TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-82/10+252-1		

4. Title and Subtitle	5. Report Date
MIXTURE DESIGN PROCEDURE FOR RECYCLED ASPHALT PAVEMENTS	May 1982
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Thomas W. Kennedy, Freddy L. Roberts, and James N. Anagnos	Research Report 252-1
9. Performing Organization Name and Address	10. Work Unit No.
Center for Transportation Research The University of Texas at Austin Austin, Texas 78712-1075	11. Contract or Grant No. Research Study 3-9-79-252
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas State Department of Highways and Public Transportation; Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	Interim
	14. Sponsoring Agency Code

15. Supplementary Notes

Study conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.
Research Study Title: "Design and Characterization of Recycled Pavement Mixtures"

16. Abstract

This report describes a procedure that can be used by an engineer to design a recycled mixture using material salvaged from an asphalt concrete roadway that is a candidate for recycling. Techniques are included for directing a study of the distressed pavement to determine the causes of the distress that produced the need for rehabilitation. After the causes of distress have been determined, the engineer can evaluate the salvaged materials to determine (1) if softening agents are needed and (2) if virgin aggregate and asphalt should be added and, if so, how much. Also included are directions for preparing candidate mixtures as well as suggested minimum values for stability and engineering properties. Example plots and tables demonstrate the use of the technique.

17. Key Words	18. Distribution Statement
recycling, mixture design procedure, asphalt concrete, condition survey, stripping, cracking, rutting, salvaged materials, material properties, tensile strength, stability, softening agent	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	34	

Form DOT F 1700.7 (8-69)

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by

Thomas W. Kennedy
Freddy L. Roberts
James N. Anagnos

Research Report Number 252-1

Design and Characterization of Recycled Pavement Mixtures

Research Project 3-9-79-252

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

May 1982

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 first in a series of reports dealing with the design and characterization of recycled pavement materials. This report includes guidelines for use by the field engineer in deciding if a section of road is a candidate for recycling, and, if so, developing a mixture design that will provide satisfactory field performance. This report includes a step-by-step design procedure as well as a description of the preliminary activities involved in recycling asphalt concrete materials.

This report was completed with the assistance of many people. Special appreciation is due to Messrs. Pat Hardeman and Eugene Betts for the extensive field and laboratory evaluations that provided the background for this report. Appreciation is expressed to Robert E. Long, Billy R. Neeley, C. Weldon Chaffin, and District personnel of the Texas State Department of Highways and Public Transportation for their assistance, both in the field and in securing specimens and material samples. Appreciation is extended to Center for Transportation Research staff for their assistance in the preparation of manuscript materials. The support of the Federal Highway Administration, Department of Transportation, is acknowledged.

Thomas W. Kennedy
Freddy L. Roberts
James N. Anagnos

May 1982

LIST OF REPORTS

Report No. 252-1, "Mixture Design Procedure for Recycled Asphalt Pavements," by Thomas W. Kennedy, Freddy L. Roberts, and James N. Anagnos, provides an evaluation and mixture design procedure that includes the use of salvaged materials from a road that is to be recycled. May 1982.

ABSTRACT

This report describes a procedure that can be used by an engineer to design a recycled mixture using material salvaged from an asphalt concrete roadway that is a candidate for recycling. Techniques are included for directing a study of the distressed pavement to determine the causes of the distress that produced the need for rehabilitation. After the causes of distress have been determined, the engineer can evaluate the salvaged materials to determine (1) if softening agents are needed and (2) if virgin aggregate and asphalt should be added and, if so, how much. Also included are directions for preparing candidate mixtures as well as suggested minimum values for stability and engineering properties. Example plots and tables demonstrate the use of the technique.

KEY WORDS: Recycling, mixture design procedure, asphalt concrete, condition survey, stripping, cracking, rutting, salvaged materials, material properties, tensile strength, stability, softening or rejuvenating agent, antistripping additives.

SUMMARY

This report includes a suggested procedure that can be used by the engineer to determine if recycling is a viable option for a particular roadway. The engineer must first determine the cause for the distress that led to the need for rehabilitation. The failure must be categorized to determine whether the mode was brittle or nonbrittle. Materials that fail in the brittle mode need rejuvenating agents while those failing in the nonbrittle mode do not. If the pavement structure was underdesigned, strengthening should be included in the total rehabilitation analysis.

Once recycling is determined to be a cost effective option for a particular pavement, three phases in design must occur: general design, preliminary design, and final design. General design includes evaluating causes of failure and determining whether the problems are mixture related or structure related. In addition, a sampling plan must be developed and materials secured for the next step in design. Preliminary design includes evaluating the effects of various softening agents on the properties of the extracted asphalt cement. Softening agents, if required, should restore the aged asphalt cement to its original viscosity. Preliminary design occurs in the laboratory and involves determining the combinations of components, such as softening agents, if needed, new aggregates, and antistripping additives, that are to be considered. Final design involves preparing specimens at various combinations to provide an indication of the effects of these components on test results. The test recommended for use in these evaluations are stability, unconfined compression, indirect tensile strength, and resilient modulus of elasticity. The last step in the final design includes comparing test results from the best recycled mixture combinations with a range of properties taken from recycled pavements that have provided good field performance.

When construction begins in the field, it may be necessary to modify the final design to provide a mixture that will meet construction requirements; however, these changes should be very carefully recorded and their effect anticipated and monitored.

IMPLEMENTATION STATEMENT

Based on the experience gained in this study, it is recommended that the Texas State Department of Highways and Public Transportation implement this mixture design procedure on a trial basis. To assist in this implementation, a step-by-step field laboratory manual (Research Report 252-2) was prepared. This manual is based on the general procedures and guidelines contained in this report but the orientation is directed towards the actual production of a recycled mixture design rather than an analysis of the factors prior to developing the mixture design itself. Trial use should provide information on the difficulties encountered in using the procedure by personnel in the Districts. It would be most desirable to duplicate some testing in both the District and the Center for Transportation Research laboratories, especially where District personnel are not familiar with the recycled mixture design procedure. These early evaluations are expected to lead to an expanded, more useable recycling mixture design procedure.

Utilization of this report and the companion manual will allow the Texas State Department of Highways and Public Transportation to begin to routinely recycle asphalt mixtures and will help to assure quality pavements which will exhibit performance equal to that of conventional mixtures and pavements. In addition, it is anticipated that a significant savings in cost can be realized.

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INTRODUCTION

At the time this study was initiated there was no readily available and accepted procedure for the design of recycled asphalt mixtures. Subsequently, as a part of the study, a preliminary design procedure was formulated and has been used on a number of projects (Refs 1, 3, and 4). The following recommendations are based on the experience gained to date (Ref 2). It is anticipated that modifications will be required as additional information and experience are developed.

The design procedure involves

(1) identifying the original cause of distress that created the need for recycling,
(2) correcting the cause of the distress and/or restoring the asphalt characteristics to a level appropriate for the mixture, and
(3) establishing the asphalt-additive content and virgin aggregates required to produce a satisfactory mixture.

DESIGN PROCEDURE

The steps necessary for the design of recycled asphalt mixtures have been subdivided into the following three categories

(1) general design,
(2) preliminary design, and
(3) final design.

GENERAL DESIGN

The basic factors of the general design category are

(1) determining the nature and causes of distress,
(2) determining the gradation of the recycled aggregate,
(3) determining the residual asphalt content of the recycled mixture,

(4) determining the penetration/viscosity of the recycled asphalt, and
(5) specifying the aggregate gradation after pulverization and the addition of new aggregate.

Since evaluation of most of these factors is fairly straight forward and laboratory procedures well established, no discussion of each factor is included. However, because the first factor is not always included as a step in current recycled mixture design procedures, and because of its importance in selecting the proper additives for a candidate mixture, a brief discussion of it is included in the next section. A discussion of sampling is also included because the selection of locations for securing materials for the laboratory study is also affected by results from the condition survey conducted as part of item 1.

Determine Causes of Distress

It is essential that the cause of the distress which led to the need for recycling be identified and corrected. The three most common basic causes in Texas are

(1) aging (brittleness) of the asphalt cement,
(2) stripping of the asphalt from the aggregate, and
(3) structural inadequacy.

