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16. Abstract

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Both dry lime and lime slurry produced beneficial effects and improved moisture resistance of the laboratory and field mixtures as measured by the Texas boiling test, Texas freeze-thaw pedestal test, and the wet-dry indirect tensile test. Nevertheless, it appeared that lime slurry produced slightly improved moisture resistance. The only technique which was questionable involved introducing dry lime into the drum mix plant. Under the conditions of this study it appeared that a great deal of the lime was lost prior to mixing with asphalt.

In laboratory prepared mixtures, it was also noted that washing the aggregate prior to use appeared to reduce the moisture resistance of the resulting asphalt mixture.

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A FIELD EVALUATION OF TECHNIQUES FOR TREATING ASPHALT MIXTURES WITH LIME

by

Thomas W. Kennedy
James N. Anagnos

Research Report Number 253-6

Moisture Effects on Asphalt Mixtures
Research Project 3-9-79-253

conducted for

Texas
State Department of Highways and Public Transportation

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

Center for Transportation Research
Bureau of Engineering Research
The University of Texas at Austin

November 1984

PREFACE

This is the sixth in a series of reports dealing with the findings of a research project concerned with moisture effects on asphalt mixtures. This report is concerned with a field evaluation of techniques for treating asphalt mixtures with hydrated lime to increase the resistance to moisture damage or stripping.

Special appreciation is extended to Messrs. Pat Hardeman and Eugene Betts for their assistance in the testing program. The authors would also like to express their appreciation to Messrs. Billy R. Neeley, Materials and Tests Engineer, and Paul E. Krugler of the Texas Department of Highways and Public Transportation, for their suggestions, encouragement, and assistance in this research effort, and to Mr. Carol D. Zeigler, District Engineer, and Mr. Nick Turnham, both of District 17, Bryan. In addition, the participation and help of Young Brothers Contractors and Mr. Charles Smoot at the Texas Hot Mix Pavement Association is acknowledged. Appreciation is also extended to the Center for Transportation Research staff who assisted in the preparation of the manuscript. The support of the Federal Highway Administration, Department of Transportation, is acknowledged.

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December 1984

LIST OF REPORTS

Report No. 253-1, "Stripping and Moisture Damage in Asphalt Mixtures," by Robert B. McGennis, Randy B. Machemehl, and Thomas W. Kennedy, summarizes a study to determine the extent, nature, and severity of moisture related damage to asphalt mixtures used in pavements in Texas.

Report No. 253-2, "An Evaluation of the Asphaltene Settling Test," by Thomas W. Kennedy and Chee-Chong Lin, summarizes a testing program designed to evaluate the Asphaltene Settling Test, the test procedure, factors affecting the test results, and relationships between settling time and asphalt characteristics.

Report No. 253-3, "Texas Freeze-Thaw Pedestal Test for Evaluating Moisture Susceptibility for Asphalt Mixtures," by Thomas W. Kennedy, Freddy L. Roberts, Kang W. Lee, and James N. Anagnos, includes a detailed description of the Texas Freeze-Thaw Pedestal Test and describes how it can be used to distinguish between stripping and nonstripping asphalt concrete mixtures or individual aggregates.

Report No. 253-4, "Lime Treatment of Asphalt Mixtures," by Thomas W. Kennedy and James N. Anagnos, summarizes information related to stripping of asphalt mixtures and the use of hydrated lime as an antistripping agent and makes recommendations concerning the construction techniques for adding lime.

Report No. 253-5, "Texas Boiling Test for Evaluating Moisture Susceptibility of Asphalt Mixtures," by Thomas W. Kennedy, Freddy L. Roberts, and James N. Anagnos, includes a detailed description and evaluation of the Texas Boiling Test Method and also describes how it can be used to distinguish between stripping and nonstripping asphalt concrete mixtures or individual aggregates.

Report No. 253-6, "A Field Evaluation of Techniques for Treating Asphalt Mixtures with Lime," by Thomas W. Kennedy and James N. Anagnos details a field study to evaluate the use of dry lime and lime slurry in asphalt mixtures.

ABSTRACT

This report summarizes a field study to evaluate methods of treating asphalt mixtures with both dry hydrated lime and hydrated lime slurry to reduce or alleviate moisture damage. Both batch and drum plants were used to produce the treated and untreated field mixtures. In addition to plant produced mixtures, laboratory mixtures were prepared using methods which simulated the field procedures. Cores were taken from the roadway approximately six months after construction, but the results are not contained in this report.

Both dry lime and lime slurry produced beneficial effects and improved moisture resistance of the laboratory and field mixtures as measured by the Texas boiling test, Texas freeze-thaw pedestal test, and the wet-dry indirect tensile test. Nevertheless, it appeared that lime slurry produced slightly improved moisture resistance. The only technique which was questionable involved introducing dry lime into the drum mix plant. Under the conditions of this study it appeared that a great deal of the lime was lost prior to mixing with asphalt.

In laboratory prepared mixtures, it was also noted that washing the aggregate prior to use appeared to reduce the moisture resistance of the resulting asphalt mixture.

KEY WORDS: stripping, water damage, asphalt mixtures, stripping aggregates, stripping asphalt mixtures, lime, hydrated lime, field study

SUMMARY

A field study was conducted to evaluate methods of treating asphalt mixtures with both dry hydrated lime and hydrated lime slurry in order to minimize moisture damage. Both batch and drum plants were used to produce the teated and untreated field mixtures. In addition, laboratory mixtures were prepared using methods intended to simulate field procedures.

Both dry lime and lime slurry produced improved moisture resistance of both the laboratory and field mixtures. The lime slurry, however, produced slightly better results. The only technique which was judged not to be beneficial involved injecting dry hydrated lime into the drum mixer just before the asphalt was introduced. This lack of improvement was due to the fact that the hydrated lime was lost prior to mixing with asphalt.

It was also concluded that the wet-dry indirect tensile test, Texas boiling test, and Texas freeze-thaw pedestal test were effective in identifying moisture susceptible aggregates. When using the wet-dry indirect tensile test, care should be taken to insure that approximately 7 percent air voids exist in the tested specimen and that the degree of saturation is between 60 and 80 percent.

Based on the results of this study, it is felt that the recommendations contained in Research Report 253-4 should be followed with respect to techniques for adding hydrated lime to asphalt mixtures to alleviate moisture damage.

IMPLEMENTATION STATEMENT

The results of this study substantiate previous findings related to the beneficial effects of using hydrated lime as an antistripping additive. Lime slurry appeared to produce slightly better moisture resistant mixtures; however, dry lime was also effective.

All of the methods of adding lime to the mixture in the field were effective with the possible exception of introducing dry lime into the drum mix plant, which resulted in the lime being lost prior to coating the aggregate with asphalt.

If hydrated lime is to be used as an antistripping additive, the lime should be incorporated into the asphalt mixture following the recommendations contained in Research Report 253-4, "Lime Treatment of Asphalt Mixtures."

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CHAPTER 1. INTRODUCTION

Moisture-induced damage of asphalt concrete mixtures has produced serious pavement distress problems, reduced the acceptable performance period of pavements, created skid resistance problems, and increased maintenance requirements. Pavements with moisture-related distress have been reported throughout the United States, especially in the southeast and southwest.

Moisture-related damage occurs primarily because of stripping of the asphalt film from the aggregate and softening of the asphalt matrix (Ref 1). Stripping often produces bleeding, rutting, alligator cracking, and corrugations. The distress can develop rapidly on high traffic facilities and often becomes evident during periods of heavy rainfall and high temperatures. The cost of reconstruction, rehabilitation, and maintenance resulting from moisture-induced damage in asphalt concrete mixtures has become excessive in many states, including Texas. Clearly the most economic approach is to prevent the problem, not to repair its effect (Refs 1 through 17).

Research Project 3-9-79-253, entitled "Moisture Effects on Asphalt Mixtures," was initiated at The University of Texas at Austin and funded by the Texas State Department of Highways and Public Transportation and the Federal Highway Administration through the Cooperative Highway Research program (Refs 1-7). The objectives of the project were to determine the extent, severity, and nature of moisture damage in Texas; to develop test methods to evaluate the moisture susceptibility of asphalt mixtures; and to develop recommendations and procedures to eliminate or at least alleviate moisture damage.

A common method of reducing the water-susceptibility of asphalt concrete mixtures has been to use antistripping additives such as liquid antistripping agents or hydrated lime. Most liquid antistripping agents, although easy to handle from a construction standpoint, were found to be relatively ineffective and highly mixture dependent, as measured by laboratory tests (Refs 2 and 13) and actual pavement performance. By far the most effective additive was hydrated lime applied to the aggregate (Refs 3, 16, 17, and 18). Most of the laboratory research indicated that the most effective method for applying hydrated lime is in the form of a lime slurry or lime in the presence of moisture placed on the surface of the aggregate (Refs 3 and 17).

This report concerns the findings of a field study to evaluate techniques for adding dry lime and slurried lime in batch and drum mix plants. The field study was performed on a pavement widening project in Bryan, Texas, with the cooperation of the Texas State Department of Highways and Public Transportation, Young Brothers, Inc., contractors of Waco, Texas, and the Texas Hot Mix Asphalt Pavement Association. Testing and evaluation were performed by three agencies, Texas State Department of Highways and Public Transportation - District 17, The University of Texas at Austin, and Texas A&M University.

The primary objectives of this field study were to 1) determine the effectiveness of lime as an antistrip additive when added either dry or in slurry, 2) investigate the effect of time delay after lime treatment of aggregate, 3) evaluate the point of entry of lime in the production system, 4) assess the differences in mixtures produced in the batch and drum mix plants, and 5) correlate laboratory tests with performance.

Chapter 2 contains a description of the experimental program conducted by the Center for Transportation at The University of Texas at Austin. Chapter 3 summarizes the findings of the study, and Chapter 4 contains conclusions and recommendations.

CHAPTER 2. EXPERIMENTAL PROGRAM

The field study was conducted on a pavement widening project in Bryan, Texas. Testing and evaluations were conducted by The University of Texas at Austin, Texas A&M University, and District 17 of the State Department of Highways and Public Transportation. The experimental program, materials, and construction techniques are summarized below, along with a description of the testing and evaluation program conducted at The University of Texas. Details of the other two evaluations can be found in References 19 and 20, and a summary of the total study is contained in Reference 21.

MATERIALS AND PAVING MIXTURE

An AC-20 asphalt cement from the Exxon refinery in Baytown, Texas, was used throughout this study. Properties of the original asphalt are given in Table 1.

Three aggregates--crushed pea gravel, washed sand, and field sand, were combined to produce the project gradation. All three of the aggregates are siliceous. Gradations of the individual aggregates, the project gradation, percentages of each aggregate combined, specific gravities, and the specification are given in Table 2.

Dry hydrated lime was supplied in bags. When used as a slurry, it was mixed in a slurry mixer at a ratio, by weight, of 30 percent hydrated lime to 70 percent water, which is about the maximum ratio which can be pumped with conventional equipment. The lime was added to the asphalt mixture at a rate of 1.5 percent of dry hydrated lime by weight of the dry aggregate.

The asphalt concrete mixture used in this study met the Texas State Department of Highways and Public Transportation (SDHPT) specifications of Item 340, Type D (Modified) fine graded surface course (Ref 22). The mixture was designed without hydrated lime; however, in actual practice the lime should be included during the mixture design phase. Laboratory test results from this mixture design (Ref 19) are given below:

Asphalt Content - 5 percent

Average Density - 95.5 percent of theoretical maximum

TABLE 1. Properties of Asphalt Cement

Characteristic Measured	Measurement
Viscosity	
77°F (25°C), poise	2.75×10^6
140°F (60°C), poise	1983
275°F (135°C), poise	3.78
Penetration	
77°F (100 gm, 5 sec)	60
39.2°F (4°C) (100 gm, 5 sec)	0
39.2°F (4°C) (200 gm, 60 sec)	12
Softening Point, °F	122
Flash Point, °F	600+
Specific Gravity	1.03
After Thin Film Oven Test	
Viscosity @ 140°F	5316
Penetration @ 77°F	31
Weight Loss, percent	0*
Ductility, cm	150+
Viscosity Ratio	2.68
Retained Penetration, percent	52

*Actually a slight gain in weight (0.07%) was indicated by repeated tests.

TABLE 2. Aggregate Gradations and Specific Gravities*

	Processed Pea Gravel	Washed Sand	Field Sand	Combined Gradation	Specification**
Gradation, percent					
Plus 1/2 in.	0			0	0
1/2 to 3/8 in.	0.4	0		0.3	0-5
3/8 to No. 4	61.6	3.6		38.7	20-50
No. 4 to No. 10	35.5	18.7		24.8	10-30
Plus No. 10	97.5	22.3	0	63.8	50-70
No. 10 to No. 40	2.0	49.3	0.4	8.7	0-30
No. 40 to No. 80	0.2	26.2	48.0	15.0	4-25
No. 80 to No. 200	0.1	1.7	44.8	10.7	3-25
Minus No. 200	0.2	0.5	6.8	1.8	0-6
Percent Combined	62 +	15 +	23 =	100	
Bulk Specific Gravity***					
Plus No. 10	2.639	2.615	-		
Minus No. 10 - Plus No. 80	-	2.637	2.637		
Minus No. 80	-		2.709		
Combined	-	-	-	2.646	

*Data furnished by Texas SDHPT District 17 laboratory personnel (Ref 19).

**Item 340, Type D (modified) (Ref 22).

***Test Methods Tex-201-F and Tex-202-F (Ref 23).

Air Void Content - 4.5 percent

Hveem Stability - 41

Cohesiometer Value - 164

PAVEMENT TEST SECTIONS

The test pavements were installed on Villa Maria Road in Bryan, Texas, in August, 1982, and involved reconstruction and widening to four lanes of a major urban arterial. The test sections were installed in the two northbound lanes. Each test section was approximately three inches thick, 12 feet wide, and 600 feet long and contained approximately 150 tons of the experimental asphalt concrete. Descriptions of the test sections are contained in Table 3 and numbered in chronological order of construction. The location of the fifteen test sections and a typical cross section of the test pavement structure are shown in Figures 1 and 2.

During construction the two northbound lanes were temporarily designated as a two-way facility to carry all the traffic in both directions for eight months. Average daily traffic (ADT) was approximately 8,500 in January, 1981.

FIELD OPERATIONS

Batch and drum mix plants, located at the same site, were used to prepare hot mixed asphalt mixtures containing dry or slurried lime. Identical materials sources were utilized throughout the experiment.

Treatment of Aggregates

Methods of adding the hydrated lime to the aggregates are listed in Table 3 and are summarized below.

Dry Lime. Three methods were used for the addition of dry lime and varied depending on plant type.

a. Batch Plant

Dry lime was manually placed in the pugmill after an initial 15-second dry mixing and was mixed with the aggregate for about 15 seconds prior to the addition of the asphalt cement; mixing then continued for an additional 20 seconds.

TABLE 3. Methods of Adding Lime to Asphalt Mixtures

Type of Plant	Method of Adding Lime	Test Section No.
Batch Plant	Control (No Lime)	3
	Dry Lime in Pugmill*	4
	Slurry on Total Aggregate + 2 days in Stockpile	7
Drum Mix Plant	Control (No Lime)	13
	Dry Lime on Total Aggregate at Cold Feed Belt	12
	Dry Lime at Center of Drum thru Fines Feeder	14
	Slurry on Field Sand at Cold Feed Belt	1
	Slurry on Washed Sand at Cold Feed Belt	2
	Slurry on Pea Gravel at Cold Feed Belt	5
	Slurry on Total Aggregate at Cold Feed Belt	6
	Slurry on Field Sand + 2 days in Stockpile	8
	Slurry on Washed Sand + 2 days in Stockpile	9
	Slurry on Pea Gravel + 2 days in Stockpile	10
	Slurry on Total Aggregate + 2 days in Stockpile	11
	Slurry on Total Aggregate + 30 days in Stockpile	15

*Dry lime was added and mixed for approximately 15 seconds prior to addition of asphalt cement.

