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16. Abstract

The objective of this study was to provide the Texas Department of Transportation with a means to assure quality of cold-applied asphalt stabilized maintenance mixtures. Samples of 17 different maintenance mixtures were obtained from across the state and 14 of these were stockpiled at Texas A&M's Riverside Campus. These materials were evaluated in terms of field aging and field workability. To evaluate the aging of the field materials, laboratory tests were performed to determine resilient moduli, tensile strength and extracted binder properties. Findings indicated that only minimal aging occurred in most of the mixtures in a six-month period.

The workability of the stockpiled field materials was subjectively evaluated and compared to laboratory measurements aimed at quantifying workability. Comparisons of field ratings to laboratory measurements indicated that there was no clear relationship.

Two test procedures were evaluated regarding their potential to quantify the workability of HMCL asphaltic mixtures: (1) a triaxial compression test, and (2) unconfined compression test. Test results indicated that both procedures provide a relatively good measure of workability.

Two laboratory aging procedures were evaluated for their ability to predict workability of a stockpiled maintenance mixture after 6 months of stockpile aging.

Test protocol and acceptance criteria were developed to estimate the relative ability of a maintenance mixture to retain adequate workability after outdoor stockpile storage.

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EVALUATION AND IMPROVEMENT OF BITUMINOUS MAINTENANCE MIXTURES

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IMPLEMENTATION STATEMENT

Repair of potholes and surface irregularities of asphalt pavements is one of the most commonly performed maintenance operations for most road and highway agencies; therefore, the findings of this study have potential for widespread implementation.

At the onset of this study, area engineers expressed the need to obtain maintenance mixtures which would retain adequate workability for more than 6 months, particularly during winter. Researchers found that there were no suitable specifications for ensuring workability or stockpile life nor test procedures for quantifying workability of maintenance mixtures. These shortcomings have occasionally resulted in the acquisition of unsuitable maintenance mixtures that are incapable of being used in cold weather -- the time they are needed most.

Based on the research performed in this study, test protocols along with acceptance criteria were developed for HMCL asphaltic maintenance mixtures for winter use. The test protocols are designed to estimate the relative ability of a maintenance mixture to retain adequate workability after 6 months of outdoor stockile storage. Findings indicate that these test protocol and acceptance criteria should be implemented on a trial basis. The test procedures developed in this study are modifications of existing TxDOT procedures for soils and unbound aggregate and do not require the purchase of any new equipment. Most district laboratories are equipped to perform the recommended tests.

Requiring materials suppliers to meet this new specification may initially result in a higher cost for maintenance mixtures. Once they learn the formulations required to meet the specification, materials costs should return to normal.

Implementation of the findings of this research will have national significance. Paving materials acceptance criteria, test methods, and pavement maintenance practices may be impacted by the findings of this study. Therefore, materials producers, suppliers, pavement maintenance contractors, as well as state and federal highway and transportation officials, and even municipal public works administrators will be involved in the implementation of research results.

DISCLAIMER

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

SUMMARY

The goal of this study was to provide the Texas Department of Transportation (TxDOT) with a means to assure the quality of cold-applied asphalt stabilized maintenance mixtures.

A literature review and survey of TxDOT districts was performed to aid in the conduct of the research activities. Samples of 17 different maintenance mixtures were obtained from across the state and stockpiled at the Riverside Campus at Texas A&M University. These materials were evaluated in terms of field aging and field workability. To evaluate the aging of the field materials, laboratory tests were performed to determine resilient moduli, tensile strength, and extracted binder properties. Findings indicated that only minimal asphalt hardening occurred in most of the mixtures in a six-month period.

The workability of the stockpiled field materials was subjectively evaluated and compared to laboratory measurements aimed at quantifying workability. There were no clear correlations between field ratings and laboratory measurements.

Several potential stockpile treatment methods were evaluated for their effectiveness at reducing the intrusion of water into the stockpile. Pavement striping paint (sprayed on the stockile surface) was found to be the most effective and practical treatment for HMCL mixtures.

Two test procedures were evaluated regarding their potential to quantify the workability of HMCL asphaltic mixtures: (1) a triaxial compression test, and (2) unconfined compression test. Test results indicated that both procedures correlate to subjective workability ratings.

Two laboratory aging procedures were evaluated for their ability to predict workability of a stockpiled maintenance mixture after 6 months of stockpile aging.

Test protocol and acceptance criteria were developed to estimate the relative ability of a maintenance mixture to retain adequate workability after outdoor stockpile storage.

1.0 INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

Pothole and surface repair of asphalt pavements is one of the most commonly performed maintenance operations for most highway agencies, especially in areas where cold winters and warm, wet springs contribute to accelerated, perpetual pavement break-up every year. Without question, potholes hold the ominous distinction of being the most aggravating pavement distress to the travelling public.

Bituminous materials have consistently proven to be the most versatile of all highway maintenance materials because of their comparatively low cost, generally good stability, relative quality, and ease of application. They have the ability to deal with virtually all types of highway surface repair problems. However, these indispensable maintenance materials are not without problems.

During a recent TxDOT study performed by TTI with the purpose of identifying alternative pavement maintenance materials to use in place of limestone rock asphalt, a number of deficiencies of typical hot mix-cold laid asphalt patching materials (Specification Item 350) were detected. The chief problems associated with these mixtures were cold weather workability in the stockpile and on the road, moisture susceptibility as evidenced by raveling and stripping, poor stability in deep patches, and, in general, inconsistent behavior when the mixture is prepared and applied in accordance with standard specifications and guidelines.

It is suspected that standard laboratory sample preparation procedures may not be producing specimens with properties comparable to similar mixtures compacted in the field. Laboratory testing methods do not appear to relate well to stresses produced by traffic and the environment.

Furthermore, there are no suitable specifications for ensuring workability nor test procedures for quantifying workability of maintenance mixtures. These shortcomings have occasionally resulted in the acquisition of unsuitable maintenance mixtures that are incapable of being used in cold weather. Such unsuitable mixtures left in an unprotected stockpile for more than a few weeks may form a hard crust two to six inches thick. This hard crust not only makes workability difficult in the stockpile but also on the roadway. During loading and hauling, the crusted material is only partially broken up which leaves clumps or clods that must be dealt with during patching operations. This, of course, is frustrating and time consuming for the maintenance engineer and his staff.

The final unsatisfactory result of the problems discussed above is visible to the travelling public and often serves to generate a negative impact on the public image of the Department.

1.2 OBJECTIVES

The goal of this study was to provide the Department with methods to assure the quality of cold-applied asphalt stabilized maintenance mixtures. Specific objectives are as follows:

- Determine what effect aging has on stockpiled maintenance mixtures;
- Develop material modifications and/or stockpile treatments that can be used to minimize age-hardening of stockpiled maintenance mixtures;
- Develop a laboratory test procedure with artificial aging that can be used to measure and predict workability of maintenance mixtures that have been stockpiled for several months;
- Field test and evalulate the materials, modifications, stockpile treatments, and test methods developed; and
- Work with TxDOT in the preparation of specifications and test methods that can be successfully implemented.

1.3 LITERATURE REVIEW

Repair of potholes, alligator cracked areas, edge breakups, and other asphalt pavement problems that are intensified during the winter months are the most visible signs of maintenance efforts to the travelling public. Although winter patching is very difficult because of the cold temperatures, water-logged base courses, and excessive stiffness of the patching materials, the public still demands that the road be kept smooth and that lane closures be kept to a minimum.

Several recent studies by the Strategic Highway Research Program (SHRP) (1) and others (2 and 3 through 11) have contributed to solutions for the problems outlined in the introduction. The SHRP H-106 project (2) is the most extensive pavement maintenance experiment ever conducted; however, many other studies (12 through 26) also have contributed to this effort.

Hundreds of papers have been presented on cold-mix or temporary patching, pothole patching, winter patching, and related topics. Most studies appeared to address problems in colder climates. Although stability of the maintenance mix was often determined, aging in the stockpile and workability of aged and unaged mixes was rarely included as a part of the study. Very few studies discussed aging of material in stockpile and the problems associated with placing, compacting, and resultant performance of this aged mix.

The experimental design and research plan of the SHRP H-106 study (1) is titled "Innovative Pothole Repair Materials and Procedures for Asphalt Surfaced Pavements". In this study, over 1200 patches were placed at eight locations. Two of the sites are particularly important. One site was near Greenville, Texas on FM 1570 and the other site was in Las Vegas, New Mexico. The climates for these two sites are typical of the wet and dry climates in Texas. The combinations of material type and patching technique studied in Texas and New Mexico were:

1. UPM[*] throw and roll;
2. UPM[*] throw and roll with tack coat along edges of patch;
3. UPM[*] partial depth patch (recommended policy);
4. PENN DOT 485 mixture throw and roll;
5. PENN DOT 486 mixture throw and roll;
6. Local material throw and roll;
7. HFMS-2 w/Styrelf throw and roll;
8. Perma-Patch[*] throw and roll;
9. QPR 2000[*] throw and roll; and
10. Spray injection.

[*] proprietary material

It is important to note that although most other types of patches had high survival rates after more than one year of service (>67%), the local Texas material had only a 20% survival after only five weeks and no patches survived to one year (1).

There are many deficiencies of the mixtures that are in current use. These deficiencies are reflected in poor performance or premature failure, which may be initiated in the stockpile, during handling and placement, or in service. A list of the types of inadequate performance and their probable causes is given in Table 1. The most commonly encountered mixture deficiencies at the stockpile are poor workability and stripping (1) with binder drainage being a problem (4) with certain types of mixtures. Curing characteristics of the binder are also very important during stockpiling. Although some "skinning" or "crusting" may be expected in the stockpile, it should not be so pronounced that the mix is lumpy or hard to work. To avoid this, the viscosity-temperature characteristics of the binder must permit the mixture to be worked throughout the range of temperatures encountered during handling and placement.

During transport and placement, the primary concerns are workability and compactability (which is related to workability). Workability refers to the ease with which a mixture can be handled, shoveled, and raked. It is not a fundamental property of asphalt concrete, but it is one of the key properties that must be satisfied (27, 28). Workability is gained by using an adequate amount of a relatively soft binder. Immediately after compaction, before the binder cures, the mix must be stable and not susceptible to pushing or shoving. This immediate stability is obtained primarily through careful attention to aggregate properties. Mixture properties designed to improve workability may oppose stability; therefore, these two must be carefully balanced.

The most frequently encountered in-service failures are pushing or shoving, raveling, and dishing. "Dishing" is compaction under traffic which leaves a depression in the repaired surface; it is invariably a result of inadequate compaction. Other failure mechanisms may include freeze-thaw deterioration, poor skid resistance, and lack of adhesion to the side or bottom of the repair (Table 1). Mixture design factors that should be considered for conventional cold-applied asphalt maintenance materials are summarized in Table 2. These are generally the factors that affect any asphalt mixture, but here they have been directed specifically toward maintenance mixtures.

Table 1. Problems and Failure Mechanisms in Cold-Mix Patching Materials (Modified after Reference 4).

Problem or Symptom of Failure	**Probably Causes Failure Mechanisms**
	In Stockpile
Hard to work	Binder too stiff To many fines in aggregate, dirty aggregate Mix too coarse or too fine
Binder drains to bottom of pile	Binder too soft Stockpiled or mixed at too high a temperature
Loss of coating in stockpile	Stripping Inadequate coating during mixing Cold or wet aggregate
Lumps - premature hardening	Binder cures prematurely
Mix too stiff in cold weather	Binder too stiff for climate Temperature susceptibility of binder too great Too many fines in aggregate, dirty aggregate Mix too coarse or too fine
	During Placement
Too hard to shovel	Binder too stiff Too many fines, dirty aggregate Mix too coarse or too fine
Softens excessively upon heating (when used with hot box)	Binder too soft
Hard to compact (Appears "tender" during compaction)	Insufficient mix stability Too much binder Insufficient voids in mineral aggregate Poor aggregate interlock Binder too soft
Hard to compact (Appears stiff during compaction)	Binder too stiff Excess fines Improper gradation Harsh-mix - aggregate surface texture or particle shape

Table 1. (continued)

Problem or Symptom of Failure	**Probable Causes - Failure Mechanisms**
In Service	
Pushing, shoving	Poor compaction Binder too soft Too much binder Tack material contaminates mix Binder highly temperature-susceptible, causing mix to soften in hot weather Inservice curing rate too slow Moisture damage--stripping Poor aggregate interlock Insufficient voids in mineral aggregate
Dishing	Poor compaction Mixture compacts under traffic
Raveling	Poor compaction Binder too soft Poor cohesion in mix Poor aggregate interlock Moisture damage-stripping Absorption of binder by aggregate Excessive fines, dirty aggregate Aggregate gradation too fine or too coarse
Freeze-thaw deterioration	Mix too permeable Poor cohesion in mix Moisture damage--stripping
Poor skid resistance	Excessive binder Aggregate not skid resistant Gradation too dense
Shrinkage or lack of adhesion to sides of hole	Poor adhesion No tack used, or mix not self-tacking Poor hole preparation

Note: In some instances items appear as both symptoms and causes. It is difficult to separate the symptoms from the causes in some cases.

Table 2. Design Considerations for Cold Mixes (Modified after Reference 4).

Design Considerations	Effect on Mixture
Binder consistency (before and during placement)	Too stiff may give poor coating during mixing Too stiff makes mix hard to shovel, compact Too soft causes drain-down in stockpile Too soft may cause stripping in stockpile Too soft may contribute to "tenderness" during compaction
Binder consistency (after placement)	Too soft accelerates stripping, moisture damage inservice Too soft accentuates rutting, shoving Too soft may lead to bleeding, which causes poor skid resistance Must cure rapidly to develop cohesion High temperature susceptibility causes softening and rutting in summer
Binder content	Maximize to improve workability Excess causes drain-down in stockpile Excess may lower skid resistance (bleeding) Excess may cause shoving and rutting Insufficient yields poor cohesion & moisture susceptibility
Antistripping additive	Correct type and quantity may reduce moisture damage Some may affect workability
Aggregate shape and texture	Angular and rough aggregate gives good resistance to rutting and shoving but is hard to work Rounded and smooth gives good workability but poor resistance to rutting and shoving
Aggregate gradation	Reduced fines improves workability (2% max) Excess fines can reduce "stickiness" of mix Coarse (>25 mm) mixes are hard to shovel & spread Open-graded mixes can cure rapidly but allow water ingress Well-graded mixes are more stable Dirty aggregate may increase moisture damage Too dense a gradation will lead to bleeding or thin binder coating, and a dry mixture with poor durability Open or permeable mix may be poor in freeze-thaw resistance
Other additives	Short fibers increase cohesion, increase workability Polymers may increase mix toughness and cohesion

Most cold, wet weather, stockpiled patching materials are produced with cutback asphalt cement. The diluent or solvent is typically gas oil or kerosene, which is supposed to evaporate after placement. However, much of the solvent remains with the material for a relatively long period, thereby imparting some flexibility to the patch. The primary advantages of cutback asphalts are their relative simplicity and low cost. The main disadvantage of cutback-based materials is their emission of hydrocarbon vapors (21).

Emulsified asphalts are sometimes used as alternatives to cutback asphalts. To obtain the necessary workability in the stockpile, mixing-grade emulsions are generally used. These emulsions are often made using cutback asphalt; however, the percentage of solvent is considerably reduced. Emulsions may be modified with surfactants to produce high-float products which exhibit thixotropic characteristics. A thixotropic emulsion forms a gel when static but becomes thin upon stirring or shearing. This thixotropic attribute permits the retention of much thicker films of residual asphalt and aids in workability since the asphalt becomes more fluid as it is worked. Although asphalt emulsions are a little more expensive than cutback asphalts, they offer the advantage of reduced air pollution (4, 26).

In recent years, very little has been done to develop test procedures and criteria to gauge the quality and determine acceptability of maintenance mixtures. Performance requirements for asphalt patching materials are listed below:

- Workability in stockpile and on road
- Stripping Resistance (uncured)
- Drainage Resistance in stockpile
- Self-Tacking to the patched area
- Complete Curing (at the proper time)
- Stability
- Flushing Resistance
- Nonraveling
- Freeze-Thaw Resistance
- Safe for Workers

- Environmentally Acceptable
- Skid Resistance

The SHRP study on development of materials for pothole repair (1) included a series of tests on the materials evaluated. The laboratory testing was an attempt to define pertinent material characteristics which could be related to the performance of the materials in the field. The tests which were performed on the materials were intended to characterize properties of the mixture, as well as the aggregate and binder. The majority of the tests performed were originally developed for hot mix asphalt materials. Due to the different properties of the cold mixes, the materials were "aged" in an oven to simulate field conditions prior to testing. A complete list of the tests performed is given below:

- Resilient Modulus @ 25°C and three frequencies
- Marshall Stability and Flow, ASTM D 1559
- Sieve Analysis, ASTM D 136
- Binder Content, ASTM D 2172
- Penetration (recovered binder only), ASTM D 5
- Ductility (recovered binder only), ASTM D 113
- Softening Point (recovered binder only), ASTM D 36
- Viscosity (recovered binder only), ASTM D 2171
- Workability, Pennsylvania Transportation Institute method (described below)
- Maximum and Bulk Specific Gravity, ASTM D 2041 & D 2726
- Water Susceptibility, ASTM D 1664

The SHRP study measured workability of freshly produced maintenance mixtures using a Pennsylvania Transportation Institute (PTI) method (4) which is essentially resistance to penetration by a modified CL-70 Soiltest pocket penetrometer inserted into the side of a container of uncompacted mixture. The penetrometer was modified by attaching a 9.5 mm by 75 mm extension to the penetrometer foot. Material was placed loosely into a 100-mm by 100-mm steel box. Workability was measured by pushing the penetrometer foot through one of the holes in the box and then into the mix until a peak load was obtained. The peak load required to penetrate the mix was recorded as the measure of workability.

The laboratory procedure (1) described above utilized a 9.5 mm diameter probe developed by PTI. When this attachment was compared directly to a blade attachment developed by the SHRP researchers, the reading of the blade attachment was approximately five times larger. The circular probe seemed to work for stiffer mixes, where the smaller cross section presents less resistance. The blade attachment seemed to work for softer mixes, where the length of the blade in contact with the mix provides more resistance.

In 1970, the Texas Transportation Institute performed a study on winter maintenance of bituminous pavements (30). In this study a procedure was developed for evaluation of workability of maintenance mixtures. The test was essentially an unconfined compression test. Specimens were prepared by static compaction, which furnished a reliable representation of field compaction. Test data showed that the mixtures with higher subjective workability had higher unconfined compressive strength.

1.4 DISTRICT SURVEY - 1992

As part of the literature review in this study, a report was reviewed concerning TxDOT's experience with patching materials on the basis of method of application, performance and cost (primarily for pothole/spall repairs) (31). This report was prepared in 1992 as a result of a district survey conducted by the Maintenance Section of TxDOT's Maintenance and Operations Division. The survey revealed that 13 districts reported the use of LRA for pothole repair. The material could be used throughout the year and with moderate success in wet conditions; however, it is most often used when conditions are cold and dry. LRA was reported to be successfully stockpiled for an average period of 13 months with almost no problems regarding workability.

Hot-mix cold-laid (HMCL) asphaltic concrete was reported by 12 districts for the repair of potholes in asphaltic pavement (31). It is used primarily for making permanent repairs. It was reported that this material can be used almost any time of the year during dry conditions; however, it is more commonly used during warmer periods. HMCL can be stockpiled for an average of 10 months, although the majority of districts using this material experienced workability problems with stockpiled HMCL.

The use of rapid curing asphalt concrete (RCAC) was reported by 4 districts and is used exclusively for repairing potholes in asphaltic pavement (31). Two common brand names of material supplied under this category include Instant Road Repair and Barriere Perma-Instant Fill. This material can be used throughout the year but is most commonly used in winter and spring under wet conditions. This material is generally furnished in bags or buckets and has an average storage life of about 12 months.

The use of patching mixtures such as UPM manufactured by Sylvax Corporation was reported by 14 districts for the repair of potholes (31). It is used primarily for making a combined quick/permanent repair. This material was reported to be used anytime of the year under all conditions, although it is predominantly used during cold and/or wet conditions. It is reported to have an average stockpile life of 16 months. Four districts reported problems with stockpile workability.

1.5 DISTRICT SURVEY - 1993

A survey was conducted at the onset of this study. The questionnaire and summary of results are presented in Appendix A.

2.0 LABORATORY AND FIELD EVALUATION OF THE EFFECTS OF AGING ON ASPHALTIC MAINTENANCE MIXTURES

2.1 MATERIALS USED

During the first year of this study, researchers obtained samples of maintenance mix from across the state. Most of the mixtures were requisitioned as "winter" maintenance mixtures for the respective areas. Some of the mixtures, however, were sampled because, in the opinion of the maintenance personnel supplying the materials, they were specifically reported to have poor workability .

The maintenance mixtures which were sampled fall into three general categories: (1) hot mix-cold lay (HMCL) asphalt concrete, (2) limestone rock asphalt (LRA) concrete, and (3) improved or specialty mixtures such as UPM and Instant Road Repair.

A total of 17 different maintenance mixtures were sampled from across the state for laboratory and field evaluation. Mixtures supplied and areas which supplied them are shown in Table 3.

Large quantities of the maintenance mixtures were obtained, when possible, and small stockpiles were created at Texas A&M's Riverside Campus. Fourteen of the mixtures were stockpiled at the Riverside Campus and workability and stripping characteristics were subjectively evaluated periodically. The stockpiles were also sampled periodically for laboratory testing.

2.2 EFFECT OF AGING ON STOCKPILED MIXTURES

Highway engineers have recognized that binder "aging" has serious detrimental effects on stockpiled maintenance mixtures particularly when the age-hardened material must be used during cold weather (3, 4, 14, 18, 19, 29). Laboratory tests were performed on the field-stockpiled materials to evaluate the change in material properties as the stockpiles aged. This included testing on the compacted mixtures as well as on extracted and recovered binder.

Table 3. Maintenance Mixtures Sampled Across the State for Laboratory and Field Evaluation.

Mixture Designation	Mixture Type	Area Supplying Mix	Specification Item
1*	HMCL	Amarillo	334
2*	HMCL	Amarillo	334
3	HMCL	Austin	334
4	HMCL	Bryan	334
5	HMCL	Bryan	334
6	HMCL	Livingston	334
7	HMCL	Longview	334
8	HMCL	San Antonio	334
9	HMCL	Schulenberg	334
10	HMCL	Texarkana	334
11	LRA	Austin	330
12	LRA	Atlanta	330
13	LRA	La Grange	330
14	LRA	San Antonio	330
15	Specialty	Bryan	9200
16	Specialty	Livingston	9200
17*	Specialty	Manufacturer	Instant Road Repair

* Insufficient material was obtained to perform field evaluations.

2.2.1 Resilient Modulus Testing

Resilient modulus tests were performed on the compacted mixtures at two time periods: (1) when the mix was new and (2) after 6 months of stockpile aging. Samples were compacted using the Texas Gyratory Compactor and standard procedures but at a temperature of 25°C. Air void contents for the compacted mixtures ranged between about 10 and 15 percent.

Resilient modulus provides for a measure of mixture stiffness and was measured in accordance with ASTM D 4123-82 using the Mark III resilient modulus device. The test is performed by applying a diametral load for a duration of 0.1 seconds while monitoring the diametral deformation perpendicular to the loaded plane.

Resilient modulus was measured as a function of temperature. The resilient moduli for the unaged HMCL materials are shown in Figure 1. Mixtures 6, 7 and 8 appear to have a higher stiffness at all temperatures than the other HMCL mixtures.

Resilient moduli for the LRA mixtures are shown in Figure 2. The LRA mixtures appear to be less stiff at the low temperatures than the HMCL samples. In addition, the LRA mixtures appear to be a little less temperature susceptible than the HMCL mixtures as indicated by the slope of the plotted line which is generally flatter for the LRA samples. The specialty mixtures, shown in Figure 3, plot similarly to the LRAs exhibiting low stiffness at low temperatures and better temperature susceptibility.

Resilient moduli were also measured after the mixtures had been aged in a stockpile for six months. These data are presented below in Figures 4 through 18.

The effects of stockpile aging on resilient modulus for the HMCLs are presented in Figures 4 through 10. While some of the mixtures appeared to stiffen with time, it did not seem to be a significant factor at the low temperatures. Very little change with time was noted for the LRAs and specialty mixtures as shown in Figures 11 through 17.

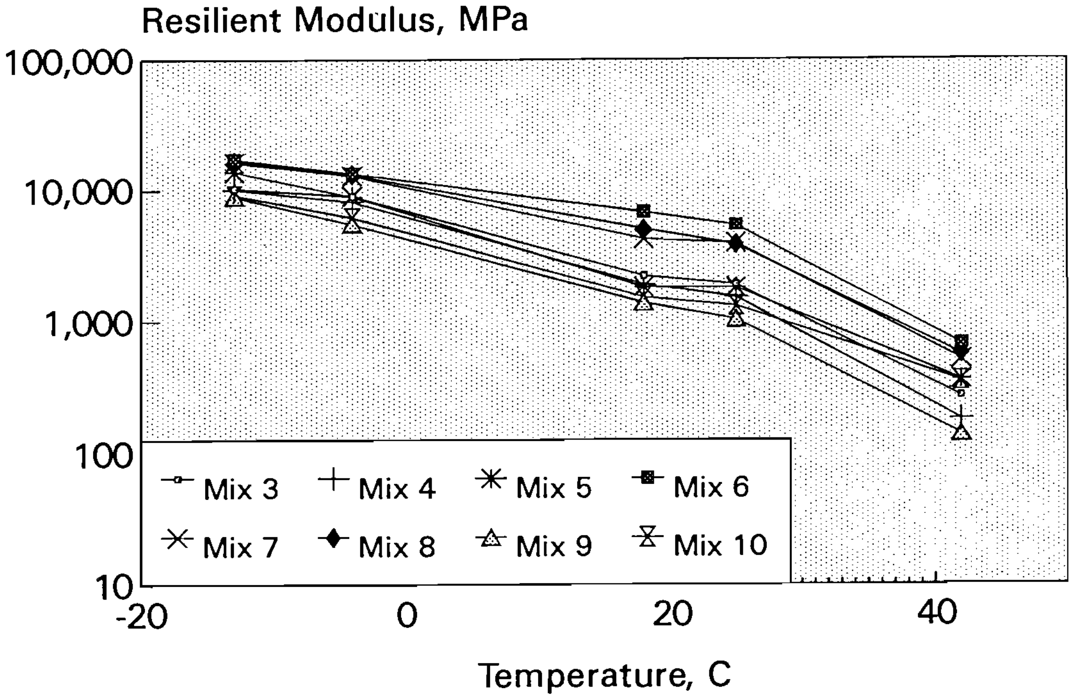


Figure 1. Resilient Modulus Versus Temperature for Unaged HMCL Mixtures.

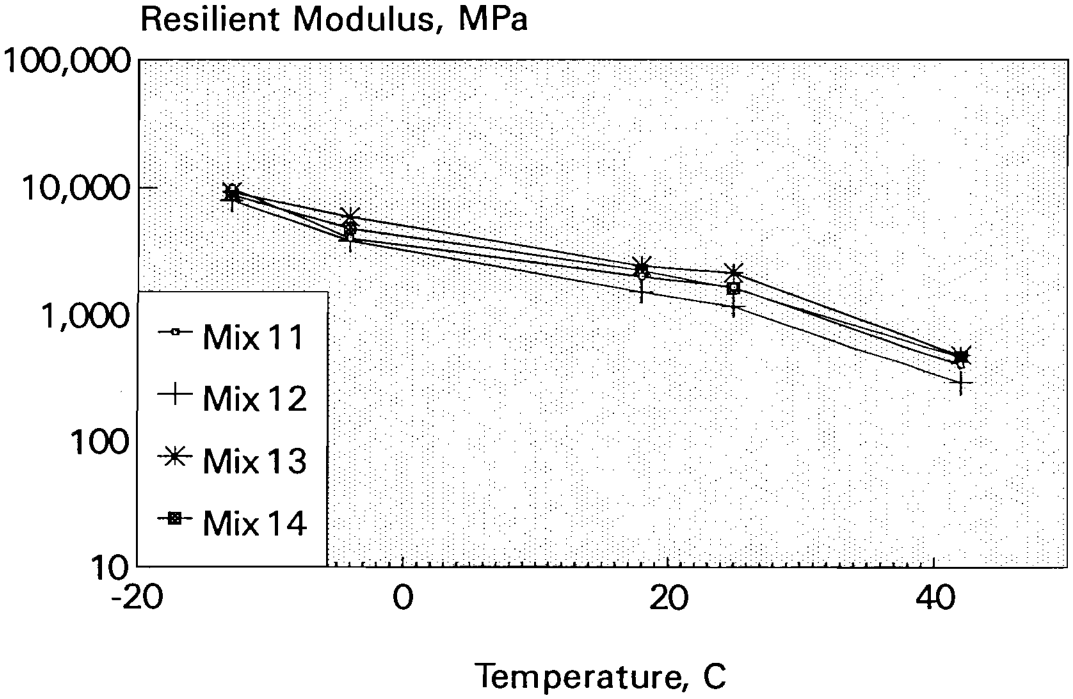


Figure 2. Resilient Modulus Versus Temperature for Unaged LRA Mixtures.

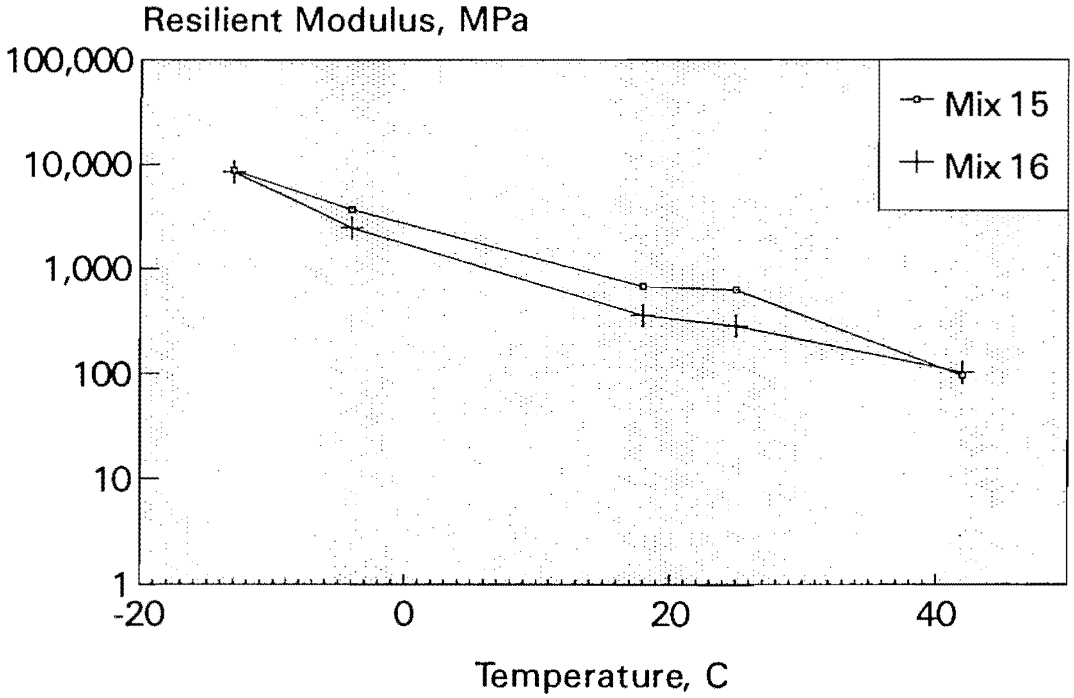


Figure 3. Resilient Modulus Versus Temperature for Unaged Specialty Mixtures.

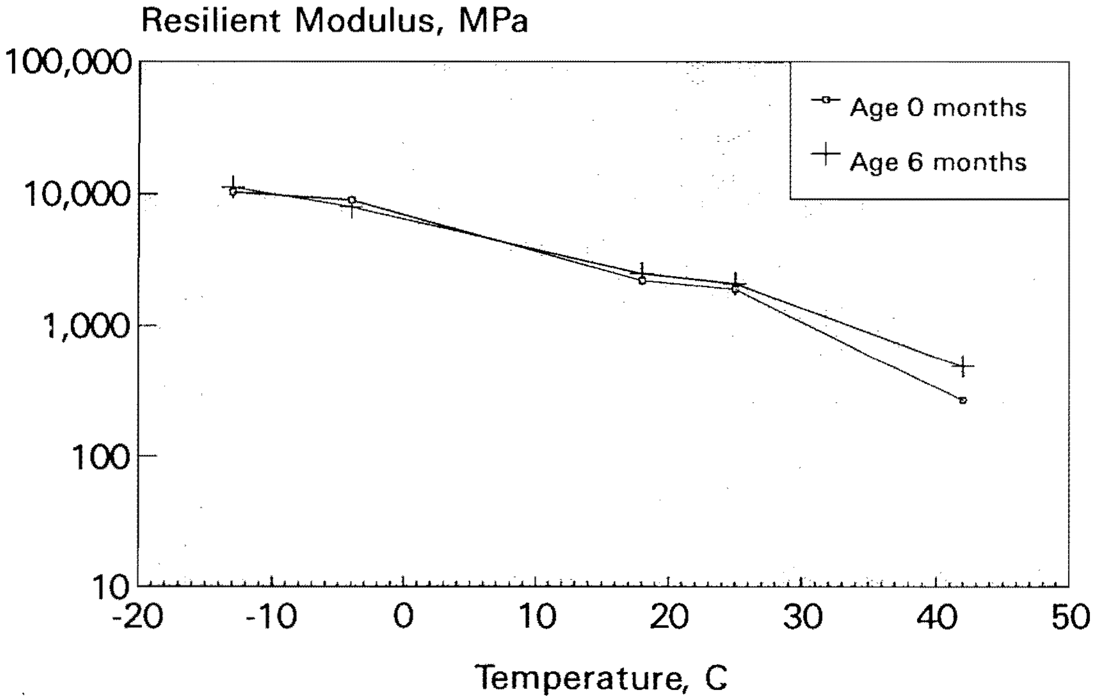


Figure 4. Resilient Modulus Versus Temperature for New and Aged HMCL Mixture 3.

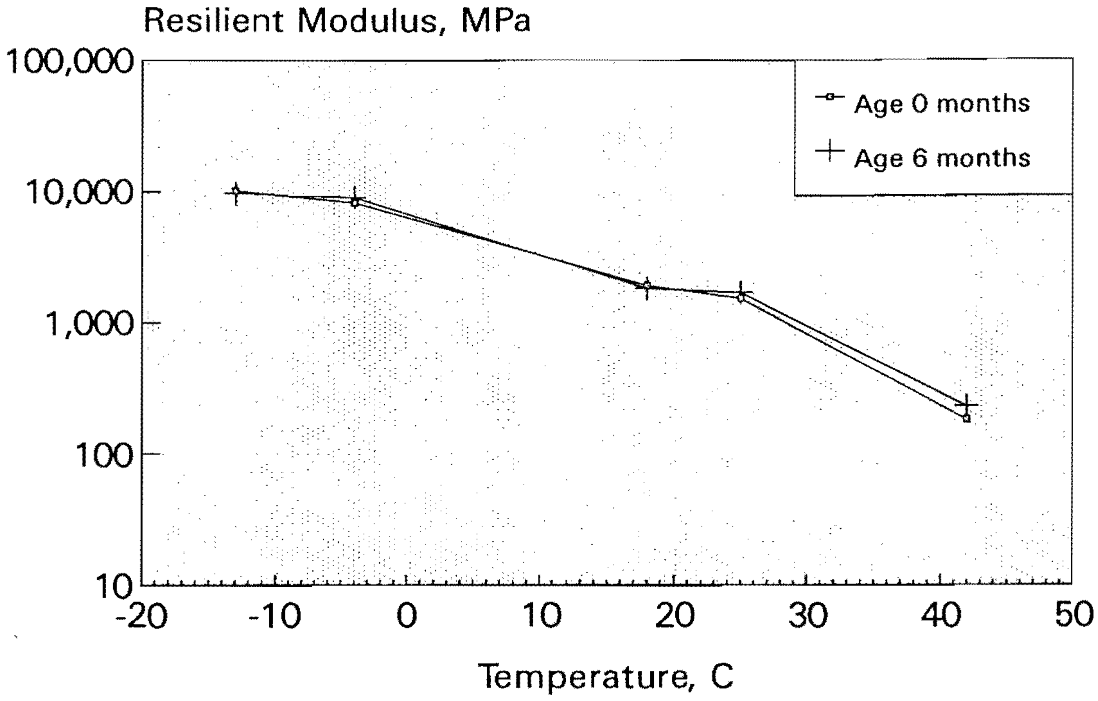


Figure 5. Resilient Modulus Versus Temperature for New and Aged HMCL Mixture 4.

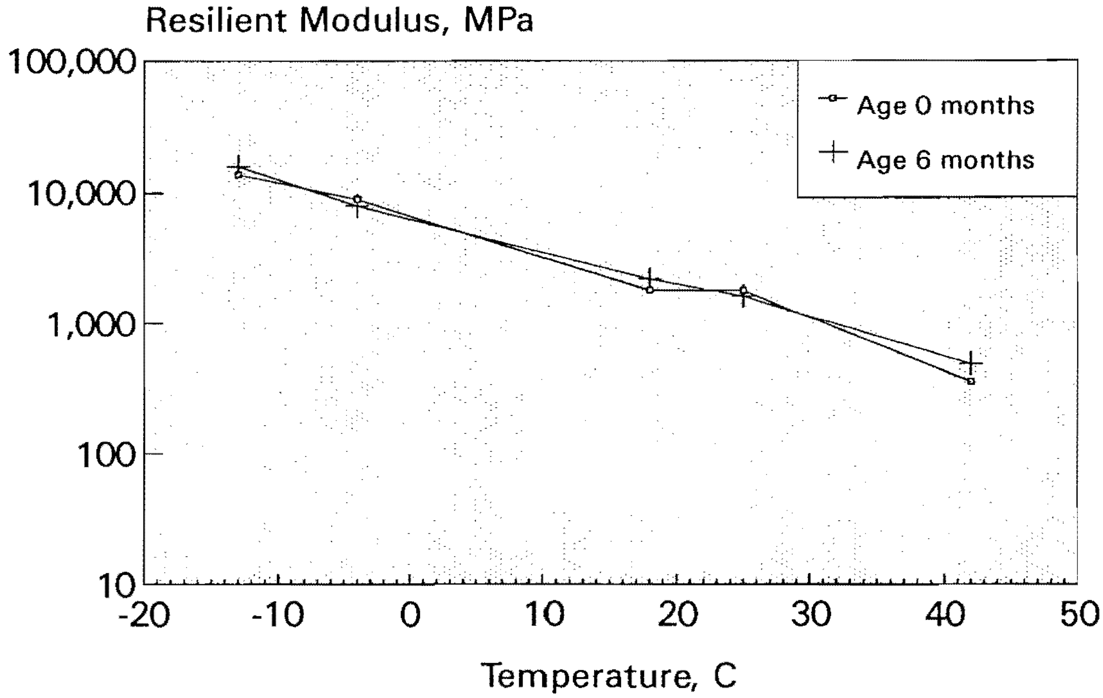


Figure 6. Resilient Modulus Versus Temperature for New and Aged HMCL Mixture 5.

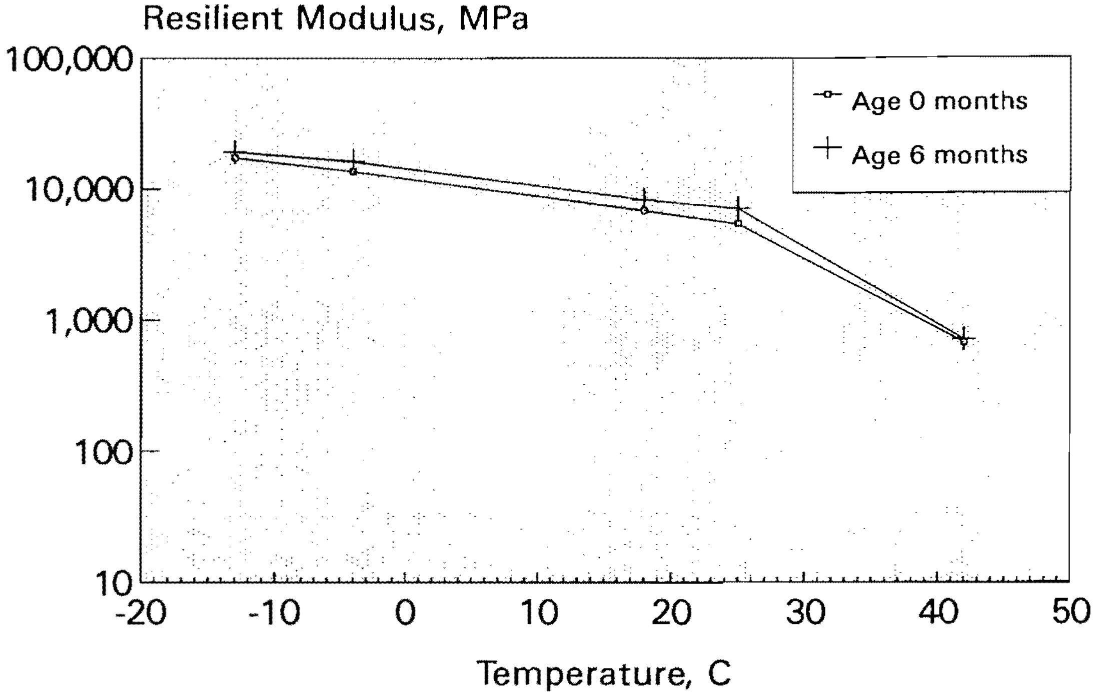


Figure 7. Resilient Modulus Versus Temperature for New and Aged HMCL Mixture 6.

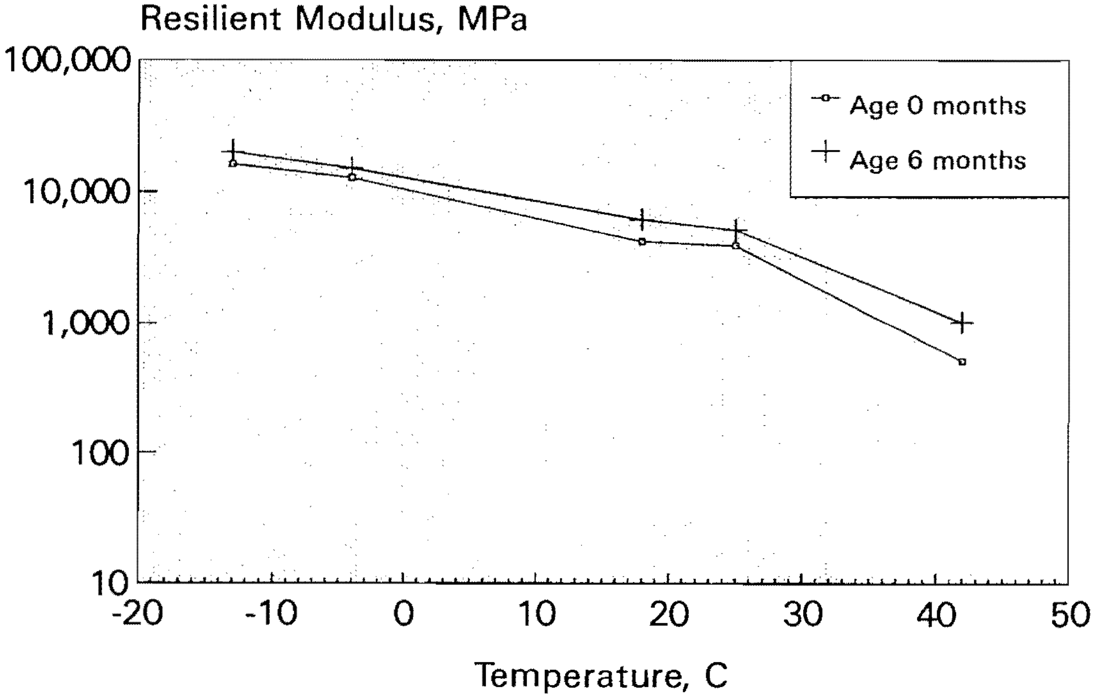


Figure 8. Resilient Modulus Versus Temperature for New and Aged HMCL Mixture 7.

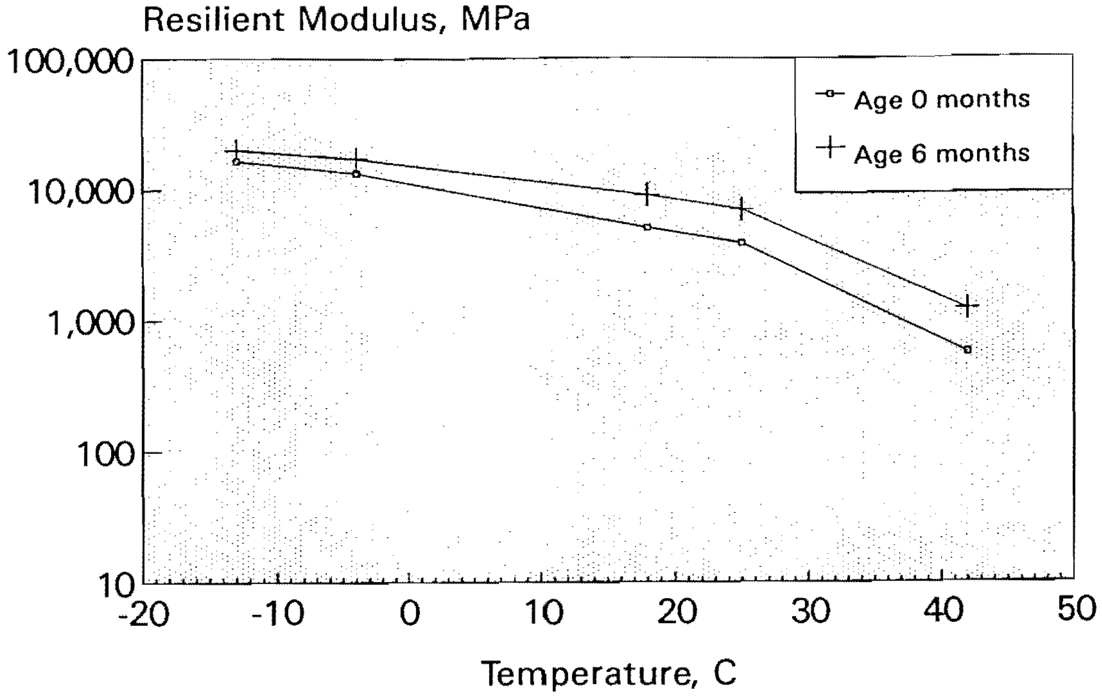


Figure 9. Resilient Modulus Versus Temperature for New and Aged HMCL Mixture 8.

