TECHNICAL REPORT STANDARD PAGE

1. Report No. FHWA/LA-02/306	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Evaluation of the fundamental engineering properties of bituminous mixtures containing hydrated lime	5. Report Date April 2002 6. Performing Organization Code
7. Author(s) Louay N. Mohammad, Ph.D. and Rana Altinsoy	8. Performing Organization Report No. 306
9. Performing Organization Name and Address Louisiana Transportation Research Center 4101 Gourrier Avenue Baton Rouge, LA 70808	10. Work Unit No. 93-3B 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Louisiana Transportation Research Center 4101 Gourrier Avenue Baton Rouge, LA 70808	13. Type of Report and Period Covered Final Report October 1994 – March 1996 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The increasing volume of truck traffic combined with the hot and moist climate of Louisiana are the major contributing factors to severe pavement distresses. Permanent deformation and moisture damage are the most common distresses of Louisiana pavements, resulting in the rutting and stripping of the asphaltic concrete. The use of hydrated lime decreases moisture susceptibility and increases mixture stiffness.

In this study, conventional asphaltic concrete mixtures and mixtures modified with hydrated lime were evaluated for their fundamental engineering properties as defined by indirect tensile strength and strain, permanent deformation characteristics, resilient modulus, and fatigue resistance.

A dense graded mixture meeting the Louisiana Department of Transportation and Development (LA DOTD) Type 3 specification (low stability, low volume 2500 ADT) was used. The test factorial included two aggregate types, limestone and gravel, and two asphalt cement types, a conventional AC-30 and a polymer modified PAC-40HG. Hydrated lime was used as the mineral filler.

The results indicated that the addition of hydrated lime as mineral filler improved the permanent deformation characteristics and fatigue endurance of the asphaltic concrete mixtures. This improvement was particularly apparent at higher testing temperatures in mixtures with or without polymer modified asphalt.

17. Key Words HMA mixtures, pavement materials characterization, mineral filler hydrated lime	18. Distribution Statement Unrestricted. This document is available through the National Technical Information Service, Springfield, VA 21161.

19. Security Classif. (of this report) N/A	20. Security Classif. (of this page) None	21. No. of Pages	22. Price N/A

Evaluation of the Fundamental Engineering Properties of Bituminous Mixtures Containing Hydrated Lime

by
Louay N. Mohammad, Ph.D.
Associate Professor of Civil and Environmental Engineering
Director, Engineering Materials Characterization Research Facility

Rana Altinsoy
Graduate Research Assistant

LTRC Project No. 93-3B
State Project No. 736-99-0333

Conducted for

Louisiana Department of Transportation and Development
Louisiana Transportation Research Center

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April 2002

ABSTRACT

The increasing volume of truck traffic combined with the hot and moist climate of Louisiana are the major contributing factors to severe pavement distresses. Permanent deformation and moisture damage are the most common distresses of Louisiana pavements, resulting in the rutting and stripping of the asphaltic concrete. The use of hydrated lime decreases moisture susceptibility and increases mixture stiffness.

In this study, conventional asphaltic concrete mixtures and mixtures modified with hydrated lime were evaluated for their fundamental engineering properties as defined by indirect tensile strength and strain, permanent deformation characteristics, resilient modulus, and fatigue resistance.

A dense graded mixture meeting the Louisiana Department of Transportation and Development (LA DOTD) Type 3 specification (low stability, low volume < 2500 ADT) was used. The test factorial included two aggregate types, limestone and gravel, and two asphalt cement types, a conventional AC-30 and a polymer modified PAC-40HG. Hydrated lime was used as the mineral filler.

The results indicated that the addition of hydrated lime as mineral filler improved the permanent deformation characteristics and fatigue endurance of the asphaltic concrete mixtures. This improvement was particularly apparent at higher testing temperatures in mixtures with or without polymer modified asphalt.

