ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA-AZ90-350

LABORATORY EVALUATION OF TYPICAL ADOT ASPHALT CONCRETE

Final Report

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August 1990

Prepared for:
Arizona Department of Transportation
206 South 17th Avenue
Phoenix, Arizona 85007
in cooperation with
U.S. Department of Transportation
Federal Highway Administration

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-AZ90-350		

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
LABORATORY EVALUATION OF TYPICAL ADOT ASPHALT CONCRETE	5. Report Date: August 1990 6. Performing Organization Code:
7. Author (s)	**8. Performing Organization Report No.**
Michael S. Mamlouk and Punya P. Khanal	
9. Performing Organization Name and Address	**10. Work Unit No. / 11. Contract or Grant No.**
Center for Advanced Research in Transportation Arizona State University Tempe, Arizona 85287-6306	10. Work Unit No.: 11. Contract or Grant No.: HPR-PL-1-37 (350)
12. Sponsoring Agency Name and Address	**13. Type of Report & Period Covered / 14. Sponsoring Agency Code**
ARIZONA DEPARTMENT OF TRANSPORTATION 206 S. 17TH AVENUE PHOENIX, ARIZONA 85007	13. Type of Report & Period Covered: Final Report 14. Sponsoring Agency Code:

15. Supplementary Notes

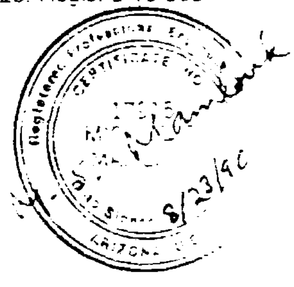
Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

A typical ADOT asphalt concrete mixture was evaluated based on the Asphalt-Aggregate Mixture Analysis System (AAMAS) procedure (NCHRP Project 9-6(1)). Two sets of ADOT asphalt concrete specimens were prepared using the California kneading compactor and the Marshall hammer. All tests recommended by the AAMAS project were performed. The test results were analyzed using the AAMAS guidelines.

It was found that the diametral resilient moduli of the ADOT mixture are within the acceptable range. A typical AASHTO structural layer coefficient is recommended. The rutting potential is low in some cases and moderate in other cases. Recommendations for the evaluation of fatigue cracking and thermal cracking are provided. The potential for moisture damage is high, while the potential for disintegration is marginal.

23. Registrant's Seal



17. Key Words	18. Distribution Statement
Asphalt Concrete, AAMAS, Laboratory Evaluation, Resilient Modulus, Strength, Creep	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

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

CHAPTER 1. INTRODUCTION

1.1 PROBLEM STATEMENT

The asphalt concrete mix design in Arizona is based on the Marshall procedure (Ariz. method 815c). Since the Marshall method of mix design is basically empirical, it results in index-type values such as Marshall stability and flow. In general, empirical characterization parameters are useful for comparison of materials under specific conditions. However, empirical correlations are valid only for conditions similar to those under which they were originally developed. Further, empirical methods of characterization do not provide material properties needed for fundamental or theory-based structural analysis of pavements. With the continuous increase in truck weight, tire pressure and traffic volume, and with the fast deterioration of the nation's highway system, more rational philosophy for asphalt concrete characterization is needed so that the pavement design can be based on a more optimal manner.

NCHRP Project 9-6 (1), "Development of Asphalt-Aggregate Mixture Analysis System" (AAMAS) has been recently completed and the final report is being revised(1). One of the objectives of that project was to develop a more rational mixture characterization procedure based on performance-related criteria. Phase II, Volume I of the final report is a procedural manual that provides a complete evaluation procedure of hot-mixed asphalt concrete. Although the AAMAS method is not a mixture design procedure by itself, it provides rational evaluation procedure that is directly related to the mixture performance in the field. Since the project has been recently completed, the AAMAS procedure has not been implemented by most states. However, various highway agencies are planning to implement it in the near future. The implementation of the AAMAS procedure by ADOT could be a major step forward towards rationalizing the asphalt concrete mix design process.

According to the AAMAS procedure, six test types should be performed. Since some of these tests are nondestructive, each specimen could be tested using different test types and at different test temperatures. Some specimens are to be tested without "conditioning" while others should be "conditioned" in which they are subjected to some treatments before testing. The detailed test and analysis procedure are reported in Reference 1. A summary of the test procedure is presented in Chapter 2.

1.2 OBJECTIVES

The objectives of this study are:

1) To evaluate typical ADOT hot-mixed asphalt concretes using the AAMAS (NCHRP Project 9-6 (1)) recommendations.
2) To expand the ADOT database by providing typical lab test values for ADOT asphalt concrete.
3) To evaluate the amount of effort and equipment cost required for the AAMAS procedure and discuss its potential use by ADOT engineers.

1.3 SCOPE OF WORK

The study includes laboratory evaluation of two sets of typical ADOT hot-mix asphalt concrete specimens prepared using the California kneading compactor and the Marshall hammer. All tests recommended by the AAMAS project (1) were performed at ASU highway materials laboratory. The test results are analyzed using the AAMAS guidelines. The study is limited to one asphalt grade (AC-30), one aggregate type and gradation, and one asphalt content.

CHAPTER 2. SUMMARY OF THE AAMAS RECOMMENDED PROCEDURE

2.1 BACKGROUND

The AAMAS project was performed under NCHRP Project 9-6 (1) by Brent Rauhut Engineering as the prime contractor. The objective of the project was to develop an asphalt aggregate mixture analysis system (AAMAS) for design of optimum paving mixtures based on performance-related criteria. The AAMAS concept as it currently exists is applicable to hot-mixed asphalt concrete, and includes mixture variables such as binders, aggregates and fillers used in the construction of asphalt concrete pavements.

Specific items addressed in the current version of the AAMAS report include compaction of laboratory mixtures to simulate the characteristics of mixtures placed in the filed, preparation and mixing of materials in the laboratory to simulate the asphalt concrete plant production process, simulation of the long-term effects of traffic and the environment (this includes accelerated aging and densification of the mixes caused by traffic), and the conditioning of laboratory samples to simulate the effects of moisture induced damage and hardening of the asphalt.

Recommendations are made for laboratory methods of executing the AAMAS and evaluating the expected performance of dense graded asphalt concrete mixtures. Suggested recommendations for incorporating results of the AAMAS program into a final mixture design procedure are also provided. However, it should be noted that the AAMAS program developed and reported in the current version is an evaluation procedure of a selected mixture and not a mix design procedure in itself.

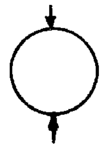
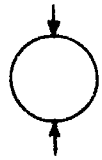
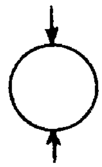
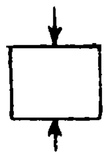
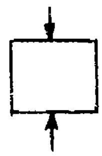
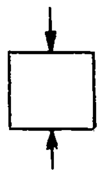
Current version of the AAMAS report(1) is only interim because of additional work being conducted under Phase III of Project 9-6 (1) and because of the extensive SHRP (Strategic Highway Research Program) asphalt research program currently underway. Some modifications to the current procedure may be required after these other multi-million dollar research programs are completed. The expected year of completion for the SHRP program is 1993.

At the time of this report, only a draft version of the AAMAS report was available. The final version of the AAMAS report is expected to be released in the near future. According to the principal author of the report, the difference between the current version and the final version is not significant.

2.2 LABORATORY TESTS

Volume I of the AAMAS report includes a detailed laboratory program to simulate the characteristics of mixtures placed in the field. The complete AAMAS procedure requires six types of tests as shown in Table 2-1. The following paragraphs summarize these tests. These paragraphs are not intended to provide a step-by-step procedure, but to discuss the significance and use of each test. The relation between the test results and the pavement response is also discussed.

Table 2 - 1. Lab tests recommended by the AAMAS project

Test No.	Test Name	Loading	Sketch
1	Diametral resilient modulus test	Paulses with 0.1 sec. duration and 0.9 sec. rest period (ASTM D 4123)	
2	Indirect tensile strength test	Loading until failure with a constant rate of deformation of 0.05 or 2 in/min.	
3	Indirect tensile creep test	Static load with a specified magnitude for 60 min. and unloading for 60 min.	
4	Uniaxial compression resilient modulus test	Pulses with 0.1 sec. duration and 0.9 sec. rest period to compute resilient modulus	
5	Unconfined compressive strength test	Axial loading at a rate of 0.6 in/min. until failure	
6	Uniaxial creep test	Static load with a specified magnitude for 60 min. and unloading for 60 min.	

TEST 1 - DIAMETRAL RESILIENT MODULUS TEST

When traffic moves over a pavement structure, a large number of stress pulses are rapidly applied to the different pavement layers. The concept of repeated load tests was developed to approximate the dynamic loading conditions that actually occur beneath the pavement surface. One of the common repeated load tests is the resilient modulus test. Briefly, pulse loads are applied to asphaltic concrete specimens and the corresponding recoverable strains are measured. The resilient modulus (E_R) is defined as the ratio of the applied stress to the recoverable strain when a pulsating load is applied. It is used as one of the inputs of the multilayer elastic and the finite element design methods of the highway pavement. In fact, the resilient modulus of a visco-elastic material such as asphalt concrete is similar to Young's modulus of a linear elastic material.

The resilient modulus for the asphalt concrete can be determined in the laboratory by using several different modes of repeated loads. Among these modes are the triaxial compression test, uniaxial compression test, flexural beam test, direct tension test and diametral indirect tension test. The diametral indirect tension test is preferred over the other tests because it is simple, rapid and requires Marshall size specimens (2).

The diametral test procedure to determine the resilient modulus of asphaltic concrete was developed by Schmidt (3) and is standardized by ASTM D4123-82 test procedure. According to this method, a pulsating compressive load is applied across a vertical diametral plane of Marshall specimens every 1-3 seconds with a 0.1 second duration and the corresponding horizontal deformation is recorded. This type of load produces a relatively uniform tensile stress acting perpendicular to the applied load plane. Either the horizontal deformation only or both horizontal and vertical deformations are measured. If both horizontal and vertical deformations are measured, both resilient modulus and Poisson's ratio can be determined. If the horizontal deformation only is measured, Poisson's ratio has to be assumed in order to determine the resilient modulus. The test is recommended to be performed at 41, 77 and 104^{o}F since the mixture response is very temperature susceptible. Typical values of 0.3, 0.35 and 0.4 have been commonly assumed for Poisson's ratio. Figure 2-1 shows a device that can be used to attach horizontal and vertical

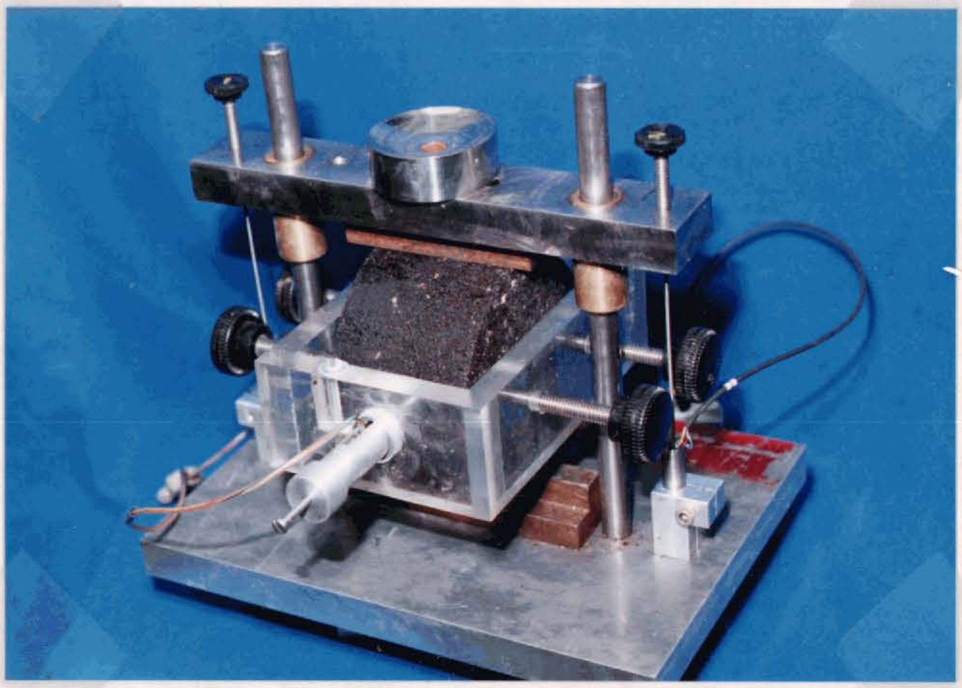


Figure 2-1. A device to attach horizontal and vertical LVDTs during the diametral resilient modulus test

LVDTs to measure deformations.

Typical Plots for load versus time and horizontal deformation versus time are shown in Figure 2-2. Two resilient moduli can be determined, instantaneous and total, depending on whether the instantaneous or the total deformation is used. The AAMAS procedure requires the determination of the total resilient modulus only which can be calculated as follows:

$$E_{RT} = \frac{P\,(v + 0.27)}{t\,H_{RT}} \qquad (2\text{-}1)$$

where E_{RT} = Total indirect tension resilient modulus (psi)

P = Repeated load (lb)

v = Total resilient Poisson's ratio

t = Thickness of specimen (in.)

H_{RT} = Total recoverable horizontal deformation (in.)

The test is performed at two perpendicular positions and the results are averaged. The test procedure is currently being revised by ASTM in order to ensure more accurate and consistent results.

TEST 2 - INDIRECT TENSILE STRENGTH

When the load is applied on the pavement a tensile stress is developed at the bottom of the asphalt concrete layer in most cases. Due to the repeated traffic load, these tensile stresses might result in cracking the asphalt concrete layer. The knowledge of the tensile strength (the tensile stress at failure) is important in developing a mechanistic method of pavement design.

The test is summarized in applying a compressive load with a constant rate of deformation along a diametrical plane of a Marshall-size specimen until failure. This type of loading produces a failure due to tensile stresses acting perpendicular to the applied load plane. The load at failure is recorded from which the indirect tensile strength is computed. The vertical and horizontal deformations at failure are also recorded. The horizontal deformation at failure can be used to compute the indirect tensile strain at failure. The AAMAS procedure requires that the diametral

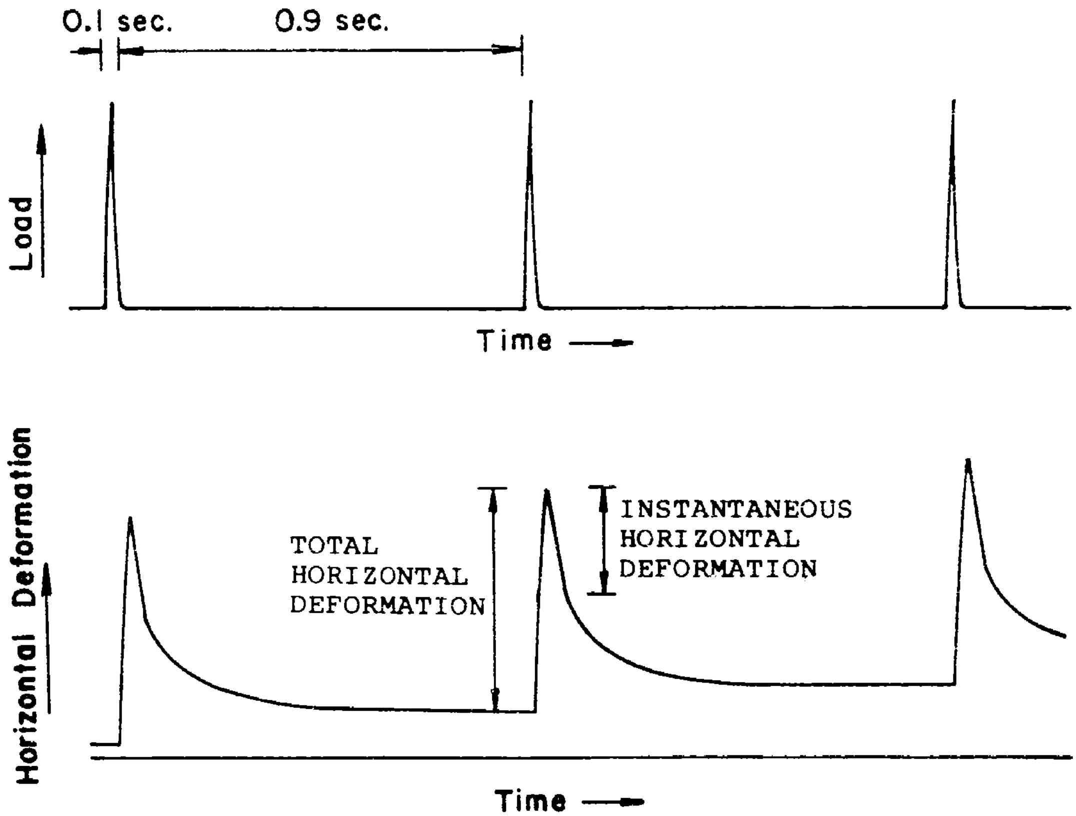


Figure 2-2. Typical plot of load and horizontal deformation during the resilient modulus test

resilient modulus test to be performed before the indirect tensile strength test. The indirect tensile strength test is required to be performed along the axis of lower resilient modulus. It is also required to use a deformation rate of 0.05 in./minute at 41°F and 2 in./minute at 77 and 104°F.

The indirect tensile strength and the tensile strain at failure are calculated as follows:

$$S_t = 0.156 \frac{P_{fail}}{h} \tag{2-2}$$

$$\varepsilon_t = X_t \cdot \frac{0.03896 + 0.1185\ \nu}{0.0673 + 0.2494\ \nu} \tag{2-3}$$

where:

S_t = Indirect tensile strength (psi)

P_{fail} = Total load at failure (lb)

h = Thickness of specimen (in.)

ε_t = Tensile strain at failure (in./in.)

X_t = Total horizontal deformation at failure (in.)

ν = Poisson's ratio

TEST 3 - INDIRECT TENSILE CREEP TEST

The response of a viscoelastic material such as asphalt concrete can be divided into two parts, elastic and viscous. The elastic response is instantaneous, while the viscous response is time dependent. Therefore, when a constant load is applied on an asphalt concrete specimen, it will deform instantaneously and it will continuously deform (creep) as long as the load is applied. The longer the load is applied, the larger the deformation. An example of this phenomenon is when a heavy truck is parked for a long time on an asphalt pavement on a hot day, deformation under the wheels could be noticed. On the other hand, if the same truck is driven on the same pavement, no deformation could be noticed since the load is applied for a short period of time. When the parked truck is removed most of the deformation will eventually be recovered. A small portion of the deformation, however, may not recover causing permanent deformation (rutting).