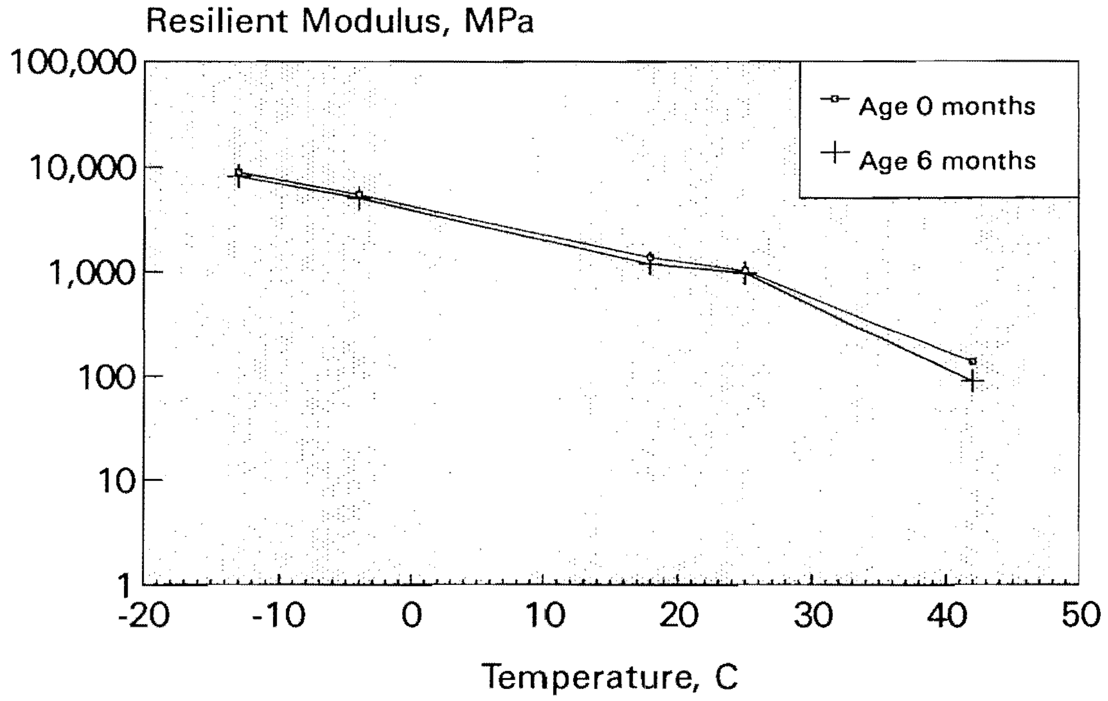


Figure 10. Resilient Modulus Versus Temperature for New and Aged HMCL Mixture 9.

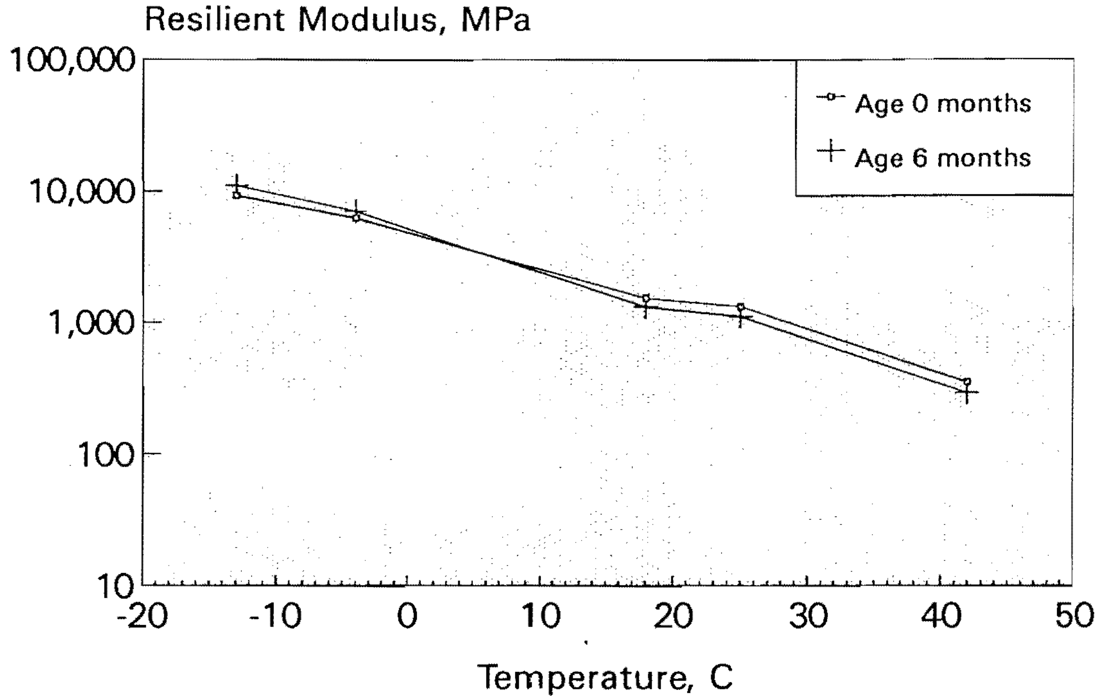


Figure 11. Resilient Modulus Versus Temperature for New and Aged HMCL Mixture 10.

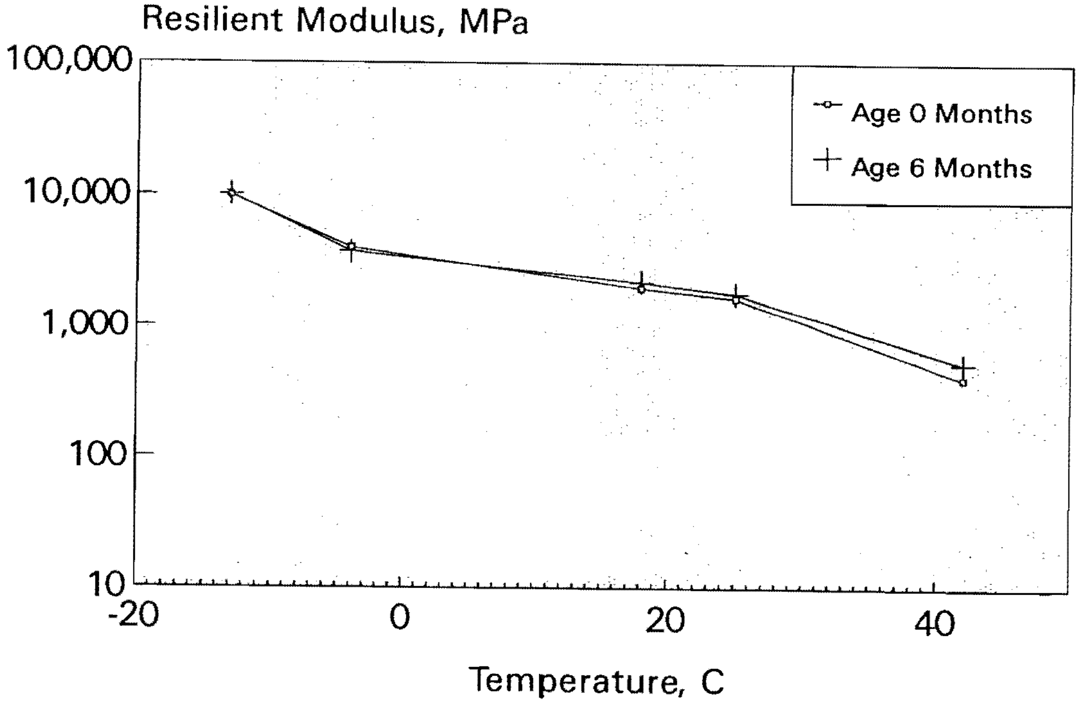


Figure 12. Resilient Modulus Versus Temperature for New and Aged LRA Mixture 11.

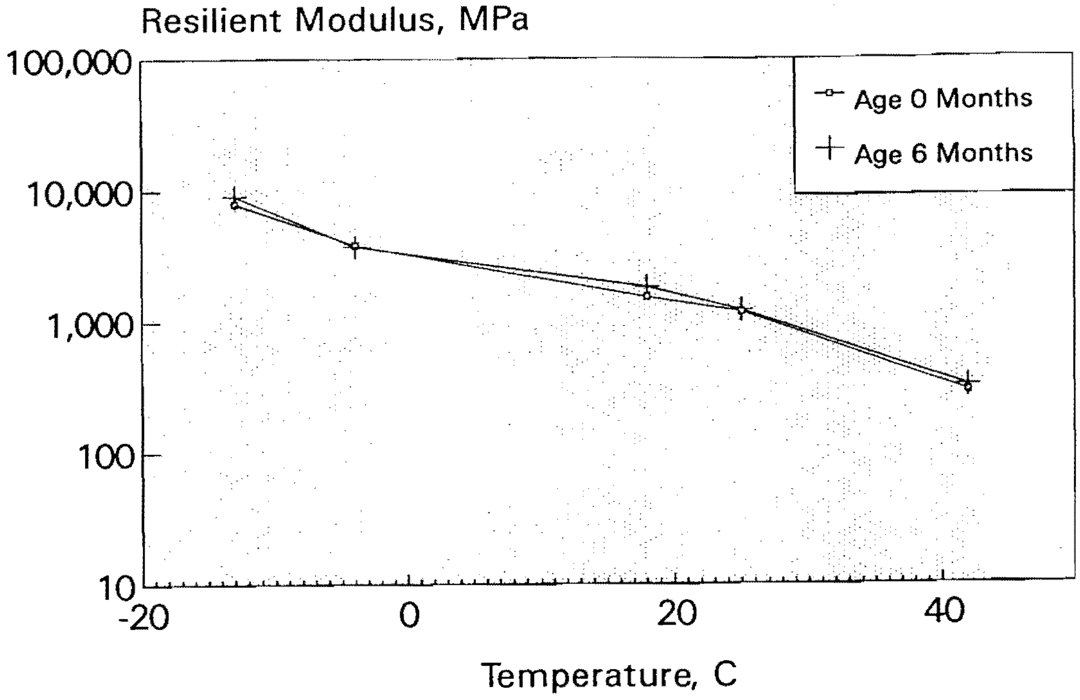


Figure 13. Resilient Modulus Versus Temperature for New and Aged LRA Mixture 12.

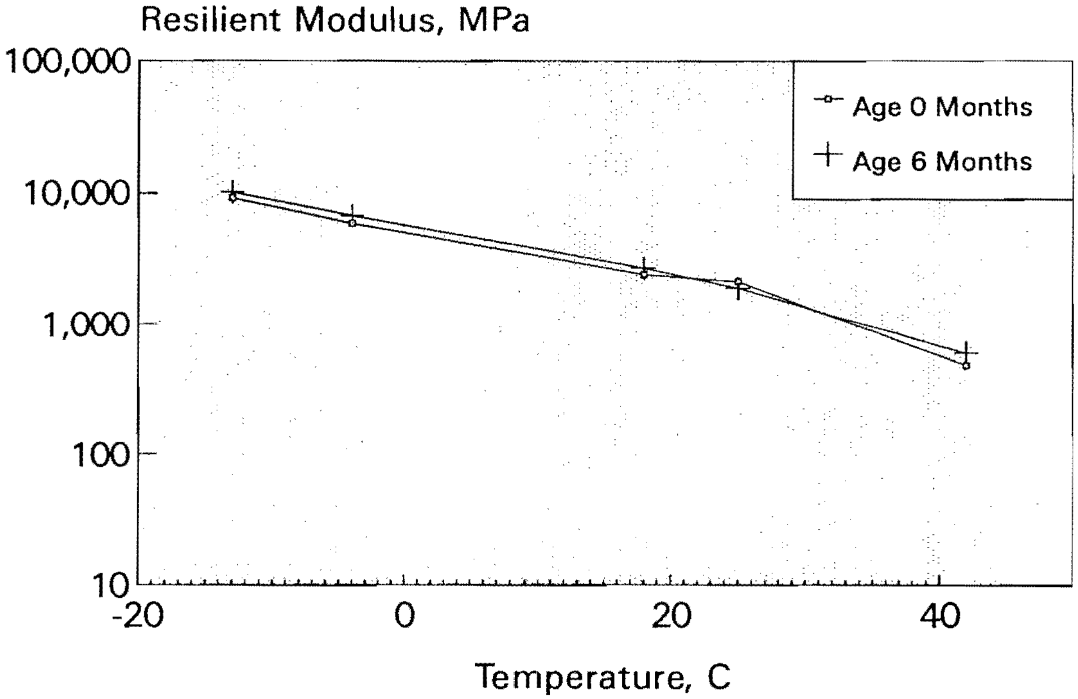


Figure 14. Resilient Modulus Versus Temperature for New and Aged LRA Mixture 13.

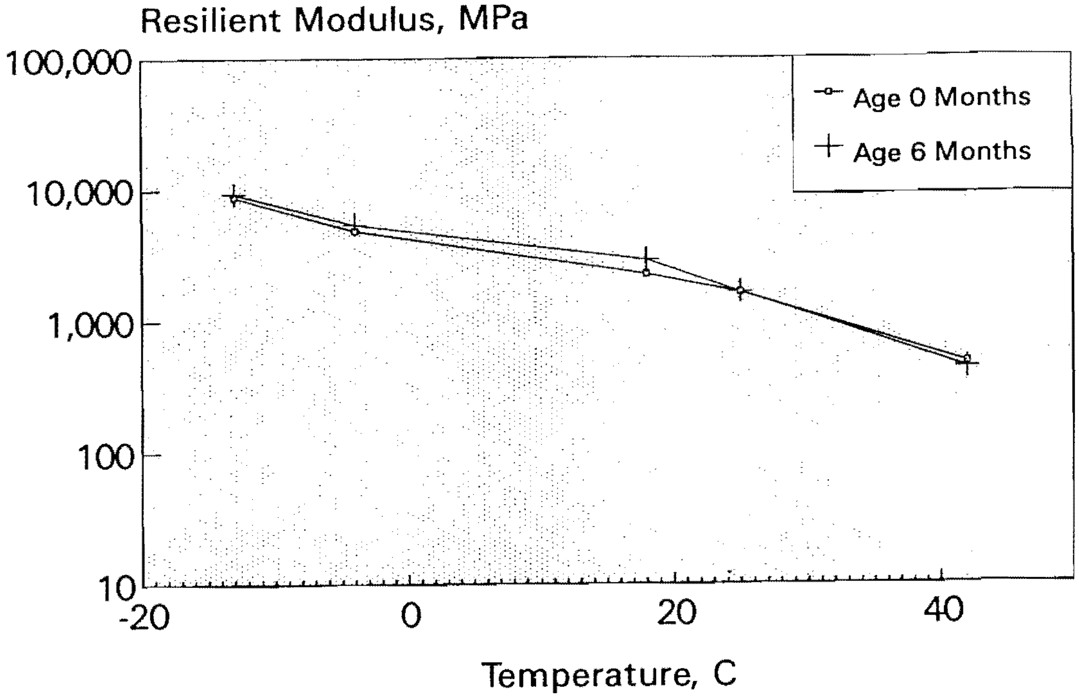


Figure 15. Resilient Modulus Versus Temperature for New and Aged LRA Mixture 14.

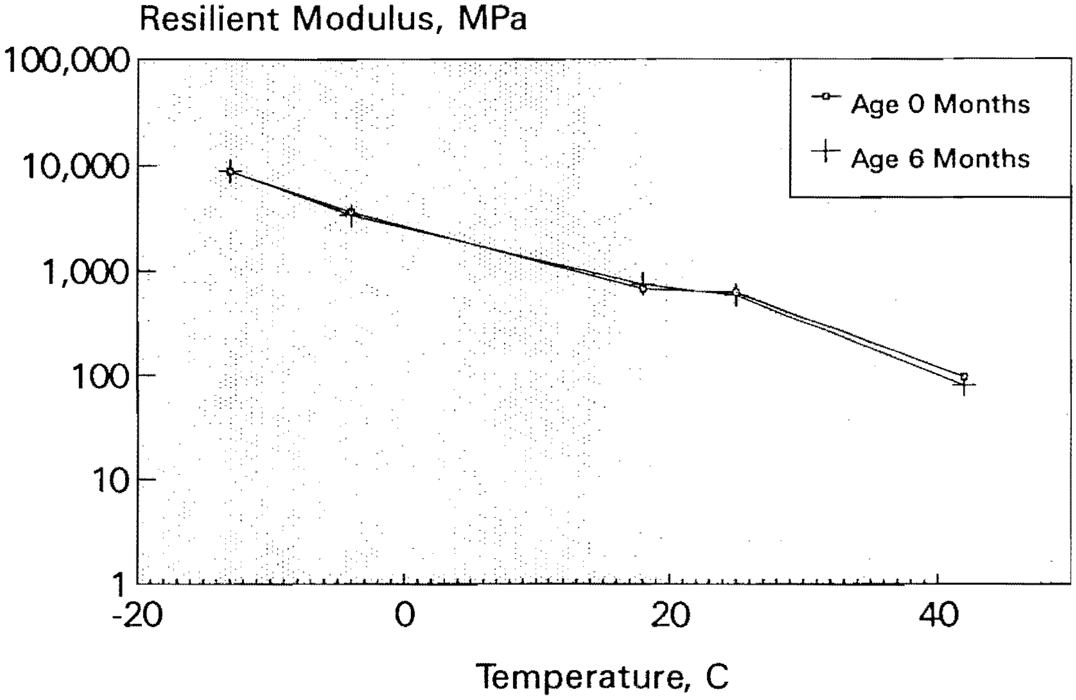


Figure 16. Resilient Modulus Versus Temperature for New and Aged Specialty Mixture 15.

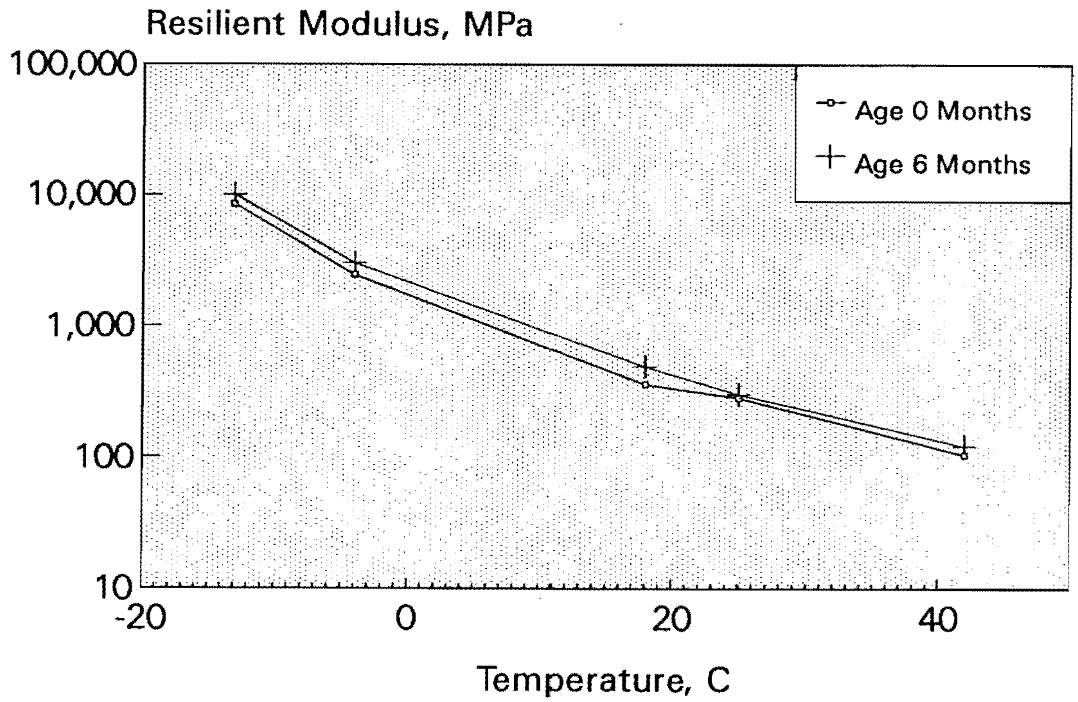


Figure 17. Resilient Modulus Versus Temperature for New and Aged Specialty Mixture 16.

2.2.2 Indirect Tensile Strength Testing

As with the resilient modulus test, indirect tensile strength (Tex-226-F) was also measured on the new maintenance mixtures and compared with tensile strength data after 6 months of stockpile aging. Compacted specimens were loaded diametrally at a constant rate of deformation until complete failure occurred. The tests were performed at 25°C and at a deformation rate of 50 millimeters per minute.

Tensile strength data for the HMCL materials are shown in Figure 18. Tensile strength for the unaged HMCLs ranged from about 180 to 400 kPa. Six of the ten HMCL mixtures increased in strength after 6 months of stockpile aging.

Tensile strengths for the unaged LRA materials ranged from 290 to 420 kPa as shown in Figure 19. After 6 months of aging, 2 of the mixtures exhibited slightly higher strengths and 2 others exhibited lower strengths. Similar data are presented for the specialty mixtures in Figure 20.

Any binder age hardening that may have occurred during 6 months of stockpile aging is not consistently indicated by indirect tensile strength test.

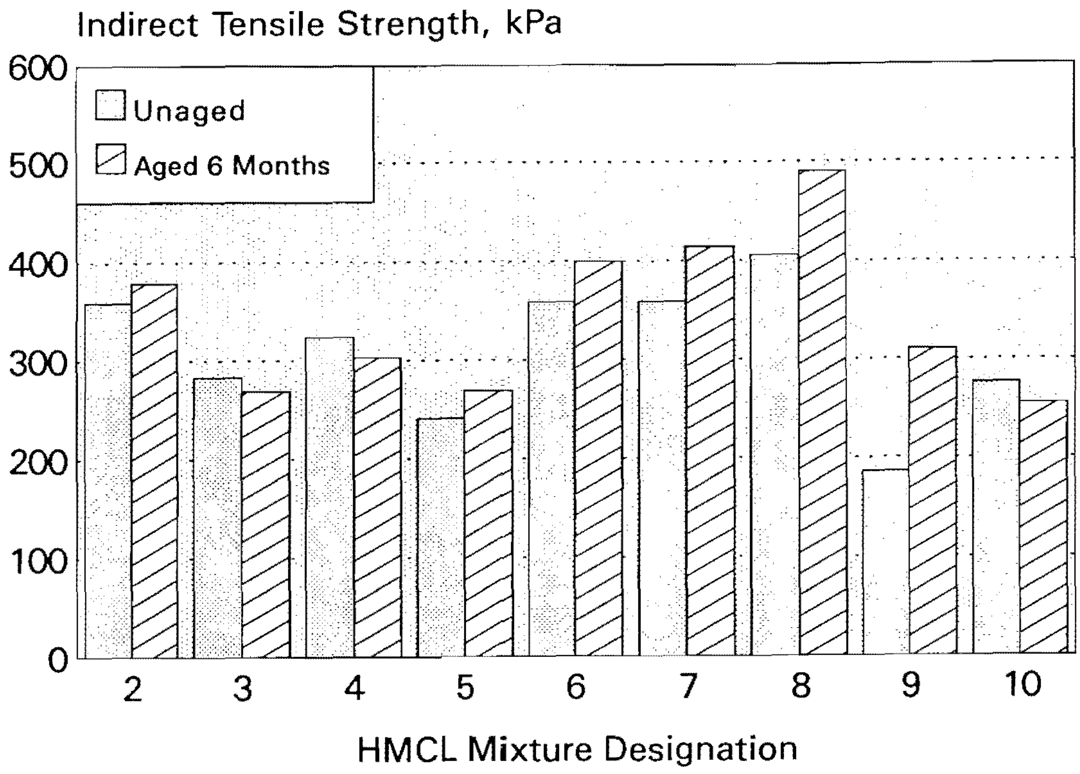


Figure 18. Indirect Tensile Strength for HMCL Mixtures Before and After Field Aging.

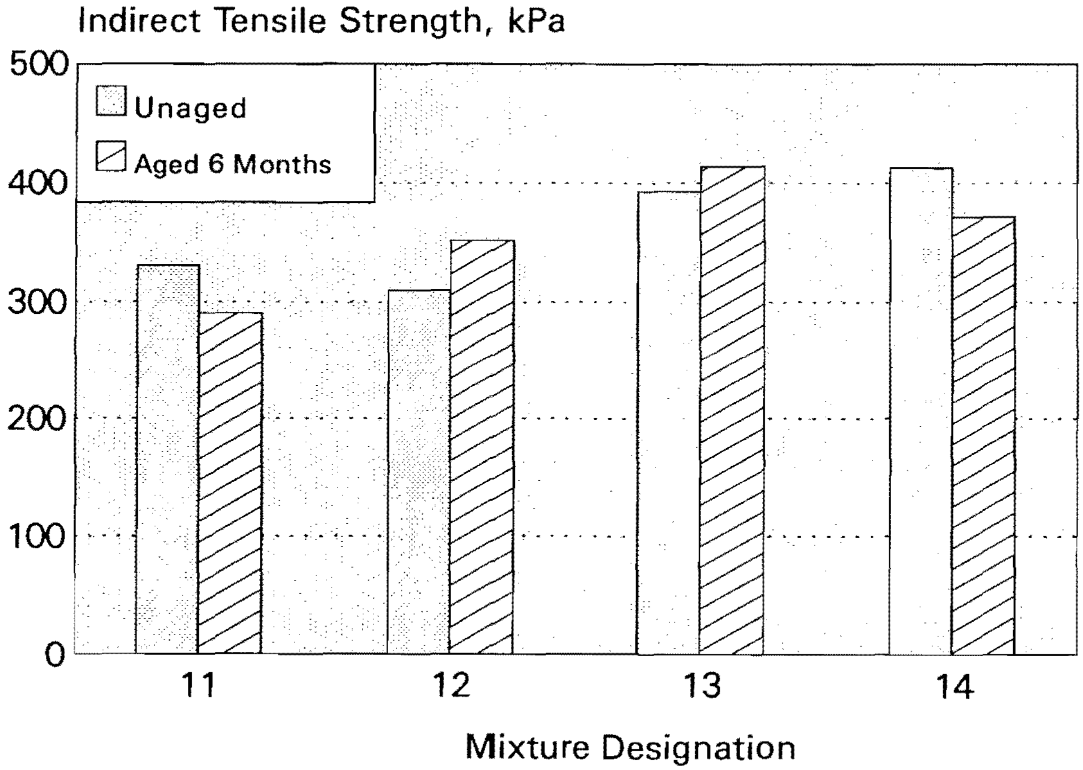


Figure 19. Indirect Tensile Strength for LRA Mixtures Before and After Field Aging.

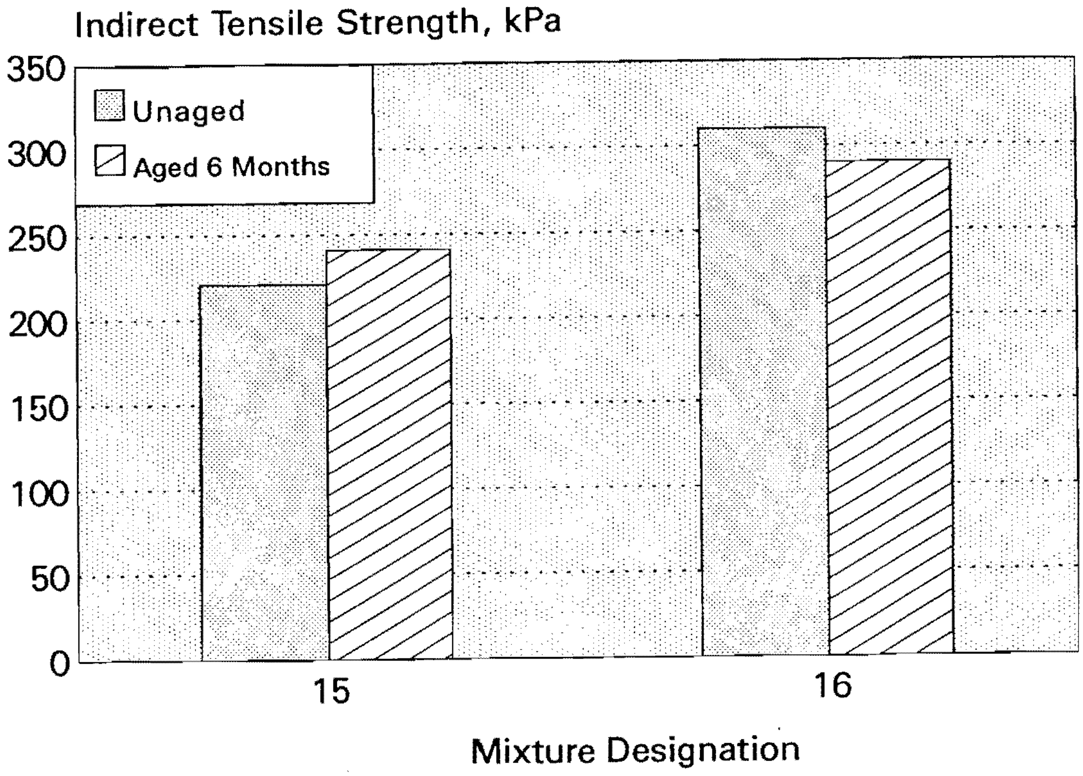


Figure 20. **Indirect Tensile Strength for Improved Specialty Mixtures Before and After Field Aging.**

2.2.3 Properties of Extracted Binders

The binder was extracted and recovered from the maintenance mixtures at three different times: (1) prior to field aging, (2) at 3 months of field aging, and (3) at 6 months of field aging. Viscosities of the recovered binders were measured at 60°C. Penetration was measured at 4°C. Viscosities of the HMCL materials are shown in Figure 21. Most of the binders did not exhibit appreciable aging during the 6-month field aging period. Mixtures 6, 7, and 8 showed significant increases in viscosity. Penetration data for these mixtures are shown in Figure 22. Penetration shows more evidence of differentiation between binders. Binders from mixtures 6, 7, and 8 exhibit the lowest penetration after 6 months of aging.

Viscosity data from the LRA materials were obtained at the 3-month point and tested as presented in Figure 23. Researchers noted that these binders exhibited significantly higher viscosities than the HMCL. However, this is probably due to the naturally occurring bitumen inherent in the aggregate which is known to be very viscous. Some of the naturally occurring bitumen that does not act as binder was probably being extracted during the extraction process. Since this clouded the results, no further binder testing was performed on the LRA materials. Binder data for the specialty mixtures (Figures 24 and 25) do not indicate any appreciable aging of these mixtures.

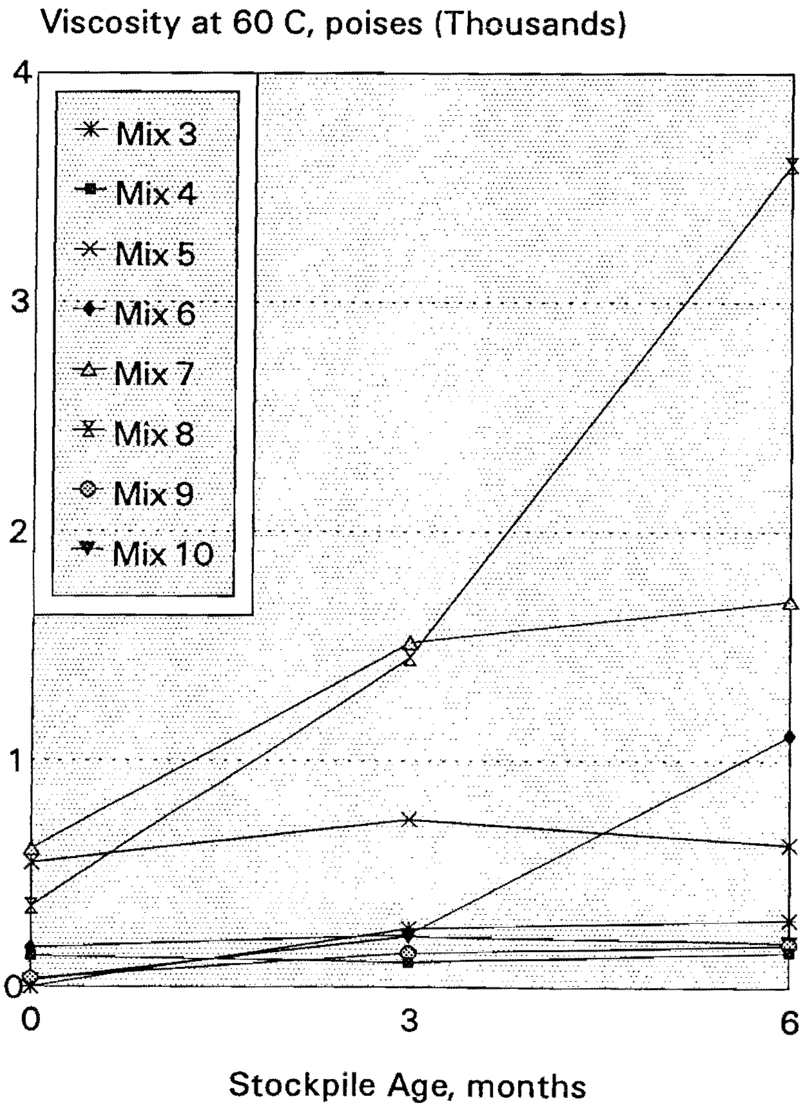


Figure 21. Viscosity Versus Time for Binder Extracted from Stockpiled HMCL Mixtures.

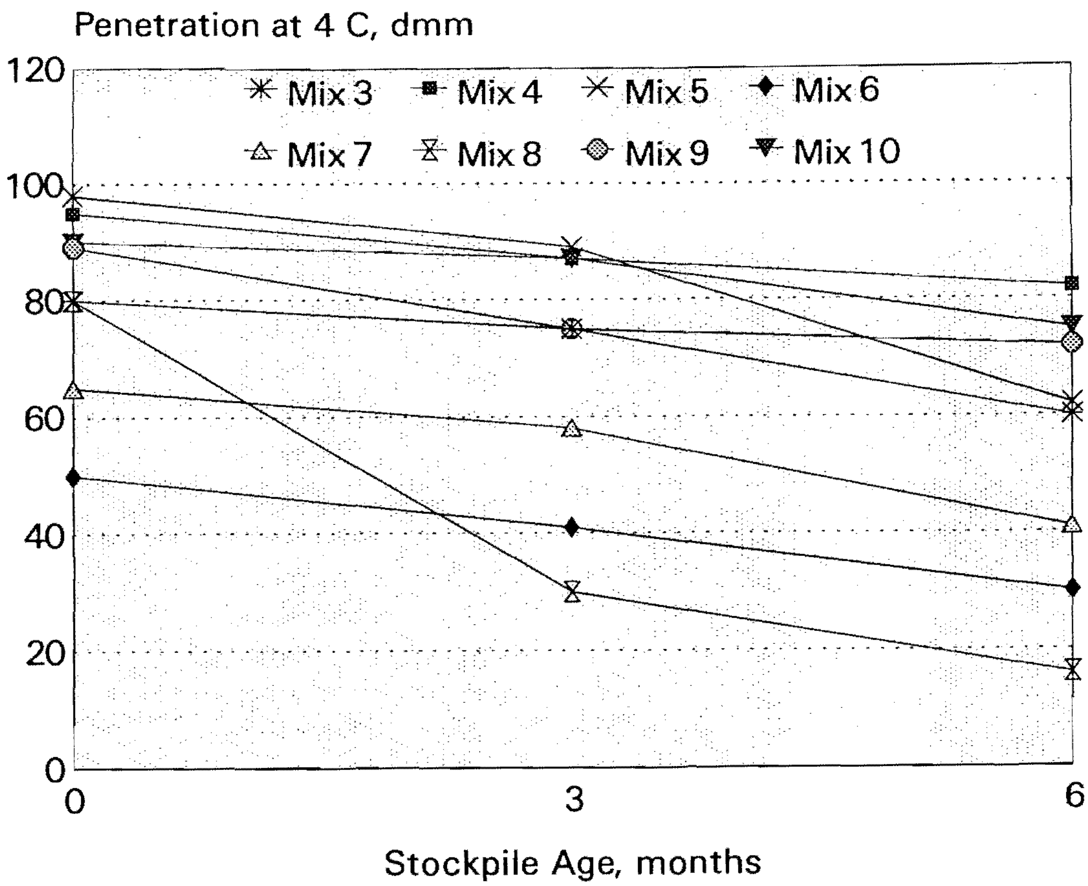


Figure 22. **Penetration Versus Time for Binder Extracted from Stockpiled HMCL Mixtures.**

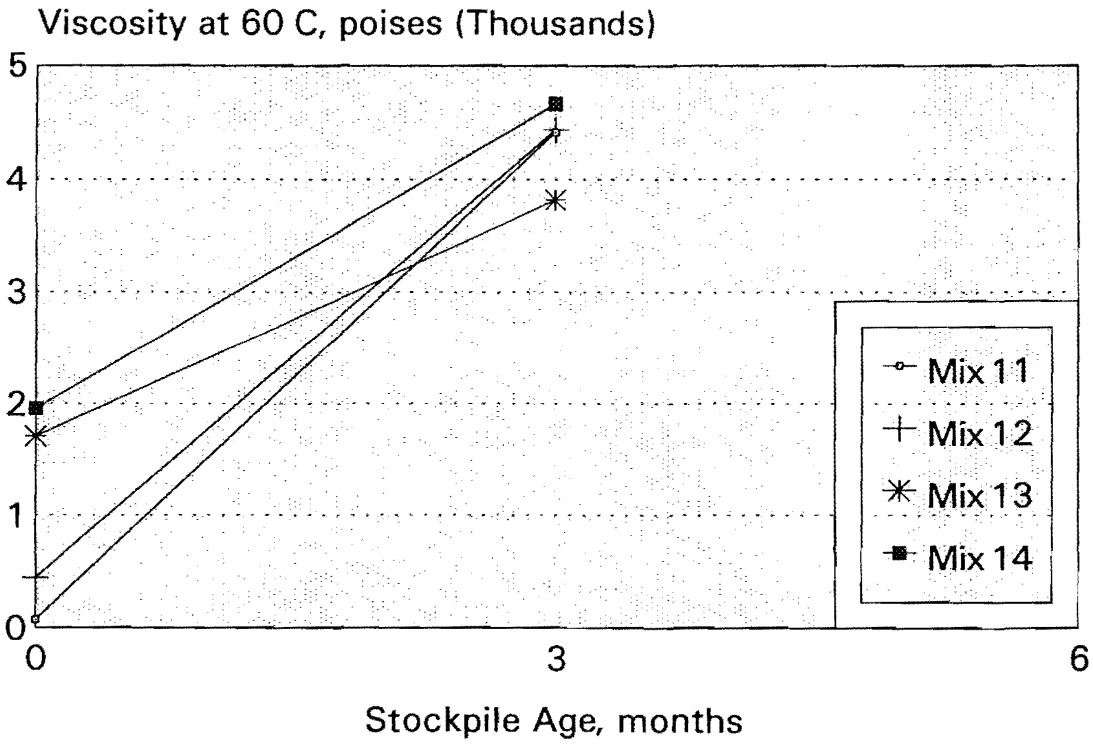


Figure 23. Viscosity Versus Time for Binder Extracted from Stockpiled LRA Mixtures.

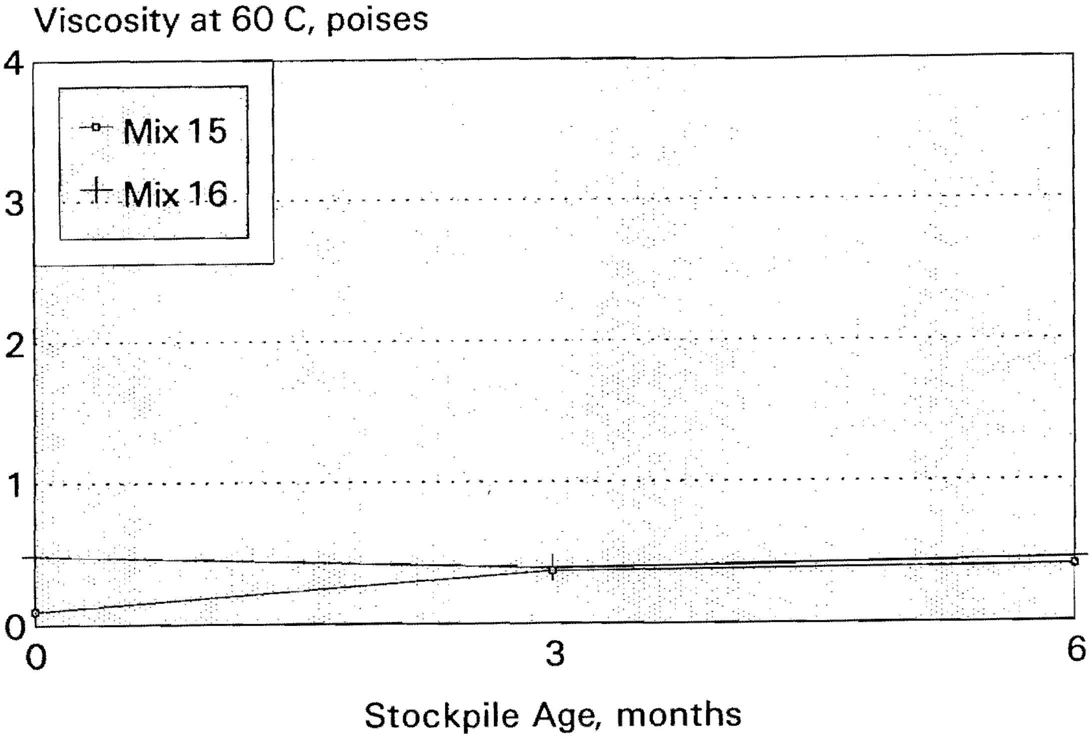


Figure 24. Viscosity Versus Time for Binder Extracted from Stockpiled Specialty Mixtures.

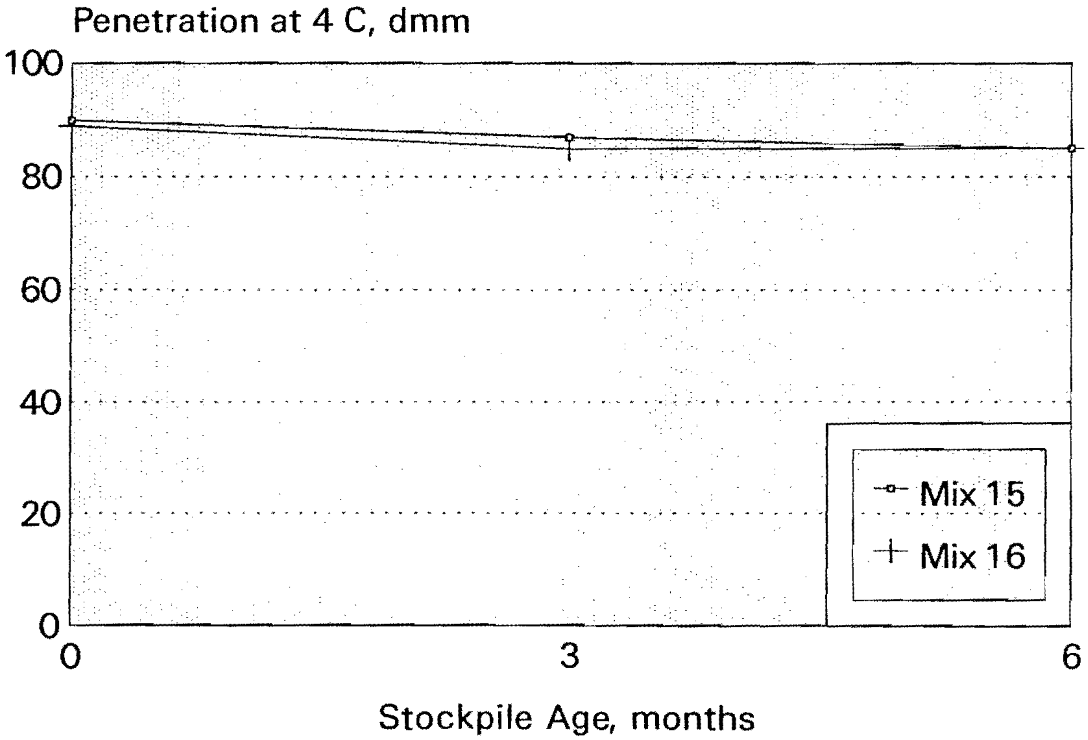


Figure 25. Penetration Versus Time for Binder Extracted from Stockpiled Specialty Mixtures.

2.3 SUMMARY

As a result of the data presented in this chapter, researchers arrived at the following conclusions:

- Resilient modulus testing indicates that the LRA and specialty mixtures are less stiff at low temperatures than HMCL materials. These mixtures also show tendencies for improved temperature susceptibility.
- Resilient modulus data did not indicate significant stiffening of the mixtures at low temperatures after stockpile aging. This was true for all types of mixtures tested.
- Tensile strength measurements performed on all field aged mixtures did not indicate serious detrimental effects as a result of the field aging.
- Viscosity and penetration of the extracted asphalt cement for the HMCL materials indicated that significant aging occurred in only 3 of the mixtures. Extracted asphalt cement properties for the specialty mixtures indicated no significant change in material properties as a result of aging. Extracted asphalt cement properties for LRA were inconclusive.
- Resilient modulus and indirect tensile strength testing was only partially successful in identifying mixtures with significantly hardened binders after stockpile aging.

3.0 LABORATORY AND FIELD EVALUATION OF MIXTURE WORKABILITY AND METHODS OF MEASUREMENT

The objective of this portion of the study was to evaluate the workability of stockpiled field materials and to relate the field workability to a laboratory measurement of workability. Several laboratory methods were evaluated which were thought to have potential for measurement of workability and these are discussed in this chapter.

3.1 WORKABILITY OF FIELD-STOCKPILED MATERIALS

Workability of field stockpiles were evaluated when the ambient temperature was 4°C or lower. These were subjective evaluations and workability was rated according to the following classifications:

(1) Good,
(2) Average, or
(3) Poor.

Field workabilities of the different mixtures are shown in Table 4. Mixtures 1 and 2 were not evaluated as part of the field evaluation; however, district personnel provided comments on their field performance which are included in the table. It should be noted that the specialty mixtures (Mixtures 15 and 16) are shown to have poor workability in our subjective evaluation. These materials, however, are used primarily for pothole repair and are known to perform that function very well.

3.2 ANALYSIS OF MIXTURE COMPONENTS

Asphalt was extracted from all of the field mixtures to determine aggregate gradation and asphalt content. Aggregate gradations for these mixtures are shown in Appendix B.

Based on information from the literature, workability of asphaltic maintenance mixtures can be detrimentally affected by either too much coarse aggregate or excess filler. For purposes of this report, the coarse aggregate fraction is defined as that percentage retained on a 4.75 mm sieve. The filler is defined as that percentage passing a 75 micron sieve. These components

Table 4. Field Workability of Maintenance Mixtures at Temperatures Below 4°C.

Mixture Designation	Mixture Type	Field Workability Rating
1	HMCL	Good
2	HMCL	Poor
3	HMCL	Poor
4	HMCL	Good
5	HMCL	Average
6	HMCL	Poor
7	HMCL	Poor
8	HMCL	Average
9	HMCL	Good
10	HMCL	Good
11	LRA	Good
12	LRA	Good
13	LRA	Good
14	LRA	Good
15	Specialty	Poor
16	Specialty	Poor
17	Specialty	Not Available

are plotted in Figures 26 through 29. The quantity of coarse aggregate in the HMCL materials ranges from 20 to 50 percent. For the LRA mixtures the coarse aggregate fraction comprises 20 to 30 percent of the mix. Specialty mixtures 15 and 16 have very large quantities of coarse aggregate: more than 60 percent.