IMPLEMENTATION STATEMENT

The laboratory performance of asphalt mixtures modified with hydrated lime was evaluated. The results indicated that the addition of hydrated lime as mineral filler improved the permanent deformation characteristics and fatigue endurance of the asphaltic concrete mixtures. The authors recommend specification changes to require the use of hydrated lime in all asphalt mixtures.

The findings of this research were published in the 2000 Journal of the Transportation Research Board Transportation Research Record No. 1723. The paper, entitled "Mechanistic Evaluation of Hydrated Lime in HMA Mixtures," was also selected to be included in the 2000 TRB Catalog of Practical Papers. In addition, the results of this research were disseminated at several national and international conferences.

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INTRODUCTION

With ever-increasing truck traffic volumes and wheel loads, pavements are becoming distressed much earlier than the pavement design life predicts. Heavy loads, coupled with the hot and moist climate of Louisiana, are the major contributing factors in the development of severe pavement distresses such as permanent deformation and moisture damage.

Permanent deformation, also known as rutting, occurs due to repeated loads that cause the progressive movement of material in any of the pavement layers of the subgrade. Rutting can occur through the consolidation or the plastic flow of the materials. In the case of consolidation, the Hot Mix Asphaltic Concrete (HMAC) that was constructed with an air void above the targeted air void level, is further compacted by traffic loads. An improved compaction effort could solve this problem. However, in the case of plastic flow, the loss of internal friction between aggregate particles can result in the loads being carried by the asphalt cement rather than the aggregate structure. Plastic flow can be minimized by the use of larger, angular, and rough-textured coarse aggregate, and/or by the use of mineral fillers. Fillers are added to improve the cohesion of the binder and/or increase the stiffness of the asphaltic concrete mixture. The stabilizing effect of mineral fillers can be explained by two theories *[1]*. The first presumes that the fine particles fill the voids between the aggregate particles, thereby increasing the density and strength of the compacted mixture. In the second theory, the suspension of the fine particles in the asphalt binder leads to a mastic formation. The suspended fine particles tend to absorb asphaltic components, causing an increase in the viscosity of the binder, thereby stiffening the mixture and improving the mixture's resistance to traffic load.

The other common form of pavement distress in Louisiana is moisture damage, also known as stripping. Stripping is the weakening and/or eventual loss of bond between the asphalt cement and the aggregate in the presence of water. It can be prevented by selecting compatible aggregate and asphalt materials, changing the mix design or the construction and design practices, or treating the moisture susceptible aggregates and asphalts with antistrip additives. The most common practice is the use of antistrip agents, one of which is hydrated lime. In the presence of water, hydrated lime enhances adhesion between the aggregate and the asphalt cement, creating an interaction between the lime and the asphalt cement that is much greater than if the two materials were acting independently *[2]*.

This research was conducted to evaluate the fundamental engineering properties of asphaltic concrete mixtures modified with hydrated lime. Hydrated lime consists of different-size fractions. The larger fraction increases the stiffness of the asphaltic concrete mixture. The smaller size fraction increases the viscosity of the binder, improving the binder cohesion. This, in turn, allows the asphalt cement to coat the aggregate particles with a thicker film. The adhesion increase between the aggregate and binder result in decreased mixture segregation *[1,2]*.

Over the years, the hydrated lime treatment has been applied to many pavements. Antistripping tests with treated mixtures have proved the lime's effectiveness as an antistrip agent. Tests such as the boiling test, the freeze-thaw pedestal test, and the wet-dry indirect tensile strength test have been conducted. However, the filler properties of the treated asphaltic mixture have not been fully investigated in terms of fundamental engineering properties.

A comparative study of conventional and modified mixtures will provide the necessary data to determine if the use of hydrated lime as a mineral filler leads to any improvement in the fundamental engineering properties of HMAC.

