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LIME TREATMENT OF ASPHALT MIXTURES

by

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

conducted for

Texas
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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. This report does not constitute a standard, specification, or regulation.

PREFACE

This is the fourth 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 stripping and with the use of hydrated lime to alleviate the tendency for stripping to occur. Included is a summary of moisture damage and stripping, methods for reducing damage in pavements containing moisture susceptible mixtures, and recommendations related to the use of hydrated lime and methods for introducing lime during construction.

The work required to develop this report was done by many people. Special appreciation is extended to Messrs. Pat Hardeman and Eugene Betts for their assistance in the testing program. In addition, the authors would like to express their appreciation to Messrs. Paul E. Krugler and Billy R. Neeley of the Texas Department of Highways and Public Transportation for their suggestions, encouragement, and assistance in this research effort. 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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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.

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

ABSTRACT

This report contains a summary of moisture damage and stripping of asphalt mixtures, methods for reducing the damage, and recommendations related to the use of hydrated lime and methods for introducing lime during construction.

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

SUMMARY

The use of hydrated lime to treat the aggregates in asphalt mixtures, which are susceptible to moisture damage, generally provides significantly increased resistance to stripping and moisture damage. Methods of field application discussed for drum mix and conventional batch plants include the use of

(1) dry hydrated lime

(2) hydrated lime slurry, and

(3) hot lime slurry.

All of the above produce improved resistance to stripping of asphalt mixtures. Generally treatment with a lime slurry or at least with lime in which moisture is present is more effective than treatment with dry lime.

The final decision as to method should be based on relative effectiveness and cost and, within certain limits as established by the resident engineer, should be left to the contractor in order to minimize costs and disruptions to the production cycle.

IMPLEMENTATION STATEMENT

Recommendations contained in this report are based on laboratory and field experience in Texas and supplemented by the experience and findings in other states. The recommendations contained in this report represent the current status of knowledge pertaining to the use of hydrated lime and other techniques to decrease moisture damage to asphalt mixtures.

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CHAPTER 1. INTRODUCTION

During the past few years, asphalt pavement mixtures have suffered extreme damage due to the effects of moisture. Such damage occurs in two forms, softening and stripping. Of primary concern is stripping, which has been shown to be a major cause of distress for asphalt mixtures in Texas.

Stripping involves the physical separation of the asphalt cement and the aggregate, primarily due to the action of moisture (Ref 1). A similar separation can also occur due to surface coatings on the aggregate or to smooth aggregates with minimum surface texture. Softening is characterized by a reduction of cohesion, which produces a reduction in strength and stiffness of the asphalt mixture.

One of the more promising methods for reducing stripping is to treat the aggregate with hydrated lime (Ref 2). There are, however, various techniques for lime treatment of the aggregate, which must be evaluated in terms of effectiveness and cost.

This report is primarily concerned with stripping and with the use of hydrated lime to reduce the tendency for stripping to occur and to protect the mixture after construction.

Chapter 2 provides background and a summary of moisture damage, stripping, and methods for reducing the damage in pavements containing moisture-susceptible, asphalt-aggregate mixtures. Chapter 3 summarizes techniques and makes recommendations related to the use of hydrated lime and methods for introducing lime during construction.

CHAPTER 2. STRIPPING OF ASPHALT MIXTURES

Stripping is related to both the aggregate and asphalt in the mixture. While the predominant cause is related to the aggregate, it has been shown that the asphalt cement can also be quite important and that some asphalts have a greater tendency to strip than others.

In addition, it is important to consider the finer aggregates as well as the coarse aggregates. Since the finer aggregates make up the matrix which provides the strength to the mixture, stripping of these components will produce more serious damage and distress than will be produced by stripping of the coarse aggregates.

EVIDENCE OF STRIPPING

Preliminary visual evidence of stripping of asphalt pavement mixtures often occurs as patch bleeding, or flushing, and localized instability. Localized flushing occurs when stripped asphalt cement rises to the surface of the pavement, producing localized shiny areas of asphalt. This bleeding or flushing is not necessarily confined to the wheel paths but rather is often distributed randomly across the pavement surface. Deformations in the form of shoving and rutting may also develop due to the loss of structural strength, stiffness, and stability and due to instability caused by the excessive amounts of asphalt which accumulate near the surface. Shoving can be expected in areas carrying only moderate traffic and rutting will begin to develop.