Filler (passing 75 micron sieve) quantities are shown in Figures 28 and 29. For the HMCL mixtures, the fines range from 2 to 6 percent. The LRA mixtures typically contain more than 5 percent and the specialty mixtures have generally less than 5 percent fines. None of the mixtures have the less than 2 percent which is reported by Anderson to be required for acceptable

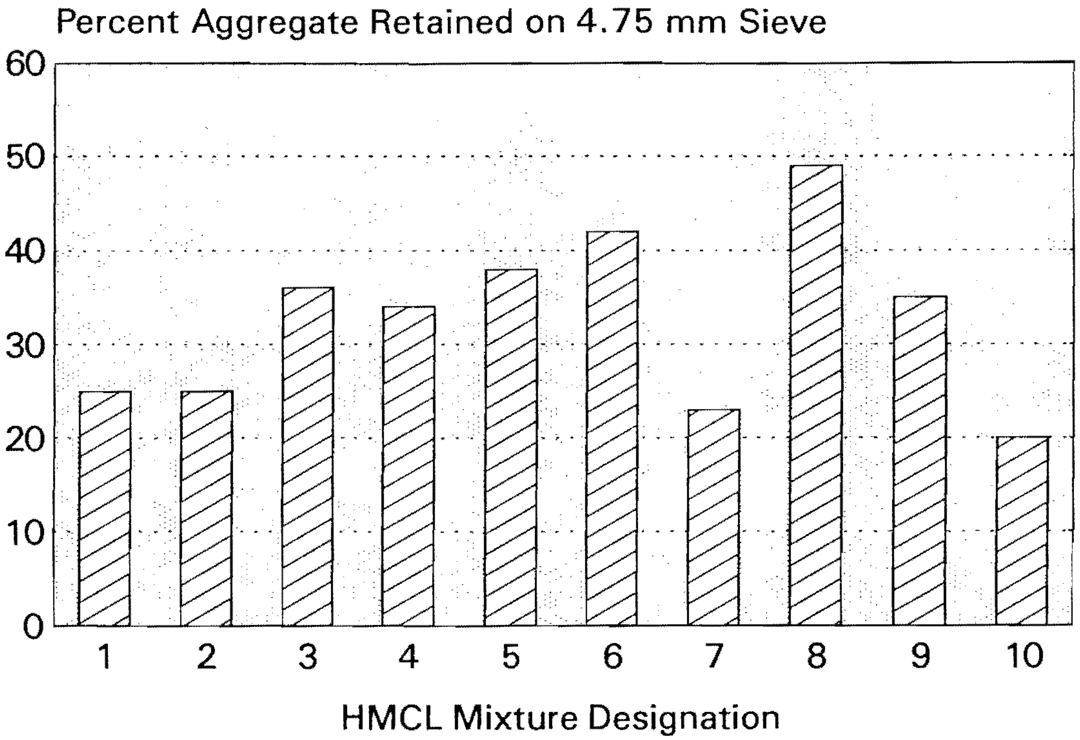


Figure 26. Quantity of Coarse Aggregate in HMCL Mixtures.

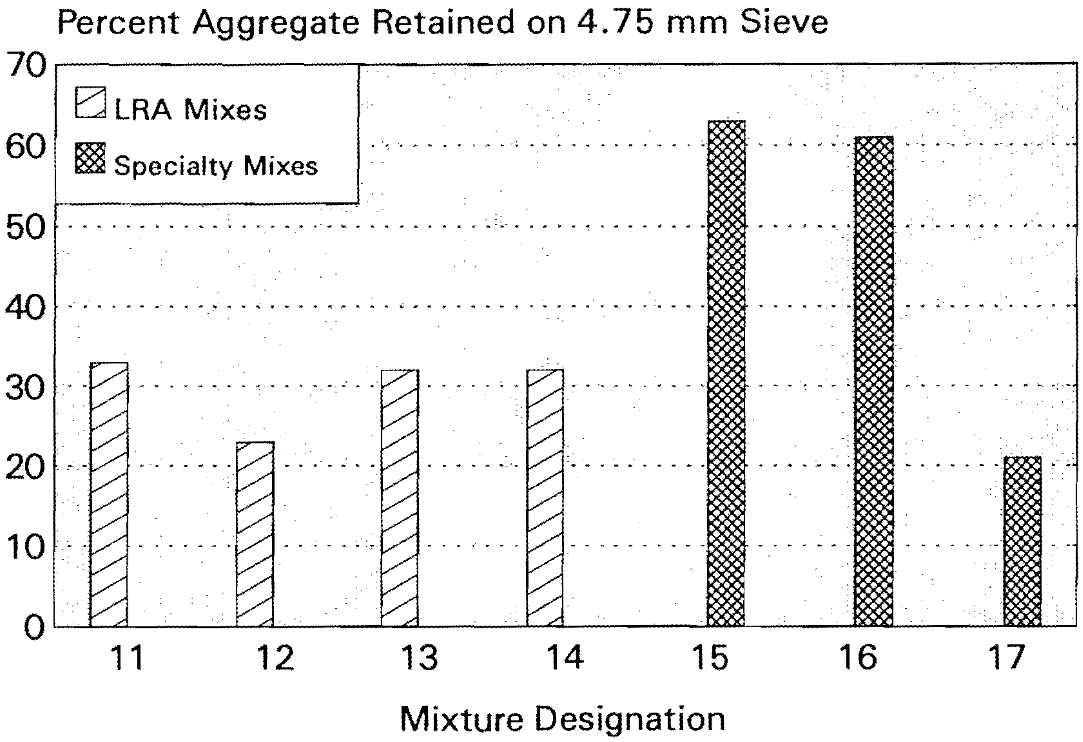


Figure 27. Quantity of Coarse Aggregate in LRA and Specialty Mixtures.

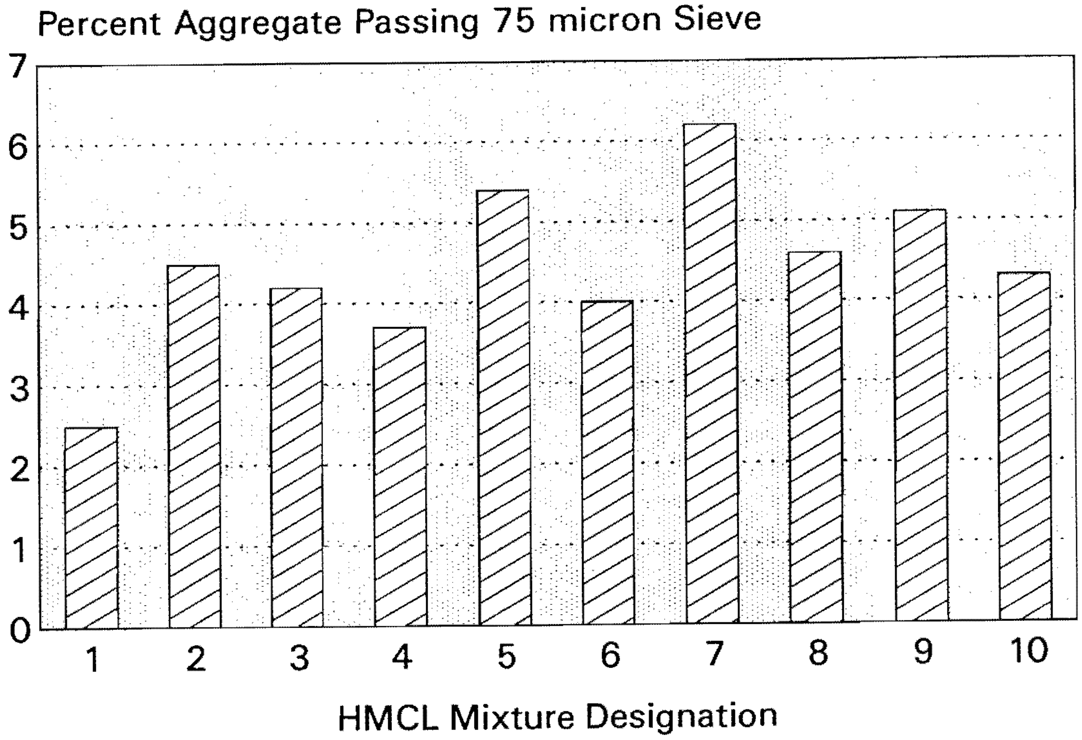


Figure 28. Quantity of Fines in HMCL Mixtures.

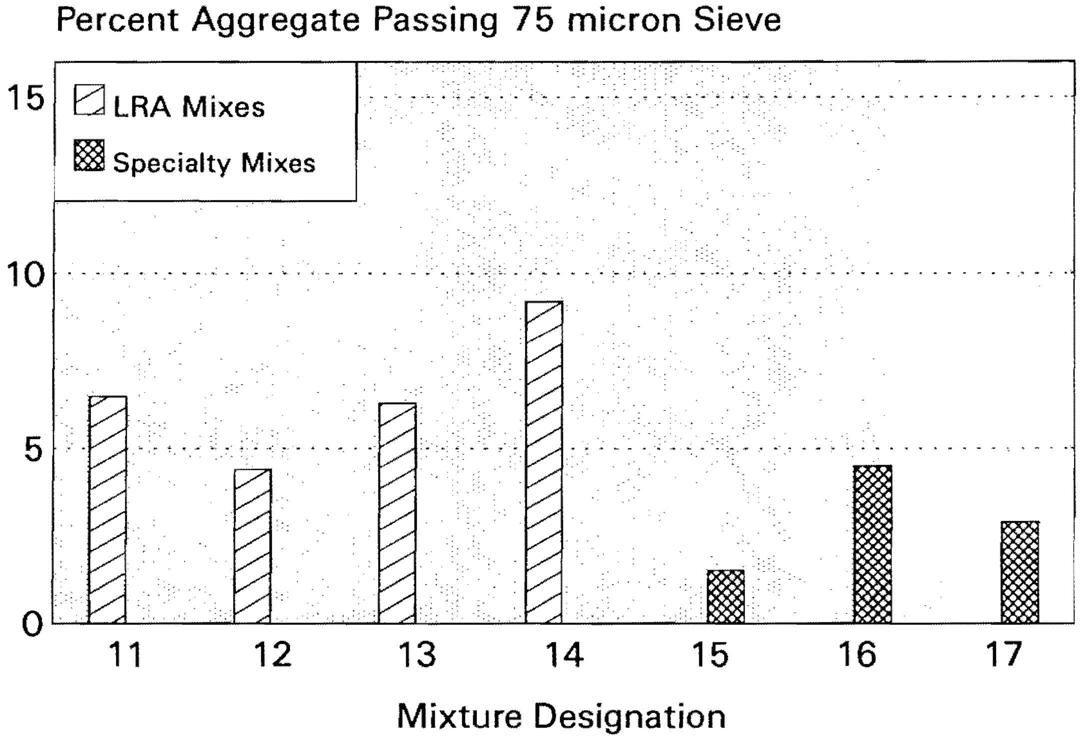


Figure 29. Quantity of Fines in LRA and Specialty Mixtures.

workability (4).

Extracted asphalt content was determined for each mixture and is shown in Figure 30. Asphalt content for the LRA mixtures is not shown since the naturally occurring asphalt in the aggregate caused the results to be in error. Since required asphalt content in a mixture depends on the aggregate gradation, perhaps a more equitable basis of comparison between mixtures would be the asphalt film thickness. Film thicknesses were calculated and are shown in Figure 31. As expected, the specialty mixtures (which have a more gapped gradation) have greater asphalt film thickness. Asphalt film thicknesses for the HMCL mixtures range from 5 to 11 microns.

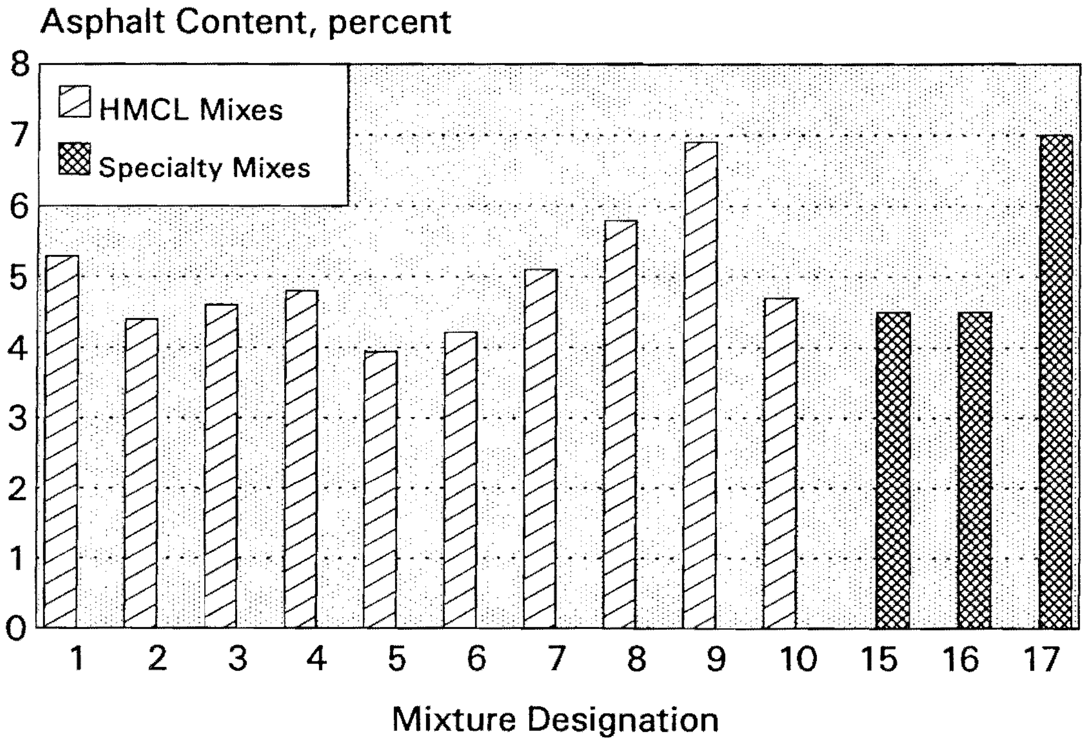


Figure 30. Extracted Asphalt Content for HMCL and Specialty Mixtures.

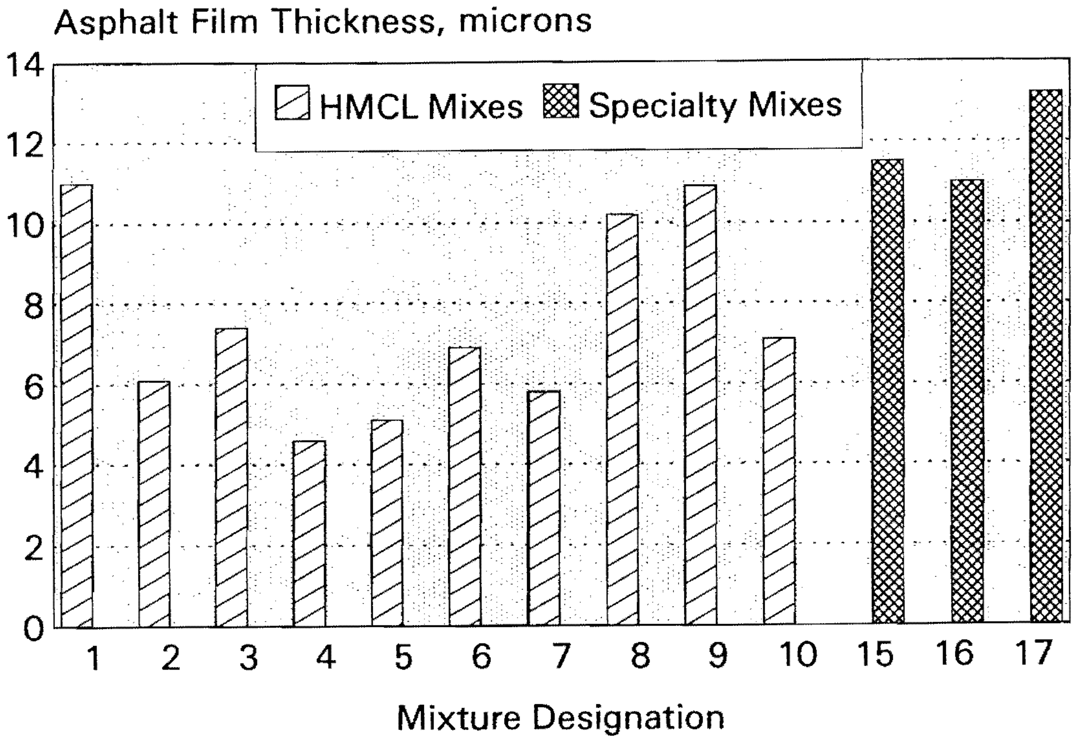


Figure 31. Calculated Asphalt Film Thicknesses for HMCL and Specialty Mixtures.

3.3 EVALUATION OF MIXTURE WORKABILITY AND METHODS TO MEASURE WORKABILITY

Several different methods were investigated for their potential at measuring the workability of asphalt maintenance mixtures. This was a very critical part of the research because development of a specification hinged on being able to measure the workability of a mixture before and after a laboratory aging procedure.

3.3.1 SHRP Workability Test

As part of the Strategic Highway Research Program, a manual of practice was developed for asphalt pavement repair (32). Included in this manual is an acceptance testing procedure to be used for quantifying the workability of maintenance mixes. The workability test was not intended to guarantee success for the material tested, but to indicate the potential for poor performance of the proposed materials.

The workability test requires a small box, a pocket penetrometer (normally used for soil testing) and a penetrometer adapter. The workability box measures 102 mm on all sides and has a 10 mm hole on one side. The penetrometer is fitted with an adapter which increases the diameter of the penetrometer to 9.5 mm.

The test is performed by preparing 3 samples at 4°C. The cooled mixture is dropped loosely into the workability box. The penetrometer with adapter is pushed through the hole in the side of the box and the resistance is recorded. This measurement is recorded as workability. An average workability reading between 3 and 4 would be considered marginal, while a value over 4 should be rejected. Values under 3 are acceptable.

This test was performed on all of the field maintenance mixtures and the results are shown in Figures 32 and 33. All of the HMCL materials and LRA materials had a SHRP workability rating of less than 1. Each measurement shown represents an average of 5 tests, and analysis of the data indicated there was no significant difference between mixtures 1 through 14. The specialty mixtures had a significantly higher SHRP workability rating as shown in Figure 33.

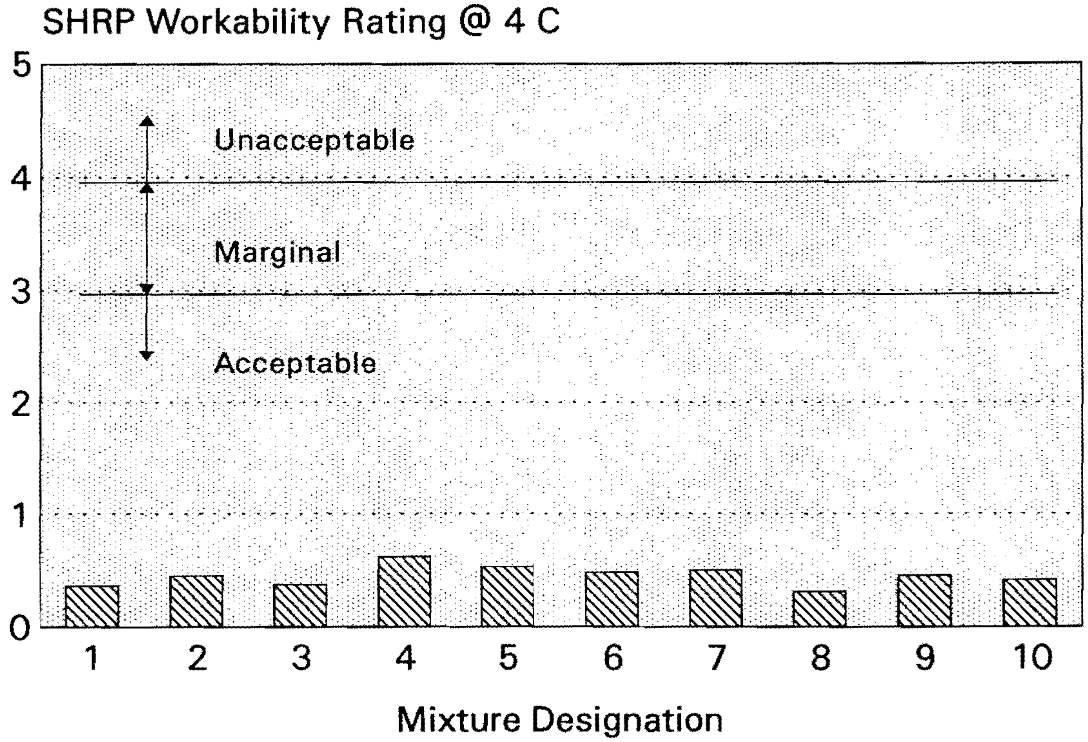


Figure 32. SHRP Workability Rating for HMCL Mixtures.

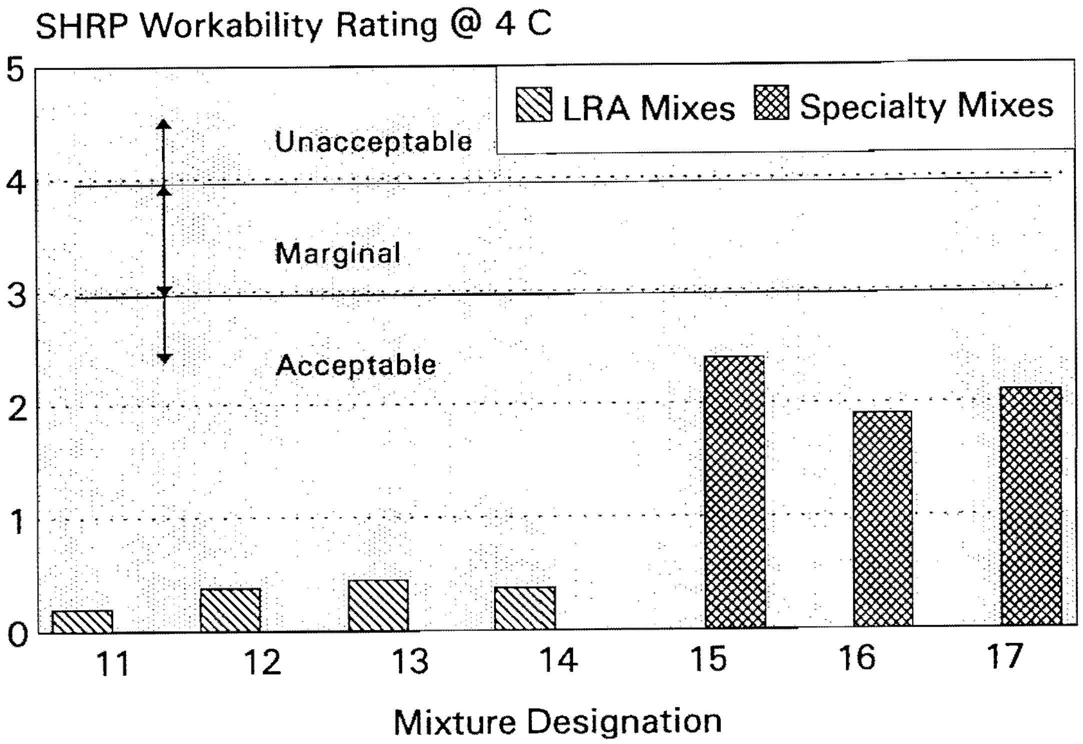


Figure 33. SHRP Workability Rating for LRA and Specialty Mixtures.

3.3.2 Modified SHRP Workability - First Modification

The SHRP workability test failed to produce a measure of workability which was needed to differentiate between the mixtures; therefore, researchers made a slight modification to the test and repeated the experiment. In the above test, the penetrometer is inserted into a hole in the side of the workability box. This hole is located in the center of one side panel of the box. The box was modified by locating the hole in the bottom third portion of the side panel and the testing was repeated. These results are presented in Figures 34 and 35. This modification effected slightly higher workability ratings in most of the maintenance mixtures.

3.3.3 Modified SHRP Workability - Second Modification

The above modification to the SHRP workability test still did not produce the desired significance needed to distinguish a workable mix from an unworkable mix, based on the field performance evaluations. Thus, researchers made a second modification and repeated the testing. For this experiment the workability box was eliminated and replaced with standard-size

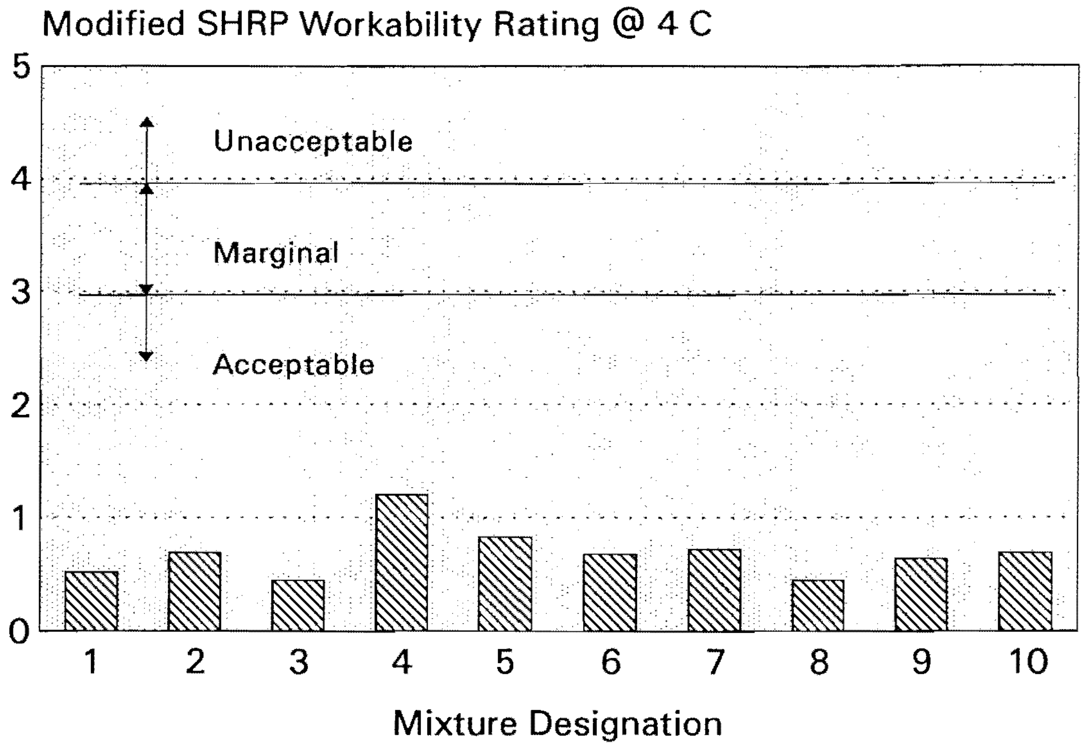


Figure 34. SHRP Workability (First Modification) for HMCL Mixtures.

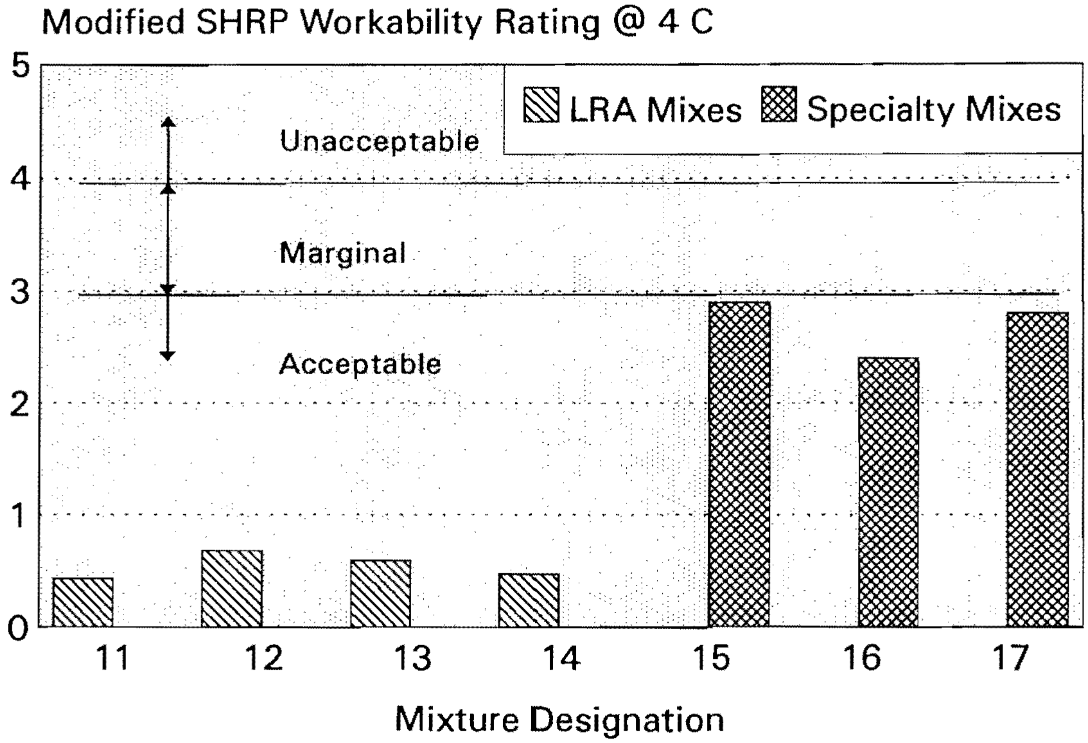


Figure 35. SHRP Workability (First Modification) for LRA and Specialty Mixtures.

coffee cans. The reason for using coffee cans instead of the workability box was so that testing could proceed at a faster pace. Only one workability box was available.

In the SHRP workability test, the material is placed loosely in the box and then tested. In this second modification, the material was placed loosely in the coffee can but then stored at 4°C overnight to allow for consolidation prior to testing. Testing then proceeded as previously described. Results of these tests are presented in Figures 36 and 37. This test showed improvement over the SHRP test in that significant differences could be detected between mixtures; however, correlation with field evaluations of workability were not good. This will be presented later.

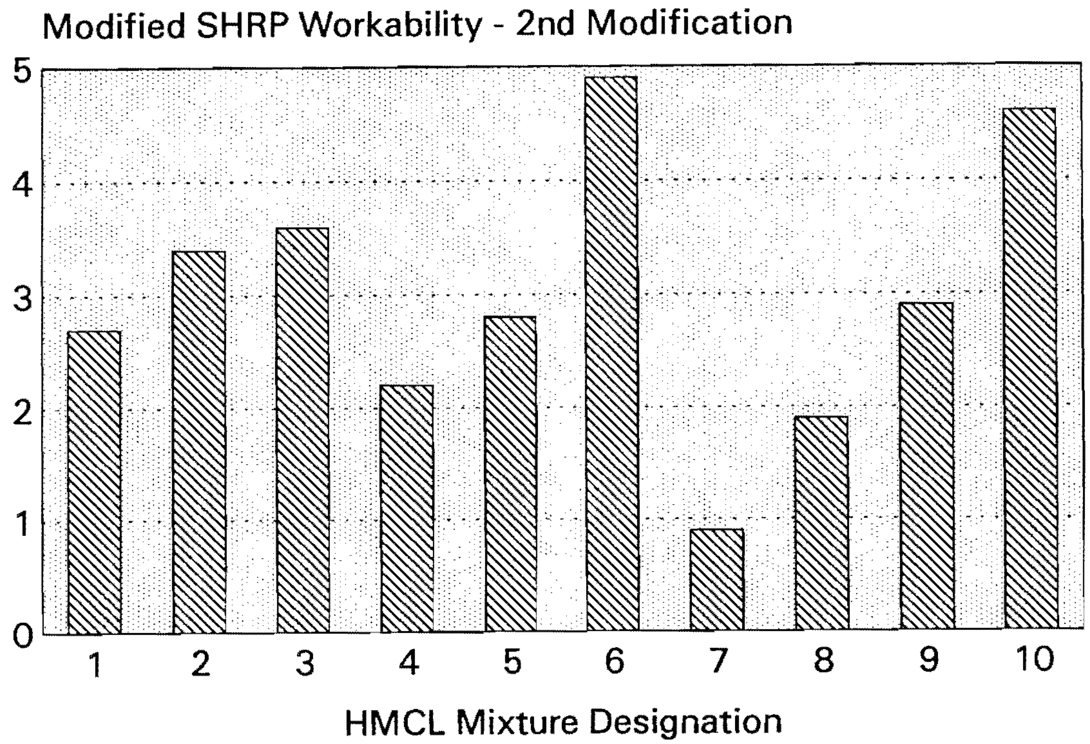


Figure 36. SHRP Workability (Second Modification) for HMCL Mixtures.

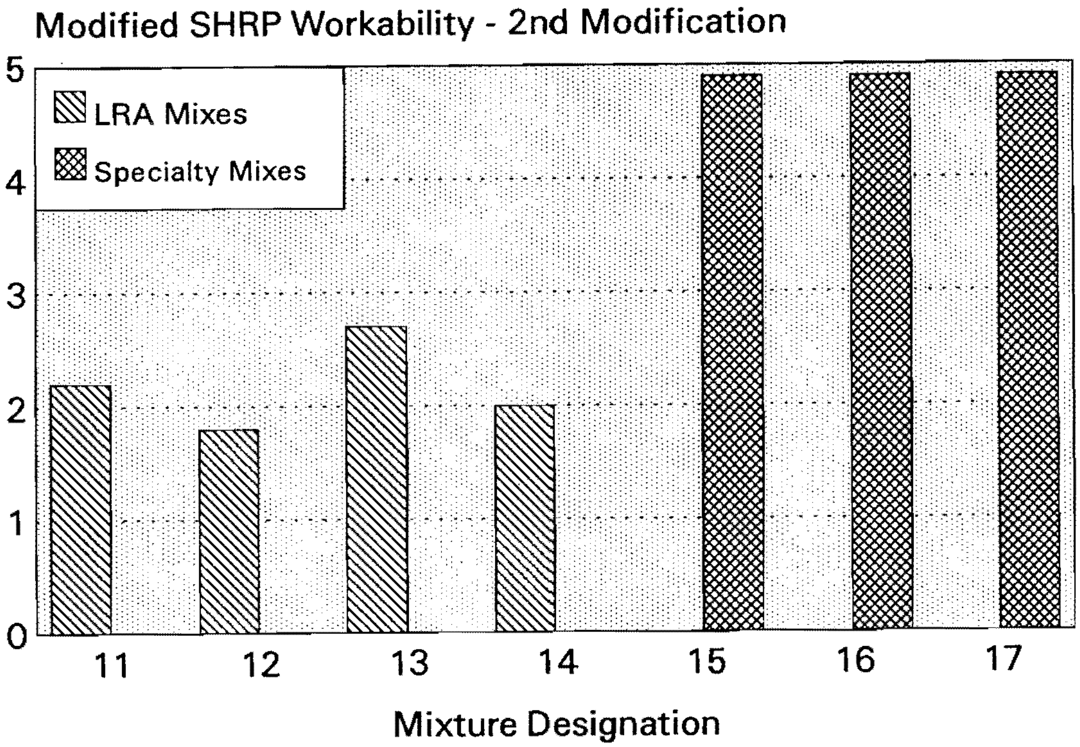


Figure 37. SHRP Workability (Second Modification) for LRA and Specialty Mixtures.

3.3.4 Workability as Measured with Texas Gyratory Compactor

The gyratory compactor was used in an attempt to quantify the workability of maintenance mixtures. This was done by simply counting the number of revolutions of the mold required to achieve the specified pressures for compaction (Tex-206-F). Fewer revolutions should indicate a more easily compactable or workable mixture. Samples were compacted at two temperatures: 25°C and 4°C. These results are presented below in Figures 38, 39, and 40. As expected, it generally took more effort to compact mixtures at 4°C than at 25°C.

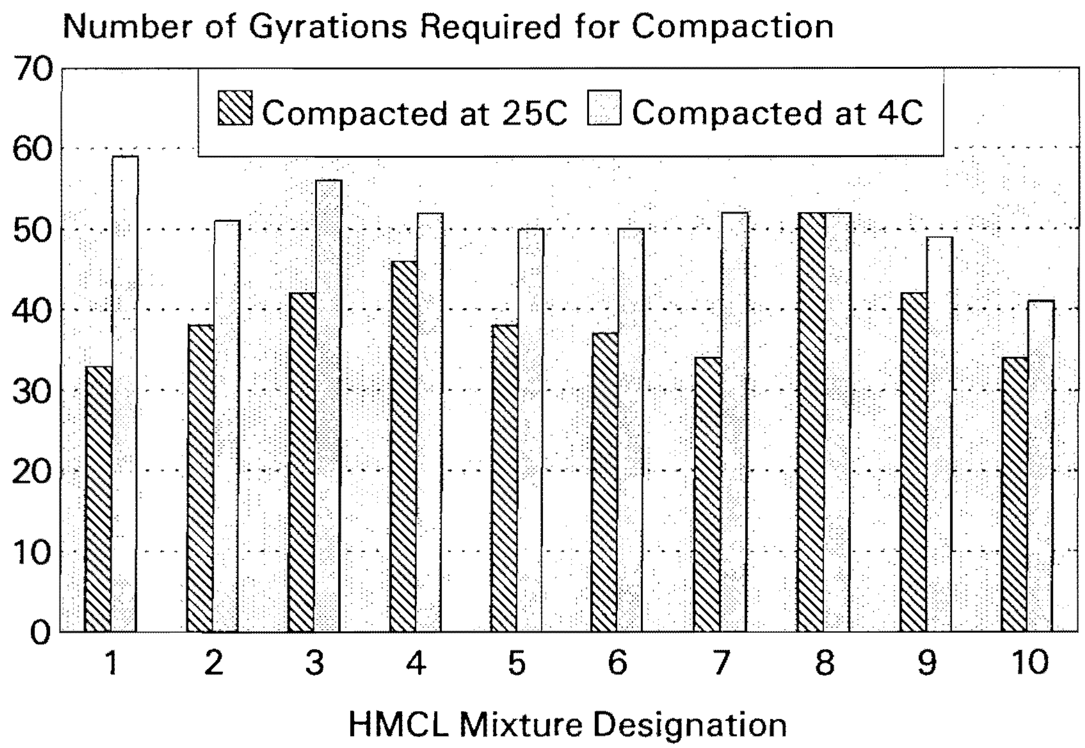


Figure 38. Workability of HMCL Mixtures as Measured with Gyratory Compactor.

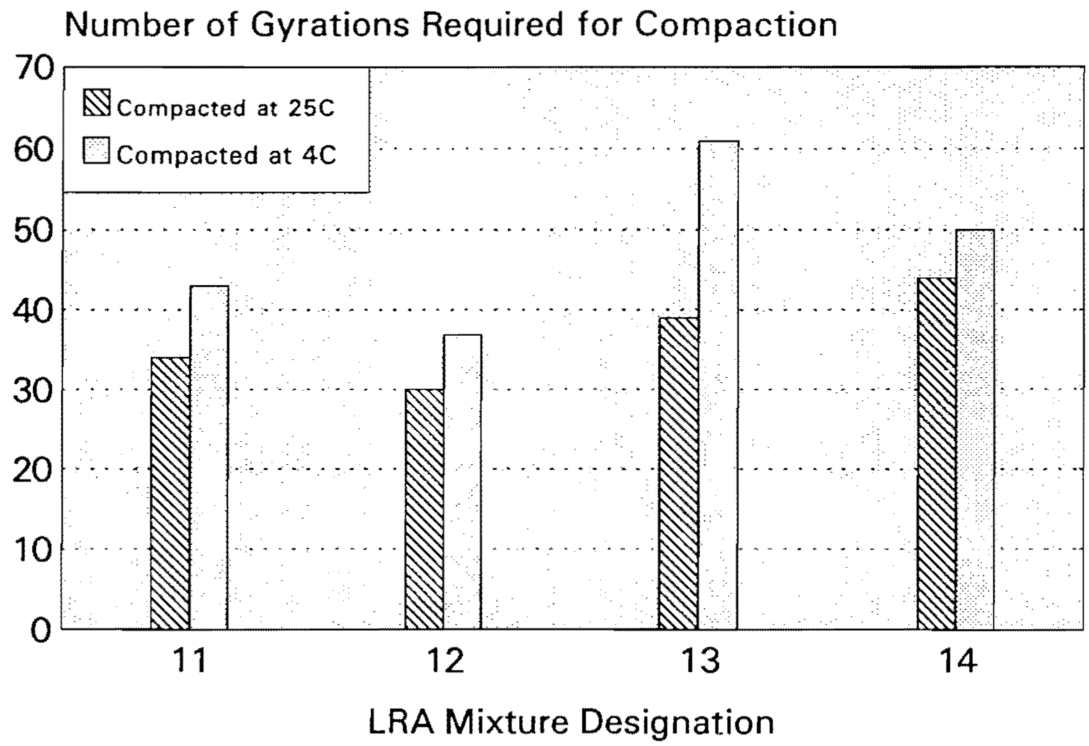


Figure 39. Workability of LRA Mixtures as Measured with Gyratory Compactor.

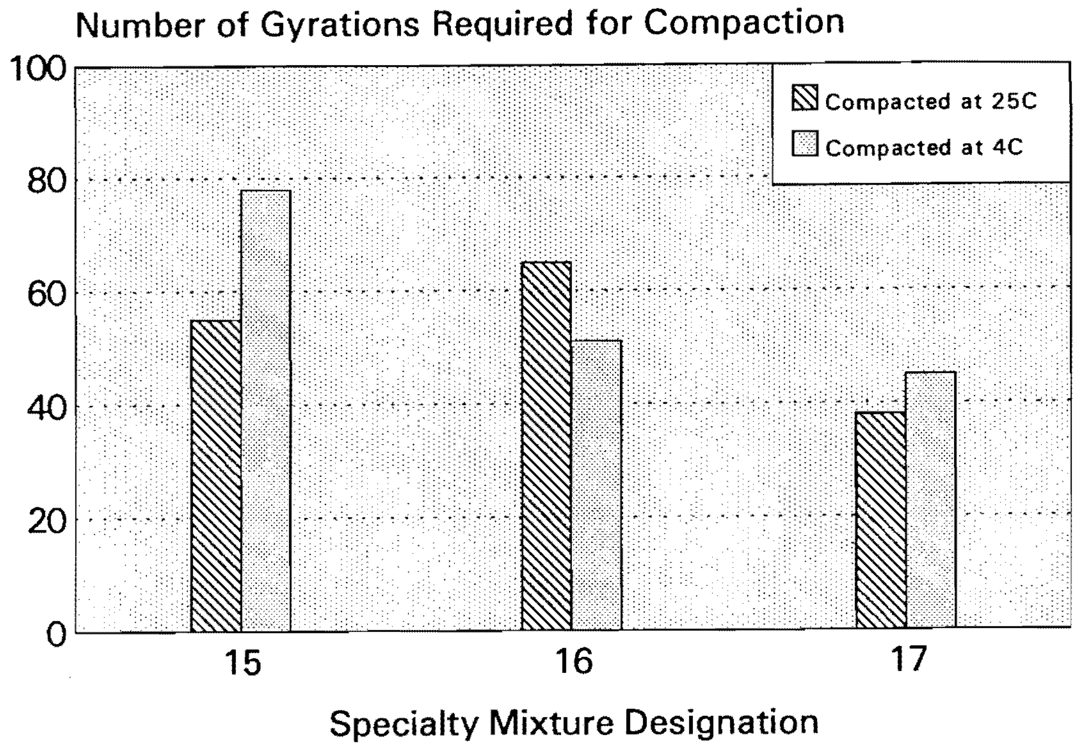


Figure 40. Workability of Specialty Mixtures as Measured with Gyratory Compactor.

3.4 RELATIONSHIP BETWEEN FIELD EVALUATIONS OF WORKABILITY AND LABORATORY MEASUREMENTS

As described in section 3.1, workability of field stockpiles were subjectively evaluated at temperatures of 4°C or lower. The workability of the different field mixtures was ranked as good, average, or fair. The laboratory measurements presented in this chapter were plotted as a function of the field workability ratings to establish any relationships that might exist. These data are presented in Figures 41 through 48. There is no real trend in any of the data indicating a relationship between the quantitative laboratory measurements of workability and the subjective field ratings of workability.

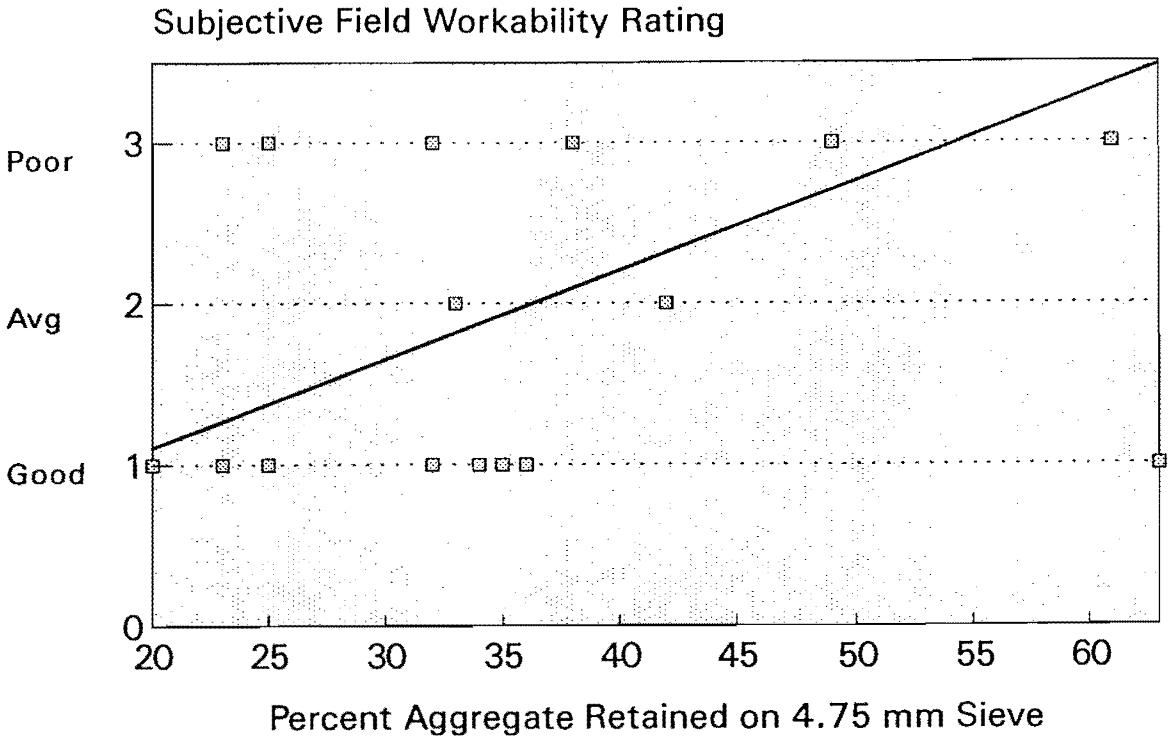


Figure 41. Field Workability Rating as Related to Coarse Aggregate Quantity.

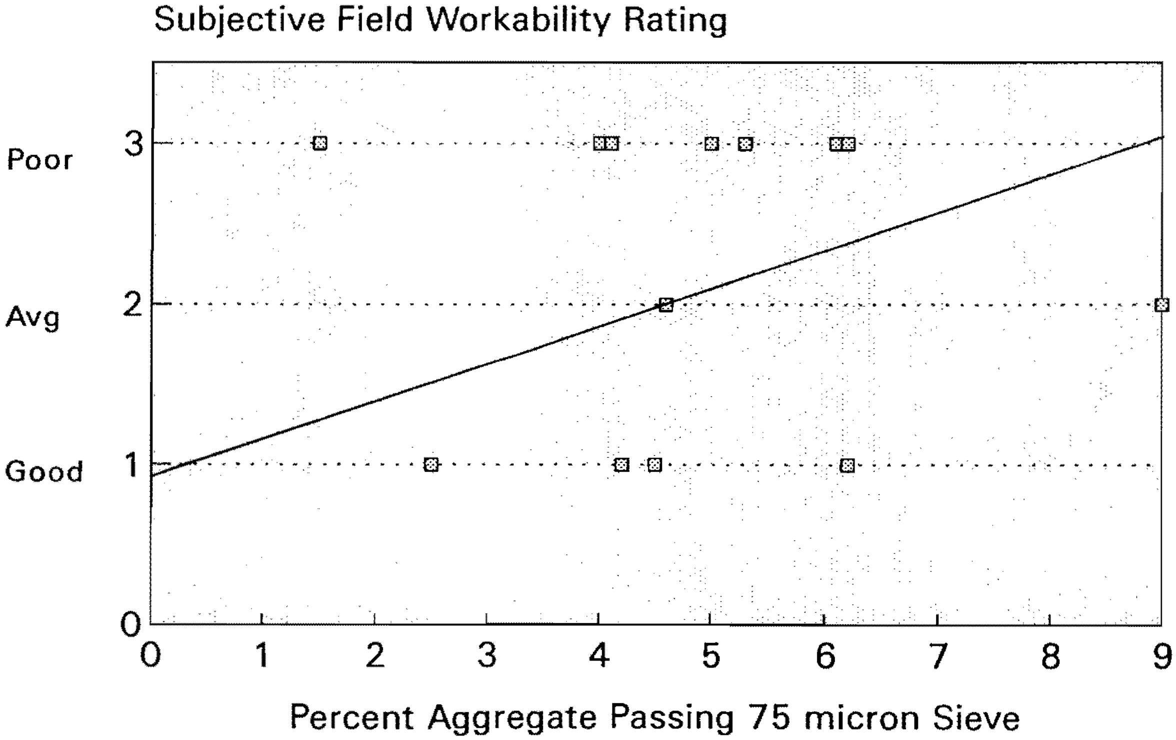


Figure 42. Field Workability Rating as Related to Fine Aggregate Quantity.