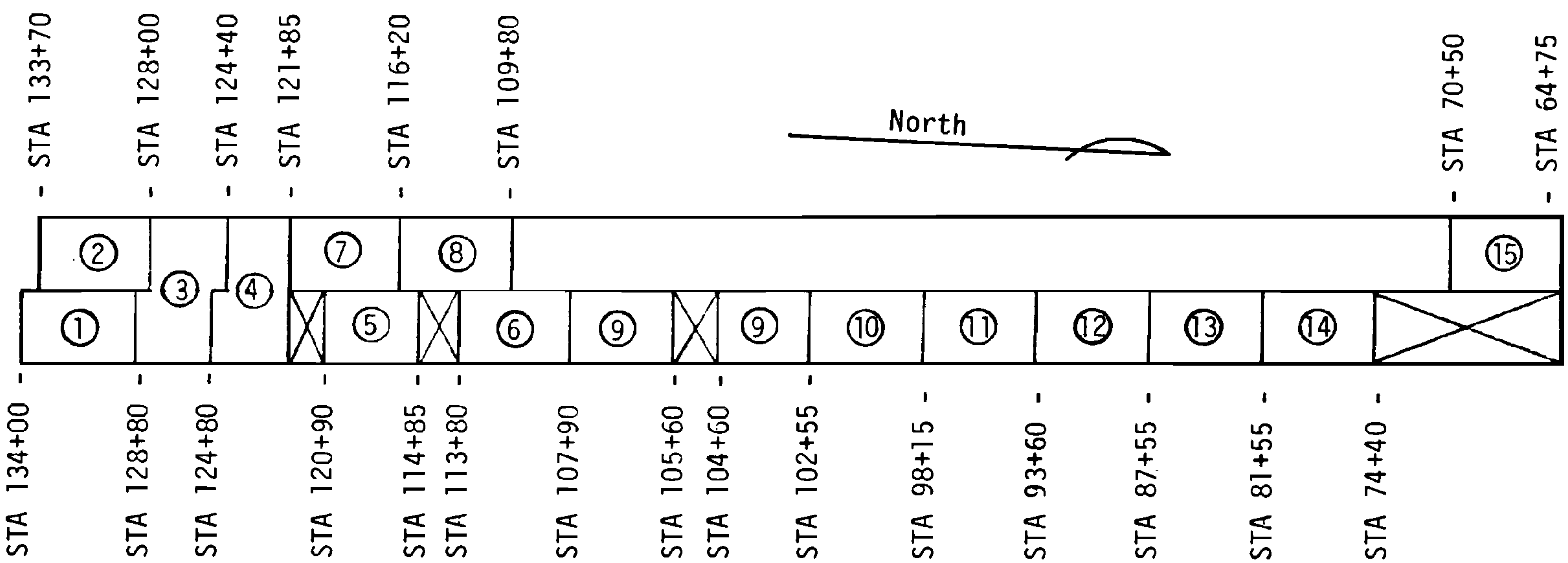

Figure 1. Map Showing Location of Test Sections in Northbound Lanes of Villa Maria Road in Bryan (not to scale). (Sections are identified in Table 3.)

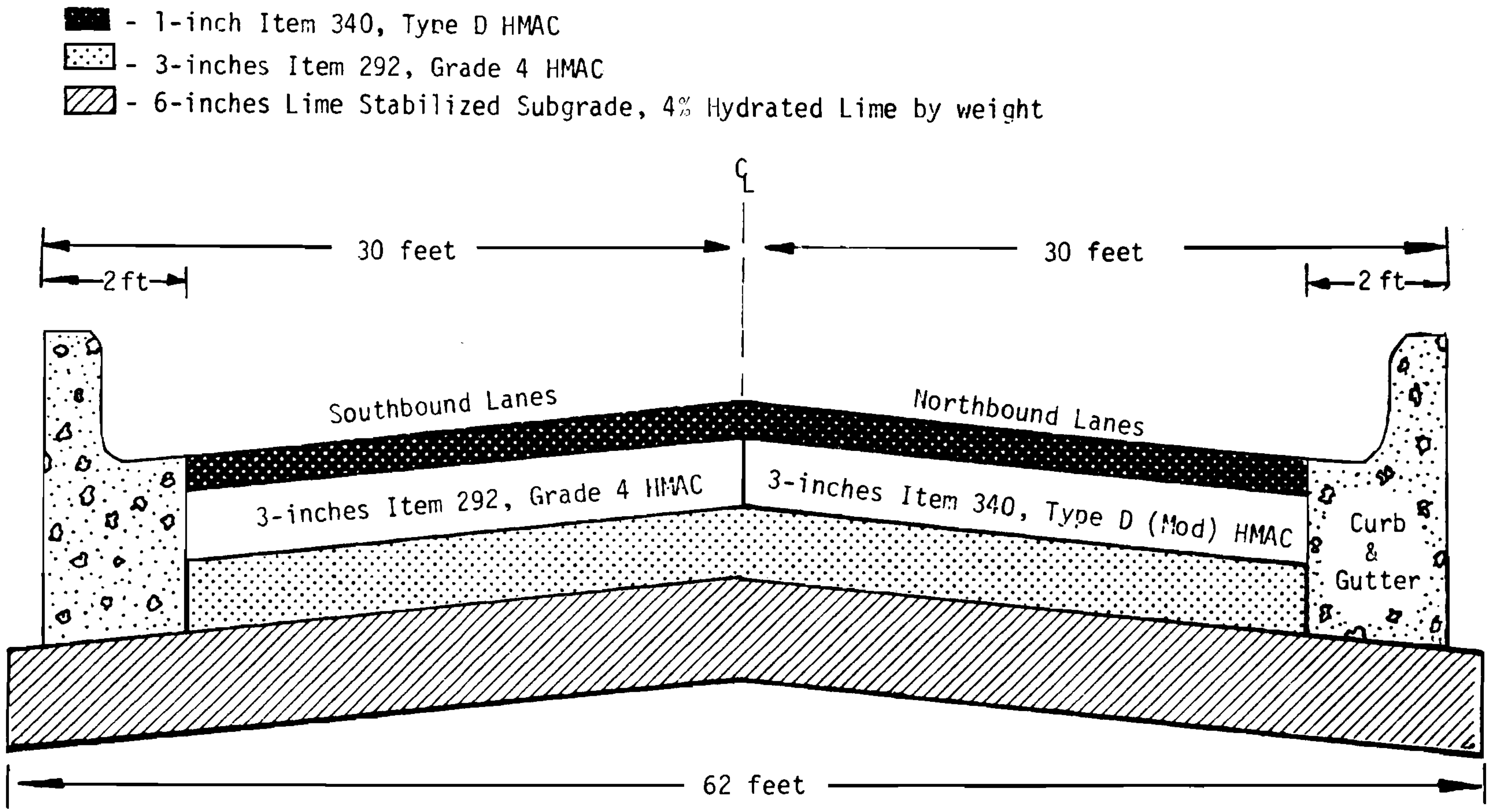

Figure 2. Typical Section of Pavement Structure on Villa Maria Road (not to scale).

b. Drum Plant

Two methods were utilized to introduce dry lime into the mixtures produced in the drum plant. One method employed the fines feeder from the baghouse. Dry lime was metered into the fines feeder using a vane feeder equipped with a compressed air stream to insure continuous flow of the lime. The lime was then blown into the drum just ahead of the asphalt stream. This location was selected so that the dry lime would immediately encounter the asphalt cement and minimize the loss of lime into the baghouse. The second method involved adding the dry lime directly to the aggregates on the cold feed belt utilizing the above vane feeder system.

Slurried Lime. Lime slurry was added to the individual aggregates immediately after being discharged from the cold feed bins on the cold feed belt (Fig 3). This allowed individual aggregates or combination aggregates to be treated. For aggregates which were stockpiled the individual aggregates were treated using the same system and stockpiled separately.

a. Batch Plant

The only procedure utilized for the batch plant involved treating all aggregates and stockpiling for 2 days prior to mixing with asphalt.

b. Drum Plant

The addition of slurried lime involved

1) treatment of all aggregates;
2) treatment of individual aggregates with the other two aggregates untreated followed by immediate mixing and stockpiling for 2 days prior to mixing;
3) treatment of all aggregates and stockpiling for 30 days prior to mixing.

When lime slurry was introduced on the cold feed belt, minimal mixing occurred until the lime-treated aggregate passed through the scalping screen (Fig 3). Nevertheless, when lime slurry was added to a given aggregate (field sand, washed sand, or pea gravel) at a rate of 1.5 percent by weight of that particular aggregate, the net effect was to simply reduce the lime content of the final paving mixture.

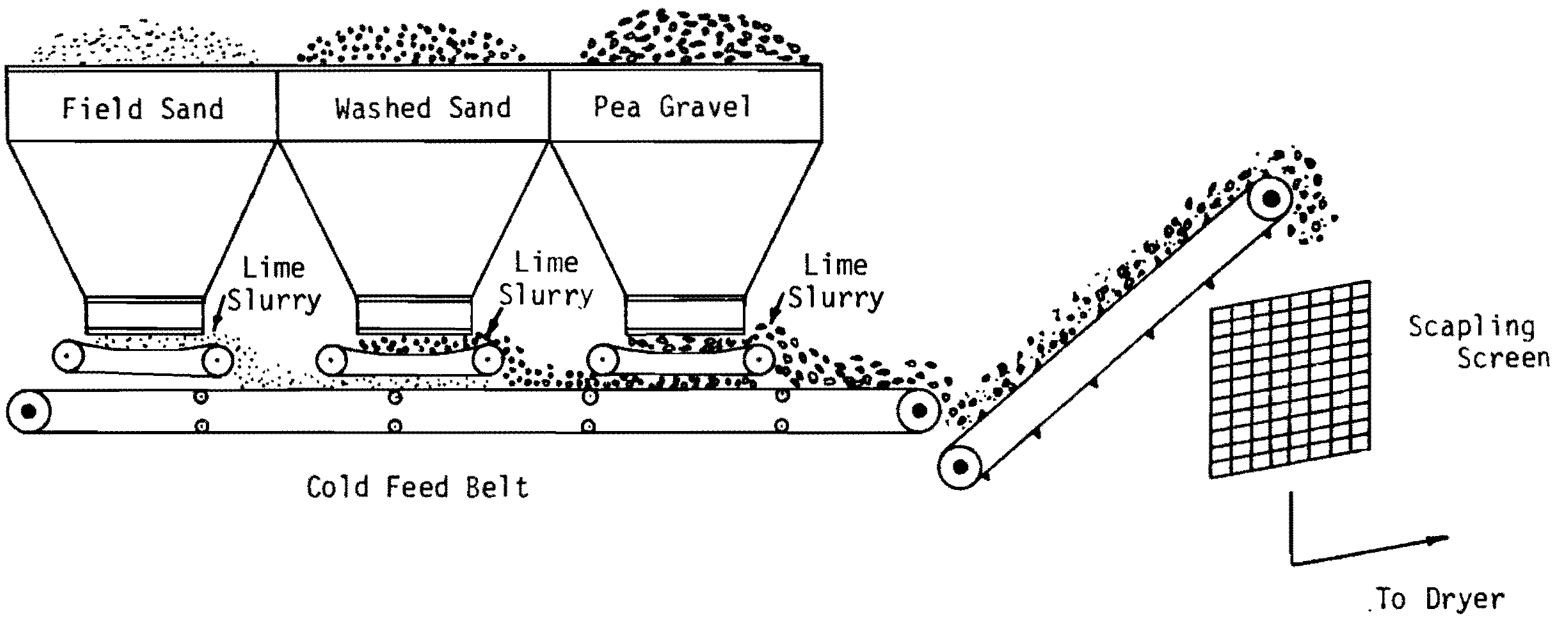

Figure 3. Process by which Lime Slurry was Added to the Individual Aggregates on the Cold Feed Belt.

Compaction

Compaction of the three-inch lift was initiated approximately 20 to 40 minutes after placement by the paver. Two vibratory passes were made using a 15-ton vibratory roller, followed by two or three more passes made using the same roller with no vibration. Final rolling involved using an 8-ton pneumatic roller. Compaction using the vibratory steelwheel roller was accomplished when the mix temperature was between 170 and 260°F. The mix temperature was considerably cooler when the pneumatic roller was applied.

LABORATORY TESTING

Laboratory tests were performed on mixtures which were 1) mixed and compacted in the laboratory, and 2) mixed in the field and compacted in the laboratory. Tests were also scheduled for mixtures which were mixed in the field and compacted in the field (cores). Tests were also performed by Texas A&M University (Ref 20) and District 17 of the Texas SDHPT (Ref 19).

Based on a literature review and previous project findings and experience, the following tests were used to evaluate the moisture susceptibility of the treated and untreated mixtures:

1. Indirect Tensile Test with Lottman Conditioning (Ref 11),
2. Texas Freeze-Thaw Pedestal Test (Refs 5 and 17), and
3. Texas Boiling Test (Refs 4 and 17).

Laboratory Mixed/Laboratory Compacted Mixtures

Samples of the project asphalt cement, aggregates, and lime were obtained. These materials were mixed and compacted or prepared for testing in the laboratory in accordance with the design established by Texas SDHPT. Selected specimens were compacted at a reduced compactive effort to produce a higher air void content and thus provide a more severe test of moisture susceptibility.

Field Mixed/Laboratory Compacted Mixtures

Samples of the field mixtures were obtained at the asphalt mixing plant. They were immediately transported to the laboratory and compacted to fabricate 4-inch diameter specimens. Reheating was necessary to maintain a compaction temperature of 250°F; but reheating was kept to a minimum in order to minimize any changes in mixture properties.

Field Mixed/Field Compacted Mixtures

Field mixed and field compacted specimens consisted of 4-inch diameter pavement cores were obtained one to six weeks and six months after construction of the test pavements. Additional cores are scheduled for two years after placement.

TEST METHODS

Three test methods were utilized in the study. These tests, which are described below, were the wet-dry indirect tensile test, Texas freeze-thaw pedestal test, and the Texas boiling test.

Wet-Dry Indirect Tensile Test

Dry and wet specimens were tested using the indirect tensile test. The moisture susceptibility was measured in terms of the ratio of tensile strength in a wet condition to that in a dry condition, i.e., tensile strength ratio. Some of the earliest work in applying the indirect tensile test to the study of moisture damage was performed by Lottman (Ref 11).

In the indirect tensile test a cylindrical specimen is subjected to compressive loads distributed along two opposite generators that create a relatively uniform tensile stress perpendicular to and along the diametral plane containing the applied load which causes a splitting failure. Estimates of the tensile strength, modulus of elasticity, and Poisson's ratio can be calculated from the applied load and corresponding vertical and horizontal deformations.

Mixtures were prepared using 1) the standard gyratory compaction procedure used by SDHPT (approximately 3 percent air voids), and 2) a modified procedure which produced about 7 percent air voids.

Wet specimens were prepared by subjecting 4-inch diameter specimens to 26 inches (mercury) vacuum while submerged in water. After vacuum saturation, specimens were placed in a plastic bag along with a small amount of water and subjected to one cycle of freeze-thaw. All wet specimens were submerged in a water bath before testing. Mixtures which retained less than

70 percent of their dry strength were considered to be moisture susceptible; however, strength retention is highly dependent on moisture content. For proper evaluation, mixtures should have about 7 percent air voids and it is tentatively recommended that they should be conditioned to produce a degree of saturation equal to 60 to 75 percent rather than by the specified procedure used. Details of the test procedure are contained in Reference 6.

Texas Freeze-Thaw Pedestal Test

This test determines the number of freeze-thaw cycles required to induce cracking on the surface of a specimen. The pedestal test involves subjecting miniature asphalt-aggregate specimens to repeated freeze-thaw cycles (15 hours at 10°F and 9 hours at 120°F) while submerged in distilled water. The specimens, which are highly permeable (>30 percent air voids), allow easy penetration of water and are designed to minimize mechanical interlock of the aggregate particles by using a uniform aggregate size. Thus, the mixture properties are largely determined by the asphalt-aggregate adhesion. The moisture susceptibility of an asphalt concrete mixture is evaluated in terms of the number of freeze-thaw cycles required to crack a specimen seated on a beveled pedestal. Based on field performance, mixtures with less than 10 cycles are highly susceptible to stripping, while mixtures exhibiting more than 25 to 35 cycles are relatively nonsusceptible. Details of the test procedure are described in References 5 and 17.

Texas Boiling Test

In this test, which is a combination of boiling tests performed by various agencies, a visual observation is made of the extent of stripping of the asphalt from aggregate surfaces after the mixture has been subjected to the action of water at elevated temperatures for a specified time. To perform this test the cool, loose asphalt mixture, either plant or laboratory mixed, is boiled in distilled water for 10 minutes. After boiling, the mixture is allowed to cool, the water is drained, the mixture is allowed to dry, and the mixture is then compared to a standard reference which establishes the amount of asphalt retained. Mixtures with less than 70 percent retained asphalt are considered to be moisture susceptible; mixtures between 70 and 85 percent would probably benefit from treatment. Details of the test procedure are contained in References 4 and 17.

CHAPTER 3. TEST RESULTS AND EVALUATION

Test results include those performed on mixtures which were laboratory mixed and field mixed. Evaluations conducted by Texas A&M and District 17 are contained in References 19 and 20 and a summary of the test results obtained by all three agencies is contained in Reference 21.

For purposes of evaluation and discussion, the test results have been subdivided as follows:

- untreated aggregates,
- laboratory mixtures, and
- field mixtures.

UNTREATED AGGREGATES

Figure 4 contains the results of boiling and pedestal tests conducted on the combined and individual aggregates. The aggregates were tested as received without washing (unwashed) and after being washed in the laboratory (washed) to remove surface coatings. All untreated aggregates were susceptible to moisture damage except for the unwashed field sand which was moisture resistant as measured by the Texas boiling test and the Texas freeze-thaw pedestal test. Washing of the field sand, however, caused the material to be moisture susceptible, which was not consistent with the results reported by District 17 (Ref 19). It is also apparent that washing generally did not improve the resistance to moisture damage; however, the results were inconsistent.

LABORATORY MIXTURES

The results of pedestal tests, boiling tests, and indirect tensile test for combinations of all aggregates and individual aggregates which were treated with dry lime and with lime slurry followed by various curing periods prior to mixing with asphalt are shown in Figures 5 through 16.

Pedestal Tests

Pedestal test results for the total aggregate combination and for the individual aggregates separately are shown in Figures 5 through 8.

Figure 5 illustrates the significant improvements in moisture resistance produced by treating with either dry lime or lime slurry. No differences between techniques were detected although it appeared that the aggregates which were washed prior to treatment did not improve as much as the unwashed aggregates. In addition, there was no consistent trend related to curing time for the slurry treated mixtures.

