts varied between 2 and 5 percent. Other types of distress such as cracking and rutting could be found on some of the sections.

Key Words: stripping, moisture damage, asphalt mixture, hydrated lime, antistripping additives, indirect tensile strength, moisture conditioning

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SUMMARY

Stripping and moisture damage in asphalt mixtures can produce serious pavement distress, reduce pavement performance, and increase maintenance costs. Previous studies have indicated that the primary factors which relate to stripping are the environment, aggregate, asphalt, and/or the use of stripping agents.

CTR Research Reports 441-1 and 441-2F presented results of the field studies to evaluate the effectiveness of different antistripping agents and lime in preventing moisture damage. The results of that study indicated little evidence of stripping in the pavements which were about four years old at the time the project was finished.

The purpose of the present research was to continue monitoring the field performance of different test sections constructed using different antistripping agents during Research Project 441. This report summarizes the results of this continuation study.

The field test sections, with or without antistripping, did not indicate any deterioration due to moisture even after the pavements have been exposed to traffic and precipitation for an additional three years. Even the sections which yielded low tensile strength ratios in the laboratory study did not exhibit noticeable moisture damage. The laboratory study included conditioning specimens obtained from the field cores based on test methods Tex-531-C and AASHTO T283.

CHAPTER 1

INTRODUCTION

It has long been recognized that moisture has a detrimental influence on asphalt concrete pavements. The large number of pavements that are distressed and deteriorated as a result of moisture damage is an indication of the significance and the severity of the problem.

Extensive research has been performed in the past in regard to the moisture damage problem (References 1 through 5). Moisture damage ranges in severity from stripping to minor softening of the asphalt mixture. Physical separation of the asphalt cement and the aggregate, known as stripping, is caused by the loss of adhesion between the asphalt cement and the aggregate surface. Stripping is influenced by the characteristics of asphalt cement and aggregate used in the mixture, as well as by environmental conditions such as the quantity of moisture present, temperature, and traffic. In general, aggregate is a hydrophilic material, while asphalt cement is hydrophobic. This phenomenon aggravates the stripping problem in the presence of moisture. Aggregate characteristics and conditions such as surface roughness, porosity, and surface coating (layer of dust or adsorbed moisture) influence the quality of adhesion between the aggregate and the asphalt cement. Asphalt binder properties such as surface tension and viscosity may also affect adhesion to various degrees. It has also been indicated that asphalts obtained from different sources may exhibit different susceptibilities to stripping. Extensive literature is available on the mechanism of stripping and moisture damage (References 6 through 14).

During the past decade or two, a number of test procedures have been developed and used to evaluate the moisture damage potential of asphalt-aggregate mixtures. Tests such as the ASTM stripping test, Texas film stripping test, boiling test, and thin-layer chromatography test were developed to evaluate initial coating and adhesion. Other tests such as the California swell test, immersion-compression test, Texas freeze-thaw pedestal test, and wet-dry indirect tensile test were developed for evaluating the long-term resistance to moisture damage. These tests are explained in References 15 through 26 listed at the end of this report.

A number of procedures and recommendations have been introduced to eliminate or minimize the moisture damage problem. One of these procedures involves treating the asphalt mixture with commercially available antistripping additives. These additives are surface active agents, and tend to reduce the surface tension of asphalt and improve the adhesion and bonding between the aggregate and asphalt. There have been a number of studies on the effectiveness of these additives in reducing stripping and moisture damage potential (References 27 through 40).

In 1986, the Texas Department of Transportation (TxDOT) sponsored a research project (Project 3-9-86-441) to investigate stripping and moisture damage in hot mix asphalt pavements treated with hydrated lime and antistripping agents. During that study, over 90 field sections were constructed with various antistripping agents in eight districts.

The first phase of the study included performing a series of different moisture susceptibility tests on unaged field cores as well as on laboratory compacted specimens from both plant and laboratory mixes. The tests included in that part of the study were wet-dry indirect tensile tests with different conditioning methods. The conditioning methods included TxDOT Test Method Tex-531-C (with and without cure), original Lottman, AASHTO T283 (Root-Tunnicliff), and cyclic freeze-thaw. The Texas boiling test was also included in that part of study. The results from the various methods were analyzed to evaluate the effectiveness of the antistripping agents and select appropriate moisture susceptibility tests. The results of that study are presented and discussed comprehensively in Research Report 444-1 (Reference 41).

The second phase of the research study concentrated on testing cores from the constructed field sections after they had been exposed to traffic and environmental conditions. The laboratory tests used in this part of study included the wet-dry indirect tensile strength test with conditioning according to Tex-531-C (without curing) and the Texas boiling test. A visual inspection of the test sections was also included in this phase. The results obtained from this phase of the study were reported in Research Report 441-2F (Reference 42).

Upon completion of the study in 1990, a field condition survey of all test sections indicated little evidence of distress related to moisture damage or stripping. Recognizing that long-term pavement performance was difficult to evaluate with test sections which were only two to four years old at the time of completion of the study, the Texas Department of Transportation continued monitoring and testing the test sections for approximately one more year. Beyond this period, under a cooperative research program with TxDOT, The University of Texas at Austin continued monitoring and testing of the field test sections for two more years (1991 through 1993). This research was entitled "Long-Term Evaluation of Stripping and Moisture Damage in Asphalt Pavements Treated with Lime and Antistripping Agents," and was sponsored by the Texas Department of Transportation.

The results of this continuation project, as well as the work carried out by TxDOT personnel, are presented and discussed in this report. The experimental program is explained in Chapter 2, which summarizes the information on the field test sections and their construction, the monitoring and testing schedule, and the type of tests performed. The results of analysis and testing are presented and discussed in Chapter 3. Conclusions and recommendations are given in Chapter 4.

CHAPTER 2

EXPERIMENTAL PROGRAM

Scope of Work

The objectives of this study were to determine the long-term effectiveness of hydrated lime and selected liquid antistripping agents to prevent or inhibit moisture damage, to evaluate field performance of different mixtures using different antistripping agents, and to correlate test values to actual performance.

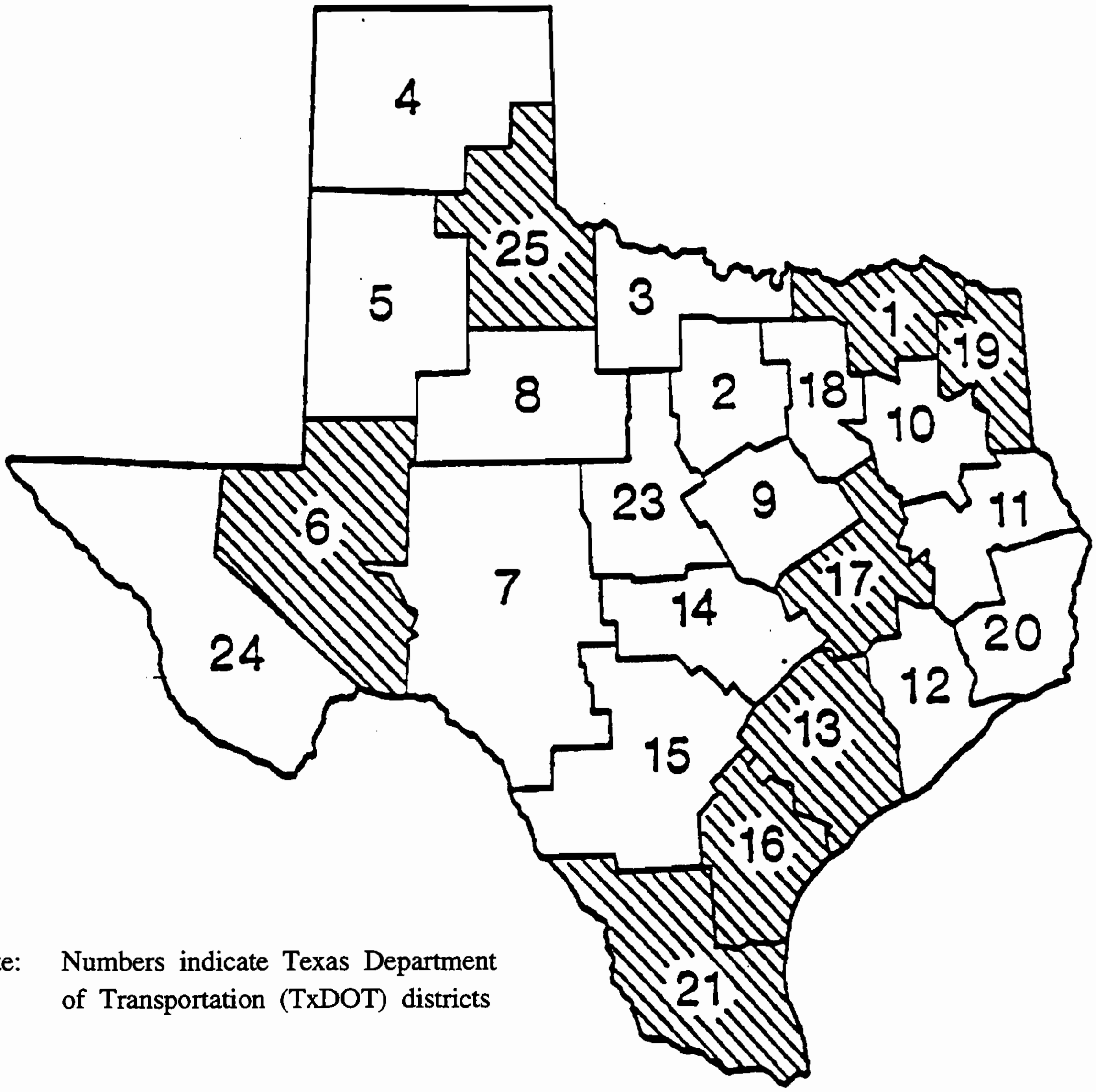
To achieve these objectives, both field and laboratory studies were developed and conducted in cooperation with the Texas Department of Transportation (TxDOT). The field experimental program involved eight highway test projects which were constructed in eight different districts and involved a range of traffic and climatic conditions, asphalt cements, and aggregates. The testing program involved obtaining field core samples, visual test section condition surveys, and wet-dry indirect tensile tests.

Field Experimental Projects

During Research Project 441, eight full-scale experimental test projects were selected and designed in cooperation with the Materials and Tests Division of the Texas Department of Transportation, and with the districts in which the test projects were constructed. Field construction was supervised by applicable district personnel, with technical guidance provided by research project personnel. Figure 2.1 shows the location of field test projects. Table 2.1 gives information on the temperature, precipitation, traffic, and construction date for each test project. The test projects are presented in the order of their construction dates.

Experimental Design

Hydrated lime and two or more commercially available antistripping additives were included in each project. In addition, control sections with no additive were also included in each test project. The selection of antistripping additives to be included was based upon the experience and recommendation of the districts and the willingness of the proposed additive manufacturers to participate in the study. Each treatment and control section was constructed with both high and low densities, i.e., low and high air voids. The low air void sections were targeted for a range of 3 to 8 percent as specified by TxDOT. The high air void sections were targeted to have approximately 4 percent more air voids than the low air void sections.



Note: Numbers indicate Texas Department of Transportation (TxDOT) districts

Figure 2.1. Location of field test projects

TABLE 2.1. SUMMARY OF THE TRAFFIC AND CLIMATOLOGICAL DATA FOR FIELD TEST PROJECTS

District and Location	*Construction Date (Month/Year)*	*ADT* (1)	*Average Annual Temperature, °F* (2)	*Average Annual Precipitation, inches* (3)
17 – Hearne	7/86	2,000	66.7	36.6
16 – Odem	8/86	11,800	71.6	29.6
13 – Victoria	10/86	4,200	70.6	36.6
6 – Midland	11/86	13,900	63.2	17.1
25 – Childress	5/87	5,800	61.1	24.5
1 – Ector	9/87	5,000	64.0	46.1
19 – DeBerry	10/87	6,700	63.7	54.6
21 – Mercedes	10/87	10,600	75.1	19.9

(1) Average Daily Traffic, estimated at the year of construction

(2) Estimated from data of 1986-1988, Texas Water Commission, Austin, Texas

(3) Estimated from data of 1985-1989, Texas Water Commission, Austin, Texas

1 Δ°F = 0.56 Δ°C

1 inch = 25.4 mm

Materials and Additives

The eight field test projects involved a total of 92 test sections containing a range of asphalt cements, aggregates, and various antistripping additives. Information about the source of asphalt, asphalt cement content, and types of aggregate utilized in the eight test projects is summarized in Table 2.2. Gradations of the individual aggregates, the project gradation, and percentages of aggregates from each stockpile are reported in Research Report 441-2F (Reference 42). The same sources of asphalt cements and aggregates were used for all test sections in each field test project. In several cases, the actual asphalt contents used in the field mixtures deviated from the preliminary laboratory design values as a result of decisions made during construction.

Fourteen different antistripping additives, including hydrated lime, were used in the eight field projects. The additive information is summarized in Table 2.3. The plan was to use 1 percent lime by weight of dry aggregates and 1 percent liquid antistripping additive by weight of asphalt cement according to the manufacturer's recommended dosage in all mixtures containing antistripping additives. Information regarding type and dosage of antistripping additives used in the field test sections is presented in Table 2.4. In most cases, the proper amounts were mixed in the field according to the plan; however, in a few cases, the desired dosages were not achieved due to the constraints of field construction.

Construction of Test Sections

All field test sections were constructed as the surface course of the pavement. Seven of the eight field projects utilized drum mix plants, and one (District 13 at Victoria) utilized a batch plant. The field application techniques utilized to incorporate the various antistripping additives into the mixture are summarized in Table 2.5. In six projects, lime was placed on the aggregates in a slurry form; in two projects (Districts 6 and 19 at Midland and DeBerry, respectively), dry lime was added to the damp aggregate. At the seven drum plants, liquid additives were metered into the asphalt cement by means of an in-line blending system, whereas in the batch plant (District 13), liquid additives were mixed with the asphalt cement in the storage tank. The actual dosage levels were obtained by monitoring the meter or scale at the mixing plant for all except the DOW additive. The DOW antistripping additive was in pellet form and was mixed with the asphalt cement either in a storage tank (Districts 1 and 16 at Odem and Bonham, respectively) or at the refinery (District 21 at Pharr) by the DOW chemical company. Depending on the mixing time and the rate of dissolution, the dosage of DOW antistripping additive was difficult to determine immediately. The percentage of the dosage was determined later in DOW Chemical's laboratory by analyzing a sample of the blended asphalt cement and additive obtained from the storage tank.

TABLE 2.2. SUMMARY OF MATERIALS USED IN THE FIELD TEST PROJECTS

			Asphalt Content, %	
District	*Aggregates*	*Asphalt*	*Design**	*Field***
17	55% Processed gravel 25% Washed sand 10% Coarse sand 10% Fine sand	AC-20 Texas Gulf Refinery	4.9	4.9
16	58% Limestone "D" 22% Limestone screenings 20% Field sand	AC-20 Gulf States Refinery	4.3	5.1
13	50% Crushed gravel 10% Limestone 20% Limestone screenings 20% Field sand	AC-20 Texas Fuels & Asphalt Refinery	5.0	5.0
6	56% Rhyolite "D" 37% Screenings 7% Field sand	AC-20 American Petrofina Refinery	6.2	6.2
25	20% Coarse aggregates 34% Intermediate aggregates 46% Screenings	AC-20 Diamond Shamrock Refinery	5.2	5.2
1	55% Coarse sandstone 30% Unwashed screenings 15% Field sand	AC-20 Total Petroleum Refinery	6.0	5.5
19	20% Coarse "C" aggregates 40% "D" aggregates 20% Screenings 20% Field sand	AC-20 Lion Oil Refinery	5.3	5.6
21	35% Coarse aggregates 20% Uncrushed aggregates 25% Screenings 20% Field sand	AC-10 Texas Fuel Coastal Refinery	5.2	5.2

* Laboratory optimum asphalt content for the mixture design

** Actual asphalt content used for the field test project mixtures

TABLE 2.3. SUMMARY OF ANTISTRIPPING ADDITIVES USED IN THE FIELD TEST PROJECTS

	*TxDOT District**							
Antistripping Additive	*17*	*16*	*13*	*6*	*25*	*1*	*19*	*21*
Control (no additive)	x	x	x	x	x	x	x	x
Hydrated Lime	x	x	x	x	x	x	x	x
ARR-MAZ (Adhere Regular)							x	
ARR-MAZ (Adhere HP)						x		x
Aquashield		x						
Aquashield II					x		x	x
BA 2000	x		x				x	
DOW		x				x		x
FINA-A					x	x		
FINA-B								x
Indulin AS-1						x		
Pavebond LP		x		x				x
Pavebond Special						x		
Perma-Tac				x	x		x	x
Perma-Tac Plus	x		x			x		
Unichem 8150				x	x			
Number of treatments applied in each district:	4	5	4	5	6	8	6	8
Number of test sections** constructed in each district:	8	10	8	10	12	16	12	16
Total number of test sections constructed:								92

* In chronological order of field construction

** For each additive/treatment, one low air voids test section and one high air voids test section were constructed.

TABLE 2.4. TYPE AND DOSAGE OF ANTISTRIPPING ADDITIVES USED IN THE FIELD TEST PROJECTS

District	*Test Sections*	*Additive Dosage*, %*
17	Control (no additive)	–
	Hydrated Lime	1.5
	BA 2000	1.0
	Perma-Tac Plus	1.0
16	Control (no additive)	–
	Hydrated Lime	1.0
	Aquashield	0.5
	DOW	0.41
	Pavebond LP	0.5
13	Control (no additive)	–
	Hydrated Lime	2.0
	BA 2000	1.0
	Perma-Tac Plus	1.0
6	Control (no additive)	–
	Hydrated Lime	1.0
	Pavebond LP	1.0
	Perma-Tac	1.0
	Unichem 8150	1.0
25	Control (no additive)	–
	Hydrated Lime	1.0
	Aquashield II	1.0
	FINA-A	1.0
	Perma-Tac	1.0
	Unichem 8150	1.0
1	Control (no additive)	–
	Hydrated Lime	1.5
	ARR-MAZ (Adhere HP)	0.75
	DOW	0.45
	FINA-A	1.0
	Indulin AS-1	1.0
	Pavebond Special	1.0
	Perma-Tac Plus	1.0
19	Control (no additive)	–
	Hydrated Lime	1.0
	ARR-MAZ (Adhere Regular)	1.0
	Aquashield II	0.8
	BA 2000	0.5
	Perma-Tac	1.0
21	Control (no additive)	–
	Hydrated lime	1.0
	ARR-MAZ (Adhere HP)	1.0
	Aquashield II	0.41
	DOW	0.5
	FINA-B	0.41
	Pavebond LP	1.0
	Perma-Tac	1.0

* The percentage of hydrated lime is measured by the total weight of dry aggregates. The percentage of liquid antistripping additives is measured by the weight of asphalt cement.

TABLE 2.5. SUMMARY OF FIELD APPLICATION TECHNIQUES FOR ANTISTRIPPING TREATMENTS

	Field Application Method	
District	*Hydrated Lime*	*Liquid Antistripping Agents*
17	Lime slurry was applied to the aggregates on cold feed belt of the drum mix plant.	Liquid additives were metered into the aphalt cement by an in-line blending system.
16	Lime slurry was applied to the aggregates on cold feed belt of the drum mix plant.	Liquid additives were metered into the asphalt cement by an in-line blending system. * DOW polyethylene pellets were mixed with asphalt cement in a separate storage tank 12 hours prior to use.
13	Lime slurry was applied to the aggregates on cold feed belt of the batch mix plant.	Liquid additives were mixed with the asphalt cement in the storage tank.
6	Coarse aggregates stockpile was wetted and dry lime was added in layers 12 hours prior to use.	Liquid additives were metered into the asphalt cement by an in-line blending system.
25	Lime slurry was applied to the aggregates on cold feed belt of the drum mix plant.	Liquid additives were metered into the asphalt cement by an in-line blending system.
1	Lime slurry was applied to the aggregates on cold feed belt of the drum mix plant.	Liquid additives were metered into the asphalt cement by an in-line blending system. * DOW polyethylene pellets were mixed in asphalt distributor truck for 1 hour prior to use.
19	Dry lime was added to aggregate stockpile and sprayed with water to hold lime to aggregates 12 hours prior to use.	Liquid additives were metered into the asphalt cement by an in-line blending system.
21	Lime slurry was applied to the aggregates on cold feed belt of the drum mix plant.	Liquid additives were metered into the asphalt cement by an in-line blending system. * DOW polyethylene pellets were blended with asphalt cement at the refinery.

* DOW antistripping additive was in pellet form.

Seven projects involved test sections approximately 1,000 feet (300 meters) in length, while the test sections of one project (District 1) were approximately 500 feet (150 meters) in length. The goal was to achieve both high and low air void levels for each test section, as outlined in the experiment design. However, it was difficult to develop the rolling pattern for a particular target air void content within the time available. A detailed description of the location and layout of test sections for each field test project is included in Appendix A.

Testing Program

The testing program developed and conducted for this study involved activities including field core sampling, test section condition surveys, and wet-dry indirect tensile strength tests. The following section gives a description of these activities.

Field Core Sampling

As explained in Research Report 441-2F (Reference 42), the first series of field cores were taken immediately following construction of each of the test sections; additional field cores were obtained later, at six months after construction, and then yearly after construction, over a period of approximately four years. The field cores were approximately 4 inches (100 millimeters) in diameter and approximately 1 to 2 inches (25 to 50 millimeters) in thickness. Three pairs of cores were obtained in the wheel path from each test section at approximately 200-foot (60-meter) intervals, with the first and last cores located approximately 300 feet (90 meters) from the beginning and the end of the test section. The distance between the two paired cores was approximately 3 to 6 inches (75 to 150 millimeters).

Since the beginning of the field test pavement evaluation through the end of the Summer of 1991, all sections were cored every year on a regular basis according to the coring plan described above. However, as the previous study extended into this new phase (i.e., Research Study 1286), during the Summer of 1992, cores were obtained only for the District 17 test sections at Bryan, mainly because no signs of stripping had been observed on the various test sections until that time.