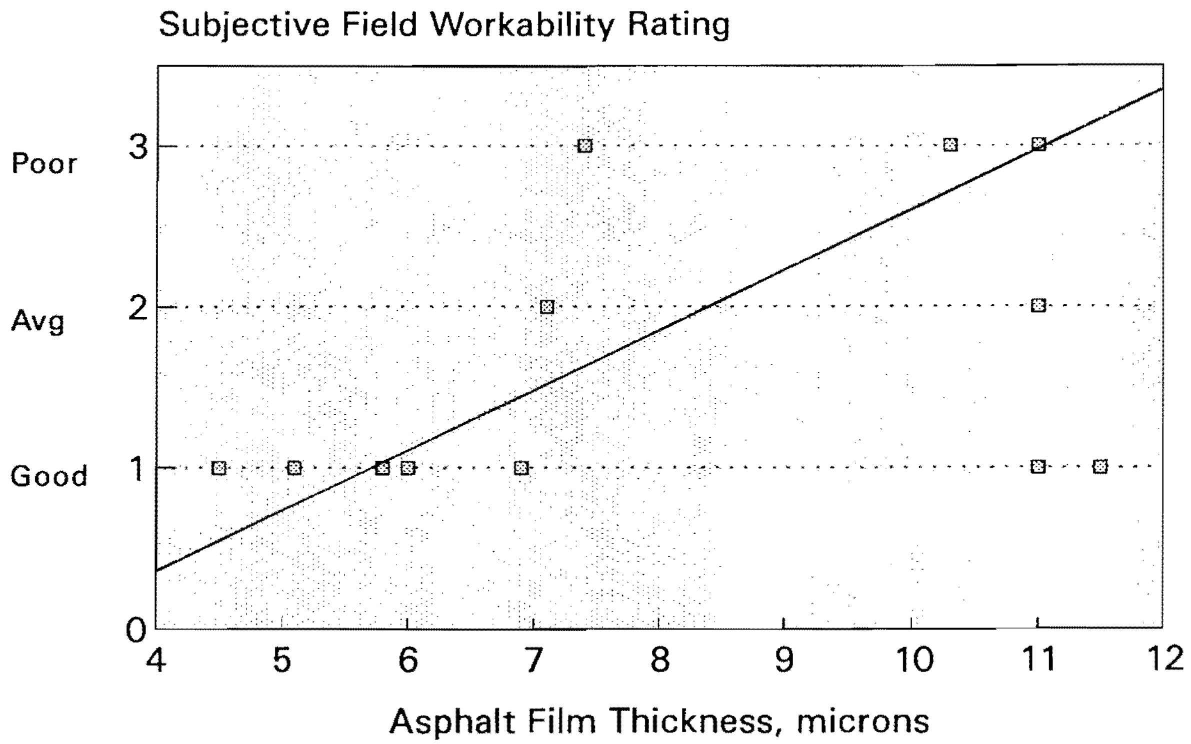


Figure 43. Field Workability Rating as Related to Asphalt Film Thickness.

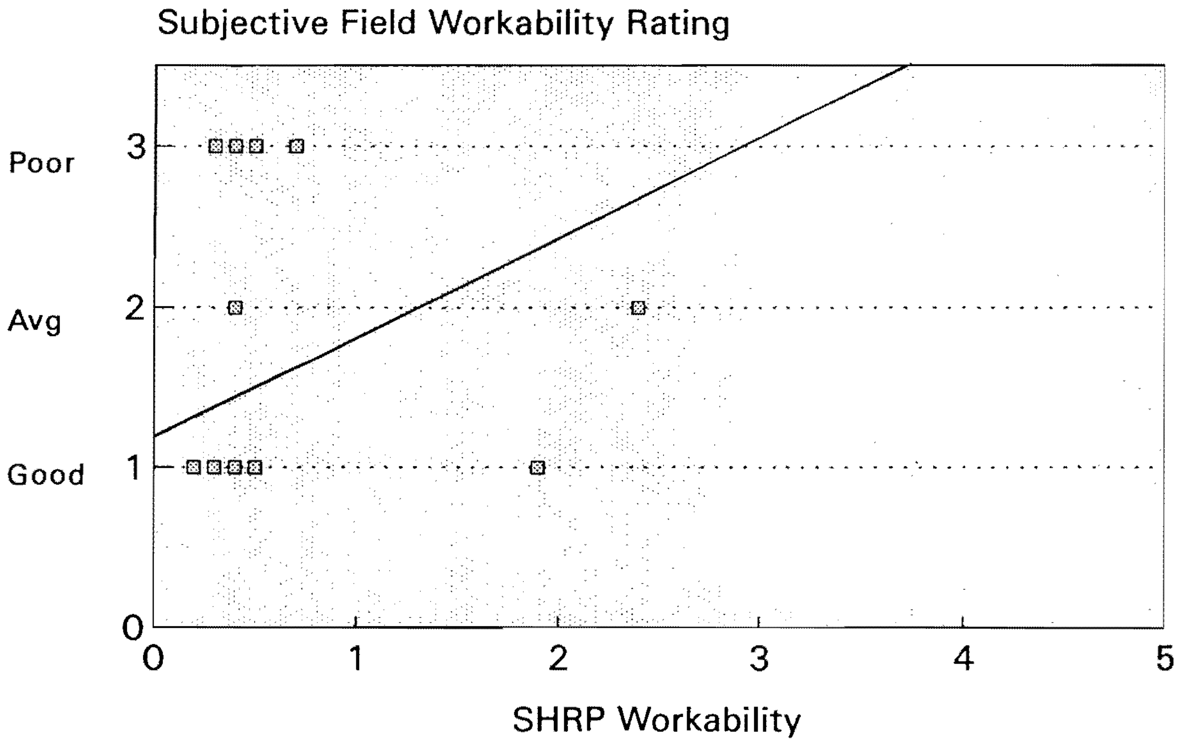


Figure 44. Field Workability Rating as Related to SHRP Workability Test.

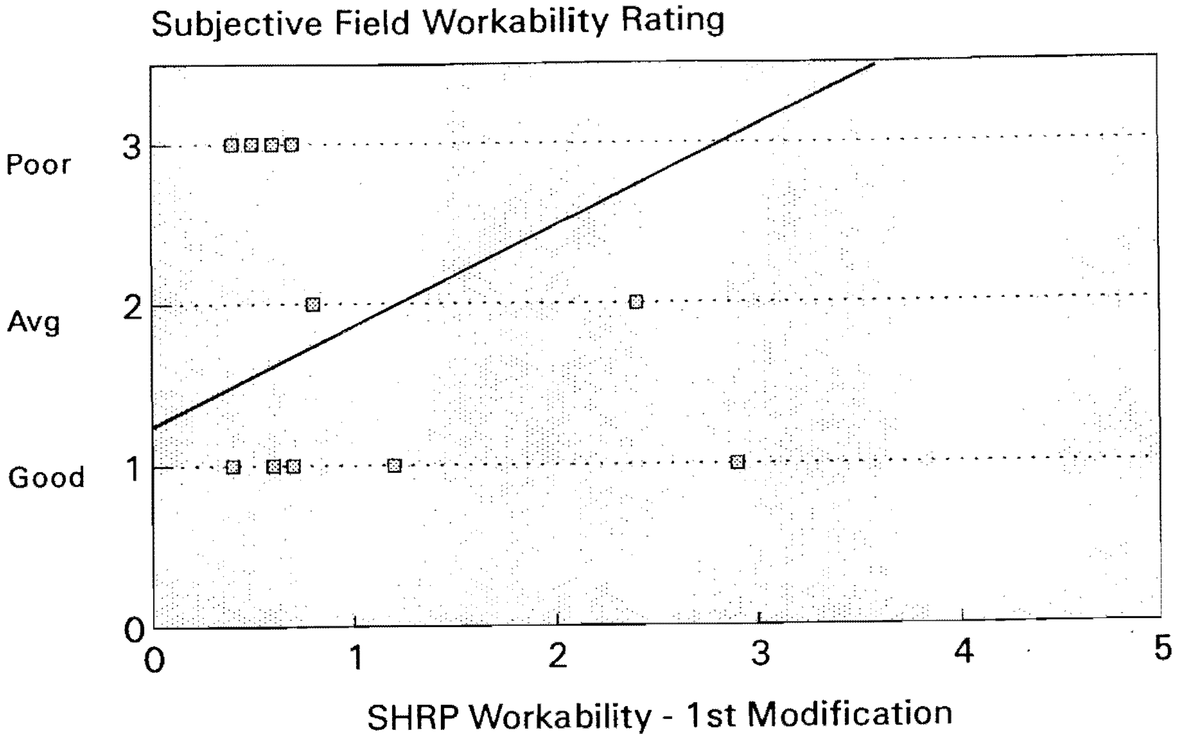


Figure 45. Field Workability Rating as Related to SHRP Workability Test (First Modification).

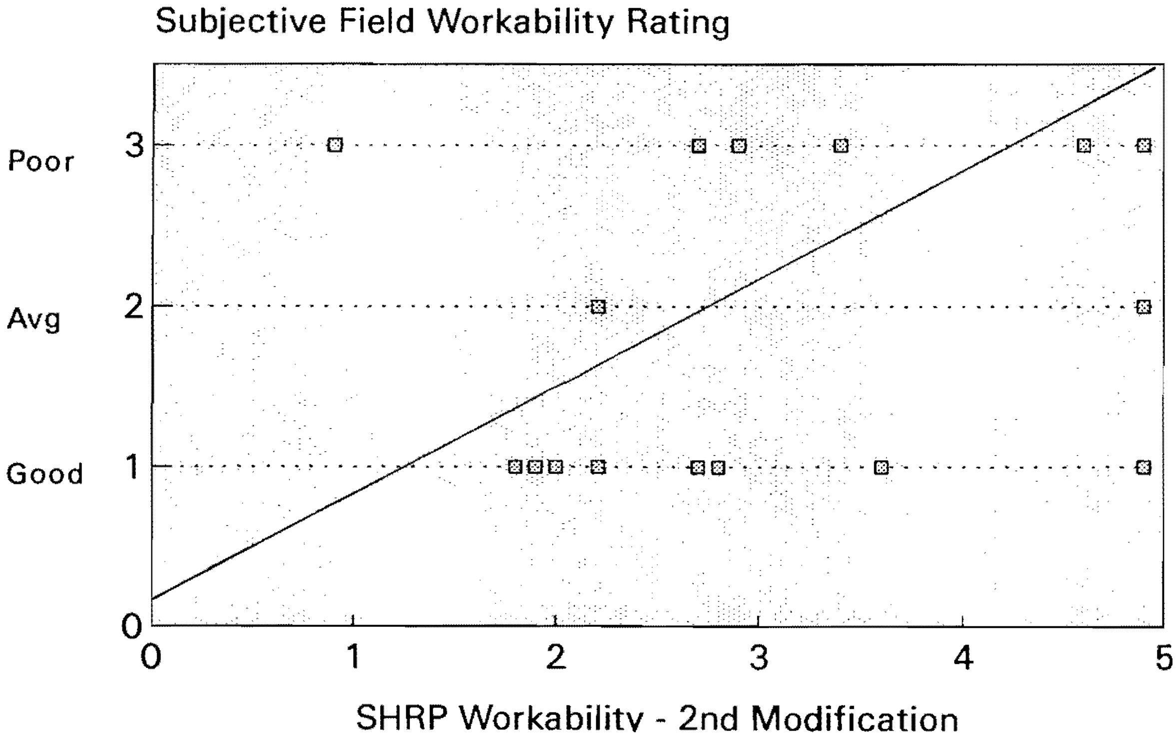


Figure 46. Field Workability Rating as Related to SHRP Workability Test (Second Modification).

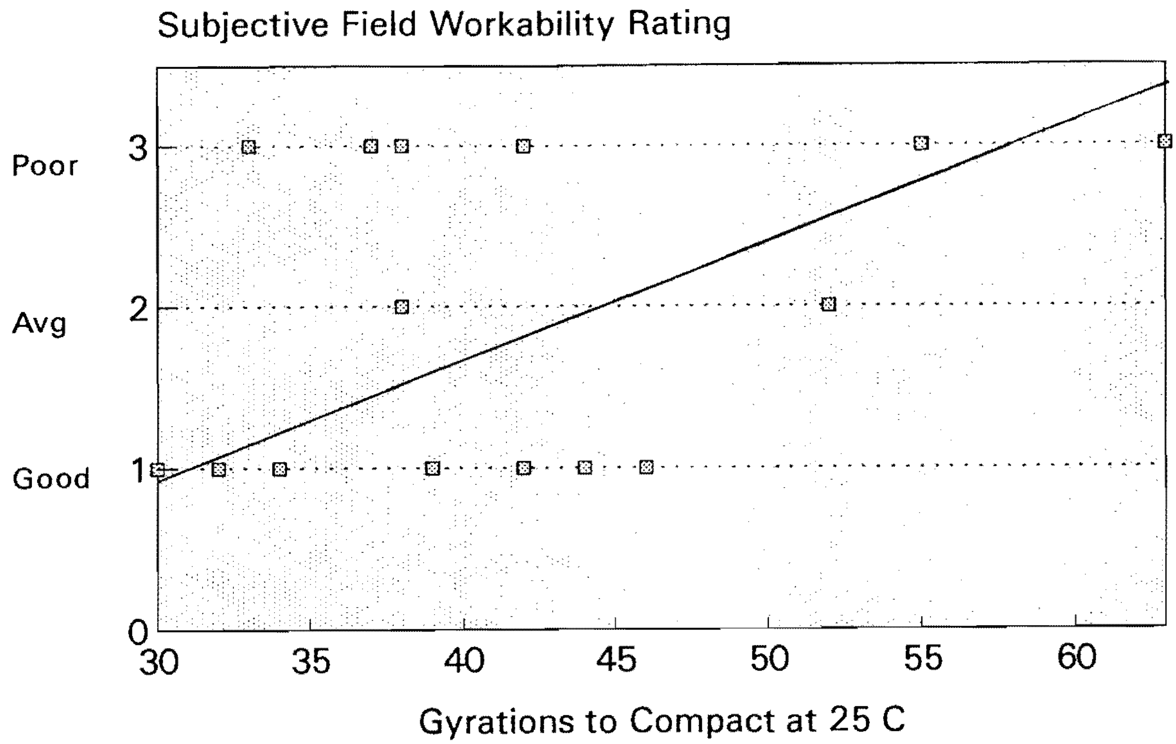


Figure 47. Field Workability Rating as Related to Ease of Compaction at 25°C.

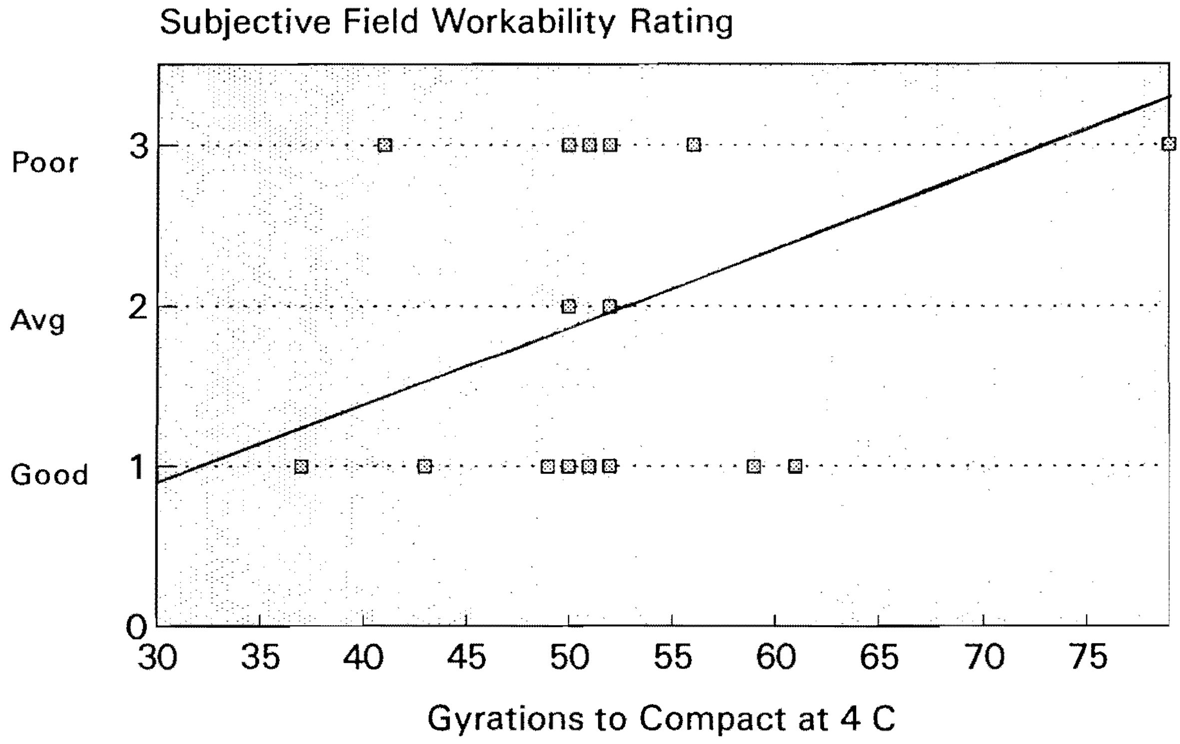


Figure 48. Field Workability Rating as Related to Ease of Compaction at 4°C.

3.5 SUMMARY

In this portion of the study, the workability of stockpiled field materials was subjectively evaluated and compared to laboratory measurements aimed at quantifying workability. These laboratory measurements included the following:

- Quantity of coarse aggregate in mixture;
- Quantity of fine aggregate in mixture;
- Asphalt film thickness;
- SHRP workability test;
- Two different modifications of SHRP workability test;
- Ease of compaction at 25°C; and
- Ease of compaction at 4°C.

Comparisons of the laboratory workability measurements to the field measurements indicated that there was no clear relationship between them. Therefore, none of these material properties and test procedures were pursued further in this research.

4.0 EVALUATION OF LABORATORY TESTS TO IDENTIFY WATER SUSCEPTIBLE MAINTENANCE MIXTURES

The Texas Department of Transportation (TxDOT) currently uses two tests to measure moisture damage to asphalt concrete mixtures: Tex-530-C (boiling stripping test) and Tex-531-C (modified Lottman). The modified Lottman test has also been recommended by SHRP for measurement of water susceptibility of asphalt concrete mixtures.

4.1 TEX-530-C, BOILING TEST

For evaluation of HMCL materials, the boiling test (Tex-530-C) requires that a 200-gram specimen of mix be boiled for 10 minutes in 1000 ml of water. The water is decanted and the mix then dumped on a paper towel to dry. The dry mix is examined for stripping and a visual rating of percentage of stripping is assigned based on the total surface area of the mix. A visual estimation of more than 10 percent uncoated surface area indicates a potential for stripping.

As mentioned in previous chapters, several maintenance mixtures were obtained from across the state and stockpiled at Texas A&M's Riverside Campus for field evaluation. These materials were tested, as received, according to Tex-530-C. Results of these tests on the HMCL materials are shown in Figure 49. Tests were also performed on the LRA and specialty mixtures (Mixes 11 through 17 described in Tables 3 and 4) and on all of these mixtures, no uncoated aggregate was observed.

Visual evaluations were performed on the field-stockpiled materials after 6 months. Field mixtures were characterized as good, fair, or poor with regard to stripping in the stockpile. The visual evaluations are shown in Table 5. These visual evaluations are compared to results of Tex-530-C as shown in Figure 50. According to Figure 50, Tex-530-C reasonably predicts the potential for maintenance mixtures to strip in the stockpile.

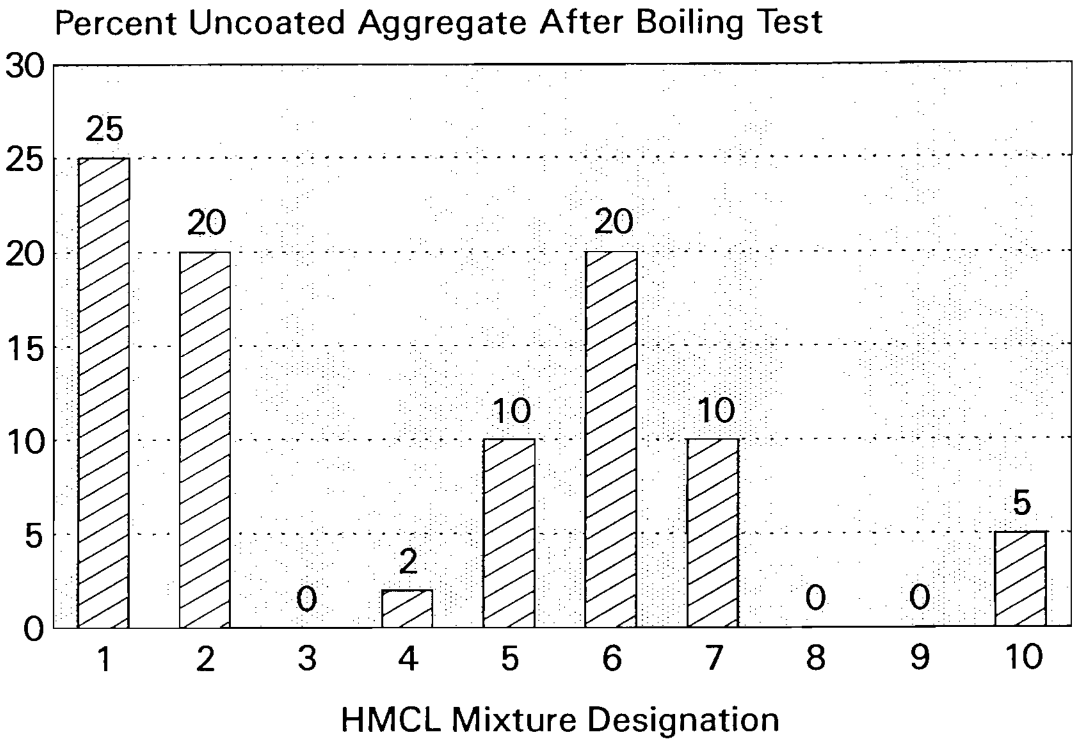


Figure 49. Results of Boiling Test (Tex-530-C) on HMCL Mixtures.

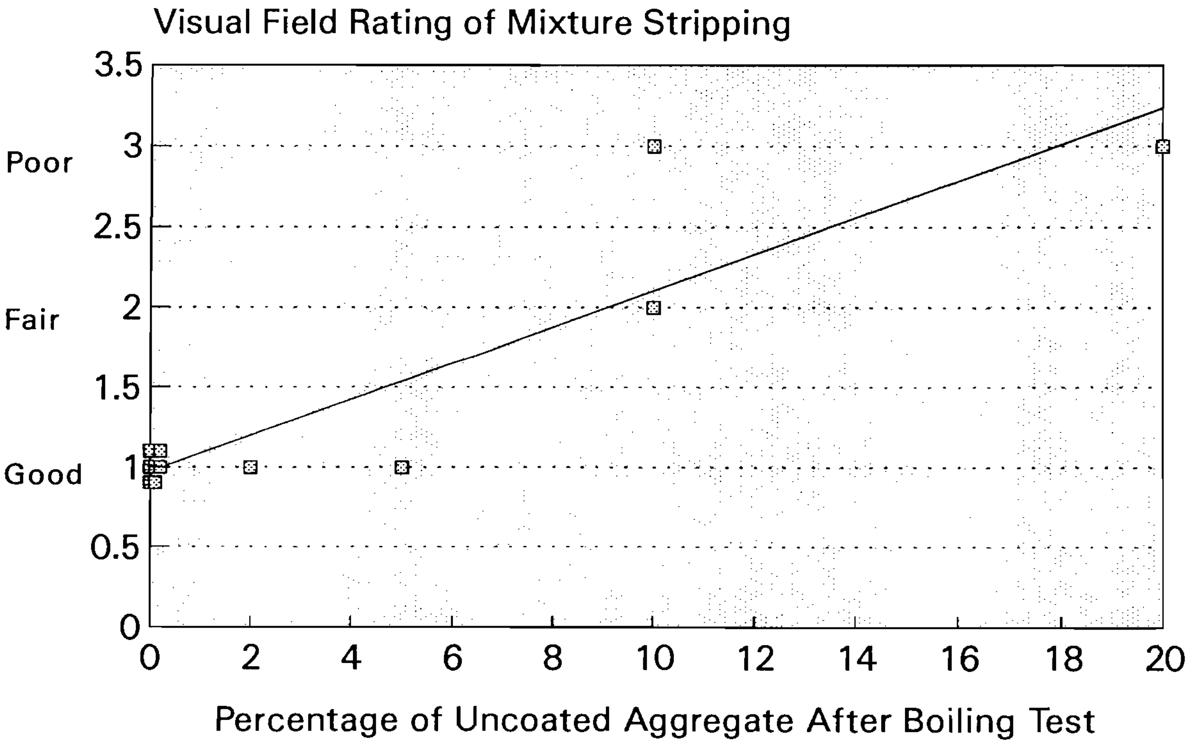


Figure 50. Field Stripping Rating as Related to Tex-530-C Boiling Test.

Table 5. Visual Evaluation of Stripping of Stockpiled Maintenance Mixtures.

Mixture Designation	Mixture Type	Field Stripping Rating
1	HMCL	Not Available
2	HMCL	Not Available
3	HMCL	Good
4	HMCL	Good
5	HMCL	Fair
6	HMCL	Poor
7	HMCL	Poor
8	HMCL	Good
9	HMCL	Good
10	HMCL	Good
11	LRA	Good
12	LRA	Good
13	LRA	Good
14	LRA	Good
15	Specialty	Good
16	Specialty	Good
17	Specialty	Not Available

4.2 TEX-531-C, MODIFIED LOTTMAN

The modified Lottman test is performed on samples molded in the Texas gyratory compactor. One group of specimens is left unconditioned while a second group is moisture conditioned. Moisture conditioning consists of vacuum saturating to 60 to 80 percent voids filled. These samples are then sealed in a plastic bag and placed in a freezer for 15 hours, taken from the bags and placed in a 60°C water bath for 24 hours. Both conditioned and unconditioned samples are tested at 25°C for indirect tensile strength. The tensile strength ratio (TSR) of a mix may be calculated as the indirect tensile strength of the moisture-conditioned samples divided by the indirect tensile strength of the unconditioned samples. The TSR is, therefore, an indication of the loss of strength produced by the moisture conditioning. For hot-mix, hot-laid asphalt concrete, a tensile strength ratio of 0.70 or higher is generally needed to insure adequate stripping resistance.

Tensile strength ratios for the maintenance mixtures are presented in Figures 51 and 52. Comparison of these data to field performance information is presented in Figure 53. Based on the results shown in Figure 53, it appears that Tex-531-C is not an appropriate test for maintenance mixtures. Results from these tests are quite variable, do not relate to criteria for HMHL mixtures, and do not correlate with field performance.

4.3 SUMMARY

The ability of two test procedures to predict water susceptibility of stockpiled maintenance mixtures was evaluated: Tex-530-C (boiling stripping test) and Tex-531-C (modified Lottman test). Test results were compared to visual ratings regarding stripping characteristics of the same materials after 6 months in the stockpile.

Tex-530-C was found to reasonably predict the stripping potential of maintenance mixtures while Tex-531-C did not. Present acceptance criteria for Tex-530-C (boiling stripping test) appears to be adequate.

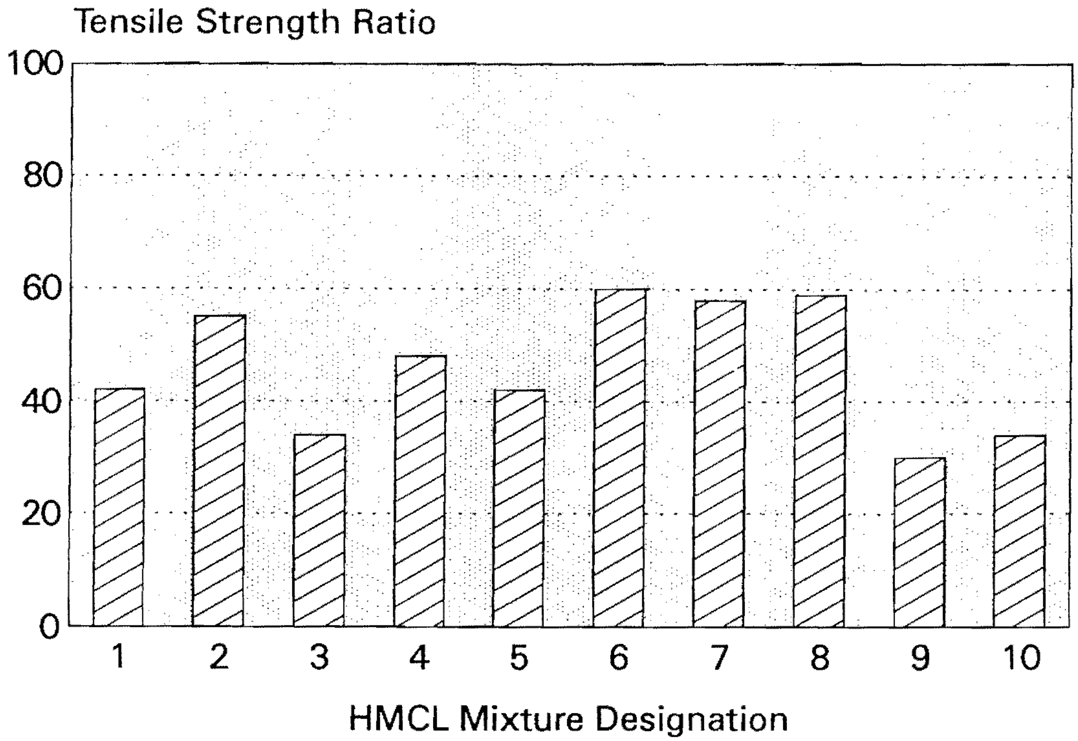


Figure 51. Tensile Strength Ratios for HMCL Mixtures.

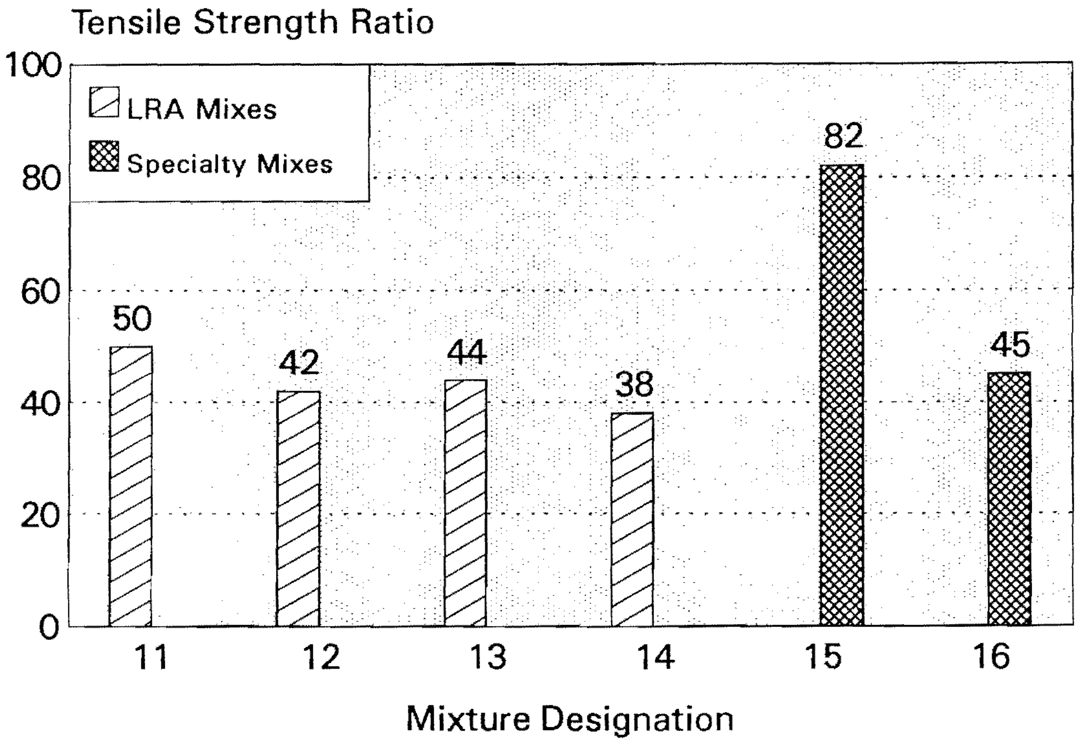


Figure 52. Tensile Strength Ratios for LRA and Specialty Mixtures.

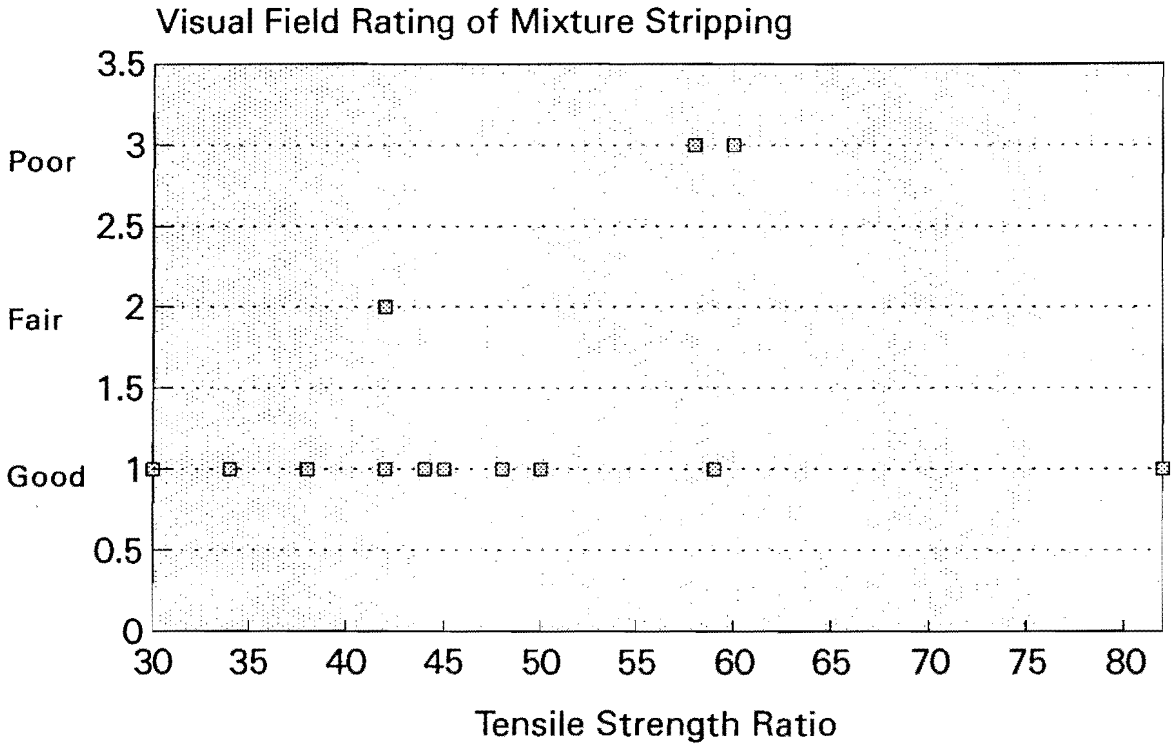


Figure 53. Field-Stripping Rating as Related to Tensile Strength Ratio.

5.0 EVALUATION OF PROTECTIVE TREATMENTS FOR STOCKPILES

According to the survey of maintenance personnel in the districts, stripping of the asphalt from aggregate surfaces in stockpiled maintenance mixtures is a problem. The goal of this portion of the project was to find a simple method of treatment or covering for the stockpile to prevent the stripping caused by rainfall. Several different coverings were evaluated in the laboratory. Sheet coverings were not evaluated.

Laboratory evaluation was performed on a small sample of mixture which was placed in an aluminum pan with holes in the bottom, The pan was positioned on an incline of approximately 15 degrees. A predetermined amount of water was dripped onto the mixture. The amount of water that went through the mixture was subtracted from the total amount of water applied and then divided by the total amount of water. This gave the percent water repelled. This procedure was performed on HMCL and LRA mixtures.

Methods of treatment and coverings included sprayed on emulsified asphalt, pavement-striping paint, spray paint, rubberized spray paint, and rubberized roof sealant.

5.1 TREATMENT AND COVERING METHODS

The emulsion and pavement striping paint were diluted with water and applied to the mixtures in the laboratory. The emulsion yielded 0.68 l/m^2 of residual asphalt, and the striping paint was applied at two residual rates: 0.23 and 0.68 l/m^2. The emulsion and paint were sprayed on using a hand-pumped pressure sprayer. The spray paint and rubberized spray paint (bought in spray cans) were sprayed on and the rubberized roof sealant was painted on with a brush so as to give an even but thorough coat.

5.2 RESULTS

The effectiveness of the treatments varied between the HMCL and LRA mixtures as shown in Table 6. The LRA mixture without any treatment at all generally repelled more water than with the treatment methods. The LRA samples treated with the asphalt emulsion were significantly more susceptible to water intrusion than the untreated sample. It is unclear why this occurred. The asphalt emulsion was also not very effective on the HMCL mixture.

Table 6. Laboratory Results of Stockpile Treatment Methods

Type of Treatment	Application Rate	% Water Repelled HMCL	% Water Repelled LRA
None	-	26	97
Pavement Striping Paint	0.23 l/m^2 0.68 l/m^2	49 51	93 83
Asphalt Emulsion	0.68 l/m^2	32	38
Spray Paint	523 g/m^2	-	80
Rubberized Spray Paint	510 g/m^2	-	85
Rubberized Roof Sealant	550 g/m^2	-	100

The pavement striping paint was effective for the HMCL. It improved the resistance to water intrusion of the samples tested by almost 200%. This paint reduced the LRA's water resistance, and there was even less resistance with the increased application of paint.

The spray paint did not show an improvement in resistance to water intrusion of the LRA. Moreover, this method of covering would not be practical for field application.

The rubberized spray paint was more resistant than the spray paint, but it did not greatly increase the LRA's resistance to water intrusion. This cover was not chosen for further consideration due to its high cost.

The rubberized roof sealant increased the resistance to water intrusion of the LRA sample to 100%, but it has a very high cost and was very difficult to apply. For these reasons, it is considered impractical for field use.

Stockpile coverings such as plastic sheeting or fabrics would certainly be effective at minimizing the intrusion of water in the stockpile; however, interviews with maintenance personnel considered this type of covering to be impractical.

5.3 FIELD EVALUATION

Based on the results of the laboratory study, the pavement striping paint was chosen for field study. A portion of a HMCL stockpile was treated with the striping paint applied at a rate of about 0.6 l/m^2. Periodic evaluations of the treated and untreated portions of the stockpile were performed for a 3 month period. No discernable differences were detected between the treated and untreated portions since no stripping was observed in either case.

5.4 SUMMARY

Several potential stockpile treatment methods were evaluated in the laboratory for their effectiveness at reducing the intrusion of water into the stockpile. No treatment method could be recommended for LRA mixtures since this mixture repelled water well with no treatment. Treatment of the LRA with asphalt emulsion significantly increased intrusion of water into this mix. Pavement striping paint was found to be the most effective and practical treatment for HMCL mixtures; however, field evaluation of this treatment was inconclusive.

6.0 DEVELOPMENT OF TEST PROCEDURES

Several laboratory test methods which were thought to have potential for measurement of workability were evaluated as discussed in Chapter 3; however, none of the test methods were successful at quantifying workability. The objective of this portion of the study was to develop (1) a test procedure to simulate approximately 6 months of stockpile aging, and (2) a test procedure to quantify workability of maintenance mixtures. The protocol developed in this study based on the results presented in this chapter is designed to estimate the relative ability of a maintenance mixture to retain adequate workability after outdoor stockpile storage. This protocol could be useful as part of a specification to promote quality.

6.1 MATERIALS

As presented in previous chapters, three types of maintenance mixtures were chosen for evaluation: hot mix-cold laid (HMCL) asphaltic concrete, limestone rock asphalt (LRA), and specialty mixes such as UPM and IRR. The specialty mixtures are used mostly for pothole repair and are reported as performing adequately by most maintenance personnel. The LRA mixtures come from a single source, are generally consistent in their quality, and are routinely used successfully for winter maintenance operations. No field problems were reported regarding LRA mixtures. The HMCL materials seem to be the most inconsistent and unpredictable in terms of stockpile life and performance. Therefore, this portion of the study addressed the HMCL materials and development of test procedures to predict aging and workability.

New HMCL mixtures (Item 334) formulated for winter use were sampled from several area offices:

- Livingston,
- Fairfield,
- Paris, and
- Bryan.

Two summer mixtures which had been stockpiled for approximately six months were obtained from the following areas:

- Denton and
- Longview.

Workability of these 6 mixtures was evaluated in the field in accordance with the evaluation form presented in Appendix C. Attempts were made to perform these field evaluations at temperatures of 4°C or lower; however, unusually warm temperatures prevented this; therefore, the evaluations were performed typically between temperatures of 10 and 15°C. The Denton and Longview (old summer mixes) exhibited marginal workability while the other four field mixtures had acceptable workabilities.

At the time of this experiment, the desired range in workability (from bad to good) in HMCL mixtures was not available. Since one of the objectives was to develop a test procedure to quantify workability, two mixtures were fabricated in the laboratory to expand the range in mixture types. One mixture was purposely designed to be "workable at low temperatures" and another "unworkable."

The "workable" mixture was composed of a subrounded river gravel and field sand combined with an AC-3 modified with diesel. The "unworkable" mix was composed of 100% crushed limestone aggregate blended with an AC-20. These two mixtures were formulated to represent the two extremes in terms of workability.

Another mixture included in this study was obtained from a supplier of a material known as cold-mix asphalt (CMA). This material is reported to have improved binder characteristics and is designated in the following discussion as the "Bridgeport" material.

6.2 DEVELOPMENT OF TESTS

Two approaches were used to measure workability. In one instance, samples of mixtures were lightly compacted and subjected to unconfined compression tests. While another set of samples (compacted in the same manner) were tested in triaxial compression (modification of Tex-117-E). All tests were performed at 4°C.

Mixtures were then aged according to two different procedures and tested in the manner described above. Several aging procedures were examined on a limited basis in order to ascertain the sensitivity of the compression testing to mixture aging. The aging procedures which were chosen for further study are described as follows:

> *Procedure A*
>
> Place the 7000 g of loose mixture about 50 mm deep in a pan. Age the mixture for 48 hours in a forced-draft oven at 120°C.
>
> *Procedure B*
>
> Aging Procedure B is the same as Procedure A except that the mixture is aged for 96 hours.

Samples were compacted using the motorized gyratory soils press and sample size was 152 mm in diameter and about 152 mm in height. Several different trial compaction efforts were evaluated. The lightest compactive effort which would produce a sample that would not disintegrate under its own weight was chosen for the study. This light effort was chosen in an attempt to simulate stockpile consolidation.

6.3 TRIAXIAL TESTING

The strength of a soil is usually defined in terms of the stresses developed at the peak of the stress-strain curve. Data are typically generated from six triaxial tests, each at a different confining stress. Mohr circles are drawn to represent the states of stress at the peak points of the stress-strain curves. Then a line is drawn tangent to the Mohr circles. This line is called the Mohr failure envelope. This type of test is performed routinely by TxDOT. Testing and analysis procedures are described in detail in test method Tex-117-E, *Triaxial Compression Tests for Disturbed Soils and Base Materials*.

Triaxial testing was performed on all the mixtures described above both before and after aging. The Livingston mixture is not shown here because this mixture was depleted during the development phase of the aging and compaction procedures. Mohr failure envelopes for mixtures from Bryan, Paris, Fairfield, and Bridgeport are shown in Figures 54 through 57, respectively. Note that the angle of internal friction (angle of the failure envelope) remains generally constant both before and after aging; however, the cohesion value (y-intercept) increases with progressive levels of aging. Stress-strain data for individual specimens are shown in Appendix D.

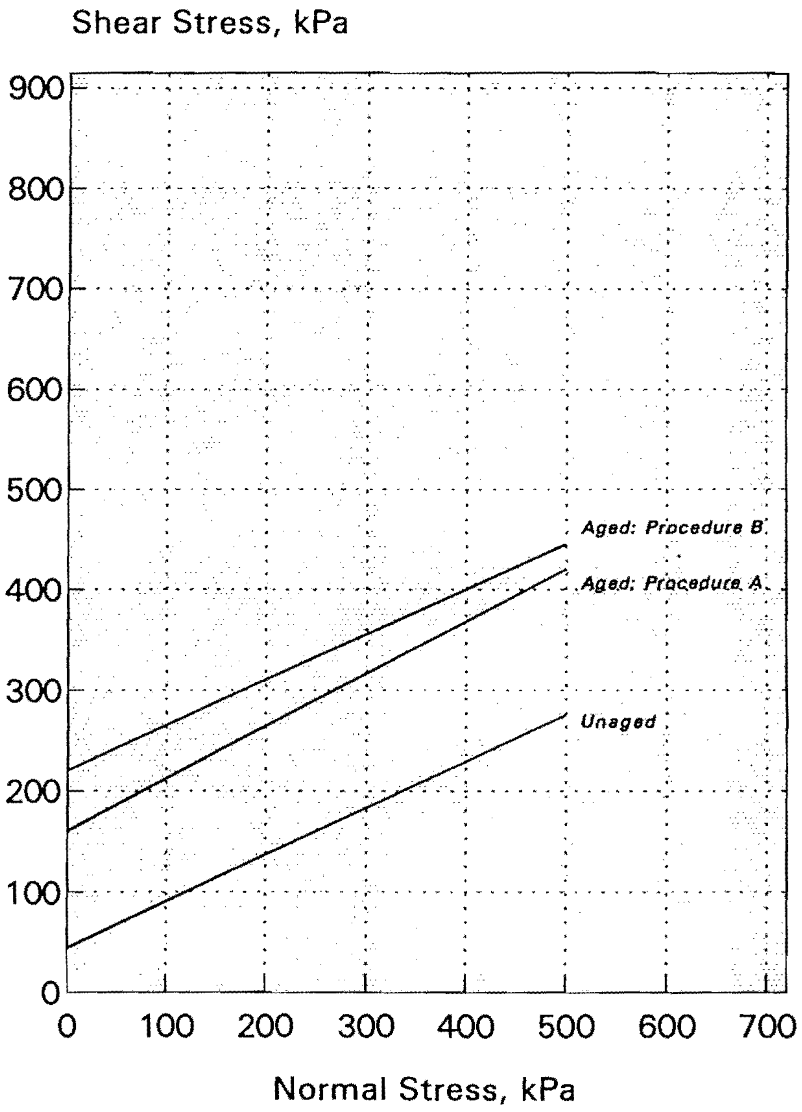


Figure 54. **Failure Envelopes from Triaxial Tests on Bryan HMCL Before and After Laboratory Aging.**

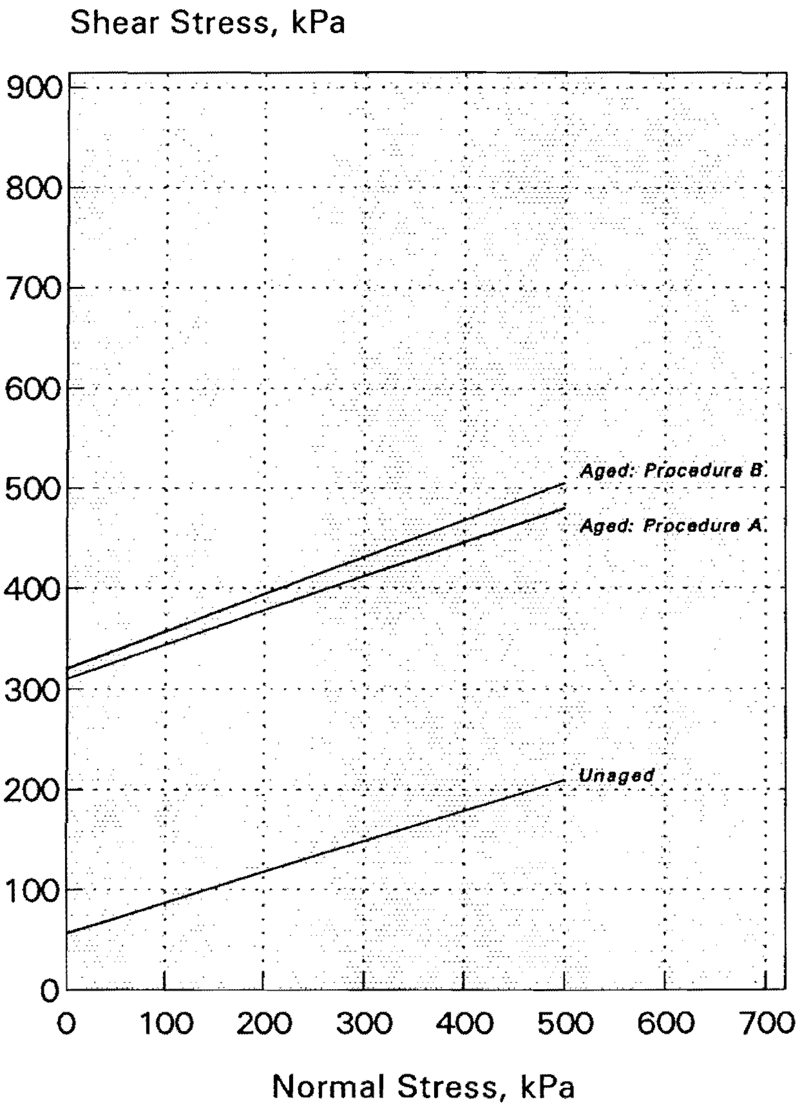


Figure 55. Failure Envelopes from Triaxial Tests on Paris HMCL Before and After Laboratory Aging.