Similar trends are also evident for the individual aggregates which were treated and tested separately (Figs 6 through 8). The pea gravel (Fig 6) exhibited the greatest improvement; however, no difference in technique could be detected since the treated specimens did not fail. For the field sand (Fig 7) there was actually a reduction in moisture resistance for the unwashed condition; however, it must be remembered that there is some question related to the values obtained for the untreated mixture. Nevertheless, for the washed aggregates the improvements were only minimal. Similarly, the improvements were only minimal for the washed sand (Fig 8).

Boiling Tests

Boiling test results for the total aggregate combination and for the individual aggregates separately are shown in Figures 9 through 12.

Figure 9 illustrates the beneficial effects of hydrated lime added to the aggregate and cured for as much as 30 days, added to the aggregate as a filler, and added to the asphalt cement. In all cases, the moisture resistance was significantly improved although generally the improvement did not increase the retained asphalt to levels exceeding the recommended value of 70 percent.

For the crushed pea gravel (Fig 10) the resistance to moisture damage was increased to about 85 percent retained asphalt except for the aggregate which was washed prior to treatment with dry lime. For the field sand, both dry lime and lime slurry significantly improved the moisture resistance of the washed aggregate but had little effect on the unwashed aggregate. The unwashed aggregate, however, exhibited satisfactory resistance without treatment. For the washed sand, the lime slurry treatment was effective but treatment with dry lime produced essentially no improvement.

Indirect Tensile Test

For indirect tensile test evaluations, only the total combined mixture was tested; however, in some cases only one aggregate component was treated prior to mixing with the asphalt cement. In addition, the mixtures were compacted using the standard gyratory compaction procedure, which produces a compacted mixture with about 3 percent air voids, and a modified procedure, which produces approximately 7 percent air. The results are summarized in Figures 13 through 16.

Figures 13 through 16 illustrate the results for specimens compacted using standard procedures and modified procedures. Figure 13 indicates that both dry lime and lime slurry were beneficial to improving the moisture susceptibility of specimens compacted using the standard procedure, although lime slurry was slightly better. Figure 14 indicates that lime slurry treatment of individual components was beneficial but that the treatment of only the field sand or washed sand did not generally produce as much benefit as the treatment of the pea gravel or the total aggregate.

Similar results were also observed for specimens produced using the modified compaction procedure (Figs 15 and 16). The improvement when only certain aggregates were treated, however, was not as great as with standard compaction, presumably because of the higher void content which allowed more water to enter the specimens and the fact that less lime was incorporated into the mixture.

General

The moisture resistance of asphalt-aggregate mixtures treated with hydrated lime in the laboratory was significantly improved. It also appeared that the improvement was slightly greater for lime slurry treatment than for treatment with dry lime. Generally, however, there were few, if any, consistent differences.

FIELD MIXTURES

The results for mixtures which were processed through the two plants and then compacted and/or tested in the laboratory are shown in Figures 17 through 28.

Boiling Tests

Boiling tests on the untreated drum and batch plant mixtures did not indicate serious moisture susceptibility (Figs 17, 18, and 19). In fact, the batch plant mixtures retained approximately 85 percent of the asphalt while the drum plant had a retained value of about 65 percent. Thus, for the batch plant, the addition of lime produced no significant improvements. Mixtures processed through a drum plant did exhibit improvements, with lime slurry being slightly more effective (Fig 17).

When only certain aggregates were treated with a lime slurry, and then processed through the drum plant without curing, the total mixture still showed improved moisture resistance (Fig 18). With a 2-day cure, the level of resistance was essentially the same regardless of whether the total mixture or individual aggregates were treated (Fig 19). It should also be noted that aggregates which were treated with lime slurry and then stockpiled produced favorable results although previous work in the laboratory (Ref 7) had indicated that the benefits of lime deteriorated with increased curing, presumably because of carbonation of the lime. A possible explanation is the fact that project stockpiles were relatively impermeable and that the environmental conditions were dry.

A comparison of values for laboratory and drum plant mixtures indicated that the values were reasonably close except for the untreated mixtures (Fig 19).

Indirect Tensile Tests

Dry and wet indirect tensile strengths and the tensile strength ratios, i.e., the ratios of wet strengths to dry strengths, are shown in Figures 24 through 28. For batch plants the lime slurry was more effective, especially for specimens with modified compaction (Fig 24). Similarly, for drum plants the lime slurry tended to be more effective, especially in comparison to the procedure in which dry lime was introduced into the drum (Figs 25 and 26). Standard compaction also produced higher resistance to moisture damage. For drum plant mixtures, slurry treatment of only a given aggregate component provided satisfactory mixtures (Figs 27 and 28); however, for modified compaction the resistance to moisture change was greater when the pea gravel was treated (Fig 28), presumably because of the higher overall lime content.

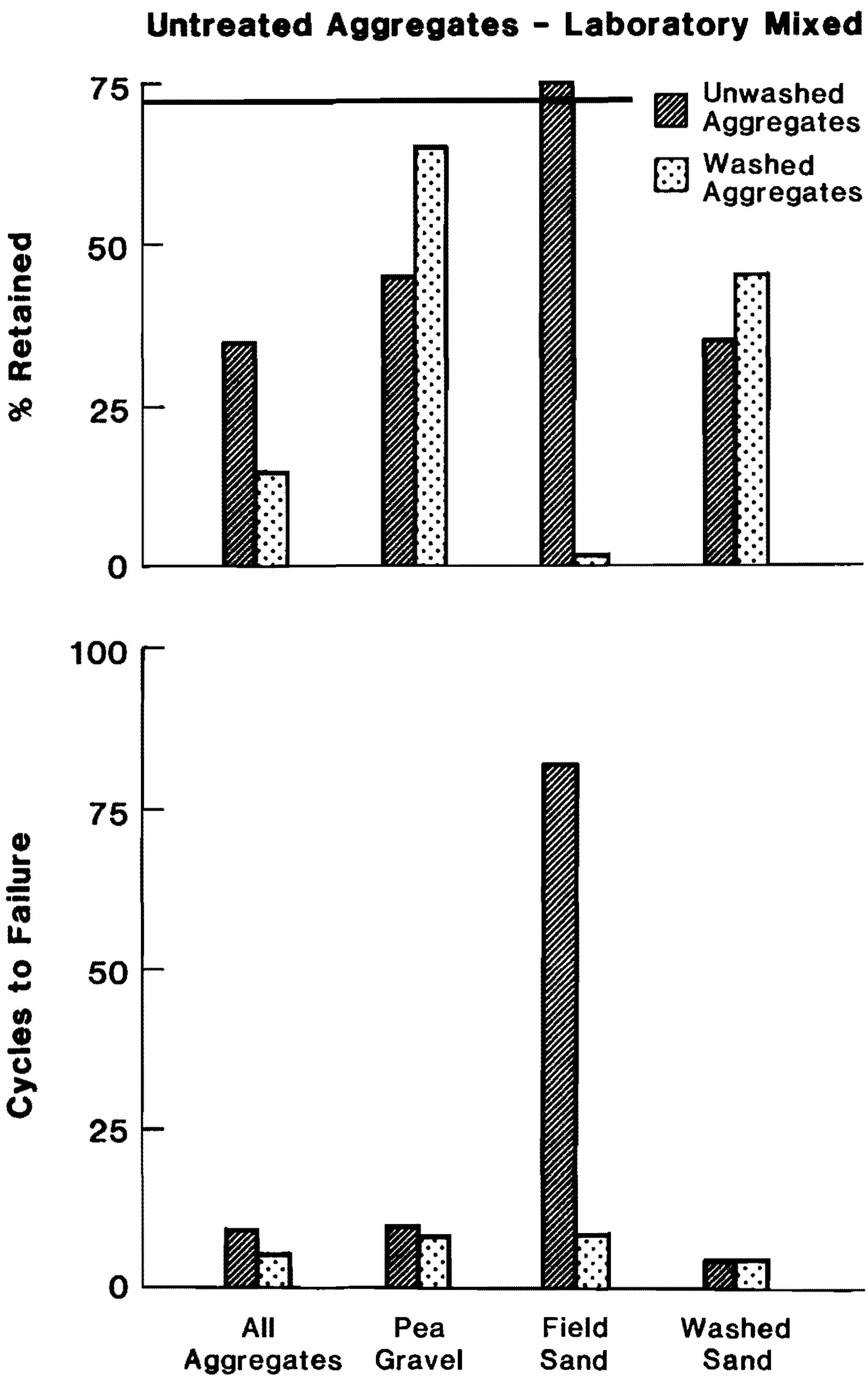

Fig 4. Boiling and pedestal test results for laboratory prepared untreated mixtures containing all aggregates and individual aggregates.

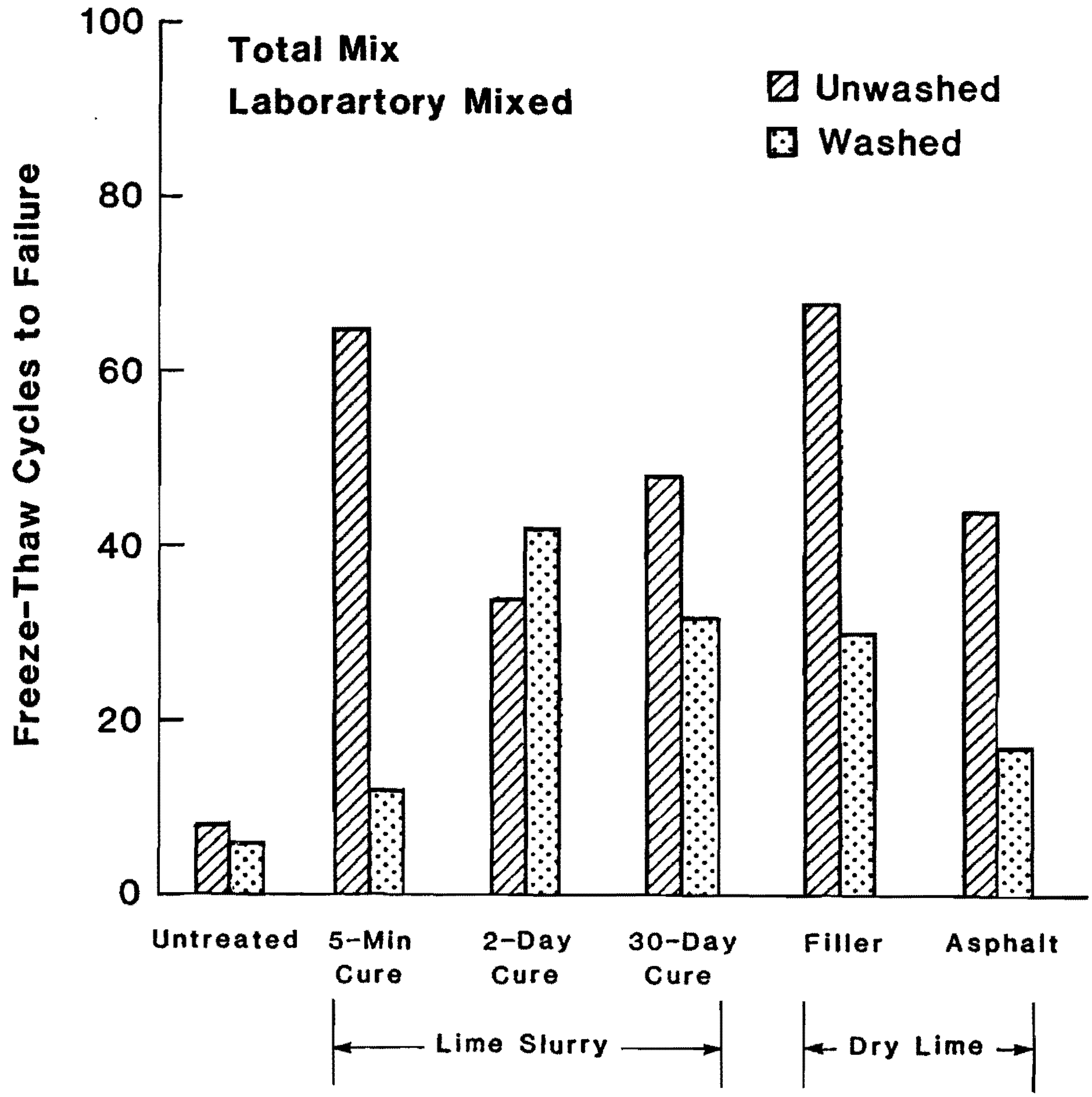

Fig 5. Pedestal test results for laboratory prepared mixtures treated with dry and slurry lime.

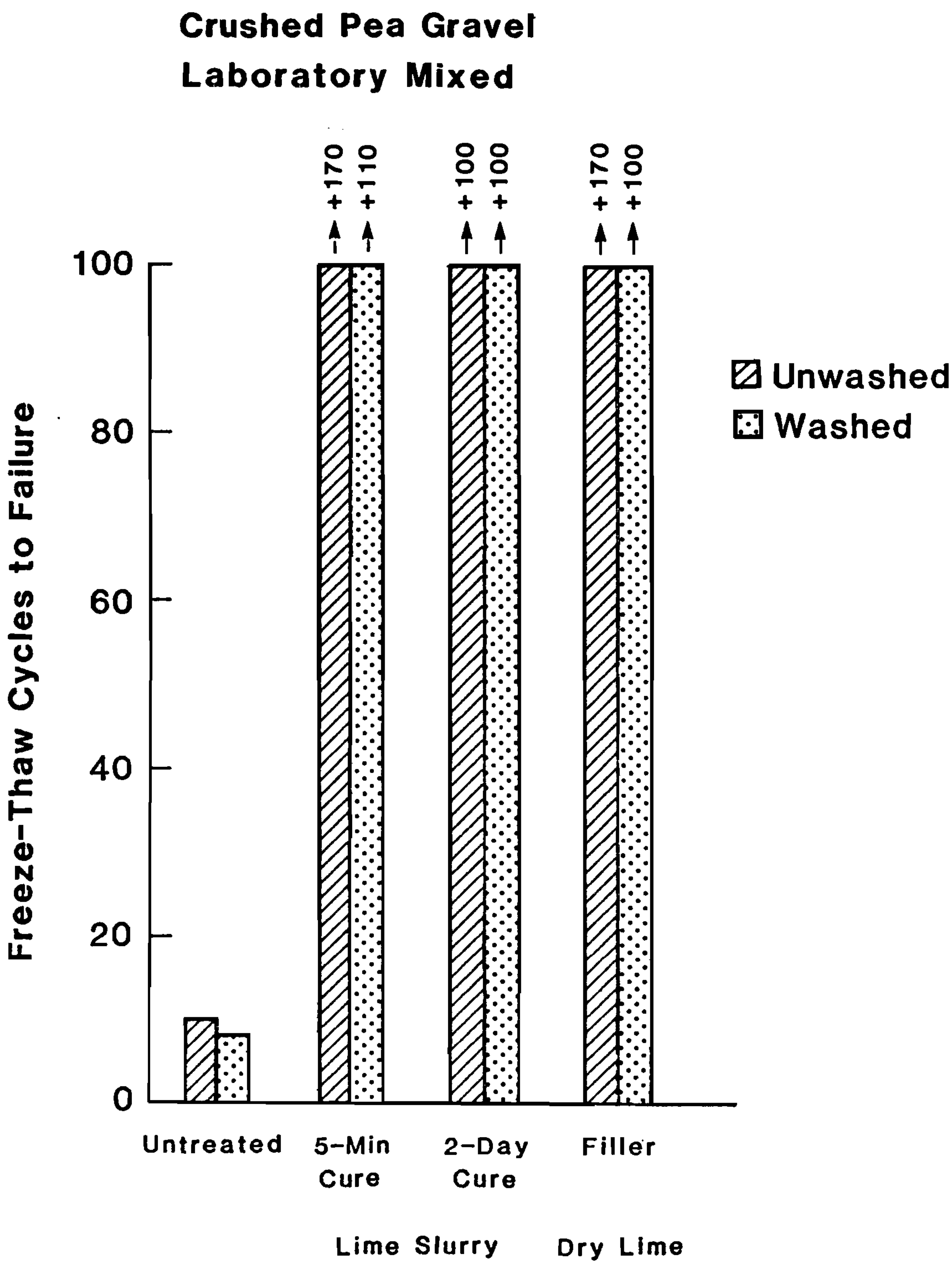

Fig 6. Pedestal test results for laboratory prepared mixtures containing only the crushed pea gravel treated with dry and slurry lime.