In the creep test, a constant load is applied to the specimen and the deformation is continuously measured. The load is then removed and the deformation is continuously measured.

In the indirect tensile creep test, a constant magnitude compression load is continuously applied along the vertical diametral plane of a Marshall-size specimen. This type of load will result in a tensile stress perpendicular to the applied load plane. Both vertical and horizontal deformations are continuously recorded. The horizontal deformation is then used to calculate the tensile creep strain and the tensile creep modulus at a particular duration of time. After the load is released, the rebound vertical and horizontal deformations are recorded over a fixed duration of time. The indirect tensile creep modulus is calculated at any loading time as follows:

$$C_t(t) = \frac{\sigma_t}{\varepsilon_t(t)} \tag{2-4}$$

where:

$C_t(t)$ = Indirect tensile creep modulus at time t (psi)

σ_t = Tensile stress (psi) = $0.156 \frac{P}{h}$

P = Applied load (lb)

h = Thickness of specimen (in.)

$\varepsilon_t(t)$ = Tensile strain at time t (in./in.)

= $\Delta H(t)\left[\frac{0.03896 + 0.1185\,\nu}{0.0673 + 0.2494\,\nu}\right]$

$\Delta H(t)$ = Horizontal deformation at time t (in.)

ν = Poisson's ratio

The detailed test procedure is shown in the AAMAS report. Currently, no ASTM or AASHTO procedure exists for the indirect tension creep test.

TEST 4 - UNIAXIAL COMPRESSION RESILIENT MODULUS TEST

The concept of the uniaxial compression resilient modulus test is similar to the diametral indirect tension resilient modulus test except that an axial load is applied. Unlike the diametral resilient modulus test, the uniaxial test results in uniform axial compressive stresses in the specimen. In this test a pulsating uniaxial load is applied on a cylindrical specimen every one second with a 0.1 second duration and the corresponding axial deformation is recorded. Similar to the diametral method of loading, two types of resilient moduli can be determined, instantaneous and total, depending on whether the instantaneous or total axial deformation is used. The AAMAS procedure require the determination of the total resilient modulus only which can be calculated as follows:

$$E_{CT} = \frac{\text{Repeated stress (psi)}}{\text{Total recoverable axial strain}} \tag{2-5}$$

where:

E_{CT} = Total uniaxial compressive resilient modulus (psi)

Repeated stress = Repeated axial load (lb)/A

A = Cross sectional area (in.^{2})

Total recoverable axial strain = total recoverable axial deformation (in.)/G

G = Gage length or specimen height (in.)

A 4 in. diameter and 4 in. high specimen is recommended by the AAMAS report. No ASTM or AASHTO test procedure is currently available. The axial load versus time and axial deformation versus time plots are similar to those in Figure 2-2 for the diametral loading.

TEST 5 - UNCONFINED COMPRESSIVE STRENGTH TEST

In this test a uniaxial compressive load is applied on a cylindrical specimen with a specified rate of deformation until failure. The test is standardized by AASHTO T167/ASTM D1074. In the AAMAS report, however, a rate of strain of 0.15 inches/inch/minute is required. Therefore, for 4 in. high specimens the rate of deformation is 0.6 inches/minute. Also, the AAMAS procedure requires a test temperature of 104°F.

At failure, the compressive stress, strain and strength are calculated as follows:

$$\sigma_{qu} = \frac{P}{A} \tag{2-6}$$

$$\varepsilon_{qu} = \frac{\Delta}{G} \tag{2-7}$$

$$S_{qu} = \frac{\sigma_{qu}}{\varepsilon_{qu}} \quad (2\text{-}8)$$

where:

σ_{qu} = Unconfined compressive stress at failure (psi)

P = Unconfined compressive load at failure (lb)

A = Cross sectional area (in.^{2})

ε_{qu} = Compressive strain at failure (in./in.)

Δ = Axial deformation at failure (in.)

G = Axial length or specimen height (in.)

S_{qu} = Unconfined compressive strength (psi)

TEST 6 - UNIAXIAL CREEP TEST

In this test, a uniaxial constant magnitude compressive load is applied on a cylindrical specimen, while the axial deformation is continuously recorded. The compressive stress, compressive creep strain and the compressive creep modulus can be computed at any loading time as follows:

$$\sigma_c = \frac{P}{A} \quad (2\text{-}9)$$

$$\varepsilon\,(t) = \frac{\Delta\,(t)}{G} \quad (2\text{-}10)$$

$$C_c\,(t) = \frac{\sigma_c}{\varepsilon\,(t)} \quad (2\text{-}11)$$

where:

σ_C = Compressive stress (psi)

P = Compressive load (lb)

A = Cross sectional area (in.^{2})

ε (t) = Compressive creep strain at time t (in./in.)

Δ (t) = Vertical deformation at time t (in.)

G = Gage length or specimen height (in.)

$C_c(t)$ = Compressive creep modulus (psi)

Currently, a tentative ASTM procedure for the uniaxial creep test is being developed. No AASHTO procedure is available at that time. The AAMAS procedure requires 4" x4" specimen size and a test temperature of 104°F. A loading time of 60 minutes and an unloading time of 60 minutes are required. A typical plot of vertical deformation versus time is shown in Figure 2-3. The slope and intercept of the creep curve can be obtained from this plot.

2.3 SPECIMEN CONDITIONING

A rational evaluation of asphalt concrete specimens should simulate the field condition in the lab as much as possible. Of course, it would be impractical, and may be impossible, to exactly duplicate the field condition in the lab because of the many factors involved. However, a reasonable and practical laboratory conditioning is needed.

Conditioning the specimen in the lab to simulate field conditions should not be confused with load conditioning used in some lab tests. Conditioning to simulate field conditions include moisture conditioning, aging, traffic densification, etc. On the other hand, load conditioning is used for other purposes in order to ensure proper deformation measurements. For example, during the resilient modulus test the load has to be applied to the specimen a few hundred times before the results are recorded in order to exclude the permanent deformation and to ensure full contact between the specimen and the loading heads. In the AAMAS report, as well as this report, the term "conditioning" is used for both purposes. Sometimes, the term "preconditioning" is also used.

The AAMAS study recommends three types of specimen conditioning. The detailed procedure is shown in the AAMAS report. A summary of the procedure is as follows:

a. Moisture Conditioning

Specimens are vacuum saturated until the water absorption is greater than 80%. Specimens are then frozen for 16 hours and thawed at 140°F for 24 hours and at 77°F for 2 hours.

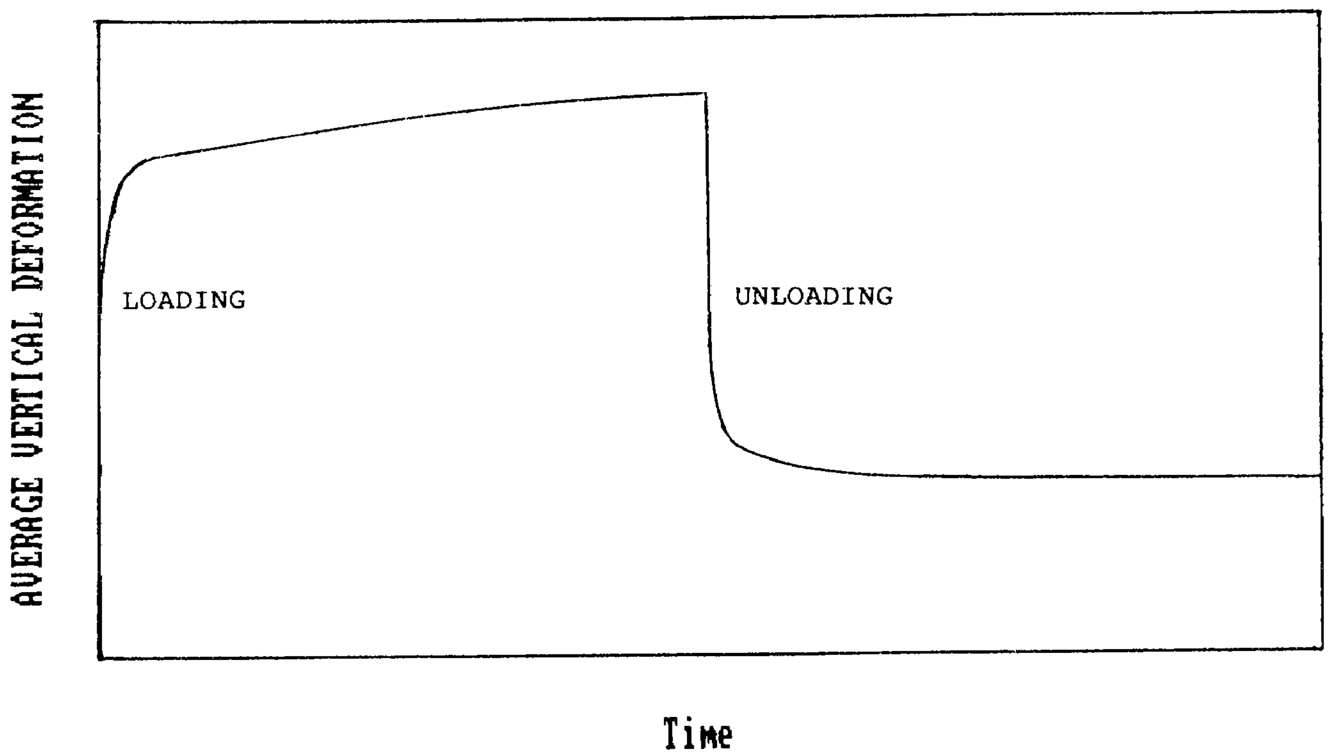


Figure 2-3. Typical plot of axial deformation versus time during the uniaxial creep test

b. Environmental Aging (Temperature Conditioning)

Specimens are heated at 140°F for 2 days and at 225°F for 5 days. Specimens are then cooled at 41°F for one day.

c. Traffic Densification

Specimens are further compacted to simulate traffic until refusal or until the final air void level is reached. The gyratory testing machine (ASTM D3387) or the gyratory shear compactor (ASTM D4031) is recommended. If either of the gyratory machines is not available, the California kneading compactor can be used (AASHTO T247/ASTM D1561).

Table 2-2 shows a summary of specimen conditioning names and procedure.

Table 2-2. Specimen conditioning

Conditioning No.	Name	Procedure
a	Moisture conditioning	Vacuum saturation + freeze and thaw
b	Environmental aging	Heating for 7 days + cooling for one day
c	Traffic densification	Heating and further compaction

2.4 GROUPING AND TEST SEQUENCE

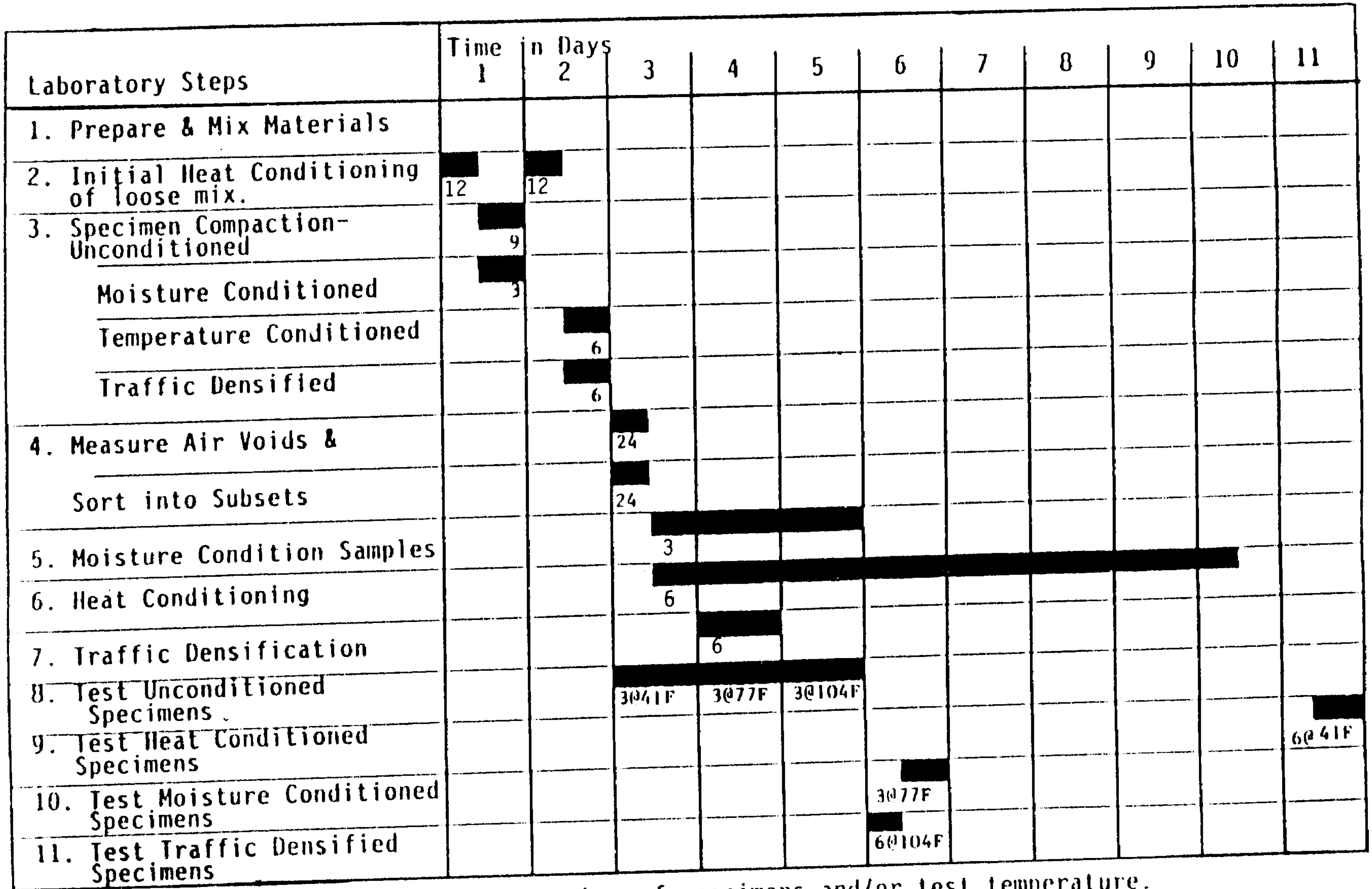
The complete AAMAS procedure requires 24 specimens; eighteen 4" x 2.5" specimens and six 4" x 4" specimens. Specimens are grouped into 8 sets of 3 specimens each. The first 6 sets have 4" x 2.5" specimens, while the last 2 sets have 4" x 4" specimens. The specimens are grouped in such a way that the average unit weight (and air voids) of the different sets are approximately equal. Table 2-3 shows the conditioning as well as test type, sequence, temperature and measurements for each specimen set. Table 2-4 shows the approximate time required to complete the AAMAS evaluation of one set of asphalt mixture.

Table 2-3. Conditioning, test sequence and measurements

Set No.	No. of Speci- mens	Size (in.)	Condit- ioning*	Test No.**, Sequence & Temperature	Measurement
1	3	4 x 2.5	None	1, 2 (41°F)	Diametral resilient modulus, indirect tensile strength, tensile strain at failure
2	3	4 x 2.5	None	1, 2 (77°F)	Same as set 1
3	3	4 x 2.5	None	1, 2 (140°F)	Same as set 1
4	3	4 x 2.5	a	1, 2 (77°F)	Same as set 1
5	3	4 x 2.5	b	1, 2 (41°F)	Same as set 1
6	3	4 x 2.5	b	3 (41°F)	Slope and intercept of creep curve, tensile creep modulus
7	3	4 x 4	c	4, 5 (104°F)	Axial resilient modulus, unconfined compressive strength, compressive strain at failure
8	3	4 x 4	c	6 (104°F)	Compressive creep strain, compressive creep modulus

* See Table 2-2
** See Table 2-1

Table 2-4. Time Schedule for the AAMAS process



Note: Numbers in blocks represent the number of specimens and/or test temperature.
The total time frame to complete the entire AAMAS process is less then 2 weeks.

CHAPTER 3. EVALUATION OF ADOT MIXTURE PROPERTIES

3.1 SPECIMEN PREPARATION

The complete AAMAS procedure requires 24 specimens; eighteen 4" x 2.5" specimens and six 4" x 4" specimens. The AAMAS report recommends the use of the gyratory compactor (ASTM D3387 or D4013) since it closely simulates the mix compaction in the field. The report further concludes that the California kneading compactor (AASHTO T247/ASTM D1561) is the next preferred device, while the Marshall hammer (AASTO T245/ASTM D1559) is the least desirable compactor. Since the Marshall hammer is the most commonly used compactor and it is the compactor currently used by ADOT, there is a need to compare between the responses of Marshall-compacted specimens and specimens compacted by other devices. Also, since the gyratory compactor is not currently available at either ADOT or ASU lab, it was decided to evaluate two sets of 24 specimens; one set compacted by the kneading compactor and the other set compacted by the Marshall hammer. It was also decided that the bulk specific gravities and air voids of all specimens should be similar to those of typical ADOT mixes.

The aggregate was provided by ADOT which was originally obtained from United Metro No. 1 located in Phoenix, Arizona. The aggregate is river deposit produced from the Salt River in Arizona. Table 3-1 shows the aggregate gradation.

Table 3-1. Aggregate gradation

Sieve Size	% Passing
3/4 in.	100
1/2 in.	98
3/8 in	83
1/4 in	64
No. 4	58
No. 8	45
No. 40	19
No. 200	4.5

An AC-30 asphalt cement was used in this study which was provided by ADOT and originally obtained from Sahuaro Petroleum and Asphalt Company in Phoenix, Arizona.

The mix ingredient was designed by ADOT according to ARIZ 815c procedure (4). The design asphalt content was 4.7% by total weight of mix. The bulk density according to ARIZ 415a test procedure was 145.2 pcf. The maximum theoretical density of the loose mixture (Rice test) was determined by ADOT according to ARIZ 806c procedure and found to be 152.4 pcf. The air voids of the compacted specimens is 4.7%.