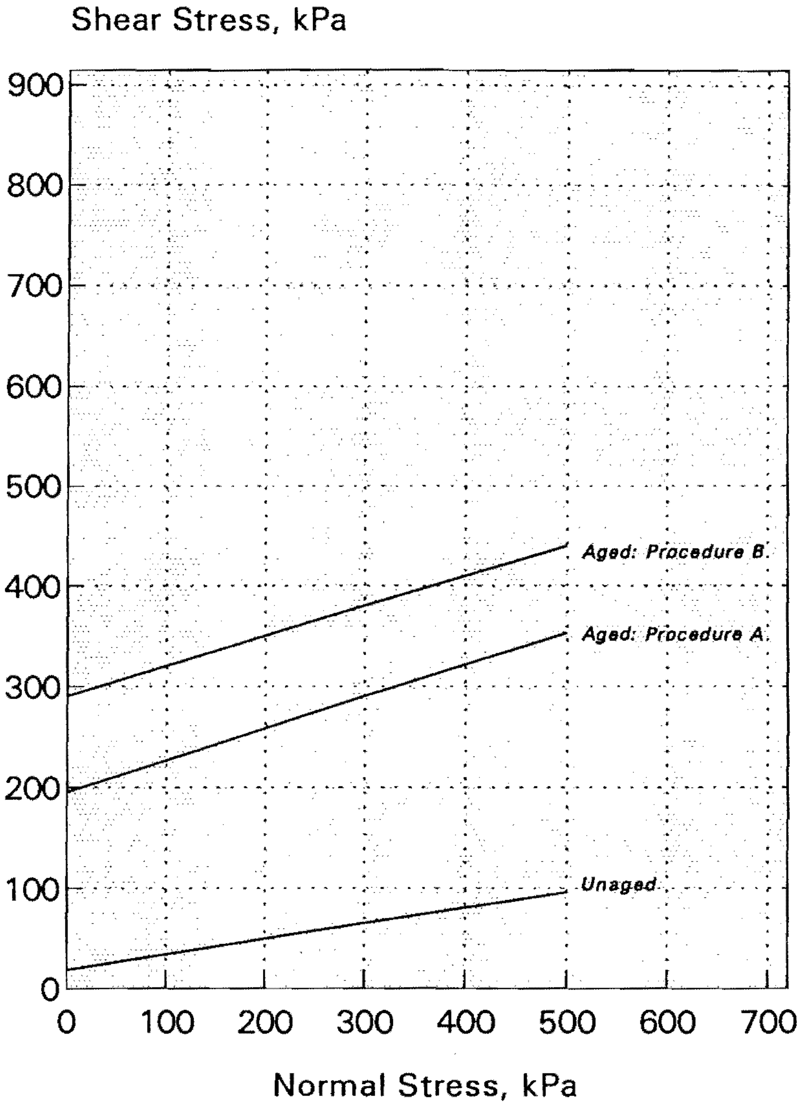


Figure 56. Failure Envelopes from Triaxial Tests on Fairfield HMCL Before and After Laboratory Aging.

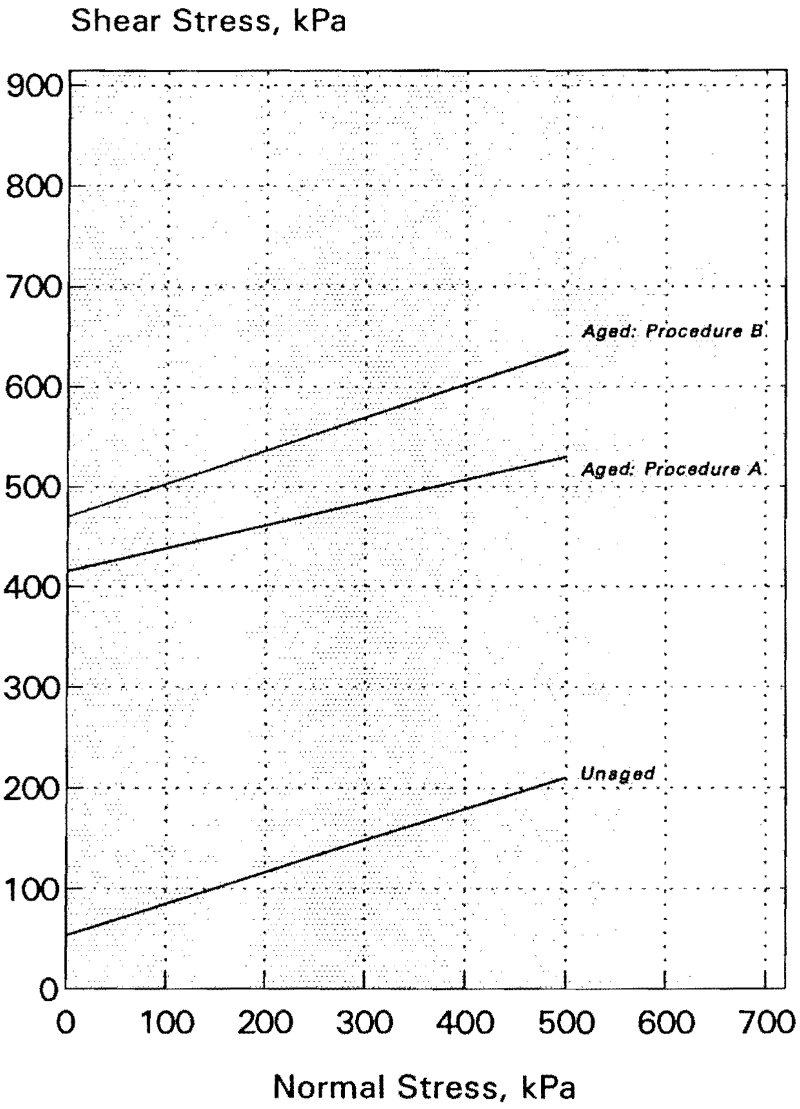


Figure 57. **Failure Envelopes from Triaxial Tests on Bridgeport HMCL Before and After Laboratory Aging.**

Failure envelopes from the triaxial tests performed on the laboratory fabricated mixtures termed as "workable" and "unworkable" are shown in Figures 58 and 59, respectively. The workable mixture exhibits a very low cohesion value and very low friction angle while the opposite is true for the unworkable mix. This is a very good indication that the test procedure is measuring workability. There is one irregularity for the unworkable mix which is exhibited in Figure 59. For all the other mixes tested before and after aging, the cohesion value increases with increasing levels of laboratory aging. For this mixture, however, the more severely aged material (Procedure B) has a lower cohesion than that aged according to Procedure A. A possible explanation is that the mastic in this mix was quite stiff even prior to aging (AC-20 + limestone fines), and further laboratory aging caused the binder to harden excessively and lose its cohesive qualities. Selective absorption of the ligher asphalt componenets by the limestone may have also contributed to this phenomenon.

The two mixtures (old summer mixtures) which had been stockpiled for about 6 months at the time of sampling are shown in Figures 60 and 61. These mixtures were not aged in the laboratory since they were intended to provide a baseline for evaluation of the aging procedures.

Figure 62 presents the failure envelopes for all of the unaged mixtures. All of the mixtures (except for the "unworkable" mix) have a cohesion value less than 100 kPa. In addition, all of the field mixtures generally have failure envelopes that lie between the lab fabricated workable and unworkable mixes. These field mixtures also exhibited good low temperature workability as measured subjectively in the field.

Failure envelopes after aging according to Procedure A are shown in Figure 63. Also shown are the two field aged materials: Denton and Longview. The failure envelopes for the two field aged mixtures are shown as dashed lines. Most of these mixtures (except for the lab-fabricated unworkable mix) have cohesion values ranging from 200 to 450 kPa. Failure envelopes for the laboratory aged (Procedure A) mixtures approximate the field aged materials with reasonable success.

Materials aged according to Procedure B are shown in Figure 64. Failure envelopes for these mixtures deviate more from the field aged materials than those aged by Procedure A which indicates that aging Procedure A may approximate 6 months of field aging more

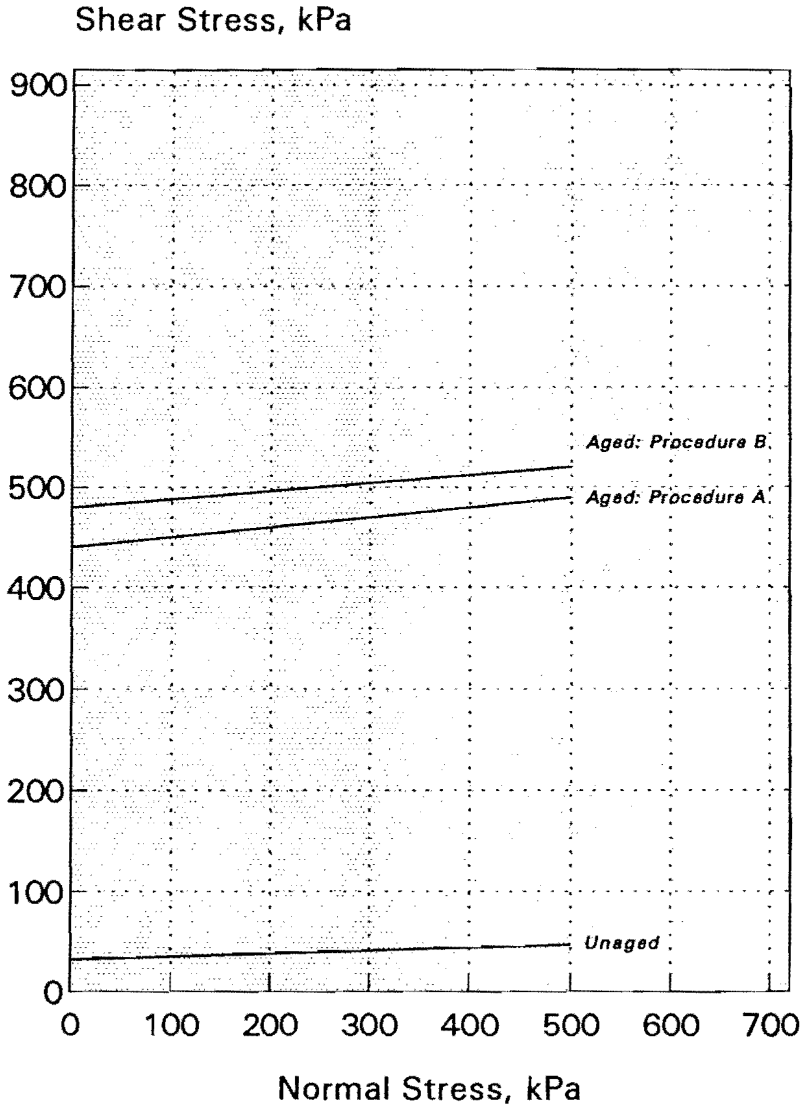


Figure 58. Failure Envelopes from Triaxial Testing on Laboratory Fabricated "Workable" Mix Before and After Laboratory Aging.

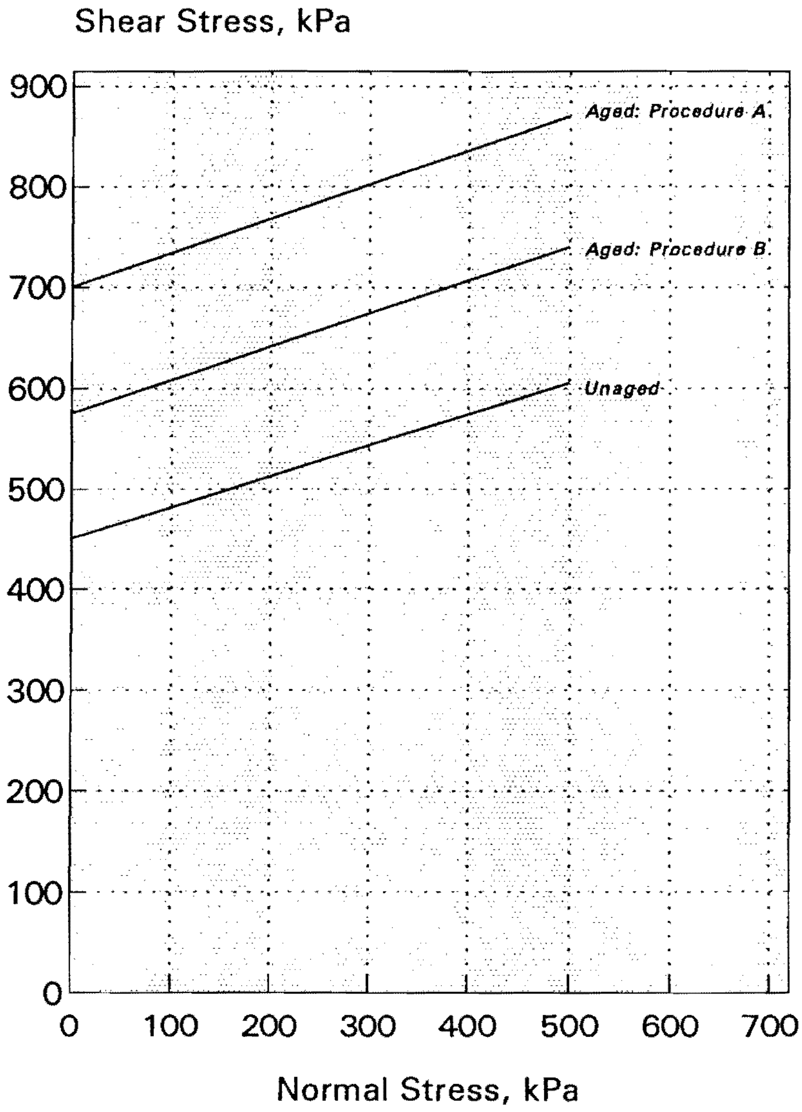


Figure 59. **Failure Envelopes from Triaxial Testing on Laboratory Fabricated "Unworkable" Mix Before and After Laboratory Aging.**

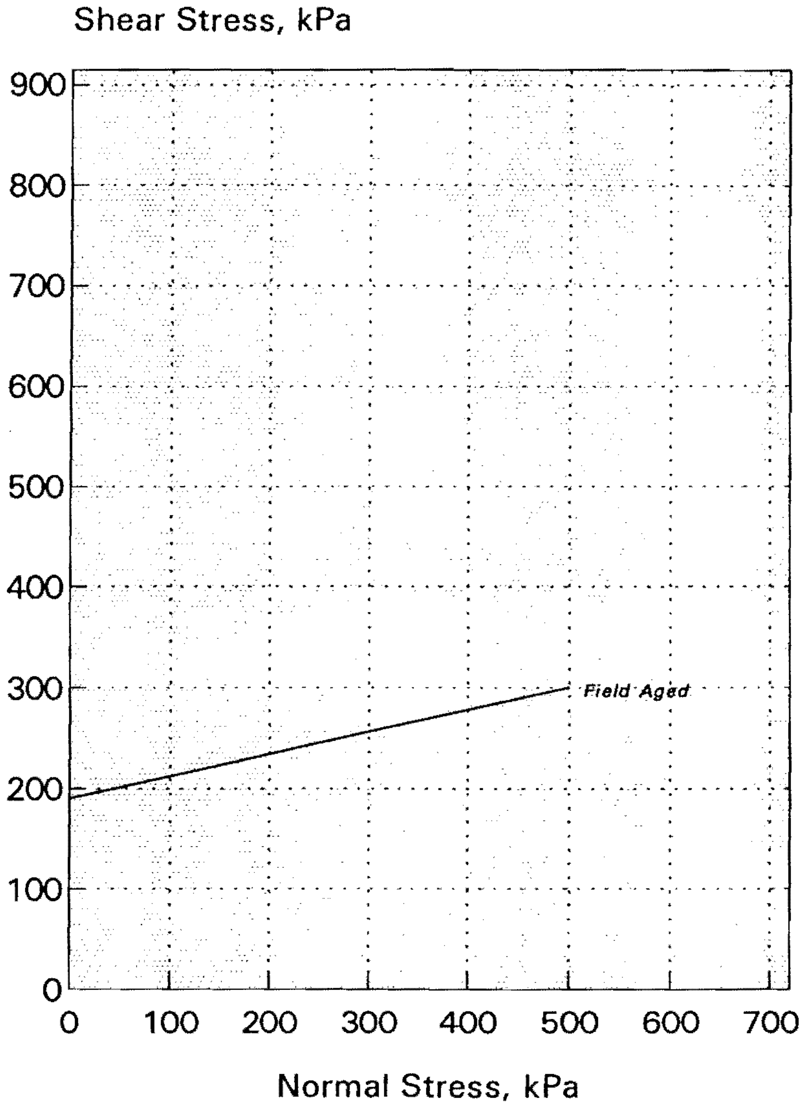


Figure 60. Failure Envelopes from Triaxial Testing on Denton Old Summer Mix (about 6 months old).

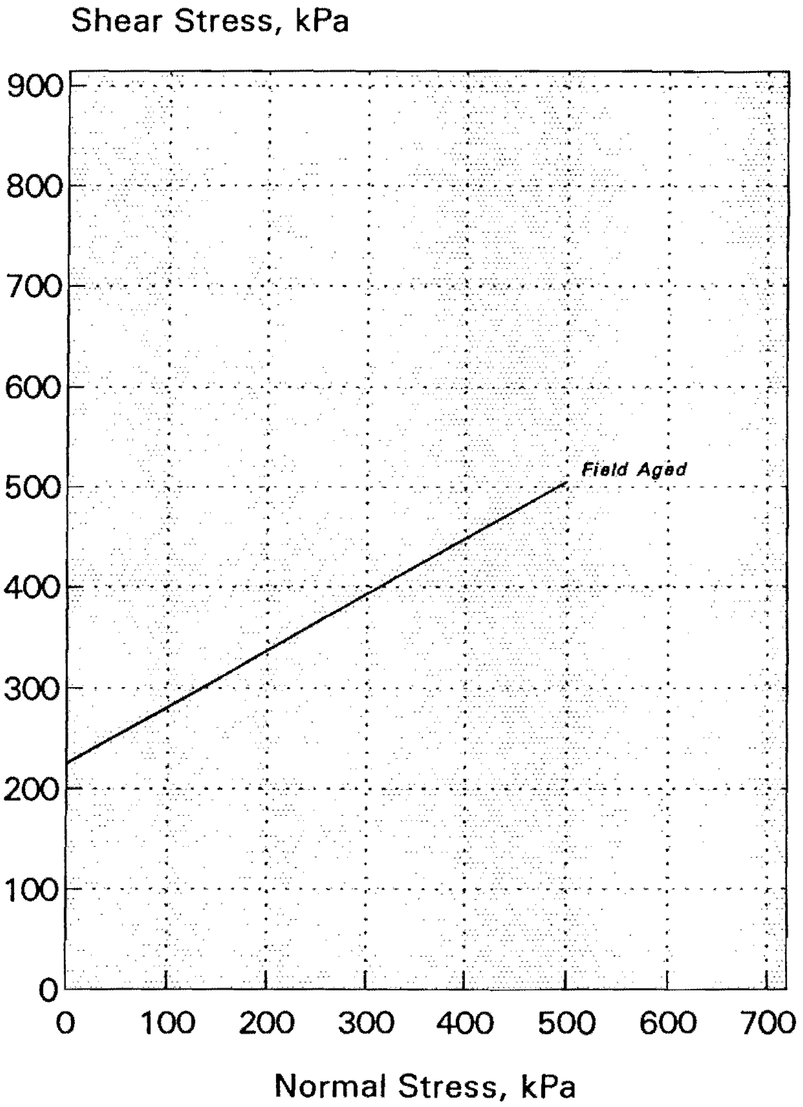


Figure 61. **Failure Envelopes from Triaxial Testing on Longview Old Summer Mix (about 6 months old).**

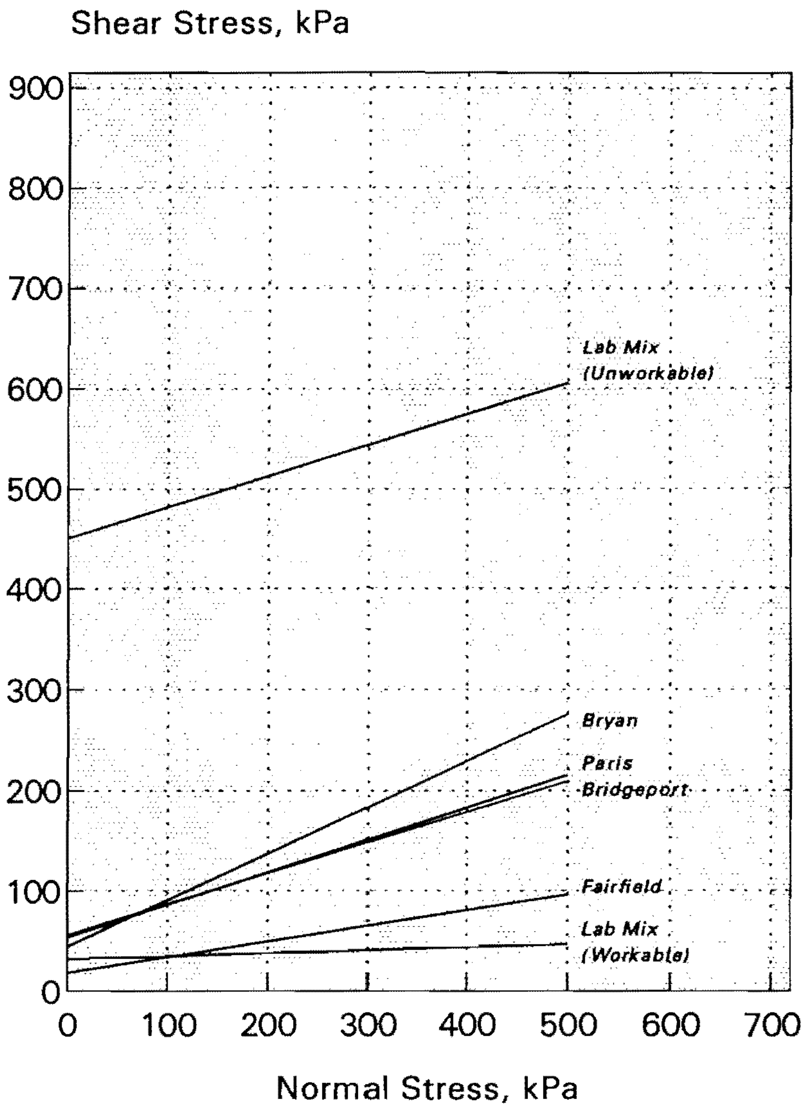


Figure 62. Failure Envelopes from Triaxial Tests on Unaged Mixtures.

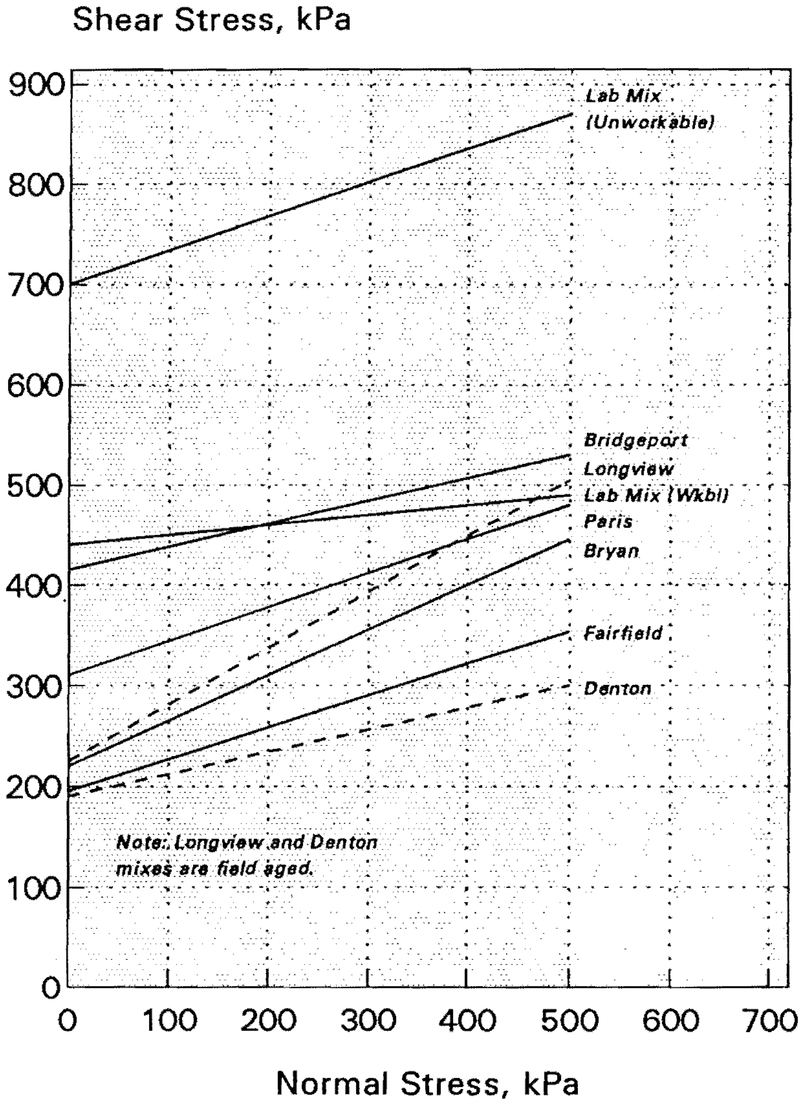


Figure 63. Failure Envelopes from Triaxial Tests on Mixtures Aged in the Laboratory According to Procedure A.

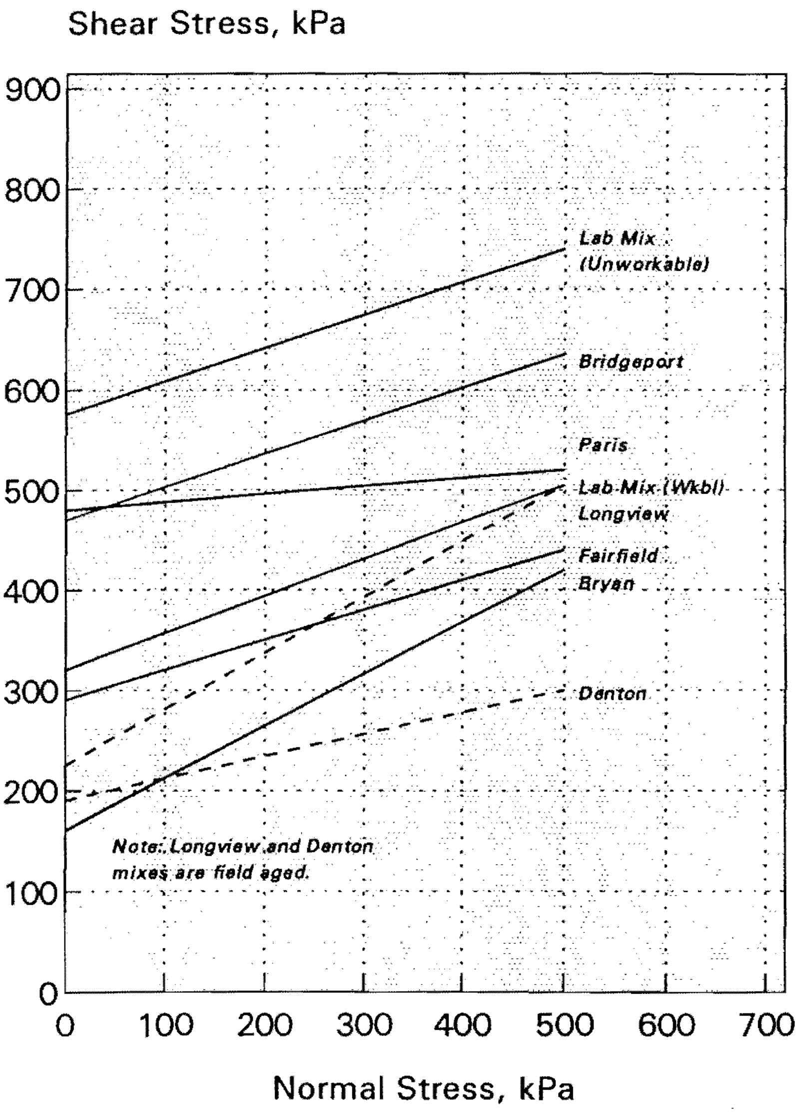


Figure 64. **Failure Envelopes from Triaxial Tests on Mixtures Aged in the Laboratory According to Procedure B.**

closely. In fact, aging Procedure A followed by triaxial testing of lightly compacted maintenance mixtures estimates the effects of 6 months of aging on workability reasonably well.

6.4 UNCONFINED COMPRESSION TESTS

Unconfined axial compression tests were performed on the compacted specimens before and after laboratory aging as performed in the triaxial tests. These results are presented in Figure 65. Compressive strengths for the unaged materials (except the lab-fabricated unworkable mix) are less than 200 kPa. Four of the mixtures aged according to Procedure A exhibited strengths between 500 and 1000 kPa which were also in the general range of the strengths measured on the two field aged mixtures. The Bridgeport material exhibited strengths nearest those of the unworkable lab mix.

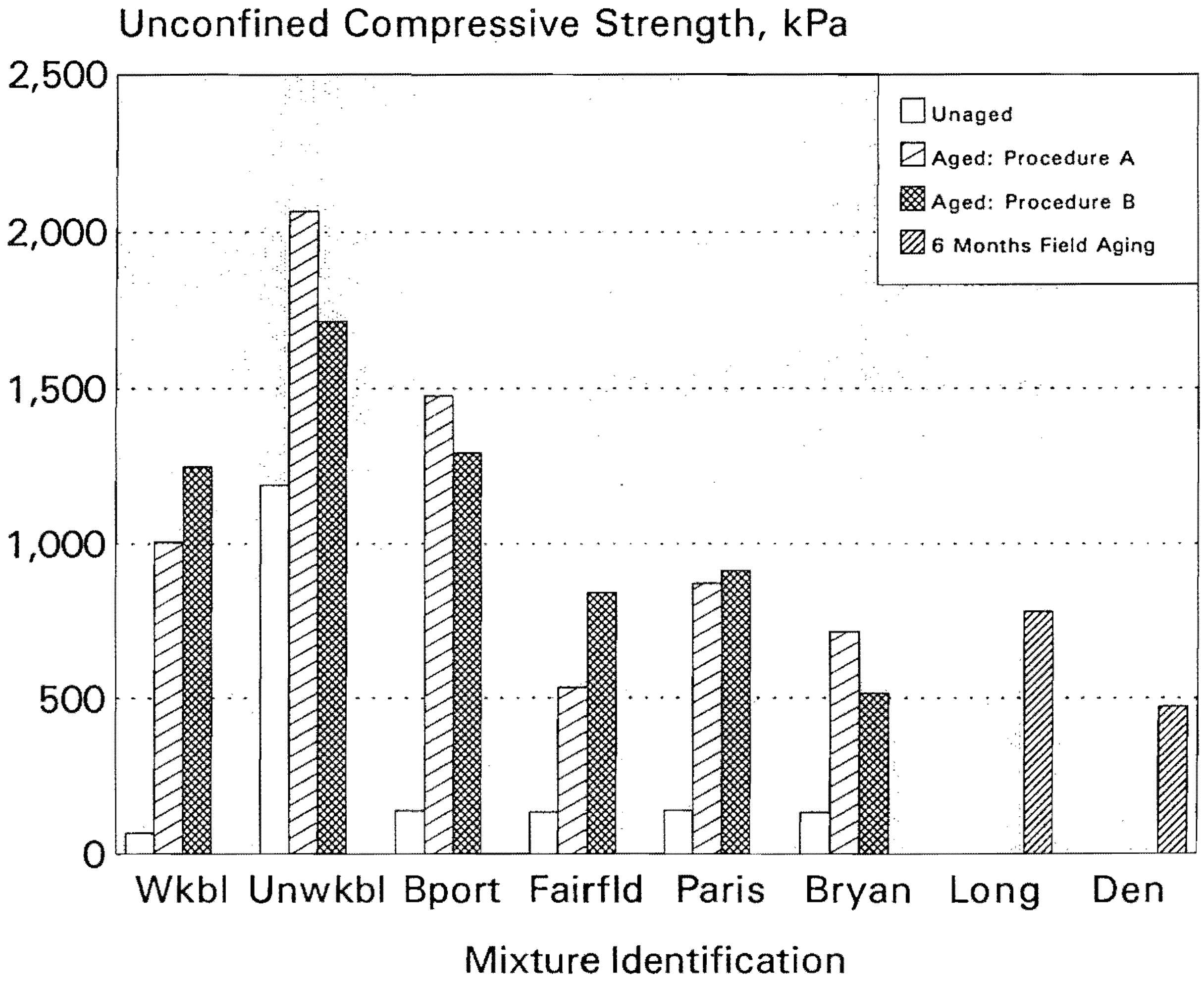


Figure 65. Unconfined Compressive Strengths for Mixtures Before and After Aging.

6.5 SUMMARY

Two test procedures were evaluated regarding their potential to quantify the workability of maintenance mixtures: (1) triaxial test, and (2) unconfined compression test. Test results indicated that both procedures provide a relatively good measure of workability before and after aging.

Two laboratory aging procedures were evaluated for their ability to predict workability of a stockpiled maintenance mixture after 6 months of field aging. One of the procedures (Procedure A) appeared to provide a reasonable approximation of 6 months of field aging.

7.0 TEST PROCEDURE AND SPECIFICATION RECOMMENDATIONS

Based on the results of this study, the following tests and acceptance criteria are recommended for the use of HMCL asphaltic maintenance mixtures. This protocol could be used to ensure that a maintenance mixture will be suitable for its intended purposes after having been stockpiled for at least 6 months.

7.1 AGING TEST

Scope

This procedure provides a means of accelerated aging of HMCL asphaltic materials to simulate about 6 months of stockpile aging for evaluation of workability characteristics.

Procedure

1. Obtain 7000 gram sample of maintenance mixture as received from supplier.
2. Loosely place material approximately 50 mm thick in a pan.
3. Place pan in 120°C forced-draft oven for 48 hours.
4. Remove from oven, cool to 38°C and mold specimen according to procedures described for workability test.

7.2 WORKABILITY TEST

Scope

This test procedure is intended to evaluate the cold-weather workability of HMCL asphaltic mixtures at 4°C. Tests can be performed on the material in the as-received condition as well as on mixtures which have been aged according to the aging test described above. The intended use of this test procedure is to predict the workability of HMCL asphaltic materials after 6 months of stockpile aging.

Apparatus

1. Apparatus used in Test Methods Tex-126-E and Tex-117-E:
    - Motorized Gyratory Soils Press (capable of gyrating 152.4 mm I.D. molds,
    - Molding assembly,
    - Axial Cells described in Tex-117-E,
    - Air Compressor,
    - Screw jack press and assembly (Tex-117-E),
    - Pressure regulator, gauges and valves,
    - Micrometer dial gauge, and
    - Dial housing and loading block to transmit load to specimen,
2. Means of cooling molded specimens to a temperature of 4° prior to testing.

Procedure

1. Compaction of Specimens

Specimens should be molded at a temperature of 38°C using the motorized gyratory soils press. Operation of the press is described in Tex-126-E. The following procedure should be used to produce a lightly compacted sample indicative of stockpile consolidation:

> Place about 6700 g of mixture in mold in 3 lifts. Using spatula, rod once around the outside of the mold. Gyrate the mold at a pressure of 345 kPa for 1 minute. Apply a leveling load of 1333 N for 30 seconds. Let the sample cool for one hour in the mold prior to extrusion. This should produce a sample about 152 mm in height. Make a total of 6 samples according to this procedure.

2. Testing of Specimens

Cool specimens to 4°C overnight prior to testing. Test specimens according to Tex-117-E, Part F using the following lateral pressures: 0 (2 samples), 34.4 kPa, 69 kPa, 103.5 kPa, and 138 kPa. Obtain failure envelope as described in Tex-117-E and plot envelope on Figure 66.

Specimens should be tested on fresh mix as well as mixtures which have been aged according to the procedure described above in Section 7.1.

7.3 WORKABILITY ACCEPTANCE CRITERIA

Proposed workability acceptance criteria for HMCL asphaltic mixtures are shown in Figure 66.

7.4 ALTERNATIVE WORKABILITY TEST AND ACCEPTANCE CRITERIA

An alternative to the above workability test is proposed using the unconfined compressive strength test. This method is less labor intensive and simpler.

Scope

This test procedure is intended to evaluate the cold-weather workability of HMCL asphaltic mixtures at 4°C. Tests can be performed on the material in the as-received condition as well as on mixtures which have been aged according to the aging test described above. The intended use of this test procedure is to predict the workability of HMCL asphaltic materials after 6 months of stockpile aging.

Procedure

At least 3 specimens should be aged and molded according to the procedures described in Sections 7.1 and 7.2 above. Compression tests should be performed as described above in Section 7.2 except that no confining pressure should be applied. Tests should be performed at 4°C on both unaged and oven-aged mixtures.

Acceptance Criteria

The following acceptance criteria is proposed for HMCL asphaltic mixtures:

- Average Unconfined Compressive Strength (prior to aging) should be less than 200 kPa.

- Average Unconfined Compressive Strength (after aging test) should be no more than 1000 kPa.

7.5 MOISTURE SUSCEPTIBILITY TEST

Test method Tex-530-C (boiling stripping test) which is currently used for HMCL asphaltic materials appears to be the best method available for predicting susceptibility of these mixtures to water damage. No change in acceptance criteria is proposed.

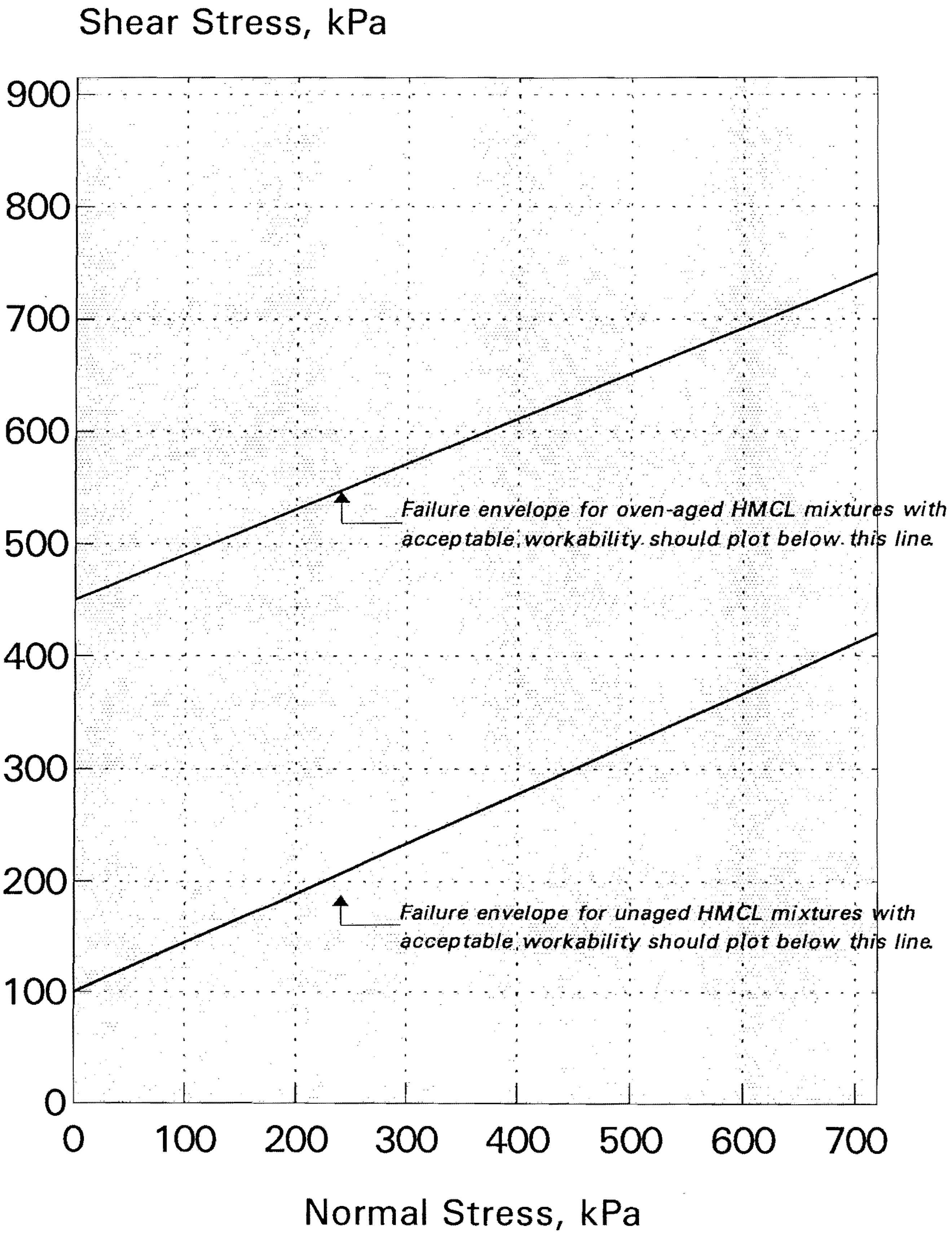


Figure 66. Failure Envelope Acceptance Criteria for Workability Test.

8.0 CONCLUSIONS

Samples of maintenance mixtures for laboratory and field evaluation were obtained from across the state. Several test procedures were used to evaluate the aging characteristics of the mixtures: (1) resilient modulus as a function of temperature, (2) indirect tensile strength, and (3) extracted asphalt cement properties.

The following conclusions were reached as a result of the field aging portion of this study:

- Resilient modulus testing indicates that the LRA and specialty mixtures are less stiff at low temperatures than HMCL materials.
- Resilient modulus data did not indicate significant stiffening of the mixtures at low temperatures after 6 months of stockpile aging. This was true for all types of mixtures tested.
- Tensile strength measurements performed on all field aged mixtures did not indicate serious detrimental effects as a result of the 6 months of field aging.
- Viscosity and penetration of the extracted asphalt cement for the HMCL materials indicated that significant aging occurred in only 3 of the mixtures. Extracted asphalt cement properties for the specialty mixtures indicated no significant change in material properties as a result of aging. LRA extracted asphalt cement properties were inconclusive.

Workability of stockpiled field materials was subjectively evaluated and compared to laboratory measurements aimed at quantifying workability. These laboratory measurements included the following:

- Quantity of coarse aggregate in mixture;
- Quantity of fine aggregate in mixture;
- Asphalt film thickness;
- SHRP workability test;
- Two different modifications of SHRP workability test;

    - Ease of gyratory compaction at 25°C, and
    - Ease of gyratory compaction at 4°C.

- Comparisons of the laboratory workability measurements to the field measurements indicated that there was no clear relationship between them. Therefore, none of these test procedures were pursued further in this research.
- Two test procedures were evaluated for predicting water susceptibility of stockpiled maintenance mixtures: Tex-530-C (boiling stripping test) and Tex-531-C (modified Lottman test). Test results were compared to visual ratings regarding stripping characteristics of the same materials after 6 months in the stockpile. Tex-530-C was found to reasonably predict the stripping potential of maintenance mixtures while Tex-531-C did not. Present acceptance criteria for Tex-530-C (boiling-stripping test) appear to be adequate.

Several potential stockpile treatment methods were evaluated in the laboratory for their effectiveness at reducing the intrusion of water into the stockpile. No treatment method could be recommended for LRA mixtures since the untreated mixture repelled water fairly well. In fact, surface treatment of the LRA with asphalt emulsion significantly increased the intrusion of water into this mix. Pavement striping paint (sprayed on the stockpile surface) was found to be the most effective and practical treatment for HMCL mixtures in the laboratory evaluation; however, field evaluation of this treatment was inconclusive.

Two test procedures were evaluated regarding their potential to quantify the workability of HMCL asphaltic maintenance mixtures: (1) a triaxial compression test, and (2) unconfined compression test. Test results indicated that both procedures provide a relatively good measure of workability.

Two laboratory aging procedures were evaluated for their ability to predict workability of a stockpiled maintenance mixture after 6 months of stockpile aging. One of the procedures (Procedure A) appeared to provide a reasonable approximation of 6 months of field aging.

Test protocol and material acceptance criteria for HMCL asphaltic concrete materials were developed and are presented in Chapter 7.

REFERENCES

1. Evans, L. D., Mojab, C. G., Patel, A. J., Romine, A. R., Smith, K. L., and Wilson, T. P., "SHRP-H106 Innovative Materials Development and Testing," Report No. SHRP -89-H-106, Strategic Highway Research Program, National Research Council, December, 1992.

2. Sequeira, L. J., Saylak, D., and Button, J. W., "Alternate Materials for Limestone Rock Asphalt," Research Report No. FHWA/TX-91-1176-1F, Texas Transportation Institute, Texas A&M University, College Station, Texas, May 1990.

3. Al Nageim, H. and Fordyce, D., "A Measure of the Workability of Asphaltic Materials," Highways, Vol. 56, D.R. Publications Limited, England, January, 1988, pp. 28 - 30.

4. Anderson, D. A., Thomas, H. R., Siddique, Z., and Krivohlavek, D. D., "More Effective Cold, Wet-Weather Patching Materials for Asphalt Pavements," Report No. FHWA-RD-88-001, Pennsylvania Transportation Institute, Pennsylvania State University, University Park, Pennsylvania, December, 1988.

5. Maupin, G. W., Jr., "Guidelines for Rehabilitating Flexible Pavements," Virginia Highway and Transportation Research Council, Charlottesville, Virginia, January, 1986.