OBJECTIVE

This research was conducted to characterize asphaltic concrete mixtures containing hydrated lime as a mineral filler. A Louisiana gravel mix and a limestone mix, both modified with hydrated lime, were used as comparison against the conventional HMACs. The specific aims of this research were:

1) to evaluate the fundamental engineering properties of asphaltic concrete mixtures containing hydrated lime as compared with the conventional mix and

2) to define any changes in the mix characteristics caused by the application of hydrated lime.

SCOPE

A dense graded mixture meeting the LA DOTD Type 3 specification was used in this research. Two aggregate types were included in the test factorial, a limestone and a gravel, and two asphalt cement types, an AC-30 and a polymer-modified asphalt meeting Louisiana specifications for PAC-40HG. The mineral filler that was used was hydrated lime (HL).

Tests conducted in this study were the Indirect Tensile Strength and Strain Test (ITS), Indirect Tensile Creep Test (CRI), Uniaxial Creep Test (CRA). Indirect Tensile Resilient Modulus Test (MRI) and the Indirect Tensile Fatigue Test (FAT). The resulting test data were statistically analyzed using the Statistical Analysis System (SAS) software.

METHODOLOGY

Test Equipment

The MTS Model 810

The MTS Model 810 is a closed-loop controlled servo-hydraulic test system. This system is equipped with an environmental chamber, and the machine is rated for 55,000 lbs (244,640 N). Its state-of-the-art digital controller, which is operated under IBM OS/2 and MTS Teststar software, conducts the data acquisition and equipment control. Figure 1 shows the MTS test system with its environmental chamber whereas figure 2 shows the testing head that was used for tests in the indirect tensile mode.

Environmental Test System. The asphaltic concrete specimens were tested at three different temperatures; therefore, some of the tests were conducted in the temperature chamber manufactured by Thermotron Industries. This chamber has the inside dimensions of 14 inch (35.6 cm) depth x 14 inch (35.6 cm) width x 22 inch (55.9 cm) height. In this chamber test temperatures ranging from -100°F (-73°C) up to 600°F (316°C) can be applied. The 409.80 MTS Temperature Controller is a microprocessing control unit that provides temperature control temperatures inside the chamber during heat applications.

The Louisiana Modified Indirect Tension Test Device. In order to perform testing in the indirect tension mode, the Louisiana Modified Indirect Tension Test device, as shown in figure 2, was used. This device was built in accordance with the Federal Highway Administration (FHWA) and was manufactured in LSU's civil engineering department *[3]*. For deformation measurement, the vertical LVDTs were mounted 180 degrees apart on the piston-guided plate as can be seen in figure 2. The output of each LVDT was monitored independently and simultaneously compared with each other. If the difference in the peak value was greater than 10 percent, the seating load was adjusted *[4]*.

The Axial Creep Test Device. A different testing device, as seen in figure 3, was used for the uniaxial creep test. The Axial Creep Test device was designed according to the device used in Test Method Tex-231-F *[5]*. For deformation measurement, the LVDTs were mounted 180 degrees apart on the LVDT holders of the device. To minimize the effects of platen to sample end frictions on creep deformation, the sample was placed in smooth steel caps during testing.