3.1.1 KNEADING COMPACTED SPECIMENS

The first set of specimens was compacted at ASU using the California kneading compactor (Figure 3-1). Although the AASHTO T247 calls for 20 kneading blows at 250 psi and 150 blows at 500 psi for the 4" x 2.5" specimens, the compacting effort was adjusted on a trial-and-error basis to achieve a bulk specific gravity and air voids similar to those of typical ADOT mixtures. After several trials it was found that 20 blows at 250 psi followed by 100 blows at 500 psi provide the required density. The 4" x 4" specimens were compacted using the same procedure except for 20 blows at 250 psi and 120 blows at 500 psi. Table 3-2 shows the thicknesses and unit weights of the kneading compacted specimens. Note that specimens are numbered and grouped into 8 sets in such a way that the average unit weights of all sets are similar as recommended in the AAMAS report (1). The percent air voids and actual diameters are shown in the data sheets in Appendix A.

3.1.2. MARSHALL COMPACTED SPECIMENS

The second set of specimens was compacted by ADOT using the manual Marshall hammer. Seventy five blows on each side of the specimen were applied on the 4" x 2.5" specimens, while 100 blows on each side were applied on the 4" x 4" specimens. Table 3-3 shows the thicknesses and unit weights of the Marshall compacted specimens. As before, specimens were numbered and grouped into 8 sets in such a way that the average unit weights of all sets are approximately equal as recommended in the AAMAS report. The percent air voids and actual diameters are shown in the data sheets in Appendix B.

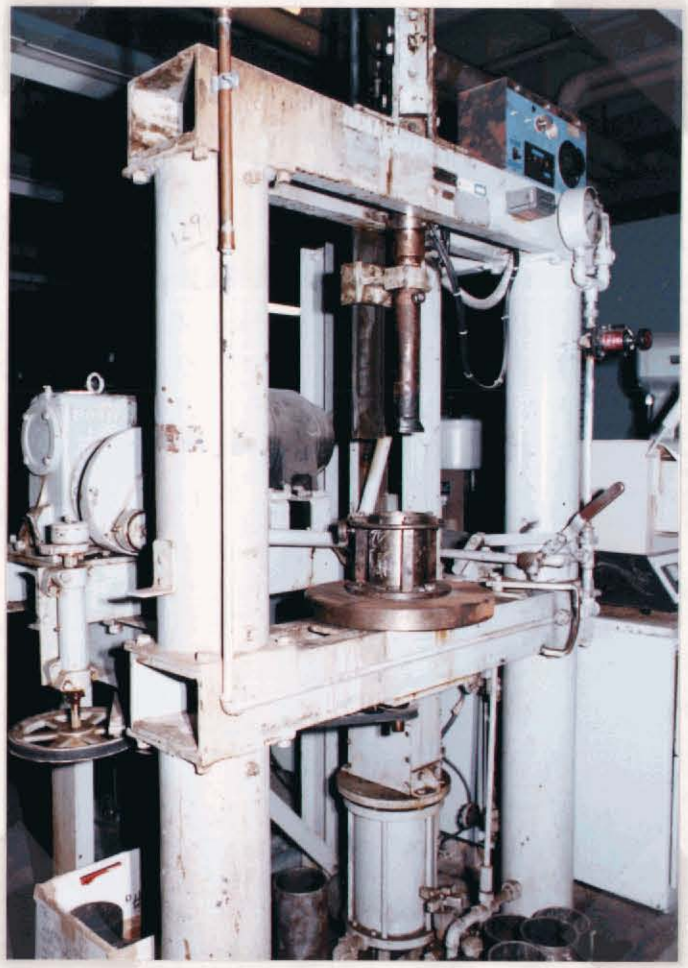


Figure 3-1. California kneading compactor

Table 3-2 Thickness and unit weights of kneading compacted specimens

Set No.	Specimen No.	Nominal Thickness(in.)	Actual Thickness(in.)	Unit Weight (pcf)	Average Set Unit Weight (pcf)
1	1	2.5	2.438	145.1	145.2
	2	2.5	2.411	145.8	
	3	2.5	2.415	144.7	
2	4	2.5	2.429	145.2	145.2
	5	2.5	2.424	145.7	
	6	2.5	2.431	144.8	
3	7	2.5	2.449	145.6	145.3
	8	2.5	2.442	144.6	
	9	2.5	2.420	145.7	
4	10	2.5	2.414	145.7	145.2
	11	2.5	2.436	145.3	
	12	2.5	2.438	144.6	
5	13	2.5	2.425	144.9	145.2
	14	2.5	2.422	145.8	
	15	2.5	2.423	145.0	
6	16	2.5	2.409	145.7	145.2
	17	2.5	2.404	145.4	
	18	2.5	2.440	144.6	
7	19	4.0	3.790	145.1	145.3
	20	4.0	3.812	145.5	
	21	4.0	3.933	145.2	
8	22	4.0	3.811	144.7	145.3
	23	4.0	3.811	144.8	
	24	4.0	3.858	146.3	

Table 3-3 Thicknesses and unit weights of Marshall compacted specimens

Set No.	Specimen No.	Nominal Thickness(in.)	Actual Thickness(in.)	Unit Weight (pcf)	Average Set Unit Weight (pcf)
1	1	2.5	2.465	144.8	145.3
	2	2.5	2.450	145.1	
	3	2.5	2.439	146.0	
2	4	2.5	2.453	144.9	145.3
	5	2.5	2.440	145.2	
	6	2.5	2.459	145.7	
3	7	2.5	2.452	144.8	145.3
	8	2.5	2.451	145.6	
	9	2.5	2.456	145.4	
4	10	2.5	2.460	145.3	145.3
	11	2.5	2.459	145.3	
	12	2.5	2.469	145.2	
5	13	2.5	2.457	144.9	145.2
	14	2.5	2.490	143.9	
	15	2.5	2.432	146.8	
6	16	2.5	2.477	144.5	145.2
	17	2.5	2.465	144.6	
	18	2.5	2.443	146.5	
7	19	4.0	3.968	144.4	145.2
	20	4.0	3.951	145.0	
	21	4.0	3.933	146.2	
8	22	4.0	3.963	144.8	145.2
	23	4.0	3.938	145.0	
	24	4.0	3.915	145.8	

3.2 SPECIMEN CONDITIONING

Both kneading compacted and Marshall compacted specimens were conditioned according to the AAMAS procedure. Three types of conditioning were used; moisture conditioning, environmental aging and traffic densification as discussed in Chapter 2.

The moisture conditioning was performed as recommended by the AAMAS study. When the water absorption was computed after vacuum saturation a value of slightly more than 100% was obtained for all specimens. This indicates that there was a minor error in either the bulk specific gravity or in the theoretical maximum specific gravity determination. It was felt, however, that the 80% minimum saturation requirement has been satisfied.

Since the gyratory compactor was not available, the California kneading compactor was used for the traffic densification of both kneading compacted and Marshall compacted specimens. Since it was not easy to define "refusal" using the kneading compactor, 500 kneading blows were applied to each specimen in order to ensure that refusal have been reached. Table 3-4 shows the bulk unit weights and air voids before and after traffic densification.

3.3 LABORATORY TESTING

All tests were conducted at the ASU highway materials lab. The two main pieces of equipment used in the study are two electrohydraulic closed-loop testing machines. The first machine is manufactured by the Structural Behavior Engineering Laboratory (SBEL) in Phoenix, Arizona (Figure 3-2), while the second machine is manufactured by Instron Corporation in Canton, Massachusetts (Figure 3-3). Both machines are connected to microcomputers and are capable of applying either static or dynamic loads with different loading types and magnitudes. The reason for using two machines in this study is that the load cell size and the computer program of the SBEL machines are suitable for applying small loads necessary for resilient modulus testing, while the Instron machine is suitable for applying heavy loads required for other tests. It should be noted, however, that these equipment qualifications are specific to the machine models available to the ASU highway materials lab and either manufacturing company is capable of manufacturing

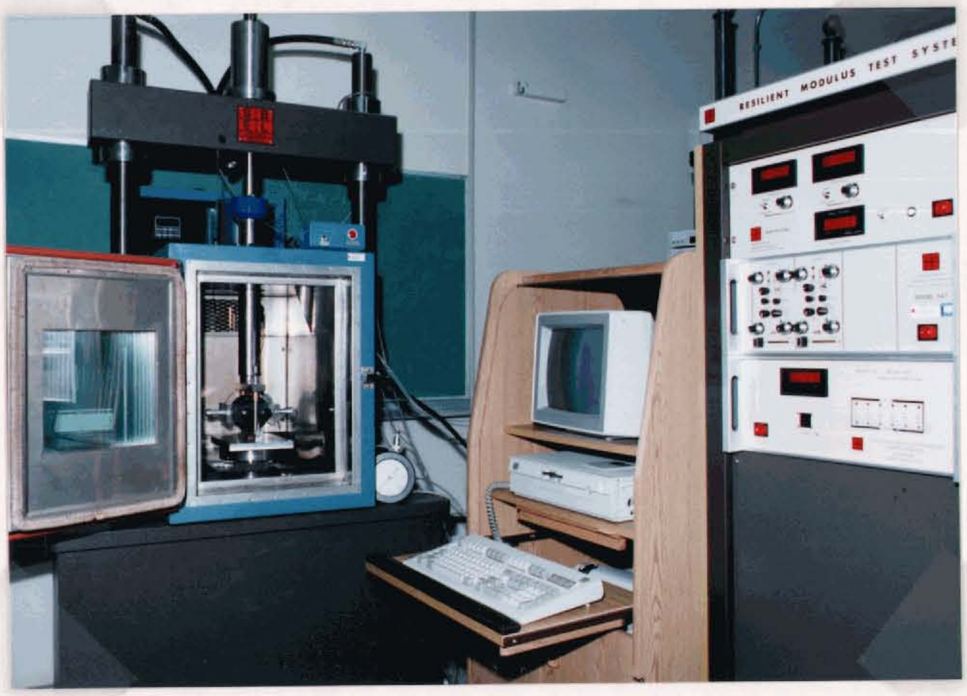


Figure 3-2. SBEL electrohydraulic closed-loop testing machine during the diametral resilient modulus test

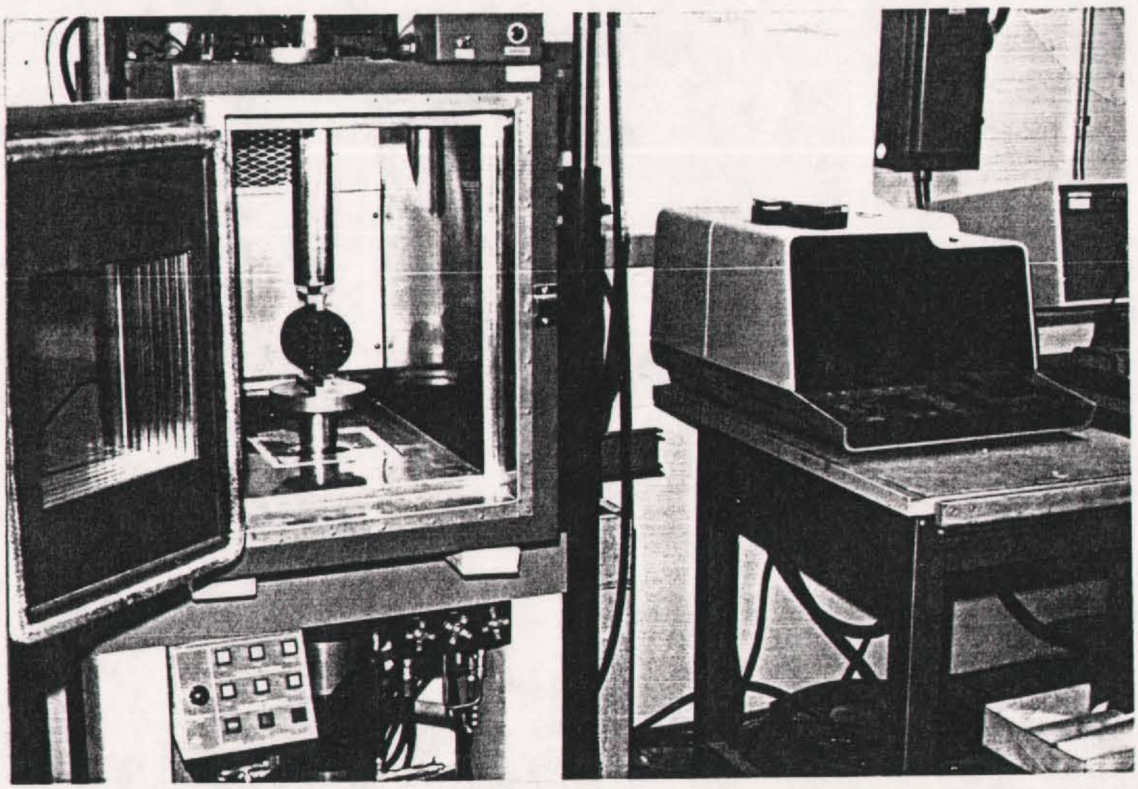


Figure 3-3. Instron electrohydraulic closed-loop testing machine during the indirect tensile strength test

machines with a wide range of capabilities. In this study, the SBEL machine was used to perform tests 1, 3, 4 and 6, while the Instron machine was used for tests 2 and 5 as defined in Table 2-1.

Table 3-4 Average unit weights and air voids before and after traffic densification

Property	Set No.	Kneading Compacted	Marshall Compacted	Average
Unit weight before (pcf)	7	145.3	145.2	145.3
Unit weight after (pcf)	7	148.4	147.1	147.8
Unit weight before (pcf)	8	145.3	145.2	145.3
Unit weight after (pcf)	8	148.8	147.4	148.1
Air voids before (%)	7	4.7	4.8	4.8
Air void after (%)	7	2.6	3.4	3.0
Air voids before (%)	8	4.7	4.8	4.8
Air void after (%)	8	2.4	3.3	2.9

An environmental chamber manufactured by BEMCO Inc. in Pacoima, California was used during testing. The chamber can be attached to either testing machines so that the test could be performed at the required temperature. The chamber is capable of maintaining a wide range of temperatures above and below room temperature.

Testing was performed as specified in the AAMAS study. In the unconfied compressive strength test (test 5), however, an incorrect rate of deformation was initially used. Therefore, the incorrect results were discarded and the test was later repeated using the correct rate of deformation on the specimens which were tested for uniaxial creep (test 6). It is believed that the creep effect was fully removed after several days of storing the specimens in an unloading condition.

In the indirect tensile strength test (test 2) the horizontal deformation could not be measured due to technical difficulties in the electronic equipment. Instead, the vertical deformation was measured from which the horizontal deformation was computed according to Equation 3-1 from ASTM D4123-82.

$$\nu = 3.59 \frac{\Delta H}{\Delta V} - 0.27 \qquad (3\text{-}1)$$

where:

ν = Poisson's ratio

ΔH = horizontal deformation, in.

ΔV = vertical deformation, in.

3.4 TEST RESULTS

The detailed test results are shown in Appendices A and B for kneading compacted and Marshall compacted specimens, respectively. Tables 3-5 through 3-8 show the average test results of unconditioned, moisture conditioned, environmental conditioned and traffic densified specimens, respectively. Figure 3-4 illustrates the average diametral resilient modulus at different temperatures obtained from Table 3-5.

Table 3-5 Average test results of unconditioned specimens

Property	Set No.	Temp F	Kneading Compacted	Marshall Compacted	Average
Diametral E_R (ksi)	1	41	2,414	2,371	2,393
Tensile strength (psi)	1	41	274	357	316
Tensile strain (mils/in)	1	41	3.0	4.0	3.5
Diametral E_R (ksi)	2	77	785	943	864
Tensile strength (psi)	2	77	283	322	303
Tensile strain (mils/in)	2	77	6.7	6.5	6.6
Diametral E_R (ksi)	3	104	192	179	186
Tensile strength (psi)	3	104	93	107	100
Tensile strain (mils/in)	3	104	8.2	6.0	7.1

Table 3-6 Average test results of moisture conditioned specimens

Property	Set No.	Temp F	Kneading Compacted	Marshall Compacted	Average
Diametral E_R (ksi)	4	77	399	296	348
Tensile strength (psi)	4	77	87	81	84
Tensile strain (mils/in)	4	77	6.4	4.0	5.2

Table 3-7 Average test results of environmental conditioned specimens

Property	Set No.	Temp F	Kneading Compacted	Marshall Compacted	Average
Diametral E_R (ksi)	5	41	3,086	3,912	3,499
Tensile strength (psi)	5	41	392	443	418
Tensile strain (mils/in)	5	41	2.6	2.7	2.7
Slope of creep curve (10^{-5} mils/sec)	6	41	2.9	0.6	1.8
Intercept of creep curve (mils)	6	41	0.1	0.1	0.1
Tensile creep modulus at 3,600 sec.(ksi)	6	41	92	475	284

Table 3-8 Average test results of traffic densified specimens

Property	Set No.	Temp F	Kneading Compacted	Marshall Compacted	Average
Axial E_R (ksi)	7	104	30	31	31
Compressive strength (psi)	8	104	715	705	710
Compressive strain (mils/in)	8	104	24.0	18.5	21.3
Slope of creep curve (10^{-5} mils/sec)	8	104	25	31	28
Intercept of creep curve (mils)	8	104	7.2	8.0	7.6
Compressive creep modulus (ksi)					
at 10 sec	8	104	15.5	15.2	15.4
100 sec	8	104	11.1	10.4	10.8
1,000 sec	8	104	9.8	8.0	8.9
3,600 sec	8	104	9.2	8.1	8.7