Texas experience would suggest that one or more of these causes are involved in most failures leading to recycling.

A detailed condition survey should be conducted to determine the severity and extent of the distress present on the job for which recycling is being considered. The standard condition survey forms of the Texas State Department of Highways and Public Transportation (DHT) should be used.

A separate condition survey should be conducted for each section of road that is determined to be different, based on

(1) surface thickness or mixture design,
(2) evidence of discontinuous heavy maintenance carried out along the section,
(3) seal or friction coat difference,
(4) half-section skin patching, etc.

For each section identified using the suggestions listed above, the types of distress and the severity should be evaluated to determine the primary cause of the distress.

It is most important to identify whether these failures are associated with the characteristics of the mixture to be recycled or with the pavement structure, either local or general. In the case of mixture problems the failure can be categorized as either brittle or nonbrittle. An excellent discussion of pavement failure analysis was prepared by Finn and Epps (Ref 5).

Mixture Problems. Aging or brittleness, stripping, and stability problems are usually mixture associated. Brittle failures occur when axle loads, thermally-induced stresses, and shrinkage of underlying layers combine with aged asphalt cements to produce cracking, e.g., alligator, transverse, and block (map) and longitudinal. Typically, when such an asphalt mixture is to be recycled, softening agents or soft asphalts must be added to restore the salvaged asphalt cement to its original viscosity.

Nonbrittle failures are usually associated with mixtures that are either stripping or exhibiting poor stability. Distresses typical of these conditions are rutting, shoving, corrugations, and bleeding. Rutting can also occur as a result of lateral flow of nonbituminous layers. The cause of rutting in each case is different and the treatment to alleviate the problem must be selected and applied either prior to or during the recycling operation if the recycled pavement is expected to perform adequately.

In the case of a stripping mixture, an appropriate treatment must be applied to the salvaged mixture to solve the stripping problem or the mixture must be discarded or used for other purposes, such as low volume road patching or shoulders. Once the stripping problem is solved, the salvaged mixture can be evaluated and a new mixture design developed. Softening agents, which can produce a very soft and unstable mixture that is prone to shoving and rutting, often will not be required.

Poor stability often can be improved by adding new aggregate during recycling to improve gradation and introduce more angular aggregate particles. Better gradation may also result in a higher density, which would be beneficial with respect to moisture damage. Grading curves similar to those shown in Fig 1 have resulted in excellent performance. It is also recommended that serious consideration be given to using approximately equal percentages of recycled material and new material, with a recommended maximum of 70 percent recycled material.

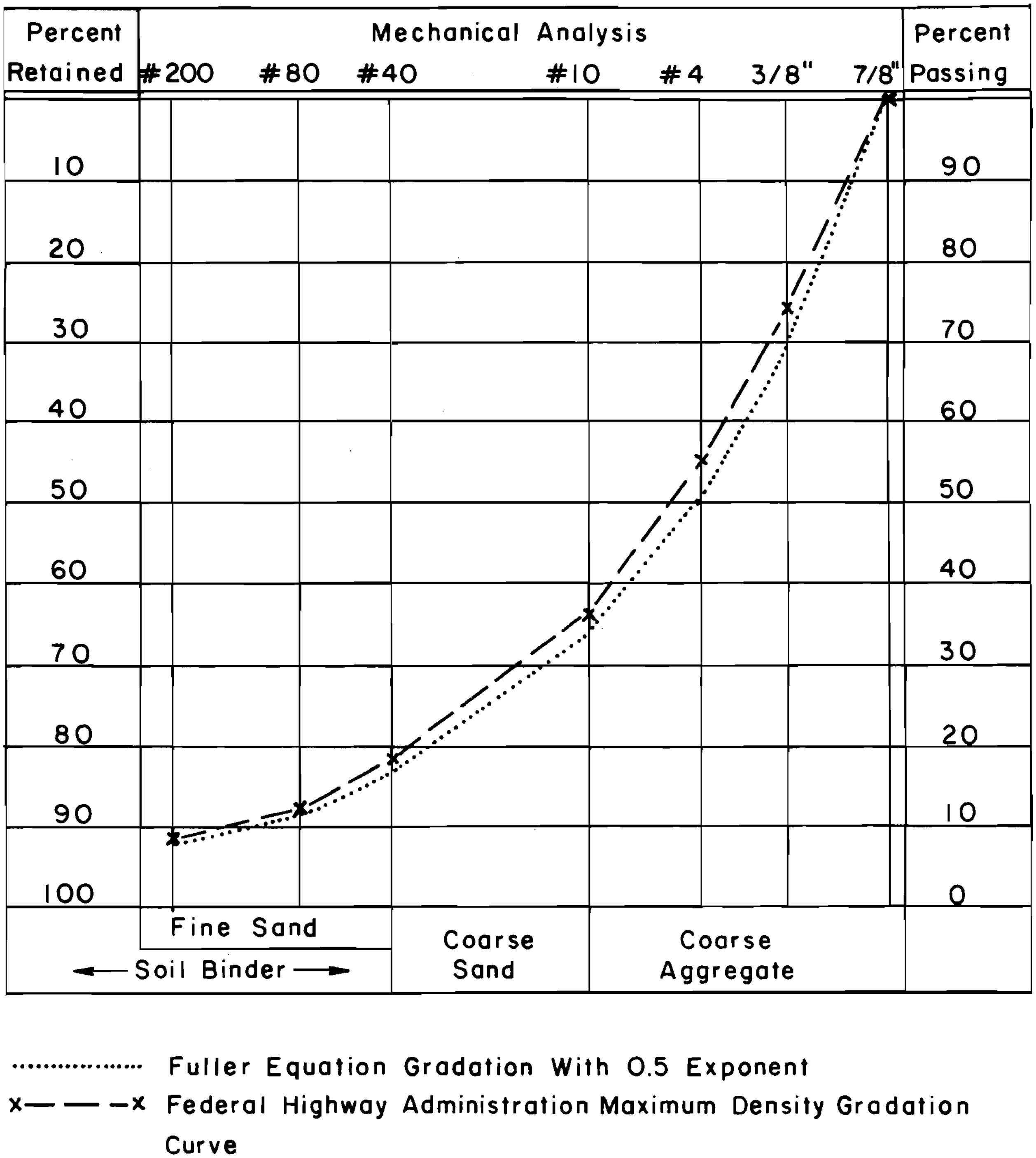


Fig 1. Grading curves for dense graded asphalt concrete mixtures (Ref 4).

Structural Problems. Structural deterioration may occur as the result of underdesign, increased traffic volumes and axle loads, decreased support values due to the action of water, and brittleness of asphalt due to aging, all of which can produce increased stresses and strains. If these increased stresses and strains exceed limiting values, premature fatigue or longitudinal cracking in the surface layer or permanent deformations can occur. This cracking can be localized or quite extensive.

An evaluation of the strength conditions of the existing pavement structure can be made by performing and analyzing a Dynaflect survey or other nondestructive testing. Such an analysis will help define the extent of soft spots and establish the limits on sections where the underlying support characteristics or layer thicknesses are different or inadequate. Application of these techniques and formulas for estimating moduli for underlying layers have been presented by Lytton and Machalak (Ref 7).

Sampling Plan

Each identified subsection should be treated as a separate design and a representative sample should be secured from each. Sampling sites within each subsection should be selected randomly. The engineer should choose at least six sampling sites for each subsection and secure a minimum of 200 pounds of material for subsequent laboratory analysis (Ref 8).

The effect of discontinuities or variations of material properties along the length of the pavement or across the width may lead to difficulties in securing representative materials. The effect of large discontinuous areas of patching, the addition of hot mixed overlays or seal coats to surface courses which were originally cold mixed, and variations in material combinations in the cross-section may make selection of representative samples for a single mixture design for the entire pavement difficult if not impossible. In such cases further subdivision of the subsection may be necessary or the recycling alternative may have to be abandoned if only short subsections can be identified.