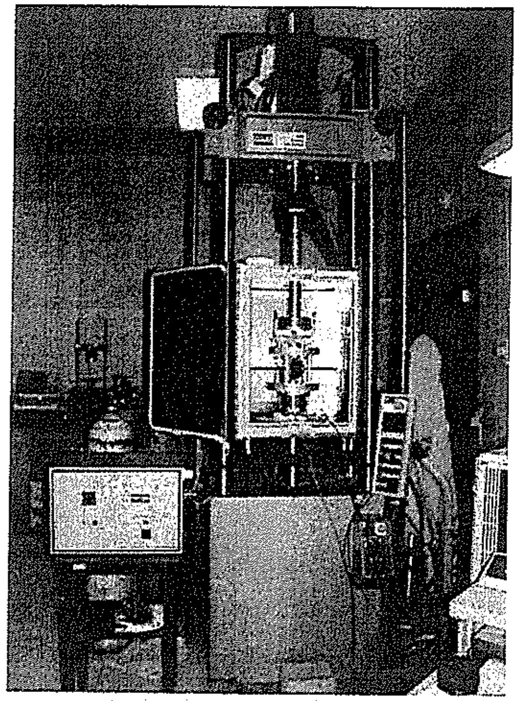


Figure 1. MTS with environmental chamber

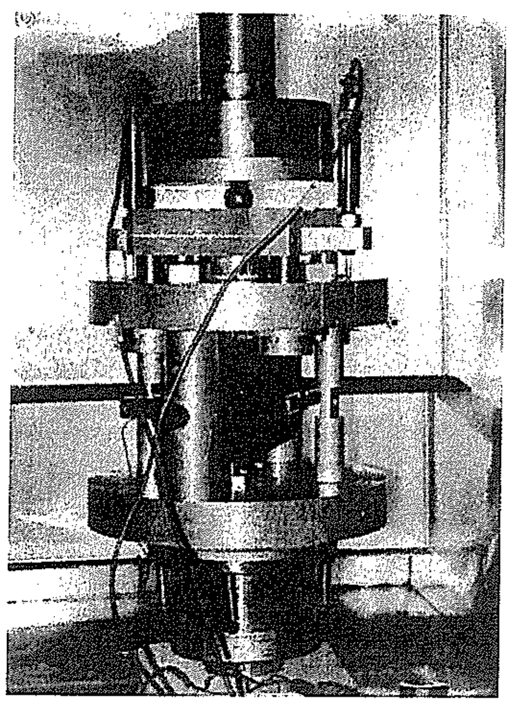


Figure 2. Testing head for indirect tensile testing mode

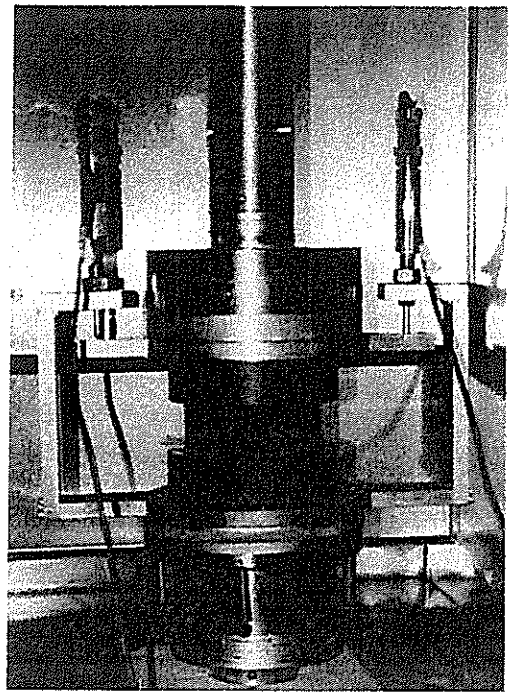


Figure 3. Testing head for the uniaxial testing mode

The Hamburg Wheel Tracking Device

Further testing using the Hamburg Wheel Tracking Device (HWTD) was conducted on limestone and gravel mixtures. This evaluation was performed by KOCH MATERIALS Laboratory in Terre Haute, Indiana. The HWTD has been used in Germany since 1974 for research of asphalt binder course mixes and, recently, as a specification tool. The device is used to measure resistance to moisture damage and permanent deformation as well as post-compaction deformation *[6, 7]*.

Helmut Wind, Inc. of Hamburg, Germany, manufactures the Hamburg Wheel Tracking Device. Figure 4 is a schematic representation of the device. This device is connected to a computer for data acquisition. A pair of samples (slabs) is tested simultaneously. A typical slab is 10.2 inches (26 cm) wide, 12.6 inches (32 cm) long, and 1.6 inches (40 mm) thick. The mass of a slab is approximately 16.5 lbs (7.5 kg), and the slab is compacted using a linear kneading compactor.