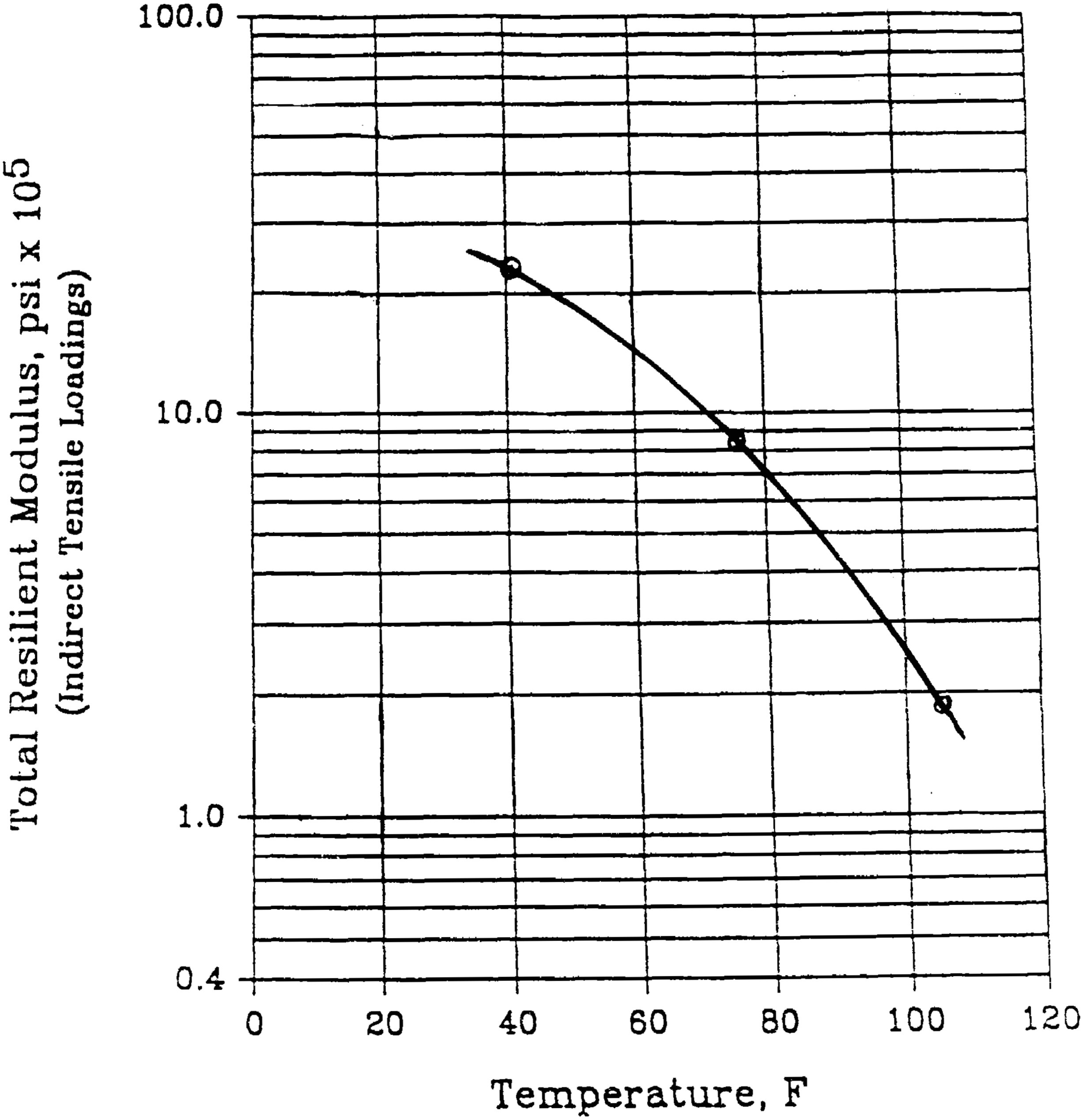


Figure 3-4. Average total diametral resilient moduli of ADOT specimens at various temperatures

CHAPTER 4. PREDICTION OF ADOT MIXTURE PERFORMANCE

4.1 BACKGROUND

The concept of relating the mixture properties to the pavement performance is logical and appropriate in order to optimize mixture and structural designs. Many models have been developed by previous researchers for this purpose. However, these models are limited in use to some degree. The main reason is that the available models are not comprehensive enough to cover all variables involved in pavement performance. The AAMAS study presents some guidelines to provide a recommended practice for evaluating asphalt concrete mixtures based on performance related criteria. These guidelines are based on models suggested for use in NCHRP Project 1-26.

The AAMAS procedure consists of a series of steps using results from the test program, discussed in Chapter 2, as well as interactions with various models predicting the types of distress more common with asphalt concrete pavements. The final product of the AAMAS are the structural and material combinations needed to meet the design requirements or assumptions used by the pavement design engineer. In this chapter, the properties of typical ADOT mixtures presented in Chapter 3 are compared with the performance-related criteria reported in the AAMAS study.

4.2 AASHTO STRUCTURAL LAYER COEFFICIENT

The 1986 AASHTO guide(5) recommends the estimation of the structural layer coefficient from the resilient modulus measured at 68°F in accordance with the ASTM D4123. The AAMAS study, however, recommends the consideration of the environmental effects on the structural design by considering the seasonal fatigue damage. In other words, use seasonal resilient moduli to calculate seasonal fatigue damage and sum the seasonal damages to determine an annual damage. From the annual damage, an effective asphalt concrete resilient modulus can be calculated which can be used to estimate the structural layer coefficient.

The following is a step by step procedure that can be used to ensure that the asphalt concrete mixture meets or exceeds the layer coefficient assumed during structural design.

- Obtain the seasonal average pavement temperature for each season.
- Determine the total resilient modulus at each seasonal temperature. Figure 4-1 shows the acceptable range of moduli (unconditioned) at various temperatures.
- Obtain the fatigue factor for each seasonal Resilient Modulus from Figure 4-2.
- Calculate the effective resilient modulus using Equation 4-1.

$$E_{RE} = \frac{\Sigma(E_{RT}^{(i)} \times FF^{(i)})}{\Sigma FF} \qquad (4\text{-}1)$$

where:

E_{RE} = Effective resilient modulus based on a fatigue damage approach

$E_{RE}^{(i)}$ = Total resilient modulus as measured by ASTM D 4123 at the average pavement temperature for season i

FF = The fatigue factors obtained from Figure 4-2

This effective resilient modulus should equal or exceed the modulus value used to estimate the AASHTO structural layer coefficient used for design (Figure 4-3 (5)). The GPS (General Pavement Sections) projects of the SHRP LTPP (Long-Term Pavement Performance) program are to provide the necessary pavement performance data to find the resilient modulus - AASHTO layer coefficient relationship to be adequate, with or without modification, or inappropriate.

Example for Determining Structural Layer Coefficient

Asphalt concrete; AC- 30

Aggregate type and gradation: as used in this study

Asphalt content: 4.7% by total weight of mix

Seasonal average pavement temperatures:

Fall:	80°F
Winter:	70°F
Spring:	85°F
Summer	100°F

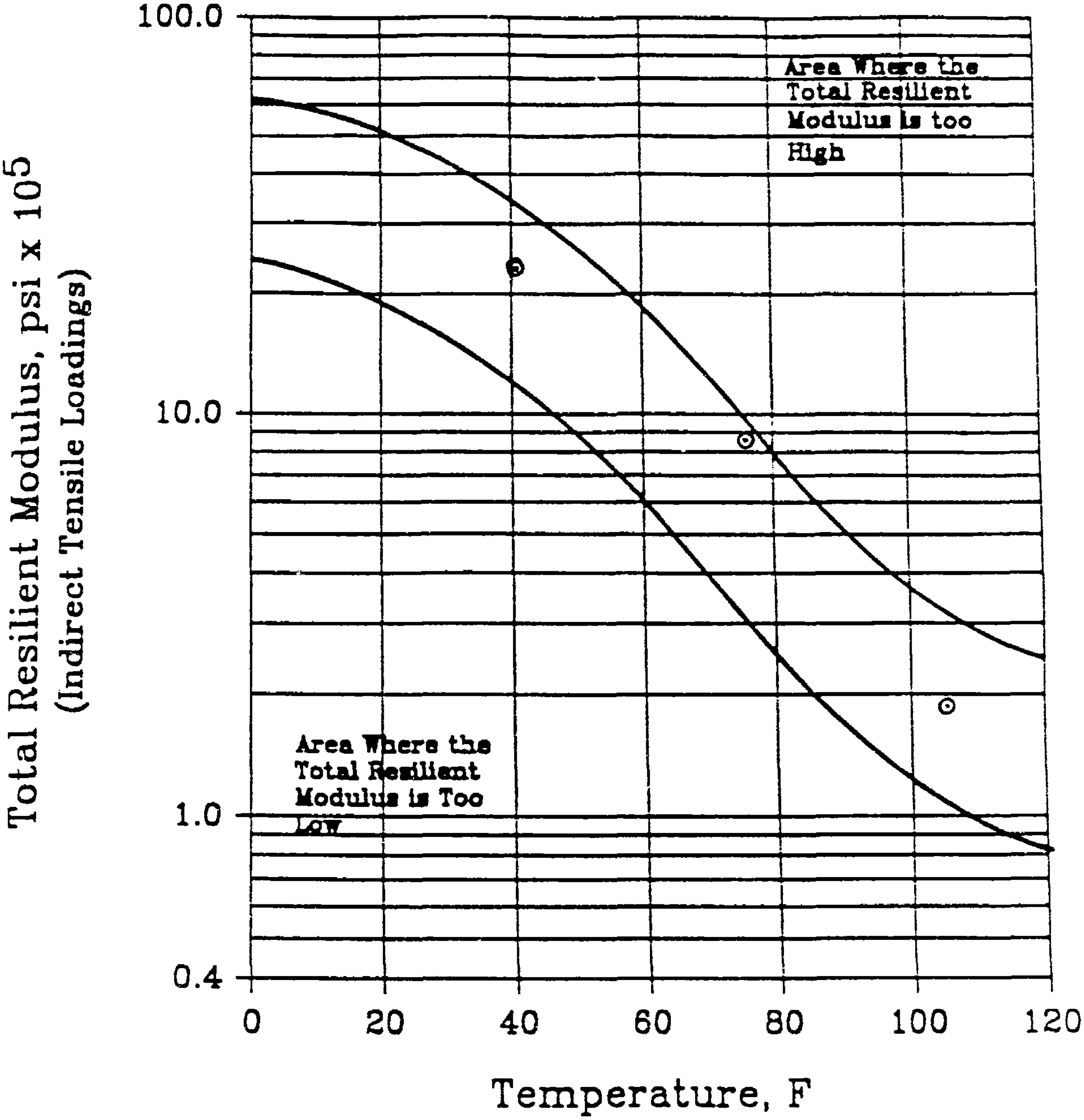


Figure 4-1. Acceptable range of diametral total resilient moduli at various temperatures(1)

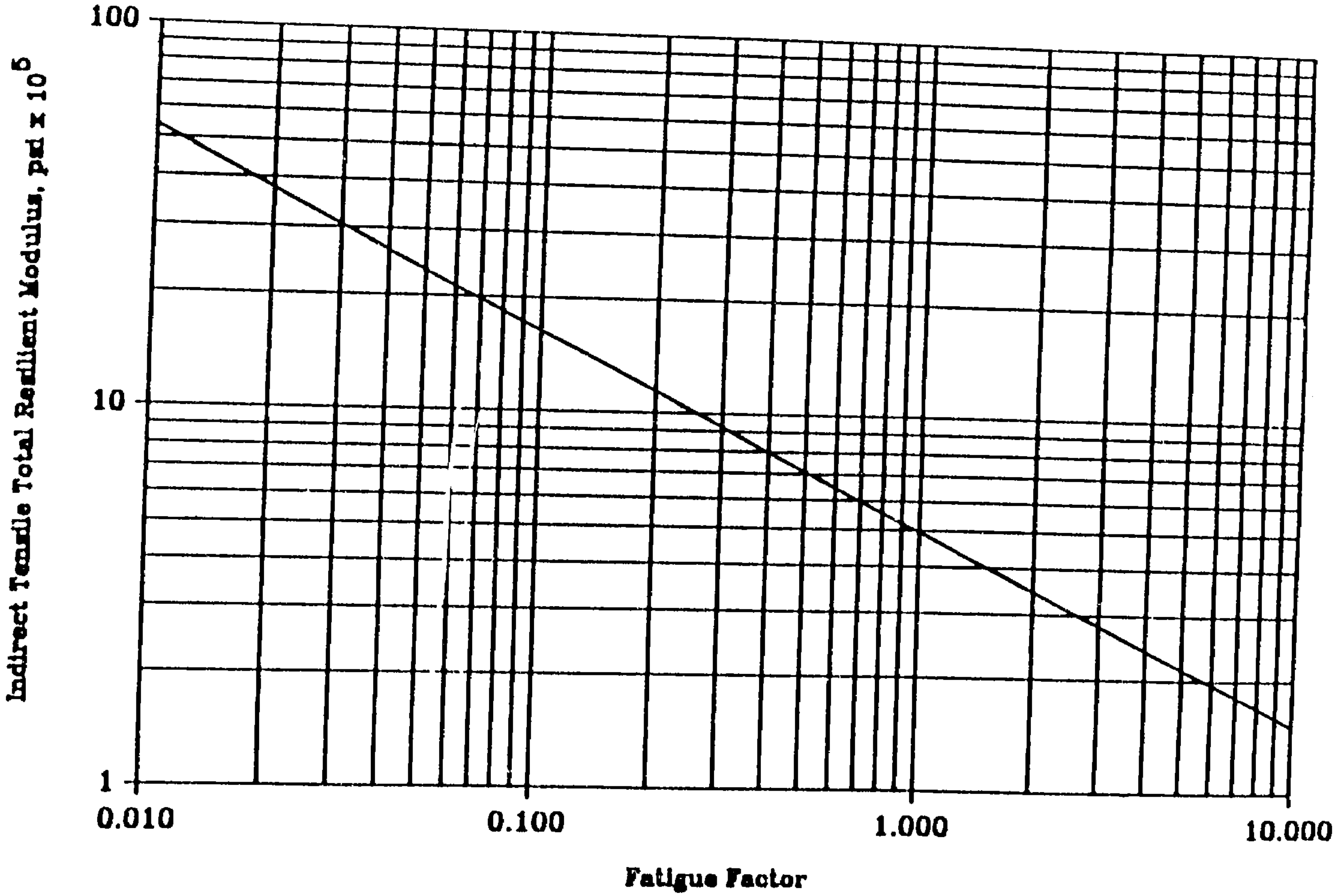


Figure 4-2. Estimation of the fatigue factor to determine equivalent annual modulus (1)

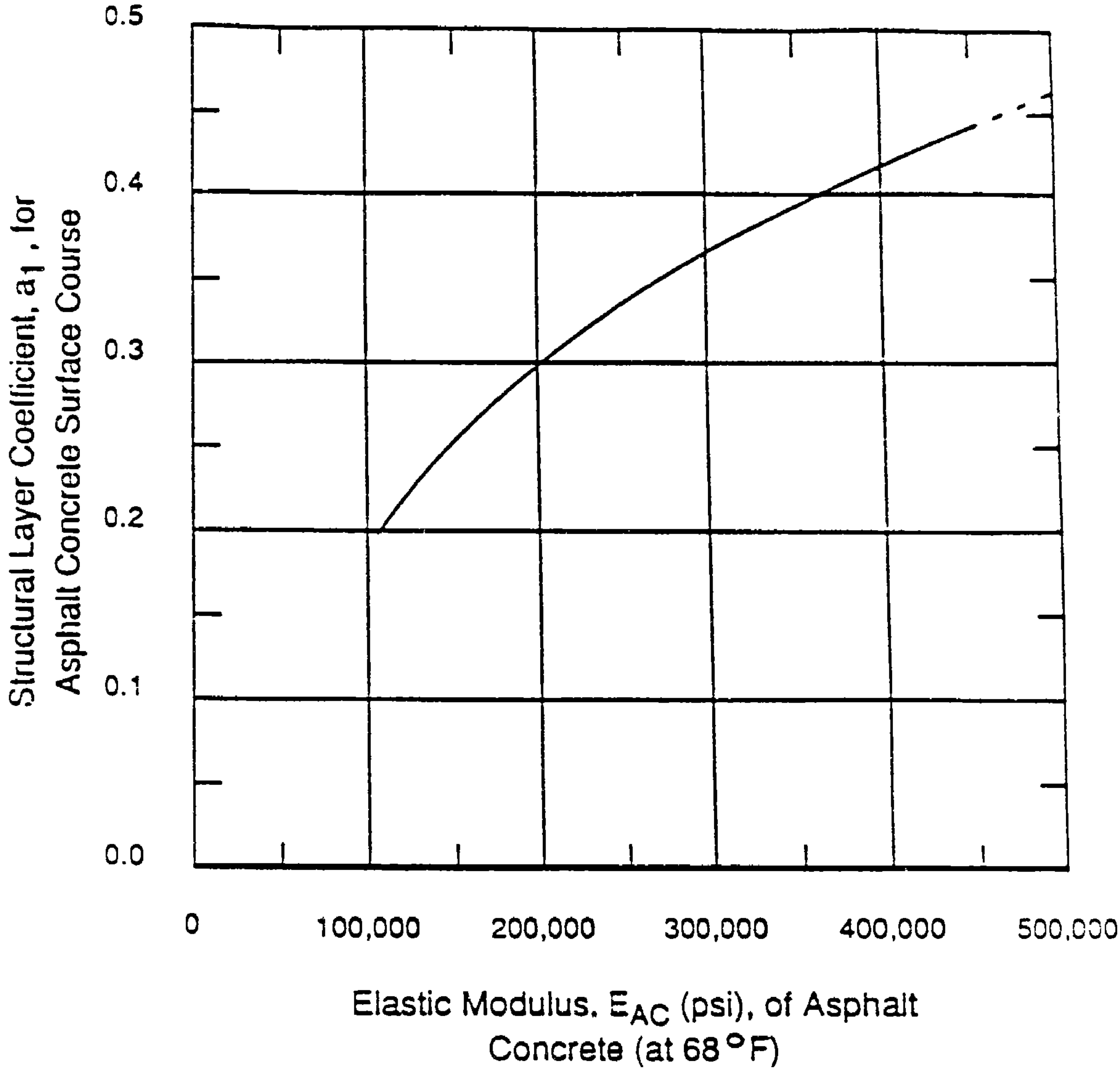


Figure 4-3. Chart for estimating structural layer coefficient of dense-graded asphalt concrete based on elastic (resilient) modulus (5)

Comparing the test results for unconditioned ADOT specimens (Table 3-5) with the recommendations in Figure 4-1, it can be seen that the average ADOT moduli are within the appropriate range at all 3 test temperatures; 41, 77 and 104°F.

From Figure 3-4 the moduli at 80, 70, 85 and 100°F are 700, 1050, 560 and 260 ksi. From Figure 4-2 the corresponding fatigue factors are 0.50, 0.22, 0.80 and 3.6. Using Equation 4-1, the effective resilient modulus is 384 ksi. Figure 4-3 shows that the structural coefficient (a_1) for this material should be 0.42. The ADOT design manual shows that if the modulus at 70°F is 1,050 ksi according to this study, the structural coefficient a_1 is outside of the normal range and should be limited to about 0.44 (Reference 4 , Figure 202.02-3).

4.3 RUTTING

Two types of rutting are considered; 1) densification or one dimensional consolidation and 2) the lateral movement or plastic flow of asphalt from wheel loads. The more severe premature rutting failures and distortion of asphalt concrete materials are related to lateral flow and/or loss of shear strength of the mix, rather than densification. Currently, there is no mechanistic/empirical model that adequately considers the lateral flow problem (1).