6. Thomas, H. R. and Anderson, D. A., "Pothole Repair: You Can't Afford Not to do it Right," Transportation Research Record 1102, Transportation Research Board, National Research Council, Washington, D.C., 1986, pp. 32-40.

7. Anderson, D. A., Thomas, H. R., and Siddiqui, Z., "Evaluation of Pothole Repair Strategies," Report No. PTI 8618, Pennsylvania Transportation Institute, Pennsylvania State University, University Park, PA, 1986.

8. Rutherford, N. F., "Pavement and Shoulder Maintenance Guides," Report No. FHWA-TS-84-208, Federal Highway Administration, Washington, D.C., 1985.

9. Rissel, M. C., "Improved Methods for Patching High-Volume Roads," Report No. FHWA/RD-86/076, Federal Highway Administration, Washington, D.C., 1986.

22. "Bituminous Stockpile Patching Material, Section 485, "Bituminous Concrete Mixtures, Design Procedures and Specifications for Special Bituminous Mixtures," Bulletin 27, Pennsylvania Department of Transportation, Harrisburg, PA, 1984.

23. "Pothole Primer," U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, NH, 1981.

24. Rutherford, N.F., "Pavement and Shoulder Maintenance Guides," Report No. FHWA-TS-84-208, Federal Highway Administration, Washington, DC, 1984.

25. Thomas, H. R., "A Procedure for Evaluating the Efficiency of Power-Operated Cutting Tools in Localized Pavement Repair," Transportation Research Record 833, Transportation Research Board, National Research Council, Washington, D.C., 1982, pp. 24-29.

26. Anderson, D. A., Thomas, H. R., and Kilareski, W. P., "Pothole Repair Management," Report No. PTI-8202, Pennsylvania Transportation Institute, Pennsylvania State University, University Park, PA, February, 1982.

27. Mehta, P. K., Concrete - Structure, Properties, and Materials, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1986.

28. Roberts, F. L., Kandhal, P. S., Brown, E. R., Lee, D. Y., and Kennedy, T. W., Hot Mix Asphalt Materials, Mixture Design, and Construction, First Edition, National Center for Asphalt Technology, National Asphalt Pavement Association Education Foundation, Lanham, Maryland, 1991.

29. Wilson, T. P., "SHRP-106 Innovative Pothole Repair Materials and Procedures for Asphalt Surfaced pavements-Summary of Results to Date," ERES Consultants, Inc., Savoy, Illinois, paper prepared for 72nd Transportation Research Board Meeting, January, 1993.

30. Hargett, E.R., "A Study of Winter Maintenance of Bituminous Pavements in Texas," Research Report No. 129-2F, Texas Transportation Institute, Texas A&M University, College Station, 1970.

31. Draft Report on Pothole/Spall Repair Materials, Texas Department of Transportation, Division of Maintenance and Operations, Maintenance Section, March, 1992.

32. Wilson, T. P. and Romine, A. R., “Materials and Procedures for the Repair of Potholes in Asphalt-Surfaced Pavements,” SHRP H-348, National Research Council, Washington, D.C., 1993.

APPENDIX A

FINDINGS FROM QUESTIONNAIRE TO DISTRICTS

FINDINGS FROM QUESTIONNAIRE TO DISTRICTS

According to preliminary investigations, the most serious problems associated with asphalt maintenance mixtures are cold-weather workability in the stockpile and on the road, moisture susceptibility as manifested by raveling and stripping, insufficient stability in deep patches, and inconsistent behavior when the mixture is prepared and applied in accordance with standard specifications and guidelines. These preliminary findings needed to be verified by direct contact with the districts. In an attempt to make the most of this study and ensure the needs of the districts were met, a questionnaire was prepared and sent to each TxDOT district to:

- make a better assessment of the overall maintenance mixture problem,
- aid in determining the severity of the stockpile aging problem,
- determine any other problems associated with specifying and storing asphalt maintenance mixtures,
- attempt to identify the source of some of these problems,
- identify successful methods (if any) for alleviating such problems,
- locate good and bad maintenance materials for laboratory evaluation, and
- solicit the help of selected districts to perform the study.

A copy of the questionnaire is provided as Exhibit X1.

The questionnaire confirmed that the most consistent problem with maintenance mixtures is rapid hardening of the binder in the stockpile which results in a loss of workability. A crust about 100 to 200 mm thick forms on the surface of the stockpile within a few months. Loading or stirring using a front-end loader produces lumps and clods that preclude its intended use. Utility and workability of this hardened material is a particular problem during winter when the temperature drops below 10°C. Other problems cited include stripping in the stockpile, stripping on the road which results in raveling and deterioration o the patch, flushing, inconsistent quality from requisition to requisition.

Stockpile life is defined as the ability of the material to retain workability in the stockpile and on the road and sustain utility for use in patching. Results from the questionnaire indicated stockpile life depends on the type of maintenance mixture. Hot mix-cold lay material has a stockpile life of typically less than 6 months; whereas, limestone rock asphalt is often reported to have a stockpile life up to 1 year. No suitable methods to prolong stockpile life were revealed from the survey. One district pointed out that a conical shaped stockpile should be maintained to avoid ponding of water and thus channeling to the center of the stockpile.

Some districts reported using material with extra diesel in an attempt to prolong stockpile life. A fresh maintenance mixture often exhibits low stability and does not cure in a reasonable amount of time. There seems to be no satisfactory midpoint; either binder is too soft or too hard or there is too much or too little.

No formal measure of mixture workability was identified by the questionnaire. Most districts indicated they subjectively gage workability based on ease of handling and observations during manipulation and placement. One district stated they take a handful of mix and compress it in the hand for several seconds to see if it will bind together, if so, it is considered suitable for use as patching. No one has a specification that requires a certain level of workability for a stipulated period.

Although some districts indicated consistent behavior between procurements, several districts indicated that even when maintenance material comes from one source, it may exhibit inconsistent behavior in the stockpile and on the road. Respondents attributed variable behavior to inconsistent aggregate grading, asphalt content, asphaltic material, particle coating, and primer content.

District personnel indicated they need a maintenance mixture that would remain workable for several months in the stockpile, particularly during cold weather, and one that would not be susceptible to rutting, stripping, or raveling. They need guidelines on how to prepare a mixture with long lasting utility and specifications that can be used to obtain high quality materials.

Exhibit X1.

QUESTIONNAIRE FOR RESEARCH STUDY 1377
IMPROVING ASPHALT MAINTENANCE MIXTURES

The objective of Research Study 1377 is to provide the Department with a means to assure quality of cold-applied asphalt stabilized maintenance mixtures. The chief problems associated with most of our maintenance mixtures are cold-weather workability in the stockpile and on the road, moisture susceptibility as evidenced by raveling and stripping, poor stability in deep patches, and in general, inconsistent behavior even when the mixture is prepared and applied in accordance with standard specifications and guidelines. Please answer the following questions to the best of your knowledge by January 1, 1994. If you have any questions, call Joe Button at Texas Transportation Institute (409)845-9965. You may fax your response to (409) 845-0278 or mail to the following address: Joe Button, Texas Transportation Institute, Texas A&M University, College Station, TX 77843-3135.

1. In what district are you located? _______________ Please provide your name, title, and phone number.

2. Please describe any problems you have with cold-applied maintenance mixtures?

3. What is the typical stockpile life for the maintenance mixtures used in your district?

4. Do you use any method (such as covering the stockpile) to prolong the stockpile life and reduce the hardening that might occur? If so, please describe.

5. Do you measure workability of a mix - in the stockpile? ____ on the road? ____ If so, how?

6. How would you like for this research study to help with any problems you have with cold-applied asphalt maintenance mixtures?

7. What sources supply most of your maintenance mixtures? (Names of plants and locations)

Spec Item ______________ Plant Name ______________ City____________

Spec Item ______________ Plant Name ______________ City____________

Spec Item ______________ Plant Name ______________ City____________

Spec Item ______________ Plant Name ______________ City ____________

8. Is there variability in the quality of HMCL (Item 350) purchased from different plants?________ Is there sometimes variability between two different shipments of mix from the same plant?________ If so, please describe.

9. Please provide a list of the different maintenance mixtures you typically use and how they are used, such as in cold or hot weather and for what types of pavement repairs.

Spec Item ______ Weather Use: Cold__ Hot__ Year Round__ Typical Repairs ____________

Spec Item ______ Weather Use: Cold__ Hot__ Year Round__ Typical Repairs ____________

Spec Item ______ Weather Use: Cold__ Hot__ Year Round__ Typical Repairs ____________

Spec Item ______ Weather Use: Cold__ Hot__ Year Round__ Typical Repairs ____________

10. In this research study, TTI will be investigating a number of different maintenance mixtures from across the state. What maintenance mixtures (used in your district) would you recommend that TTI include in their investigation?

11. Would your district be willing to ship about one ton of material to TTI for research purposes?

APPENDIX B

EXTRACTED AGGREGATE GRADATIONS OF FIELD STOCKPILED MIXTURES

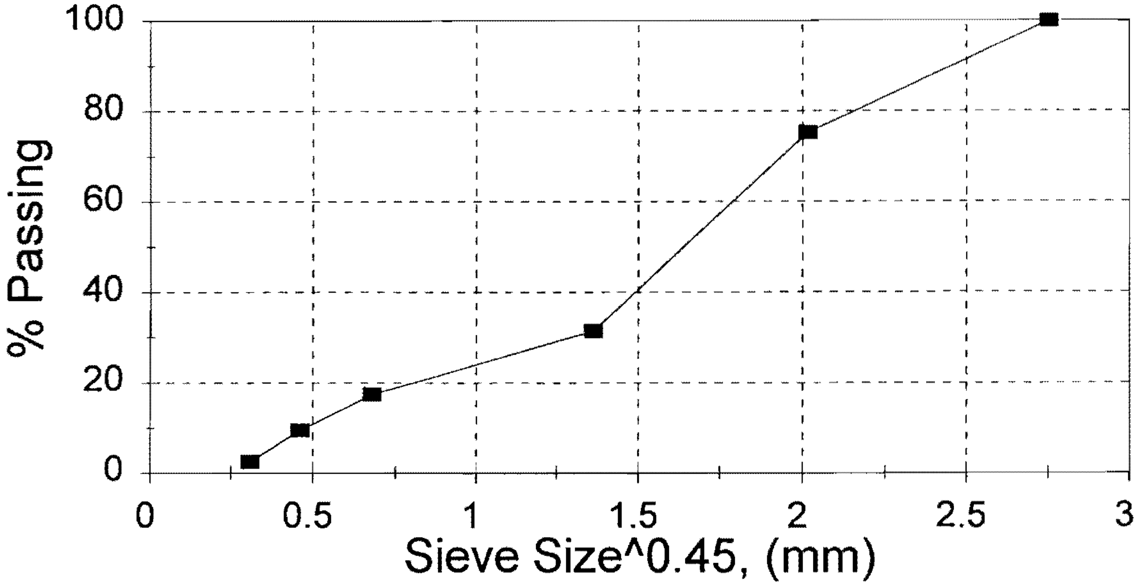


Figure B1. Aggregate Gradation for Mixture 1.

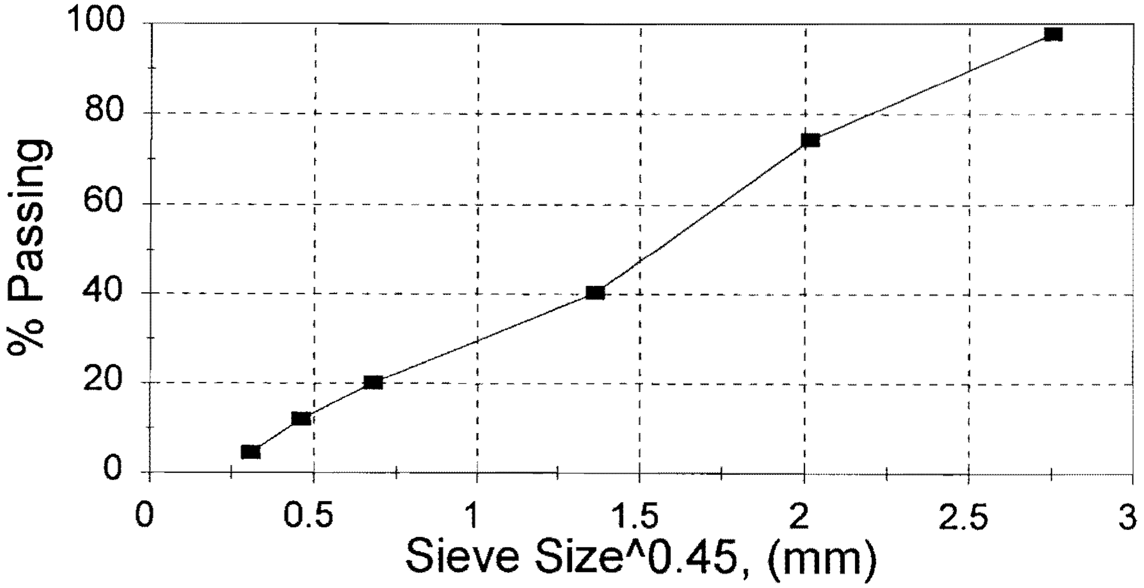


Figure B2. Aggregate Gradation for Mixture 2.

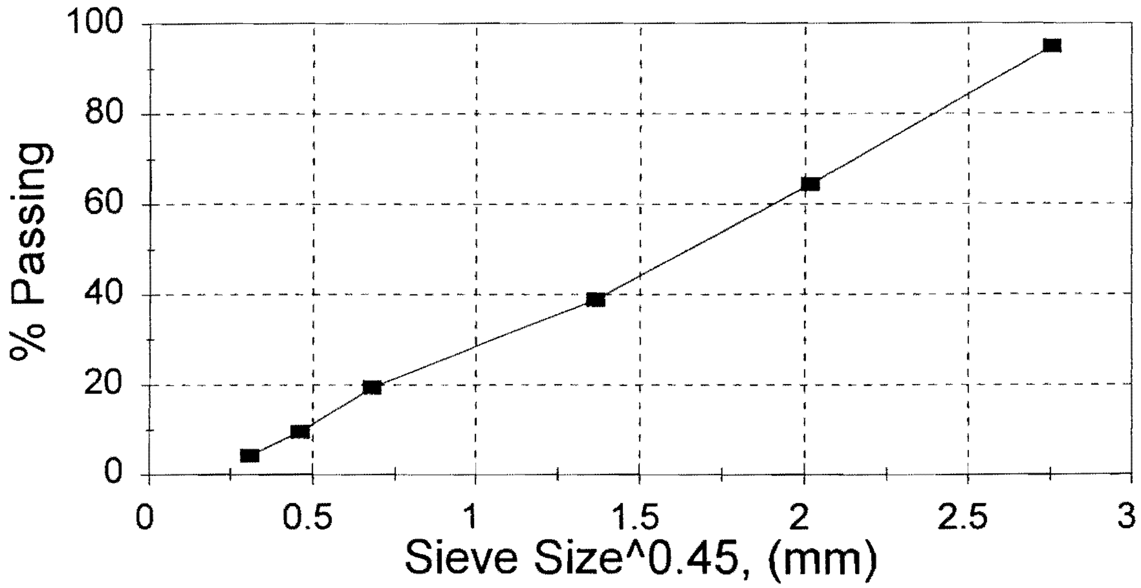


Figure B3. Aggregate Gradation for Mixture 3.

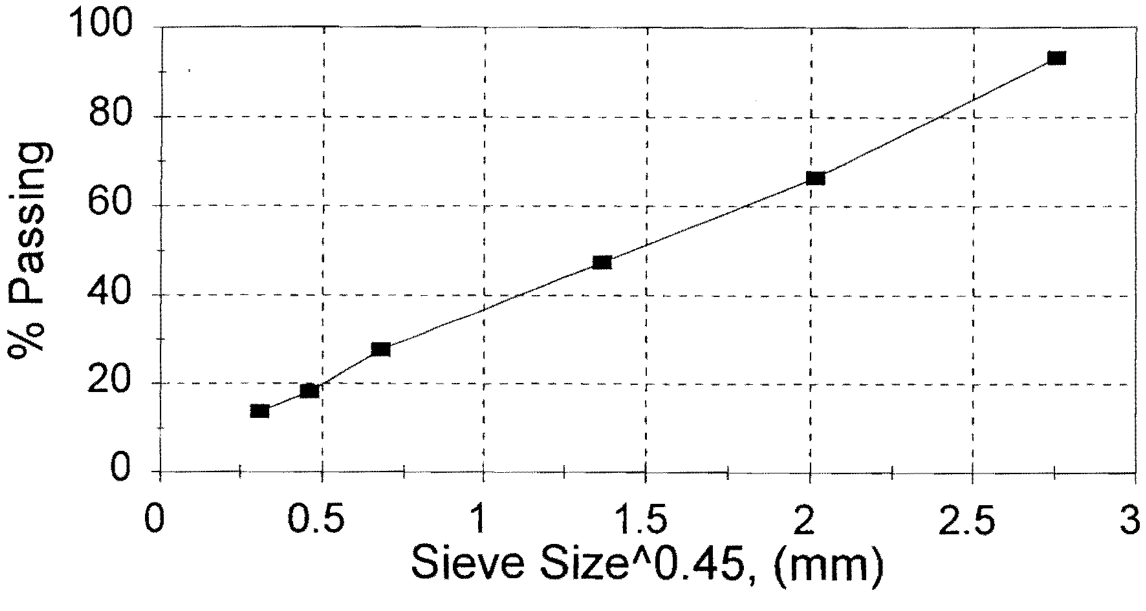


Figure B4. Aggregate Gradation for Mixture 4.

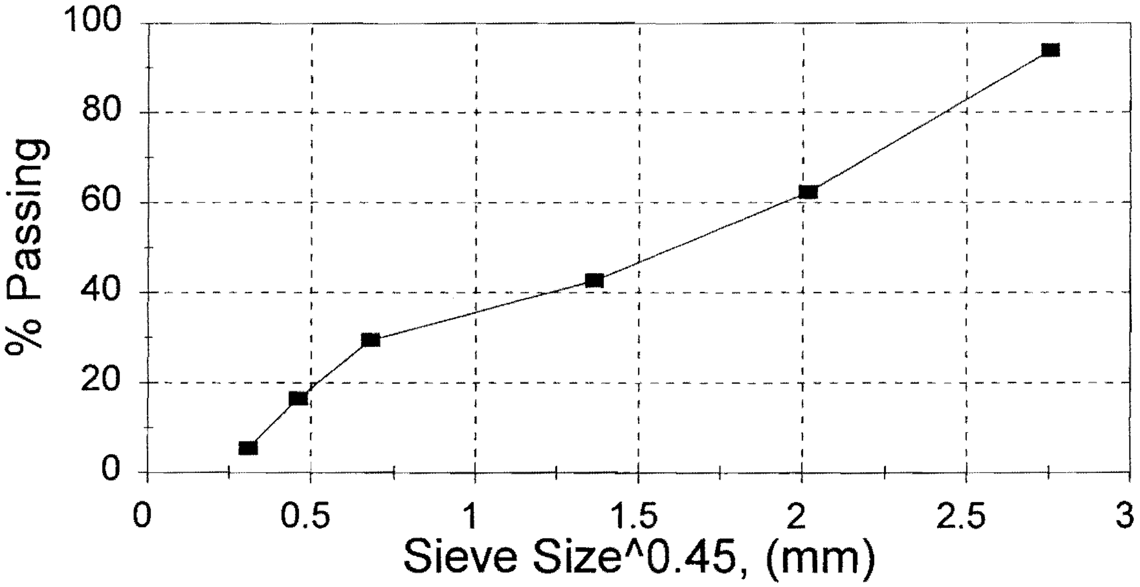


Figure B5. Aggregate Gradation for Mixture 5.

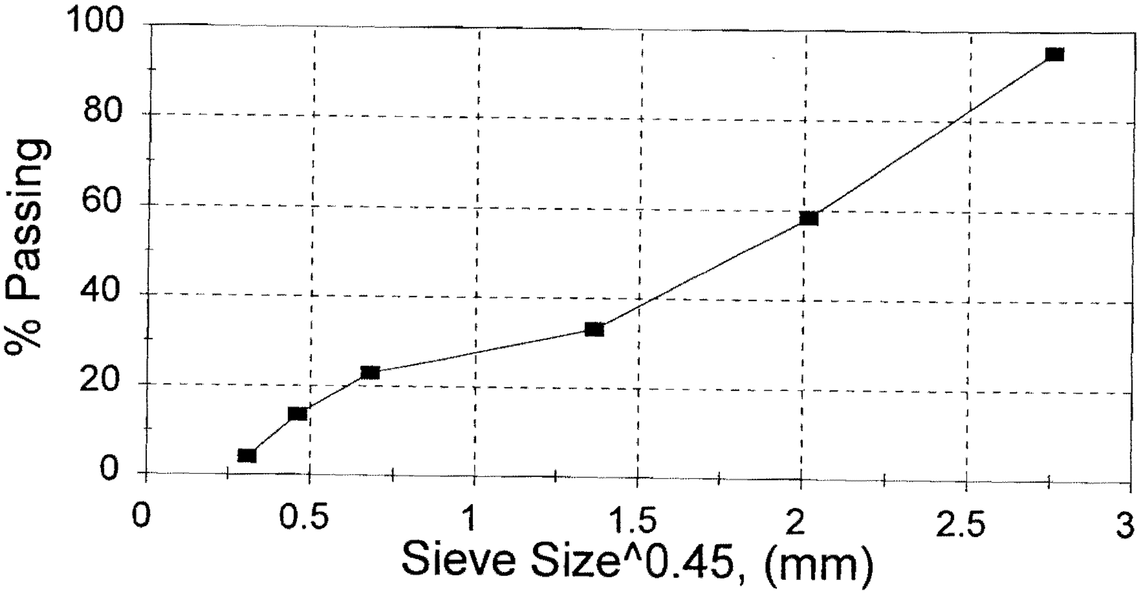


Figure B6. Aggregate Gradation for Mixture 6.

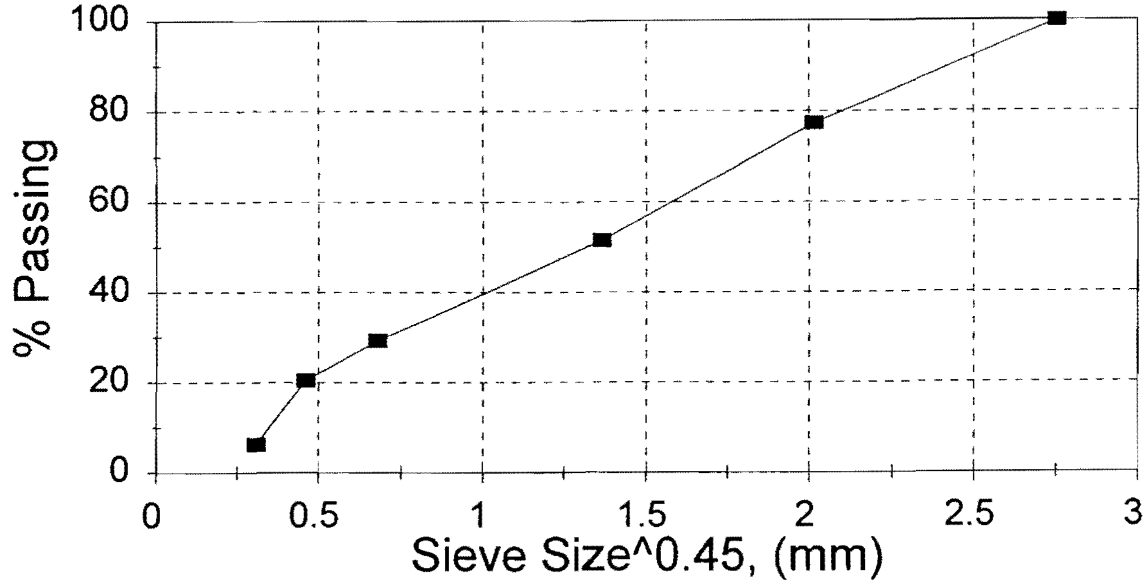


Figure B7. Aggregate Gradation for Mixture 7.

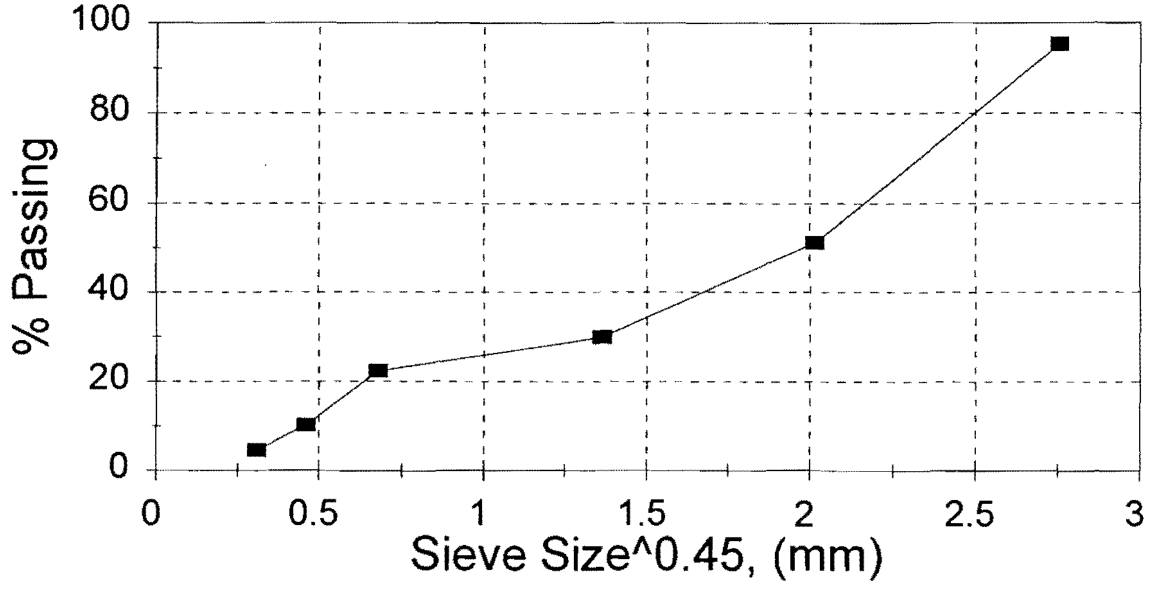


Figure B8. Aggregate Gradation for Mixture 8.

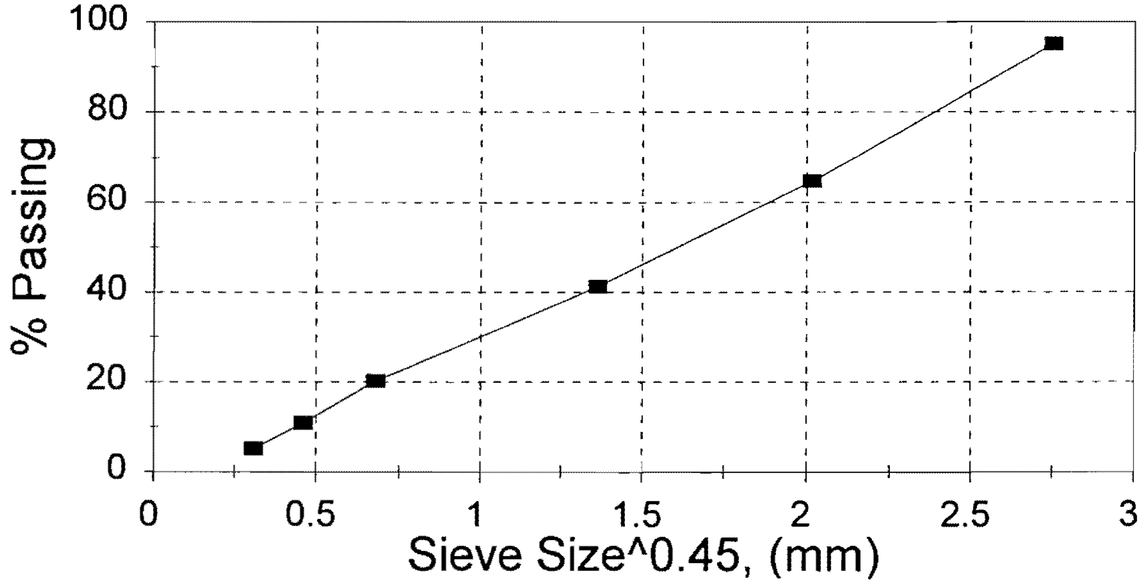


Figure B9. Aggregate Gradation for Mixture 9.

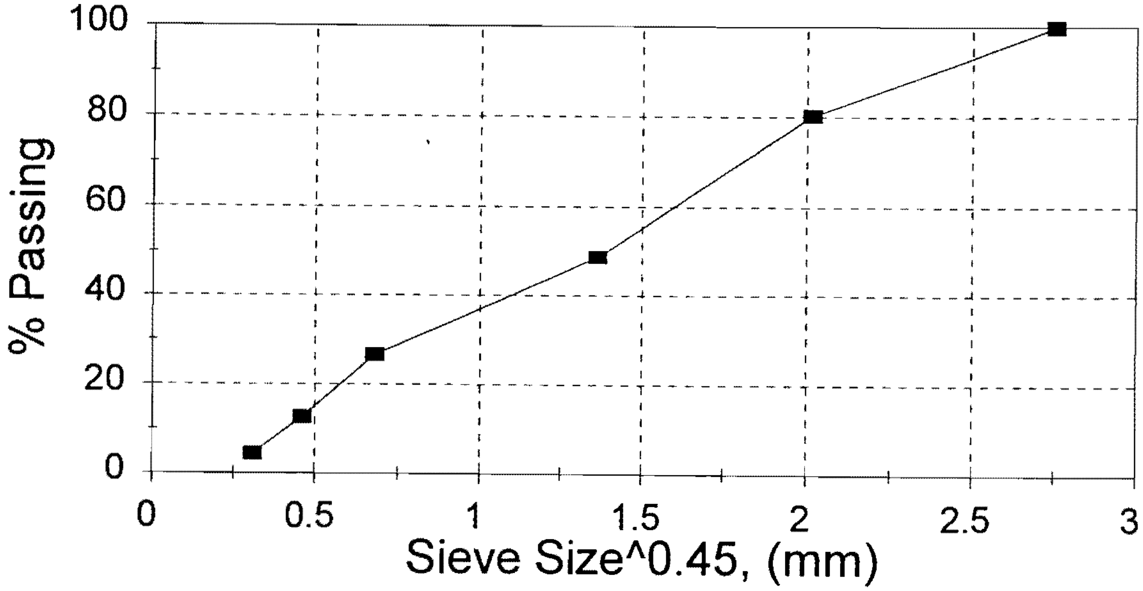


Figure B10. Aggregate Gradation for Mixture 10.

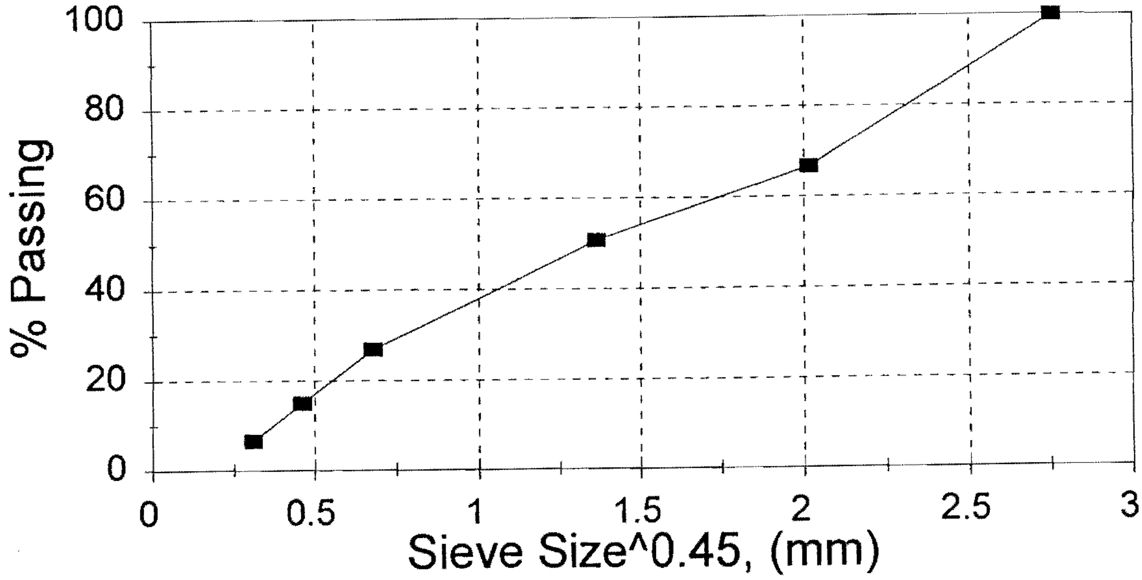


Figure B11. Aggregate Gradation for Mixture 11.

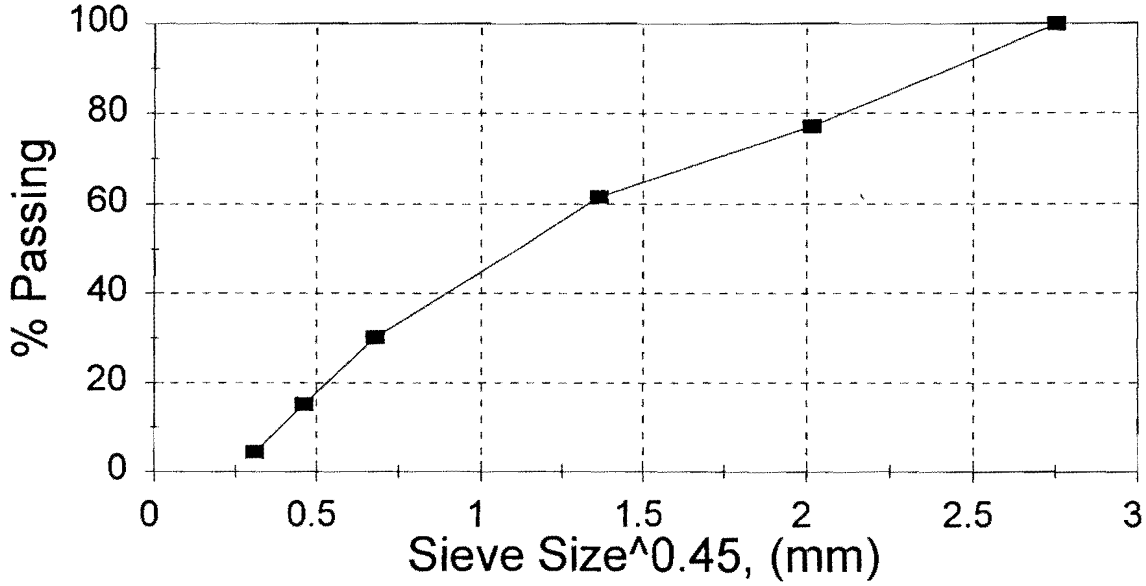


Figure B12. Aggregate Gradation for Mixture 12.

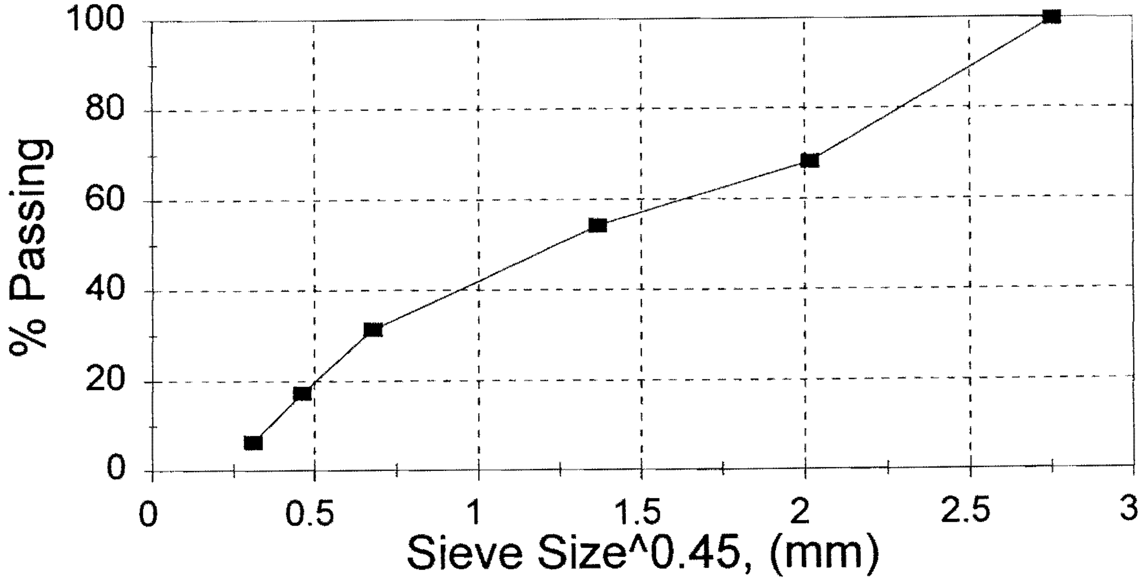


Figure B13. Aggregate Gradation for Mixture 13.

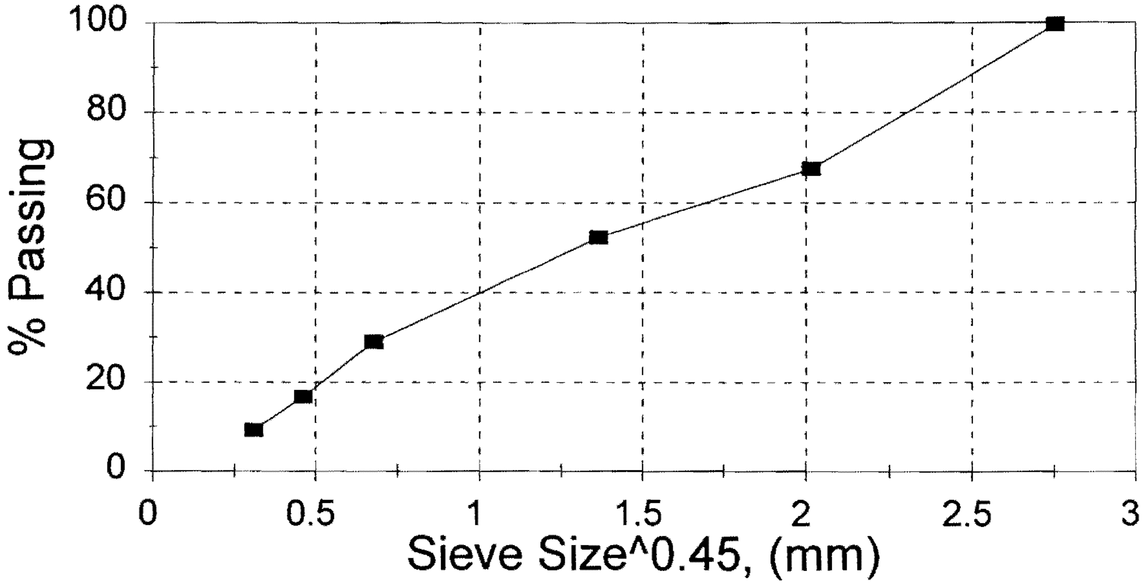


Figure B14. Aggregate Gradation for Mixture 14.

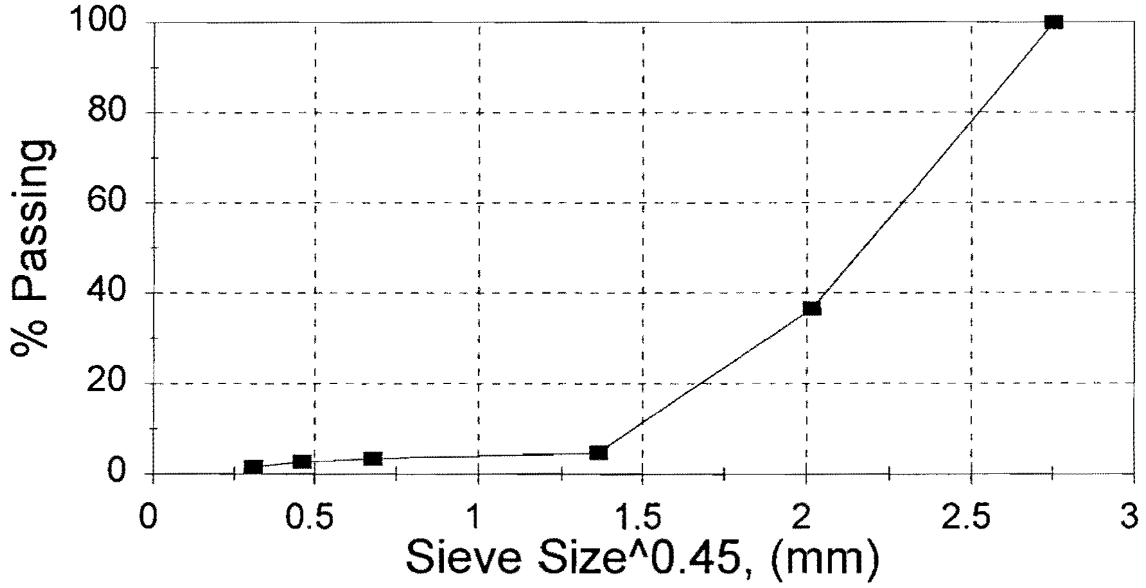


Figure B15. Aggregate Gradation for Mixture 15.

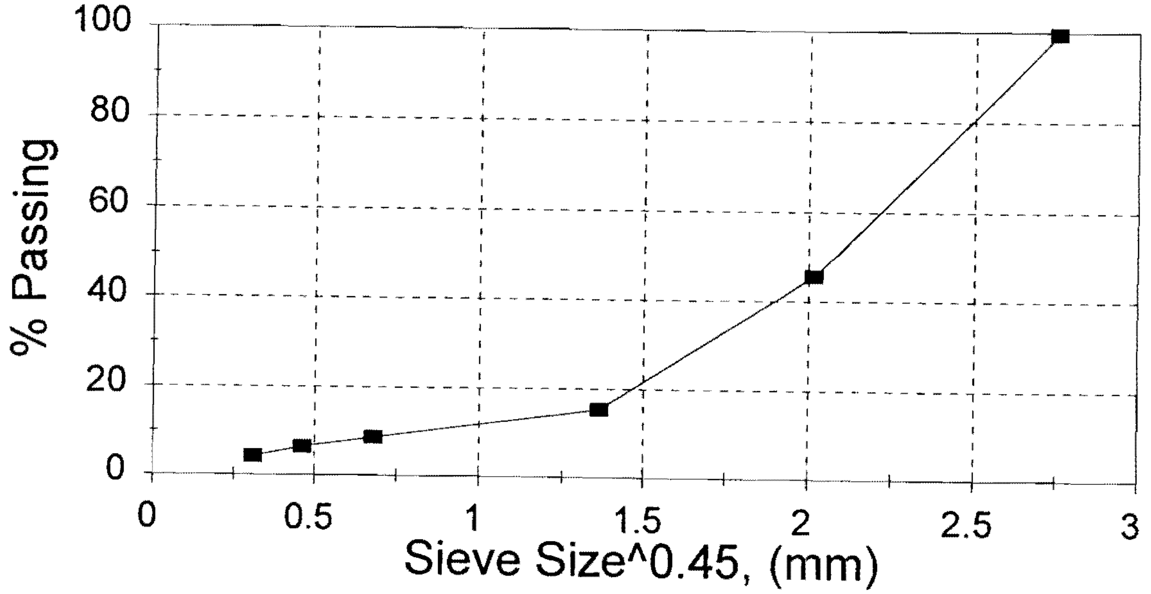


Figure B16. Aggregate Gradation for Mixture 16.

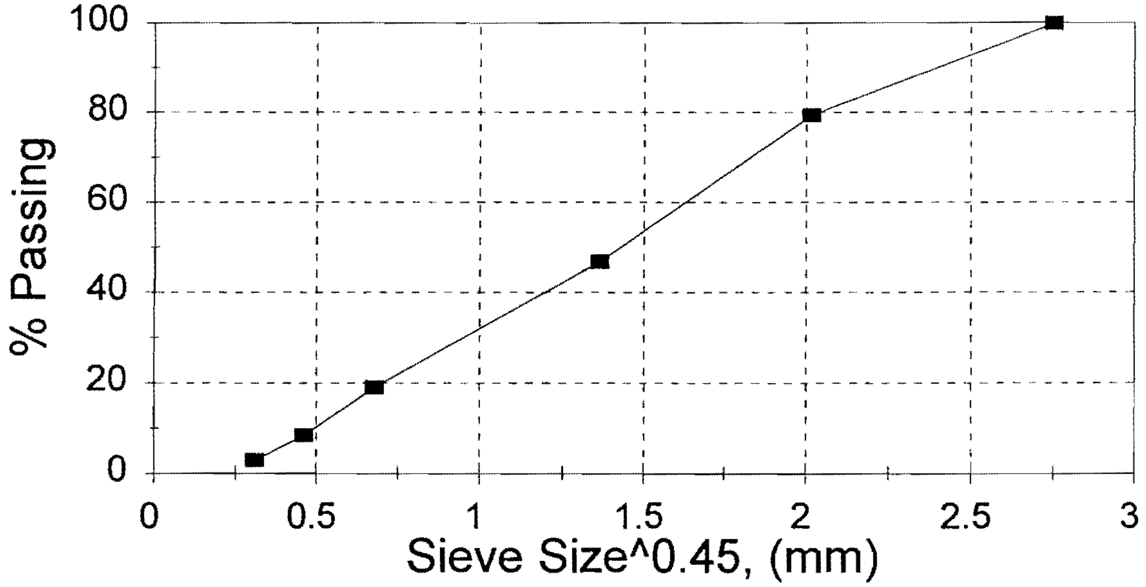


Figure B17. Aggregate Gradation for Mixture 17.

APPENDIX C

FORM FOR EVALUATION OF FIELD STOCKPILE WORKABILITY

EVALUATION OF STOCKPILE WORKABILITY

Name of Evaluator:____________________Date:____________________

Approx. Temperature:__________________Location:__________________

____

Material Description: ____

- Does stockpile have a "crust"? yes / no If so, about how thick is the crust? ______ inches.

- After the crust has been removed, how easily can the mix be shoveled?

1	2	3	4	5
(very easily)				(not at all)

- Is there an obvious presence of clumps in the mix?

1	2	3	4	5
(no clumps)				(many)

- Can you form a cohesive ball of material when squeezing it in your hand?

1	2	3	4	5
(very easily)				(not at all)

- Is there any evidence of stripping on the surface of the stockpile?

1	2	3	4	5
(none)				(more than 25%)

- What is the color of the mix (on the stockpile surface)?

1	2	3	4	5
(very black)				(light gray)

- What is your overall impression regarding the workability of this mix?