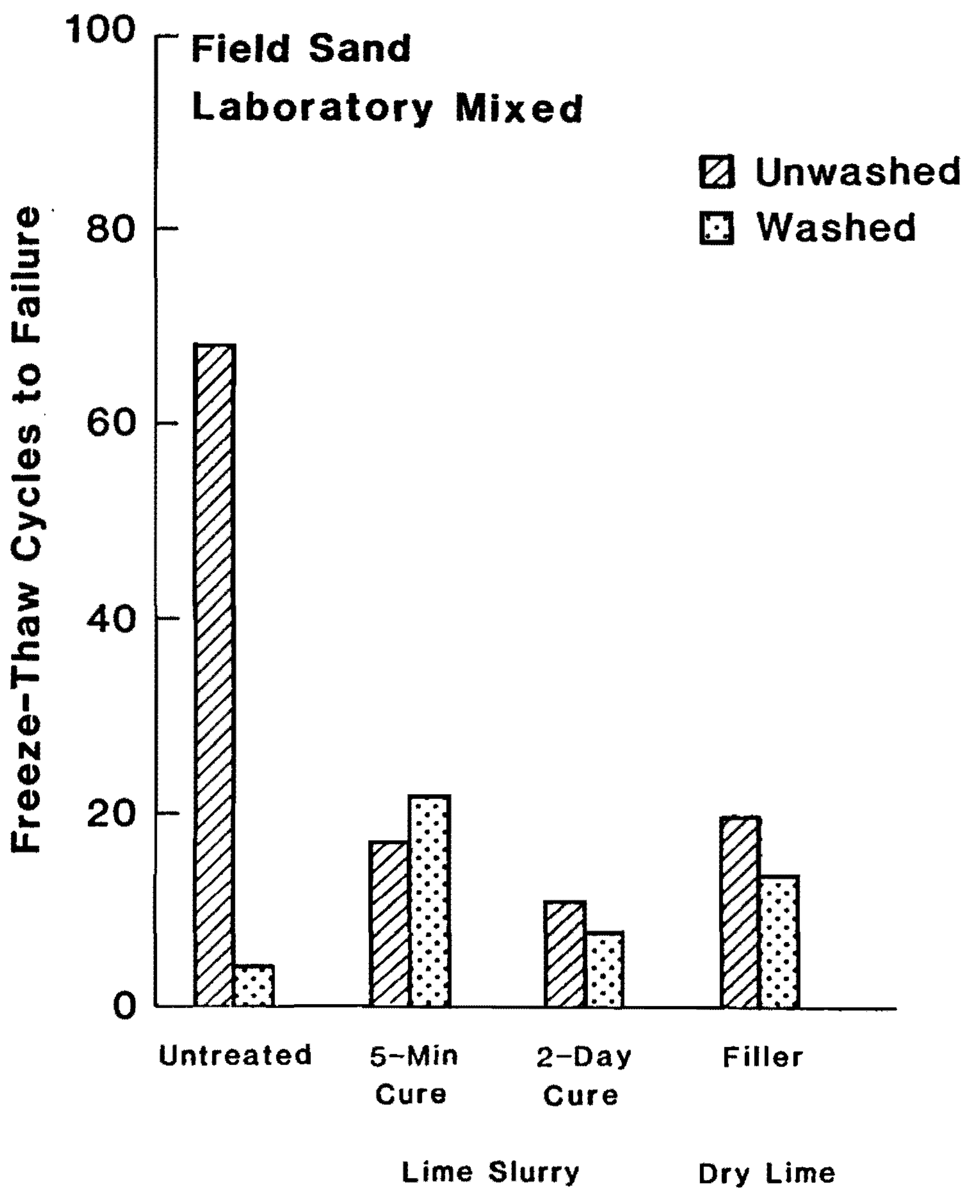

Fig 7. Pedestal test results for laboratory prepared mixtures containing only the field sand treated with dry and slurry lime.

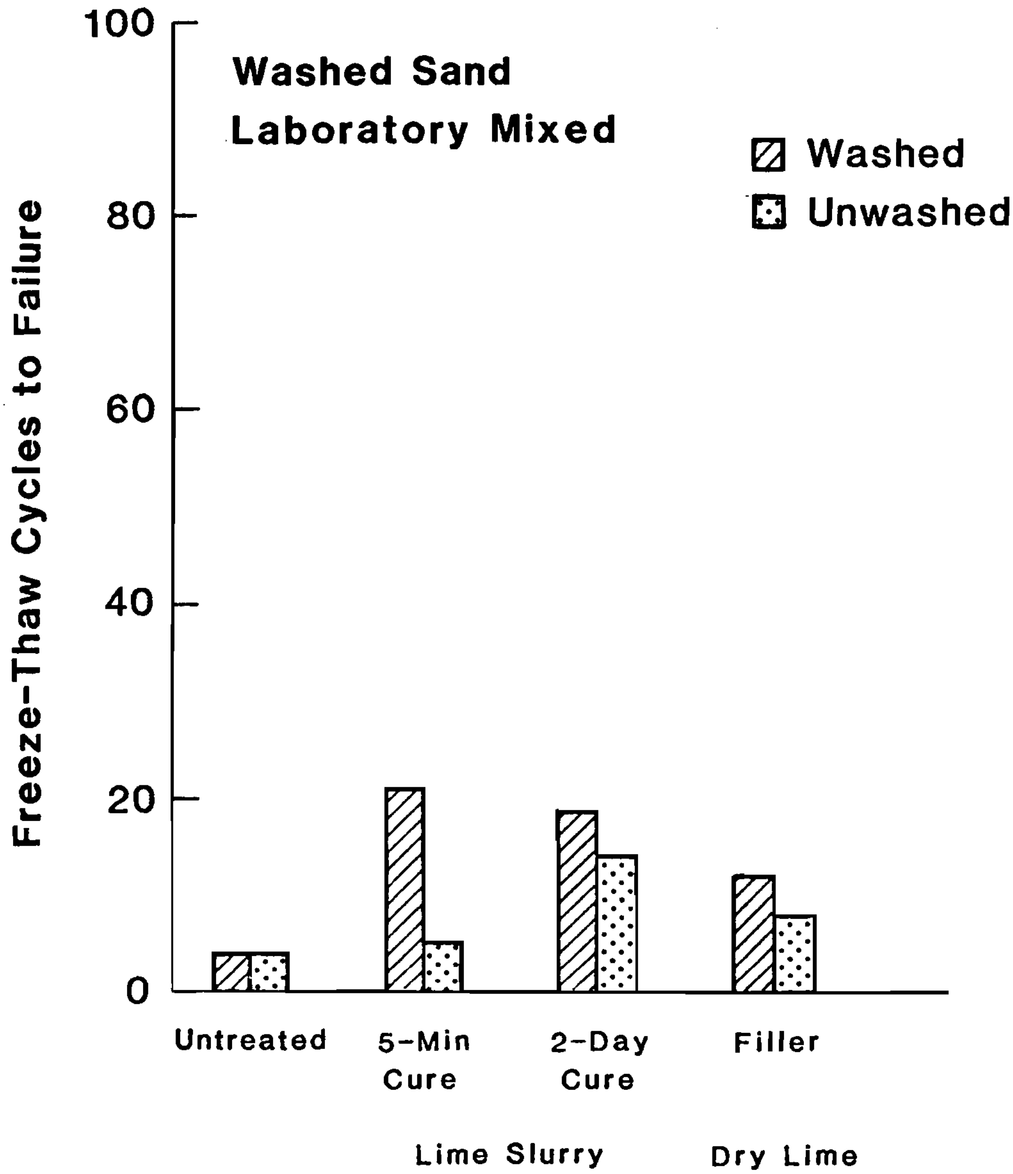

Fig 8. Pedestal test results for laboratory prepared mixtures containing only the washed sand treated with dry and slurry lime.

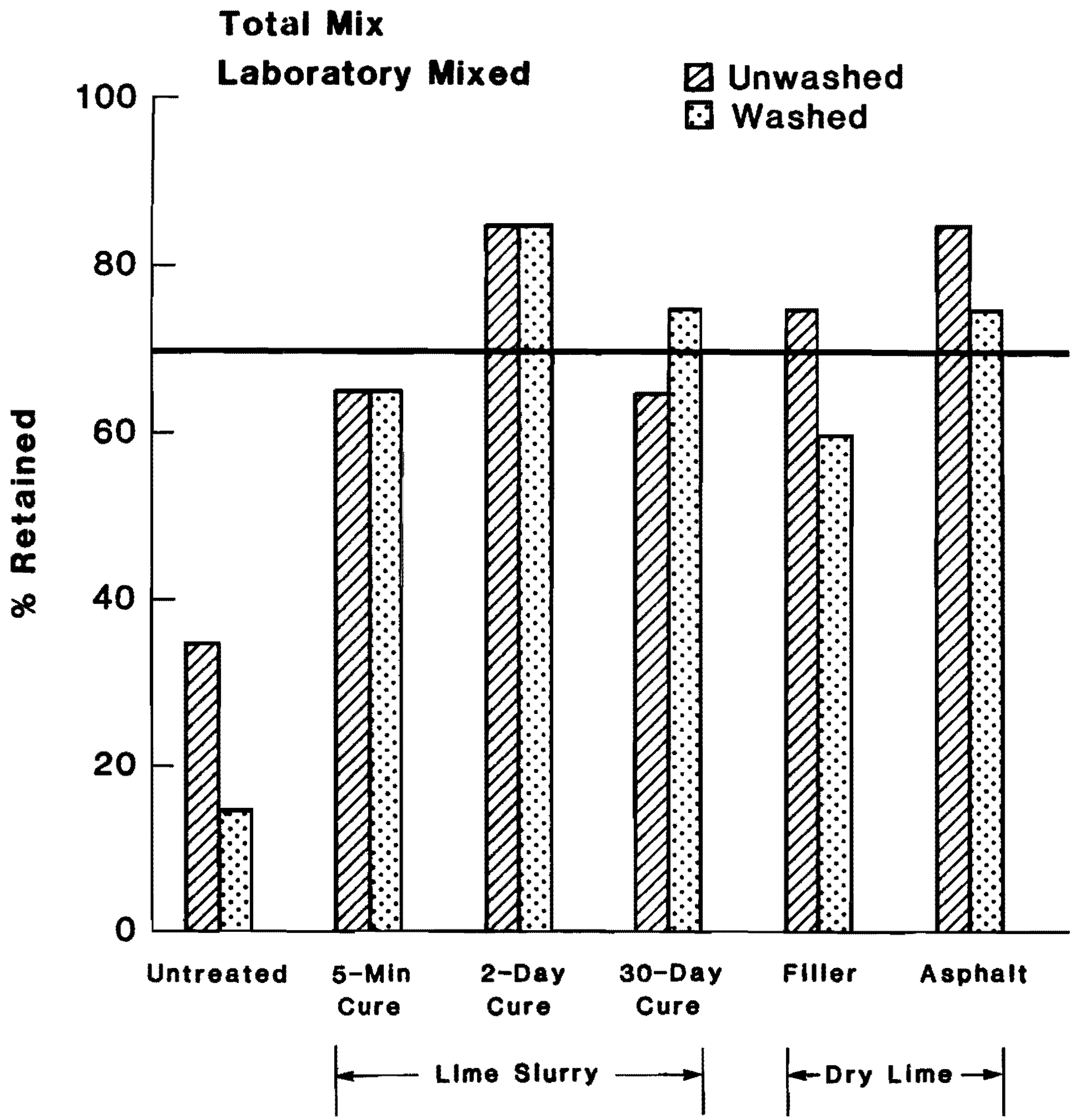

Fig 9. Boiling test results for laboratory prepared mixtures treated with dry and slurry lime.

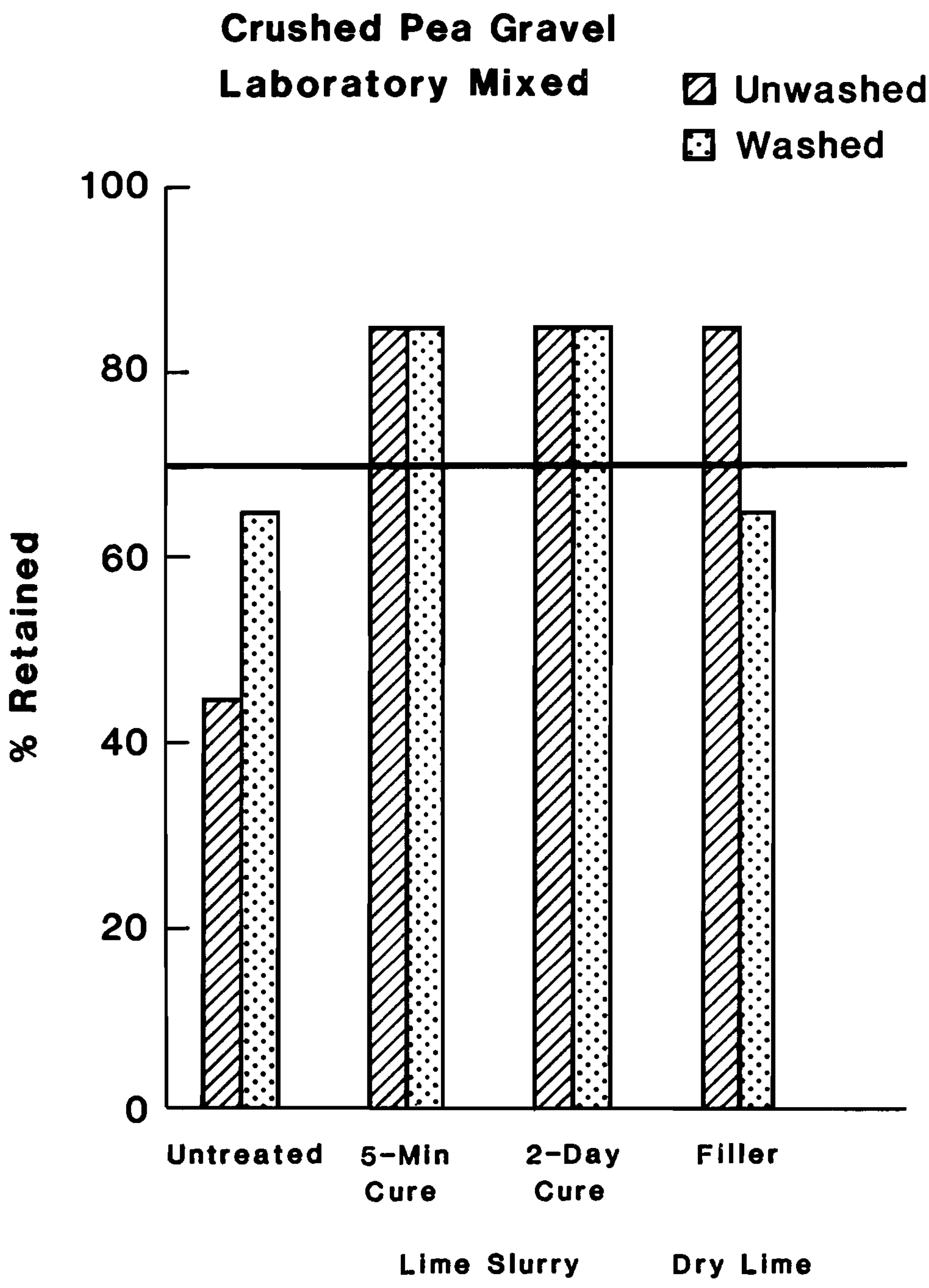

Fig 10. Boiling test results for laboratory prepared mixtures containing only the crushed pea gravel treated with dry and slurry lime.

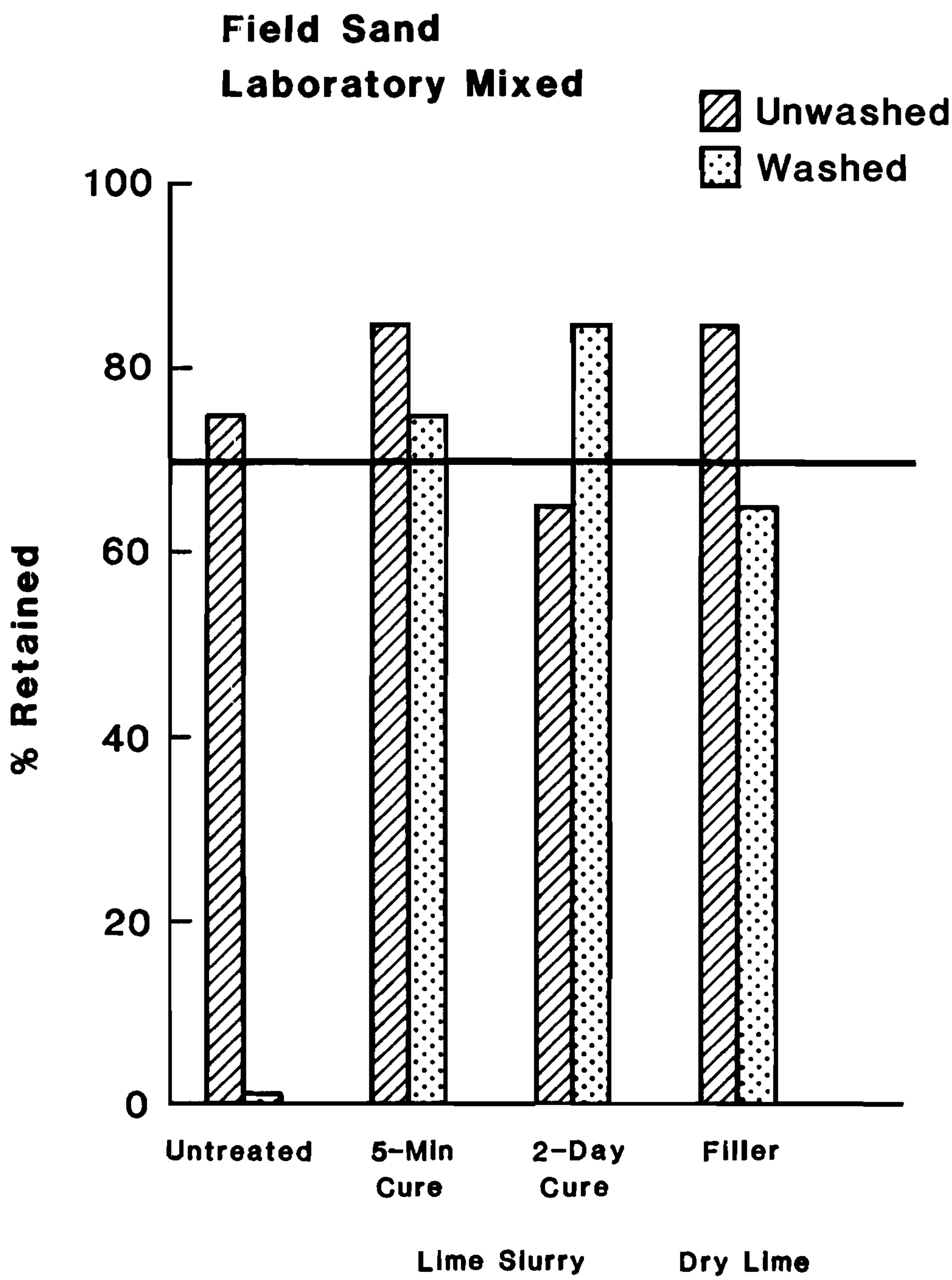

Fig 11. Boiling test results for laboratory prepared mixtures containing only the field sand treated with dry and slurry lime.