Laboratory testing of the field cores plus visual inspection of the sites, in general, did not exhibit any difference between the high air void and low air void sections. Moreover, during the Summer of 1992, it was realized that the air void content of both high and low air void sections had been reduced to about the same level (i.e., no difference between the air voids of these two sections at this stage). Therefore, the coring plan for the final set of cores (which took place during the Spring of 1993) was changed accordingly. A set of nine cores was obtained only from high air void sections for each project to be tested for indirect tensile strength for dry and wet conditioning based on the two methods (Tex-531-C and AASHTO T283).

While these test sections were being evaluated, some results from the SHRP asphalt research regarding mixture susceptibility to moisture damage became available. As part of this research, an environmental conditioning system was used at Oregon State University. The results from this research correlated well with the results from AASHTO Method T283. Therefore, this method (T283) was also included in the testing program for the final set of cores, which were obtained during the Spring of 1993.

The boiling test was extensively investigated during the first and second stages of the study, as explained in Research Reports 441-1 and 441-2F (References 41 and 42). In general, the results from the boiling test did not change with time and with the age of different test sections during the first four years of the study. Therefore, this test was not included as part of the testing program for the final set of cores obtained in the Spring of 1993.

Test Section Condition Surveys

Pavement condition surveys have played an important role in the field evaluation. Condition surveys were scheduled and performed at the test sections by the project personnel during each coring. Pavement deterioration information such as cracking, rutting, raveling, bleeding, and flushing, as well as the amount, severity level, and location, were recorded.

Wet-Dry Indirect Tensile Tests

The testing equipment for the wet-dry indirect tensile strength test included a loading frame, a load cell, and the MTS closed-loop electro-hydraulic system to control loading and deformation rate. For the static test, vertical deformations were monitored by a DC linear variable differential transducer (LVDT) positioned on the upper platen. A loading rate of 2 inches per minute (50 millimeters per minute) was applied at a test temperature of 77°F (25°C). The peak load was obtained by a direct digital readout device.

From each test section, three of the cores were tested dry for the indirect tensile strength. Three others were conditioned according to Test Method Tex 531-C, and then tested for indirect tensile strength. The remaining three cores were conditioned according to the AASHTO T283 method before being tested.

The dry (unconditioned) cores were cured at 77°F (25°C) for at least 24 hours prior to testing. As noted above, three of the cores for each test section were conditioned according to Test Method Tex-531-C. According to this method, they were immersed in distilled water at room temperature, and a partial vacuum of 15 to 17 inches (380 to 432 millimeters) of mercury was applied to achieve approximately a 60 to 80 percent degree of saturation. The saturated cores were placed in a freezer at zero degrees Fahrenheit (–18°C) for 15 hours, and then were taken from the freezer and placed in a 140°F (60°C) water bath for 24 hours. After a complete cycle of freeze-thaw, the wet-conditioned cores were cooled to room temperature in a 77°F (25°C) water bath for approximately three hours prior to testing. The remaining cores were conditioned according to the AASHTO Method T283. This procedure is similar to Test Method Tex-531-C, except that the freezing cycle was eliminated.

It should be noticed that both of these methods are designed for testing laboratory compacted specimens with 7±1 percent air voids. However, the conditioning and testing discussed in this report were performed on field cores, which had air void levels varying within a wide range from 1 to 10 percent.

CHAPTER 3

DISCUSSION OF RESULTS

Condition Survey and Visual Inspection

The test sections were inspected visually when the coring was underway. During the final coring session, pictures were taken of each section for future reference if necessary. The following is a brief description of the visual condition survey of each test section during the last coring session.

District 1 (Bonham)

No sign of stripping was observed on any of the test sections. Transverse cracks were observed about every 40 feet (12 meters) on the test section with Indulin AS-1 antistripping agent. Transverse cracks were 20 to 30 feet (6 to 9 meters) apart on the test sections with ARR-MAZ (Adhere HP) and Lime Slurry. Few transverse cracks were noticed for the control section, the test section with DOW antistripping agent, and the test section treated with Fina-A. The Permatac-Plus and Pavebond Special sections were free from any kind of cracks. The control and the lime slurry sections also exhibited minor longitudinal cracks on the inner wheel path, the latter section more noticeably.

District 6 (Odessa)

Minor cracks were observed in different sections but no sign of stripping could be found.

District 13 (Victoria)

The asphalt layer treated with different antistripping agents was covered with a 0.4-inch (10-millimeter) layer of micro-surfacing nearly a year before final coring. The cores from the test sections indicated that no stripping had occurred in the mixtures containing different antistripping agents, nor had any stripping damage occurred to the control section. However, the asphalt concrete layer under the antistripping layer exhibited significant stripping, probably due to the moisture entrapped in that layer. This phenomenon was observed throughout all the test sections on this project.

District 16 (Odem)

No signs of distress due to stripping were observed for any of the sections treated with antistripping agents or for the control section. Considerable longitudinal cracks were observed on the interior wheel path of the driving lane for the section treated with hydrated lime. The Aquashield section exhibited some longitudinal cracks; however, they were not as severe as those in the lime section. In addition, some transverse cracks were noticed for these two sections. Minor cracks were also observed in other sections but were not serious.

District 17 (Bryan)

The antistripping sections in this district did not exhibit any stripping, either. However, all sections exhibited rutting and cracking to various degrees. The control section contained minor cracks which had already been filled and repaired. The rut depth in some areas of the control section exceeded approximately 0.6 inches (16 millimeters). This section had the worst condition with regard to rutting, but the fewest cracks, when compared with other sections. The BA-2000 section was more severely cracked than other sections. The cracks were mostly longitudinal; however, transverse cracks could also be found. The section treated with Permatac-Plus also exhibited considerable rutting (not as severely as the control section but worse than all other sections). As mentioned before, all cracks had been filled and repaired.

District 19 (DeBerry)

Although no sign of moisture damage was observed on any of the test sections, severe rutting was quite noticeable in all the sections. In most cases, the rut depth was at least 0.5 inches (13 millimeters). While occasional cracks were observed for most of the test sections, the lime section exhibited more of this type of distress.

District 21 (Pharr)

Stripping was not apparent for either the antistripping test sections or the control section, and little rutting was observed. The Permatac and Pavebond Sections exhibited a greater number of cracks than the lime section. The cracks, mostly longitudinal, had been filled and repaired. The sections treated with Fina-B and ARR-MAZ (Adhere HP) antistripping additives had the best general appearance compared to all the other sections.

District 25 (Childress)

The test sections in this district, like all the other districts, did not exhibit noticeable distress due to stripping. The test section with Fina-A indicated some cracks, while the Aquashield section exhibited some minor rutting. Trends of cracking as well as major rutting were noticed for the Unichem section. Rutting and a large number of transverse and longitudinal cracks were observed on the control section.

Air Void Results

As mentioned before, the so-called high and low air void sections are similar. In other words, from the beginning, some of the sections designed as ‘high air void sections’ had air voids close to those of sections designed as 'low air void sections,' and in some cases the opposite was true (low air void sections had high air voids vice versa). However, after several years of exposure to traffic, both sections indicated the same level of air voids, one which was significantly reduced from the original level as a result of densification under traffic. In order to avoid unnecessary duplication while maintaining the ability to perform efficient coring, testing, and data analysis in a timely manner, only the sections designed for 'high air void level' were cored and tested. It was believed that the results also represented the sections designed for 'low air void level.'

Detailed air void values are given in Tables B.1 through B.8 (Appendix B) for individual cores tested for each section. The average values are presented in Table 3.1. It can be noticed that, on the average, the air void content varied between 2 and 5 percent, which is a significant reduction from the average 6 to 11 percent levels observed at the time the test sections were constructed. Most of the reduction in the air void levels had occurred during the first six months after construction. The air void levels, six months after construction, were low enough to restrict considerable moisture penetration. This prevention probably contributed to the better resistance of the pavement to stripping.

Comparison of air void contents from the most recent coring (6- to 7-year-old pavements) with those from 2-, 3-, or 4-year-old cores (Table 3.1) indicated that the changes in the air void levels were not significant. In some cases, the air voids from the last set of cores were about 1 percent higher than previous values. This difference could be a result of normal variation and the fact that some cores were closer to the center of the wheel path than others. The air void levels of the three cores taken at the same location, with a distance of about 12 inches (0.3 meters) between the cores, were very close (within 1 percent difference).

Indirect Tensile Strength Results

Once the dimensions and densities of the cores were measured, they were dried overnight before being processed for testing. The cores were tested either dry or wet-conditioned. The conditioning was done according to both Test Methods Tex-531-C (with a freeze cycle) and AASHTO T283 (without a freeze cycle). The results are shown in Tables B.1 through B.8 (Appendix B). Because the air void levels of the three cores taken at the same location were very close, these cores were included in one set to be tested for indirect tensile strength. This way, a total of three sets of cores were available for each test section. The first core was tested dry. The second core of the set was tested wet after being conditioned according to Test Method AASHTO T283. The last core of the set was tested wet after being conditioned according to Test Method Tex-531-C; then, for each set, the two tensile strength values obtained from the two conditioned specimens were divided by the tensile strength of the dry specimen to obtain TSR values. The

TABLE 3.1. COMPARISON OF PAVEMENT AIR VOIDS MEASURED AT TWO DIFFERENT AGES

District →	1	1	6	6	13	13	16	16	17	17	19	19	21	21	25	25
Age, Mo. →	24	72	36	78	36	80	36	80	48	82	24	68	24	66	36	72
Additive ↓					The following are the average air voids											
Control	5.3	5.8	7.5	6.9	2.3	3.8	3.6	5.3	2.3	3.5	4.4	2.0	2.4	2.2	3.6	3.0
Lime	3.0	4.3	7.1	5.8	1.6	2.7	2.8	4.8	1.9	1.2	3.3	2.8	4.0	3.8	2.8	3.9
ARR-MAZ (Reg)											2.6	2.4				
ARR-MAZ (HP)	3.8	4.8											1.8	2.9		
Aquashield							4.7	7.2								
Aquashield II											5.0	3.0	1.4	2.0	2.1	4.9
BA 2000					1.8	3.8			4.0	4.6	3.5	1.4				
DOW	5.1	5.7					5.9	6.6					4.9	4.8		
Fina A	3.5	4.6													2.3	3.9
Fina B													1.0	1.3		
Indulin AS-1	4.2	5.5														
Pavebond LP			5.2	5.4			3.9	5.9					2.7	2.5		
Pavebond Spcia	3.5	5.1														
Perma-Tac			5.8	4.4							4.0	1.5	3.2	3.5	1.4	3.7
Perma-Tac Plus	4.8	4.9			1.8	1.9			3.5	4.3						
Unichem 8150			5.5	6.0											2.5	2.8
Average →	4.2	5.1	6.2	5.7	1.9	3.1	4.2	6.0	2.9	3.4	3.8	2.2	2.7	2.9	2.5	3.7

results are shown in Tables B.1 through B.8. The results of testing performed by personnel of the Materials and Tests Division of TxDOT are presented in Table B.9 (Appendix B).

Dry Strength and TSR Results

Obviously, asphalt pavement properties significantly change with time due to the influence of climatic factors (temperature changes and precipitation) and traffic. The asphalt becomes stiffer due to the effects of densification and aging. At the same time, the development of hydrostatic pressures inside the pavement, due to the presence of traffic and sufficient moisture, tends to reduce the adhesion between the asphalt and aggregate and promote disintegration of the pavement. The disintegrating and stripping effects tend to reduce the tensile strength. However, aging and densification tend to increase this property. Therefore, the indirect tensile strength measured in the laboratory is a function of aging, air voids, and stripping effects. If the effect of air voids and aging on tensile strength could have been eliminated, measuring the tensile strength of dry cores and observing its variations with pavement age could have been used as a direct way of evaluating the stripping effect on the pavement after several years of exposure to moisture and traffic. The air voids have been measured at each stage, and the results can be somewhat modified for the effect of the air voids. However, the effect of other variables such as aging has *not* been measured, and the results cannot be modified for that effect. Therefore, dry strength results alone could not be used to determine the intensity of the stripping effect on the pavement during the past several years. However, the effect of such variables is minimized by using a normalized indirect tensile strength such as TSR, which is obtained by dividing the indirect tensile strength of the wet-conditioned specimen by the indirect tensile strength of the dry specimen.

The scatter plots provided in Figures B.1 through B.4 (Appendix B) exhibit the variation of tensile strength as a function of air voids for different conditioning systems for the last set of cores. A clear trend of reduction in tensile strength with increasing air voids can be observed for Districts 1, 6, and 21. For these three districts, it can be seen that the reduction in tensile strength with increasing air voids is, to some extent, more severe for conditioned specimens compared with dry specimens. For other districts, the trend is not very clear and a very wide scatter is observed.

The scatter plots in Figures B.5 through B.8 (Appendix B) indicate the relationship between the tensile strength ratio and the air voids for the two conditioning methods used. One would expect to obtain a lower ratio for specimens with higher air voids, since the action of water will be more severe during the conditioning phase. However, such a trend cannot be clearly observed except in a few cases, probably because the influences of a number of other factors are not taken into account.

The bar charts in Figures B.9 through B.16 (Appendix B) indicate how the tensile strength ratios determined for the final set of cores compare with two previous measurements for different antistripping agents and for different districts. In these figures, the bar labeled 'A' indicates the average TSR value from the last set of cores tested during Research Project 441. The bars labeled 'B' and 'C' indicate, respectively, the average TSR values from the cores tested by TxDOT personnel in 1991 and from the final set of cores obtained in this study. The charts for Districts 17 and 19 include only 'A' and 'C' bars because cores were not obtained for these districts in 1991. The horizontal dashed line in these figures indicates a TSR value of unity. It can be seen that, in most cases, the TSR value does not exceed one. However, in a few cases, TSR values greater than one were obtained. This kind of behavior has been observed in other studies as well. Comparison of the recent TSR values with the previous values indicates that in some cases the values have been reduced, while in other cases they have been increased or have not changed. No consistent pattern could be found for changes of TSR values with time. In general, it can be seen that TSR values for antistripping test sections are either equal to or higher than the values for the control section.

Some of the TSR values obtained from the cores when the pavement was two to four years old were under 0.6. Even those sections with such low TSR values did not exhibit any noticeable stripping problem during the time the last visual condition survey took place. At this time, the pavements were about four to six years old. For example, the TSR values for control, DOW, and Permatac-Plus sections in District 1 were measured to be under 0.5 at 42-month and 72-month pavement ages. However, none of these sections exhibited more stripping than other sections which had considerably higher TSR values.

The TSR values for both Test Methods AASHTO T283 (without freeze cycle) and Tex-531-C (with freeze cycle) are given in Tables B.1 through B.8 (Appendix B). One expects to see lower TSR values for the latter method compared to those for the former because of the additional freeze cycle. This is generally the case for Districts 6, 13, 16, and 25. However, for Districts 19 and 21, the TSR values from Test Method T283 with no freeze cycle are generally lower than the values obtained from Test Method Tex-531-C . For District 1, no consistent pattern exists when the TSR values of the two methods are compared. It is not clear why the behavior is so different at this point.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions are drawn based on the results presented in this report.

1. The visual inspection and condition survey of the test sections in this study indicated no evidence of stripping damage, although other types of distress, such as severe cracking and permanent deformation, could be observed in some of the test sections.

2. The test sections in District 13 were the only ones showing severe stripping in the underlying layer (i.e., the untreated layer under the test layer treated with antistripping agent). This damage is probably due to the entrapped moisture in the layer.

3. With regard to stripping, no difference was noticed between the test sections which had given TSR values less than 70 percent with those having TSR values greater than 70 percent.

4. While in some cases a significant reduction was noticed in the TSR values of the recent cores (i.e., the final set of cores) compared with those of the previous cores, in other cases the differences were not significant at all, or the TSR values from previous coring were even larger. In general, no consistent behavior was observed in the change of TSR values with time.

5. In some cases, TSR values greater than unity were found, implying that the conditioned specimens proved to have a higher tensile strength than the dry specimens.

6. In general, no significant improvement was observed in the moisture resistance behavior of the sections treated with different antistripping agents when compared with untreated sections. However, none of the antistripping additives indicated a tendency to increase the potential for moisture damage.

7. It is feasible that moisture damage may occur on these test sections with time. However, significant damage is doubtful as long as the pavements maintain their present condition of low air voids, which in turn restricts the ingress of moisture, even though some stripping may initiate from the surface under the action of moisture and traffic.

Recommendations

The following recommendations are made based on the results presented in this report.

1. The present study indicates that, with regard to moisture damage, the control sections performed as well as the sections treated with antistripping agents. Therefore, it seems that the selection of proper aggregates and proper construction practice, specifically achieving true desired air void levels, can be tantamount to treating the mix with the antistripping agents.

2. The test sections might exhibit moisture damage in the future. It is recommended that they be monitored yearly until such time as it becomes necessary to overlay them because of other types of distress.

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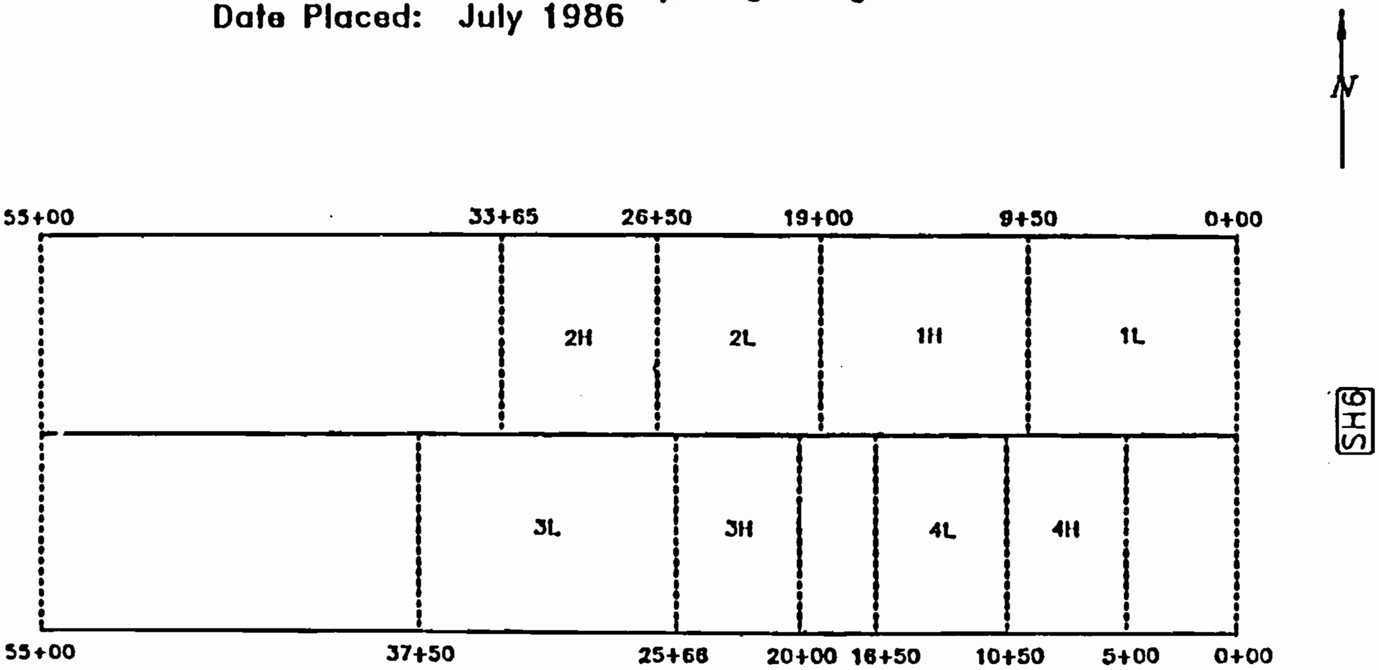
APPENDIX A

TEST SECTION LAYOUTS FOR THE FIELD TEST PROJECTS

District 17 — CTR Research Project #441
FM485 — Robertson County, Beginning @ SH6
Date Placed: July 1986