PRELIMINARY DESIGN

The primary objective of the preliminary design is to select the type and amount of additive which can be used to either recondition the asphalt or eliminate asphalt aggregate problems in the salvaged mixture. If a brittle failure has occurred, this portion of the design involves the selection of an additive which will soften the existing asphalt and return it to its original viscosity. A variety of materials are available, such as soft asphalt, commercially available softening agents, and combinations of these materials. If a nonbrittle failure has occurred, the techniques or type and amount of additive which will minimize the distress must be selected. Materials such as lime and chemical antistripping additives are believed capable of reducing stripping in asphalt concrete mixtures. Nevertheless, to secure a successful project, it is imperative that these antistripping additives be tested to ascertain their effectiveness.

Softening Agents

Often the primary criterion in the preliminary procedures is to reduce the viscosity or increase the penetration of the asphalt to a value representative of a virgin asphalt cement. The recommended steps involved in this determination are summarized below.

(1) Extract and recover asphalt from the salvaged mixture (Tex-211-F*).
(2) Mix the recovered asphalt with the selected types and amounts of additives. Generally increments of 0.5 percent additive are adequate.
(3) Measure the viscosity or penetration of the treated asphalt cement (Tex-528-C or Tex-502-C, respectively*).
(4) Plot the relationship between the amount of additive and the viscosity or penetration (Figs 2 and 3).
(5) Determine which additives or combinations of additives will produce the desired consistency in the salvaged asphalt cement, i.e., penetration or viscosity in the desired range.
(6) Select those acceptable additives or combinations of additives that warrant preparation of laboratory mixtures for further evaluation. Factors to be considered in this selection are costs, availability, construction considerations, past reliability and experience, etc.

*These test methods are for the Texas State Department of Highways and Public Transportation; other agencies should substitute their own test methods.

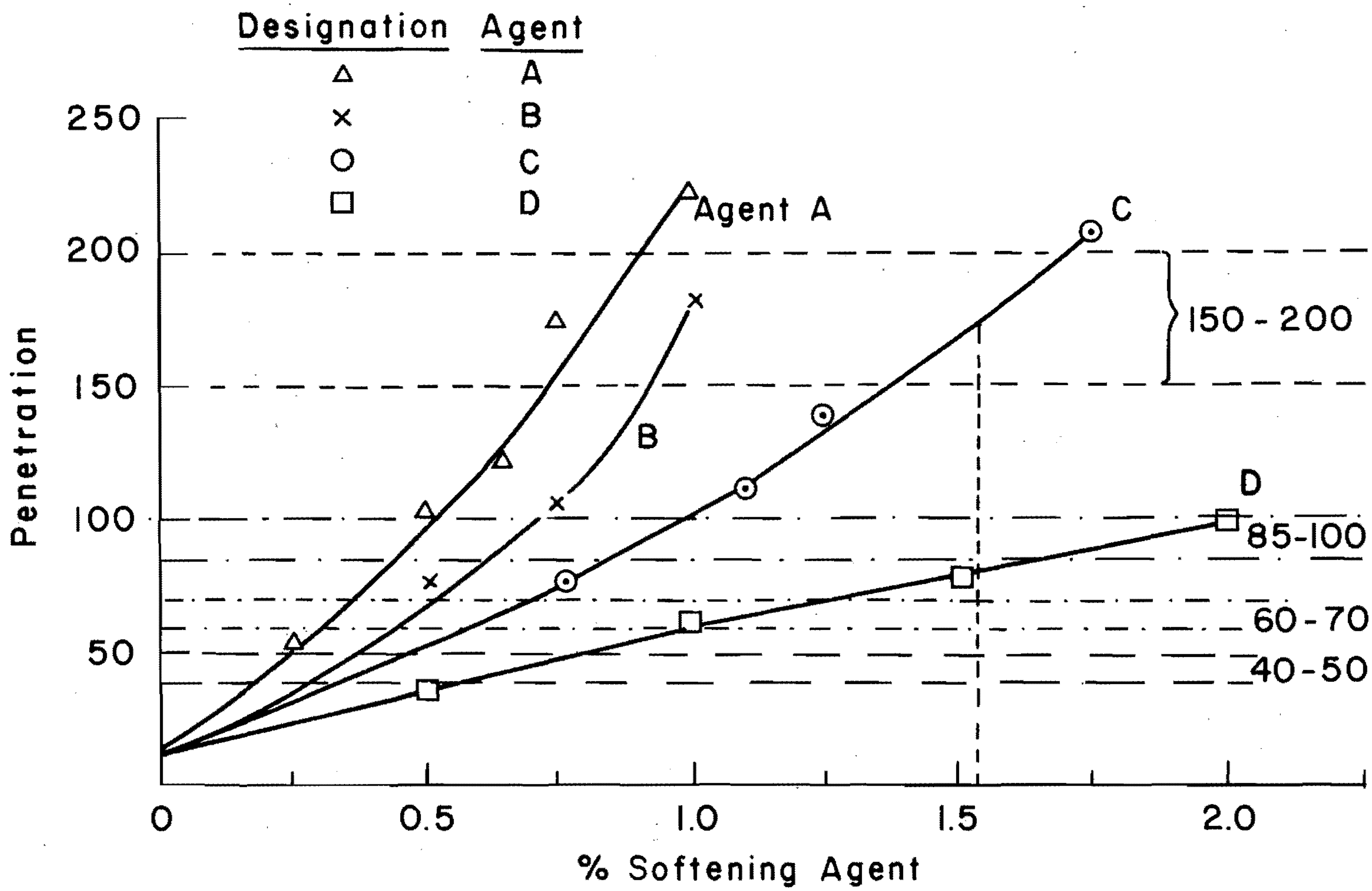


Fig 2. Typical relationships between penetration and percent softening agent for recovered brittle asphalt cement and four softening agents.

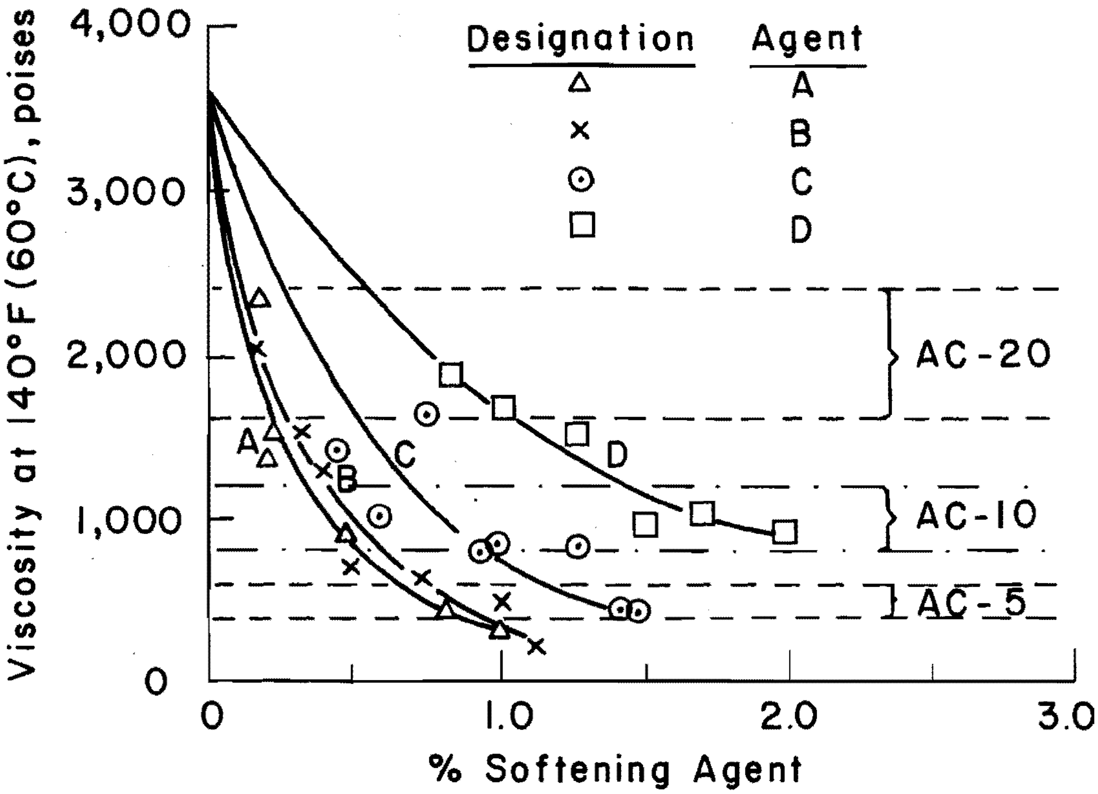


Fig 3. Typical relationships between viscosity at 140°F and percent softening agent for recovered brittle asphalt cement and four softening agents.