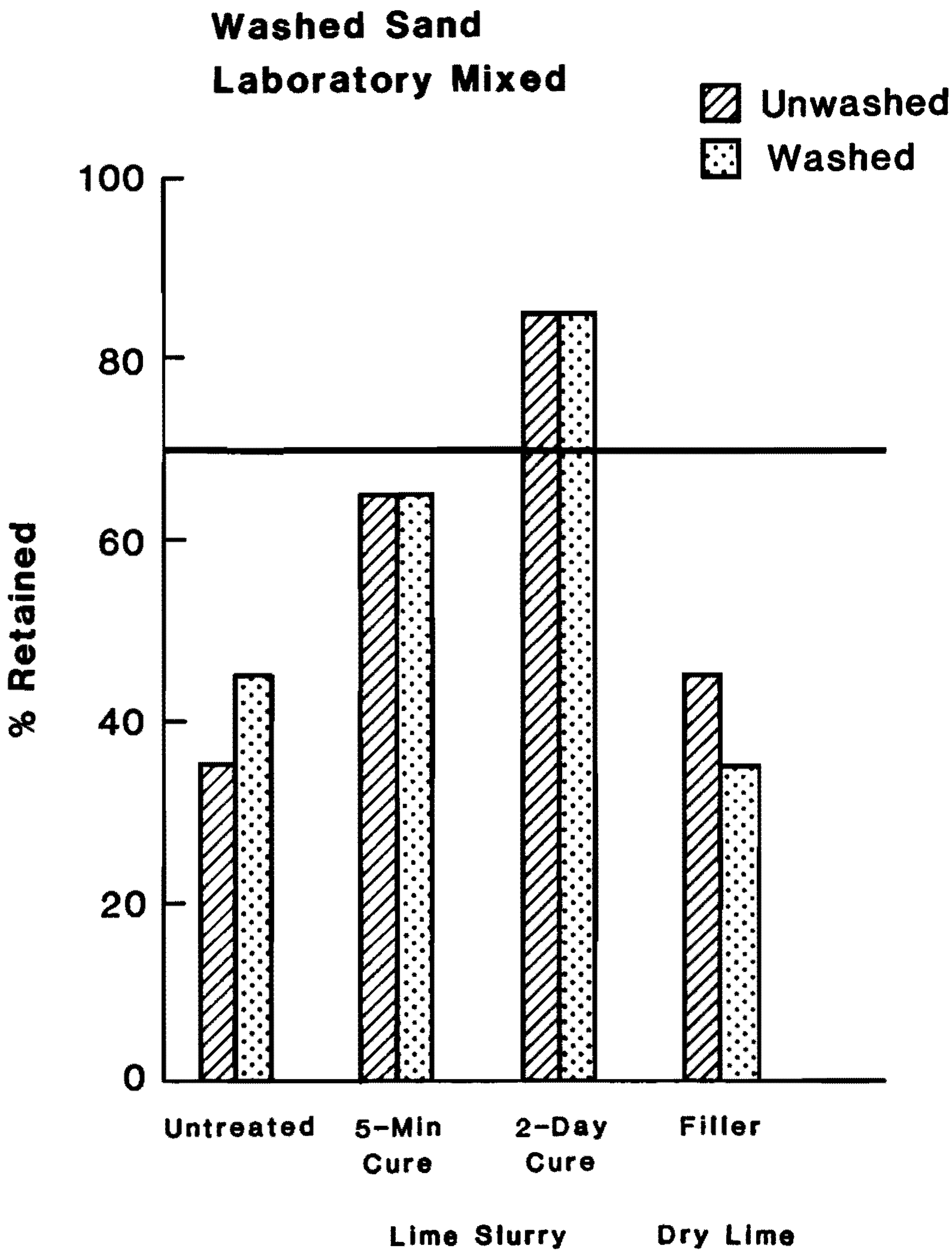

Fig 12. Boiling test results for laboratory prepared mixtures containing only the washed sand treated with dry and slurry lime.

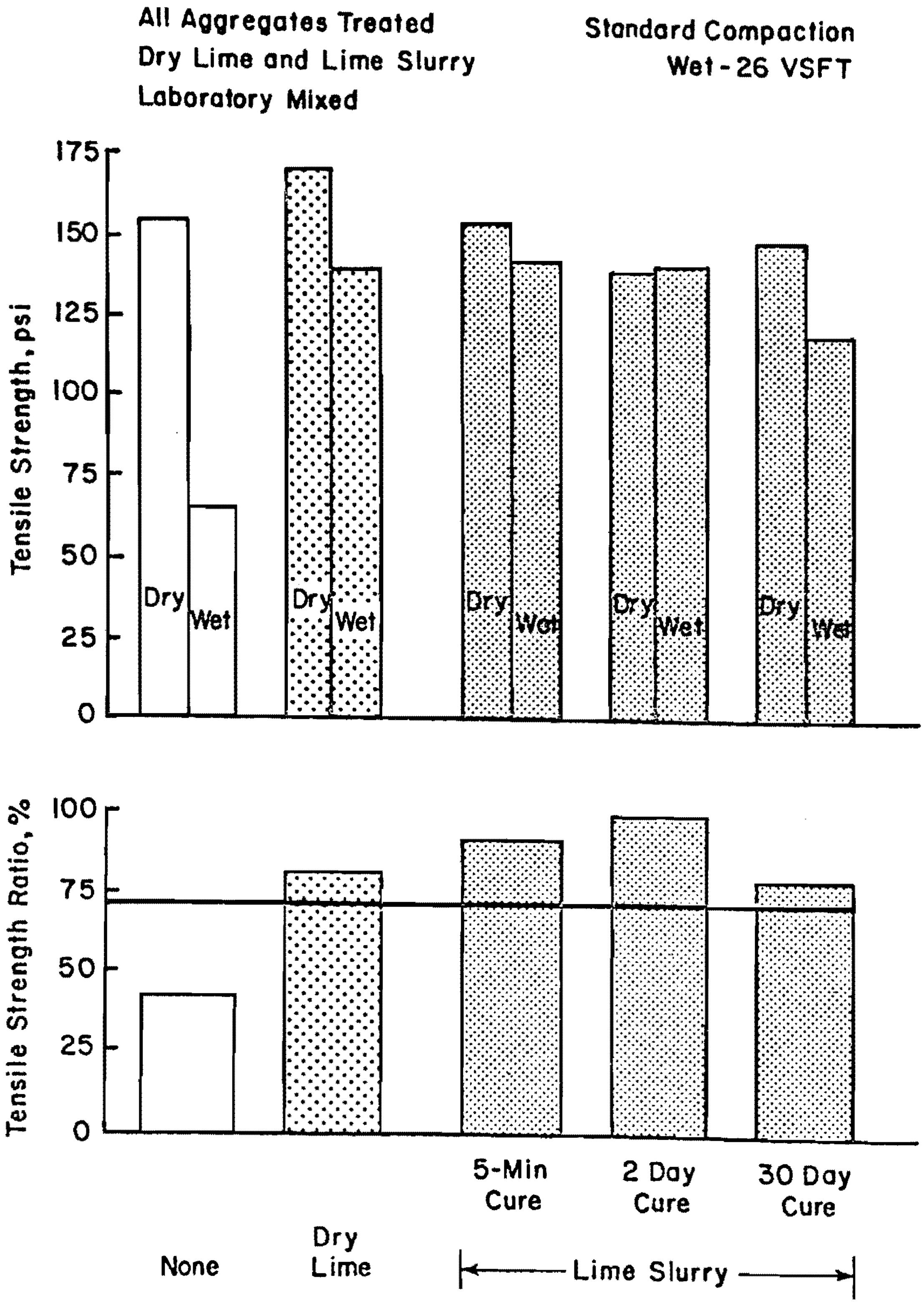

Fig 13. Indirect tensile test results for laboratory prepared combined mixture with dry and slurry lime using standard compaction.

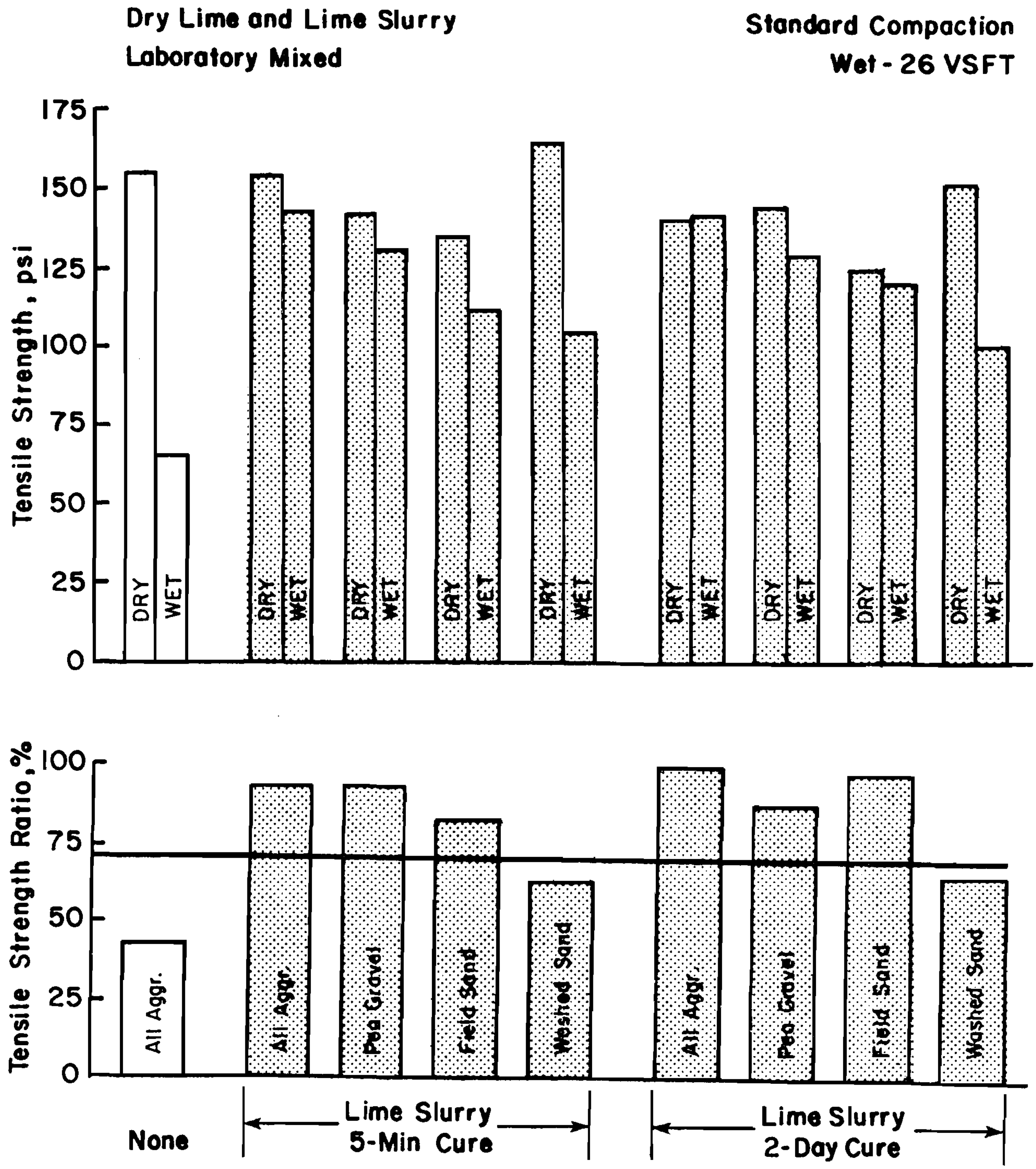

Fig 14. Indirect tensile test results for laboratory prepared combined mixtures with all and individual aggregates treated with dry and slurry lime using standard compaction.

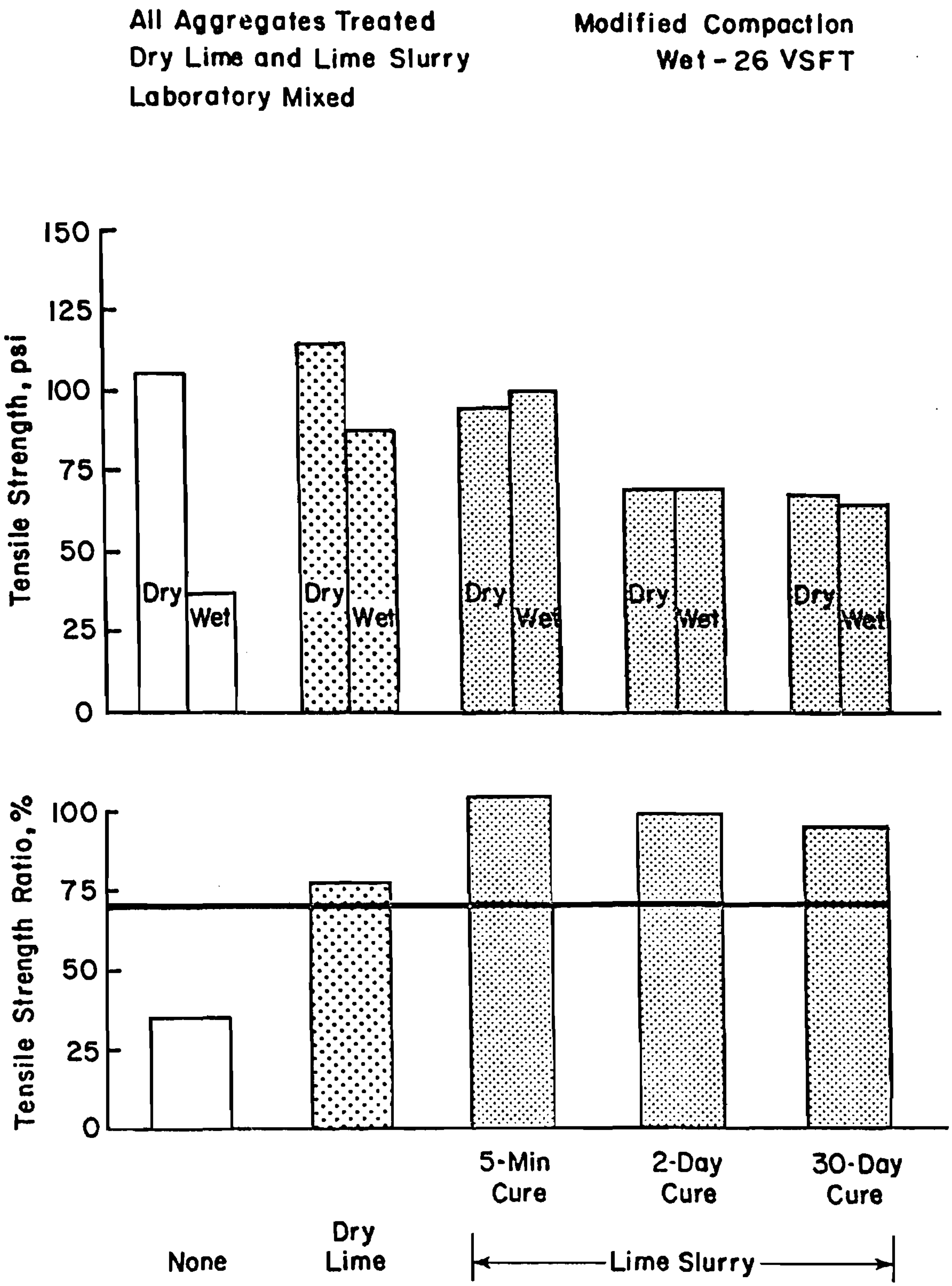

Fig 15. Indirect tensile test results for laboratory prepared combined mixtures with dry and slurry lime using modified compaction.