1 — Control
2 — 1.0% BA2000
3 — 1.0% Perma-Tac Plus
4 — 1.5% Lime Slurry

Note: L — Low Air Voids
H — High Air Voids
ADT = 2,000

Figure A.1. Location and field test sections layout for District 17

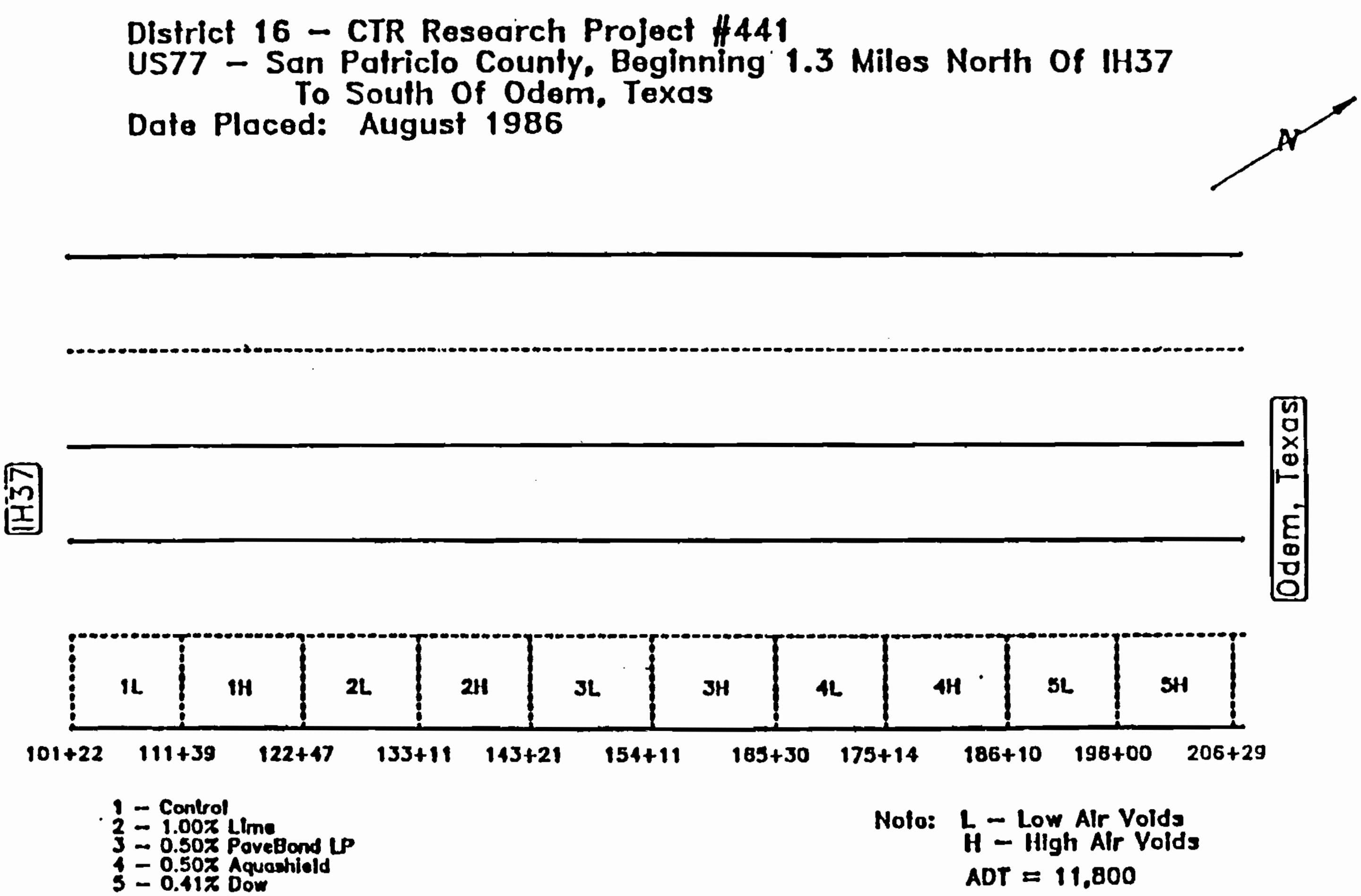


Figure A.2. Location and field test sections layout for District 16

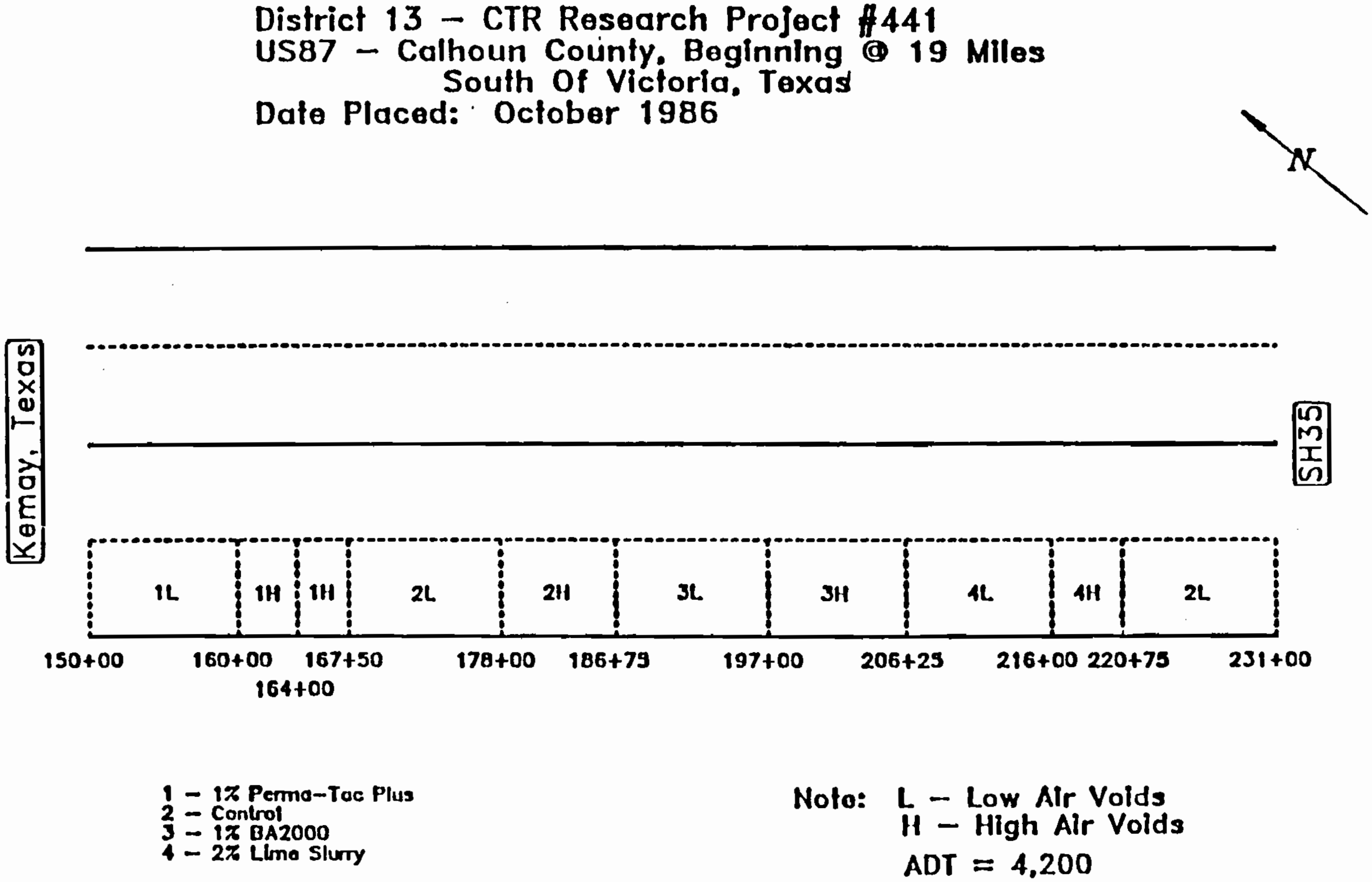
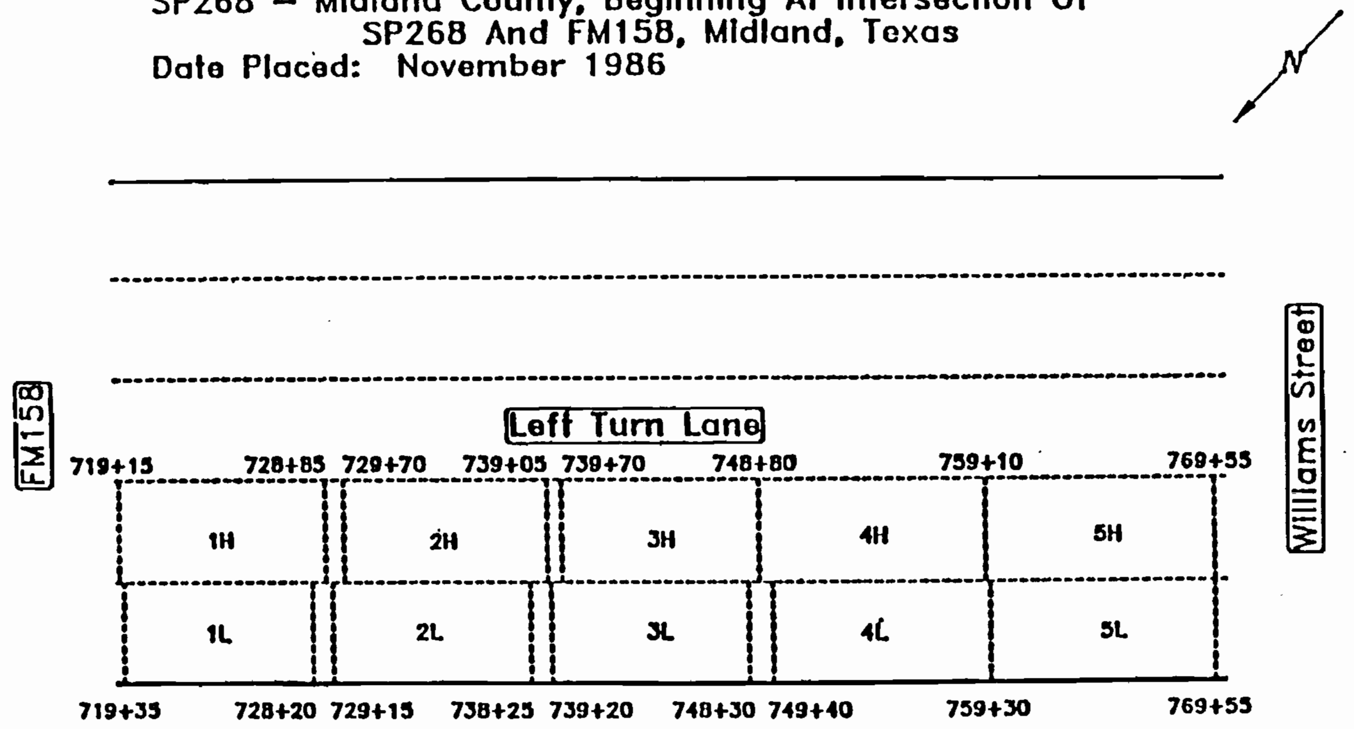


Figure A.3. Location and field test sections layout for District 13

District 6 — CTR Research Project #441
SP268 — Midland County, Beginning At Intersection Of
SP268 And FM158, Midland, Texas
Date Placed: November 1986



1 — 1% Perma-Tac
2 — 1% Unichem 8150
3 — 1% PaveBond LP
4 — Control
5 — 1% Lime Slurry

Note: L — Low Air Voids
H — High Air Voids
ADT = 13,900

Figure A.4. Location and field test sections layout for District 6

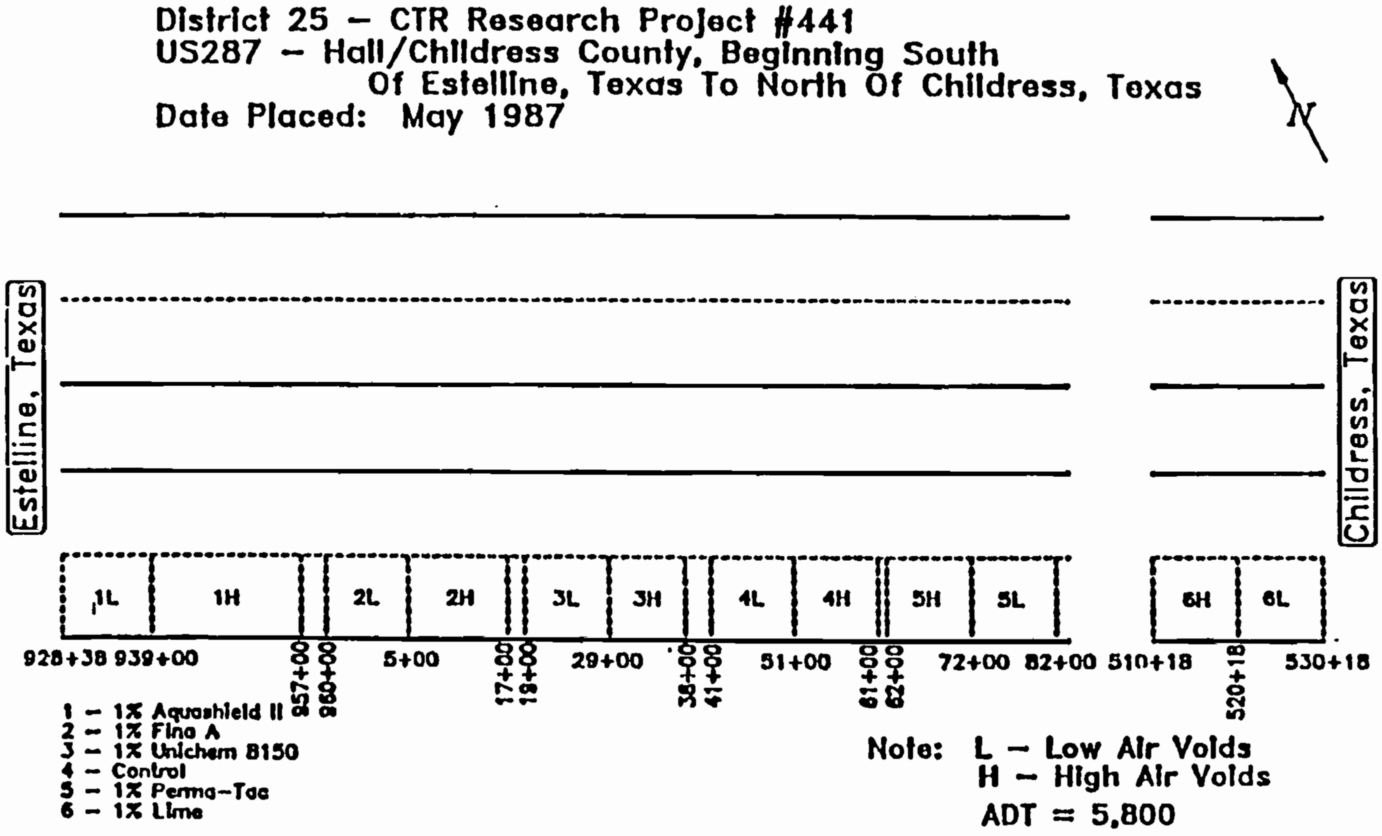
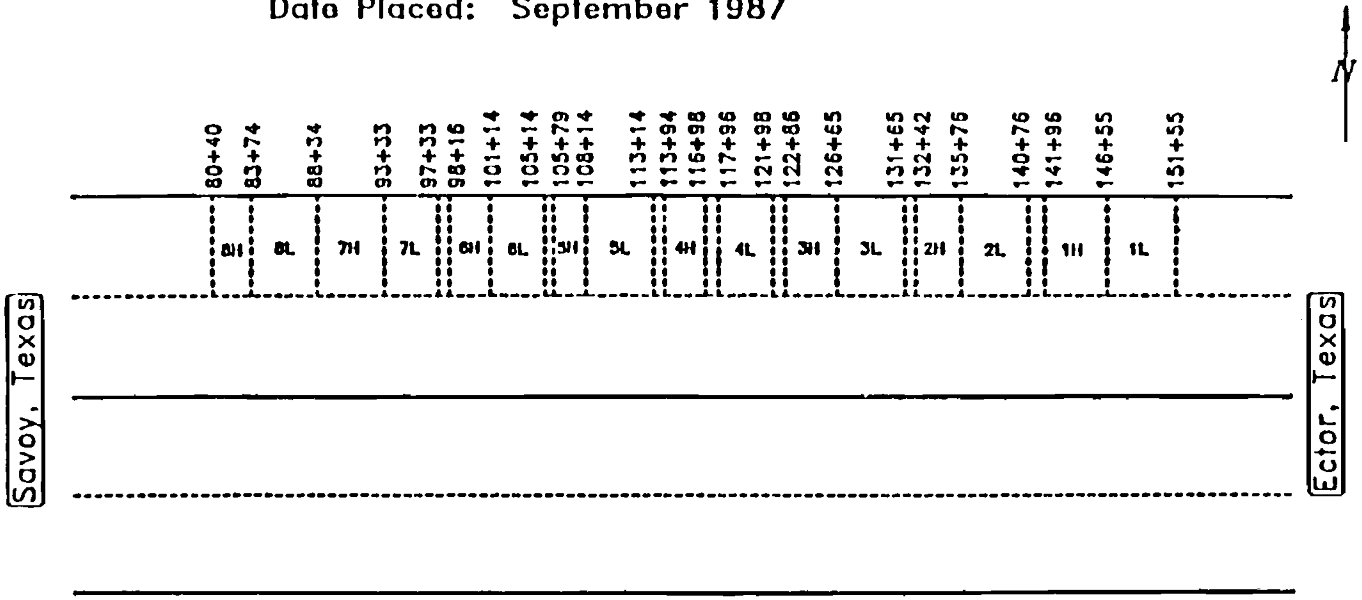


Figure A.5. Location and field test sections layout for District 25

District 1 – CTR Research Project #441
US82 – Fannin County, Beginning @ 6 Miles West
Of Bonham, Texas To Savoy, Texas
Date Placed: September 1987



1 – Control
2 – 1.00% Perma-Tac Plus
3 – 1.00% PaveBond Special
4L – 0.45% Dow
4H – 0.18% Dow
5 – 1.00% Fina A
6 – 1.00% Indulin AS-1
7 – 0.75% Adhere HP
8 – 1.50% Lime Slurry

Note: L – Low Air Voids
H – High Air Voids
ADT = 5,000

Figure A.6. Location and field test sections layout for District 1

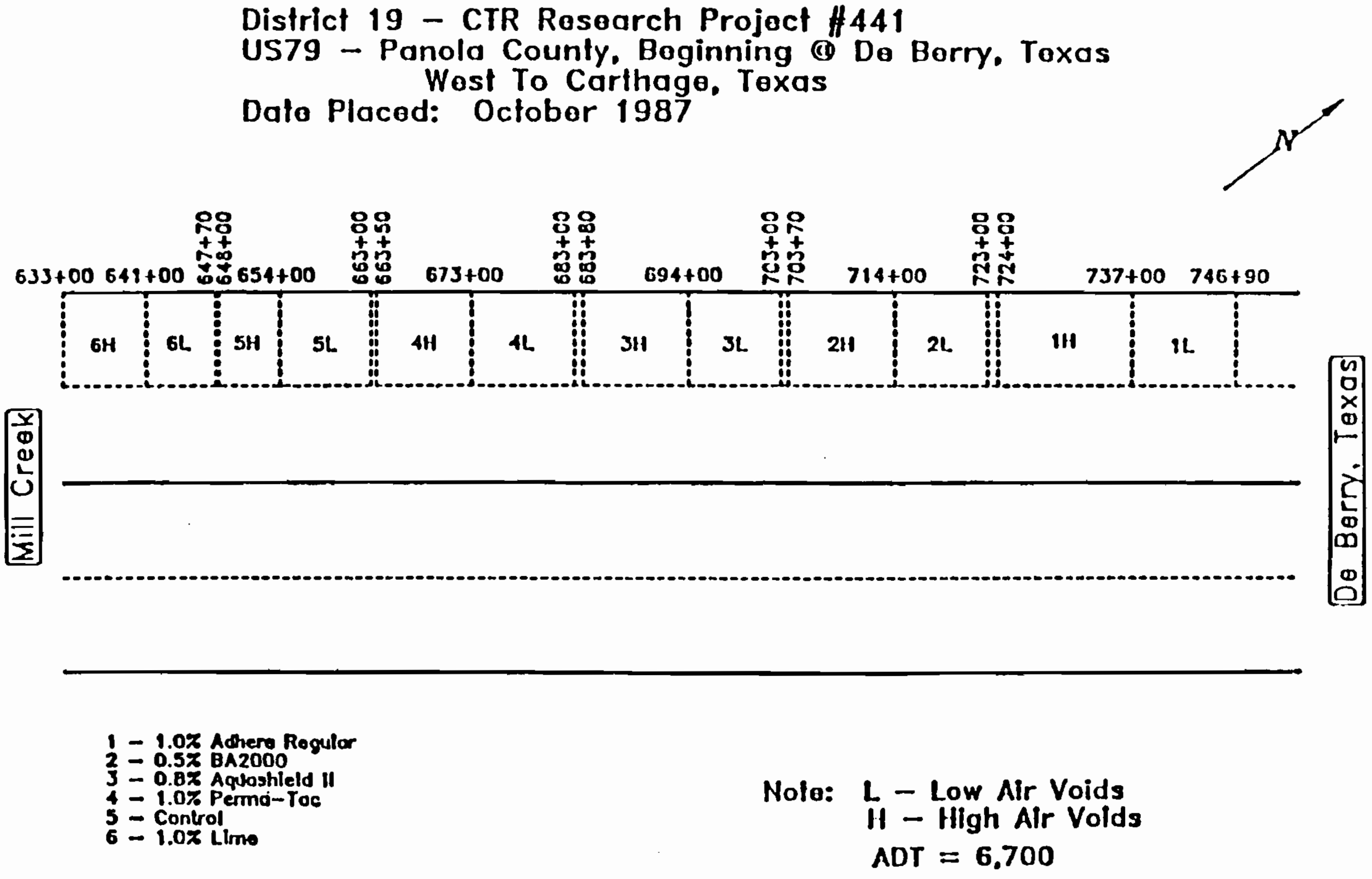


Figure A.7. Location and field test sections layout for District 19

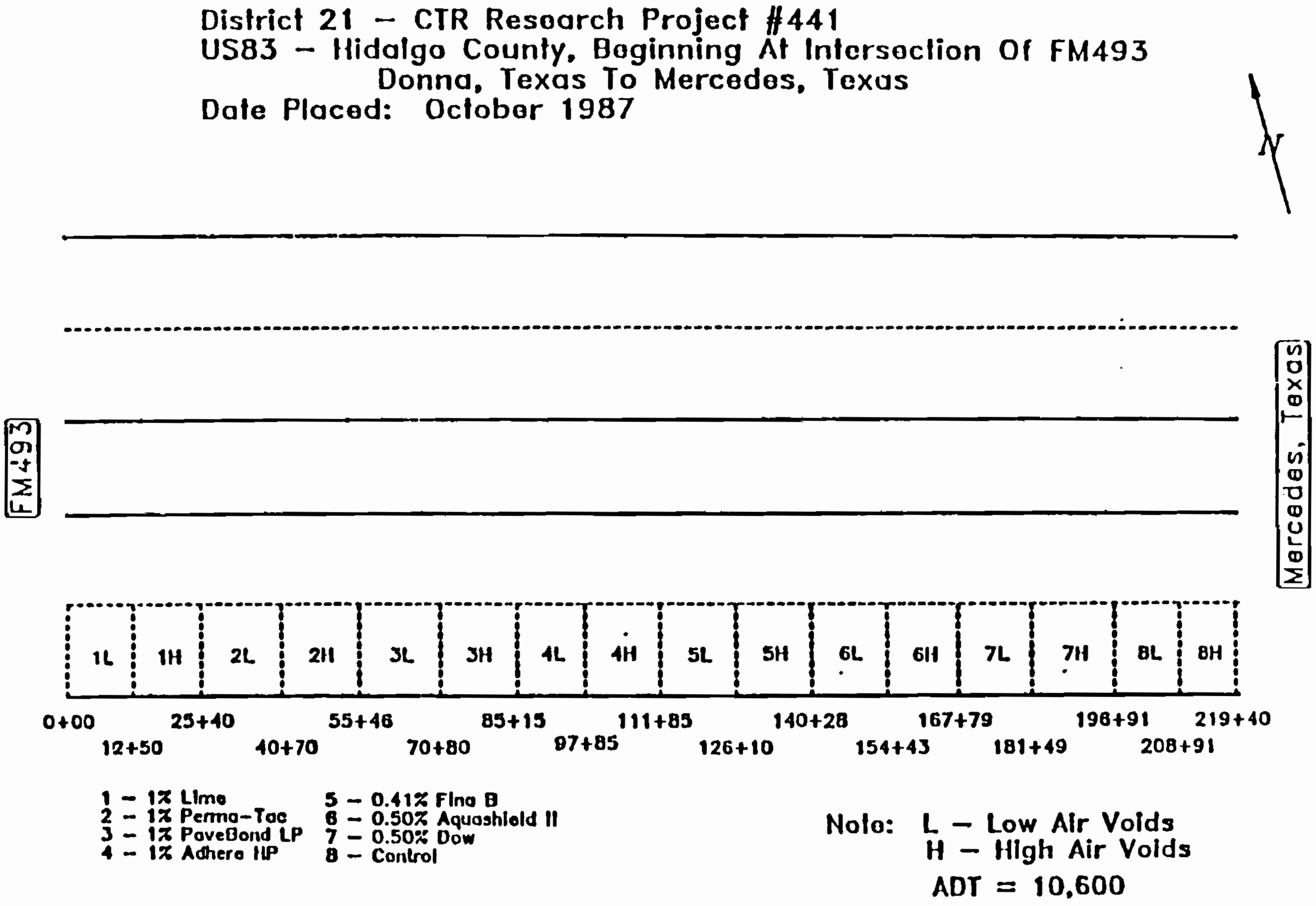


Figure A.8. Location and field test sections layout for District 21

APPENDIX B

FIGURES AND TABLES PRESENTING LABORATORY TEST RESULTS

TABLE B.1. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 82, DISTRICT 1

Table B.1. Indirect Tensile Strength Results for Field Cores of US 82, District 1
Pavement Age = 72 Months Cored on 5/19/93