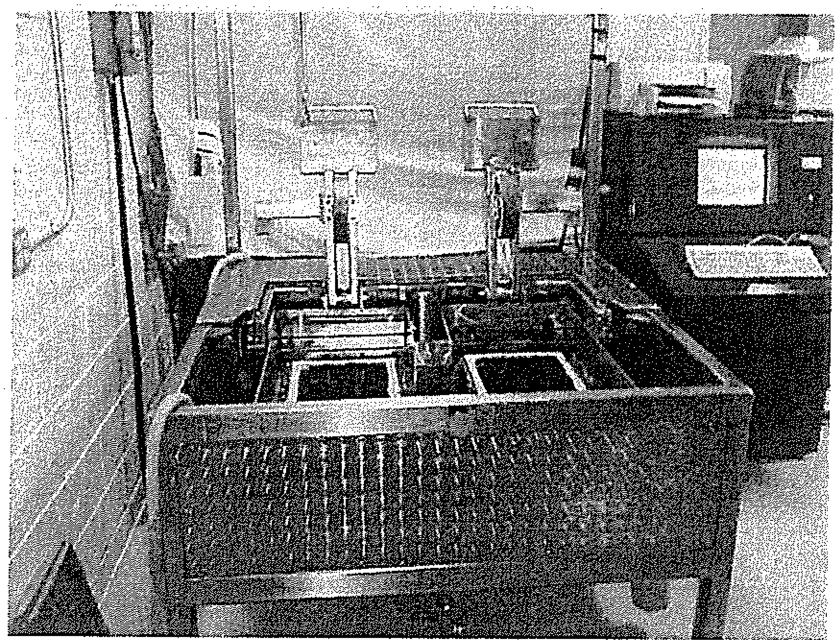


Figure 4. The hamburg wheel tracking device

Materials

Asphalt Cement

Two types of asphalt cement were used in this study, a conventional viscosity graded AC-30 *[8]* and a polymer modified asphalt cement, meeting the LA DOTD specification *[9]* for a PAC-40HG. The polymer modified asphalt cement is obtained by the modification of the asphalt cement with a styrene-butadiene block co-polymer. Specifications for both asphalt cements are given in table 1, and their properties are given in table 2.

The amount of asphalt cement used for each individual HMAC was determined with the Marshall mix design method.

Hydrated Lime

The hydrated lime (HL), used as a mineral filler in this study, was obtained from the Falcon plant in Jackson, Mississippi. The amount of hydrated lime used in the mixture was 1.5 percent of the total aggregate weight of the specimen. Table 3 provides the gradation of the HL used in this study.

Table 1
Asphalt cement specifications

	Conventional AC-30	LA DOTD Specified PAC-40HG
Viscosity, 140°F (60°C), Poises	3000 ± 600	4000 +
Viscosity, 275°F (135°C), centiStokes	min. 350	max. 2000
Penetration, 77°F (25°C), 100g, 5s, min.	50	-
Flash point, Cleveland open cup, min., °F (°C)	450 (232)	450 (232)
Solubility in trichloroethylene, min., %	99.0	99.0
Test on residue from thin-film oven test		
Viscosity, 140°F (60°C), Poises	15000	-
Ductility, 77°F (25°C), 5 cm/min, min., cm	40	-
Penetration Retention, min., % of original	-	50
Elastic Recovery, 77°F (25°C), 5 cm/min, 10 cm along., %	-	60
Separation of Polymer, 325°F (163°C), 48 hrs		
Difference in softening point from top and bottom, max., %	-	4.0
Force ductility, f2/f1, 39°F (4°C), 5 cm/min, 30 cm along., min.	-	0.3

Table 2
Asphalt cement properties

Original Properties		
Asphalt Cement Source	Marathon	Koch
Asphalt Cement Grade	AC-30	PAC-40HG
Penetration @ 25°C	57	59
Specific Gravity 25/25°C	1.03	1.03
Absolute Viscosity @ 60°C, Poises	3332	6629
Properties after R.T.F.O.		
Penetration @ 25°C	30	38
Absolute Viscosity @ 60°C, Poises	13448	18524