Rutting from one-dimensional consolidation can be estimated using the traffic densification procedure recommended in the AAMAS report (1). Limiting the air voids at mixture refusal limits the amount of additional densification caused by traffic, assuming that the mixture is properly compacted on the roadway to an air void level between 5 to 7 percent. The air voids at mixture refusal should be greater than 2 percent when compacted with the gyratory devices (1). Table 3-4 indicates that the air voids after densification of specimens tested in this study are greater than 2%. Therefore, the possibility of rutting due to one-dimensional consolidation is small.

A few mathematical models are reported in the AAMAS report to estimate the rutting rate of asphalt concrete layers in the field. Figures 4-4 through 4-7 illustrate graphical solutions of the range of data that can be generated for different pavements, climates and loading conditions. The figures can be used as gross guidelines for mixture evaluation on high-volume roadways.

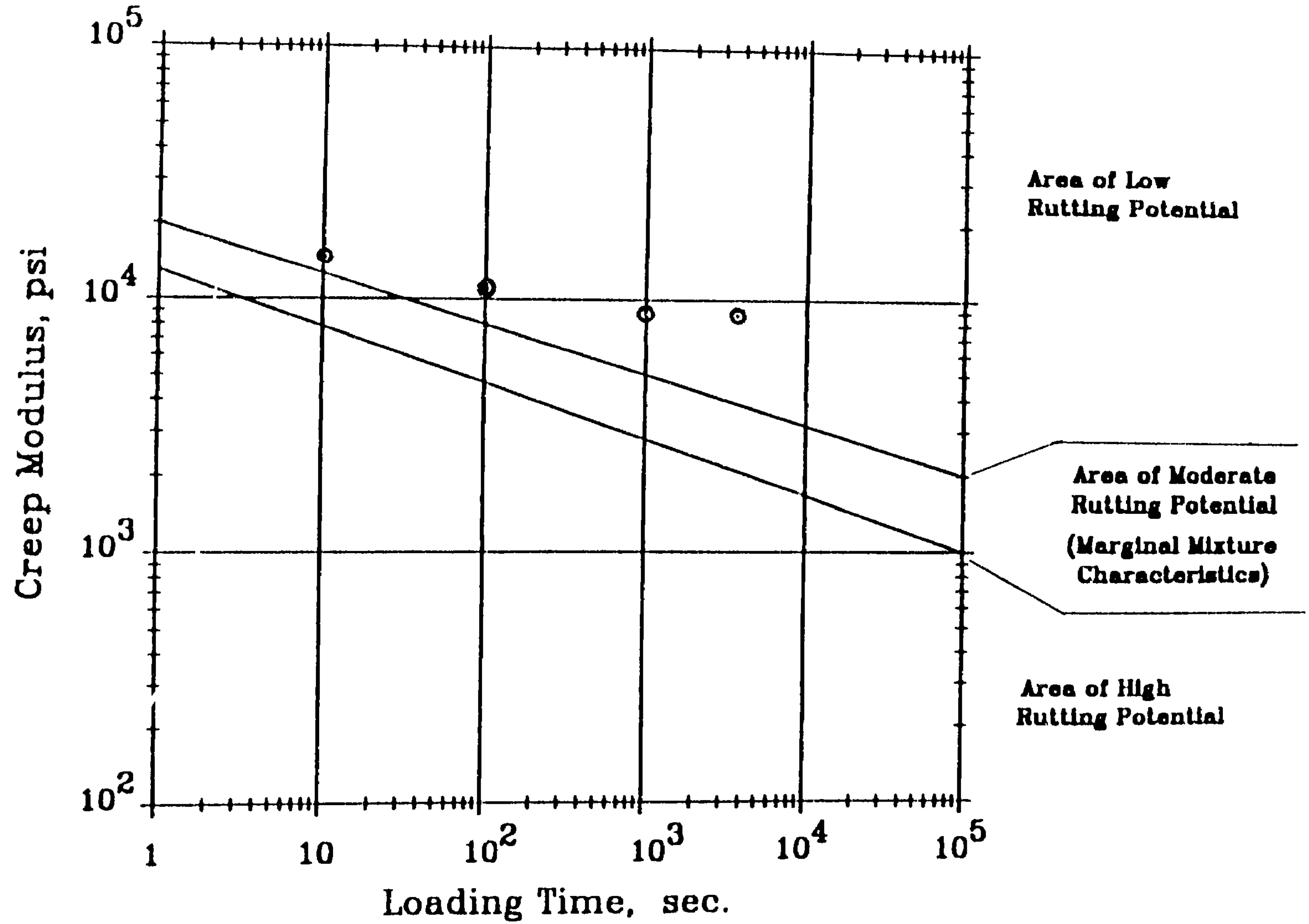


Figure 4-4. Asphalt concrete mixture rutting potential for the lower layers of full-depth asphalt pavements (1)

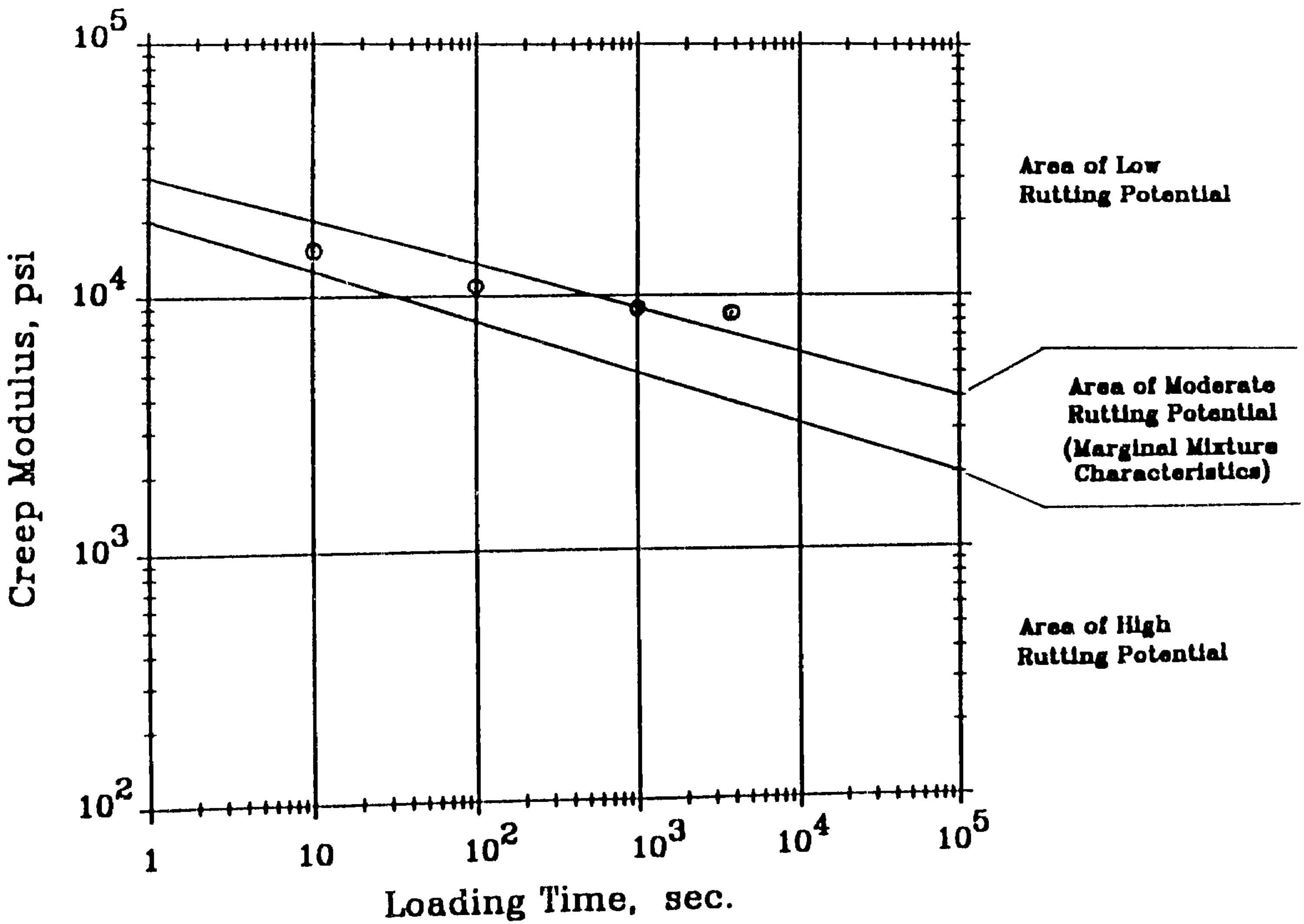


Figure 4-5. Asphalt concrete mixture rutting potential for intermediate layers in thick or full-depth asphalt pavements (1)

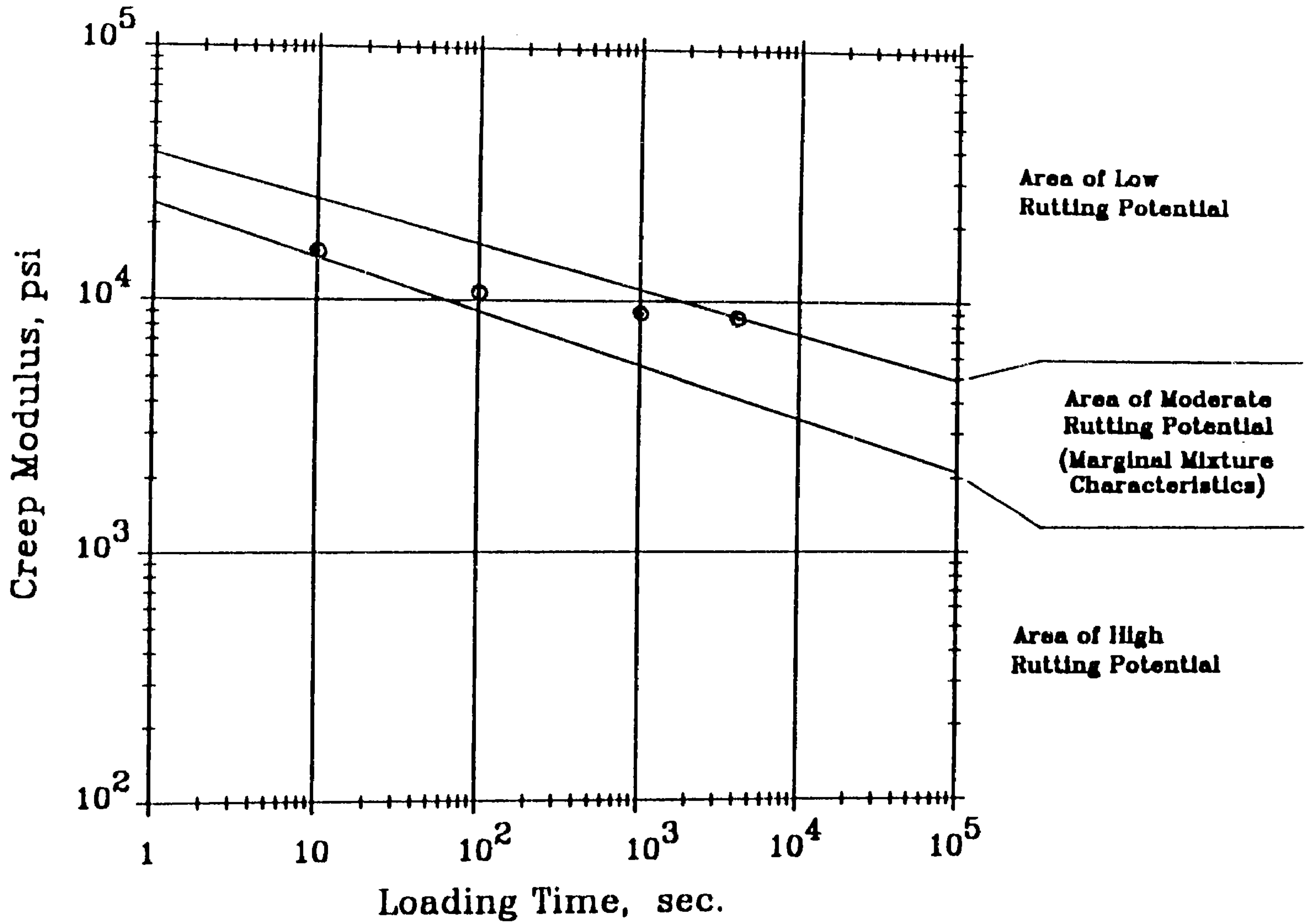


Figure 4-6 Asphalt concrete mixture rutting potential for surface layers of asphalt concrete pavements (1)

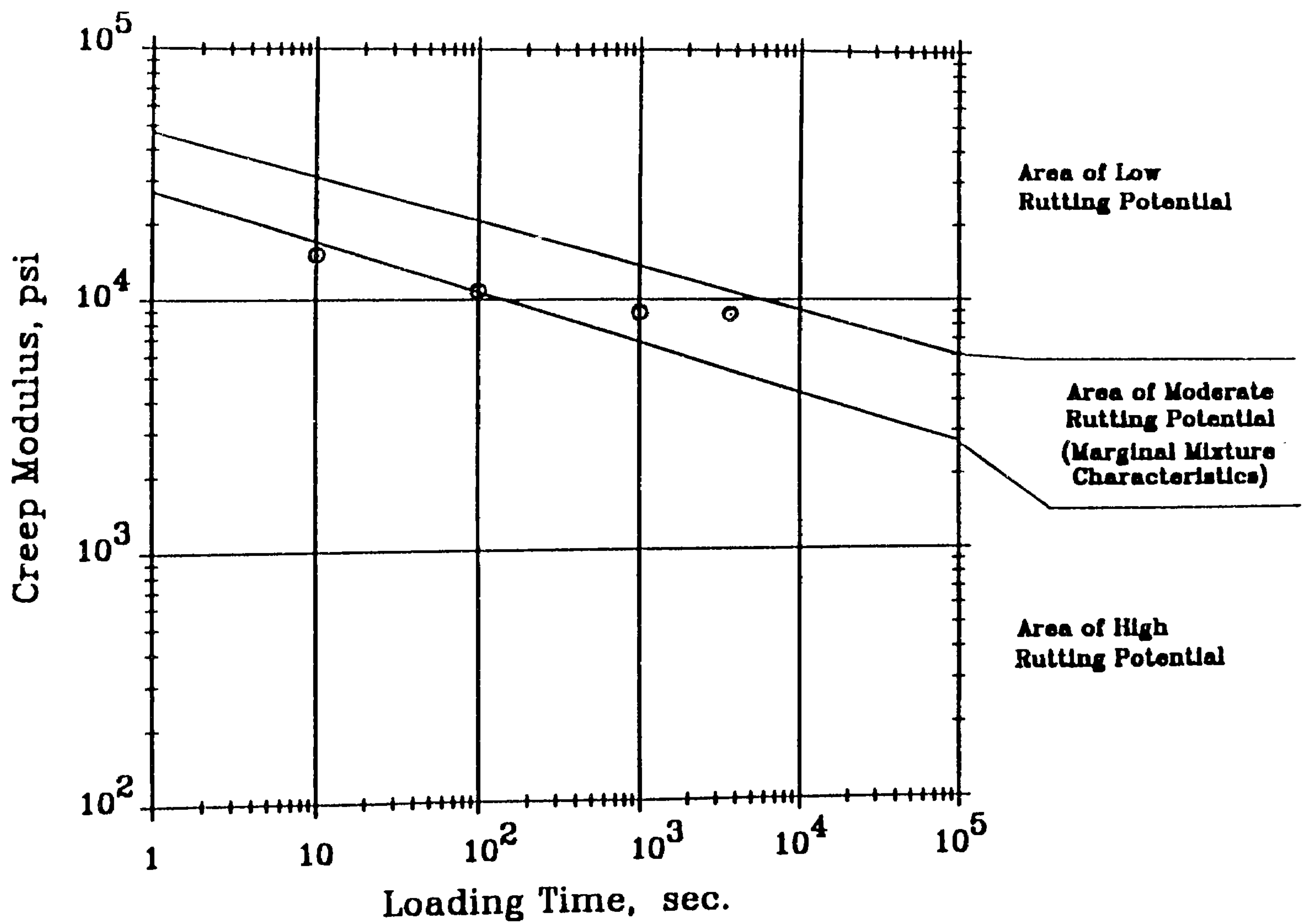


Figure 4-7. Asphalt concrete mixture rutting potential for layers placed over rigid pavements or rigid base materials (1)

The average compressive creep moduli reported in Table 3-8 for typical ADOT mixtures are plotted in Figures 4-4 through 4-7. It can be concluded that the ADOT mixture has a low rutting potential for the lower layers of full-depth asphalt pavements (Figure 4-4). On the other hand, it has a moderate rutting potential (marginal) for the intermediate layers in thick or full-depth asphalt pavements (Figure 4-5), for surface layers (Figure 4-6), and for layers placed over rigid pavements or rigid base materials (Figure 4-7).

4.4 FATIGUE CRACKING

Fatigue failures are accelerated by high air voids, which in addition to creating a weaker mix, also increases the oxidation rate of the asphalt film. The development of fatigue cracks is related to the tensile strain at the bottom of the asphalt concrete layer and to the modulus of the asphalt concrete material as follows:

$$N = K1\,(\varepsilon_t)^{-n} \qquad (4\text{-}2)$$

where:

N = Number of allowable wheel load applications

ε_t = Tensile strain at the bottom of the asphalt concrete layer

$K_1 = K_{1R}\,(E_A/E_R)^{-4}$

$n = 1.75 - 0.252 \log K_1$

E_A = Resilient Modulus of the Asphalt concrete at a selected temperature, psi

E_R = Reference Modulus (from the AASHO Road Test; $E_R = 500{,}000$ psi)

K_{1R} = Reference coefficient for $E_A = E_R$ (from AASHO Road Test data, $K_{1R} = 7.87 \times 10^{-7}$)

The tensile strain at the bottom of the asphalt layer can be calculated using the elastic layer theory (e.g. ELSYM5(6) or Chevron(7) computer program). The modulus of the asphalt concrete layer can be obtained from the lab test using the ASTM D4123 procedure (total resilient modulus).