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Stmgt PSI	TSR T283	TSR TX531
Control	1-1C	1.266	523.3	287.8	6.4	Dry	946	117		
	1-1B	1.703	765.9	423.8	5.7	T283	564	52	0.44	0.38
	1-1A	1.565	685.6	381.0	5.2	TX53	445	44		
Rice	1-2C	1.682	731.3	404.5	5.7	Dry	1421	132		
Sp. Gr.	1-2A	1.393	598.5	331.4	5.6	T283	459	51	0.39	0.31
2.374	1-2B	1.346	564.8	310.1	6.6	TX53	347	40		
	1-3B	1.185	517.8	288.2	5.0	Dry	1219	160		
	1-3C	1.268	540.3	299.1	5.6	T283	372	46	0.29	0.39
	1-3A	1.193	505.3	278.0	6.4	TX53	475	62		
Average		**1.400**			**5.8**				**0.37**	**0.36**
PermaTac	2-1A	1.478	626.7	347.4	5.8	Dry	1437	152		
Plus	2-1C	1.582	692.2	384.6	5.5	T283	628	62	0.41	0.46
	2-1B	1.322	575.5	322.7	4.4	TX53	586	69		
RICE	2-2A	1.505	655.2	362.6	6.0	Dry	1540	160		
Sp. Gr.	2-2B	1.580	700.0	392.6	4.4	T283	621	61	0.38	0.36
2.381	2-2C	1.585	695.2	387.8	5.0	TX53	585	58		
	2-3A	1.453	629.6	352.3	4.6	Dry	1486	160		
	2-3B	1.761	775.3	433.2	4.8	T283	711	63	0.39	0.40
	2-3C	1.479	661.3	372.0	4.0	TX53	602	63		
Average		**1.527**			**4.9**				**0.40**	**0.40**
PaveBond	3-1A	1.198	519.8	287.6	5.2	Dry	954	124		
Special	3-1C	1.435	620.2	343.2	5.2	T283	875	95	0.77	0.79
	3-1B	1.524	658.1	365.1	4.9	TX53	960	98		
RICE	3-2A	1.456	632.4	349.8	5.3	Dry	1194	128		
Sp. Gr.	3-2B	1.400	657.4	365.8	4.6	T283	948	106	0.83	0.70
2.362	3-2C	1.548	665.6	366.6	5.8	TX53	889	90		
	3-3B	1.238	532.2	295.0	5.0	Dry	1018	128		
	3-3C	1.566	686.5	383.5	4.1	T283	763	76	0.59	0.67
	3-3A	1.648	712.7	393.5	5.5	TX53	913	86		
Average		**1.446**			**5.1**				**0.73**	**0.72**
Dow	4-1C	1.604	694.1	383.5	5.9	Dry	1434	139		
	4-1A	1.676	728.5	405.0	5.2	T283	494	46	0.33	0.27
	4-1B	1.565	671.8	372.7	5.4	TX53	374	37		
RICE	4-2A	1.507	632.6	347.5	6.6	Dry	1168	121		
Sp. Gr.	4-2C	1.651	726.6	402.8	5.5	T283	760	72	0.59	0.32
2.375	4-2B	1.465	633.9	353.1	4.9	TX53	365	39		
	4-3B	1.541	656.5	363.7	5.6	Dry	1342	136		
	4-3A	1.525	646.6	357.3	5.9	T283	664	68	0.50	0.35
	4-3C	1.480	616.2	339.7	6.2	TX53	450	47		
Average		**1.557**			**5.7**				**0.47**	**0.31**
Fina A	5-1B	1.563	696.1	388.4	4.1	Dry	1364	136		
	5-1A	1.741	754.6	418.3	4.9	T283	1067	96	0.70	0.90
	5-1C	1.698	747.2	415.6	4.5	TX53	1335	123		
RICE	5-2B	1.748	776.4	431.2	4.7	Dry	1477	132		
Sp. Gr.	5-2A	1.707	764.8	426.9	4.1	T283	1311	120	0.91	0.78
2.360	5-2C	1.551	668.0	369.9	5.0	TX53	1024	103		
	5-3A	1.674	732.3	407.2	4.6	Dry	1464	136		
	5-3B	1.760	761.4	423.2	4.6	T283	1256	111	0.82	0.87
	5-3C	1.716	757.8	420.6	4.8	TX53	1305	119		
Average		**1.684**			**4.6**				**0.81**	**0.85**

TABLE B.1. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 82, DISTRICT 1 (Continued)

Table B.1. Indirect Tensile Strength Results for Field Cores of US 82, District 1
Pavement Age = 72 Months Cored on 5/19/93 (Cont'd)

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Strngt PSI	TSR T283	TSR TX531
Indulin	6-1A	1.583	696.3	387.6	4.8	Dry	1405	138		
AS-1	6-1B	1.790	790.5	440.3	4.7	T283	916	80	0.58	0.53
	6-1C	1.835	808.3	448.2	5.2	TX53	861	73		
RICE	6-2C	1.655	710.2	391.0	6.1	Dry	1220	115		
Sp. Gr.	6-2B	1.866	809.0	444.7	6.3	T283	1067	89	0.78	0.59
2.369	6-2A	1.764	759.3	419.7	5.6	TX53	771	68		
	6-3C	1.606	687.7	379.9	5.7	Dry	825	80		
	6-3B	1.895	783.6	431.9	6.0	T283	952	78	0.98	0.81
	6-3A	1.659	726.9	404.7	4.8	TX53	691	65		
Average		**1.739**			**5.5**				**0.78**	**0.64**
ARR-MAZ	7-1C	1.917	851.0	473.3	5.3	Dry	1459	119		
Adhere HP	7-1A	1.824	828.7	467.8	3.5	T283	1707	146	1.23	0.80
	7-1B	1.854	820.3	455.6	5.5	TX53	1124	95		
RICE	7-2B	1.734	770.4	430.1	4.8	Dry	1472	132		
Sp. Gr.	7-2C	1.791	800.8	445.0	5.4	T283	1012	88	0.67	0.79
2.379	7-2A	1.868	835.5	466.3	4.9	TX53	1247	104		
	7-3A	1.678	743.3	413.9	5.1	Dry	1507	140		
	7-3B	1.778	813.4	458.8	3.6	T283	1100	97	0.69	0.66
	7-3C	1.751	777.0	431.8	5.4	TX53	1042	93		
Average		**1.799**			**4.8**				**0.86**	**0.75**
Lime Slurr	8-1C	1.596	690.4	380.2	6.0	Dry	1291	126		
	8-1B	1.714	748.3	411.9	6.0	T283	1001	91	0.72	1.12
	8-1A	1.685	749.2	416.7	4.8	TX53	1521	141		
RICE	8-2A	1.781	798.0	459.3	0.5	Dry	1966	172		
Sp. Gr.	8-2C	1.698	736.4	407.2	5.5	T283	1157	106	0.62	1.20
2.367	8-2B	1.650	744.4	421.1	2.7	TX53	2190	207		
	8-3B	1.550	681.2	378.1	5.1	Dry	1724	174		
	8-3A	1.703	751.1	416.7	5.1	T283	1017	93	0.54	0.91
	8-3C	1.602	720.9	405.6	3.4	TX53	1616	157		
Average		**1.664**			**4.3**				**0.63**	**1.08**

1 PSI = 6,895 Pascal *1 inch = 2.54 cm* *1 pound = 0.454 kg*

TABLE B.2. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF SH 268, DISTRICT 6

Table B.2. Indirect Tensile Strength Results for Field Cores of SP268, District 6
Pavement Age = 78 Months Cored on 5/25/93

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Stmgt PSI	TSR T283	TSR TX531
Permtac	1-A	1.724	742.5	409.0	4.5	Dry	2249	204		
	1-B	1.738	764.0	422.1	4.1	T283	2192	197	0.97	0.91
	1-C	1.810	795.9	437.2	4.8	TX53	2158	186		
Rice	1-E	2.166	955.4	521.6	5.5	Dry	2638	190		
Sp. Gr.	1-D	1.858	797.7	434.2	5.9	T283	1885	158	0.83	0.80
2.331	1-F	1.962	854.4	467.6	5.2	TX53	1922	153		
	1-J	2.100	933.5	518.7	3.5	Dry	2836	211		
	1-H	2.192	989.9	550.6	3.3	T283	3265	232	1.10	0.97
	1-G	2.096	943.2	525.5	3.1	TX53	2734	203		
Average		**1.961**			**4.4**				**0.97**	**0.89**
UniChem	2-B	1.721	752.3	416.9	4.0	Dry	2287	207		
8150	2-A	1.608	707.3	391.8	4.0	T283	2451	238	1.15	1.01
	2-C	1.572	689.0	380.2	4.5	TX53	2118	210		
RICE	2-D	1.622	667.4	355.3	8.5	Dry	1572	151		
Sp. Gr.	2-E	1.571	635.3	336.1	9.1	T283	961	95	0.63	0.69
2.336	2-F	1.567	646.8	346.1	7.9	TX53	1042	104		
	2-G	1.708	737.4	401.3	6.1	Dry	2033	186		
	2-J	1.703	742.4	408.1	4.9	T283	2285	209	1.13	0.94
	2-H	1.823	789.9	432.6	5.4	TX53	2038	174		
Average		**1.655**			**6.0**				**0.97**	**0.88**
PaveBon	3-B	1.926	827.7	448.7	6.0	Dry	2310	187		
LP	3-C	1.755	741.8	401.7	6.1	T283	2001	178	0.95	0.81
	3-A	1.612	686.3	372.1	6.0	TX53	1565	151		
RICE	3-E	1.809	798.3	439.0	4.4	Dry	2420	209		
Sp. Gr.	3-F	1.972	884.9	490.9	3.3	T283	3201	253	1.21	0.99
2.323	3-D	1.828	801.8	440.8	4.4	TX53	2419	206		
	3-H	1.827	779.6	422.6	6.0	Dry	2039	174		
	3-G	1.885	810.7	438.2	6.3	T283	1701	141	0.81	0.78
	3-J	1.882	800.5	434.3	5.9	TX53	1634	135		
Average		**1.833**			**5.4**				**0.99**	**0.86**
Control	4-C	2.113	899.9	487.1	6.6	Dry	2079	153		
	4-A	2.011	880.6	479.3	5.9	T283	2306	179	1.17	0.83
	4-B	2.061	877.6	477.0	6.1	TX53	1689	128		
RICE	4-F	1.905	806.2	430.2	8.1	Dry	1846	151		
Sp. Gr.	4-D	1.860	808.8	442.0	5.5	T283	1663	139	0.92	0.64
2.333	4-E	1.820	784.6	424.0	6.7	TX53	1131	97		
	4-H	1.851	785.7	420.1	7.9	Dry	2017	170		
	4-G	1.797	753.4	403.3	7.8	T283	1291	112	0.66	0.45
	4-J	1.962	839.4	449.0	7.8	TX53	968	77		
Average		**1.931**			**6.9**				**0.92**	**0.64**
Lime	5-A	2.114	903.5	488.2	6.9	Dry	2460	182		
Slurry	5-B	2.070	899.4	489.2	6.1	T283	2152	162	0.89	0.57
	5-C	2.187	953.7	516.5	6.6	TX53	1459	104		
RICE	5-E	1.933	844.8	462.5	5.4	Dry	2504	202		
Sp. Gr.	5-D	1.971	842.5	459.0	6.0	T283	2211	175	0.87	0.99
2.336	5-F	2.000	890.8	488.4	5.2	TX53	2556	199		
	5-G	1.754	757.2	414.0	5.6	Dry	2239	199		
	5-J	1.805	790.6	432.4	5.5	T283	2282	197	0.99	0.84
	5-H	1.775	773.6	423.9	5.3	TX53	1896	167		
Average		**1.957**			**5.8**				**0.92**	**0.80**

1 PSI = 6,895 Pascal *1 inch = 2.54 cm* *1 pound = 0.454 kg*

TABLE B.3. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 87, DISTRICT 13

Table B.3. Indirect Tensile Strength Results for Field Cores of US 87, District 13
Pavement Age = 80 Months Cored on 5/4/93

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Wat	Air Void %	Cond-ition	Pult lbs.	Tensile Strngt PSI	TSR T283	TSR TX531
PermaTac	1-1C	1.418	662.5	387.6	1.2	Dry	1527	168	1.08	1.13
Plus	1-1B	1.581	714.8	414.0	2.6	T283	1836	181		
	1-1A	1.536	717.8	417.4	2.1	TX53	1872	190		
Rice	1-2C	1.437	680.8	398.8	1.1	Dry	1535	167	1.12	1.20
Sp. Gr.	1-2A	1.741	804.5	464.6	3.0	T283	2089	187		
2.440	1-2B	1.450	681.8	399.0	1.2	TX53	1853	199		
	1-3B	1.225	625.9	364.8	1.8	Dry	1587	202	1.08	0.98
	1-3A	1.357	635.9	370.0	2.0	T283	1897	218		
	1-3C	1.458	678.5	393.5	2.4	TX53	1847	198		
Average		**1.467**			**1.9**				**1.09**	**1.10**
Control	2-1B	1.355	625.5	362.8	2.4	Dry	1811	208	0.53	0.60
	2-1A	1.476	690.6	399.0	2.9	T283	1040	110		
	2-1C	1.906	857.1	484.5	5.7	TX53	1538	126		
RICE	2-2B	1.602	734.8	422.8	3.4	Dry	1286	125	0.62	0.80
Sp. Gr.	2-2A	1.487	685.5	395.7	3.0	T283	738	77		
2.439	2-2C	1.334	614.9	358.1	1.8	TX53	856	100		
	2-3A	1.506	666.2	377.3	5.5	Dry	891	92	1.75	0.73
	2-3C	1.444	634.1	358.6	5.6	T283	1494	161		
	2-3B	1.238	560.3	322.2	3.5	TX53	536	68		
Average		**1.483**			**3.8**				**0.96**	**0.71**
BA2000	3-1B	1.260	574.2	326.2	5.0	Dry	1357	168	1.11	1.11
	3-1C	1.340	593.2	336.6	5.1	T283	1603	187		
	3-1A	1.380	603.0	334.6	7.8	TX53	1656	187		
RICE	3-2B	1.342	630.3	366.0	2.1	Dry	1475	171	1.02	1.19
Sp. Gr.	3-2A	1.624	744.2	426.5	3.8	T283	1827	176		
2.436	3-2C	1.445	673.9	389.0	2.9	TX53	1888	204		
	3-3B	1.367	642.6	370.2	3.2	Dry	1779	203	0.83	1.22
	3-3C	1.363	637.4	367.7	3.0	T283	1480	169		
	3-3A	1.229	588.0	343.0	1.5	TX53	1956	248		
Average		**1.372**			**3.8**				**0.99**	**1.18**
Lime	4-1B	1.234	586.0	342.2	1.1	Dry	1131	143	1.34	1.27
	4-1A	1.364	648.8	379.6	0.8	T283	1673	191		
	4-1C	1.428	661.4	377.3	4.2	TX53	1663	182		
RICE	4-2A	1.185	550.9	318.5	2.4	Dry	1043	137	1.45	1.34
Sp. Gr.	4-2B	1.292	604.0	346.6	3.4	T283	1645	199		
2.430	4-2C	1.334	616.7	354.3	3.3	TX53	1579	185		
	4-3B	1.391	655.7	380.5	1.9	Dry	1311	147	1.22	1.09
	4-3A	1.368	635.6	367.3	2.5	T283	1579	180		
	4-3C	1.512	692.7	395.0	4.2	TX53	1553	160		
Average		**1.345**			**2.7**				**1.34**	**1.24**

1 PSI = 6,895 Pascal *1 inch = 2.54 cm* *1 pound = 0.454 kg*

TABLE B.4. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 77, DISTRICT 16

Table B.4. Indirect Tensile Strength Results for Field Cores of US 77, District 16
Pavement Age = 80 Months

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Strngt PSI	TSR T283	TSR TX531
Control	1-1A	1.030	663.0	371.7	6.1	Dry	1198	181	0.59	0.49
	1-1B	1.005	652.5	367.5	5.5	T283	689	107		
	1-2A	1.758	783.0	446.5	4.0	TX53	996	88		
Rice	1-5B	1.476	639.9	361.0	5.3	Dry	919	97	0.91	1.54
Sp. Gr.	1-3A	1.740	772.4	435.5	5.4	T283	991	89		
2.424	1-3B	1.717	772.9	437.6	4.9	TX53	1642	149		
	1-4B	1.673	746.9	422.0	5.2	Dry	1294	121	0.67	0.59
	1-5A	1.504	661.1	370.0	6.3	T283	779	81		
	1-4A	1.692	743.3	421.0	4.9	TX53	766	71		
Average		**1.511**			**5.3**				**0.72**	**0.87**
Lime	2-1A	1.622	719.1	410.3	3.7	Dry	2036	196	0.68	0.32
	2-2A	1.522	674.5	382.7	4.4	T283	1291	132		
	2-3A	1.961	885.6	503.2	4.2	TX53	794	63		
RICE	2-2B	1.545	683.2	387.6	4.4	Dry	1885	190	0.76	0.48
Sp. Gr.	2-4A	1.774	789.8	447.2	4.7	T283	1653	145		
2.418	2-3B	1.940	852.5	480.0	5.4	TX53	1147	92		
	2-5A	1.437	640.9	358.6	6.1	Dry	1721	187	0.65	0.70
	2-5B	1.334	634.8	355.8	5.9	T283	1046	122		
	2-4B	1.735	772.9	437.6	4.7	TX53	1446	130		
Average		**1.652**			**4.8**				**0.70**	**0.50**
PaveBond	3-1B	1.476	695.3	390.5	6.4	Dry	1068	113	1.19	0.41
LP	3-1A	1.578	705.2	397.9	5.9	T283	1354	134		
	3-2B	1.257	601.7	338.4	6.3	TX53	369	46		
RICE	3-2A	1.264	614.0	347.9	5.4	Dry	946	117	0.77	0.56
Sp. Gr.	3-3B	1.336	595.6	336.5	5.7	T283	768	90		
2.438	3-3A	1.268	576.3	327.5	5.0	TX53	531	65		
	3-5A	1.323	586.8	332.7	5.3	Dry	1412	166	0.50	0.36
	3-4B	1.780	781.7	437.7	6.8	T283	954	84		
	3-4A	1.797	797.0	446.4	6.8	TX53	684	59		
Average		**1.453**			**5.9**				**0.82**	**0.44**
Aqushield	4-1B	1.744	760.0	425.4	7.6	Dry	1169	105	0.89	0.78
	4-1A	1.742	769.9	430.1	7.9	T283	1037	93		
	4-3B	1.550	648.5	361.5	8.1	TX53	807	81		
RICE	4-2A	1.510	690.0	393.4	5.4	Dry	1728	179	0.87	0.55
Sp. Gr.	4-2B	1.516	699.0	398.0	5.6	T283	1511	155		
2.459	4-4B	1.660	728.9	410.2	7.0	TX53	1036	97		
	4-5A	1.696	728.5	409.5	7.1	Dry	1551	143	0.25	0.68
	4-3A	1.270	492.2	272.0	9.1	T283	296	36		
	4-5B	1.651	740.6	418.0	6.6	TX53	1027	97		
Average		**1.593**			**7.2**				**0.67**	**0.67**
Dow	5-1B	1.594	673.5	373.8	7.4	Dry	1061	104	1.40	0.80
	5-2B	1.733	770.6	435.3	5.3	T283	1614	145		
	5-1A	1.535	668.2	372.0	7.0	TX53	813	83		
RICE	5-2A	1.725	767.6	432.3	5.6	Dry	1531	138	0.69	1.12
Sp. Gr.	5-4A	1.670	721.7	402.8	6.7	T283	1024	96		
2.426	5-3B	1.742	768.3	429.7	6.5	TX53	1727	155		
	5-3A	1.736	768.3	429.7	6.5	Dry	1885	169	0.93	0.64
	5-5A	1.812	784.5	435.6	7.3	T283	1820	157		
	5-5B	1.792	775.2	430.0	7.4	TX53	1244	108		
Average		**1.704**			**6.6**				**1.01**	**0.85**