1	2	3	4	5
(very good)				(very poor)

Other Comments:____

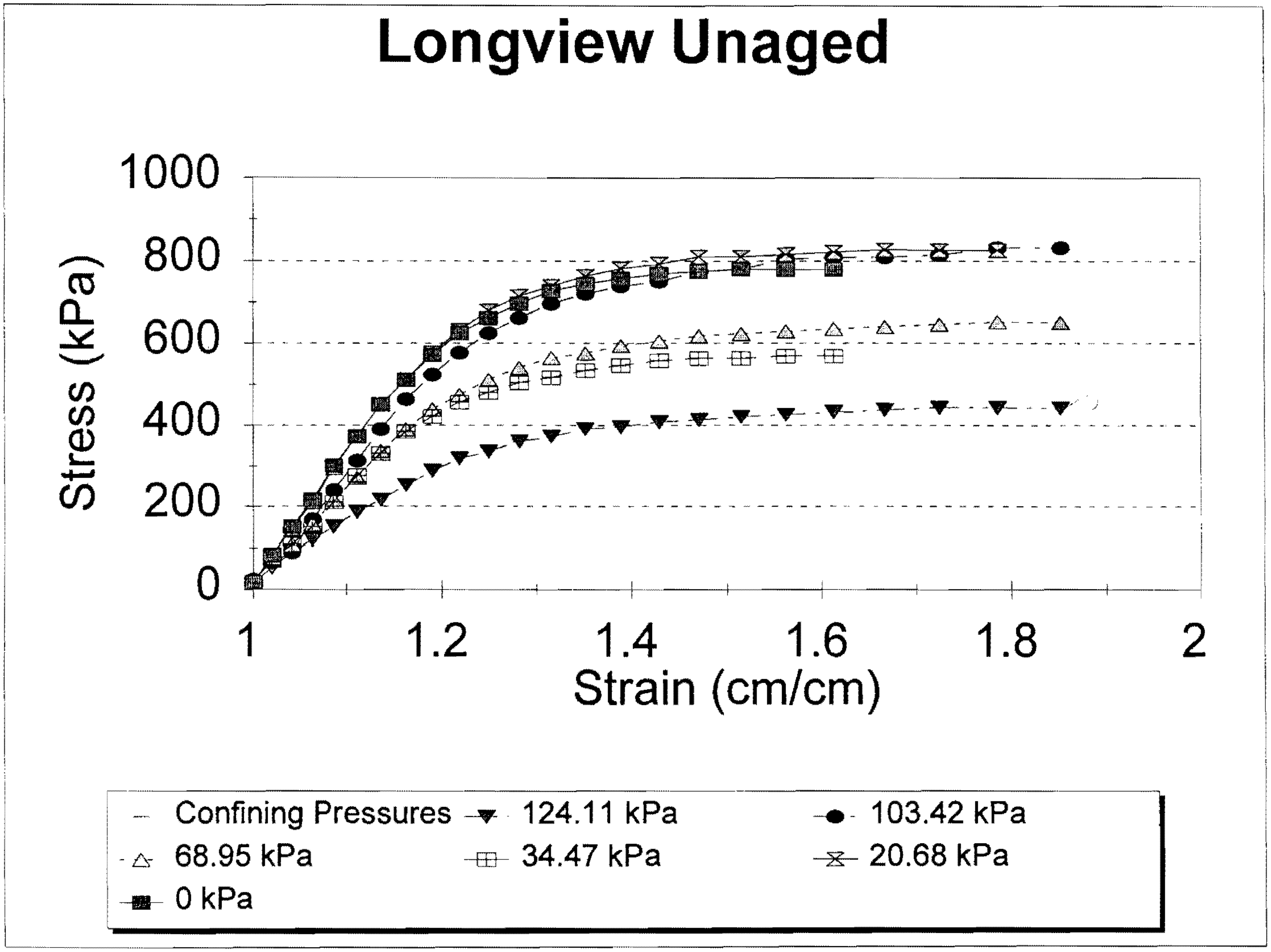
____

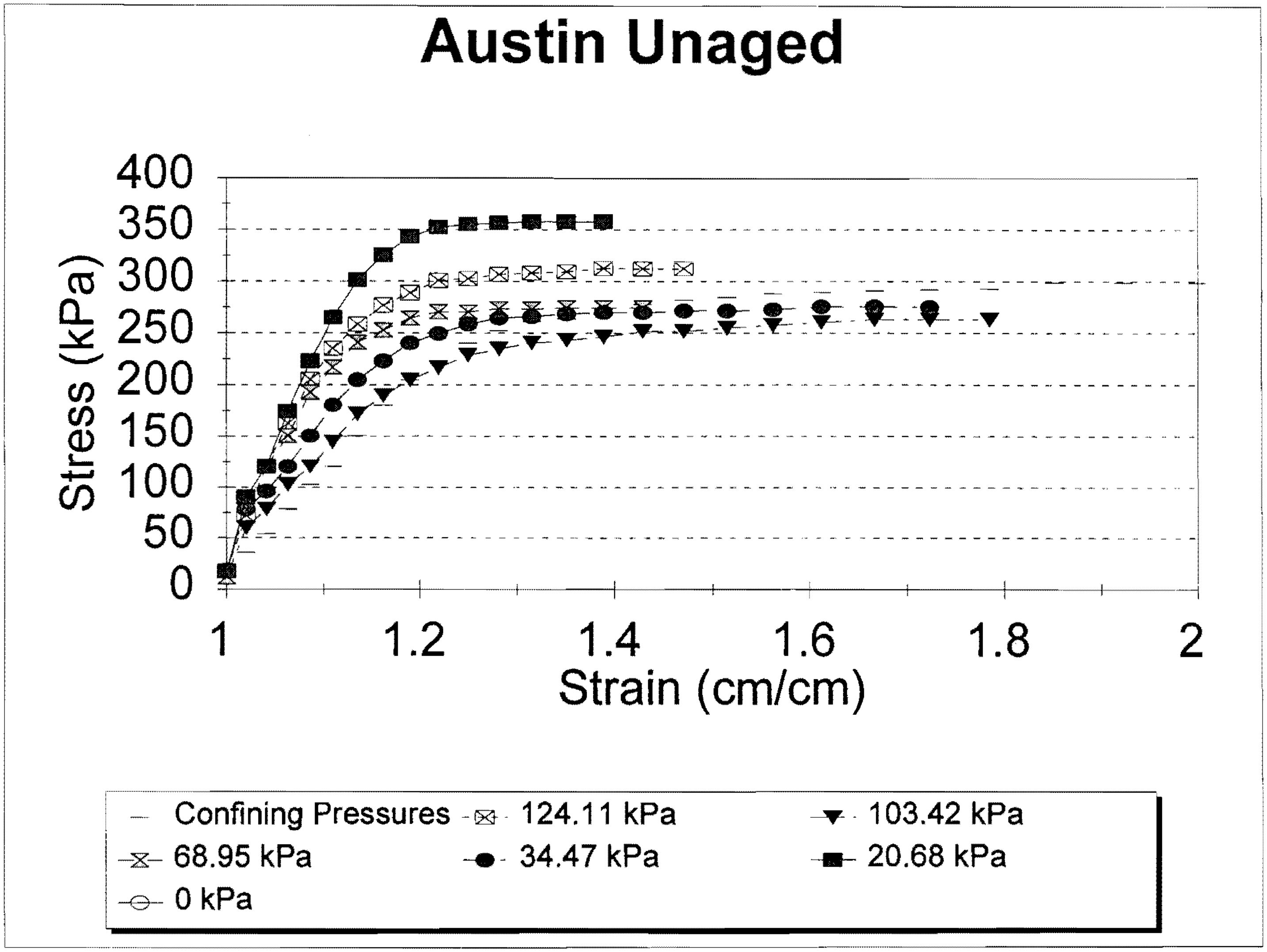
____

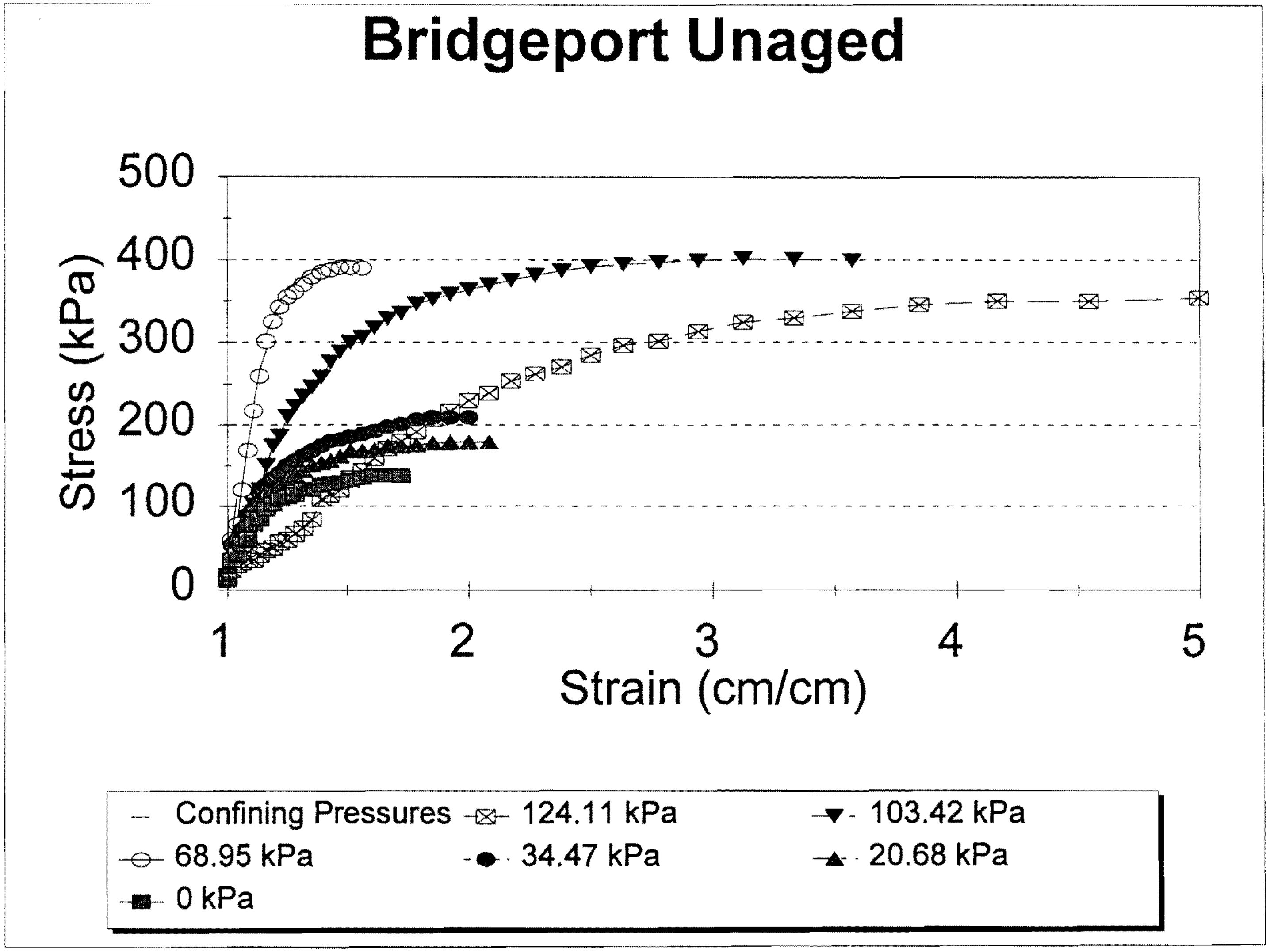
____

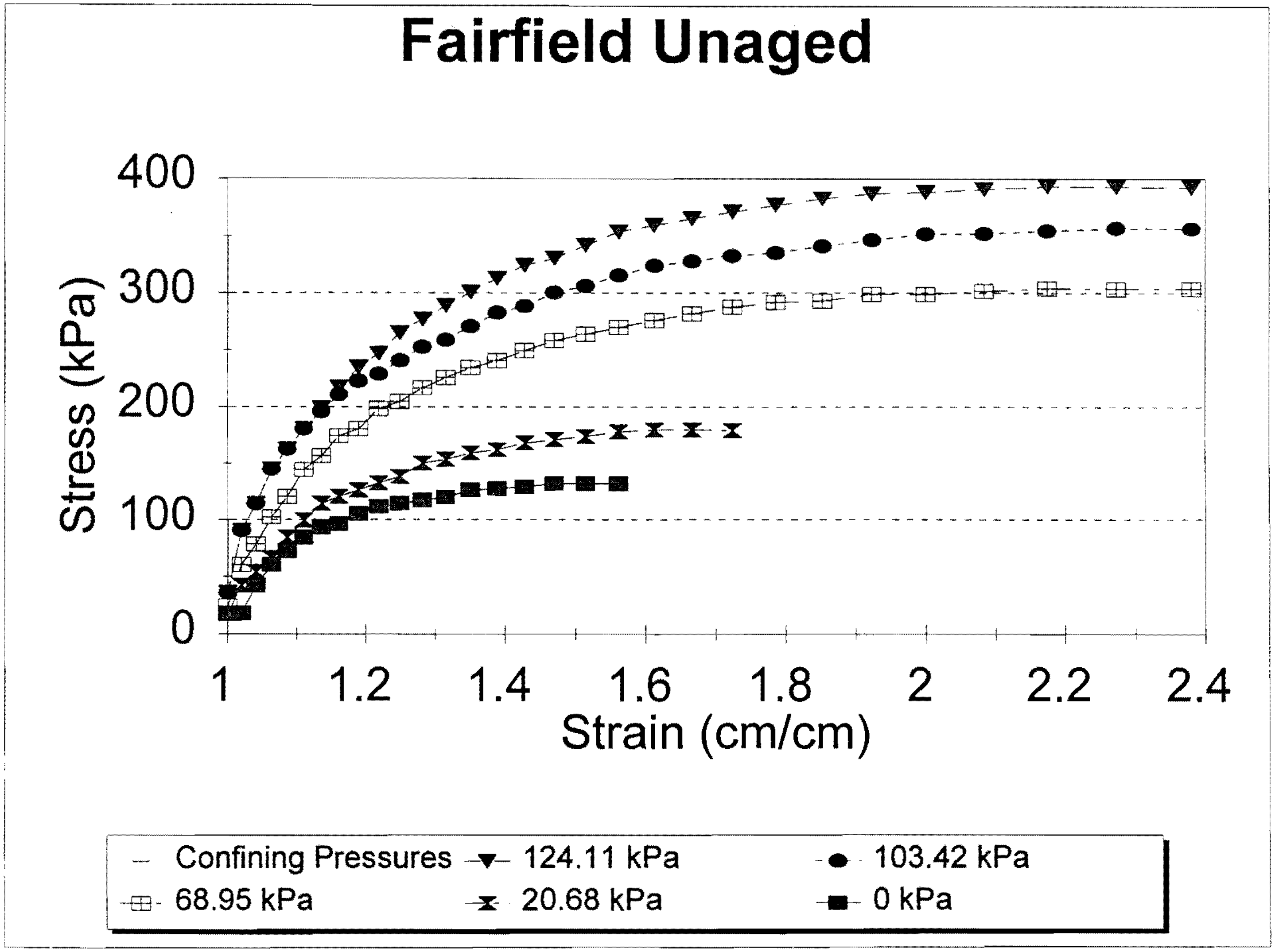
APPENDIX D

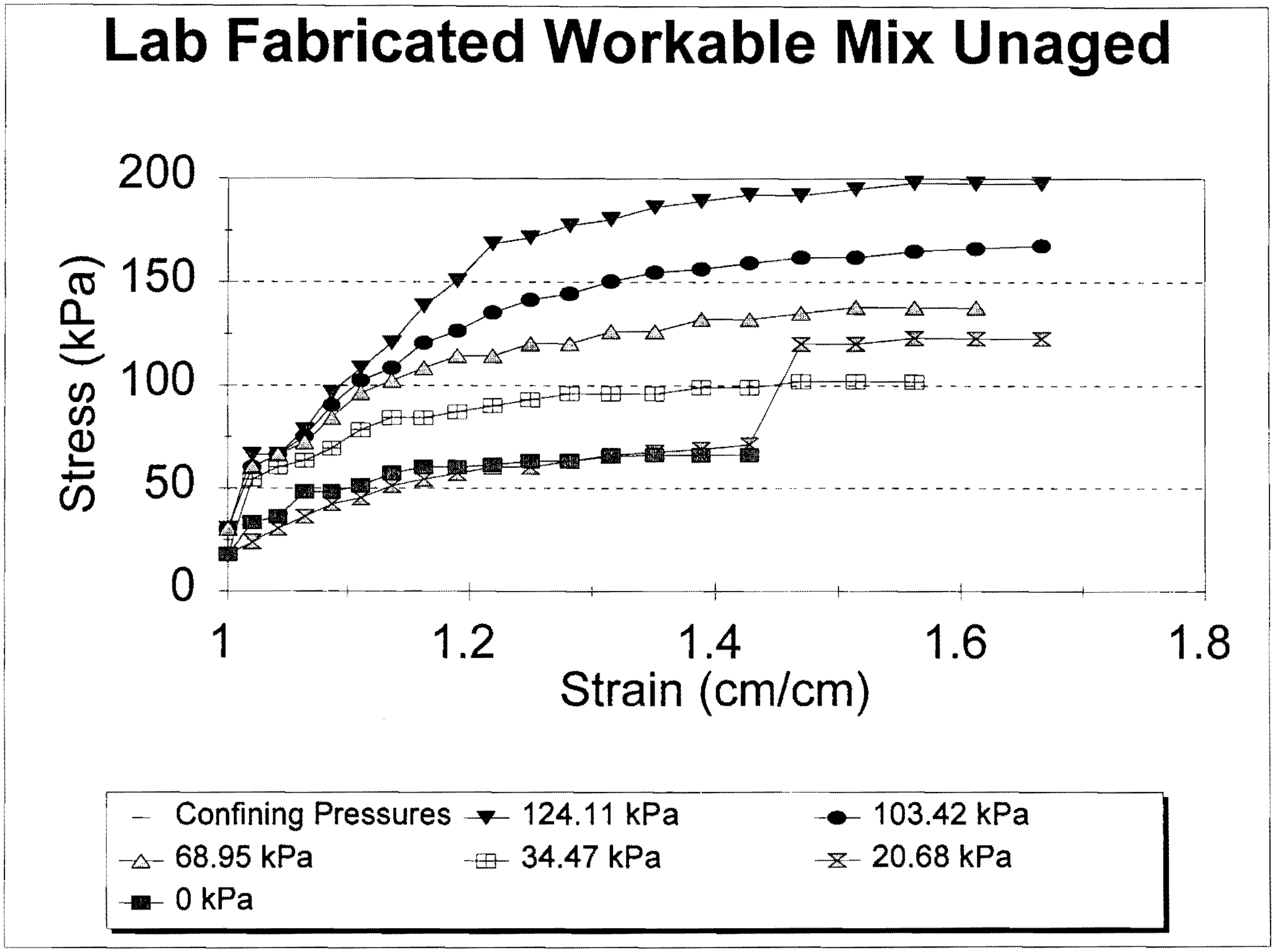
STRESS-STRAIN DATA FOR TRIAXIAL COMPRESSION TESTS

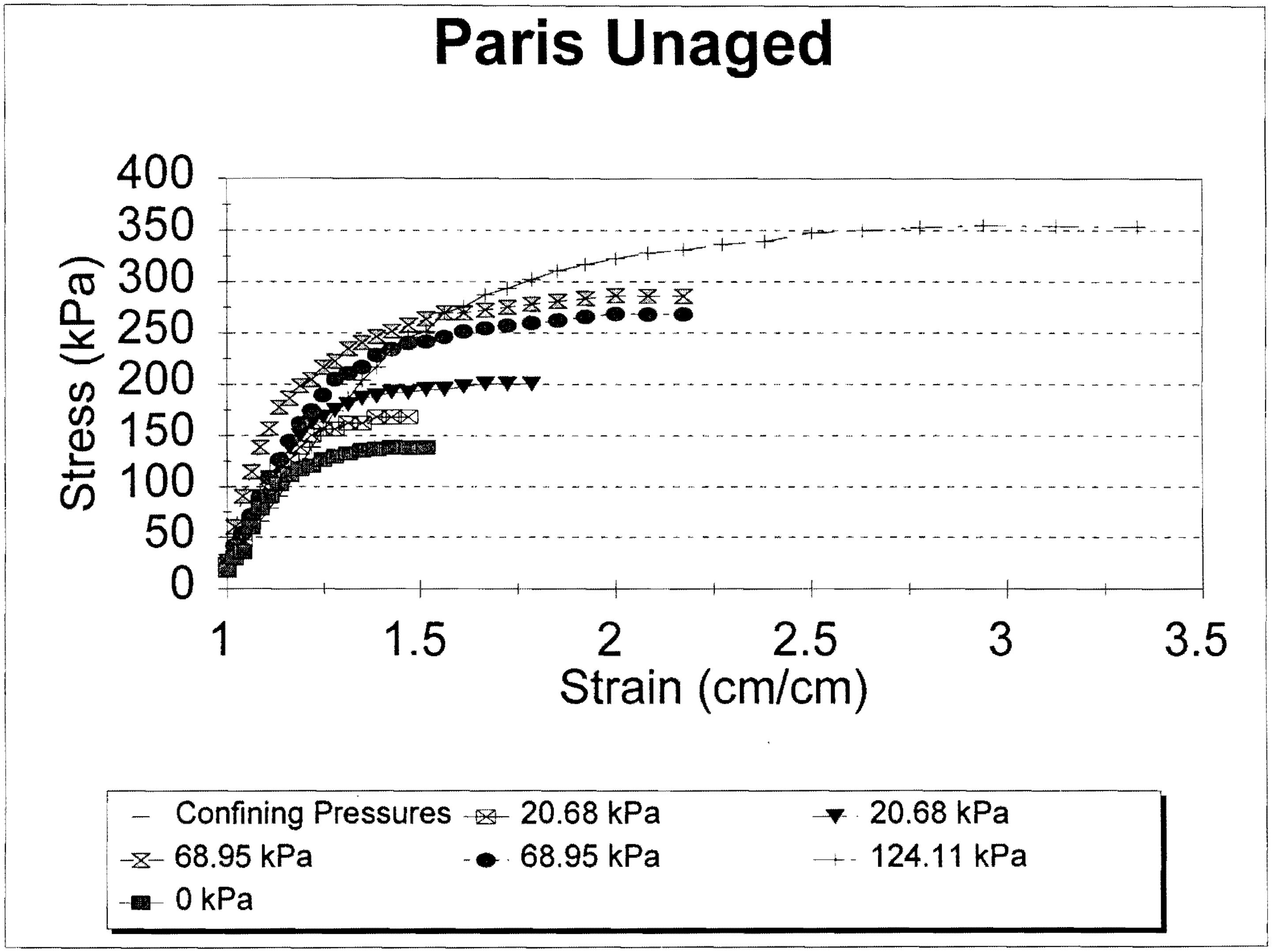

Longview Unaged
Stress (kPa)
1000
800
600
400
200
0
1
1.2
1.4
1.6
1.8
2
Strain (cm/cm)
Confining Pressures
124.11 kPa
103.42 kPa
68.95 kPa
34.47 kPa
20.68 kPa
0 kPa

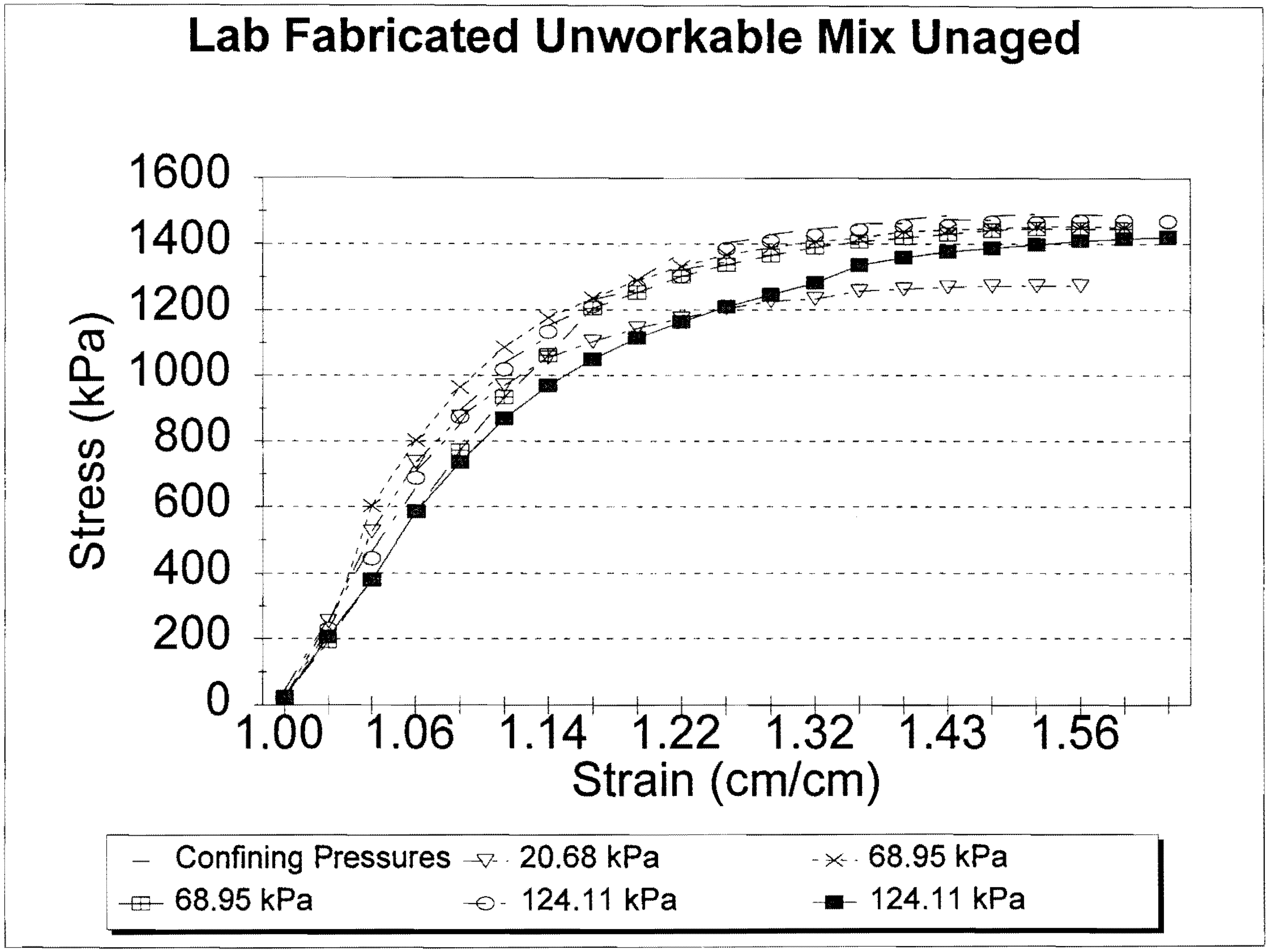

Austin Unaged
Stress (kPa)
0
50
100
150
200
250
300
350
400
Strain (cm/cm)
1
1.2
1.4
1.6
1.8
2
Confining Pressures
124.11 kPa
103.42 kPa
68.95 kPa
34.47 kPa
20.68 kPa
0 kPa

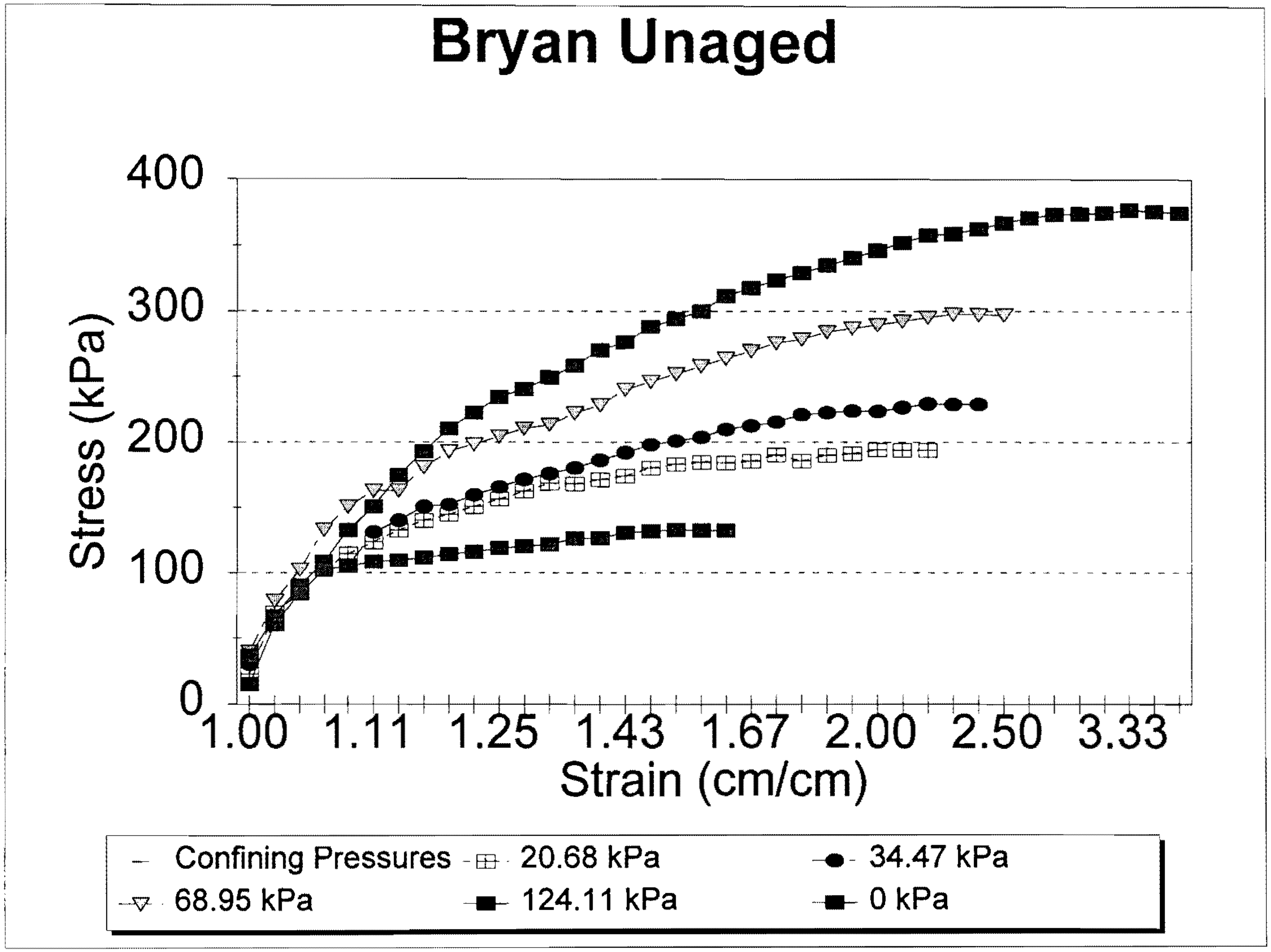

Bridgeport Unaged
500
400
300
200
100
0
Stress (kPa)
1
2
3
4
5
Strain (cm/cm)
Confining Pressures
124.11 kPa
103.42 kPa
68.95 kPa
34.47 kPa
20.68 kPa
0 kPa

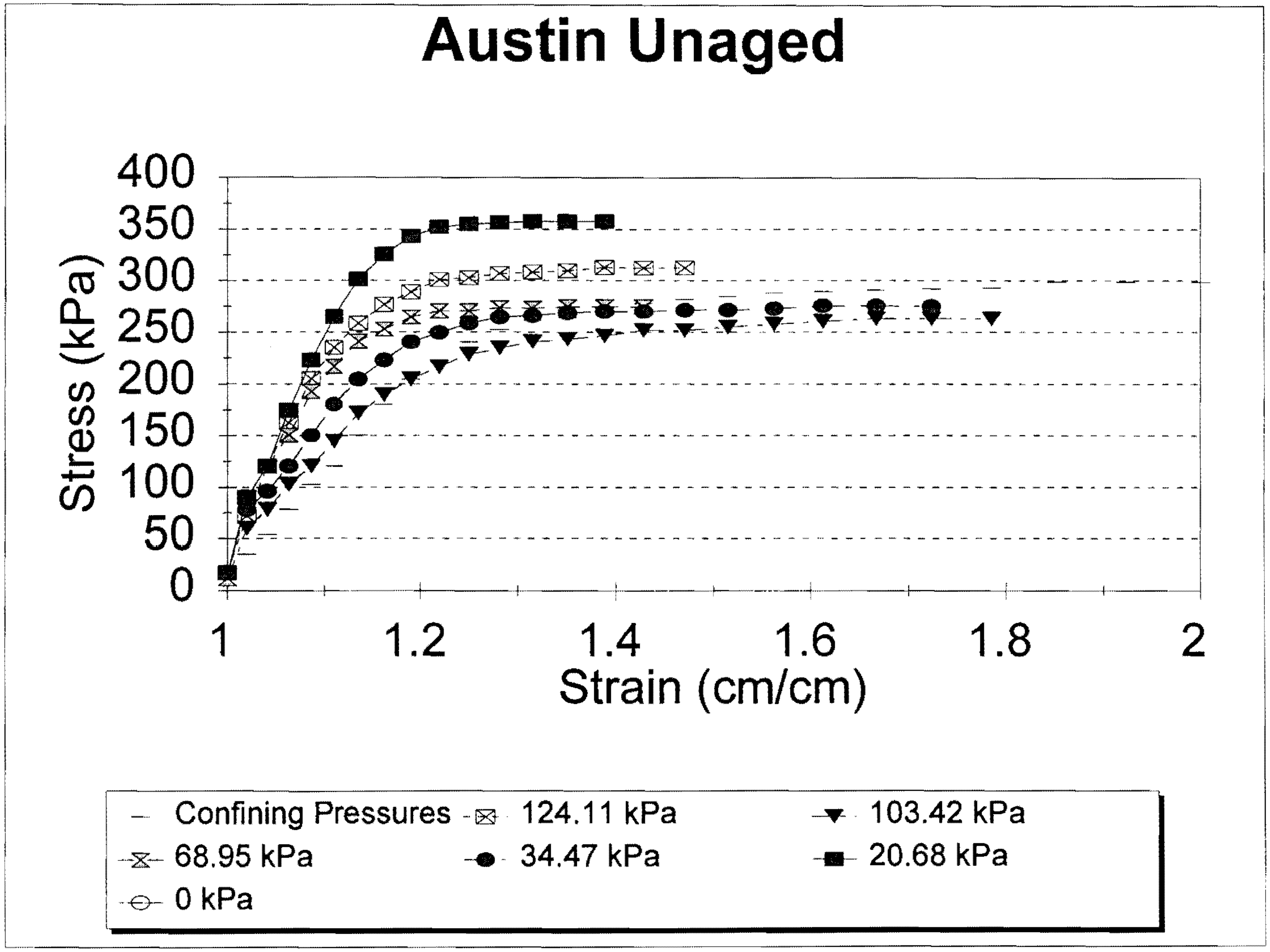

Fairfield Unaged
Stress (kPa)
400
300
200
100
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
Strain (cm/cm)
Confining Pressures
▼ 124.11 kPa
● 103.42 kPa
⊞ 68.95 kPa
⧗ 20.68 kPa
■ 0 kPa

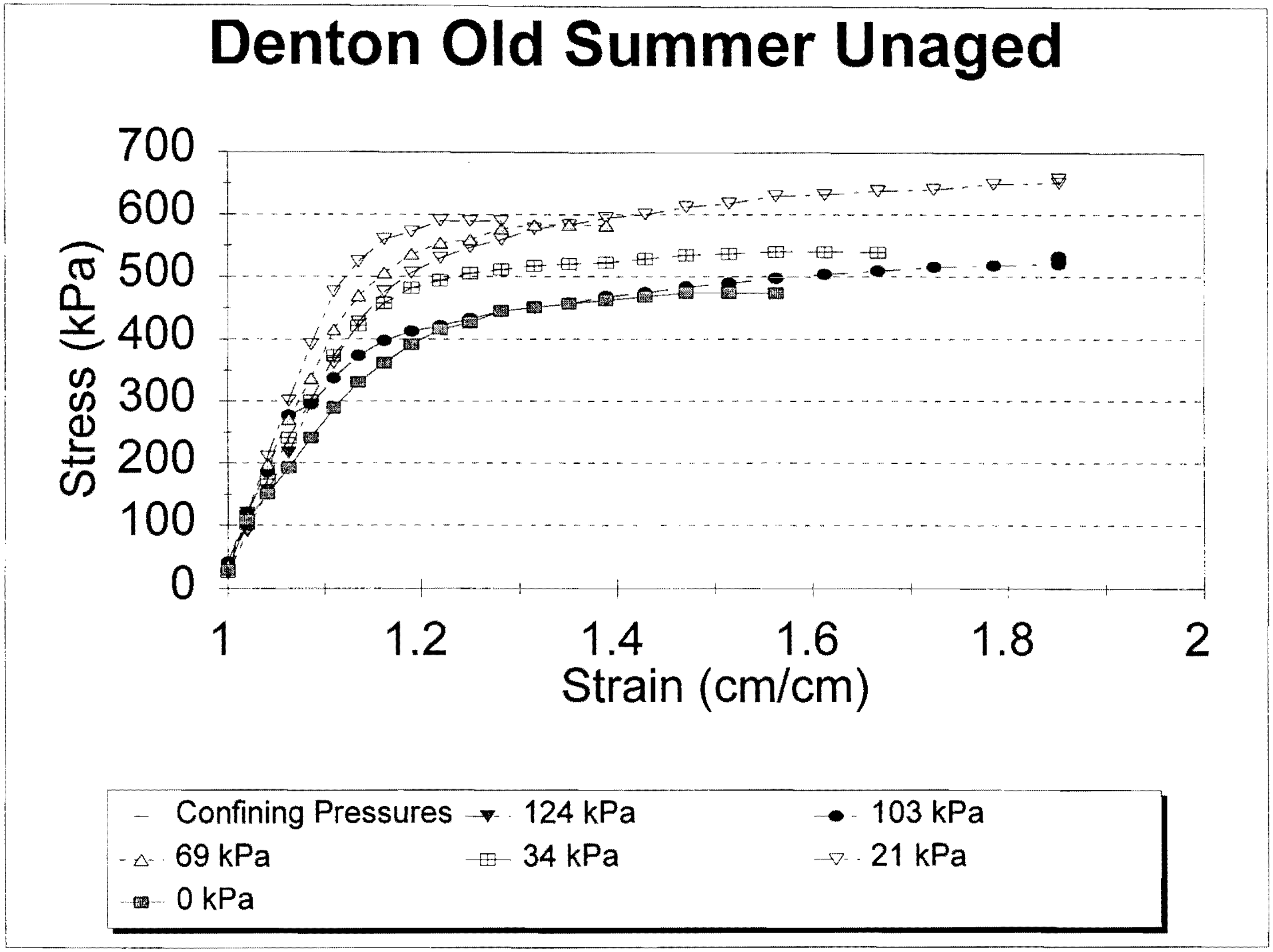

Lab Fabricated Workable Mix Unaged
200
150
100
50
0
Stress (kPa)
1
1.2
1.4
1.6
1.8
Strain (cm/cm)
Confining Pressures
124.11 kPa
103.42 kPa
68.95 kPa
34.47 kPa
20.68 kPa
0 kPa

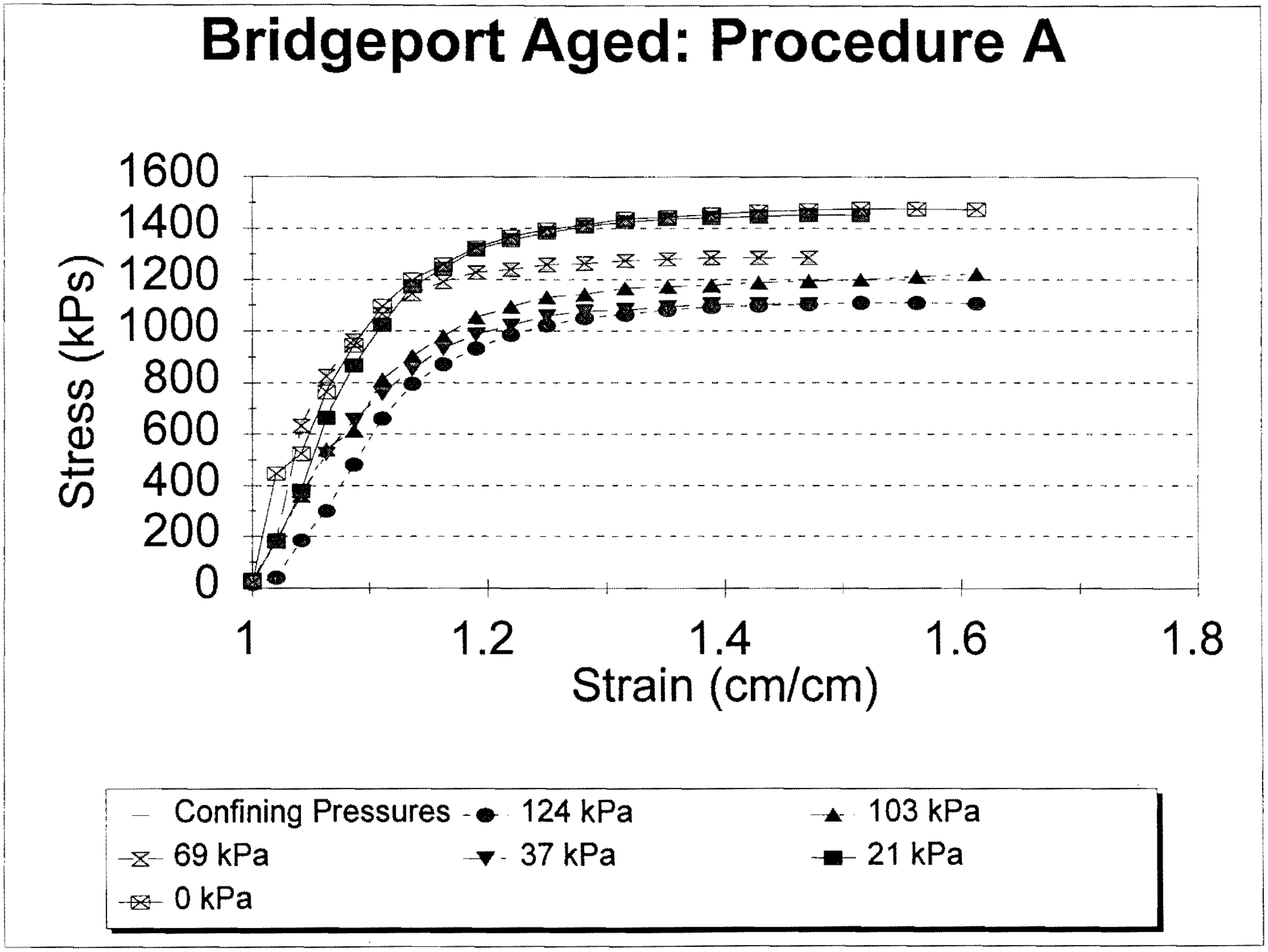

Paris Unaged
Stress (kPa)
400
350
300
250
200
150
100
50
0
1
1.5
2
2.5
3
3.5
Strain (cm/cm)
Confining Pressures
20.68 kPa
20.68 kPa
68.95 kPa
68.95 kPa
124.11 kPa
0 kPa

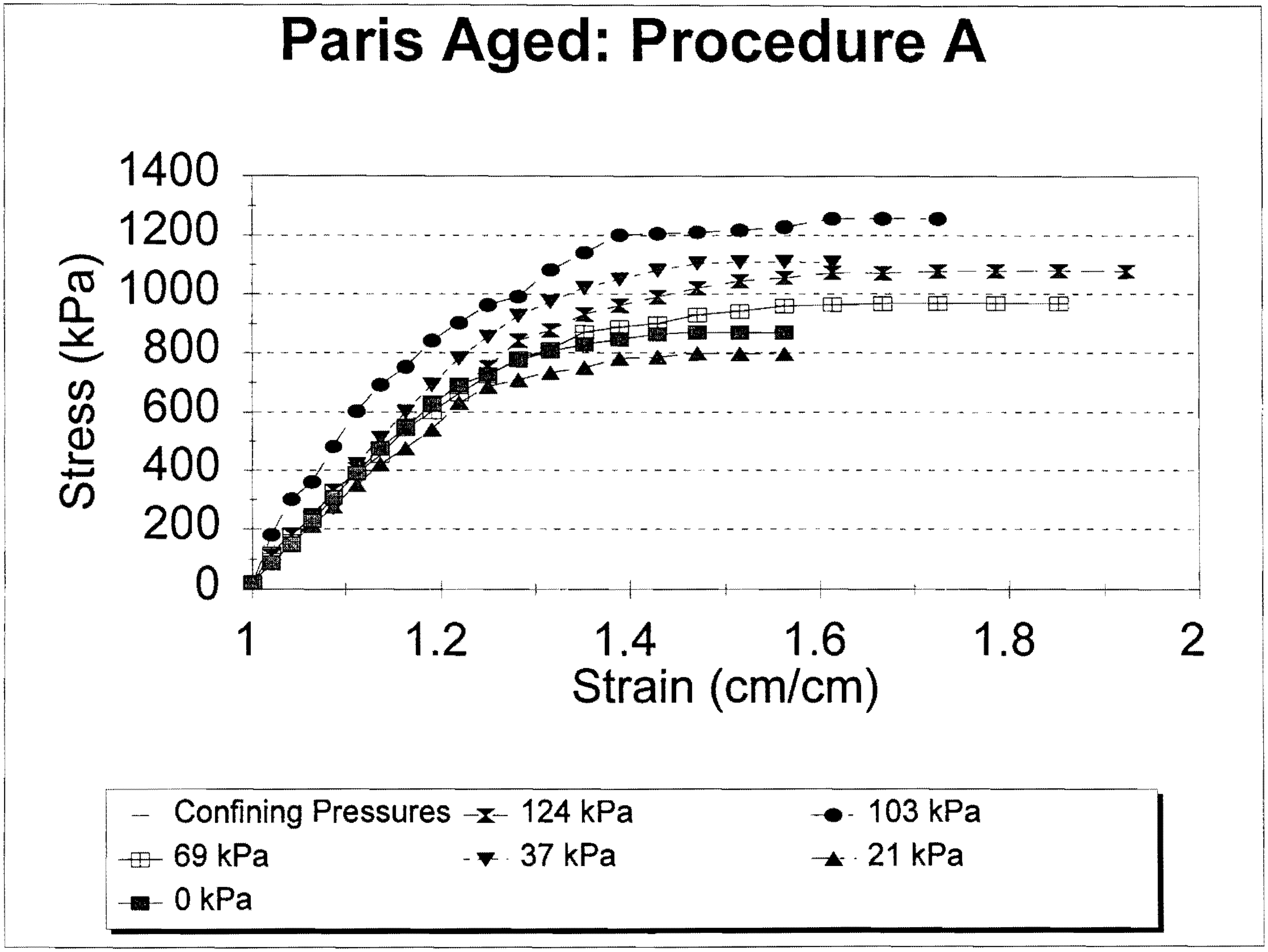

Lab Fabricated Unworkable Mix Unaged
Stress (kPa)
1600
1400
1200
1000
800
600
400
200
0
1.00
1.06
1.14
1.22
1.32
1.43
1.56
Strain (cm/cm)
Confining Pressures
20.68 kPa
68.95 kPa
68.95 kPa
124.11 kPa
124.11 kPa