Table 3
Hydrated lime gradation

Sieve Size, inches (mm)	Percent Passing
¾" (19.0)	100
1/2 " (12.5)	100
3/8" (9.5)	100
No. 4 (4.75)	100
No. 10 (2.00)	100
No. 40 (0.425)	99
No. 80 (0.180)	95
No. 200 (0.075)	78

Mixtures

The limestone aggregate was obtained from the Reed Quarry in Kentucky whereas the gravel aggregate was obtained from ACME Gravel in Baywood, Louisiana. The comparison of the composite gradation for the limestone mixtures, the gravel mixtures, and the LA DOTD type 3 binder course specification limits are given in table 4. It can be seen that both the limestone mix and the gravel mix gradations are within the specified limits.

Table 4
The La DOTD specification limits for type 3 binder course

Sieve Size in. (mm)	Limestone Total Composite (% Passing)	Gravel Total Composite (% Passing)	Specification Binder Course (% Passing)
3/4 " (19)	**100**	100	85 -100
1/2 " (12.5)	98	97	70 - 100
3/8 " (9.5)	83	83	60 - 95
No.4 (4.75)	59	**59**	40 - 70
No.10 (2.0)	40	39	28 - 50
No.40 (0.425)	21	22	14 - 30
No.80 (0.180)	12	11	8 - 20
No.200 (0.075)	6	7	3 - 8

Mixture Proportions

The aggregate mixtures were blended with each asphalt cement and with and without hydrated lime. The aggregates were combined as shown in table 5.

Table 5
Mixture nomenclature

Mixture Code	Aggregate Type	Asphalt Cement	Mineral Filler
SAC30N	LS[1]	AC-30	--
SAC30L	LS	AC-30	--
SPMACN	LS	PAC-40HG[3]	HL[4]
SPMACL	LS	PAC-40HG	HL
GAC30N	GR[2]	AC-30	--
GAC30L	GR	AC-30	--
GPMACN	GR	PAC-40HG	HL
GPMACL	GR	PAC-40HG	HL

[1]LS: Limestone Mix
[2]GR: Louisiana Gravel Mix
[3]PAC-40HG: Louisiana's polymer modified asphalt
[4]HL: Hydrated Lime

The mixture coding consists of:

aggregate type	S / G
asphalt cement type	AC30 / PMAC
presence of hydrated lime	HL / --

where,

S and G indicate limestone and gravel aggregates, respectively, and AC30 and PMAC represent the two types of binders used (AC-30 and PAC-40HG). H indicates the inclusion of hydrated lime.

The different HMACs prepared are summarized in table 6.

Figure 5 depicts the aggregate gradations for limestone mixtures, and figure 6 shows the same for gravel mixtures. The gradations are compared to the SHRP Superpave^{TM} Maximum Density Line and its control points. The gradation stays within the control points.

Table 6
Mixture proportions

Mixture Components	Limestone Mixture Types			
	SAC30N	SAC30L	SPMACN	SPMACL
Asphalt Types	AC-30	AC-30	PAC-40HG	PAC-40HG
Asphalt Content	4.7 %	4.6 %	4.7 %	4.6 %
Lime Content	--	1.5 %	--	1.5 %
Mixture Components	**Gravel Mixture Types**			
	GAC30N	GAC30L	GPMACN	GPMACL
Asphalt Types	AC-30	AC-30	PAC-40HG	PAC-40HG
Asphalt Content	5.8 %	5.0 %	5.2 %	5.2 %
Lime Content	--	1.5 %	--	1.5 %