1 PSI = 6,895 Pascal *1 inch = 2.54 cm* *1 pound = 0.454 kg*

TABLE B.5. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF FM 485, DISTRICT 17

Table B.5. Indirect Tensile Strength Results for Field Cores of FM485, District 17
Pavement Age = 82 Months Cored on 4/22/93

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Strngt PSI	TSR T283	TSR TX531
Control	1-1C	1.371	619.1	357.3	2.9	Dry	1488	169		
	1-1B	1.305	614.1	359.6	0.9	T283	1412	169	1.00	0.98
	1-1A	1.491	691.3	402.5	1.7	TX53	1588	166		
Rice	1-2A	1.775	821.3	474.4	2.8	Dry	2426	213		
Sp. Gr.	1-2B	1.895	856.3	495.4	2.6	T283	2079	171	0.80	0.70
2.436	1-2C	2.204	898.7	514.0	4.1	TX53	2107	149		
	1-3A	1.271	573.9	329.1	3.8	Dry	1179	145		
	1-3B	1.421	620.6	349.4	6.1	T283	1204	132	0.91	0.88
	1-3D	1.370	596.1	335.0	6.3	TX53	1121	128		
Average		**1.567**			**3.5**				**0.90**	**0.85**
BA2000	2-1C	1.210	561.7	324.1	3.3	Dry	1411	182		
	2-1A	1.266	533.5	307.3	3.5	T283	1333	164	0.90	0.86
	2-1B	1.357	571.6	327.7	4.1	TX53	1364	157		
RICE	2-3B	1.319	591.6	340.4	3.6	Dry	1720	203		
Sp. Gr.	2-2B	1.148	504.2	282.7	6.9	T283	1201	163	0.80	0.82
2.444	2-2C	1.242	538.0	297.6	8.4	TX53	1336	168		
	2-3D	1.310	590.7	336.1	5.1	Dry	1686	201		
	2-3A	1.245	572.9	329.4	3.7	T283	1345	169	0.84	0.36
	2-3C	1.422	646.3	373.6	3.0	TX53	664	73		
Average		**1.280**			**4.6**				**0.85**	**0.68**
PermaTac	3-1B	1.915	870.2	499.4	4.8	Dry	2233	182		
Plus	3-1C	1.819	839.6	484.4	4.1	T283	1401	120	0.66	0.47
	3-1A	1.766	806.3	465.0	4.2	TX53	973	86		
RICE	3-3A	1.400	649.2	376.1	3.6	Dry	1940	216		
Sp. Gr.	3-2C	1.460	667.8	382.3	5.1	T283	1299	139	0.64	0.76
2.465	3-2B	1.400	651.4	378.2	3.3	TX53	1471	164		
	3-3C	1.552	708.3	406.1	4.9	Dry	2041	205		
	3-3D	1.501	698.2	404.6	3.5	T283	1685	175	0.85	0.71
	3-3B	1.651	753.9	432.1	5.0	TX53	1531	145		
Average		**1.607**			**4.3**				**0.72**	**0.65**
Lime	4-1C	2.183	1042.7	610.3	1.1	Dry	2398	171		
	4-1B	2.150	1014.1	594.0	1.0	T283	2646	192	1.12	1.01
	4-1A	2.168	1035.6	606.1	1.1	TX53	2406	173		
RICE	4-3B	1.792	845.8	494.5	1.3	Dry	1815	158		
Sp. Gr.	4-2B	1.856	863.7	503.5	1.7	T283	1957	164	1.04	0.94
2.439	4-3C	1.540	725.5	424.5	1.2	TX53	1465	148		
	4-3D	1.601	770.9	450.1	1.5	Dry	1532	149		
	4-3A	1.644	773.6	453.3	1.0	T283	1861	177	1.18	1.09
	4-2A	1.815	868.1	508.3	1.1	TX53	1891	163		
Average		**1.861**			**1.2**				**1.11**	**1.01**

1 PSI = 6,895 Pascal *1 inch = 2.54 cm* *1 pound = 0.454 kg*

TABLE B.6. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 79, DISTRICT 19

Table B.6. Indirect Tensile Strength Results for Field Cores of US79, District 19
Pavement Age = 68 Months Cored 5/20/93

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Stmgt PSI	TSR T283	TSR TX531
ARR-MAZ	1-1B	1.757	779.0	443.7	2.6	Dry	2126	189	0.70	0.82
Adhere	1-1A	1.492	661.0	375.0	3.1	T283	1256	131		
Regular	1-1C	1.496	657.4	374.3	2.6	TX53	1480	154		
Rice	1-2B	1.518	665.0	379.0	2.5	Dry	1859	191	0.76	1.10
Sp. Gr.	1-2A	1.491	659.4	375.3	2.7	T283	1395	146		
2.385	1-2C	1.684	746.6	427.7	1.8	TX53	2274	211		
	1-3A	1.880	841.6	481.7	2.0	Dry	2744	228	0.88	0.90
	1-3C	1.530	678.0	387.1	2.3	T283	1967	201		
	1-3B	1.574	690.2	395.2	1.9	TX53	2058	204		
Average		**1.602**			**2.4**				**0.78**	**0.94**
BA2000	2-1A	1.524	682.8	393.8	0.7	Dry	1866	191	1.19	1.16
	2-1B	1.550	692.1	400.3	0.3	T283	2250	226		
	2-1C	1.481	648.1	374.0	0.6	TX53	2099	221		
RICE	2-2B	1.471	658.2	381.1	0.2	Dry	1878	199	0.85	0.88
Sp. Gr.	2-2A	1.560	688.0	390.0	3.0	T283	1686	169		
2.379	2-2C	1.662	735.6	416.5	3.1	TX53	1874	176		
	2-3A	1.723	773.6	445.6	0.9	Dry	1919	174	1.22	1.37
	2-3B	1.853	824.0	464.7	3.6	T283	2518	212		
	2-3C	1.531	698.2	404.3	0.1	TX53	2334	238		
Average		**1.595**			**1.4**				**1.08**	**1.14**
Aquashld	3-1B	1.594	699.2	400.8	3.1	Dry	1191	117	0.46	1.82
II	3-1C	1.670	728.4	417.9	3.0	T283	574	54		
	3-1A	1.457	639.8	365.7	3.5	TX53	1978	212		
RICE	3-2B	1.531	666.8	380.8	3.6	Dry	1588	162	0.47	1.23
Sp. Gr.	3-2C	1.492	693.3	398.5	2.8	T283	721	75		
2.419	3-2A	1.516	707.0	403.9	3.6	TX53	1929	198		
	3-3C	1.551	682.9	394.2	2.2	Dry	1858	187	0.38	0.90
	3-3A	1.503	653.5	375.9	2.7	T283	681	71		
	3-3B	1.547	681.8	393.4	2.3	TX53	1660	167		
Average		**1.540**			**3.0**				**0.43**	**1.31**
PermaTac	4-1B	1.367	601.0	347.0	1.0	Dry	1173	134	1.52	1.47
	4-1A	1.418	617.0	354.1	1.8	T283	1855	204		
	4-1C	1.641	726.5	416.5	1.9	TX53	2070	197		
RICE	4-2C	1.464	645.8	370.8	1.7	Dry	1694	181	1.12	1.27
Sp. Gr.	4-2A	1.560	687.8	394.1	2.0	T283	2020	202		
2.389	4-2B	1.356	599.5	344.0	1.8	TX53	1997	230		
	4-3A	1.620	724.9	417.8	1.2	Dry	1329	128	1.30	1.46
	4-3C	1.526	675.4	389.6	1.1	T283	1632	167		
	4-3B	1.550	700.6	403.0	1.5	TX53	1859	187		
Average		**1.500**			**1.5**				**1.32**	**1.40**
Control	5-1A	1.478	656.1	376.9	1.5	Dry	1887	199	0.25	1.13
	5-1B	1.690	721.0	408.1	3.4	T283	546	50		
	5-1C	1.642	711.2	407.1	2.0	TX53	2379	226		
RICE	5-2A	1.388	616.7	353.7	1.7	Dry	1746	196	0.24	1.28
Sp. Gr.	5-2B	1.502	631.9	358.8	3.0	T283	447	46		
2.386	5-2C	1.512	664.8	381.7	1.6	TX53	2426	250		
	5-3C	1.438	638.5	366.2	1.7	Dry	1884	204	0.31	1.02
	5-3B	1.505	665.4	381.4	1.8	T283	610	63		
	5-3A	1.541	684.8	394.3	1.2	TX53	2054	208		
Average		**1.522**			**2.0**				**0.27**	**1.14**

TABLE B.6. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 79, DISTRICT 19 (Continued)

Table B.6. Indirect Tensile Strength Results for Field Cores of US79, District 19
Pavement Age = 68 Months Cored 5/20/93 (Cont'd)

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Stmgt PSI	TSR T283	TSR TX531
Lime	6-1C	1.495	658.4	375.4	2.7	Dry	1304	136	0.31	0.45
	6-1B	1.429	620.9	354.1	2.6	T283	385	42		
	6-1A	1.494	647.2	367.3	3.3	TX53	590	62		
RICE	6-2A	1.418	617.4	349.5	3.6	Dry	860	95	0.96	0.71
Sp. Gr.	6-2B	1.455	632.9	361.0	2.6	T283	848	91		
2.390	6-2C	1.545	684.9	391.8	2.2	TX53	661	67		
	6-3B	1.577	692.2	393.1	3.2	Dry	1556	154	0.37	0.41
	6-3A	1.553	687.6	392.2	2.6	T283	573	58		
	6-3C	1.449	623.5	355.6	2.6	TX53	589	63		
Average		**1.491**			**2.8**				**0.55**	**0.52**

1 PSI = 6,895 Pascal *1 inch = 2.54 cm* *1 pound = 0.454 kg*

TABLE B.7. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 83, DISTRICT 21

Table B.7. Indirect Tensile Strength Results for Field Cores of US 83, District 21
Pavement Age = 66 Months Cored on 4/28/93

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Strngt PSI	TSR T283	TSR TX531
Lime	1-1C	1.678	720.0	408.5	3.6	Dry	2026	188		
	1-1A	1.454	647.0	366.4	3.8	T283	823	88	0.47	0.83
	1-1B	1.619	689.2	391.1	3.6	TX53	1614	156		
Rice	1-2A	1.660	693.6	386.2	5.9	Dry	1535	144		
Sp. Gr.	1-2B	1.618	620.4	348.7	4.8	T283	816	79	0.55	0.73
2.398	1-2C	1.680	706.7	395.2	5.4	TX53	1140	106		
	1-3D	1.455	592.7	330.6	5.7	Dry	1226	131		
	1-3C	1.514	614.8	343.0	5.7	T283	728	75	0.57	0.69
	1-3A	1.531	630.1	352.5	5.3	TX53	885	90		
Average		**1.579**			**4.9**				**0.53**	**0.75**
PermaTac	2-1B	1.372	607.9	343.4	4.2	Dry	1546	176		
	2-1A	1.651	722.6	404.2	5.4	T283	1137	107	0.61	0.76
	2-1C	1.408	639.7	361.5	4.2	TX53	1201	133		
RICE	2-2C	1.467	636.2	361.3	3.5	Dry	1166	124		
Sp. Gr.	2-2A	1.172	543.1	311.5	2.3	T283	1146	153	1.23	1.40
2.399	2-2B	1.274	578.8	331.5	2.4	TX53	1414	173		
	2-3A	1.156	526.3	300.3	2.9	Dry	1302	176		
	2-3D	1.177	528.6	301.0	3.2	T283	987	131	0.74	0.89
	2-3C	1.175	527.7	300.9	3.0	TX53	1172	156		
Average		**1.317**			**3.5**				**0.86**	**1.01**
PaveBond	3-1C	1.181	534.4	303.8	3.6	Dry	1358	179		
LP	3-1B	1.281	583.7	331.9	3.6	T283	960	117	0.65	0.28
	3-1A	1.111	490.1	278.2	3.8	TX53	353	50		
RICE	3-2B	1.148	520.3	298.8	2.3	Dry	1370	186		
Sp. Gr.	3-2C	1.186	540.3	309.3	2.7	T283	968	127	0.68	0.92
2.404	3-2A	1.260	572.0	329.0	2.1	TX53	1376	170		
	3-3B	1.413	647.3	373.5	1.7	Dry	1537	170		
	3-3A	1.418	655.6	379.0	1.4	T283	1768	195	1.15	1.29
	3-3C	1.268	586.0	339.0	1.3	TX53	1776	218		
Average		**1.252**			**2.5**				**0.83**	**0.83**
ARR-MAZ	4-1B	1.360	621.2	356.8	1.8	Dry	1774	203		
Adhere HP	4-1C	1.235	577.6	332.7	1.4	T283	1442	182	0.90	0.79
	4-1A	1.372	628.6	360.7	1.9	TX53	1409	160		
RICE	4-2A	1.400	635.2	360.8	3.3	Dry	1557	173		
Sp. Gr.	4-2C	1.415	645.1	367.0	3.1	T283	1317	145	0.84	0.93
2.393	4-2B	1.433	643.7	365.1	3.4	TX53	1483	161		
	4-3A	1.150	516.6	293.1	3.4	Dry	1431	194		
	4-3C	1.349	576.3	323.9	4.6	T283	756	87	0.45	0.71
	4-3D	1.300	590.9	335.0	3.5	TX53	1154	138		
Average		**1.335**			**2.9**				**0.73**	**0.81**
Fina B	5-1B	1.282	587.6	338.2	0.8	Dry	1635	199		
	5-1C	1.070	475.9	273.0	1.2	T283	1131	165	0.83	1.09
	5-1A	1.358	622.9	358.1	0.9	TX53	1883	216		
RICE	5-2B	1.244	574.0	330.0	0.9	Dry	1767	222		
Sp. Gr.	5-2A	1.380	639.5	365.7	1.6	T283	1414	160	0.72	0.85
2.374	5-2C	1.234	563.4	322.2	1.6	TX53	1498	189		
	5-3A	1.300	606.7	347.5	1.4	Dry	1575	189		
	5-3D	1.336	612.3	350.8	1.4	T283	1335	156	0.82	0.85
	5-3B	1.335	607.8	347.5	1.6	TX53	1376	161		
Average		**1.282**			**1.3**				**0.79**	**0.93**

TABLE B.7. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 83, DISTRICT 21 (Continued)

Table B.7. Indirect Tensile Strength Results for Field Cores of US 83, District 21
Pavement Age = 66 Months Cored on 4/28/93 (Cont'd)

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Strngt PSI	TSR T283	TSR TX531
Aquashld	6-1A	1.161	524.1	297.6	2.9	Dry	1231	165		
II	6-1C	1.319	587.3	332.9	3.1	T283	1365	161	0.98	1.19
	6-1B	1.124	506.3	290.6	1.5	TX53	1414	196		
RICE	6-2A	1.289	581.8	335.3	1.0	Dry	1616	196		
Sp. Gr.	6-2B	1.200	566.2	327.0	0.7	T283	1551	202	1.03	1.09
2.383	6-2C	1.196	549.7	317.0	0.9	TX53	1632	213		
	6-3C	1.435	639.5	359.7	4.1	Dry	1474	160		
	6-3A	1.143	519.3	298.4	1.3	T283	1387	189	1.18	0.98
	6-3D	1.478	679.6	385.8	2.9	TX53	1493	158		
Average		**1.261**			**2.0**				**1.06**	**1.09**
Dow	7-1A	1.260	573.4	327.0	4.1	Dry	1644	204		
	7-1B	1.002	435.2	245.5	5.4	T283	331	52	0.25	0.26
	7-1C	0.914	396.3	224.5	4.9	TX53	308	53		
RICE	7-2C	1.206	549.9	313.4	4.2	Dry	1405	182		
Sp. Gr.	7-2B	1.332	589.7	336.0	4.2	T283	1257	147	0.81	0.50
2.426	7-2A	1.137	502.0	284.1	5.0	TX53	667	92		
	7-3C	1.131	504.8	285.1	5.3	Dry	1195	165		
	7-3A	1.124	505.1	286.1	4.9	T283	801	111	0.67	0.79
	7-3D	1.178	524.5	296.3	5.3	TX53	980	130		
Average		**1.143**			**4.8**				**0.58**	**0.52**
Control	8-1A	1.170	529.3	301.2	2.2	Dry	1390	185		
	8-1B	1.663	723.3	407.3	3.5	T283	1376	129	0.70	0.95
	8-1C	1.204	546.0	310.5	2.3	TX53	1360	176		
RICE	8-2A	1.312	580.0	329.6	2.4	Dry	1563	186		
Sp. Gr.	8-2B	1.576	723.1	411.4	2.2	T283	1556	154	0.83	0.76
2.373	8-2C	1.596	729.5	413.8	2.6	TX53	1447	141		
	8-3A	1.453	679.0	389.1	1.3	Dry	1752	188		
	8-3B	1.323	615.7	352.9	1.3	T283	1484	175	0.93	0.94
	8-3C	1.338	606.5	346.6	1.7	TX53	1515	177		
Average		**1.404**			**2.2**				**0.82**	**0.88**

1 PSI = 6,895 Pascal *1 inch = 2.54 cm* *1 pound = 0.454 kg*

TABLE B.8. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 287, DISTRICT 25

Table B.8. Indirect Tensile Strength Results for Field Cores of US287, District 25
Pavement Age = 72 Months Cored on 5/4/93

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Strngt PSI	TSR T283	TSR TX531
Aquashld	1-C	1.440	614.8	335.6	9.5	Dry	1434	155		
II	1-A	1.243	524.0	285.1	9.9	T283	938	118	0.76	0.70
	1-B	1.280	543.8	296.0	9.8	TX53	898	109		
Rice	1-F	1.518	691.6	391.3	5.4	Dry	1642	169		
Sp. Gr.	1-D	1.265	598.3	348.8	1.5	T283	1425	176	1.04	1.05
2.434	1-E	1.340	633.6	369.3	1.5	TX53	1525	178		
	1-H	1.455	679.3	392.4	2.7	Dry	1327	142		
	1-J	1.440	676.2	393.4	1.8	T283	1513	164	1.15	1.00
	1-K	1.447	679.9	394.0	2.3	TX53	1324	143		
Average		**1.381**			**4.9**				**0.98**	**0.92**
Fina A	2-A	1.377	626.0	353.2	5.8	Dry	1423	161		
	2-B	1.610	677.1	379.7	6.6	T283	1431	139	0.86	0.82
	2-C	1.574	713.8	404.4	5.3	TX53	1339	133		
RICE	2-D	1.548	693.5	392.9	5.3	Dry	1673	169		
Sp. Gr.	2-E	1.514	690.5	392.6	4.9	T283	1702	175	1.04	0.93
2.437	2-G	1.367	651.7	380.7	1.3	TX53	1370	156		
	2-F	1.332	634.3	371.0	1.1	Dry	1458	171		
	2-H	1.450	678.0	395.7	1.4	T283	1674	180	1.05	0.87
	2-K	1.414	640.4	369.2	3.1	TX53	1354	149		
Average		**1.465**			**3.9**				**0.98**	**0.88**
Unichem	3-B	1.690	783.7	450.7	3.4	Dry	1598	148		
8150	3-C	1.630	771.5	449.6	1.6	T283	1525	146	0.99	0.60
	3-A	1.855	861.7	495.5	3.4	TX53	1059	89		
RICE	3-E	1.700	841.9	484.3	3.4	Dry	1478	136		
Sp. Gr.	3-G	1.726	815.9	472.5	2.5	T283	1241	112	0.83	0.80
2.436	3-D	1.733	824.5	479.3	2.0	TX53	1203	108		
	3-F	1.683	800.1	464.5	2.1	Dry	1455	135		
	3-K	1.600	794.0	456.3	3.5	T283	1150	112	0.83	0.67
	3-J	1.561	728.0	419.4	3.2	TX53	905	90		
Average		**1.686**			**2.8**				**0.88**	**0.69**
Control	4-C	1.640	776.5	451.5	2.6	Dry	1546	147		
	4-A	1.494	689.7	395.7	4.3	T283	1414	148	1.00	0.98
	4-B	1.555	728.5	421.6	3.2	TX53	1440	144		
RICE	4-F	1.591	750.6	437.0	2.4	Dry	1276	125		
Sp. Gr.	4-D	1.723	813.8	472.5	2.8	T283	1364	123	0.99	0.98
2.452	4-E	1.864	863.5	498.6	3.5	TX53	1465	123		
	4-K	1.710	797.7	459.7	3.7	Dry	1408	128		
	4-H	1.545	739.6	431.6	2.1	T283	1275	129	1.00	0.91
	4-G	1.536	724.1	421.1	2.5	TX53	1151	117		
Average		**1.629**			**3.0**				**1.00**	**0.96**
PermaTac	5-B	1.655	747.4	427.6	4.4	Dry	1638	154		
	5-C	1.741	788.8	444.5	6.3	T283	1616	145	0.94	1.02
	5-A	1.854	841.5	473.6	6.4	TX53	1872	158		
RICE	5-F	1.686	766.6	435.0	5.4	Dry	1538	142		
Sp. Gr.	5-E	1.602	755.8	438.0	2.7	T283	1739	169	1.19	1.10
2.444	5-D	1.661	763.5	436.6	4.4	TX53	1661	156		
	5-K	1.676	808.8	473.6	1.3	Dry	1638	152		
	5-J	1.628	780.3	456.8	1.3	T283	1236	118	0.78	0.79
	5-H	1.633	784.0	459.1	1.3	TX53	1260	120		
Average		**1.682**			**3.7**				**0.97**	**0.97**

TABLE B.8. INDIRECT TENSILE STRENGTH RESULTS FOR FIELD CORES OF US 287, DISTRICT 25 (Continued)

Table B.8. Indirect Tensile Strength Results for Field Cores of US287, District 25
Pavement Age = 72 Months Cored on 5/4/93 (Cont'd)