New Aggregate

According to Epps and Holmgreen (Ref 8), new aggregate may have to be added to the mixture for one or more of the following reasons:

(1) to satisfy gradation requirements,
(2) to satisfy new surface course skid resistance requirements,
(3) to meet air quality regulations associated with hot central plant recycling,
(4) to meet total pavement thickness requirements,
(5) to improve the properties of the mixture, such as stability, durability, flexibility, etc., and
(6) to allow addition of enough modifier to restore the salvaged asphalt to meet specification requirements while maintaining required mixture properties.

Gradation requirements for recycled mixtures should be designed to produce a dense, stable mixture similar to the grading curve shown in Fig 1 or one of those in ASTM D 3515.

To provide initial and long-lasting skid resistance for the recycled bituminous surface course, it may be necessary to blend coarse, nonpolishing aggregate with the salvaged material. Moderate to high-traffic-volume facilities seem to require that about 40 percent by volume of the plus No. 4 material be nonpolishing to provide adequate skid performance.

To meet air quality regulations associated with current hot central plant technology, 30 to 40 percent by volume new aggregate is typically required. However, this requirement may gradually be reduced as equipment manufacturers and contractors improve the hot recycling operation.

The salvaged material may represent only a portion of a thicker structural section required to meet predicted traffic demand. If so, and if a hot central plant is to be used, the new aggregate can be blended with the recycled pavement to meet the requirements or the engineer may elect to add layers of virgin asphalt-stabilized materials.

In addition to these reasons for adding new aggregate to the salvaged mixture, one other factor should be considered: experience in recycled construction. Generally, it is recommended that not more than 50 percent salvaged material be used since the mixture is less forgiving at higher percentages of recycled material. With experience, higher percentages of salvaged material can be used; however, in general it is recommended that not more than 70 percent salvaged material be included in the mixture.

Antistripping Additives

If it is determined that the action of moisture on the salvaged material has resulted in premature failure, the use of an antistripping additive should be considered. Chemical antistripping additives are commonly used. When specifying one of these agents, tests should be performed to evaluate the effectiveness of each proposed chemical antistripping additive when combined with the salvaged material. Preliminary results by Lee and Kennedy (Ref 9) have indicated that in many cases certain chemical antistripping additives when combined with certain asphalt aggregate mixtures do not prevent moisture damage and that these treated mixtures are still moisture susceptible. These results have also suggested that lime may be an effective antistripping additive when used properly (Refs 9 and 10). Nevertheless, it is mandatory that any proposed antistripping additives be tested with the aggregate and preferably the asphalt cement to be used to ascertain their effectiveness. Possible test methods are:

(1) Texas Freeze-Thaw Pedestal Test,
(2) Boiling Test, and
(3) Static and Repeated-Load Indirect Tensile Tests with and without moisture conditioning.

Preliminary indications suggest that the Texas Freeze-Thaw Pedestal Test may be quite valuable in evaluating potential antistripping additives and in detecting potential adverse moisture effects on various asphalt-aggregate combinations (Ref 11).

FINAL DESIGN

The materials selected in the preliminary design are evaluated to select (1) the final type and amount of additive required to either rejuvenate the asphalt cement or to prevent stripping and (2) the amount of new aggregate to incorporate into the mixture. The final design involves determining whether the engineering properties of the mixtures selected in preliminary design are acceptable. These are the steps to be followed:

(1) Prepare duplicate specimens of mixtures containing the approximate amount of selected additives based on weight of recovered asphalt, aggregate, or mixture as determined in the preliminary design and various percentages of new asphalt or other additives. The aggregate gradation, including the salvaged aggregate plus virgin aggregate, should have a gradation curve similar to that shown in Fig 1.

(2) Test the prepared specimens according to the Standard Tests used by the Texas State Department of Highways and Public Transportation

(a) for blackbase -- unconfined compression (Tex-126-E) and

(b) for asphalt concrete -- stabilometer (Tex-208-F).

(3) Compare the results from Step 2 with those required in the current specifications for conventional mixtures (Ref 12). For the Texas State Department of Highways and Public Transportation, these values for blackbases are

(a) for the best base material, unconfined compressive strength not less than

-- 340 kPa (50 psi) at the slow loading rate of 3.81 mm/min (0.15 in./min) and

-- 690 kPa (100 psi) at the fast rate of 254 mm/min (10 in./min) and

(b) for the poorest acceptable base material, unconfined compressive strength not less than

-- 210 kPa (30 psi) at the slow loading rate of 3.81 mm/min (0.15 in./min) and

-- 690 kPa (100 psi) at the fast rate of 254 mm/min (10 in./min)

and for asphalt concrete for all mixtures, Hveem stability not less than 30. However, recent experience with premature pavement failures from low stabilities indicates that the stability value probably should be at least 35 and perhaps as much as 40 for facilities handling high volumes of heavy trucks.

(4) Test the prepared specimens using the static and repeated-load indirect tensile tests. Tentative test procedures for the static test are contained in Refs 13 and 14. Tentative test procedures for the repeated-load indirect tensile test are contained in Refs 14 and 15.

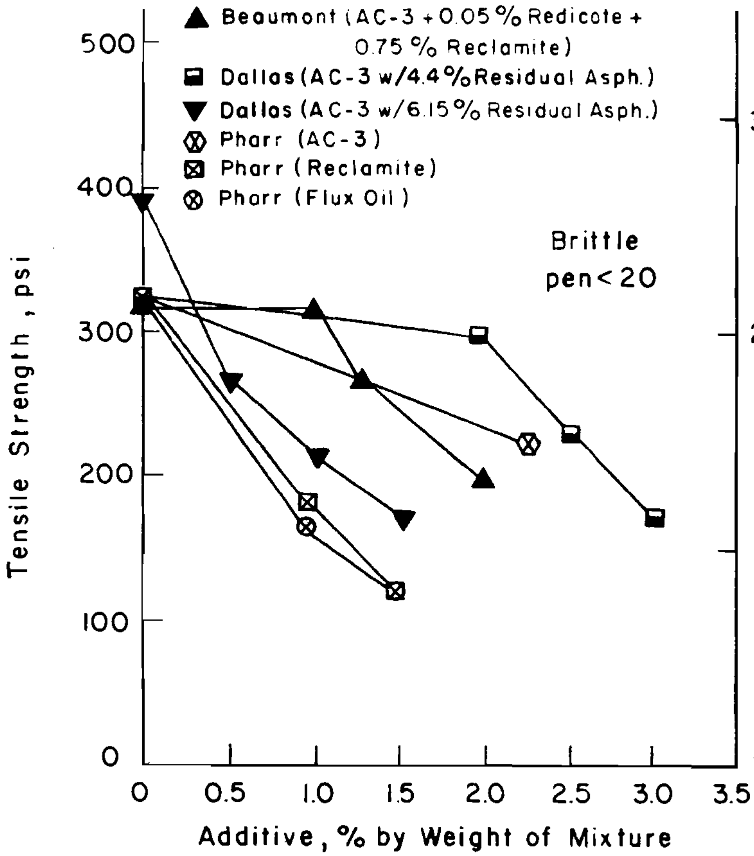
(5) Compare the results from Step 4 with those obtained for conventional mixtures. Properties recommended for consideration are

(a) tensile strength,
(b) static modulus of elasticity, and
(c) resilient modulus of elasticity.