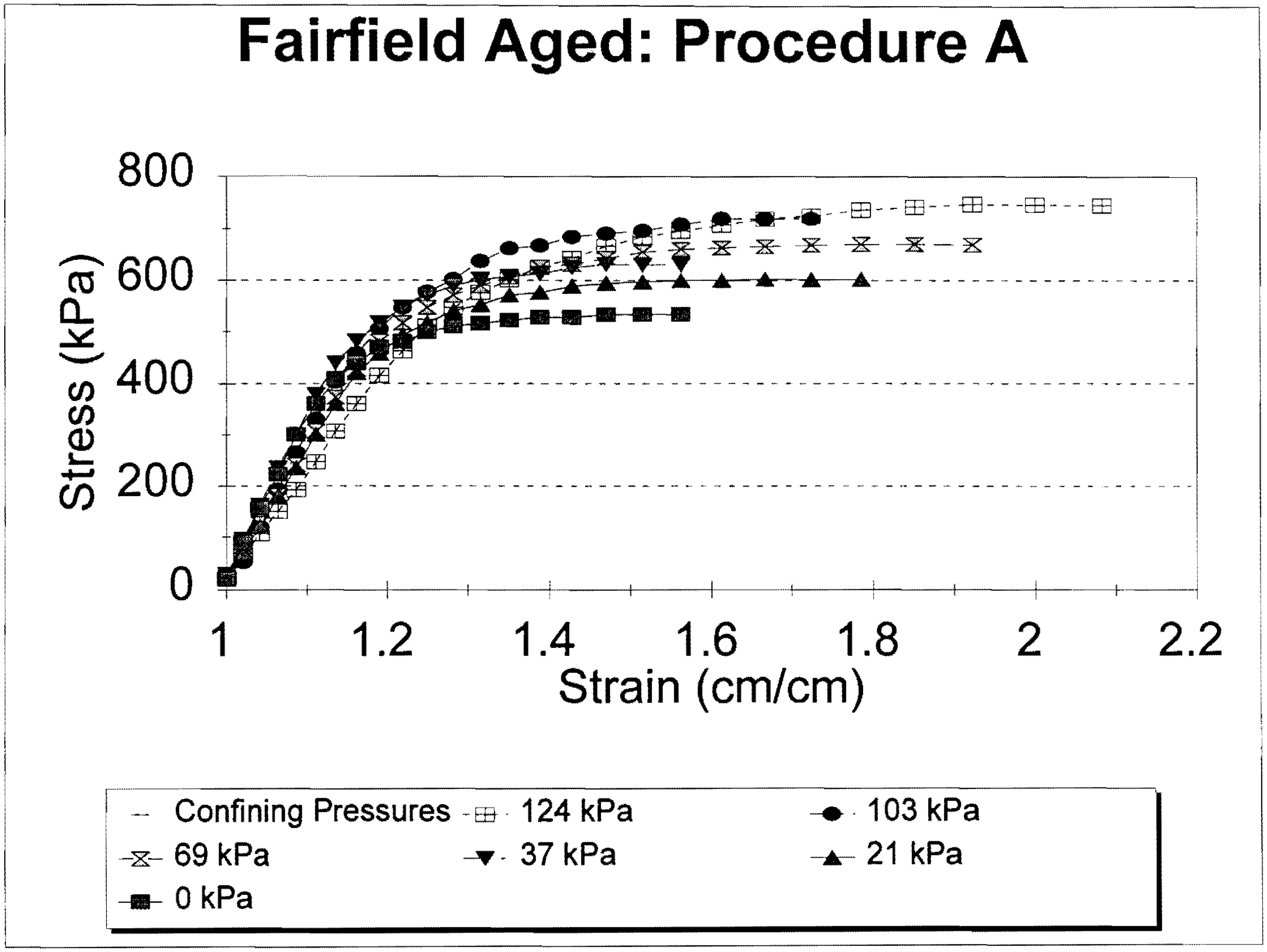

Bryan Unaged
Stress (kPa)
400
300
200
100
0
1.00
1.11
1.25
1.43
1.67
2.00
2.50
3.33
Strain (cm/cm)
Confining Pressures
20.68 kPa
34.47 kPa
68.95 kPa
124.11 kPa
0 kPa

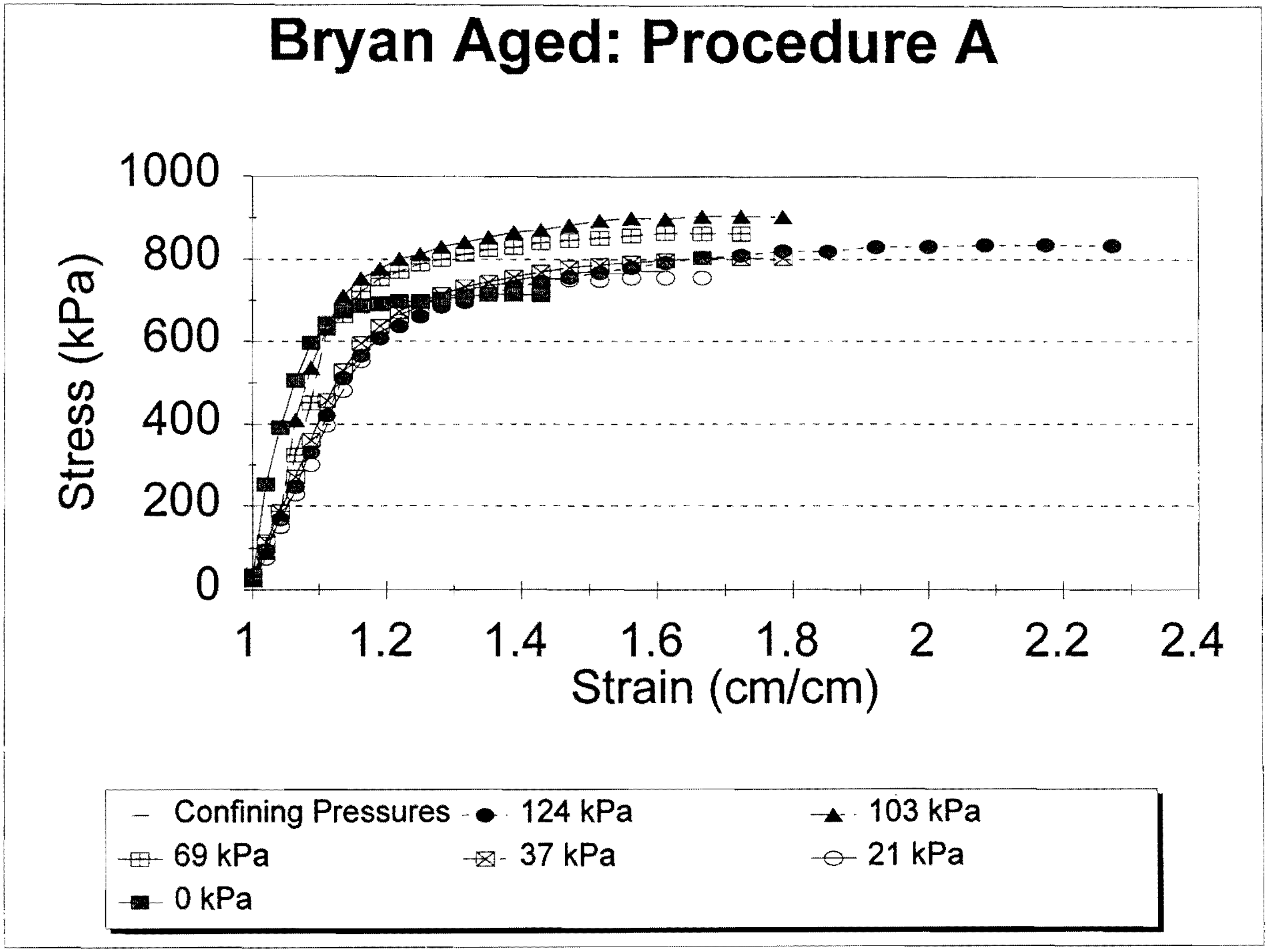

Austin Unaged
Stress (kPa)
400
350
300
250
200
150
100
50
0
1
1.2
1.4
1.6
1.8
2
Strain (cm/cm)
— Confining Pressures
⊠ 124.11 kPa
▼ 103.42 kPa
⧖ 68.95 kPa
● 34.47 kPa
■ 20.68 kPa
⊖ 0 kPa

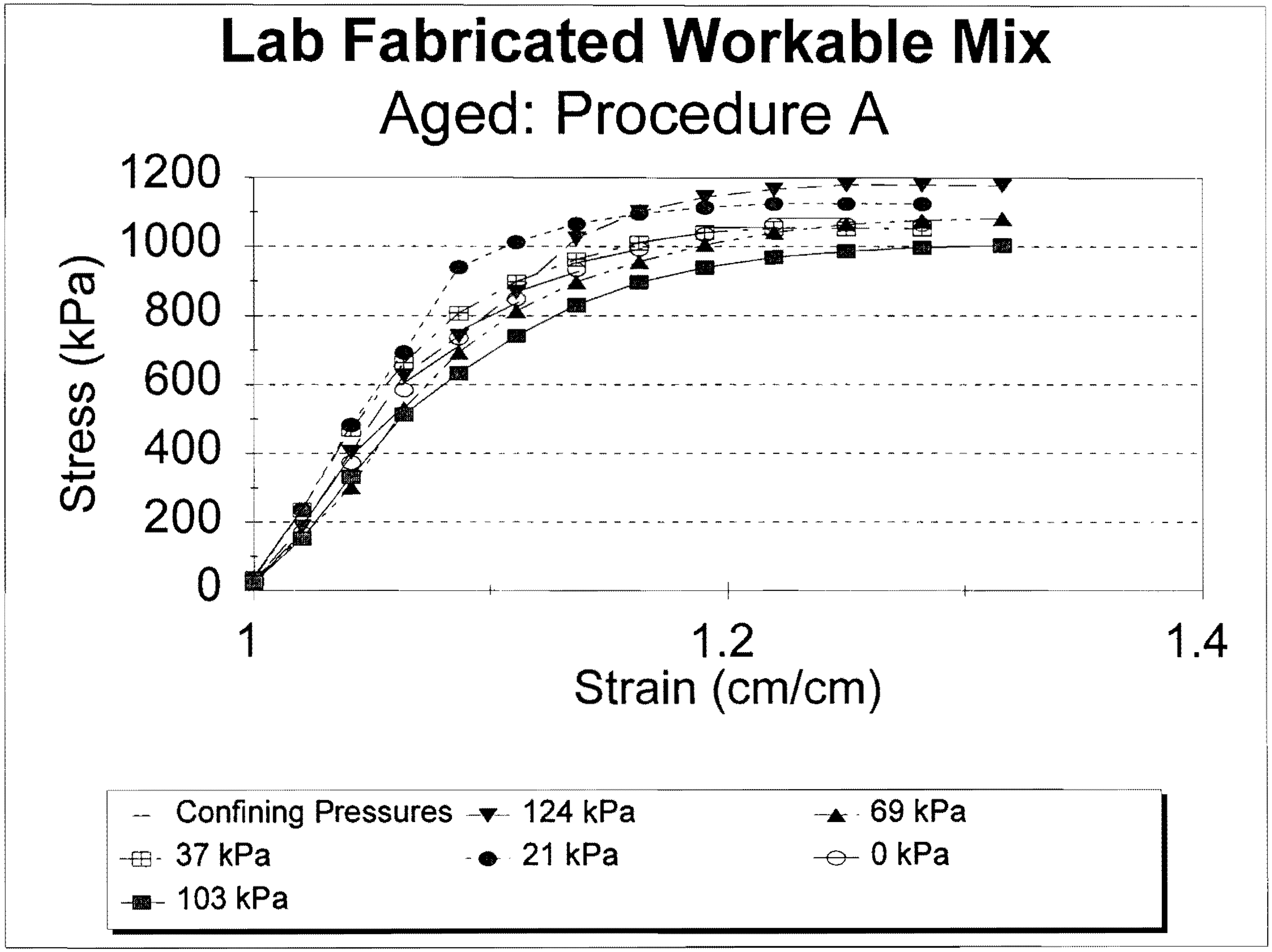

Denton Old Summer Unaged
Stress (kPa)
700
600
500
400
300
200
100
0
1
1.2
1.4
1.6
1.8
2
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
34 kPa
21 kPa
0 kPa

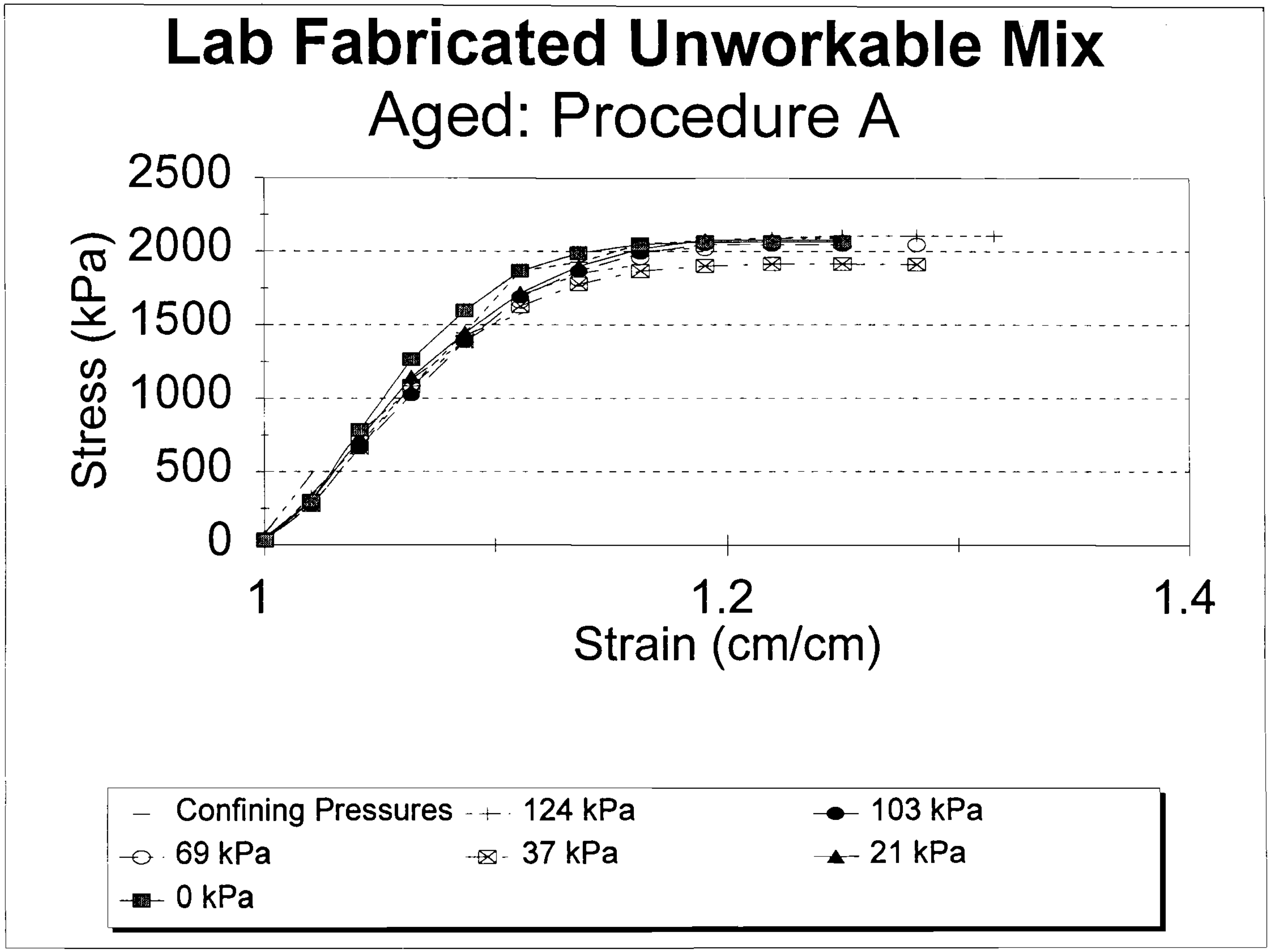

Bridgeport Aged: Procedure A
Stress (kPs)
1600
1400
1200
1000
800
600
400
200
0
1
1.2
1.4
1.6
1.8
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
37 kPa
21 kPa
0 kPa

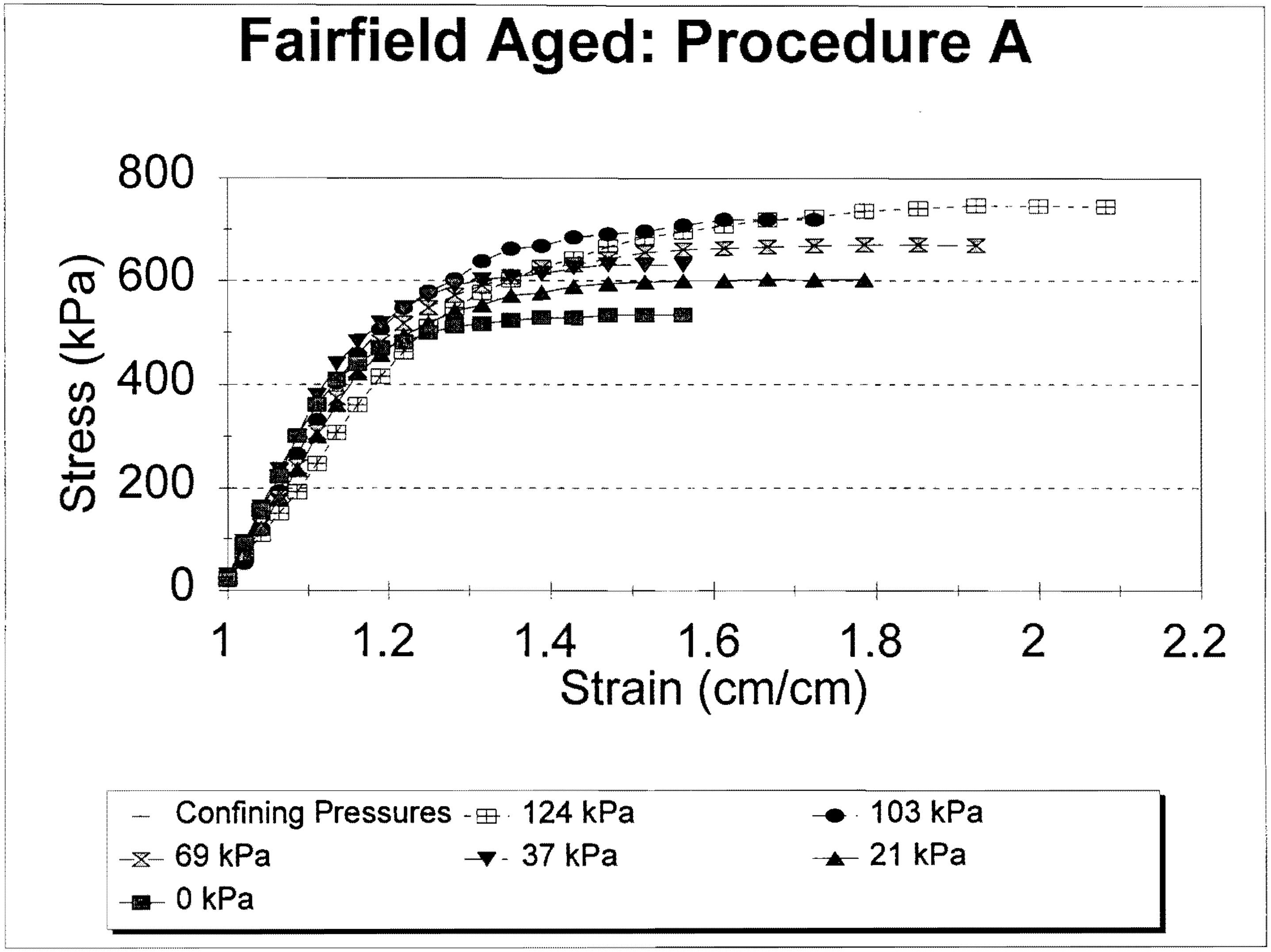

Paris Aged: Procedure A
Stress (kPa)
0
200
400
600
800
1000
1200
1400
Strain (cm/cm)
1
1.2
1.4
1.6
1.8
2
Confining Pressures
124 kPa
103 kPa
69 kPa
37 kPa
21 kPa
0 kPa

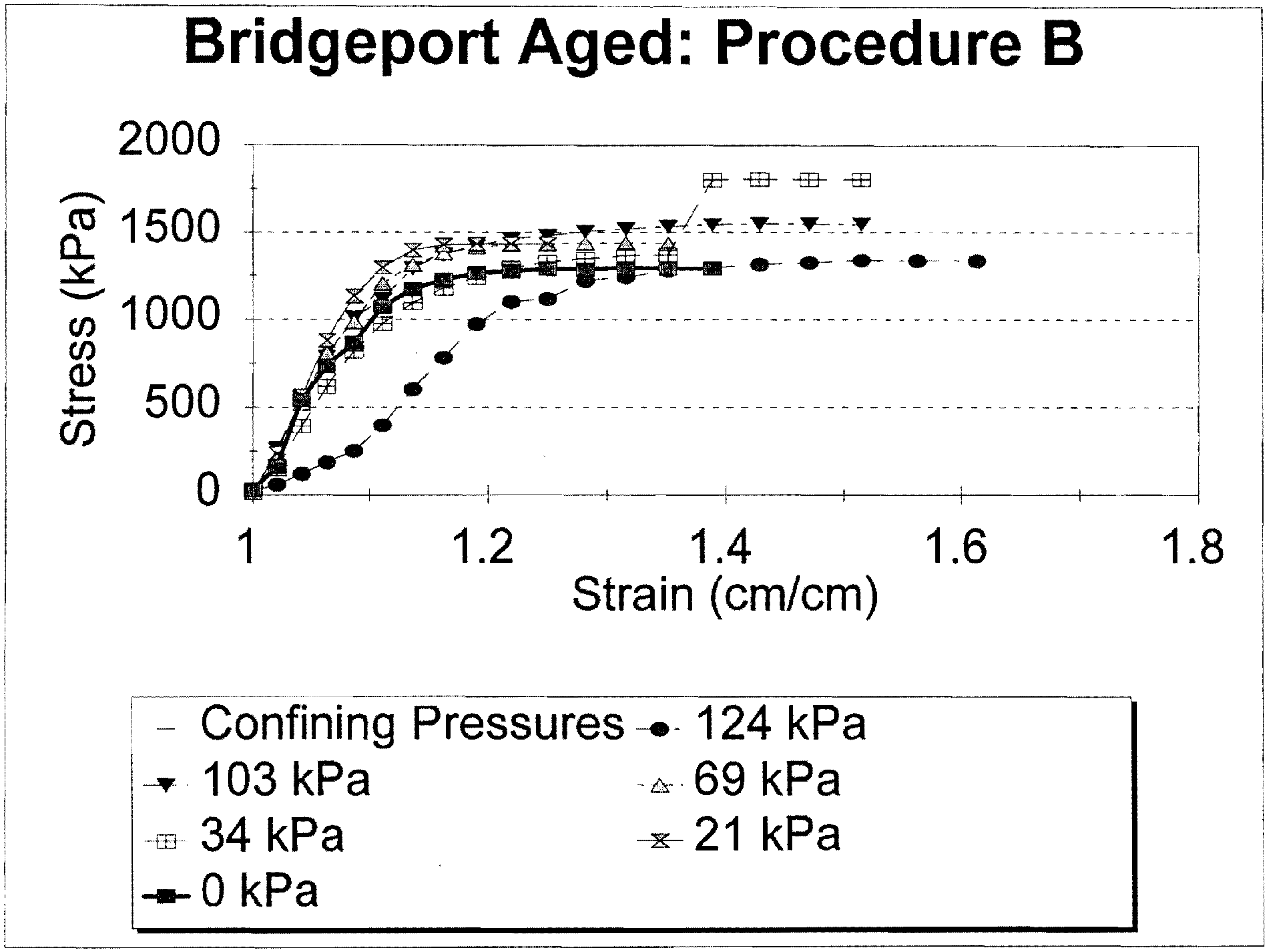

Fairfield Aged: Procedure A
Stress (kPa)
800
600
400
200
0
1
1.2
1.4
1.6
1.8
2
2.2
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
37 kPa
21 kPa
0 kPa

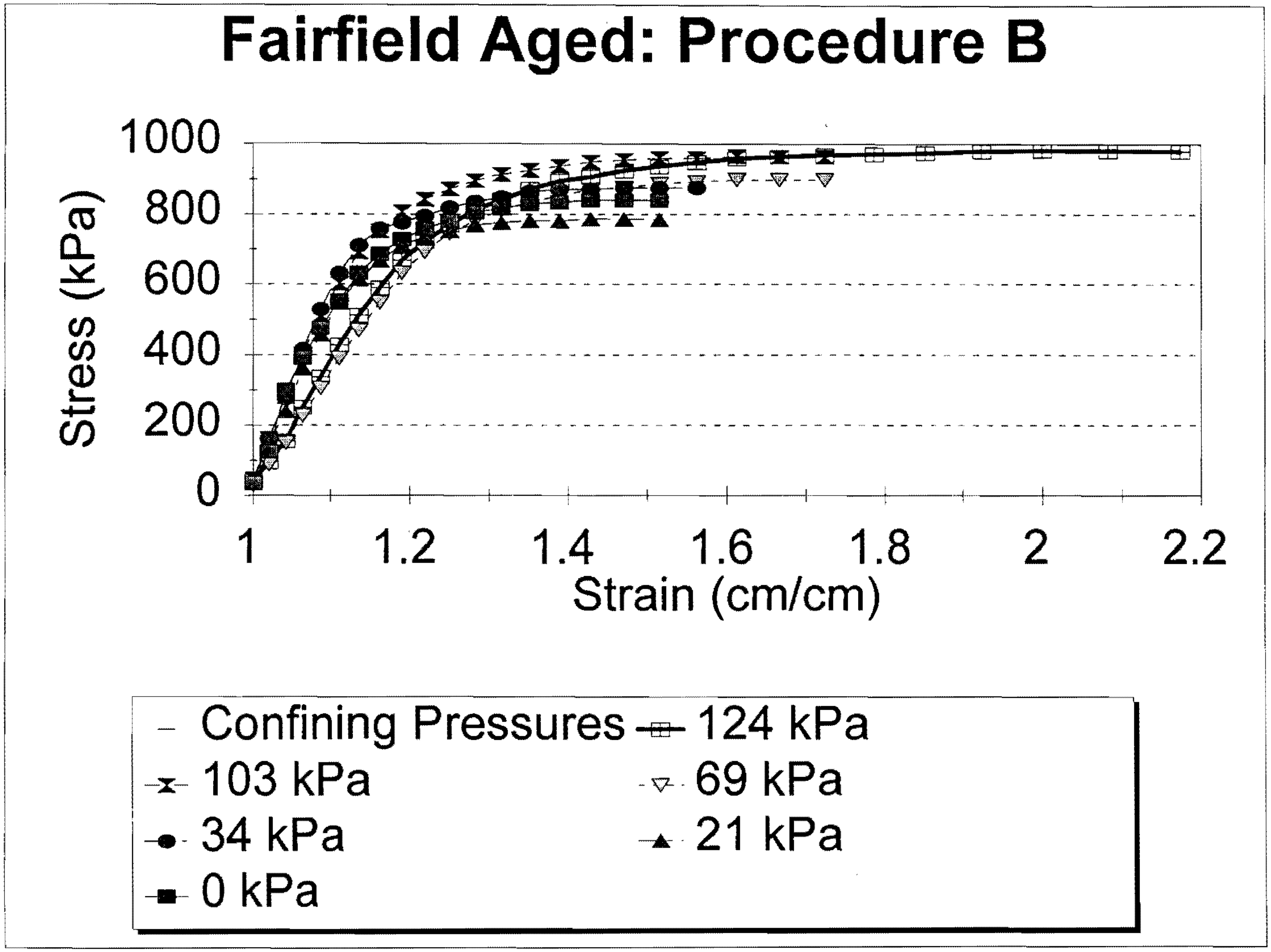

Bryan Aged: Procedure A
Stress (kPa)
1000
800
600
400
200
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
Strain (cm/cm)
Confining Pressures
● 124 kPa
▲ 103 kPa
⊞ 69 kPa
⊠ 37 kPa
⊖ 21 kPa
■ 0 kPa

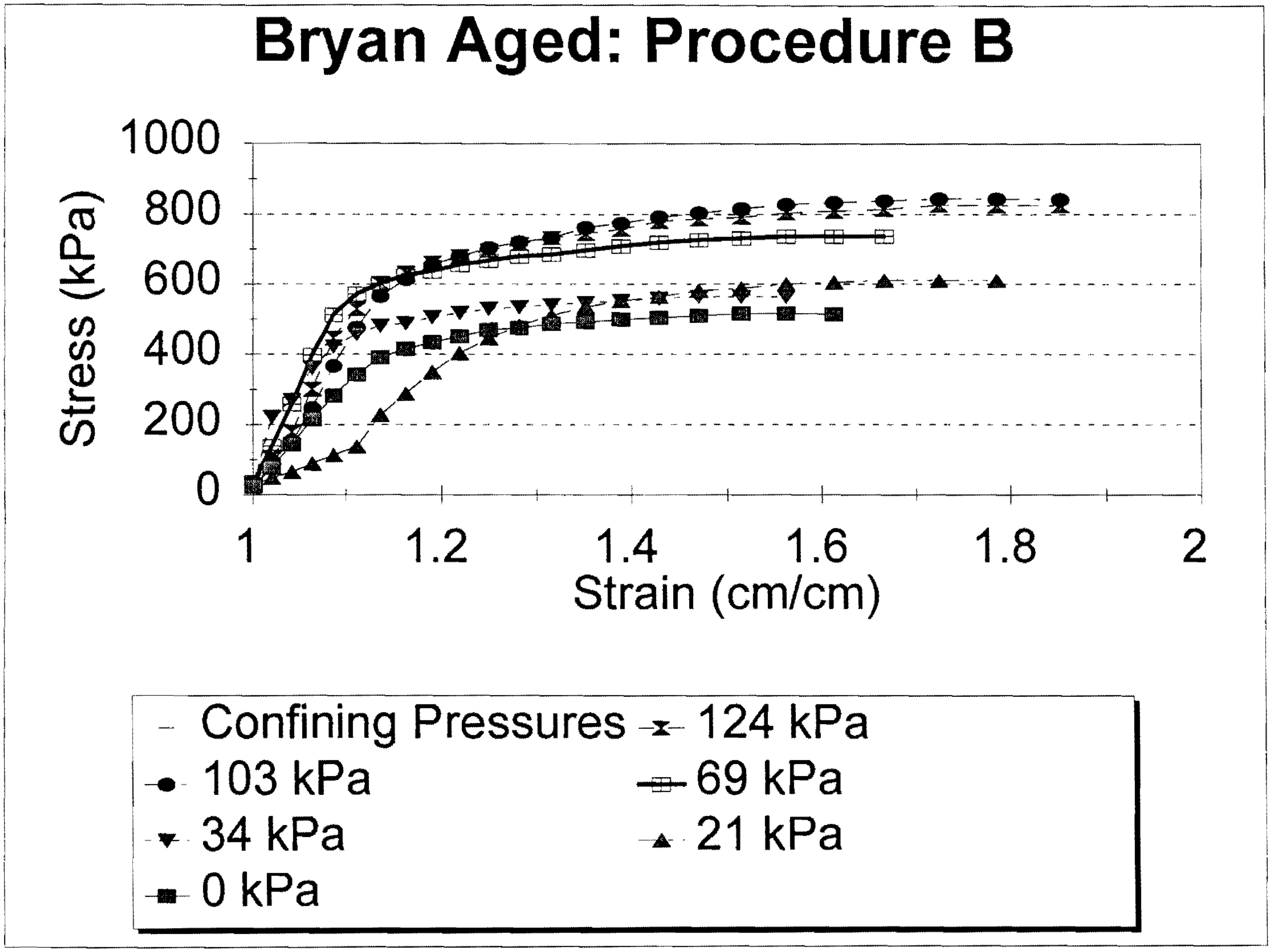

Lab Fabricated Workable Mix
Aged: Procedure A
Stress (kPa)
1200
1000
800
600
400
200
0
1
1.2
1.4
Strain (cm/cm)
Confining Pressures
124 kPa
69 kPa
37 kPa
21 kPa
0 kPa
103 kPa

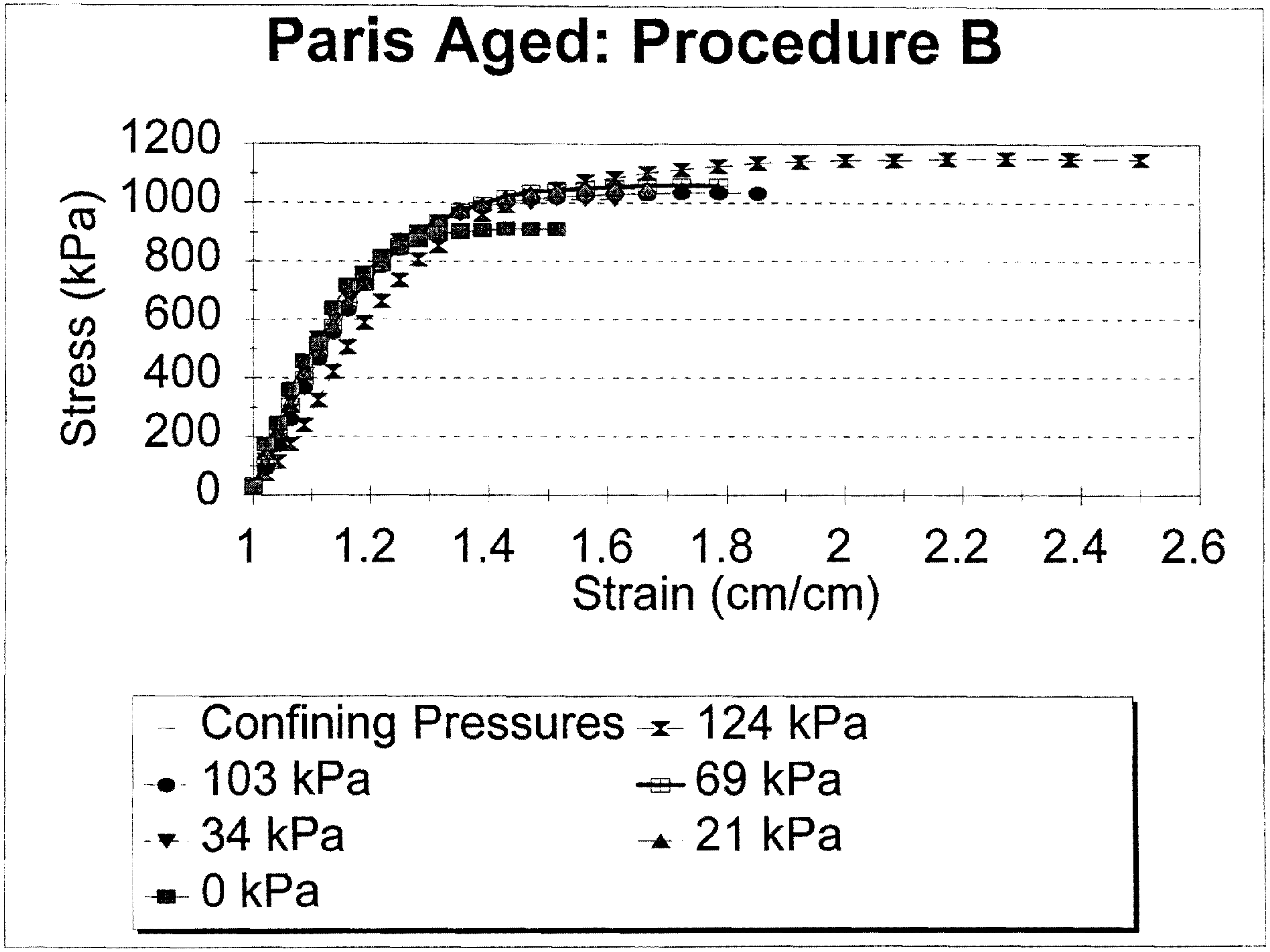

Lab Fabricated Unworkable Mix
Aged: Procedure A
Stress (kPa)
2500
2000
1500
1000
500
0
1
1.2
1.4
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
37 kPa
21 kPa
0 kPa

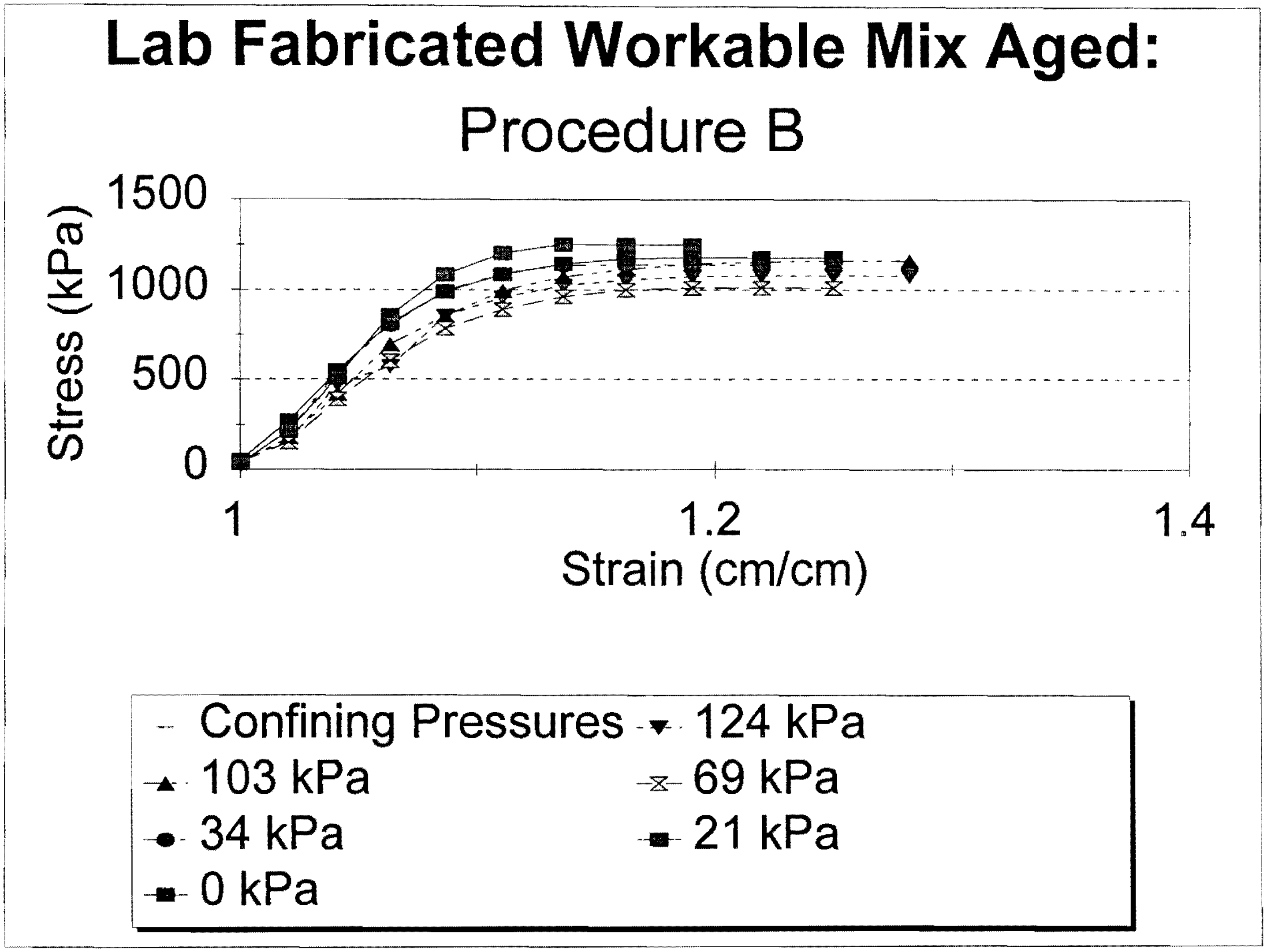

Fairfield Aged: Procedure A
800
600
400
200
0
Stress (kPa)
1
1.2
1.4
1.6
1.8
2
2.2
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
37 kPa
21 kPa
0 kPa

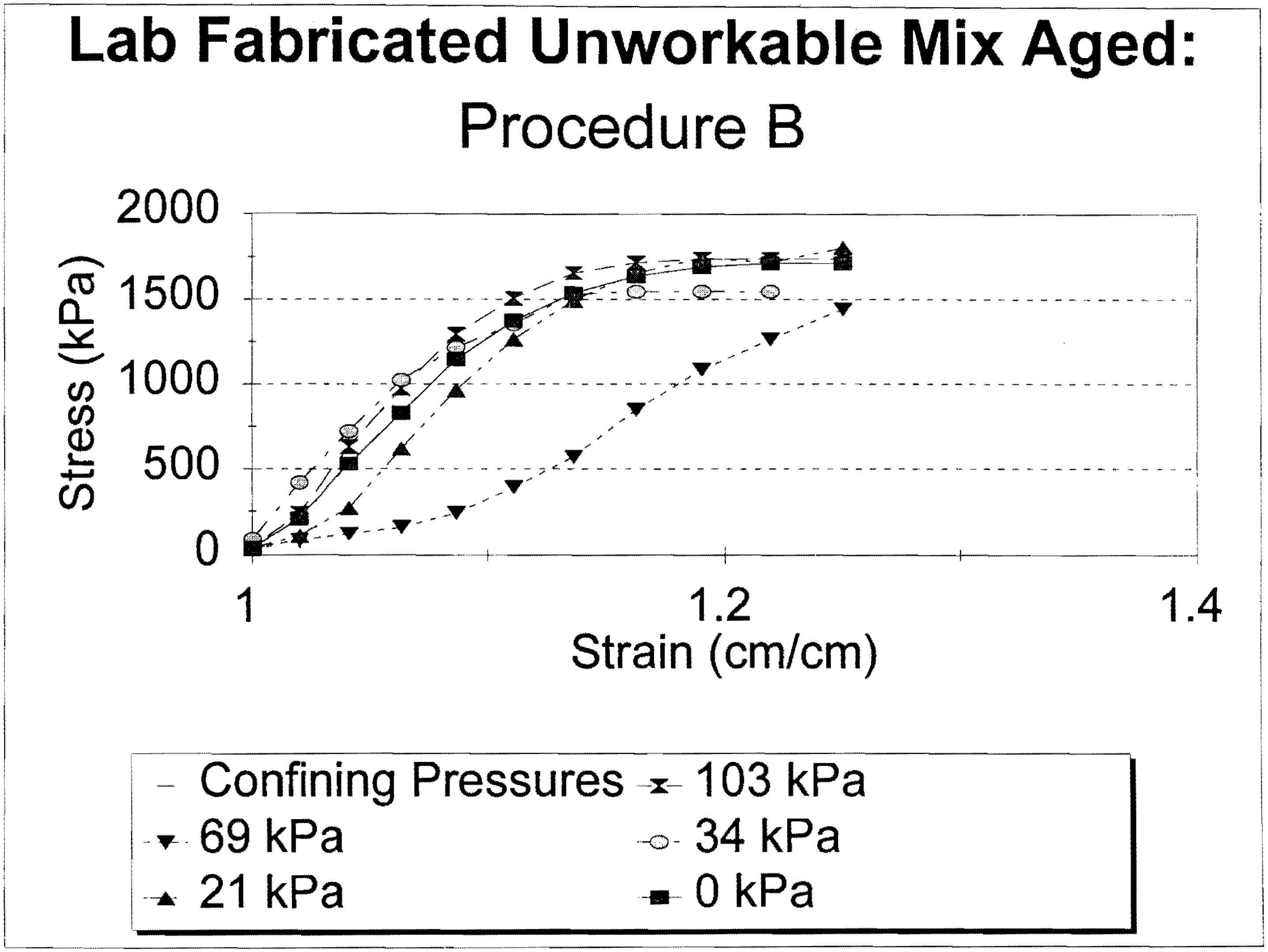

Bridgeport Aged: Procedure B
Stress (kPa)
2000
1500
1000
500
0
1
1.2
1.4
1.6
1.8
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
34 kPa
21 kPa
0 kPa

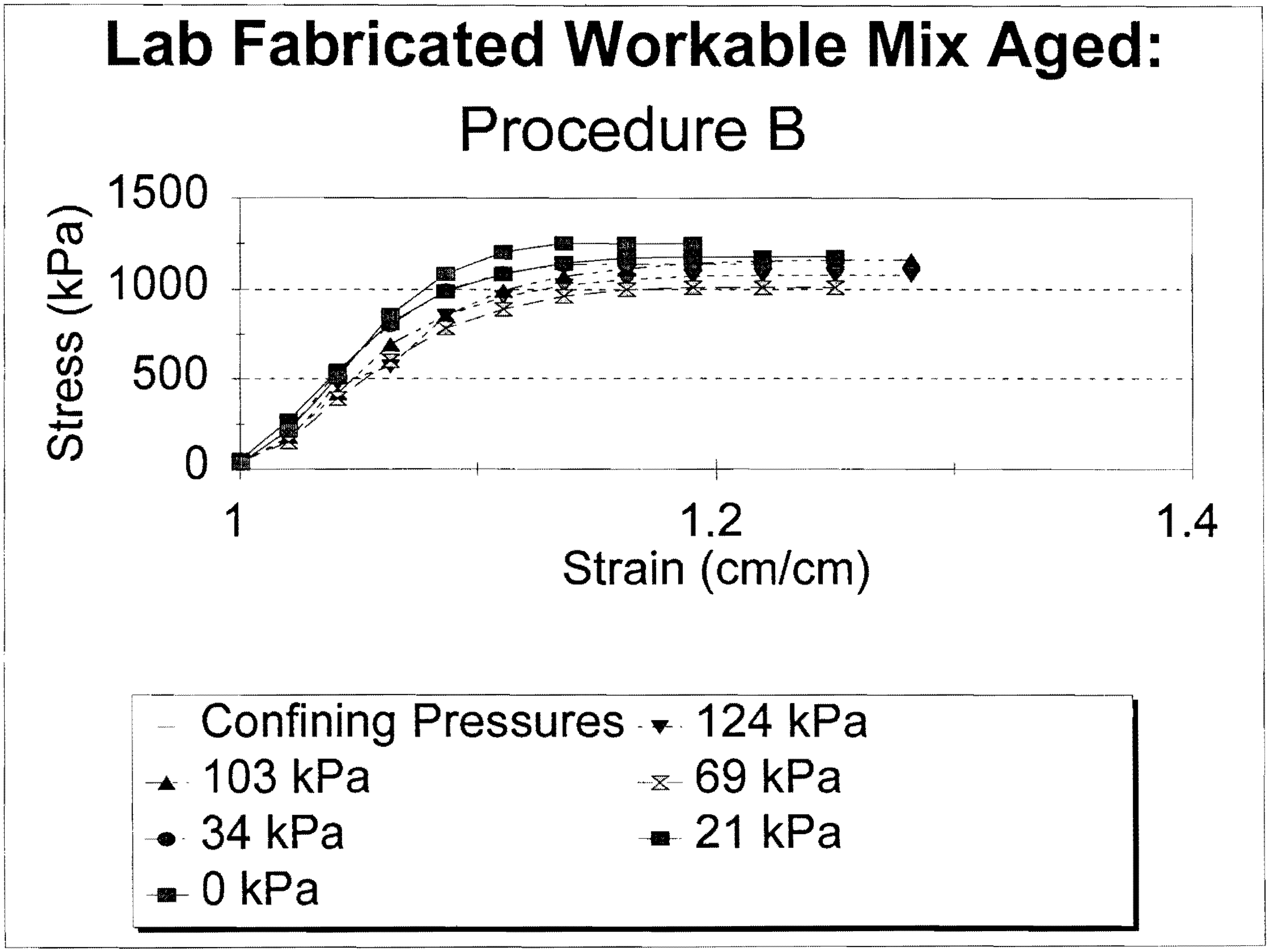

Fairfield Aged: Procedure B
Stress (kPa)
1000
800
600
400
200
0
1
1.2
1.4
1.6
1.8
2
2.2
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
34 kPa
21 kPa
0 kPa


Bryan Aged: Procedure B
Stress (kPa)
1000
800
600
400
200
0
1
1.2
1.4
1.6
1.8
2
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
34 kPa
21 kPa
0 kPa


Paris Aged: Procedure B
1200
1000
800
600
400
200
0
Stress (kPa)
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
34 kPa
21 kPa
0 kPa


Lab Fabricated Workable Mix Aged:
Procedure B
Stress (kPa)
1500
1000
500
0
1
1.2
1.4
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
34 kPa
21 kPa
0 kPa


Lab Fabricated Unworkable Mix Aged:
Procedure B
Stress (kPa)
2000
1500
1000
500
0
1
1.2
1.4
Strain (cm/cm)
Confining Pressures
103 kPa
69 kPa
34 kPa
21 kPa
0 kPa


Lab Fabricated Workable Mix Aged:
Procedure B
Stress (kPa)
1500
1000
500
0
1
1.2
1.4
Strain (cm/cm)
Confining Pressures
124 kPa
103 kPa
69 kPa
34 kPa
21 kPa
0 kPa