In addition, it may be found that cores cannot be obtained due to the lack of cohesion and strength in the lower portion of the pavement layers. Examination of the asphalt-aggregate mixture will often show that the aggregates are completely clean, without evidence of asphalt.

STRIPPING MECHANISMS

Three basic mechanisms or causes of stripping have been identified (Ref 1):

(1) physical-chemical reactions,

(2) surface coatings, and

(3) smooth surface textures.

The first, physical-chemical reactions, is of primary concern. A number of such reactions have been suggested as the cause of stripping in asphalt-aggregate mixtures and are discussed in References 1 and 2. Unfortunately, none of the proposed reactions fully explains stripping of all asphalt-aggregate mixtures. In reality, probably different reactions and, possibly, more than one reaction may cause stripping in different types of mixtures.

Surface coatings on the aggregate prevent adequate adhesion with the asphalt cement, which can be eliminated by washing the aggregate prior to use. Smooth aggregates also minimize the ability of the aggregate and asphalt to develop adequate adhesion. Crushing of the aggregate to produce surfaces with more texture will reduce stripping related to this cause.

Of primary importance is the need to identify the basic cause of the stripping in order to select the best method of treatment. In some cases, two or more of the above mechanisms may be involved and more than one treatment may be required. Washing and crushing can be expected to eliminate the latter two causes but it is necessary to consider other treatments to alleviate stripping which results from physical-chemical causes.

METHODS OF TREATMENT

A number of procedures and treatments have been proposed and are currently utilized. These procedures and treatments are

(1) providing adequate compaction,
(2) eliminating the use of moisture-susceptible aggregates and asphalts,
(3) providing adequate drainage,
(4) sealing the asphalt-aggregate mixture surfaces, and
(5) treating the moisture-susceptible aggregates and asphalt.

Providing Adequate Compaction

Adequate compaction will reduce the air voids and the continuity of the air void system. This prevents the penetration of moisture into the mixture, thus reducing the possibility for stripping to occur. The air void content should, ideally, be less than 7 percent. At void contents in excess of 7 percent, it has been shown that water can readily penetrate the mixture. Thus, compaction should achieve a relative density of at least 93 percent of the theoretical maximum density.

Eliminating Moisture-Susceptible Material

It may be desirable to eliminate the use of certain moisture-susceptible aggregates or, to a lesser extent, certain asphalts. Such an approach may be costly, especially in areas with limited aggregate and asphalt sources. Nevertheless, in view of the long-term maintenance requirements, reduced pavement life and performance, and, in some cases, the rapid and severe failure of the pavement, it may in reality be the most economical solution if adequate treatment cannot be achieved.

Providing Adequate Drainage

Adequate drainage should be provided to eliminate moisture, which causes stripping to occur. This involves rapid removal of surface water and prevention of moisture movement into the mixture from the subgrade, subbase, and base by drainage of these layers and by maintaining an adequate pavement elevation above the water table.

Sealing Mixture Surfaces

Both the top and the bottom surface of the asphalt mixture can be sealed to prevent moisture penetration. This approach requires that careful consideration be given to the source of moisture to avoid the possibility of trapping water in the mixture. Thus, sealing of the bottom surface may trap surface water by preventing drainage into the underlying layers, and similarly, surface sealing may prevent evaporation of moisture from underlying layers which is moving upward through the mixture.

Treating Materials

A number of additives have been proposed for treating the aggregate and the asphalt, with the primary emphasis placed on treatment of the aggregate. These additives are

(1) commercial liquid antistripping agents,

(2) portland cement, and

(3) hydrated lime.

While most of these additives appear to work with certain combinations of aggregate and asphalt, hydrated lime generally has been the most effective method for treating Texas aggregates. Regardless of the method of treatment selected, moisture susceptibility tests should be conducted for each combination of asphalt, aggregate, and antistripping agent.

TEST METHODS

Numerous tests and test variations have been proposed and are being used to evaluate the moisture susceptibility of asphalt-aggregate mixtures, with and without additives.

After a thorough review and evaluation of these various tests, the following three tests are recommended:

1. Indirect Tensile Test with moisture conditioning (Ref 3)
2. Texas Freeze-Thaw Pedestal Test (Ref 4)
3. Texas Boiling Test (Ref 5)

Indirect Tensile Test on Dry and Wet Specimens

The indirect tensile test subjects a cylindrical specimen to compressive loads distributed along two opposite generators that create a relatively uniform tensile stress perpendicular to and along the diametrical plane, which contains the applied load, that leads to 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.