Additive	Spec. Code	Height inch	Wght, gram Air	Wght, gram Water	Air Void %	Cond-ition	Pult lbs.	Tensile Strngt PSI	TSR T283	TSR TX531
Lime	6-A	1.708	785.4	448.0	4.9	Dry	1759	161	0.85	1.35
	6-C	2.023	934.1	536.7	4.0	T283	1773	137		
	6-B	1.684	792.2	459.0	2.9	TX53	2344	217		
RICE	6-G	1.753	819.8	470.5	4.2	Dry	1543	137	1.10	1.22
Sp. Gr.	6-D	1.892	869.8	495.7	5.1	T283	1828	151		
2.449	6-E	1.734	809.0	467.6	3.2	TX53	1864	168		
	6-J	1.518	709.2	411.9	2.6	Dry	1557	160	1.00	1.17
	6-F	1.581	747.2	432.3	3.1	T283	1616	159		
	6-K	1.800	828.5	472.7	4.7	TX53	2151	186		
Average		**1.744**			**3.9**				**0.98**	**1.25**

1 PSI = 6,895 Pascal *1 inch = 2.54 cm* *1 pound = 0.454 kg*

TABLE B.9. TSR VALUES FOR CORES TESTED BY THE TEXAS DEPARTMENT OF TRANSPORTATION (TxDOT) IN 1991

	District 16									
	Control (L)	Control (II)	1% Lime (L)	1% Lime (II)	0.5% PB LP (L)	0.5% PB LP (II)	0.5% Aqua (L)	0.5% Aqua (II)	0.41% Dow (L)	0.41% Dow (II)
531-C	0.651	0.537	0.771	0.838	0.609	0.614	0.726	0.649	0.648	0.749
Dry Str.	261	198	302	320	258	213	255	255	301	215
530-C	10-15		10-15		10-15		15-20		10-15	
	District 6									
	Control (L)	Control (II)	1% Lime (L)	1% Lime (II)	1% PB LP (L)	1% PB LP (II)	1% PT (L)	1% PT (II)	1% Unichem (L)	1% Unichem (II)
531-C	0.804	0.541	0.799	0.656	0.954	0.855	0.889	0.86	0.822	0.794
Dry Str.	211	159	224	182	163	155	171	158	173	180
530-C	10		10		10		10		10	
	District 13									
	Control (L)	Control (II)	1% Lime (L)	1% Lime (II)	1% PT+ (L)	1% PT+ (II)	1% BA 2000 (L)	1% BA 2000 (II)		
531-C	0.745	0.648	0.983	1.045	0.916	0.85	0.926	0.721		
Dry Str.	174	137	175	157	128	167	191	170		
530-C	10-15		5-7		5-7		5-7			
	District 21									
	Control (L)	Control (II)	1% Lime (L)	1% Lime (II)	1% PT (L)	1% PT (II)	1% PB LP (L)	1% PB LP (II)	1% AdhereHP (L)	1% AdhereHP (II)
531-C	0.648	0.712	0.424	0.669	0.474	0.739	0.805	0.661	0.726	0.732
Dry Str.	159	149	137	138	184	143	146	166	159	144
530-C	25		30-35		30		10-15		15-20	
	0.41%Fina B (L)	0.41%Fina B (II)	0.5% AquaII (L	0.5% AquaII (I	0.5% Dow (L)	0.5% Dow (II)				
531-C	0.848	0.795	0.905	0.638	0.661	0.515				
Dry Str.	148	143	139	160	173	133				
530-C	20		15		25					
	District 1									
	Control (L)	Control (II)	1.5% Lime (L)	1.5% Lime (II)	1% PT+ (L)	1% PT+ (II)	1% PB sp (L)	1% PB sp (II)	.75%AdhereHP(L)	.75%AdhereHP(II)
531-C	0.572	0.295	0.936	0.879	0.327	0.297	0.723	0.649	0.822	0.55
Dry Str.	165	156	175	159	180	178	175	146	173	180
530-C	15-20		3-5		15-20		10-15		5	
	1%Fina A (L)	1%Fina A (II)	1% Indulin (L)	1% Indulin (II)	0.45% Dow (L)	0.18% Dow (II)				
531-C	0.802	0.83	0.886	0.715	0.456	0.394				
Dry Str.	155	147	165	165	150	154				
530-C	5		5		15-20					
	District 25									
	Control (L)	Control (II)	1% Lime (L)	1% Lime (II)	1% PT (L)	1% PT (II)	1%Fina A (L)	1%Fina A (II)	1% Aqua (L)	1% Aqua (II)
531-C	0.815	0.815	0.921	0.926	0.906	0.835	0.784	0.819	0.902	0.885
Dry Str.	168	169	178	178	161	168	162	174	149	174
530-C	10-15		5		5		10-15		5-10	
	1% Unichem (L)	1% Unichem (II)								
531-C	0.733	0.84								
Dry Str.	165	162								
530-C	10									

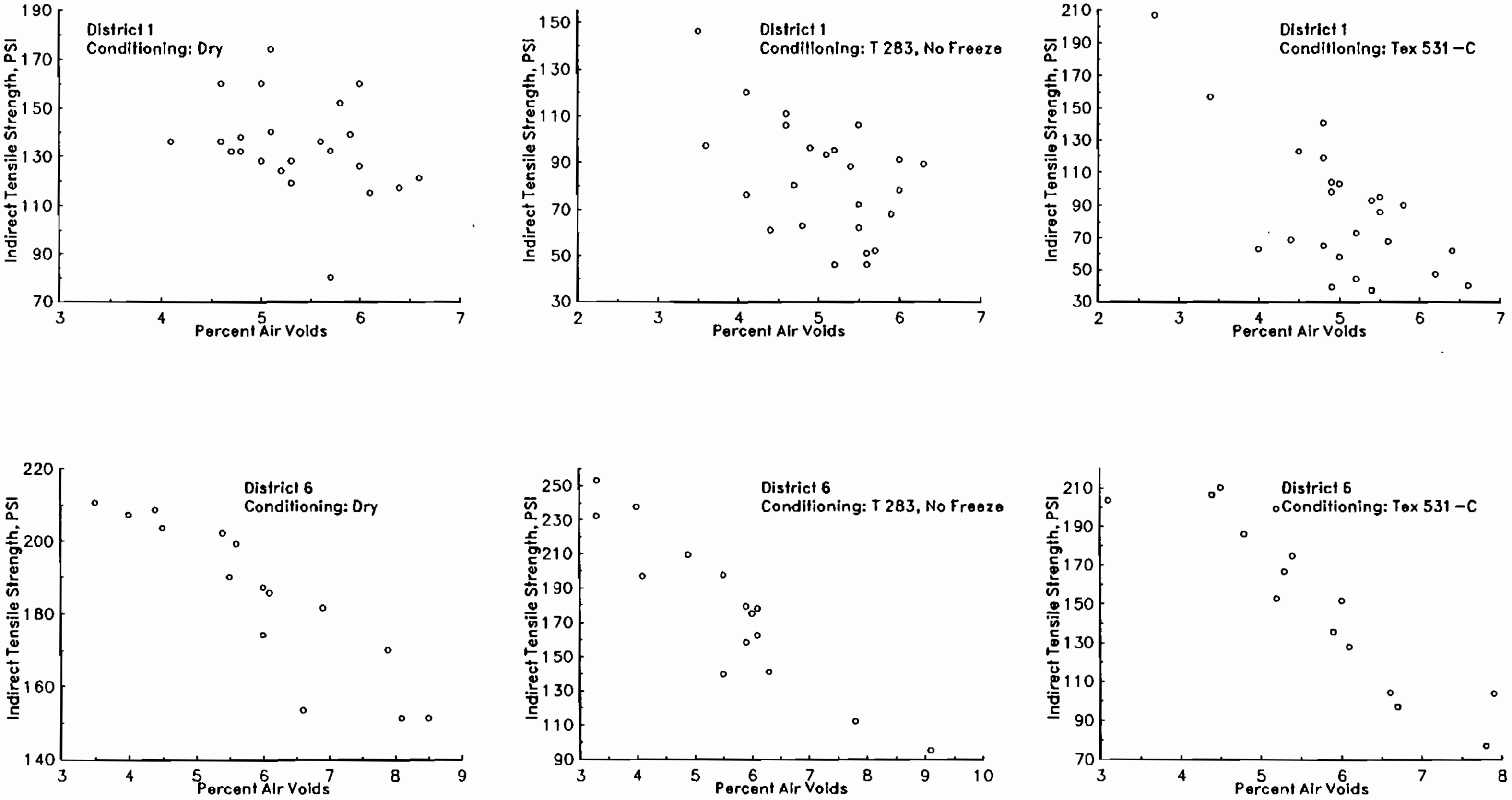


Figure B.1. Indirect tensile strength of field cores as a function of air voids for Districts 1 and 6

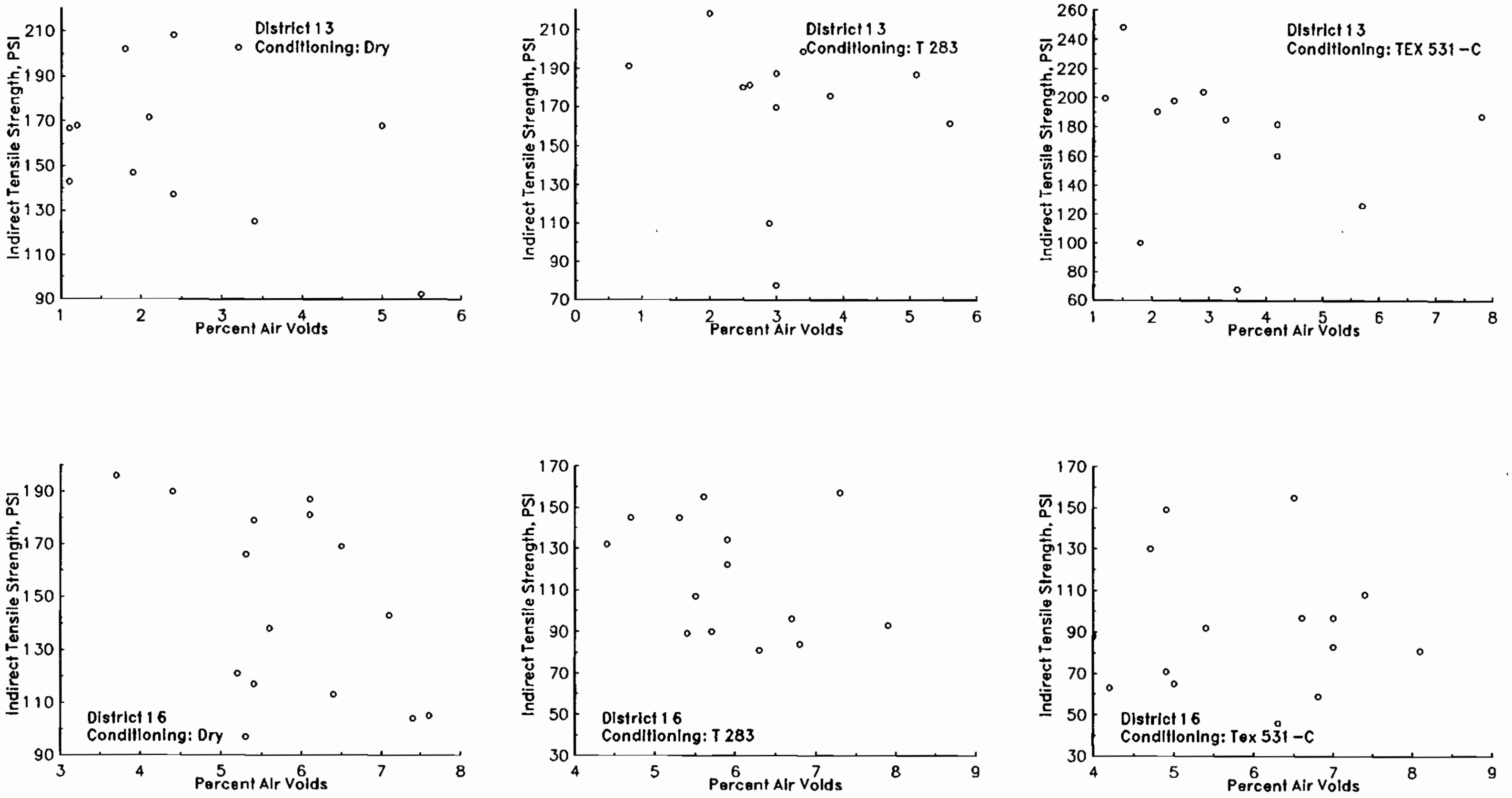


Figure B.2. Indirect tensile strength of field cores as a function of air voids for Districts 13 and 16

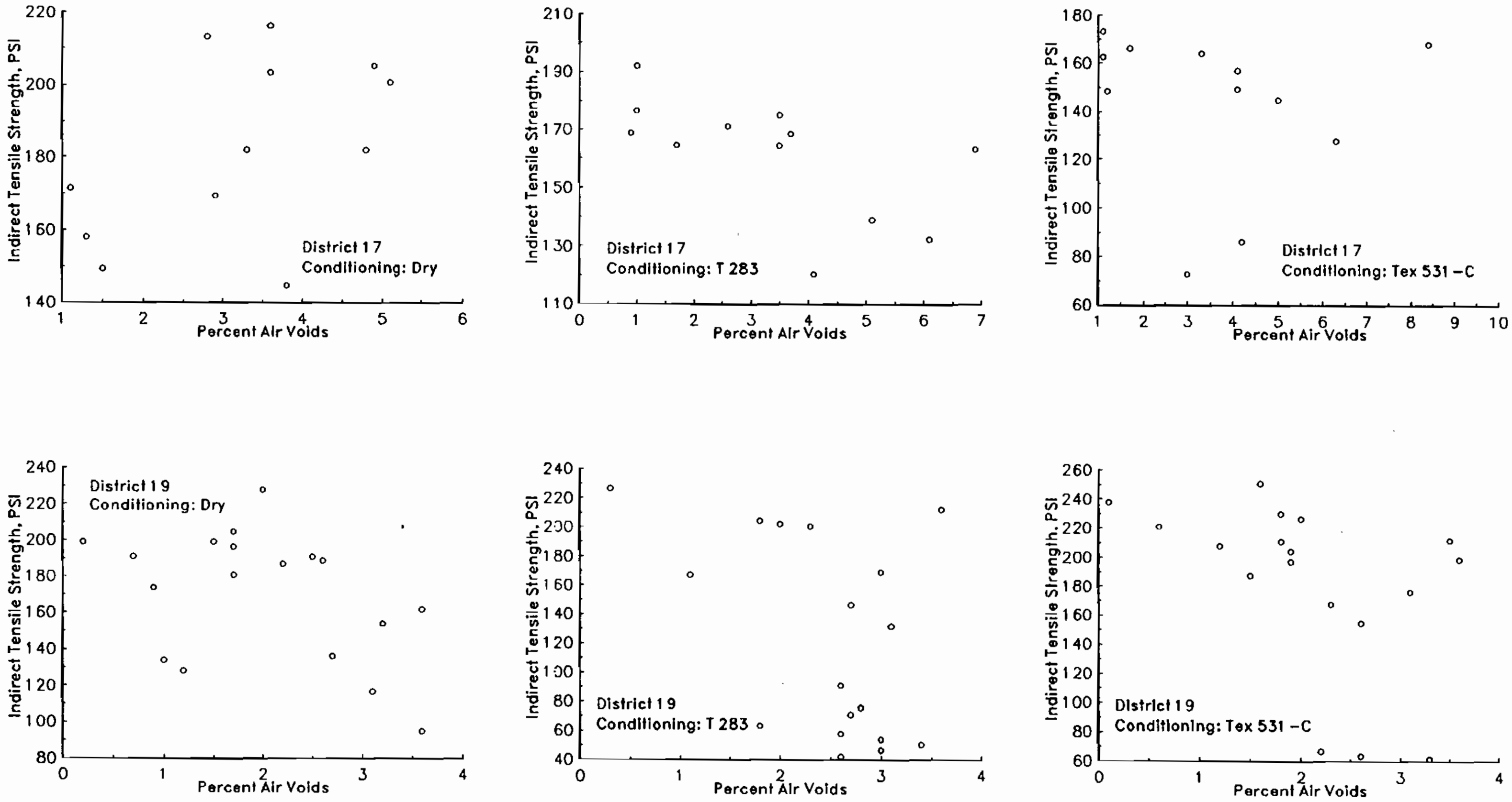


Figure B.3. Indirect tensile strength of field cores as a function of air voids for Districts 17 and 19

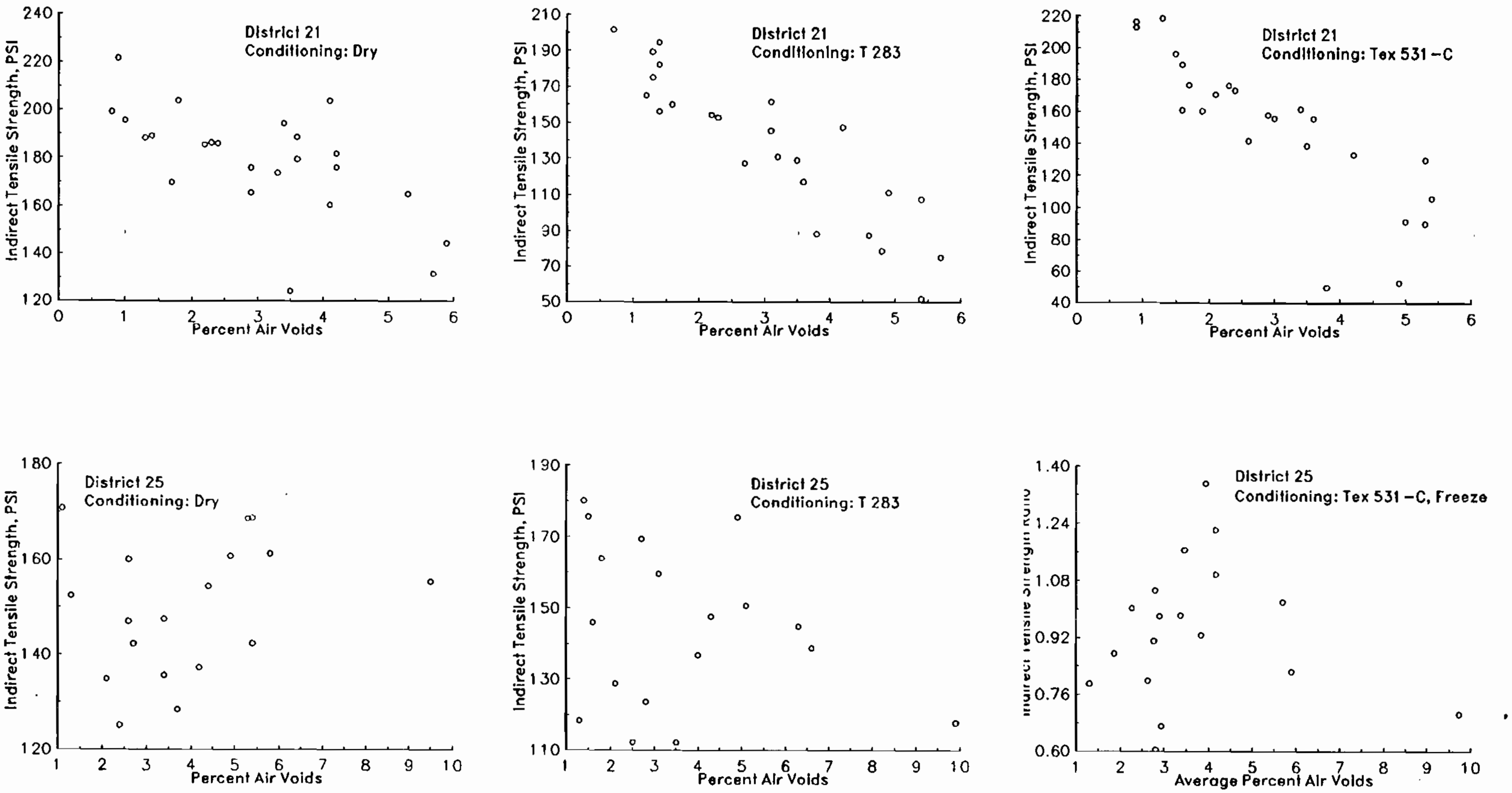


Figure B.4. Indirect tensile strength of field cores as a function of air voids for Districts 21 and 25

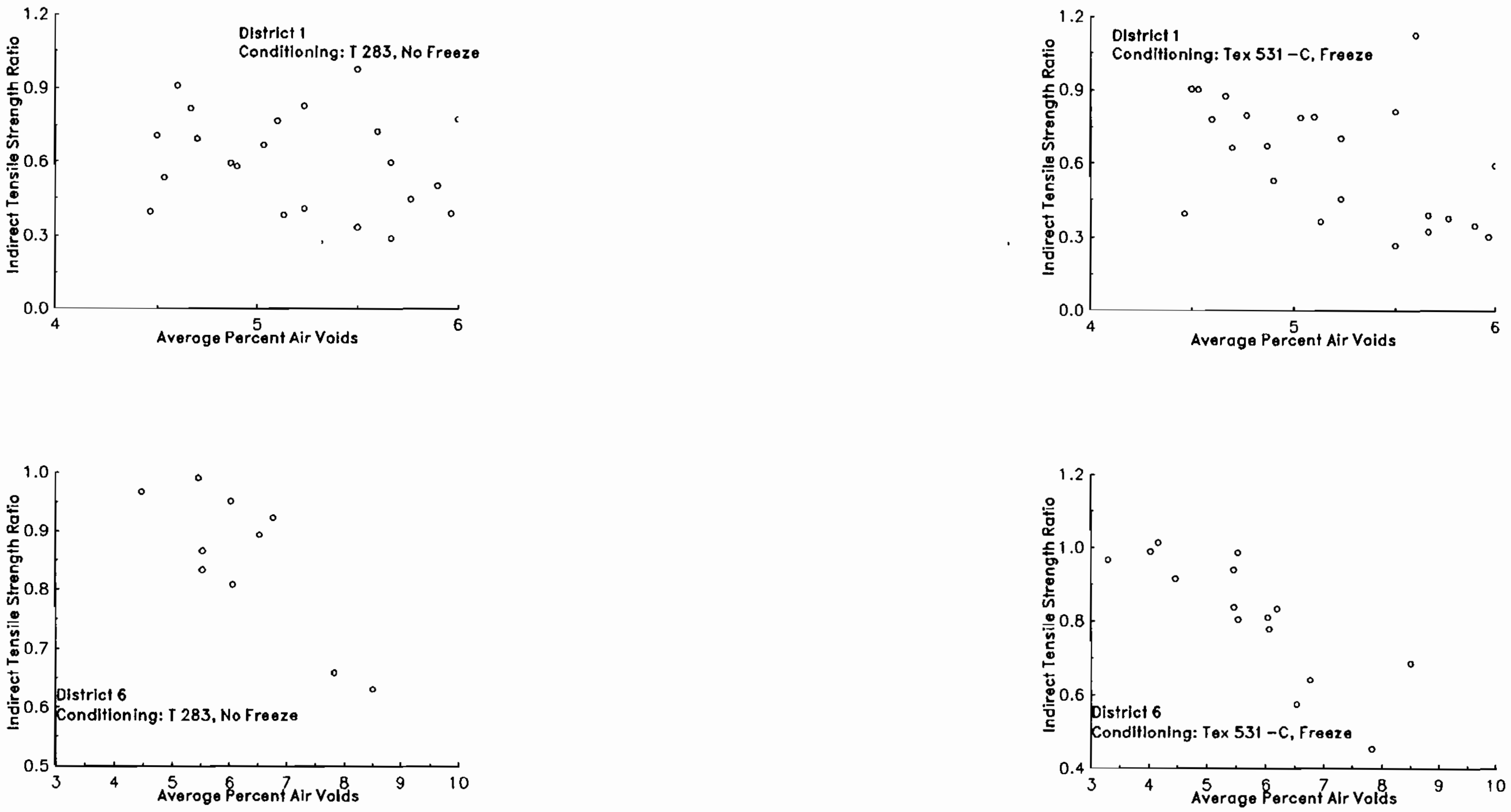


Figure B.5. Indirect tensile strength ratio as a function of average air voids for Districts 1 and 6