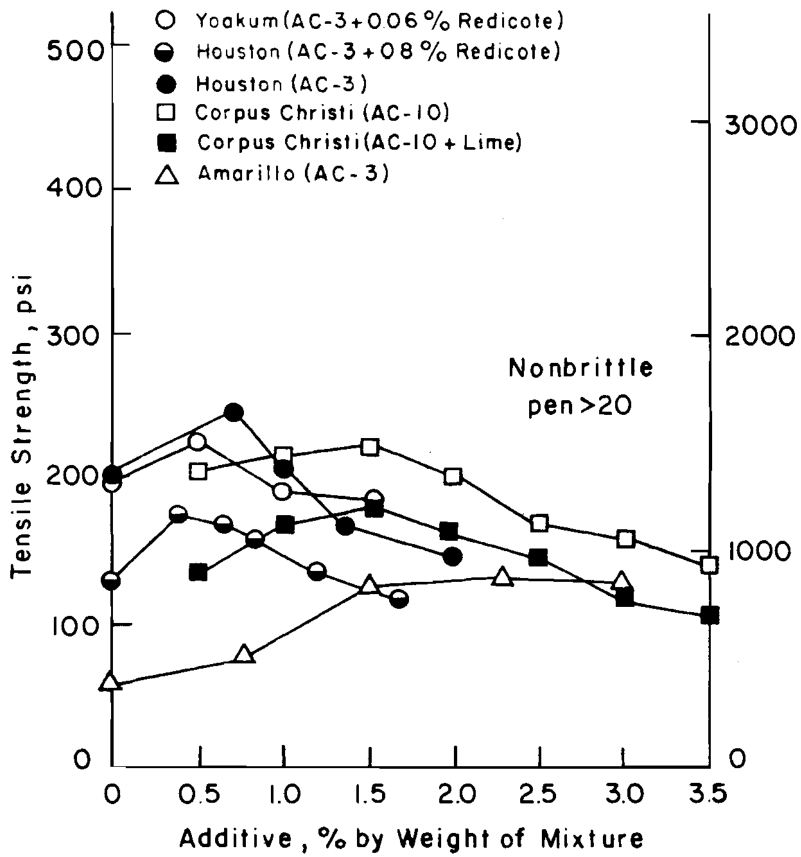
The relationships between the above properties and the amount of additive should be developed by testing recycled mixtures prepared at various additive contents and plotting the results in the manner shown in Figs 4 through 7. The resulting values should then be compared to desired values even though there is currently a limited amount of data to use to establish these desired values. Most specifications require minimum values for strength, etc. For recycled asphalt mixtures, the test values for the existing pavement material normally should be specified as a range including a maximum value since the asphalt in the salvaged mixture is often extremely stiff and brittle. It can be seen that the effect of softening agents is quite different on materials which were brittle than on nonbrittle materials. For the brittle materials, tensile strength (Fig 4a) decreases rapidly with additional additive while it does not for the nonbrittle material (Fig 4b). The same trend can be observed for static and resilient moduli in Figs 5 and 6. However, the stabilities in all cases are reduced dramatically as the percent additive increases for both the brittle and nonbrittle salvaged materials.

(6) Determine the resistance of the recycled mixture to adverse environmental moisture conditions as previously discussed. The Texas Freeze-Thaw Pedestal Test procedure is tentatively recommended for use and is described in Ref 11.

(7) Evaluate the workability of the mixture by visual inspection and make necessary adjustments in the amount of virgin aggregate and additives to be included in the recycled mixture. However, extreme care should be exercised to prevent workability requirements from adjusting gradations and binder content to the point that unstable mixes are produced.

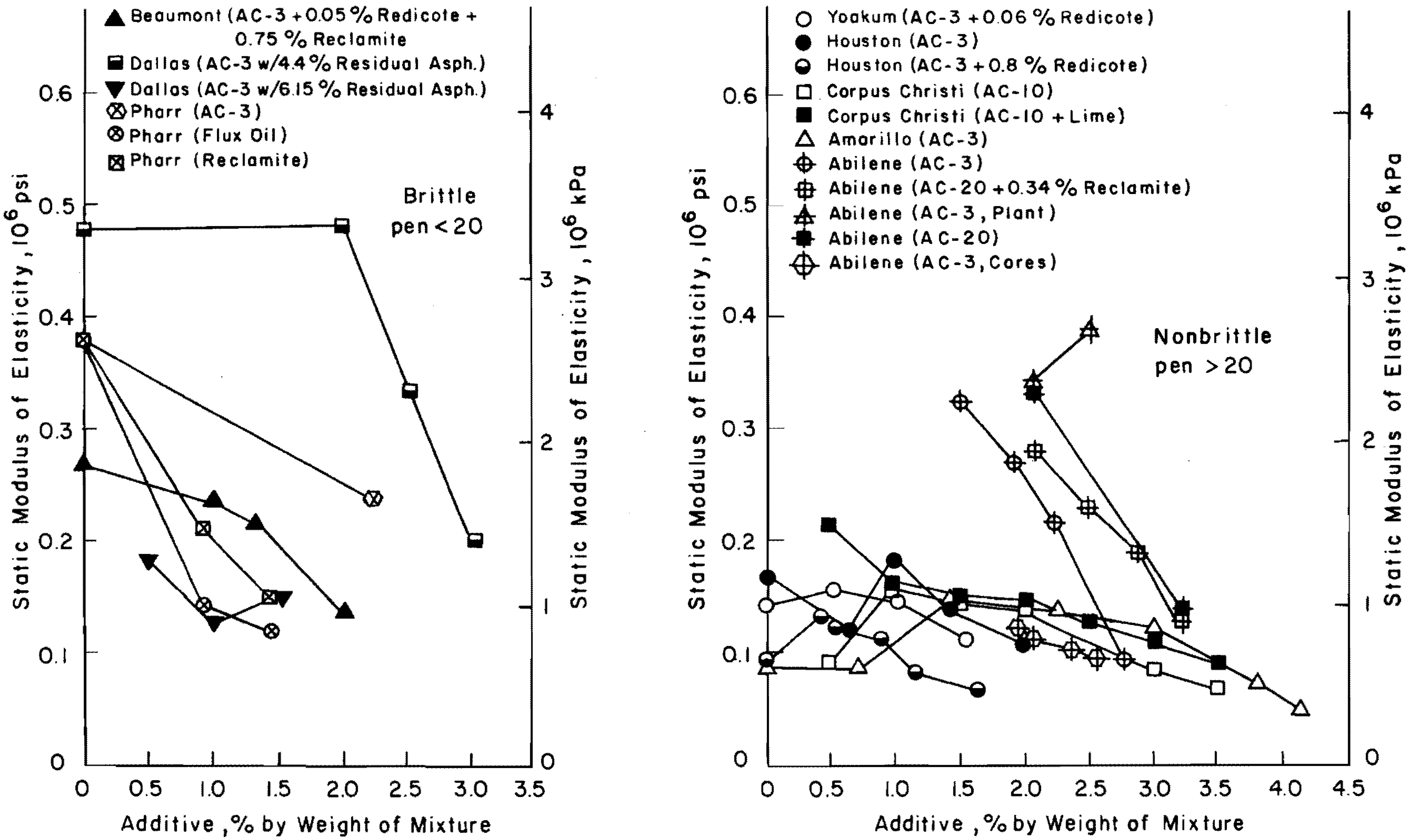


(a) With brittle asphalt cement.



(b) With nonbrittle asphalt cement.