For proper evaluation, mixtures should have about 7 percent air voids and it is tentatively recommended that compacted specimens should be conditioned to produce a constant degree of saturation in the range of 55 to 75 percent*, rather than by following a specified procedure. Moisture susceptibility is determined by the ratio of tensile strength in a wet condition to the tensile strength in a dry condition, which is called the 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 6). Details of the recommended test procedure are contained in Reference 3.

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* Work is being conducted to establish a recommended degree of saturation.

Texas Freeze-Thaw Pedestal Test

This test determines the number of freeze-thaw cycles required to induce cracking on the surface of a specimen (Refs 2, 4, and 7). The test procedure involves subjecting miniature asphalt-aggregate briquets to repeated freeze-thaw cycles (15 hours at 10°F and 9 hours at 120°F) while submerged in distilled water. The briquets, which are highly permeable, allow easy penetration of water and are designed to minimize mechanical interlocking of the aggregate particles by using a uniform aggregate size. Thus, the briquet properties are largely determined by the asphalt-aggregate bond. Moisture susceptibility of an asphalt concrete mixture is evaluated by determining the freeze-thaw cycles required to crack a briquet seated on a beveled pedestal. Details of the test procedure are described in Reference 4.

Texas Boiling Test*

In this test, which is based on a review and evaluation of boiling tests that have been 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 an asphalt mixture is prepared at 325°F and boiled in distilled water for 10 minutes. After boiling, the mixture is allowed to cool, the water is drained, and the contents are emptied on paper and allowed to dry. The extent of stripping is rated visually and compared to a standard set of mixtures, which vary from 0 to 100 percent of the asphalt cement retained. Based on field performance, mixtures which retain less than 70 percent of the asphalt cement are considered to be moisture susceptible. Details of the test procedure are described in Reference 5.

* The standard method, Tex-530-C, currently used by the SDHPT is different from the above procedure.

CHAPTER 3. LIME TREATMENT

Hydrated lime has consistently been shown to be effective in improving the moisture resistance of aggregate-asphalt mixtures. The most effective method of treatment has generally been to treat the aggregate with a lime slurry with a minimum of approximately 30 percent lime with 70 percent water. The lime must not be allowed to carbonate and should be present on the surface of the aggregate when it is coated with asphalt cement. There does not appear to be any permanent or long-term reaction with the aggregate, and thus, if the lime is removed before the aggregate is coated with asphalt, there is little, if any, increase in moisture resistance.

LEVEL OF TREATMENT

Generally the resistance to stripping will increase with increased amounts of hydrated lime. However, if the aggregates are well coated, a good estimate for making the initial determination of the amount of lime to use for treatment is one to one-and-a-half percent by weight. Finer aggregates, however, have larger surface areas and may require higher percentages of hydrated lime in order to adequately protect the pavement mixture from stripping.

METHODS OF APPLICATION

The lime to treat the aggregate can be applied as

(1) dry hydrated lime,

(2) hydrated lime slurry, and

(3) hot (quick) lime slurry.

All of these methods improve the resistance of asphalt mixtures to stripping; however, addition of dry hydrated lime to the asphalt cement is not recommended.

Laboratory studies have shown that treatment with lime slurry, or at least with lime with moisture present, is more effective than treatment with dry lime, because the wet lime is held on the surface of the aggregate until it is coated with asphalt cement and possibly because there is an improved interaction between the lime and aggregate (Ref 8). Dry lime is more easily removed from the aggregate surface; a portion of it is collected in the plant's air pollution system and a portion is lost into the mixture acting as a filler, which, while often beneficial, does not adequately treat the aggregate.

FIELD APPLICATIONS

Both dry lime and hydrated lime slurry have been shown to be effective antistripping additives although lime slurry or, at least, lime in the presence of water is the most effective. It should be noted that stiffening of the mixture may occur for cooler conditions, long haul distances, and delayed placing. This may occur as surface crusting or as stiffening of the entire mixture. Generally it will be difficult to treat only one aggregate component since mixing would be expected with the lime being transferred from the treated aggregate to the untreated aggregate.

The following summarizes the various techniques which can be used.

Dry Lime

The primary problem with the addition of dry lime is holding the lime on the surface of the aggregate until it is coated with asphalt even though there is some indication that lime in the presence of water gives a better reaction with the surface of some aggregates. The loss of lime will be greater in drum mixers, which tend to pick up the lime in the gas flow. In addition, a portion of the dry lime may be mixed into the asphalt, thus acting as a filler.