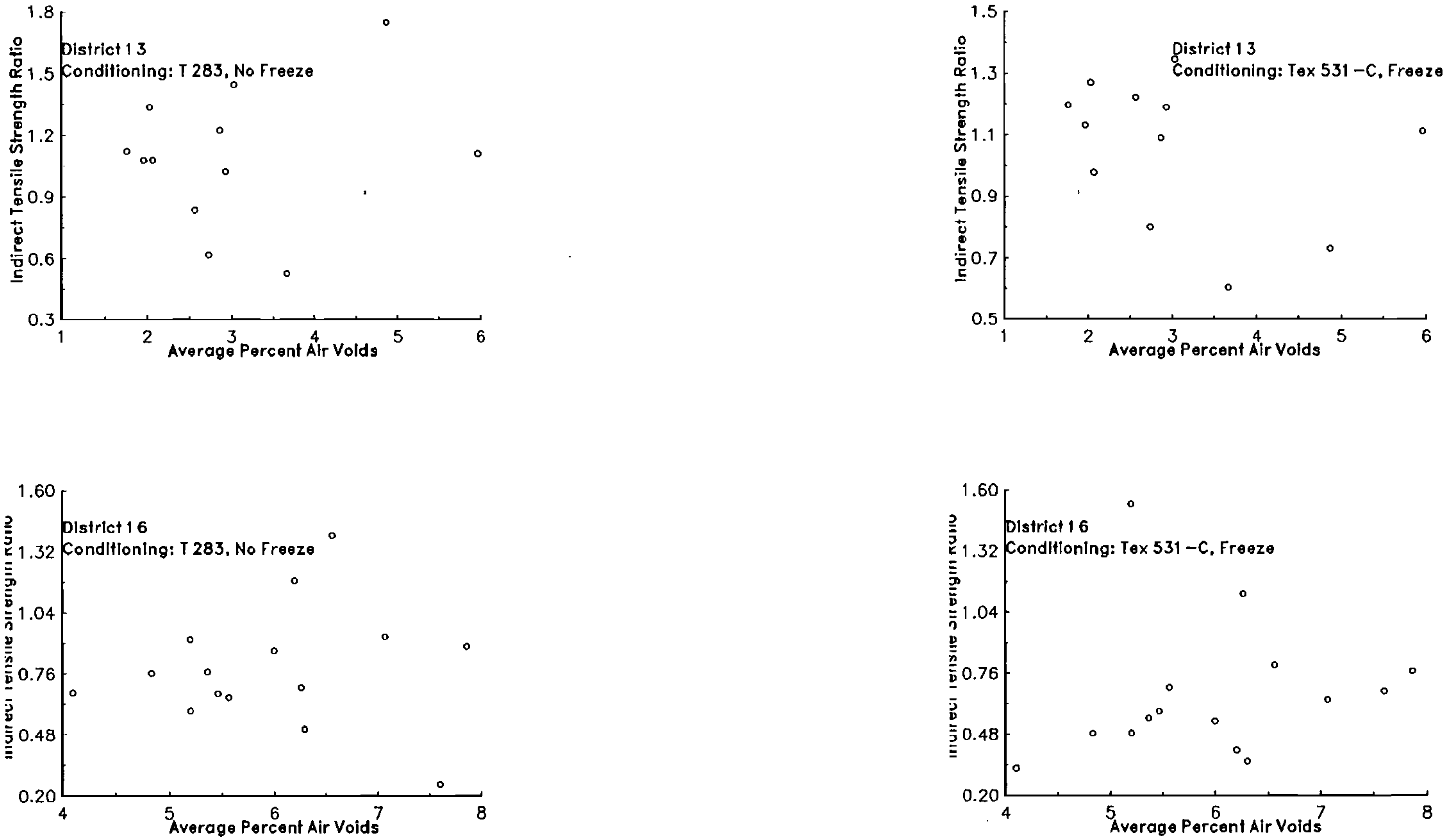


Figure B.6. Indirect tensile strength ratio as a function of average air voids for Districts 13 and 16

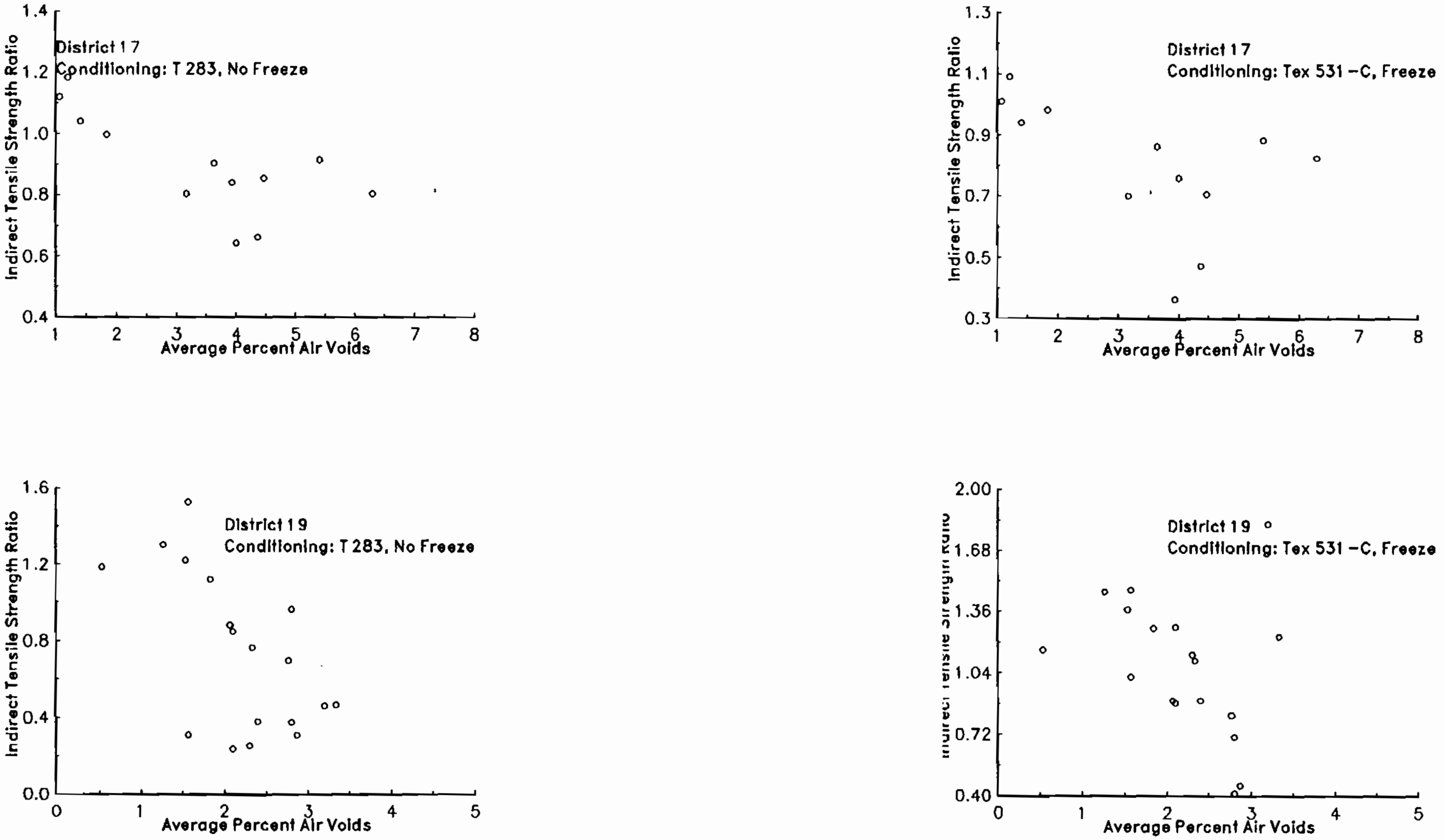


Figure B.7. Indirect tensile strength ratio as a function of average air voids for Districts 17 and 19

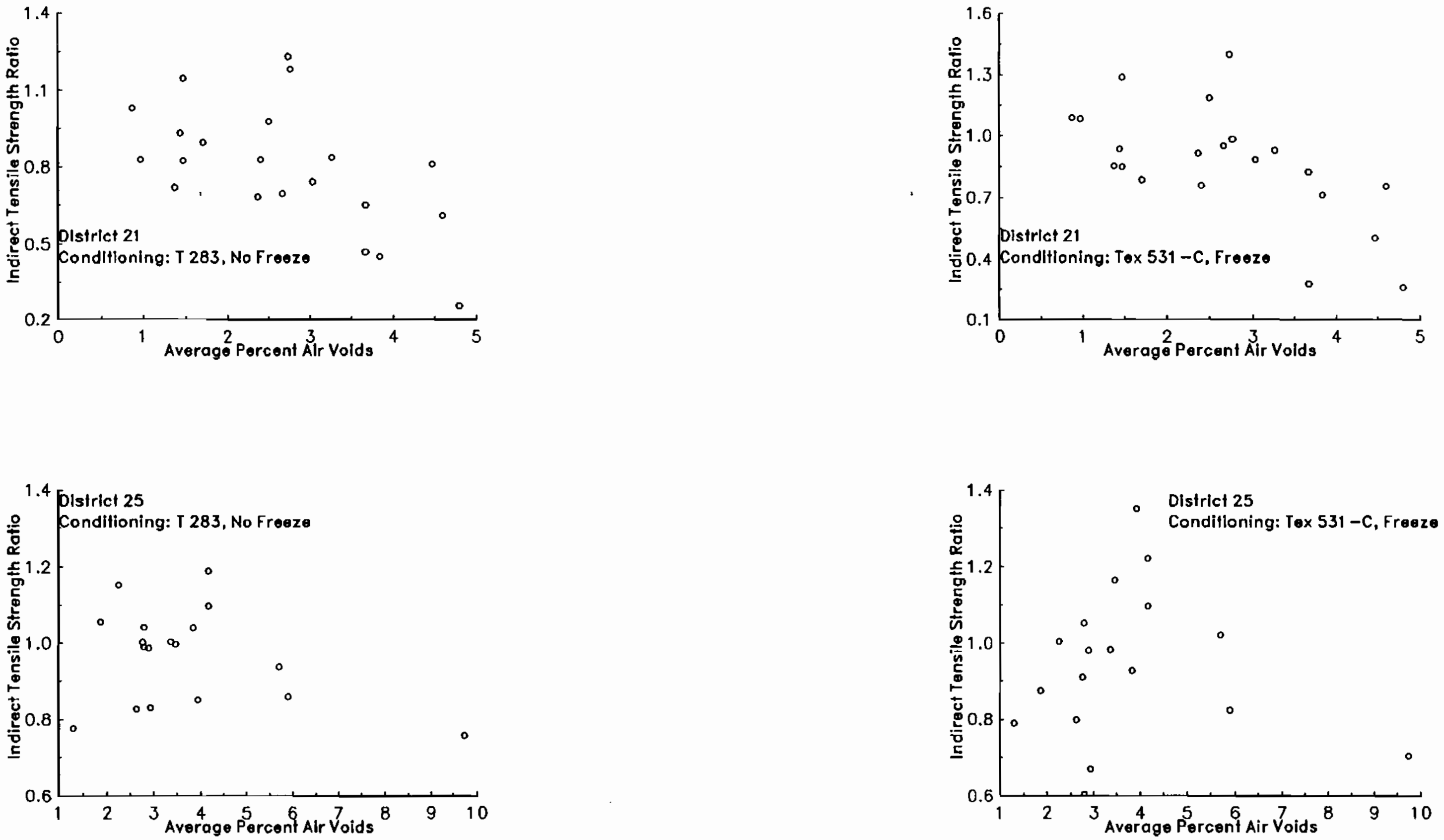


Figure B.8. Indirect tensile strength ratio as a function of average air voids for Districts 21 and 25