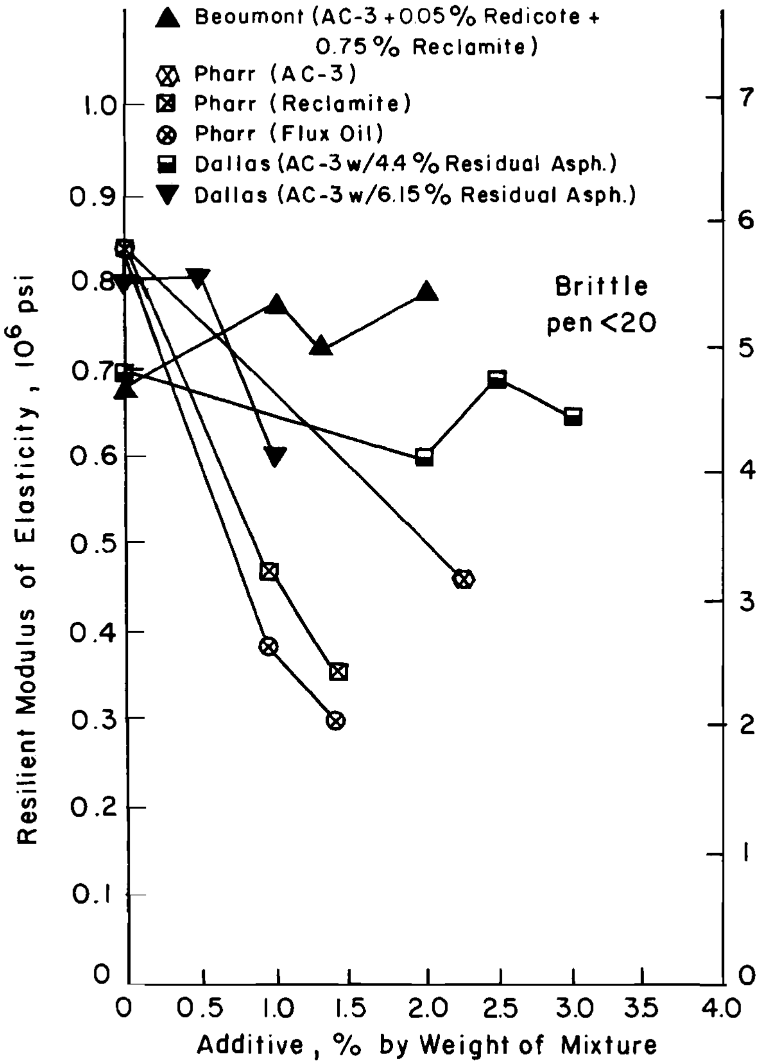
Fig 4. Effects of the amount of additive on tensile strength of salvaged mixtures.



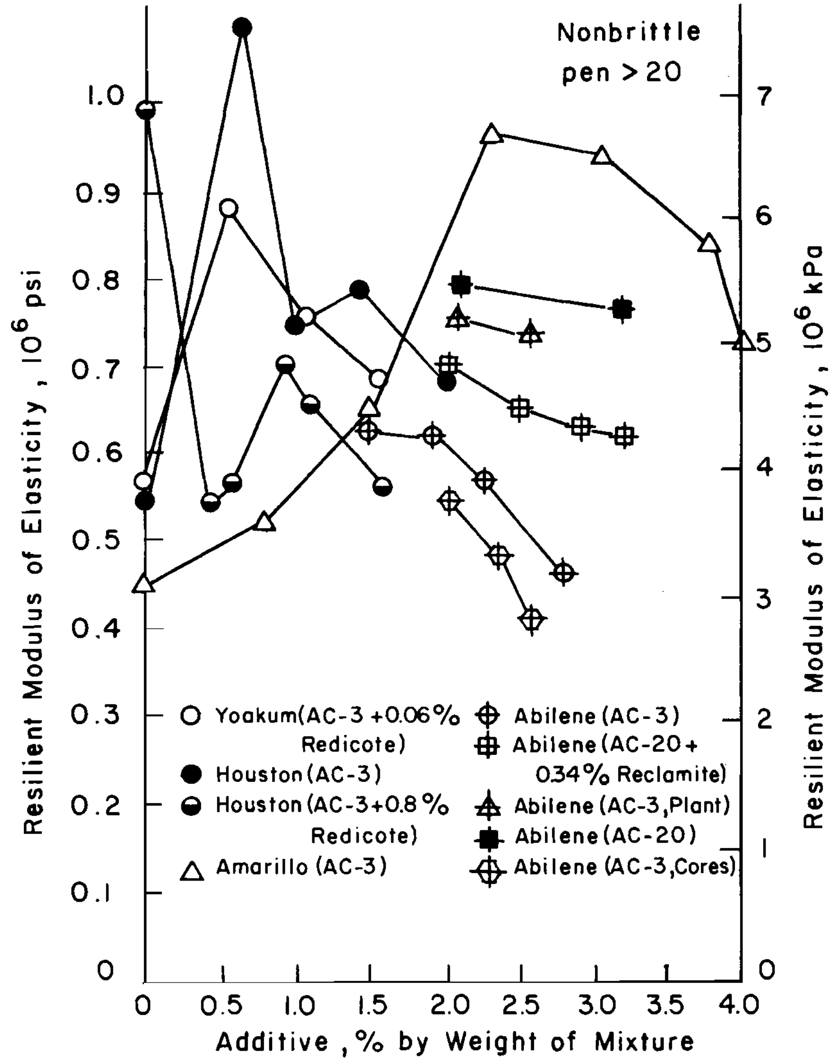
(a) With brittle asphalt cement.

(b) With nonbrittle asphalt cement.

Fig 5. Effects of the amount of additive on static modulus of elasticity of salvaged mixtures.



(a) With brittle asphalt cement.



(b) With nonbrittle asphalt cement.

Fig 6. Effects of the amount of additive on resilient modulus of elasticity of salvaged mixtures.

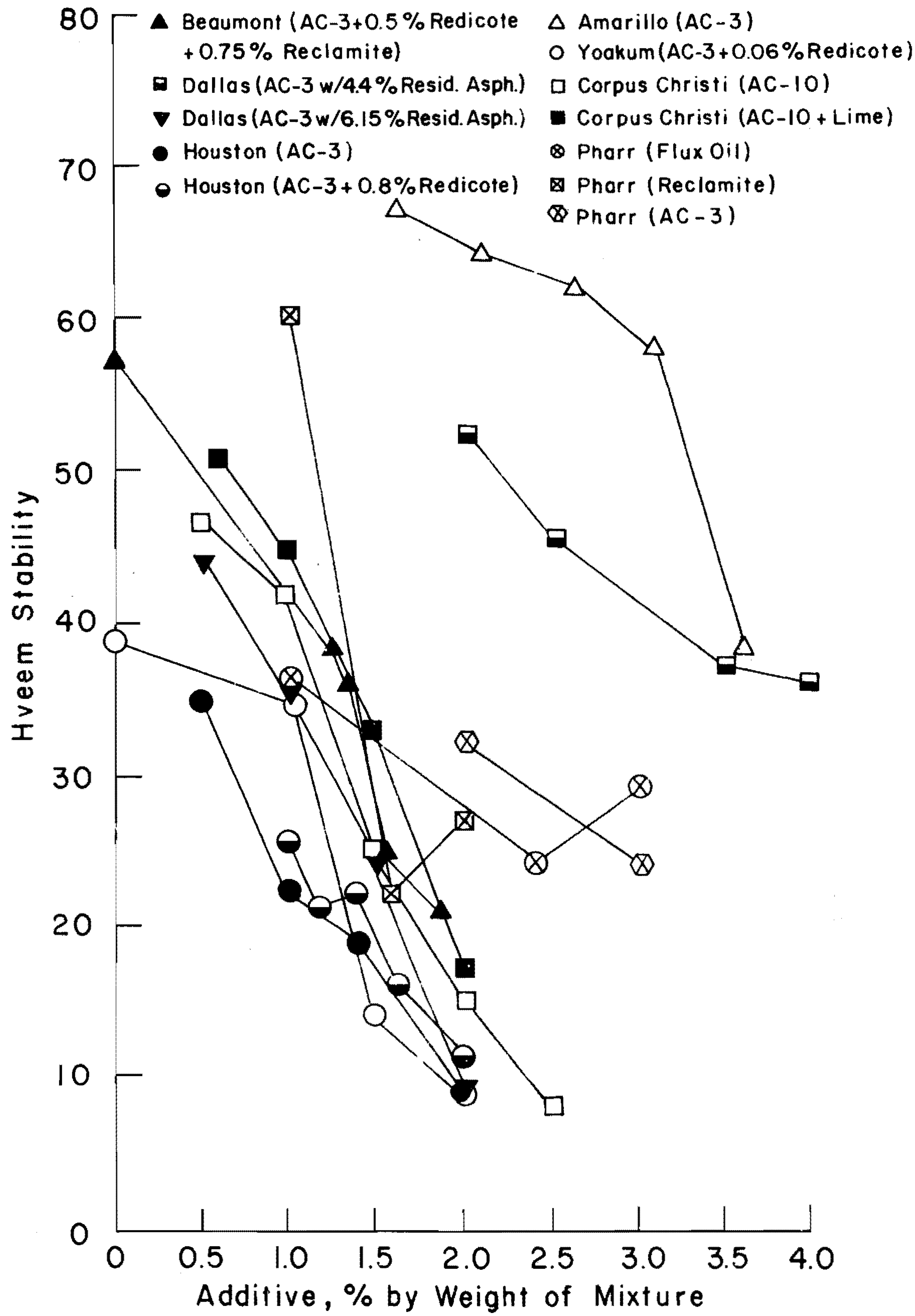


Fig 7. Effects of the amount of additive on Hveem stability of brittle and nonbrittle recycled mixtures.