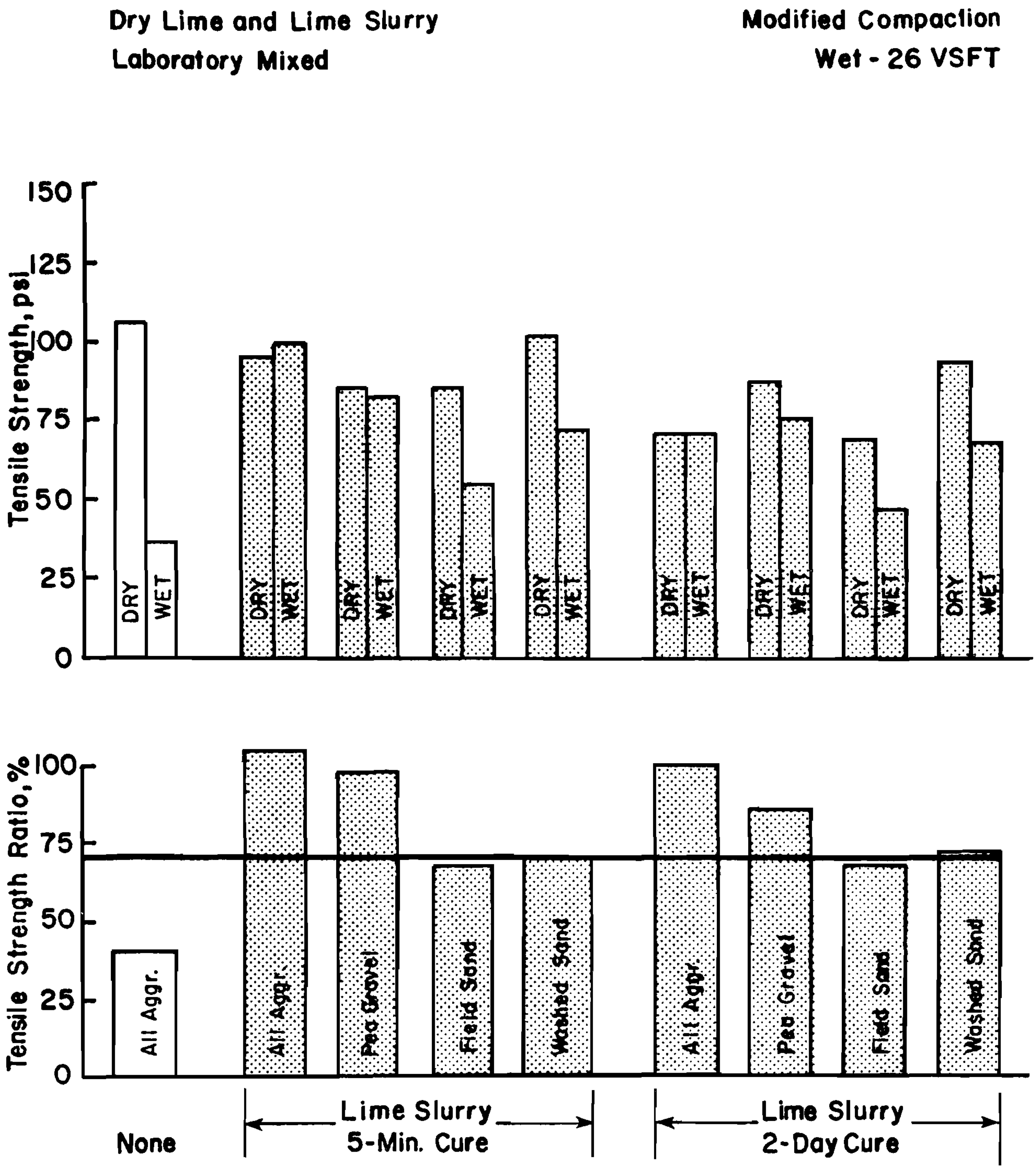

Fig 16. Indirect tensile test results for laboratory prepared combined mixtures with all and individual aggregates treated with dry and slurry lime using modified compaction.

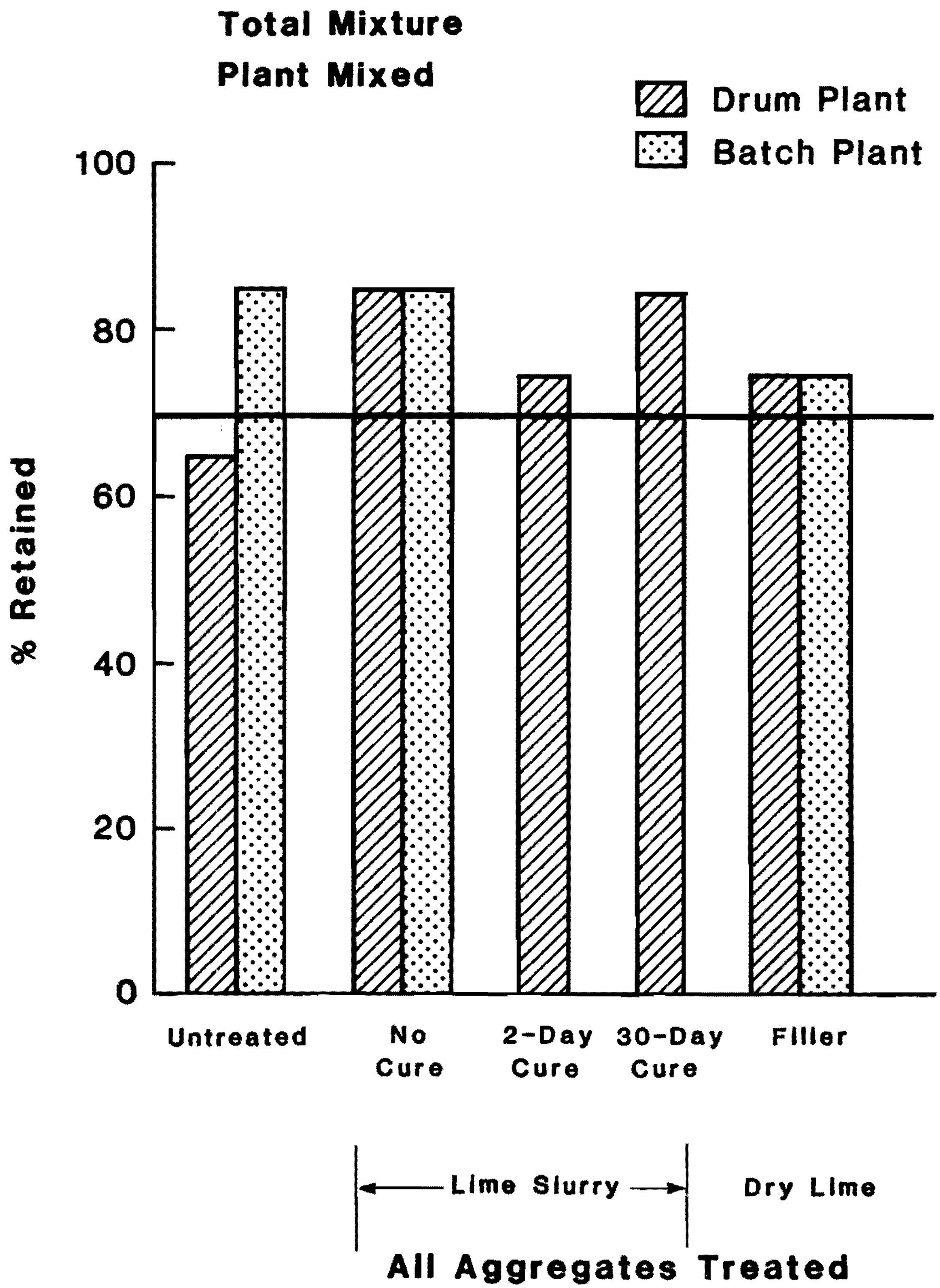

Fig 17. Boiling test results for field mixed asphalt mixtures with all aggregates treated with dry and slurry lime.

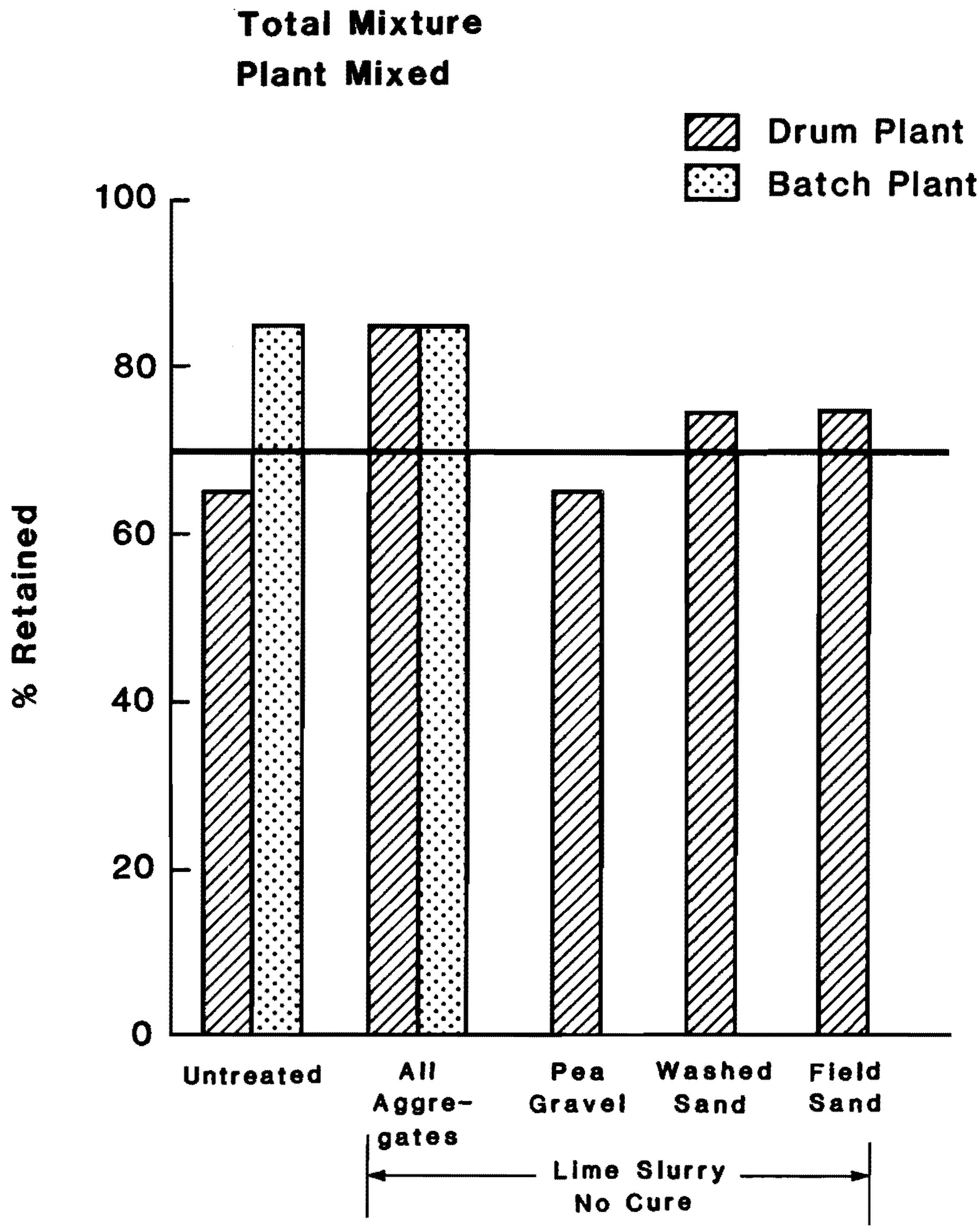

Fig 18. Boiling test results for field mixed asphalt mixtures with all and individual aggregates treated with slurry lime without curing.

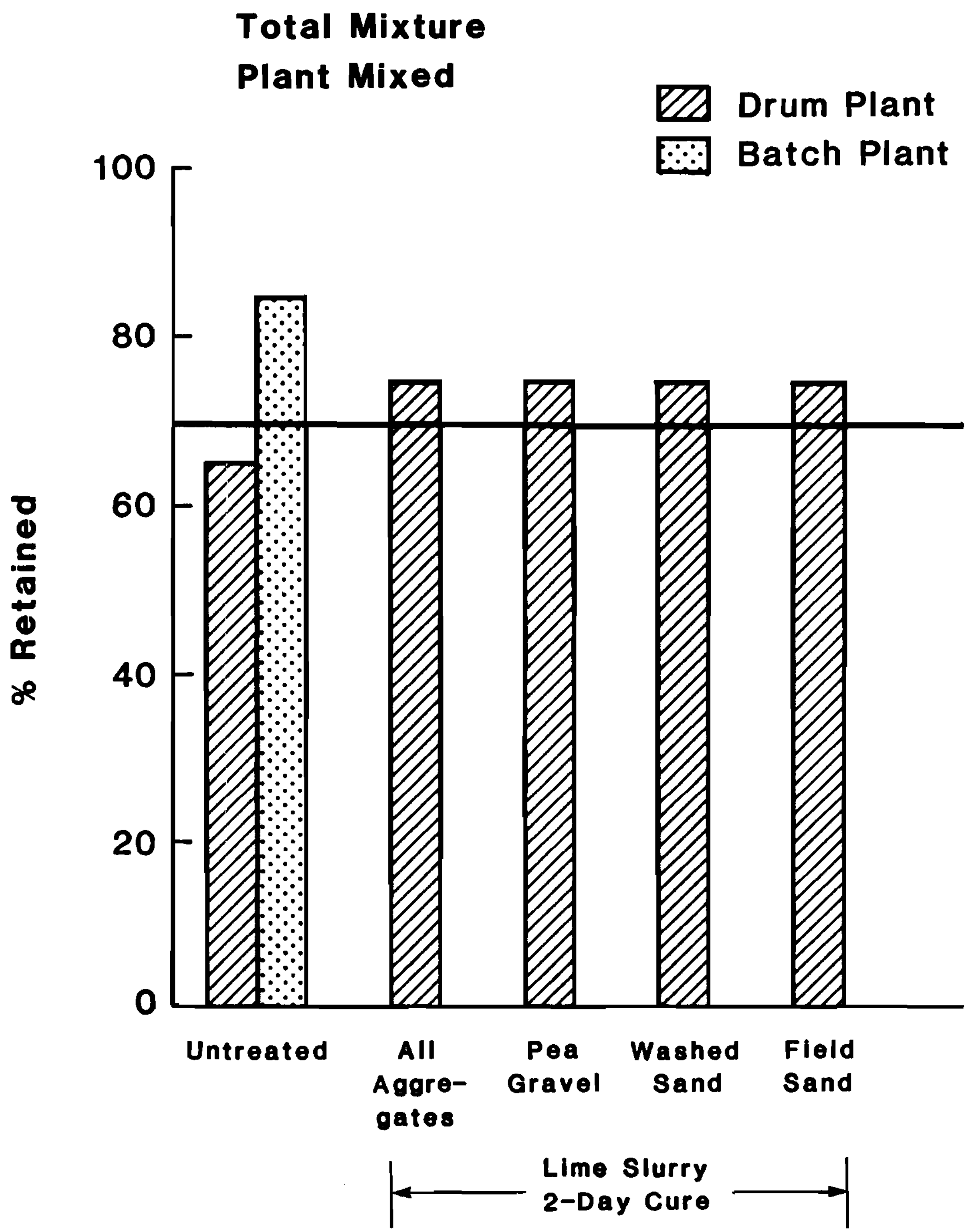

Fig 19. Boiling test results for field mixed asphalt mixtures with all and individual aggregates treated with slurry lime and 2 days curing.

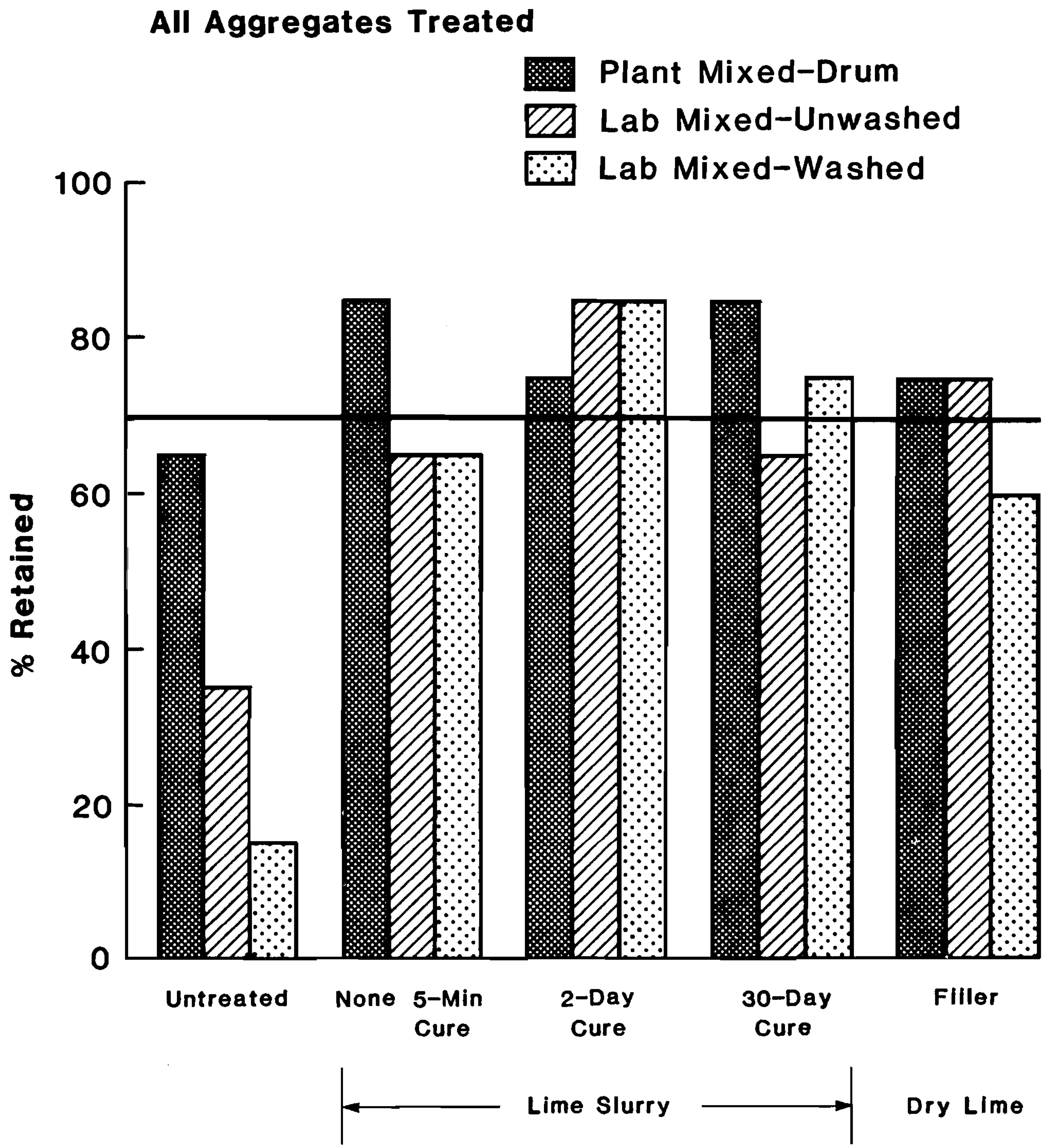

Fig 20. Comparison of boiling test results for laboratory and drum plant mixtures with all aggregates treated with dry and slurry lime.