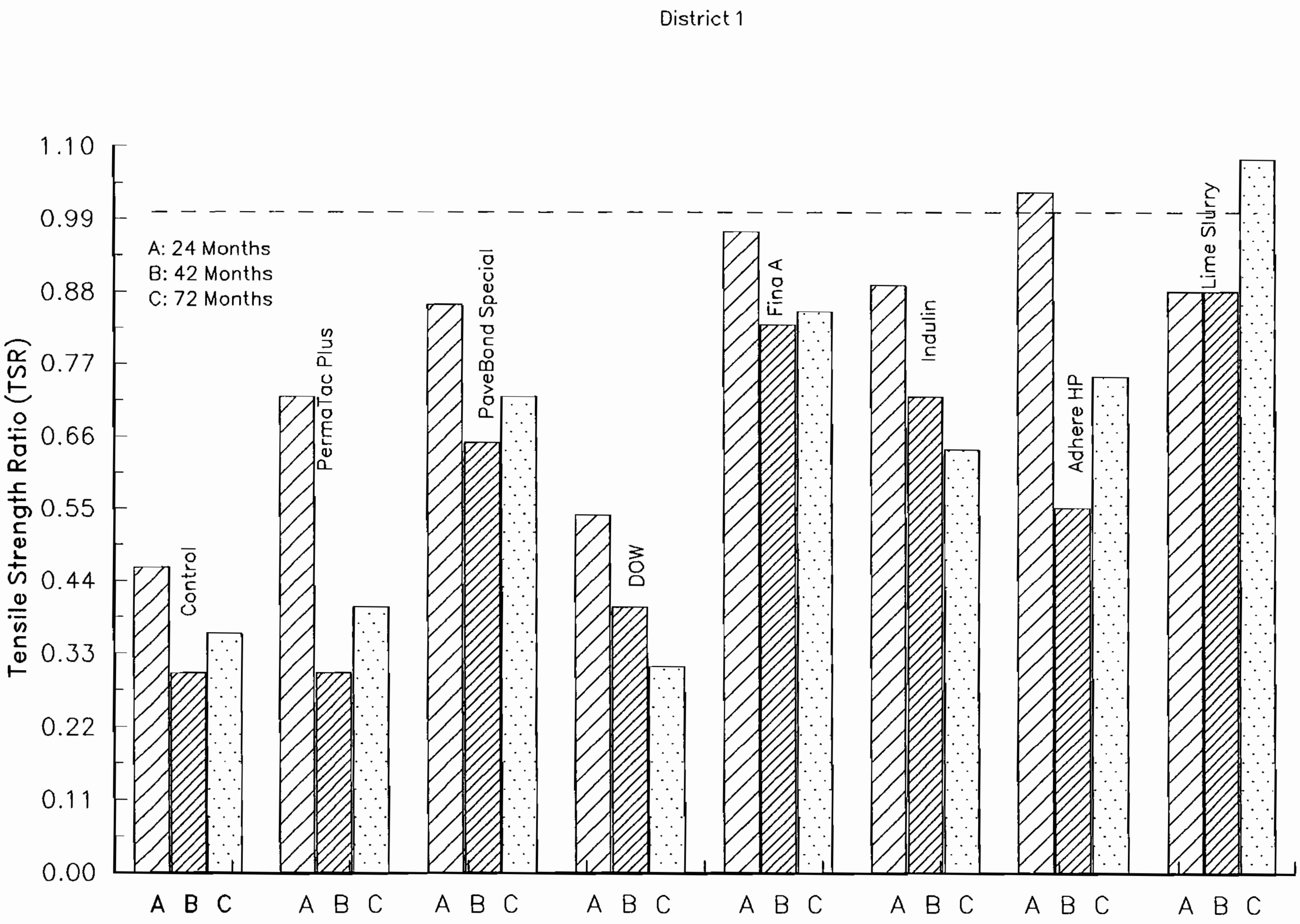


Figure B.9. TSR values at different pavement ages for District 1

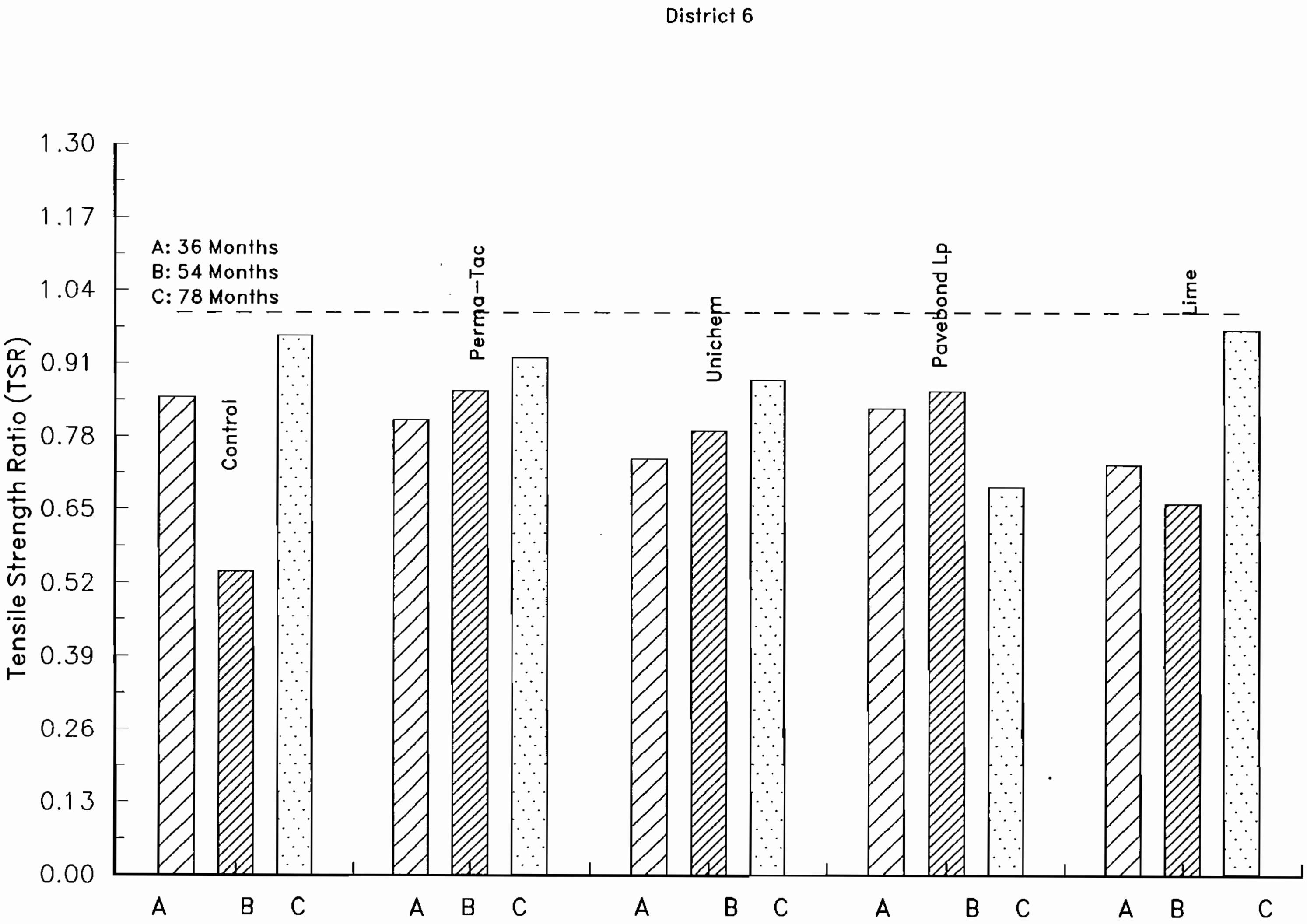


Figure B.10. TSR values at different pavement ages for District 6

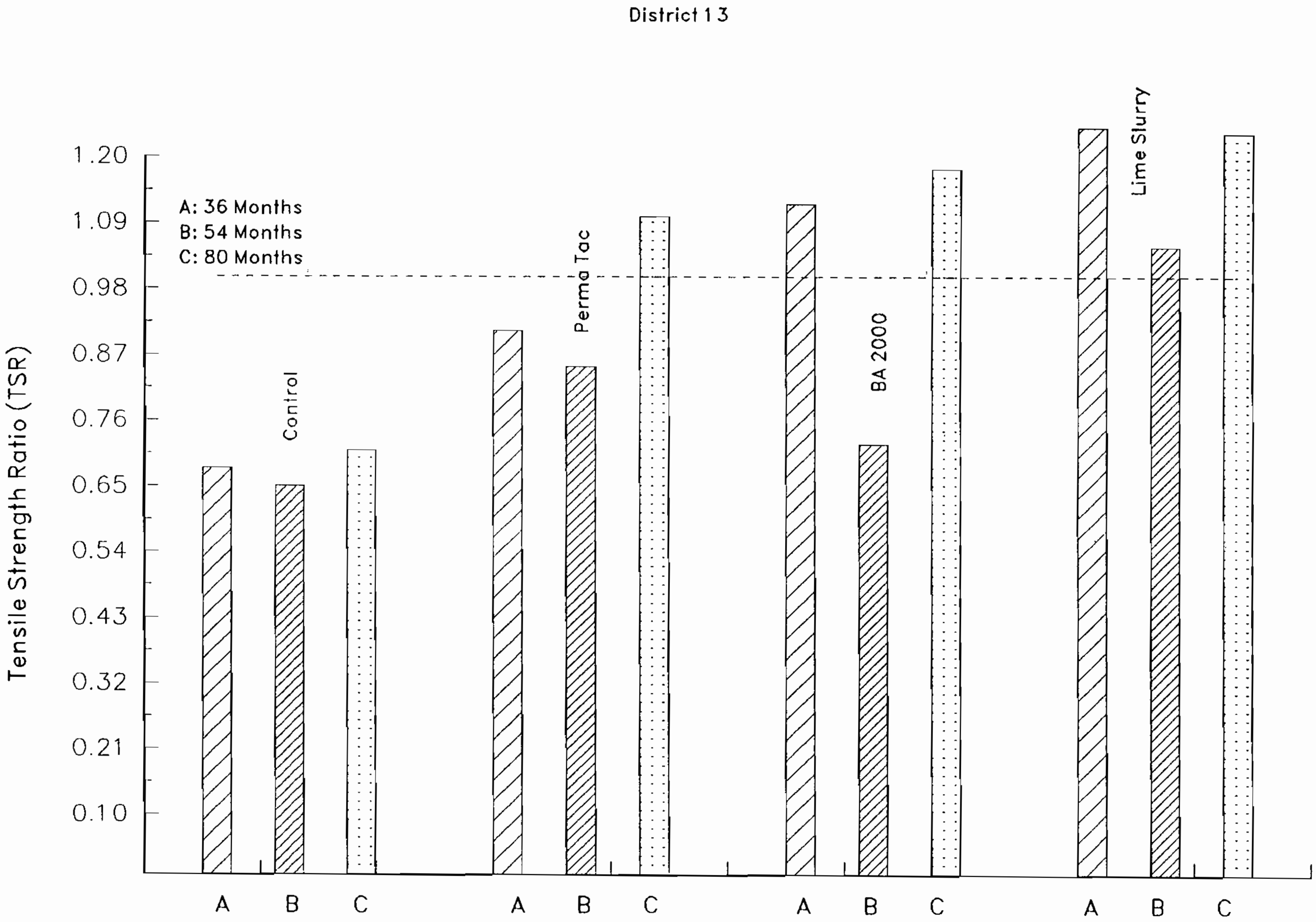


Figure B.11. TSR values at different pavement ages for District 13

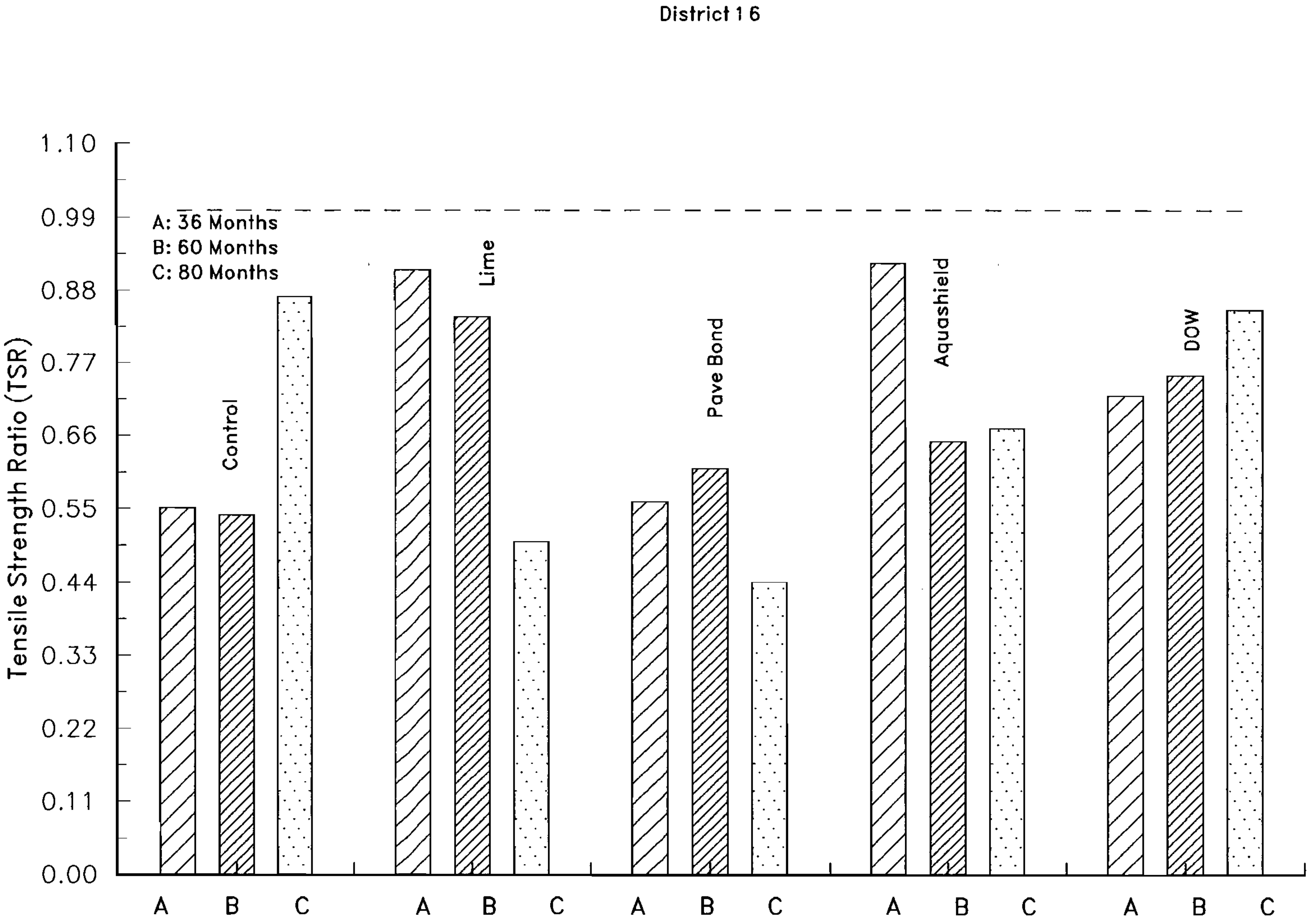


Figure B.12. TSR values at different pavement ages for District 16

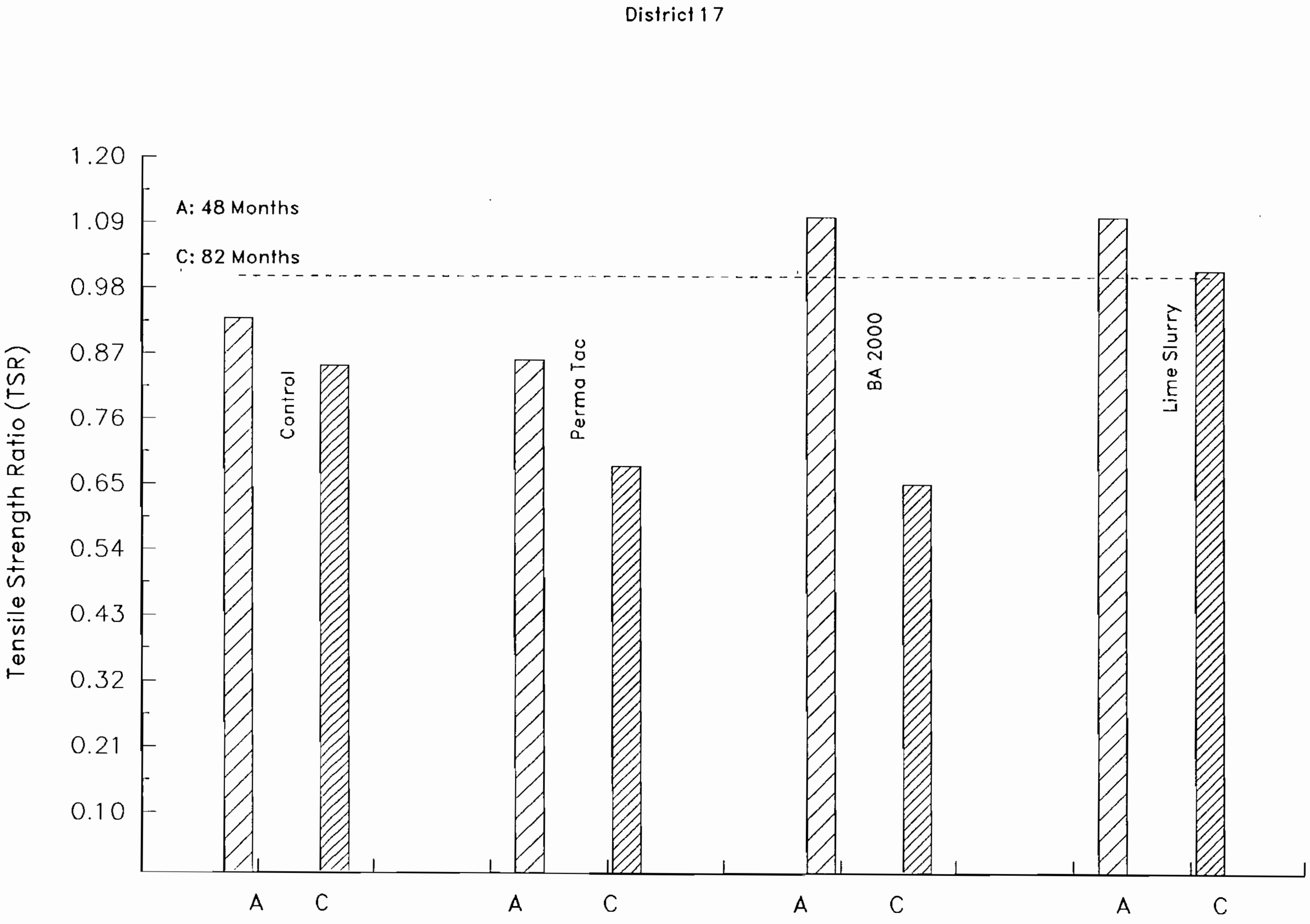


Figure B.13. TSR values at different pavement ages for District 17

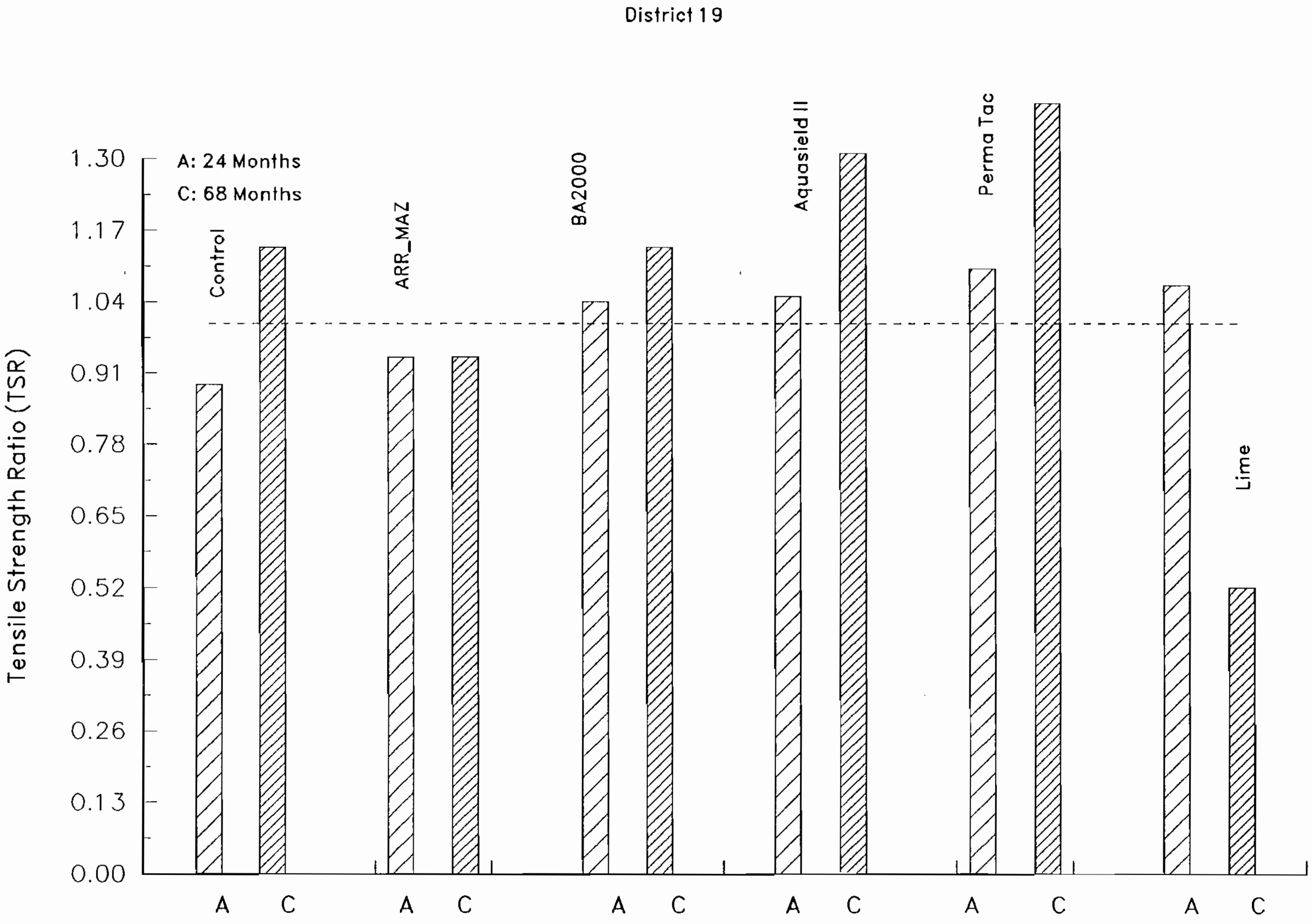


Figure B.14. TSR values at different pavement ages for District 19

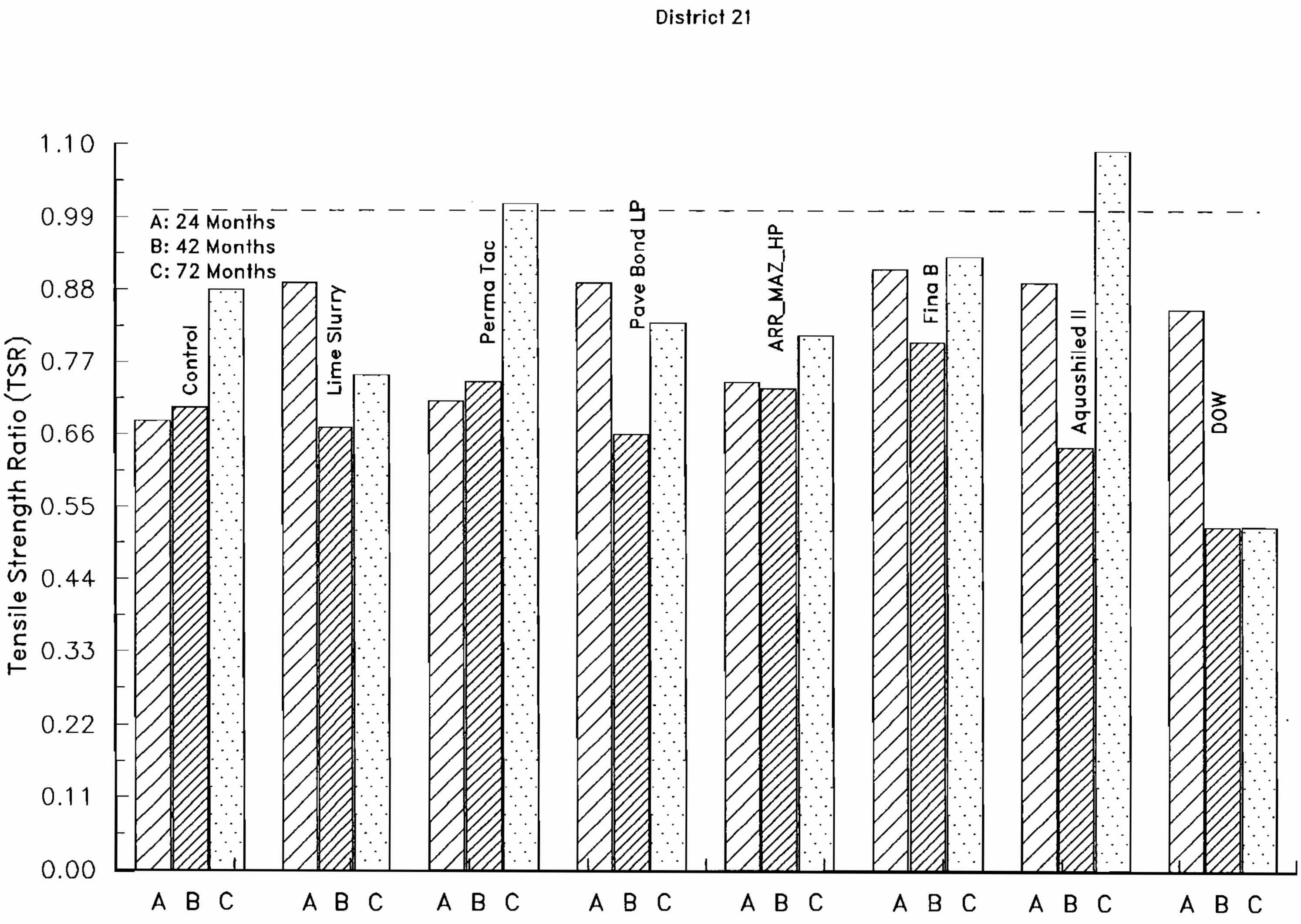


Figure B.15. TSR values at different pavement ages for District 21

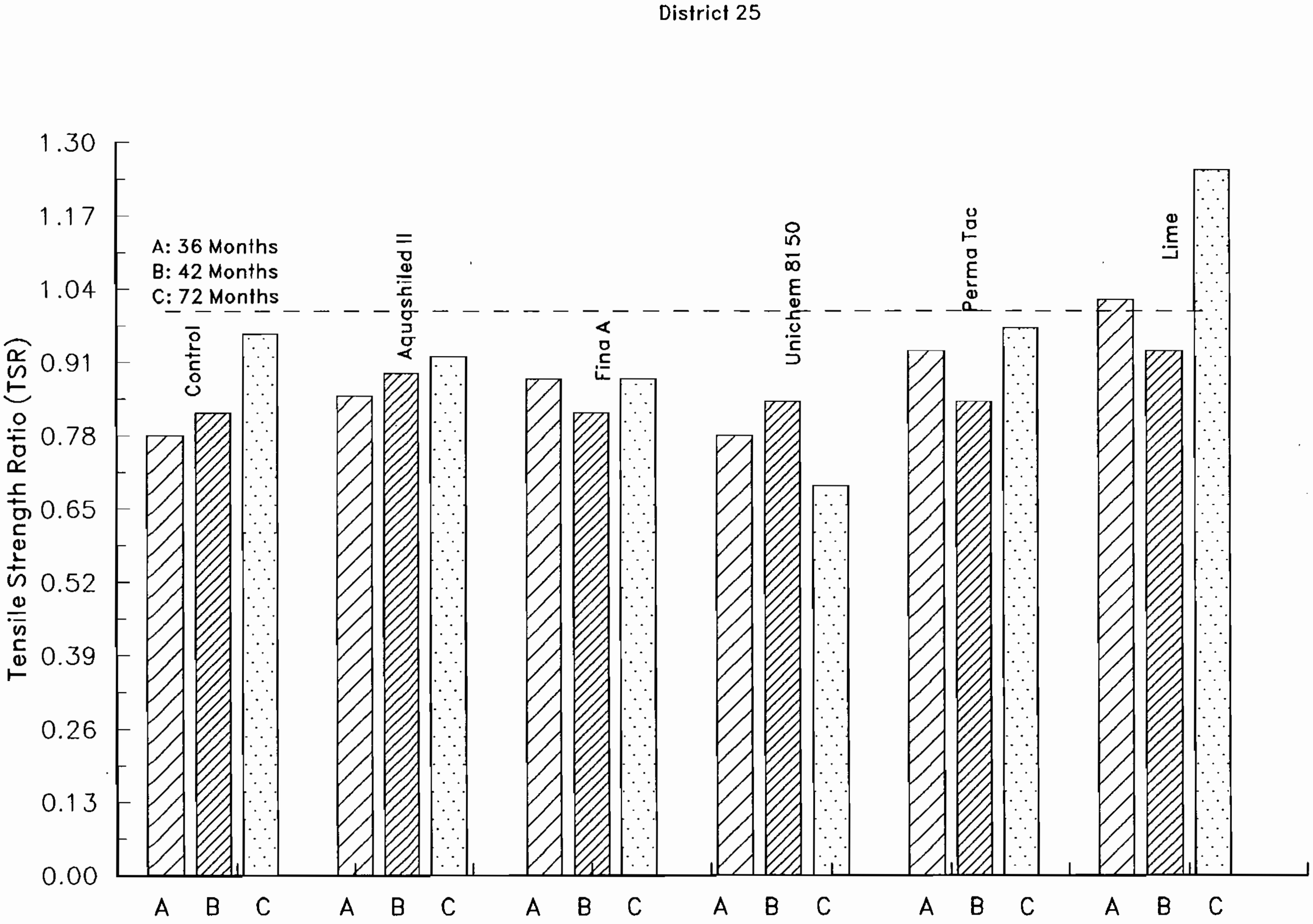


Figure B.16. TSR values at different pavement ages for District 25