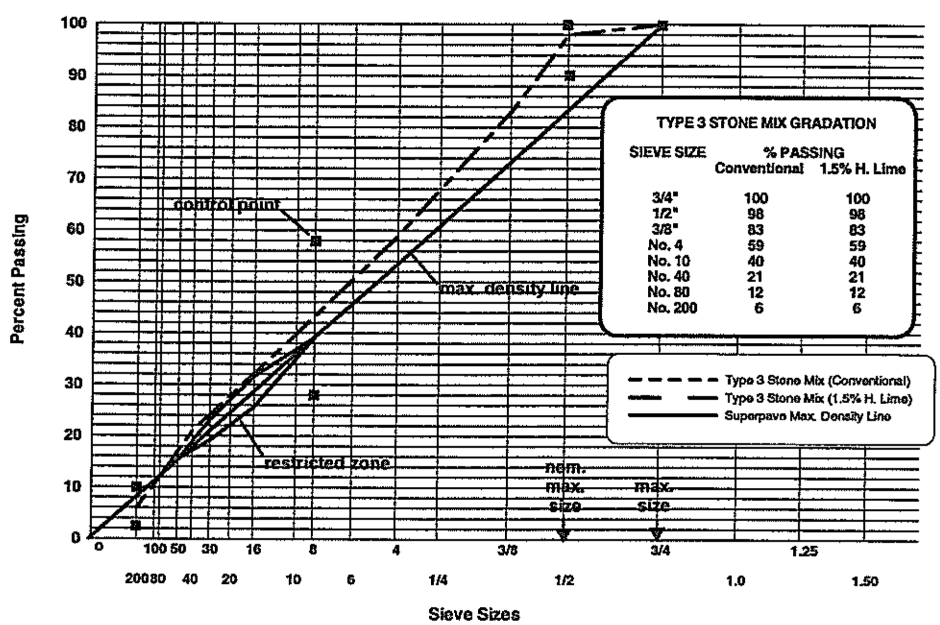


Figure 5
Aggregate gradation for the limestone mix

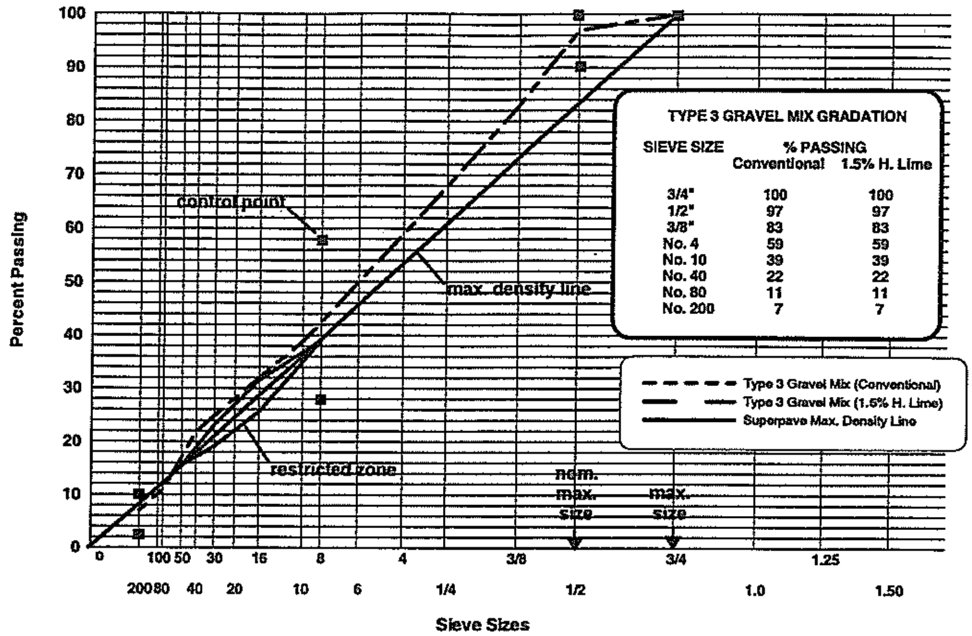


Figure 6
Aggregate gradation for the gravel mix

Specimen Preparation

The test samples were prepared in standard Marshall size (ASTM 3487) with an approximate height (thickness) of 2.5 inches (6.35 cm) and a diameter of 4 inches (10.16 cm). A total of 192 specimens were needed. In the preparation of a stone mix specimen and a gravel mix specimen, the steps were very similar. Differences existed in the preparation of the batch weight tables and the compaction of the specimens.