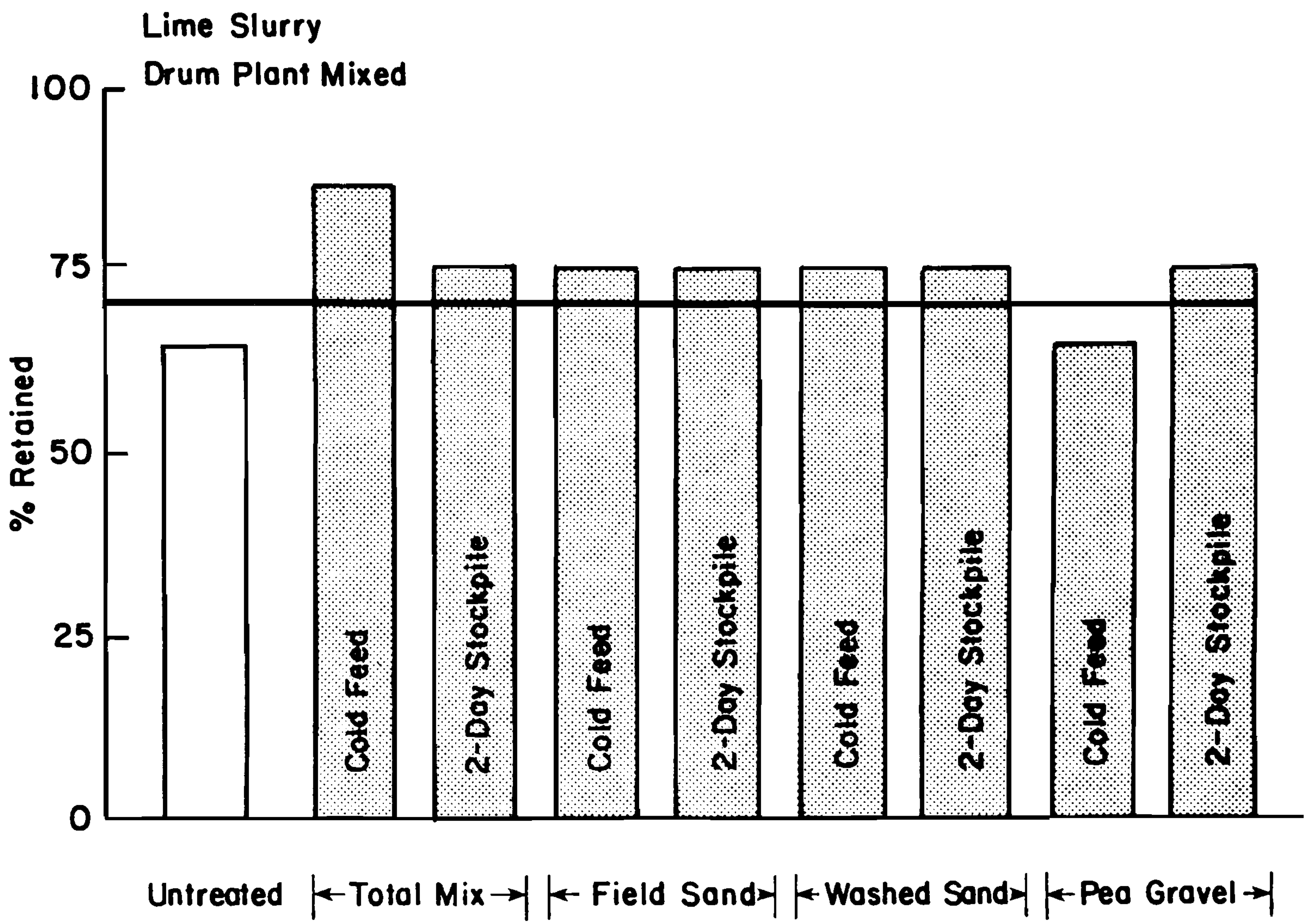

Figure 21. Boiling test results for drum plant mixtures treated with lime slurry

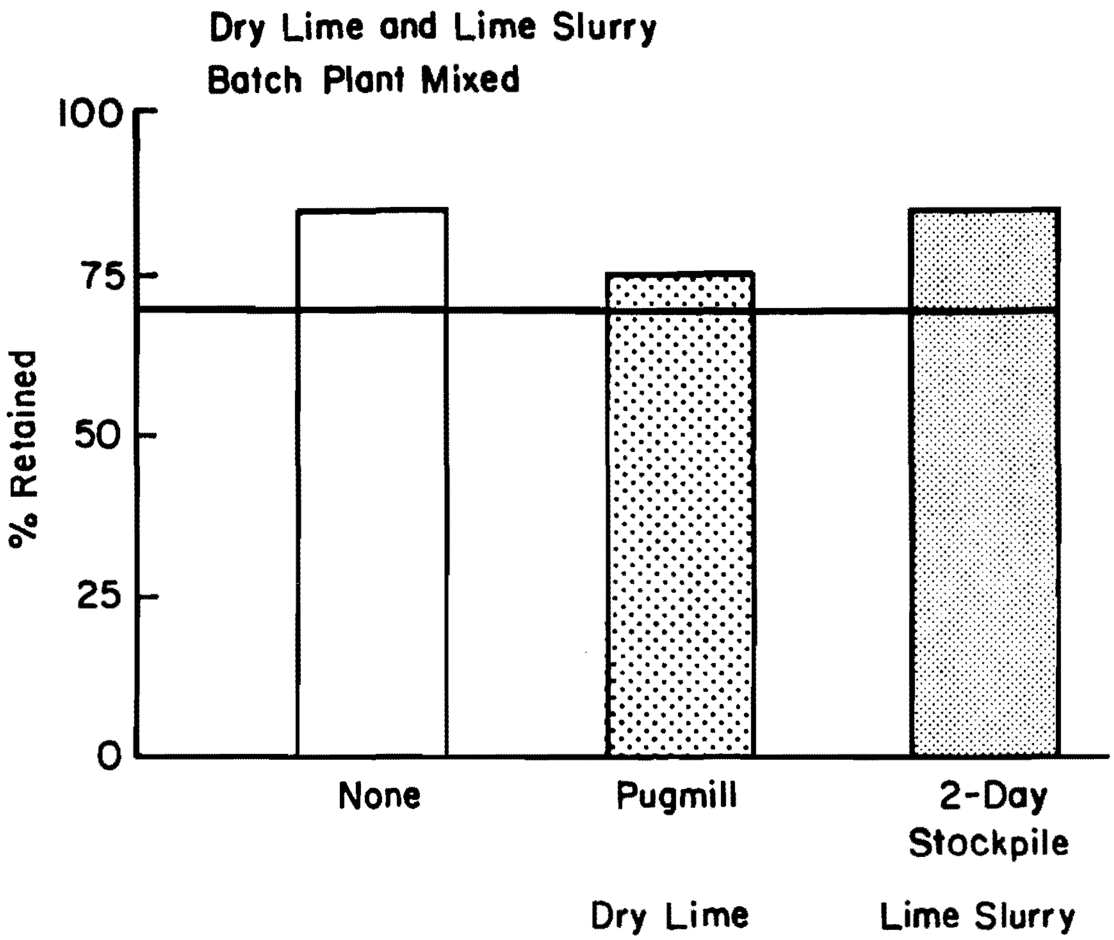

Figure 22. Boiling test results for batch plant mixtures treated with dry and slurry lime

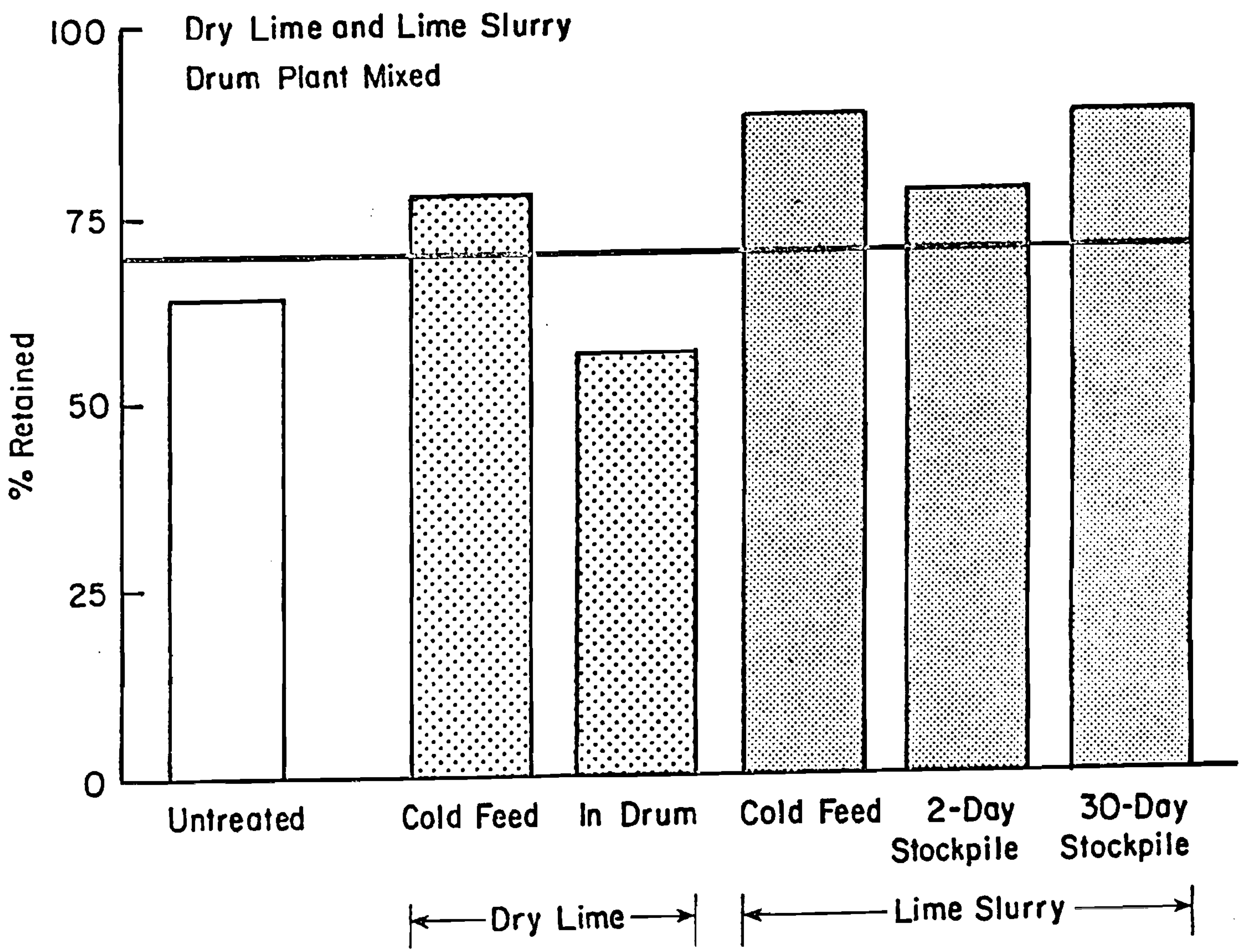

Figure 23. Boiling test results for drum plant mixtures treated with dry and slurry lime

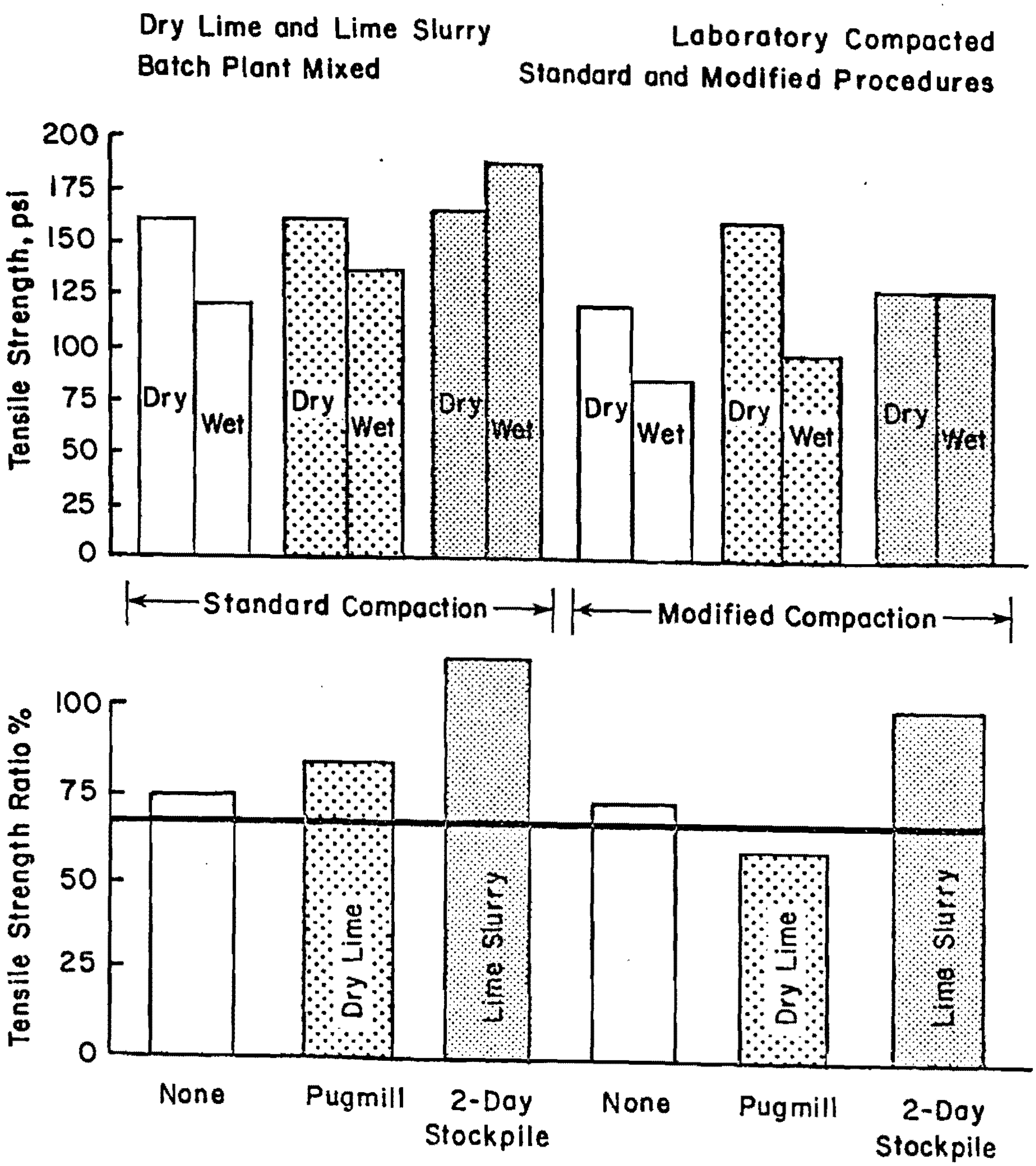

Figure 24. Indirect tensile test results for batch plant mixtures treated with dry and slurry lime