To ensure that the asphalt concrete layer has the necessary fatigue resistance for the specific structure, the following equation can be used as a check for each season:

$$\varepsilon_f(i) < \varepsilon_t(i) \qquad (4\text{-}3)$$

where:

$\varepsilon_f(i) = \varepsilon_{rt}(i) + [A + m \log N]$

$A = a_t[1 - (0.9)^{bt}]\,\varepsilon_{rt}(i)$

$m = 1.4\,(b_t)$

$\varepsilon_t(i)$ = Indirect tensile strain at failure (unconditioned) for season i

$\varepsilon_f(i)$ = Accumulated permanent tensile strain (fatigue) for season i

$\varepsilon_{rt}(i)$ = Total recovered tensile strain at the average seasonal temperature for season i

b_t, a_t = Slope and intercept of the indirect tensile creep - time curve at the average seasonal temperature for season i

Either Equation 4-2 or 4-3 can be used to estimate the "fatigue life" or fatigue resistance of a specific pavement structure. Equation 4-2 uses the resilient modulus data in Figure 3-4 together with the use of a multilayer elastic program. On the other hand, Equation 4-3 requires additional laboratory fatigue tests in addition to the test results obtained in this study.

4.5 THERMAL CRACKING

Thermal cracking is a non-traffic associated type of failure. This type of cracking presents a serious problem during mixture design, because it is difficult to evaluate and predict. The reason for this difficulty is related to the aging characteristics and visco-elastic properties of the asphalt. Low-temperature cracking results when the tensile stresses, caused by temperature drops, exceed the mixtures fracture strength. The rate at which thermal cracks occur is dependent on the asphalt rheology properties, the mixture properties and environmental factors.

To evaluate thermal cracking, certain critical mixture properties must be determined, as well as, project specific environmental conditions. The mixture properties include indirect tensile strength, low-temperature creep-modulus, failure strains and the thermal coefficient of contraction. These parameters can be used to calculate the occurrence of thermal crack with time.

The critical temperature at which cracking occurs can be calculated as follows:

$$T_{cr} = T_B - [\, S_t^{(1-n)}/a_A b_c] \quad (4\text{-}4)$$

where:

T_{cr} = Critical Temperature that cracking is expected to occur at, °F

T_B = Base Temperature, normally assumed to be the Ring and Ball Temperature of the asphalt, °F

n = Slope of the relationship between indirect tensile strength and total resilient modulus of the mixture measured at temperatures of 41, 77 and 104F (unconditioned)

b_c = Intercept on the indirect tensile creep modulus axis of the relationship between creep modulus and indirect tensile strength measured with a loading rate of 0.05 inches/minute

$\log b_c = n \log S_t(41)/\log C_t(41)$

St(41) and $C_t(41)$ = Indirect tensile strength and creep modulus measured at 41°F, respectively

α_A = Thermal coefficient of contraction of the asphalt concrete (typical values range from 1.0×10^{-5} to 1.8×10^{-5} in./in./°F

Based on this criteria the cracking potential of ADOT mixture can be evaluated. The available data, however, are not enough to provide complete evaluation.

4.6 MOISTURE DAMAGE

Moisture damage is a serious problem, particularly on high traffic roadways. It is caused by a loss of adhesion or bond between the asphalt and aggregate in the presence of moisture. Currently, the moisture damage evaluation (tensile strength and resilient modulus ratios, TSR and MRR) of AAMAS is simply used as a means of accepting or rejecting a mixture. Both of these ratios should exceed a value of 0.80 for dense graded asphalt concrete. If values less than 0.80 are measured, an asphalt additive or antistripping agent may be required or the aggregate blend may need modification.

For the ADOT mixture, the tensile strength ratio and the resilient modulus ratio at 77°F can be obtained from Table 3-6 (moisture conditioned) and Table 3-5 (unconditioned) as follows:

$$TSR = \frac{84}{303} = 0.28$$

$$MRR = \frac{348}{864} = 0.40$$

It can be seen that both ratios are less than 0.80 which indicate high potential for moisture damage. Therefore, an asphalt additive or antistripping agent may be required or the aggregate blend may need modification. According to the AAMAS study, however, additional work is being conducted in the moisture damage area and these results are not considered final.

4.7 DISINTEGRATION

Disintegration is primarily related to environmental and material factors, but the severity of the distress is dependent upon the magnitude and number of wheel load applications. Raveling and reduced skid resistance are the two disintegration distresses considered in AAMAS. Increasing the asphalt content in the mix will increase film thickness and decrease asphalt aging, reducing the severity of raveling. Conversely, this increase in asphalt content will also reduce air voids, which can increase the possibility of flushing (or bleeding) and reduce skid resistance. Thus, both upper and lower bounds on asphalt content exist and must be considered in mixture design to reduce disintegration distresses (1).

The following summarizes the AAMAS criteria that can be used as guidelines in the interim, to evaluate the acceptability of surface mixtures as related to disintegration:

- Air voids at refusal > 3%
- Indirect tensile strength ratio, TSR > 0.90
- Retained bond > 0.35
- Tensile strain at failure (77F) > 10 mils/in.

Retained bond = $\varepsilon_{t\,A}/\varepsilon_{to}$

where $\varepsilon_{t\,A}$ = Indirect tensile strain at failure measured on specimens that have been temperature conditioned (accelerated aging).

ε_{to} = Indirect tensile strain at failure measured on unconditioned specimens

The following information are obtained from the ADOT mixture.

- Air voids at refusal (Table 3-4) = 3% (OK)
- Indirect tensile strength ratio, TSR (from Tables 3-6 and 3-5) = $\frac{84}{303}$ = 0.28
- Retained bond at 41°F (from Tables 3-7 and 3-5) = $\frac{2.7}{3.5}$ = 0.77(OK)
- Tensile strain at failure (77°F) (Table 3-5) = 6.6 mils/in.

It can be seen that two of the conditions are satisfied, while the other two are not satisfied. This indicates that the ADOT mix is subjected to disintegration to some extent.

CHAPTER 5. SUMMARY AND CONCLUSIONS

In this study a typical ADOT asphalt concrete mixture was evaluated based on the Asphalt-Aggregate Mixture Analysis System (AAMAS) procedure (NCHRP Project 9-6(1)). Two sets of ADOT asphalt concrete specimens were prepared using the California kneading compactor and the manual Marshall hammer. All tests recommended by the AAMAS project were performed. The test results were analyzed using the AAMAS guidelines.

It was found that the diametral resilient moduli of the ADOT mixture are within the acceptable range. A typical AASHTO structural layer coefficient is recommended. The rutting potential is low in some cases and moderate in other cases. Recommendations for the evaluation of fatigue cracking and thermal cracking are provided. The potential for moisture damage is high, while the potential for disintegration is marginal.

Further research is currently being conducted by the Strategic Highway Research Program (SHRP). Thus, the results obtained in this study should not be considered final. More studies are needed for comprehensive evaluations of ADOT asphalt concrete performance.

CHAPTER 6. RECOMMENDATIONS FOR FURTHER RESEARCH

This study serves as a preliminary evaluation of a typical ADOT asphalt concrete based on performance-related procedure. Further work is needed for more comprehensive evaluations. The following are some guidelines for future studies.

1. A wide range of asphalt cement grades and aggregate gradations should be used.
2. Mixtures with asphalt modifiers and/or antistripping agents should be evaluated.
3. The use of the gyratory compaction device should be investigated and compared with the Marshall compactor currently being used by ADOT.
4. Field performance of pavements in Arizona should be evaluated and correlated with laboratory results in order to develop more rational models for pavement performance and a more optimal method of mixture design.
5. The need for upgrading the capability of ADOT materials lab should be considered. Possible equipment that can be obtained include the following.

	Item	Approximate Cost (K)
1.	Electrohydraulic testing machine	70 - 90
2.	Environmental chamber to be attached to the electrohydraulic machine	12 - 15
3.	Gyratory shear compactor (ASTM D4013)	8 - 12
	or Corps of Engineers Gyratory Testing Machine (ASTM D3387)	90 - 100

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3. Schmidt, R. J., "A Practical Method for Measuring the Resilient Modulus of Asphalt Treated Mixes," Record No. 404, Highway Research Board, Washington, D.C., 1972.

4. "Preliminary Engineering and Design Manual," Arizona Department of Transportation, Phoenix, AZ, March 1989.

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6. Kopperman, S., et. al., "ELSYM5 Interactive Version User's Manual," IBM-PC version, *SRA Technologies Inc.*, Arlington, VA, July 1985.

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APPENDIX A

TEST RESULTS OF KNEADING COMPACTED SPECIMENS

AAMAS DATA SHEET
SUMMARY OF TEST RUSULTS

1. IDENTIFICATION

Project No. ______________________

Highway ______________ County ______________

Mixture I.D. ______________ Asphalt Content 4.7 %

Compaction Device Kneading Max. Specific Gravity 2.446 (152.4 pcf)

2. UNCONDITIONED SPECIMEN DATA

	Temperature, F	41			77			104		
	Sample No.	1	2	3	4	5	6	7	8	9
	Bulk ~~Specific Gravity~~ Unit Weight (pcf)	145.1	145.8	144.7	145.2	145.7	144.8	145.7	144.6	145.7
	Percent Air Voids, %	4.8	4.3	5.1	4.7	4.4	5.0	4.5	5.1	4.4
TEST 1	Total Resilient Deformations, ~~in.~~ (10^{-5} in.), H_{RT}: Axis A	5.6	2.9	4.0	4.2	11.2	5.2	12.1	13.3	13.3
TEST 1	Axis B	4.4	4.3	3.5	5.9	6.5	7.3	10.6	10.7	10.8
TEST 1	Total Resilient Modulus, ksi, E_{RT}: Axis A	1,829	3,183	2,297	1,111	442	950	158	192	187
TEST 1	Axis B	2,259	2,211	2,707	805	760	643	192	218	207
TEST 2	Indirect Tensile Strength, psi, S_t	353	387	381	283	276	290	99	98	82
TEST 2	Tensile Strain at Failure, mils/in, ε_t	3.4	2.9	2.8	7.6	6.3	6.3	8.8	8.8	7.0

FIGURE II.1. AAMAS WORKSHEET AND SUMMARY OF RESULTS

3. MOISTURE CONDITIONED SPECIMEN DATA, AFTER CONDITIONING

	Temperature, F	77	77	77			
	Sample No.	10	11	12			
	Bulk ~~Specific Gravity~~ Unit Weight (pcf)	145.7	145.3	144.6			
	Percent Air Voids, %	4.4	4.7	5.1			
	Degree Saturation, %	>80	>80	>80			
TEST 1	Total Resilient Modulus, ksi, E_{RTm}: Axis A	348	521	269			
TEST 1	Axis B	418	571	265			
TEST 2	Indirect Tensile Strength, psi, S_{tm}	96	91	75			
TEST 2	Tensile Strain at Failure, mils/in., ε_{tm}	7.3	5.7	6.1			

4. ENVIRONMENTAL AGED/HARDENED SPECIMEN DATA

	Temperature, F	41			41			
	Sample No.	13	14	15	16	17	18	
	Bulk ~~Specific Gravity~~ Unit Weight (pcf)	144.9	145.8	145.0	145.7	145.4	144.6	
	Percent Air Voids, %	4.9	4.3	4.9	4.4	4.6	5.1	
TEST 1	Total Resilient Modulus, ksi, E_{RTA}: Axis A	2,552	3,484	3,660	2,073	3,434	2,499	
TEST 1	Axis B	2,639	2,573	3,609				
TEST 2	Indirect Tensile Strength, psi, S_{tA}	374	392	409				
TEST 2	Tensile Strain at Failure, mils/in., ε_{tA}	2.5	2.7	2.5				
TEST 3	IDT Creep Modulus Testing: Slope of Creep Curve, b_t	(10^{-5} mils/sec)			3.11	2.40	3.29	
TEST 3	Intercept of Creep Curve, a_t (mils)				.045	.082	.083	
TEST 3	Creep Modulus at 3,600 seconds, ksi, C_t				177	48	52	

5. TRAFFIC DENSIFIED SPECIMEN DATA

	Temperature, F	104			104					
	Sample No.	19	20	21	22	23	24			
	Prior to Densification: Bulk ~~Specific Gravity~~ Unit Weight (pcf)	145.1	145.5	145.2	144.7	144.8	146.3			
	Percent Air Voids, %	4.8	4.5	4.7	5.1	5.0	4.0			
	After Densification: Bulk ~~Specific Gravity~~ Unit Weight (pcf)	149.3	148.8	147.1	148.2	148.2	150.0			
	Percent Air Voids, %	2.0	2.4	3.5	2.8	2.8	1.6			
TEST 4	Total Resilient Modulus, ksi, E_{CT}	29	35	26						
TEST 5	Unconfined Compressive Strength, psi, S_{qu}				732	745	668			
TEST 5	Compressive Strain at Failure, mils/in., ε_{qu}				23.9	24.4	23.6			
TEST 6	Compressive Creep Modulus Testing: Slope of Creep Curve, b (10^{-5} mils/sec)				32.9	18.3	24.9			
TEST 6	Intercept of Creep Curve, a (mils)				7.38	6.84	7.26			
TEST 6	Creep Modulus, ksi, $C_c(t)$ 10 sec				14.4	16.0	16.0			
TEST 6	100 sec				9.1	11.3	12.8			
TEST 6	1,000 sec				7.8	9.9	11.6			
TEST 6	3,600 sec				7.3	9.4	10.9			

INDIRECT TENSILE STRENGTH TEST
(TEST 2)

PROJECT NO. ______________________

HIGHWAY ______________________ COUNTY ______________________

MIXTURE I.D. ______________________

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4

TEST TEMPERATURE 41 F

LOADING RATE 0.05 IN./MIN

Core/Specimen I.D.		1	2	3	
Date Cored/Compacted					
Bulk ~~Specific Gravity~~ Unit Wgt		145.1	145.8	144.7	
Air Voids, %		4.8	4.3	5.1	
Diameter, in., D_a	1	4.004	4.000	4.004	
	2	4.004	3.996	4.004	
	3	4.004	4.004	4.004	
	Avg.	4.004	4.000	4.004	
Height, in., h	1	2.438	2.412	2.414	
	2	2.438	2.411	2.411	
	3	2.439	2.410	2.419	
	Avg.	2.438	2.411	2.415	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	1,829	3,183	2,297	
	Axis 2	2,259	2,211	2,707	
	Avg.	2,044	2,697	2,502	
Total Maximum Vertical Load (At Failure), lbs., P_t		5,520	5,976	5,902	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		0.0405	0.0354	0.0334	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		0.0064	0.0056	0.0053	
Indirect Tensile Strain At Failure, in./in., ϵ_t		0.0034	0.0029	0.0028	
Indirect Tensile Strength, psi, S_t		353	387	381	

REMARKS ______________________

TESTED BY P. Khanal **DATE TESTED** 7/2/90 7/9/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

INDIRECT TENSILE STRENGTH TEST

(TEST 2)

PROJECT NO. __________

HIGHWAY __________ COUNTY __________

MIXTURE I.D. __________

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4

TEST TEMPERATURE 77 F

LOADING RATE 2.0 IN./MIN

Core/Specimen I.D.		4	5	6	
Date Cored/Compacted					
Bulk Specific Gravity		145.2	145.7	144.8	
Air Voids, %		4.7	4.4	5.0	
Diameter, in., D_a	1	4.005	4.000	4.004	
	2	4.005	4.004	4.007	
	3	4.004	4.004	4.004	
	Avg.	4.005	4.003	4.005	
Height, in., h	1	2.428	2.418	2.425	
	2	2.425	2.425	2.437	
	3	2.434	2.430	2.431	
	Avg.	2.429	2.424	2.431	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	1111	442	950	
	Axis 2	805	760	643	
	Avg.	958	601	796	
Total Maximum Vertical Load (At Failure), lbs., P_t		4,405	4,288	4,511	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		.0851	.0709	.0709	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		.0147	.0122	.0122	
Indirect Tensile Strain At Failure, in./in., ϵ_t		.0076	.0063	.0063	
Indirect Tensile Strength, psi, S_t		283	276	290	

REMARKS __________

TESTED BY P. Khanal DATE TESTED 7/5/90 7/9/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

INDIRECT TENSILE STRENGTH TEST

(TEST 2)

PROJECT NO. ____________________

HIGHWAY ____________________ COUNTY ____________________

MIXTURE I.D. ____________________

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4

TEST TEMPERATURE 104 F

LOADING RATE 2.0 IN./MIN

Core/Specimen I.D.		7	8	9	
Date Cored/Compacted					
Bulk Specific Gravity		145.6	144.6	145.7	
Air Voids, %		4.5	5.1	4.4	
Diameter, in., D_a	1	4.004	4.007	4.008	
	2	4.006	4.008	4.002	
	3	4.006	4.007	4.003	
	Avg.	4.005	4.007	4.004	
Height, in., h	1	2.443	2.442	2.418	
	2	2.456	2.447	2.422	
	3	2.448	2.438	2.419	
	Avg.	2.449	2.442	2.420	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	158	192	187	
	Axis 2	192	218	207	
	Avg.	175	205	197	
Total Maximum Vertical Load (At Failure), lbs., P_t		1,560	1,539	1,274	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		.0910	.0910	.0729	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		.0170	.0170	.0136	
Indirect Tensile Strain At Failure, in./in., ϵ_t		.0088	.0088	.0070	
Indirect Tensile Strength, psi, S_t		99	98	82	

REMARKS ____________________

TESTED BY P. Khanal DATE TESTED 7/6/90 7/10/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

INDIRECT TENSILE STRENGTH TEST
(TEST 2)

PROJECT NO. ______
HIGHWAY ______ COUNTY ______
MIXTURE I.D. ______

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4
TEST TEMPERATURE 77 F
LOADING RATE 2.0 IN./MIN

Core/Specimen I.D.		10	11	12	
Date Cored/Compacted					
Bulk Specific Gravity		145.7	145.3	144.6	
Air Voids, %		4.4	4.7	5.1	
Diameter, in., D_a	1	4.022	4.005	4.008	
	2	4.019	4.002	4.009	
	3	4.025	4.003	4.008	
	Avg.	4.022	4.003	4.008	
Height, in., h	1	2.411	2.440	2.439	
	2	2.420	2.428	2.430	
	3	2.411	2.441	2.445	
	Avg.	2.414	2.436	2.438	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	348	521	269	
	Axis 2	418	571	265	
	Avg.	383	546	267	
Total Maximum Vertical Load (At Failure), lbs., P_t		1,486	1,422	1,168	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		.0810	.0638	.0678	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		.0140	.0110	.0117	
Indirect Tensile Strain At Failure, in./in., ε_t		.0073	.0057	.0061	
Indirect Tensile Strength, psi, S_t		96	91	75	