RECOMMENDED INDIRECT TENSILE DESIGN VALUES

Results from previous studies have been used to evaluate the tensile strength, static modulus of elasticity, and resilient modulus of elasticity of both laboratory prepared and inservice asphalt mixtures. Since these materials are performing satisfactorily in the field, they represent a guide to the level of engineering properties that should provide satisfactory service for recycled mixtures.

Based on the results reported for various types of asphalt mixtures (Refs 16, 17, and 18), typical values of mixture properties were obtained. Even though additional theoretical work is needed to define the range of values required, typical values for pavements in the state of Texas are shown in Table 1. It is recommended that desirable values of engineering properties be determined for the particular location and function of the proposed recycled material.

An example of the use of the desired range of material properties to select the percent additive is shown in Figs 8 through 10. Specimens are prepared and tested at various additive contents and the results plotted as in Figs 8 through 10. At the point where the line of best fit for the test results intersects the middle of the acceptable range of properties, the optimum percent additive for that property is obtained. For example, in Figs 8, 9, and 10 these percent additives are shown for each combination of asphalt or asphalt and additive. The individual optimums for the AC-3 are 2.9, 2.6, and 2.7 for tensile strength, static modulus, and resilient modulus of elasticity, respectively. Neither the AC-20 nor the AC-20 plus 0.34 percent Reclamite reduces the resilient modulus to the desirable range while maintaining the tensile strength and static modulus in the desired range.

The range of additive for each of the properties that maintains the engineering property within the desired range for the AC-3 is shown in Table 2. Therefore, only 2.7 percent AC-3 meets all three of the engineering property requirements. It should be noted that other additives could be investigated and might be acceptable. In fact, field control for this particular mixture would probably prove to be very difficult.

TABLE 1. SUGGESTED INDIRECT TENSILE TEST DESIGN VALUES

Property	Design Value	
	psi	kPa
Tensile strength	73 - 203	500 - 1,400
Static modulus of elasticity	$0.10 - 0.51 \times 10^6$	$0.70 - 3.50 \times 10^6$
Resilient modulus of elasticity	$0.25 - 0.94 \times 10^6$	$1.70 - 6.50 \times 10^6$

TABLE 2. ADDITIVE RANGE THAT PRODUCES ACCEPTABLE ENGINEERING PROPERTIES

Property	Additive Range, %
Tensile strength	2.7 to 3.3
Static modulus of elasticity	2.4 to 2.7
Resilient modulus of elasticity	2.3 to 3.4

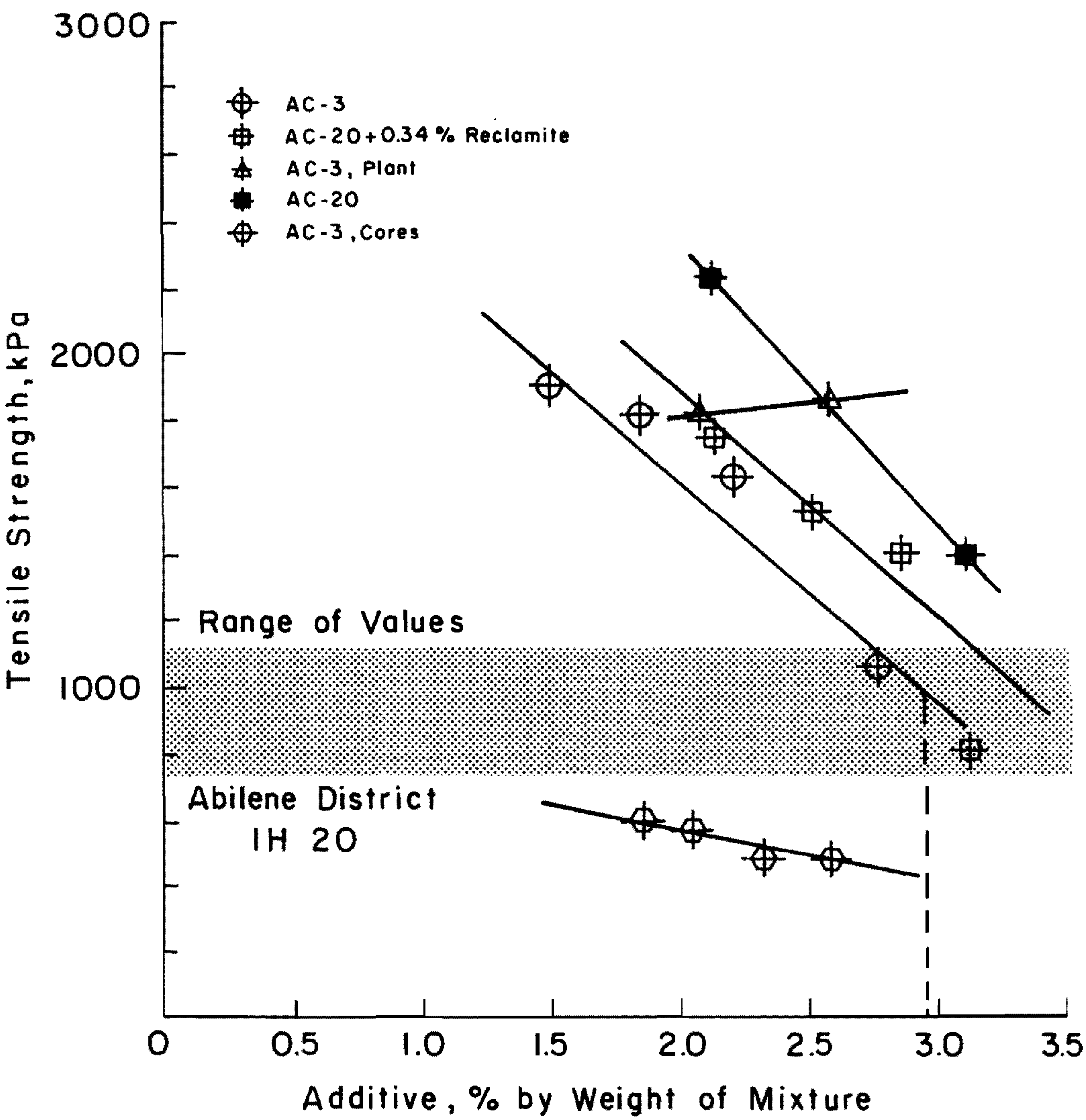


Fig 8. Determination of percent additive from a selected range of tensile strength values.