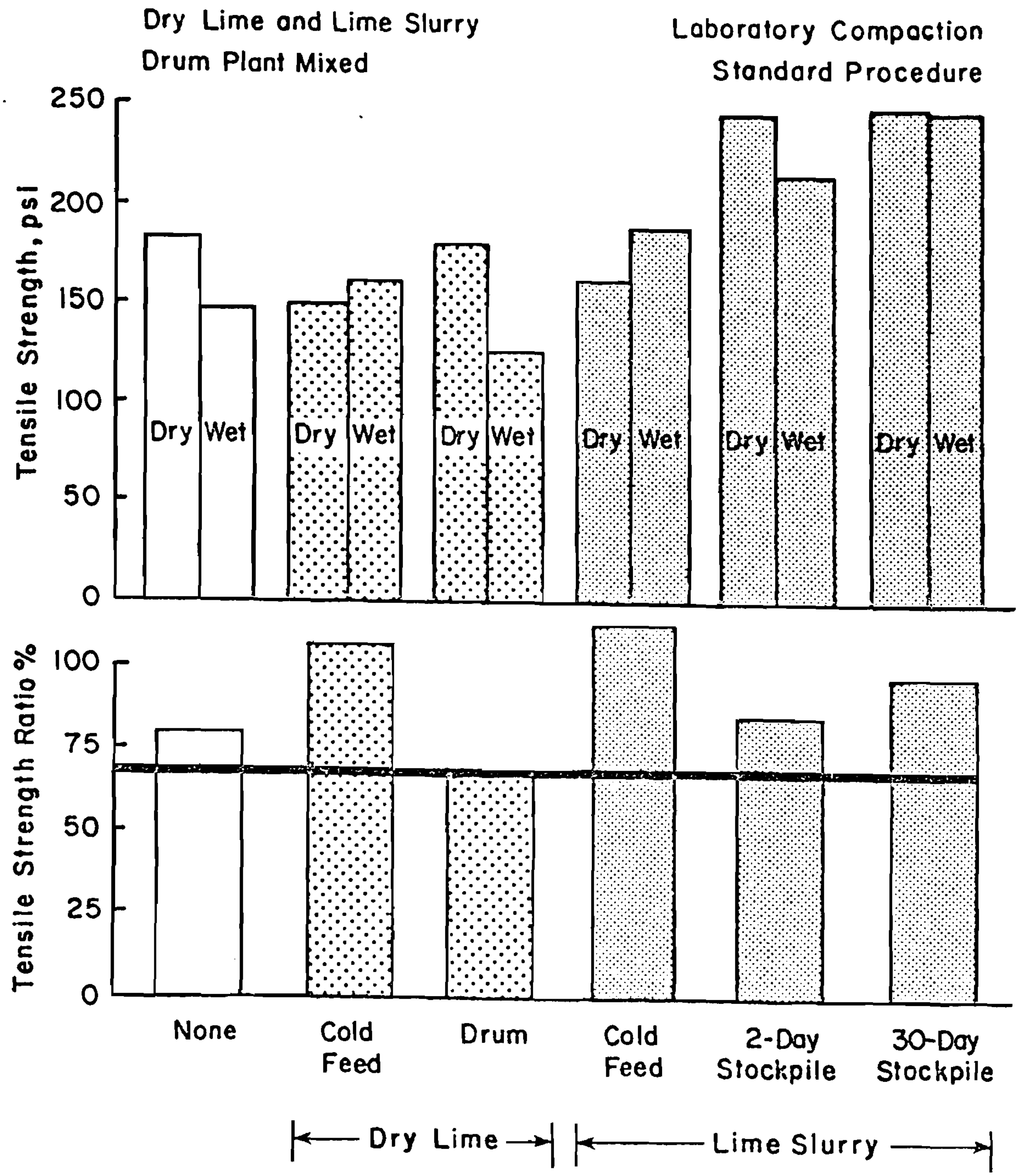

Figure 25. Indirect tensile test results for drum mixtures (standard compaction) treated with dry and slurry lime

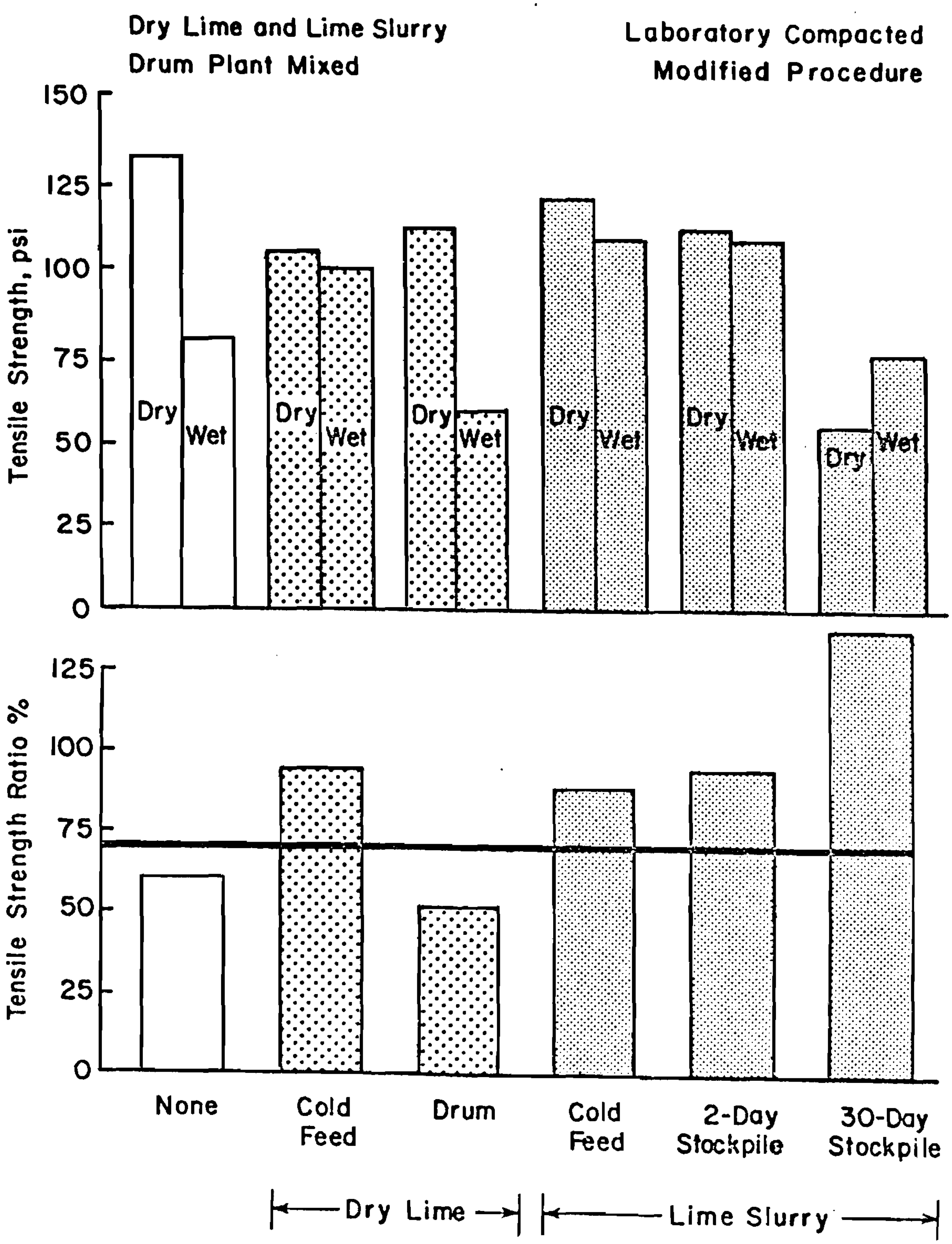

Figure 26. Indirect tensile test results for drum plant mixtures (modified compaction) treated with dry and slurry lime

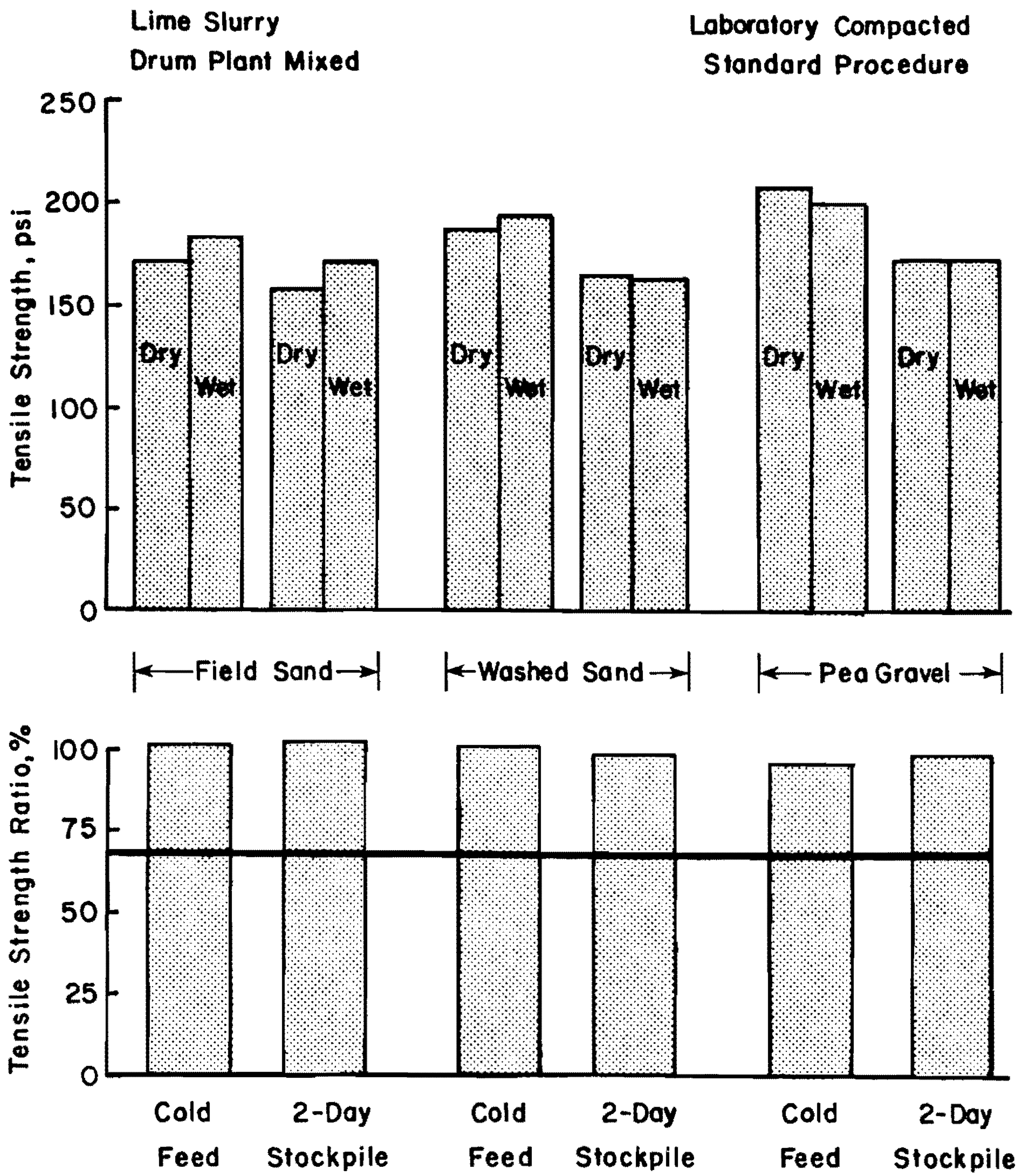

Figure 27. Indirect tensile test results for drum mixtures (standard compaction) treated with lime slurry

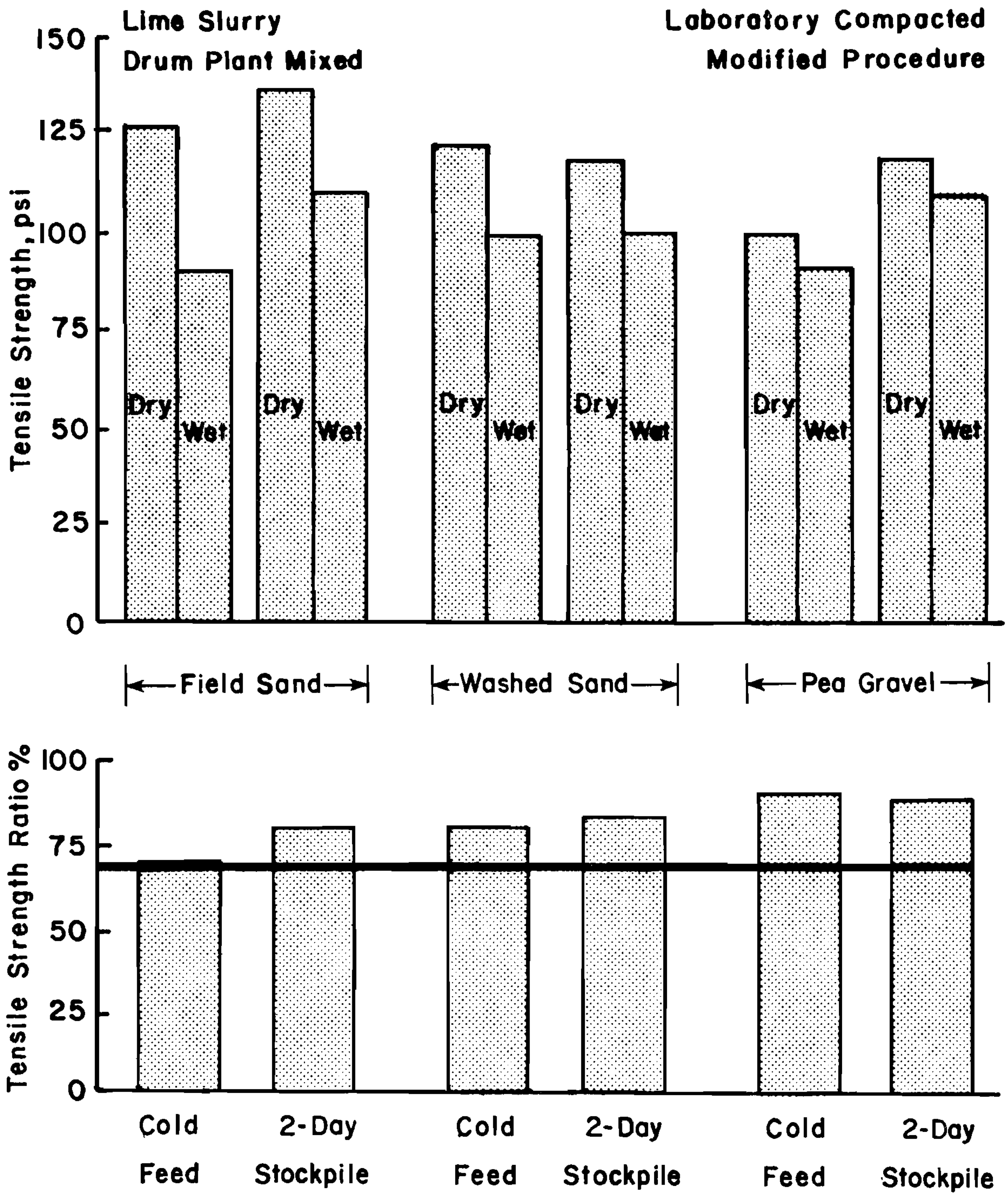

Figure 28. Indirect tensile test results for drum plant mixtures (modified compaction) treated with lime slurry

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based on the field study as well as related project experience.

STUDY CONCLUSIONS

1. Hydrated lime was effective in reducing moisture-induced damage of the asphalt paving mixture used in this study.
2. Hydrated lime is an effective antistrip additive for asphalt mixtures produced with both batch and drum mix plants.
3. Lime slurry was the most effective method for applying hydrated lime.
4. Dry lime added through a fines feeder system in a drum mix plant was ineffective as an antistrip additive.
5. Dry lime added in the pugmill of a batch plant improved moisture-susceptibility; however, lime slurry applied to the aggregate prior to entry into the batch plant was more effective.
6. The Texas boiling test, Texas freeze-thaw pedestal test, and the indirect tensile test with vacuum saturation and conditioning procedures appeared to be effective in identifying mixtures with water-susceptibility problems.
7. Air void content in compacted specimens must be carefully controlled when using the wet-dry indirect tensile test to evaluate moisture susceptibility of asphalt mixtures. Air voids should be approximately 7 percent.

GENERAL CONCLUSIONS

1. Although lime slurry was found to be more effective than dry lime, dry hydrated lime in the presence of moisture has been found to be as effective as lime slurry. Thus, a small amount of moisture can be applied to the aggregate prior to adding dry lime.
2. Dry lime can be introduced into drum mix plants, if modifications or equipment are provided to prevent the loss of the lime.

3. When hydrated lime is to be used, it should be included during the mixture design process.
4. Techniques for moisture conditioning should be closely controlled and should produce a degree of saturation of 60 to 75 percent.
5. Increased costs associated with the use of lime in asphalt concrete mixtures is expected to be of the order of 1 to 2 dollars per ton. These extra costs include the cost of lime, equipment, and labor to handle the lime and the additional fuel requirements for drying of slurry treated materials.

RECOMMENDATIONS

1. Hydrated lime, when used as an antistripping additive, should be incorporated into the asphalt mixture following the recommendations in Research Report 253-4, "Lime Treatment of Asphalt Mixtures" (Ref 3).
2. The State Department of Highways and Public Transportation should obtain additional cores from the various test sections and test the specimens to determine the effectiveness of the various treatments. This evaluation should consider the air voids since low air voids will reduce moisture damage.
3. Additional field studies should be conducted to determine the effectiveness of hydrated lime as an antistripping additive when incorporated into the mixture using various techniques.

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