REMARKS ______

TESTED BY P. Khanal **DATE TESTED** 7/5/90 7/9/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

INDIRECT TENSILE STRENGTH TEST
(TEST 2)

PROJECT NO. ______________________

HIGHWAY ______________________ COUNTY ______________________

MIXTURE I.D. ______________________

~~RICE SPECIFIC GRAVITY~~ Unit Weight (pcf)	152.4	
TEST TEMPERATURE	41	F
LOADING RATE	0.05	IN./MIN

Core/Specimen I.D.		13	14	15	
Date Cored/Compacted					
Bulk Specific Gravity		144.9	145.8	145.0	
Air Voids, %		4.9	4.3	4.9	
Diameter, in., D_s	1	4.009	4.010	4.004	
	2	4.010	4.008	4.005	
	3	4.012	4.009	4.004	
	Avg.	4.010	4.009	4.004	
Height, in., h	1	2.431	2.425	2.435	
	2	2.415	2.415	2.419	
	3	2.430	2.425	2.416	
	Avg.	2.425	2.422	2.423	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	2,552	3,484	3,660	
	Axis 2	2,639	2,573	3,609	
	Avg.	2,596	3,029	3,635	
Total Maximum Vertical Load (At Failure), lbs., P_t		5,806	6,093	6,337	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		.0304	.0324	.0304	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		.0048	.0051	.0048	
Indirect Tensile Strain At Failure, in./in., ϵ_t		.0025	.0027	.0025	
Indirect Tensile Strength, psi, S_t		374	392	409	

REMARKS ______________________

TESTED BY P. Khanal **DATE TESTED** 7/13/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

CREEP MODULUS TEST
(INDIRECT TENSILE LOADING)
(TEST 3)

IDENTIFICATION:

PROJECT NO. ______
HIGHWAY ______ COUNTY ______
MIXTURE I.D. ______

CORE I.D. ______ STATION ______ DATE CORED ______

COMPACTED SPECIMEN 16 DATE ______

REMARKS ______

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4
BULK ~~SPECIFIC GRAVITY~~ 145.7 AIR VOIDS 4.4 %
AVERAGE DIAMETER (IN.) 1) 4.006 2) 4.000 3) 4.008 AVG. 4.005
AVERAGE HEIGHT (IN.) 1) 2.404 2) 2.412 3) 2.412 AVG. 2.409

TEST CONDITIONS

TOTAL LOAD 400 LBS. TEMPERATURE 41 °F
APPLIED TENSILE STRESS 25.9 PSI COMPRESSIVE STRESS ______ PSI

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 2,255 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Horizontal Deformation ~~(in.)~~ (mils)	Tensile Creep Strain (in./in.)	Tensile Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Horizontal Deformation (mils)
0	2.02637	1.77734			0	-1.78223	2.05566
2 ~~1~~	-1.04980	1.76758	-5.117×10^{-6}	-5.06×10^{6}	2 ~~1~~	1.14746	2.00195
4 ~~3~~	-1.09863	1.79688			4 ~~3~~	1.09863	1.99707
10	-1.12305	1.81641	2.048×10^{-5}	1.26×10^{6}	10	1.14746	1.99707
30	-1.19629	1.84082			30	1.14746	1.98242
100	-1.34277	1.87012	4.860×10^{-5}	5.32×10^{5}	100	1.12305	1.96777
300	-1.46484	1.95313			300	1.17188	2.03613
1,000	-1.61133	2.01172	1.229×10^{-4}	2.10×10^{5}	1,000	1.22070	2.22168
3,600	-1.78223	2.05566	1.459×10^{-4}	1.77×10^{5}	3,600	1.26953	2.21191

TESTED BY P. Khanal DATE TESTED 7/12/90

FIGURE II.A.2. INDIRECT TENSILE CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(INDIRECT TENSILE LOADING)
(TEST 3)

IDENTIFICATION:

PROJECT NO. ______

HIGHWAY ______ COUNTY ______

MIXTURE I.D. ______

CORE I.D. ______ STATION ______ DATE CORED ______

COMPACTED SPECIMEN 17 DATE ______

REMARKS ______

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4

BULK SPECIFIC GRAVITY 145.4 AIR VOIDS 4.6 %

AVERAGE DIAMETER (IN.) 1) 4.000 2) 4.003 3) 4.000 AVG. 4.001

AVERAGE HEIGHT (IN.) 1) 2.402 2) 2.404 3) 2.406 AVG. 2.404

TEST CONDITIONS

TOTAL LOAD 400 LBS. TEMPERATURE 41 °F

APPLIED TENSILE STRESS 26.0 PSI COMPRESSIVE STRESS ______ PSI

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 3,735 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Horizontal Deformation (in.)	Tensile Creep Strain (in./in.)	Tensile Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Horizontal Deformation (mils)
0	0.219727	3.41797×10^{-5}			0	−6.27441	1.05957
2 ~~1~~	−5.54199	6.83594×10^{-5}	1.792×10^{-5}	1.45×10^{6}	2 ~~1~~	+6.37207	1.03516
4 ~~3~~	−5.56641	8.30078×10^{-5}			4 ~~3~~	−1.09863	1.03027
10	−5.56641	9.27734×10^{-5}	3.072×10^{-5}	8.45×10^{5}	10	−1.09863	1.03027
30	−5.56641	1.66016×10^{-4}			30	−1.09863	1.02051
100	−5.59082	3.56445×10^{-4}	1.69×10^{-4}	1.54×10^{5}	100	−1.09863	1.02539
300	−5.76172	6.88477×10^{-4}			300	−1.12305	1.02051
1,000	−5.93262	1.02539×10^{-3}	5.196×10^{-4}	49,955	1,000	−1.02539	0.976563
3,600	−6.27441	1.05957×10^{-3}	5.38×10^{-4}	48,290	3,600	−0.927734	0.908203

TESTED BY P. Khanal DATE TESTED 7/12/90

FIGURE II.A.2. INDIRECT TENSILE CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(INDIRECT TENSILE LOADING)
(TEST 3)

IDENTIFICATION:

PROJECT NO. ______
HIGHWAY ______ COUNTY ______
MIXTURE I.D. ______

CORE I.D. ______ STATION ______ DATE CORED ______

COMPACTED SPECIMEN 18 DATE ______

REMARKS ______

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4
BULK ~~SPECIFIC GRAVITY~~ 144.6 AIR VOIDS 5.1 %
AVERAGE DIAMETER (IN.) 1) 4.010 2) 4.006 3) 4.006 AVG. 4.007
AVERAGE HEIGHT (IN.) 1) 2.445 2) 2.432 3) 2.443 AVG. 2.440

TEST CONDITIONS

TOTAL LOAD 400 LBS. TEMPERATURE 41 °F
APPLIED TENSILE STRESS 25.6 PSI COMPRESSIVE STRESS ______ PSI

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 2,719 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Horizontal Deformation ~~(in.)~~ (mils)	Tensile Creep Strain (in./in.)	Tensile Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Horizontal Deformation (mils)
0	−2.24609	2.78320			0	−5.59082	3.73047
2 ~~1~~	−4.54102	2.82227	2.048×10^{-5}	1.25×10^{6}	2 ~~1~~	1.04980	3.70605
4 ~~3~~	−4.54102	2.82715			4 ~~3~~	−0.24414	3.70605
10	−4.76074	2.85156	3.58×10^{-5}	7.13×10^{5}	10	−3.05176	3.70117
30	−4.88281	2.91016			30	−3.05176	3.69629
100	−4.98047	3.07129	1.51×10^{-4}	1.69×10^{5}	100	−3.05176	3.69629
300	−5.17578	3.35449			300	−3.05176	3.69629
1,000	−5.37109	3.63770	4.48×10^{-4}	57,076	1,000	−3.02734	3.69141
3,600	−5.59082	3.73047	4.97×10^{-4}	51,487	3,600	−2.92969	3.71582

TESTED BY P. Khanal DATE TESTED 7/12/90

FIGURE II.A.2. INDIRECT TENSILE CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(UNIAXIAL COMPRESSION LOADING)
(TEST 6)

IDENTIFICATION:

PROJECT NO. ______________________

HIGHWAY ______________ COUNTY ______________

MIXTURE I.D. ______________________

CORE I.D. __________ STATION __________ DATE CORED __________

COMPACTED SPECIMEN 22 DATE __________

REMARKS ______________________

SAMPLE DATA

(Before/After Densification)

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4

BULK ~~SPECIFIC GRAVITY~~ 144.7/148.2 AIR VOIDS 5.1/2.8 %

AVERAGE DIAMETER (IN.) 1) 4.036 2) 4.055 3) 4.056 AVG. 4.049

AVERAGE HEIGHT (IN.) 1) 3.810 2) 3.816 3) 3.806 AVG. 3.811

TEST CONDITIONS

TOTAL LOAD 400 LBS. APPLIED STRESS 31.1 PSI TEMPERATURE 104 °F

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 32 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Compressive Creep Strain (~~in.~~ mils/in.)	Compressive Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)
0	0.000			0	-16.1865
2 ~~1~~	-5.59082	1.467	21,179	2 ~~1~~	-11.8896
4 ~~3~~	-6.64063			4 ~~3~~	-11.4502
10	-8.25195	2.165	14,349	10	-10.9131
30	-10.4736			30	-10.3027
100	-13.0371	3.421	9,082	100	-9.93652
300	-14.6240			300	-9.59473
1,000	-15.2832	4.010	7,748	1,000	-9.35059
3,600	-16.1865	4.247	7,315	3,600	-9.05762

TESTED BY P. Khanal DATE TESTED 7/14/90

FIGURE II.A.1. UNIAXIAL COMPRESSION CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(UNIAXIAL COMPRESSION LOADING)
(TEST 6)

IDENTIFICATION:

PROJECT NO. ______
HIGHWAY ______ COUNTY ______
MIXTURE I.D. ______

CORE I.D. ______ STATION ______ DATE CORED ______

COMPACTED SPECIMEN 23 DATE ______

REMARKS ______

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4
BULK ~~SPECIFIC GRAVITY~~ 144.8/148.2 AIR VOIDS 5.0/2.8 %
AVERAGE DIAMETER (IN.) 1) 4.045 2) 4.045 3) 4.058 AVG. 4.049
AVERAGE HEIGHT (IN.) 1) 3.811 2) 3.814 3) 3.808 AVG. 3.811

TEST CONDITIONS

TOTAL LOAD 400 LBS. APPLIED STRESS 31.1 PSI TEMPERATURE 104 °F

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 35 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Compressive Creep Strain (~~in.~~ mils/in.)	Compressive Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)
0	−4.8828 x10⁻²			0	−12.5977
2 ~~1~~	−5.54199	1.441	21,555	2 ~~1~~	−8.34961
4 ~~3~~	−6.32324			4 ~~3~~	−8.10547
10	−7.44629	1.941	16,007	10	−7.78809
30	−9.05762			30	−7.54395
100	−10.5713	2.761	11,253	100	−7.27539
300	−11.6211			300	−7.10449
1,000	−12.0117	3.139	9,898	1,000	−6.98242
3,600	−12.5977	3.293	9,436	3,600	−6.83594

TESTED BY P. Khanal DATE TESTED 7/14/90

FIGURE II.A.1. UNIAXIAL COMPRESSION CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(UNIAXIAL COMPRESSION LOADING)
(TEST 6)

IDENTIFICATION:

PROJECT NO. ____________________

HIGHWAY ____________________ COUNTY ____________________

MIXTURE I.D. ____________________

CORE I.D. __________ STATION __________ DATE CORED __________

COMPACTED SPECIMEN 24 DATE __________

REMARKS ____________________

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4

BULK SPECIFIC GRAVITY 146.3 / 150.0 AIR VOIDS 4.0/1.6 %

AVERAGE DIAMETER (IN.) 1) 4.003 2) 4.002 3) 4.001 AVG. 4.002

AVERAGE HEIGHT (IN.) 1) 3.861 2) 3.850 3) 3.864 AVG. 3.858

TEST CONDITIONS

TOTAL LOAD 400 LBS. APPLIED STRESS 31.8 PSI TEMPERATURE 104 °F

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 30 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Compressive Creep Strain (~~in.~~ mils/in.)	Compressive Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)
0	-4.63867×10^{-1}			0	-11.71880
2 ~~1~~	-6.76260	1.633	19,478	2 ~~1~~	-6.86035
4 ~~3~~	-7.32422			4 ~~3~~	-6.34766
10	-8.15430	1.993	15,953	10	-5.71289
30	-9.10645			30	-5.07813
100	-10.0586	2.487	12,787	100	-4.41895
300	-10.6689			300	-4.00391
1,000	-11.0352	2.740	11,605	1,000	-3.61323
3,600	-11.7188	2.917	10,900	3,600	-3.39355

TESTED BY P. Khanal DATE TESTED 7/14/90

FIGURE II.A.1. UNIAXIAL COMPRESSION CREEP MODULUS DATA SHEET

APPENDIX B

TEST RESULTS OF MARSHALL COMPACTED SPECIMENS

AAMAS DATA SHEET
SUMMARY OF TEST RUSULTS

1. IDENTIFICATION

Project No. ________________

Highway ________________ County ________________

Mixture I.D. ________________ Asphalt Content 4.7 %

Compaction Device Marshall Max. Specific Gravity 2.446 (152.4 pcf)

2. UNCONDITIONED SPECIMEN DATA

	Temperature, F	41			77			104		
	Sample No.	1	2	3	4	5	6	7	8	9
	Bulk ~~Specific Gravity~~ Unit Weight (pcf)	144.8	145.1	146.0	144.9	145.2	145.7	144.8	145.6	145.4
	Percent Air Voids, %	5.0	4.8	4.2	4.9	4.7	4.4	5.0	4.5	4.6
TEST 1	Total Resilient Deformations, ~~in.~~ (10^{-5} in.), H_{RT}: Axis A	4.4	3.9	3.4	4.6	5.9	5.1	13.2	13.2	16.8
TEST 1	Axis B	4.2	3.7	3.5	5.2	6.5	5.0	18.7	13.0	12.2
TEST 1	Total Resilient Modulus, ksi, E_{RT}: Axis A	2,092	2,344	2,608	1,078	852	985	204	181	198
TEST 1	Axis B	2,253	2,385	2,544	945	818	977	146	179	267
TEST 2	Indirect Tensile Strength, psi, S_t	344	355	373	340	293	333	106	111	105
TEST 2	Tensile Strain at Failure, mils/in, ε_t	3.9	4.2	4.0	7.3	6.3	5.9	6.8	5.5	5.8

FIGURE II.1. AAMAS WORKSHEET AND SUMMARY OF RESULTS

3. MOISTURE CONDITIONED SPECIMEN DATA, AFTER CONDITIONING

	Temperature, F	77	77	77			
	Sample No.	10	11	12			
	Bulk ~~Specific Gravity~~ Unit Weight (pcf)	145.3	145.6	145.4			
	Percent Air Voids, %	4.7	4.5	4.6			
	Degree Saturation, %						
TEST 1	Total Resilient Modulus, ksi, E_{RTm}: Axis A	235	382	308			
TEST 1	Axis B	258	347	247			
TEST 2	Indirect Tensile Strength, psi, S_{tm}	72	91	79			
TEST 2	Tensile Strain at Failure, mils/in., ε_{tm}	3.8	4.1	4.2			

4. ENVIRONMENTAL AGED/HARDENED SPECIMEN DATA

	Temperature, F	41			41			
	Sample No.	13	14	15	16	17	18	
	Bulk ~~Specific Gravity~~ Unit Weight (pcf)	144.9	143.9	146.8	144.5	144.6	146.5	
	Percent Air Voids, %	4.9	5.6	3.7	5.2	5.1	3.9	
TEST 1	Total Resilient Modulus, ksi, E_{RTA}: Axis A	2,307	3,216	3,916	6,102	3,070	3,558	
TEST 1	Axis B	3,424	5,304	5,306				
TEST 2	Indirect Tensile Strength, psi, S_{tA}	428	401	499				
TEST 2	Tensile Strain at Failure, mils/in., ε_{tA}	3.0	2.5	2.5				
TEST 3	IDT Creep Modulus Testing: Slope of Creep Curve, b_t (10^{-5} mils/sec)				0	0	0.571	
TEST 3	Intercept of Creep Curve, a_t (mils)				.12	.27	.08	
TEST 3	Creep Modulus at 3,600 seconds, ksi, C_t				125	1,100	201	

5. TRAFFIC DENSIFIED SPECIMEN DATA

Test	Property									
	Temperature, F	104			104					
	Sample No.	19	20	21	22	23	24			
	Prior to Densification: Bulk ~~Specific Gravity~~ Unit Weight (pcf)	144.4	145.0	146.2	144.8	145.0	145.8			
	Percent Air Voids, %	5.3	4.9	4.1	5.3	4.9	4.3			
	After Densification: Bulk ~~Specific Gravity~~ Unit Weight (pcf)	146.7	146.9	147.8	146.6	147.6	148.0			
	Percent Air Voids, %	3.7	3.6	3.0	3.8	3.2	2.9			
TEST 4	Total Resilient Modulus, ksi, E_{CT}	25	26	41	27	47	32			
TEST 5	Unconfined Compressive Strength, psi, S_{qu}				620	731	764			
TEST 5	Compressive Strain at Failure, mils/in., ε_{qu}				19.9	18.0	17.6			
TEST 6	Compressive Creep Modulus Testing: Slope of Creep Curve, b (10^{-5} mils/sec)				.344	.260	.324			
TEST 6	Intercept of Creep Curve, a (mils)				6.63	11.3	6.22			
TEST 6	Creep Modulus, ksi, $C_c(t)$ 10 sec				17.1	10.5	18.0			
TEST 6	100 sec				11.1	8.8	11.2			
TEST 6	1,000 sec				9.0	8.2	6.7			
TEST 6	3,600 sec				8.5	7.8	8.0			

INDIRECT TENSILE STRENGTH TEST
(TEST 2)