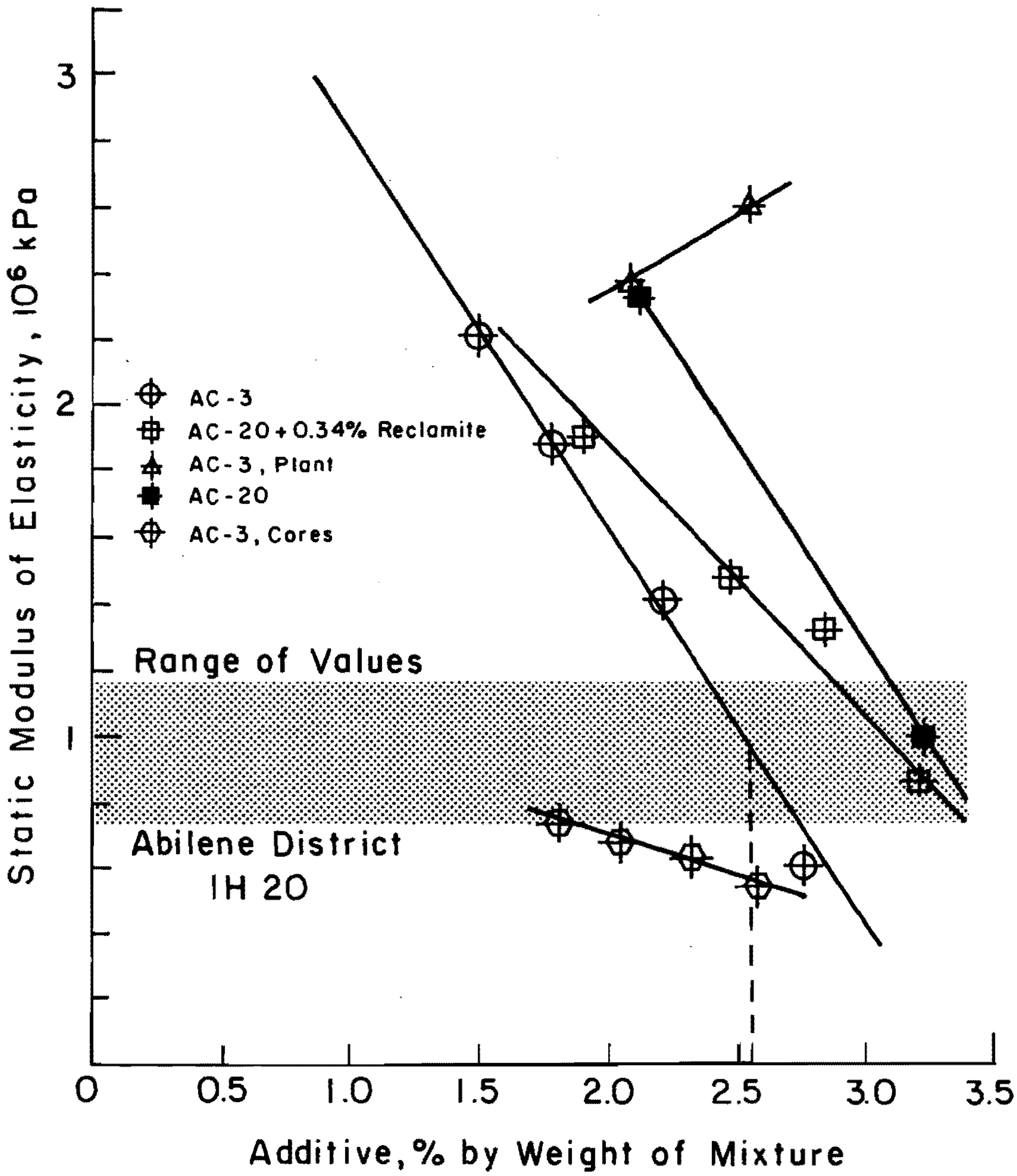


Fig 9. Determination of percent additive from a selected range of static modulus of elasticity values.

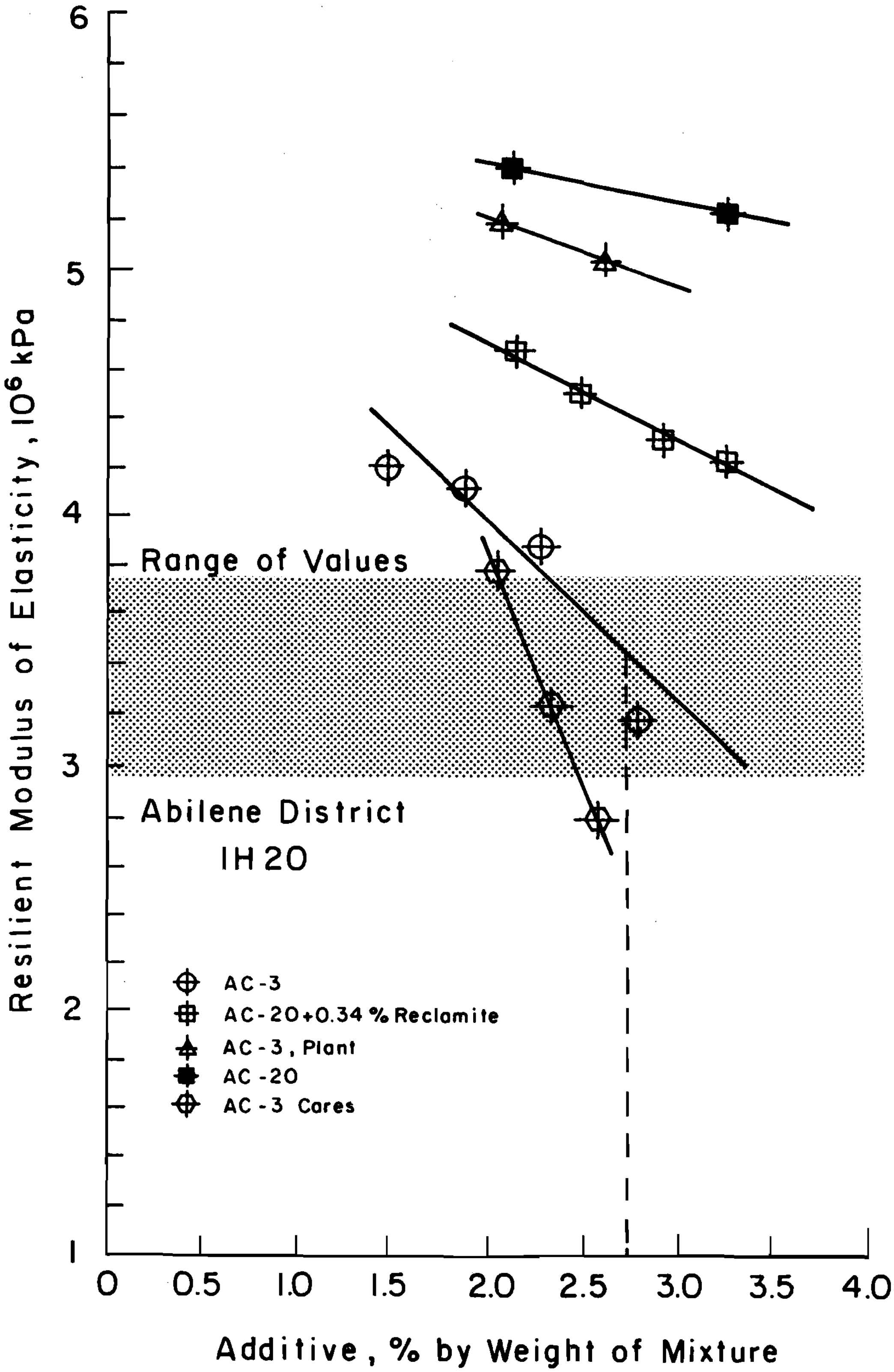


Fig 10. Determination of percent additive from a selected range of resilient modulus of elasticity values.

RECOMMENDATIONS

Based on the experience gained to date from designing mixtures for 15 recycling jobs and observing the construction process in the field in the state of Texas, the following recommendations are proposed:

(1) Identify and correct the cause of pavement distress before considering recycling as an alternative.

(2) Utilize 50 percent new material and 50 percent salvaged material in the recycled mixture. A practical maximum of salvaged material that can be used in a recycled mixture is 70 percent.

(3) Design the mixture in the laboratory under conditions as nearly like those expected in the field as possible. Once construction begins, modify the mixture design only if field evaluations justify such a change.

(4) Evaluate the following engineering properties for the laboratory prepared mixtures in order to select optimum additive contents.

    (a) stability,
    (b) unconfined compression,
    (c) indirect tensile strength, and
    (d) resilient modulus of elasticity.

(5) Increase the required Hveem stability for the recycled mixture to 35 or 40, depending on traffic volumes.

(6) Evaluate the water susceptibility of the recycled mixture using the Texas Freeze-Thaw Pedestal Test.

(7) Evaluate proposed antistripping additives for effectiveness before selection.

(8) Operate the plant as it was designed; if problems develop, call in equipment manufacturers for assistance before preparing a large volume of recycled mixture.

Consideration of these recommendations along with use of the design procedure described in this report should enable an engineer who is not experienced in recycling asphalt pavements to successfully complete a job so it will provide good field performance.

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