Aggregates can be treated by adding dry hydrated lime to the aggregates as follows:

Batch and Drum Mix Plants

1. On the aggregate cold feed

   Mixing and coating of the aggregates will be minimized. Passing the aggregate and lime through a scalping screen can improve mixing but at the same time may produce dusting and the loss of lime.

2. In a premixing pugmill

   This technique will maximize the coating of the aggregates, but lime may be lost due to dusting.

3. Prior to stockpiling

This technique probably requires that the lime be added prior to construction of the stockpile, either by pugmilling at the plant site or by having the aggregate supplier add the lime. A large portion of the lime will probably be lost prior to construction due to segregation, dusting, rainfall, etc. This method is not recommended.

Batch Plants

In the plant's pugmill prior to adding asphalt

This technique probably maximizes mixing and coating of the aggregates and minimizes losses due to dusting. A portion of the lime, however, may be lost in the asphalt cement.

Drum Mix Plants

In the drum prior to adding asphalt

This technique is definitely not recommended unless new equipment and techniques can be developed which will insure that the lime stays on the aggregate.

Lime Slurry

The primary problem with the use of lime slurry is that the water added to the aggregates must be removed by drying, thus increasing fuel costs and reducing production rates. Application techniques should minimize the amount of water which must be removed when the aggregate enters the dryer or the drum mixer.

The lime slurry should be prepared with a minimum of approximately 30 percent lime with 70 percent water by weight in order to minimize the amount of water added to the aggregate. Aggregates can be treated by adding the lime slurry as follows:

Batch and Drum Mix Plants

1. On the cold feed

Mixing and coating of the aggregates are minimized. Passage through a scalping screen may improve aggregate coating, but the mixture may foul the screens. Since mixing is minimized, it may be possible to treat only certain aggregates by arranging the cold feed bins to place the aggregate to be treated on top of the cold feed or by treating the aggregate under the cold feed bins immediately after it is placed on the cold feed belt.

2. In a premixing pugmill

   This method provides better coverage of the aggregate and allows a portion of the water to drain.

3. Prior to stockpiling

   This method allows much of the water to drain, thus minimizing required drying. However, it maximizes the chances of carbonation and the loss of lime. Preliminary indications are that hydrated lime applied in slurry form to aggregates is difficult to remove. Nevertheless, the length of time permitted in the stockpile is not well established. This technique would allow only certain aggregates to be treated. Tentatively, until more experience is acquired, it is recommended that stockpiling be limited to 10 days or less depending on the environmental conditions.

Drum Mix Plants

On the slinger belt

This method minimizes the amount of mixing and coating of the aggregates and maximizes the amount of moisture which must be removed.

Dry Lime with Water

Another technique involves adding dry hydrated lime to wet aggregates or adding dry lime to dry aggregates and then spraying a small quantity of water onto the mixture.

All techniques and recommendations pertaining to lime slurry also pertain to the application of dry lime and water. In general, it is felt that the water should be added to the aggregate before the dry lime is added, to prevent washing the lime off the aggregate surface. The exception is in a premixing pugmill where probably the water can be added after the lime is introduced.

Hot Lime Slurry

The use of quick lime which is hydrated and slurried on the plant site offers a number of advantages. First, quick lime normally costs about the same as the cost of hydrated lime, but when slaked it will result in about 30 percent more hydrated lime. In addition, slaking with excess moisture will produce a slurry with a temperature of about 180°F, which may maximize evaporation losses and the reactivity of the hydrated lime. In addition, the elevated temperature may produce a hydrated lime with smaller particle sizes, which in turn may maximize the reactivity of the hydrated lime. Thus, a more reactive lime can be obtained at a lower cost, which will partially offset drying costs.

All techniques and recommendations pertaining to lime slurry also pertain to the use of hot lime slurry.

SUMMARY

The final decision as to how lime should be added should, for the most part, be left to the contractor in order to minimize costs and disruptions to the production cycle, providing that tests of the produced mixture indicate that the desired resistance to stripping was achieved. It is recommended that the lime be added as a slurry or at least with a small amount of water. Nevertheless, the final decision should be based on relative effectiveness of the technique with respect to improving the resistance to moisture damage and the cost, and should be approved by the resident engineer. In addition, the effectiveness of the procedure chosen should be monitored during production.

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