PROJECT NO. ______
HIGHWAY ______ COUNTY ______
MIXTURE I.D. ______

RICE ~~SPECIFIC GRAVITY~~ Unit Weight (pcf) 152.4
TEST TEMPERATURE 41 F
LOADING RATE 0.05 IN./MIN

Core/Specimen I.D.		1	2	3	
Date Cored/Compacted					
Bulk ~~Specific Gravity~~ Unit Wgt.		144.8	145.1	146.0	
Air Voids, %		5.0	4.8	4.2	
Diameter, in., D_a	1	4.006	4.003	4.010	
	2	4.006	4.003	4.015	
	3	4.006	4.003	4.008	
	Avg.	4.006	4.003	4.011	
Height, in., h	1	2.465	2.450	2.435	
	2	2.475	2.445	2.443	
	3	2.455	2.455	2.440	
	Avg.	2.465	2.450	2.439	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	2,092	2,344	2,608	
	Axis 2	2,253	2,385	2,544	
	Avg.	2,173	2,365	2,576	
Total Maximum Vertical Load (At Failure), lbs., P_t		5,440	5,573	5,838	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		.0466	.0506	.0486	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		.0074	.0080	.0077	
Indirect Tensile Strain At Failure, in./in., ε_T		.0039	.0042	.0040	
Indirect Tensile Strength, psi, S_T		344	355	373	

REMARKS ______

TESTED BY P. Khanal **DATE TESTED** 7/18/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

INDIRECT TENSILE STRENGTH TEST

(TEST 2)

PROJECT NO. ______

HIGHWAY ______ COUNTY ______

MIXTURE I.D. ______

RICE ~~SPECIFIC GRAVITY~~ Unit Wgt (pcf) 152.4

TEST TEMPERATURE 77 F

LOADING RATE 2.0 IN./MIN

Core/Specimen I.D.		4	5	6	
Date Cored/Compacted					
Bulk Specific Gravity		144.9	145.2	145.7	
Air Voids, %		4.9	4.7	4.4	
Diameter, in., D_s	1	4.006	4.010	4.010	
	2	4.009	4.010	4.010	
	3	4.007	4.010	4.005	
	Avg.	4.007	4.010	4.008	
Height, in., h	1	2.445	2.440	2.455	
	2	2.456	2.442	2.475	
	3	2.458	2.437	2.448	
	Avg.	2.453	2.440	2.459	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	1,078	852	985	
	Axis 2	945	818	977	
	Avg.	1,011	835	981	
Total Maximum Vertical Load (At Failure), lbs., P_t		5,339	4,586	5,254	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		.0810	.0709	.0658	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		.0140	.0122	.0114	
Indirect Tensile Strain At Failure, in./in., ϵ_t		.0073	.0063	.0059	
Indirect Tensile Strength, psi, S_t		340	293	333	

REMARKS ______

TESTED BY P. Khanal **DATE TESTED** 7/17/90 7/18/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

INDIRECT TENSILE STRENGTH TEST
(TEST 2)

PROJECT NO. ____________________

HIGHWAY ____________________ COUNTY ____________________

MIXTURE I.D. ____________________

RICE ~~SPECIFIC GRAVITY~~ Unit Wgt (pcf) 152.4

TEST TEMPERATURE 104 F

LOADING RATE 2.0 IN./MIN

Core/Specimen I.D.		7	8	9	
Date Cored/Compacted					
Bulk Specific Gravity		144.8	145.6	145.4	
Air Voids, %		5.0	4.5	4.6	
Diameter, in., D_s	1	4.010	4.010	4.012	
	2	4.010	4.008	4.007	
	3	4.010	4.009	4.006	
	Avg.	4.010	4.009	4.008	
Height, in., h	1	2.447	2.465	2.452	
	2	2.460	2.442	2.453	
	3	2.450	2.445	2.463	
	Avg.	2.452	2.451	2.456	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	204	181	198	
	Axis 2	146	179	267	
	Avg.	175	180	233	
Total Maximum Vertical Load (At Failure), lbs., P_t		1,667	1,741	1,645	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		.0709	.0567	.0608	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		.0132	.0106	.0113	
Indirect Tensile Strain At Failure, in./in., ε_t		.0068	.0055	.0058	
Indirect Tensile Strength, psi, S_t		106	111	105	

REMARKS ____________________

TESTED BY P. Khanal **DATE TESTED** 7/19/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

INDIRECT TENSILE STRENGTH TEST
(TEST 2)

PROJECT NO. ______
HIGHWAY ______ COUNTY ______
MIXTURE I.D. ______

RICE ~~SPECIFIC GRAVITY~~ Unit Wgt (pcf) 152.4
TEST TEMPERATURE 77 F
LOADING RATE 2.0 IN./MIN

Core/Specimen I.D.		10	11	12	
Date Cored/Compacted					
Bulk Specific Gravity		145.3	145.6	145.4	
Air Voids, %		4.7	4.5	4.6	
Diameter, in., D_s	1	4.009	4.007	4.005	
	2	4.010	4.017	4.005	
	3	4.006	4.008	4.005	
	Avg.	4.008	4.011	4.005	
Height, in., h	1	2.457	2.438	2.460	
	2	2.464	2.457	2.469	
	3	2.460	2.481	2.478	
	Avg.	2.460	2.459	2.469	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	235	382	308	
	Axis 2	258.	347	247	
	Avg.	247	365	278	
Total Maximum Vertical Load (At Failure), lbs., P_t		1,136	1,433	1,247	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		.0425	.0456	.0466	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		.0073	.0079	.0080	
Indirect Tensile Strain At Failure, in./in., ε_T		.0038	.0041	.0042	
Indirect Tensile Strength, psi, S_T		72	91	79	

REMARKS ______

TESTED BY P. Khanal DATE TESTED 7/20/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

INDIRECT TENSILE STRENGTH TEST

(TEST 2)

PROJECT NO. ______

HIGHWAY ______ COUNTY ______

MIXTURE I.D. ______

RICE ~~SPECIFIC GRAVITY~~ Unit Wgt (pcf) 152.4

TEST TEMPERATURE 41 F

LOADING RATE 0.05 IN./MIN

Core/Specimen I.D.		13	14	15	
Date Cored/Compacted					
Bulk Specific Gravity		144.9	143.9	146.8	
Air Voids, %		4.9	5.6	3.7	
Diameter, in., D_a	1	4.014	4.009	4.015	
	2	4.010	4.009	4.010	
	3	4.010	4.015	4.005	
	Avg.	4.011	4.011	4.010	
Height, in., h	1	2.480	2.475	2.425	
	2	2.442	2.500	2.435	
	3	2.450	2.494	2.435	
	Avg.	2.457	2.490	2.432	
Total Resilient Modulus, ksi, E_{RT}					
	Axis 1	2,307	3,216	3,916	
	Axis 2	3,424	5,304	5,306	
	Avg.	2,866	4,260	4,611	
Total Maximum Vertical Load (At Failure), lbs., P_t		6,740	6,396	7,778	
Vertical Deformation At Maximum Vertical Load, in., V_{RT}		.0360	.0304	.0304	
Horizontal Deformation At Maximum Vertical Load, in., H_{RT}		.0057	.0048	.0048	
Indirect Tensile Strain At Failure, in./in., ϵ_t		.0030	.0025	.0025	
Indirect Tensile Strength, psi, S_t		428	401	499	

REMARKS ______

TESTED BY P. Khanal DATE TESTED 7/30/90

FIGURE II.B.1. INDIRECT TENSILE STRENGTH DATA SHEET

CREEP MODULUS TEST
(INDIRECT TENSILE LOADING)
(TEST 3)

IDENTIFICATION:

PROJECT NO. ____________

HIGHWAY ____________ COUNTY ____________

MIXTURE I.D. ____________

CORE I.D. ____________ STATION ____________ DATE CORED ____________

COMPACTED SPECIMEN 16 DATE ____________

REMARKS ____________

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit Wgt (pcf) 152.4

BULK SPECIFIC GRAVITY 144.5 AIR VOIDS 5.2 %

AVERAGE DIAMETER (IN.) 1) 4.015 2) 4.010 3) 4.010 AVG. 4.012

AVERAGE HEIGHT (IN.) 1) 2.482 2) 2.489 3) 2.460 AVG. 2.477

TEST CONDITIONS

TOTAL LOAD 800 LBS. TEMPERATURE 41 °F

APPLIED TENSILE STRESS 50.4 PSI COMPRESSIVE STRESS ____________ PSI

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 6,102 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Horizontal Deformation (in.)	Tensile Creep Strain (in./in.)	Tensile Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ mils	Horizontal Deformation (mils)
0	-0.29269	-4.88281×10^{-5}			0	5.98145	.815430
2 ~~1~~	4.88281	3.90625×10^{-5}	4.608×10^{-5}	1.09×10^{6}	2 ~~1~~	3.07617	.732422
4 ~~3~~	5.02930	3.90625×10^{-5}			4 ~~3~~	2.92969	.727539
10	5.02930	5.85938×10^{-5}	5.632×10^{-5}	8.95×10^{5}	10	2.80762	.727539
30	5.15137	1.12305×10^{-4}			30	2.61230	.727539
100	5.27344	2.97852×10^{-4}	1.818×10^{-4}	2.77×10^{5}	100	2.34375	.717773
300	5.46875	6.10352×10^{-4}			300	1.73340	.712891
1,000	5.73730	8.44727×10^{-4}	4.685×10^{-4}	1.08×10^{5}	1,000	1.46484	.688477
3,600	5.98145	8.15430×10^{-4}	4.62×10^{-4}	1.25×10^{5}	3,600	1.39160	.678711

TESTED BY P. Khanal DATE TESTED 7/31/90

FIGURE II.A.2. INDIRECT TENSILE CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(INDIRECT TENSILE LOADING)
(TEST 3)

IDENTIFICATION:

PROJECT NO. ______
HIGHWAY ______ COUNTY ______
MIXTURE I.D. ______

CORE I.D. ______ STATION ______ DATE CORED ______

COMPACTED SPECIMEN 17 DATE ______

REMARKS ______

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit wgt (pcf) 152.4
BULK SPECIFIC GRAVITY 144.6 AIR VOIDS 5.1 %
AVERAGE DIAMETER (IN.) 1) 4.006 2) 4.006 3) 4.007 AVG. 4.006
AVERAGE HEIGHT (IN.) 1) 2.465 2) 2.462 3) 2.467 AVG. 2.465

TEST CONDITIONS

TOTAL LOAD 800 LBS. TEMPERATURE 41 °F
APPLIED TENSILE STRESS 50.1 PSI COMPRESSIVE STRESS ______ PSI

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 3,070 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Horizontal Deformation ~~(in.)~~ (mils)	Tensile Creep Strain (in./in.)	Tensile Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation (mils) ~~(in.)~~	Horizontal Deformation (mils)
0	9.76563×10^{-2}	.913086			0	4.15039	1.00098
2 ~~1~~	3.29590	.966797	2.816×10^{-5}	1.8×10^{6}	2 ~~1~~	2.27051	.805664
4 ~~3~~	3.32031	.976563			4 ~~3~~	2.14844	.795898
10	3.36914	1.00098	4.608×10^{-5}	1.1×10^{6}	10	2.02637	.791016
30	3.49121	1.05469			30	1.80664	.791016
100	3.68652	1.15234	1.254×10^{-4}	4.03×10^{5}	100	1.48926	.786133
300	3.83301	1.14258			300	1.17188	.776367
1,000	3.93066	.996094	4.35×10^{-5}	1.16×10^{6}	1,000	.976563	.781250
3,600	4.15039	1.00098	4.608×10^{-5}	1.10×10^{6}	3,600	.830078	.751953

TESTED BY P. Khanal DATE TESTED 7/31/90

FIGURE II.A.2. INDIRECT TENSILE CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(INDIRECT TENSILE LOADING)
(TEST 3)

IDENTIFICATION:

PROJECT NO. ______________________

HIGHWAY ______________________ COUNTY ______________

MIXTURE I.D. ______________________

CORE I.D. ____________ STATION ____________ DATE CORED ____________

COMPACTED SPECIMEN 18 DATE ____________

REMARKS ______________________

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit wgt 152.4

BULK SPECIFIC GRAVITY 146.5 AIR VOIDS 3.9 %

AVERAGE DIAMETER (IN.) 1) 4.010 2) 4.010 3) 4.008 AVG. 4.009

AVERAGE HEIGHT (IN.) 1) 2.430 2) 2.450 3) 2.450 AVG. 2.443

TEST CONDITIONS

TOTAL LOAD 800 LBS. TEMPERATURE 41 °F

APPLIED TENSILE STRESS 51.1 PSI COMPRESSIVE STRESS ____________ PSI

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 3,558 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Horizontal Deformation (in.)	Tensile Creep Strain (in./in.)	Tensile Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation (mils) ~~(in.)~~	Horizontal Deformation (mils)
0	-.781250	-2.9297×10^{-5}			0	3.7354	.45410
~~1~~ 2	2.49023	2.9297×10^{-5}	3.072×10^{-5}	1.66×10^{6}	~~1~~ 2	1.6357	.41992
~~3~~ 4	2.58789	3.9063×10^{-5}			~~3~~ 4	1.4648	.41992
10	2.73438	4.8828×10^{-5}	3.584×10^{-5}	1.42×10^{6}	10	1.2940	.41504
30	2.80762	7.8125×10^{-5}			30	1.1231	.41016
100	2.97852	1.5137×10^{-4}	9.472×10^{-5}	5.39×10^{5}	100	.90332	.40039
300	3.17383	2.9785×10^{-4}			300	.70801	.39063
1,000	3.49121	4.3457×10^{-4}	2.422×10^{-4}	2.10×10^{5}	1,000	.63477	.37109
3,600	3.73535	4.5410×10^{-4}	2.534×10^{-4}	2.01×10^{5}	3,600	.53711	.39063

TESTED BY P. Khanal DATE TESTED 7/31/90

FIGURE II.A.2. INDIRECT TENSILE CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(UNIAXIAL COMPRESSION LOADING)
(TEST 6)

IDENTIFICATION:

PROJECT NO. ____

HIGHWAY ____ COUNTY ____

MIXTURE I.D. ____

CORE I.D. ____ STATION ____ DATE CORED ____

COMPACTED SPECIMEN 22 DATE ____

REMARKS ____

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit Wgt (pcf) 152.4

BULK ~~SPECIFIC GRAVITY~~ 144.7 AIR VOIDS 5.1 %

AVERAGE DIAMETER (IN.) 1) 4.003 2) 4.006 3) 4.000 AVG. 4.003

AVERAGE HEIGHT (IN.) 1) 3.965 2) 3.960 3) 3.963 AVG. 3.963

TEST CONDITIONS

TOTAL LOAD 400 LBS. APPLIED STRESS 31.8 PSI TEMPERATURE 104 °F

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 26.7 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Compressive Creep Strain (~~in.~~ mils/in.)	Compressive Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)
0	0.00000			0	14.8193
2 ~~1~~	5.37189	1.355	23,449	2 ~~1~~	10.5957
4 ~~3~~	6.05469			4 ~~3~~	9.96094
10	7.34863	1.854	17,138	10	9.52148
30	9.22852			30	8.98438
100	11.3770	2.871	11,070	100	8.30078
300	12.8906			300	7.86133
1,000	13.9404	3.520	9,034	1,000	7.49512
3,600	14.8193	3.740	8,499	3,600	7.08008

TESTED BY P. Khanal DATE TESTED 7/26/90

FIGURE II.A.1. UNIAXIAL COMPRESSION CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(UNIAXIAL COMPRESSION LOADING)
(TEST 6)

IDENTIFICATION:

PROJECT NO. ______

HIGHWAY ______ COUNTY ______

MIXTURE I.D. ______

CORE I.D. ______ STATION ______ DATE CORED ______

COMPACTED SPECIMEN 23 DATE ______

REMARKS ______

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit Wgt (pcf) 152.4

BULK ~~SPECIFIC GRAVITY~~ 144.8 AIR VOIDS 5.0 %

AVERAGE DIAMETER (IN.) 1) 4.010 2) 4.011 3) 4.005 AVG. 4.009

AVERAGE HEIGHT (IN.) 1) 3.945 2) 3.935 3) 3.934 AVG. 3.938

TEST CONDITIONS

TOTAL LOAD 400 LBS. APPLIED STRESS 31.7 PSI TEMPERATURE 104 °F

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 47.3 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Compressive Creep Strain (~~in.~~ mils/in.)	Compressive Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)
0	0.024414			0	16.0400
~~1~~ 2	9.81445	2.486	12,751	~~1~~ 2	12.1094
~~3~~ 4	10.6445			~~3~~ 4	11.8896
10	11.8652	3.007	10,542	10	11.7188
30	13.1348			30	11.3037
100	14.2578	3.614	8,771	100	10.7910
300	14.9170			300	10.5469
1,000	15.3320	3.887	8,155	1,000	10.3271
3,600	16.0400	4.067	7,795	3,600	9.74121

TESTED BY P. Khanal DATE TESTED 7/26/90

FIGURE II.A.1. UNIAXIAL COMPRESSION CREEP MODULUS DATA SHEET

CREEP MODULUS TEST
(UNIAXIAL COMPRESSION LOADING)

(TEST 6)

IDENTIFICATION:

PROJECT NO. ______

HIGHWAY ______ COUNTY ______

MIXTURE I.D. ______

CORE I.D. ______ STATION ______ DATE CORED ______

COMPACTED SPECIMEN 24 DATE ______

REMARKS ______

SAMPLE DATA

RICE ~~SPECIFIC GRAVITY~~ Unit Wgt (pcf) 152.4

BULK ~~SPECIFIC GRAVITY~~ 146.3 AIR VOIDS 4.0 %

AVERAGE DIAMETER (IN.) 1) 4.008 2) 4.008 3) 4.005 AVG. 4.007

AVERAGE HEIGHT (IN.) 1) 3.916 2) 3.912 3) 3.916 AVG. 3.915

TEST CONDITIONS

TOTAL LOAD 400 LBS. APPLIED STRESS 31.7 PSI TEMPERATURE 104 °F

PRECONDITIONING

NO. OF CYCLES 200 TOTAL RESILIENT MODULUS 31.5 KSI

Loading Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)	Compressive Creep Strain (~~in.~~ mils/in.)	Compressive Creep Modulus (psi)	Load Release Time (sec.)	Vertical Deformation ~~(in.)~~ (mils)
0	0.00000			0	15.4029
2 ~~1~~	4.88281	1.247	25,433	2 ~~1~~	11.7676
4 ~~3~~	4.63965			4 ~~3~~	11.4746
10	6.88477	1.760	18,037	10	11.1572
30	8.78906			30	10.6689
100	11.1321	2.843	11,155	100	10.0830
300	12.9883			300	9.69238
1,000	14.3066	3.654	8,680	1,000	9.49707
3,600	15.4029	3.960	8,010	3,600	9.30176

TESTED BY P. Khanal DATE TESTED 7/26/90

FIGURE II.A.1. UNIAXIAL COMPRESSION CREEP MODULUS DATA SHEET