Specimen Preparation Procedure

The following procedure was used for specimen preparation:

1) The stone and gravel coarse aggregate were sieved and separated into individual sieve sizes as indicated in the batch weight table.

2) The aggregate, coarse sand, and fine sand, and HL, where applicable, for a 1200 g sample was weighed and put into a small aggregate drawer.

3) If HL had to be added to the aggregate, the procedure described in section 3.3.2.1 was followed.

4) The aggregate drawers were then put into a 375°F (191°C) oven, and the aggregate mix was heated for a minimum of 3 hours for the conventional HMACs and overnight for the lime HMACs. If a lime slurry was added to the aggregate mixture, the aggregate had to be kept in the oven overnight to dry out the moisture of the slurry.

5) The molds in which the HMACs were compacted were placed into a 375°F (191°C) oven for a minimum of 3 hours.

6) The next step was to heat the asphalt cement to 330°F (165°C).

7) The aggregate drawer was taken out of the oven and the hot aggregate was transferred into a mixing bowl.

8) The measured amount of asphalt cement was poured over the aggregate and mixed so that the AC coated the aggregate properly. The mixing time, however, could not exceed 2 minutes, because over-mixing would have resulted in heat loss and made compaction difficult.

9) The HMAC was then placed into the preheated compaction molds and compacted with the Marshall hammer for the stone mix and with the GTM for the gravel mix.

10) The compacted samples were then extruded and left to cool.

Introduction of Hydrated Lime to the Hot Mix Asphalt

The hydrated lime (HL) was applied in slurry form to the weighed dry aggregate. For this procedure, the HL was first oven-dried overnight to dry out any moisture the lime might contain. HL is known to absorb moisture easily, which in this case could distort the weight of the lime. From the dry lime, the appropriate amount was weighed in a beaker as shown in figure 7. The water that was needed for the slurry was measured in milliliters as twice the number of grams of HL weight. For example a 1200 g sample with 5.2 % AC and 1.42 % of HL would need 1200 g * (1.42 %) = 17.1 g HL. Therefore, the water for the slurry = 17.1g *2 $\approx$ 34 ml water. The measured water was then poured on the pre-weighed HL in the beaker and was stirred thoroughly. Then, the lime slurry was poured onto the pre-weighed aggregate in the bowl (figure 8), the beaker was scraped carefully, and any slurry residue was rinsed out with a very small amount of water and poured onto the aggregate in the bowl.

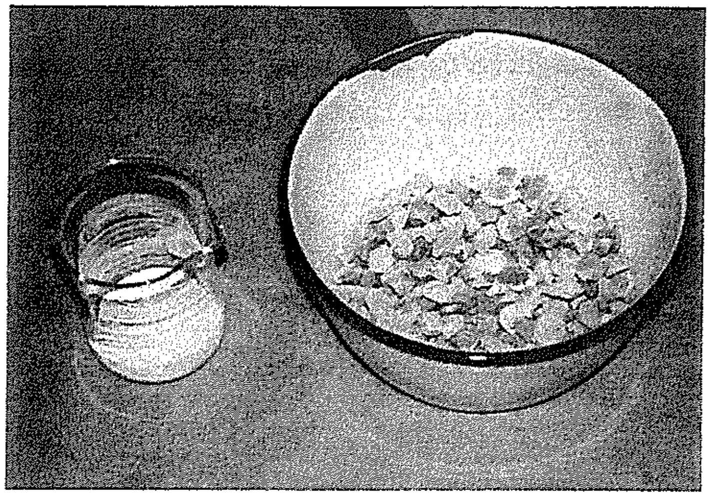


Figure 7. Hydrated lime and aggregate

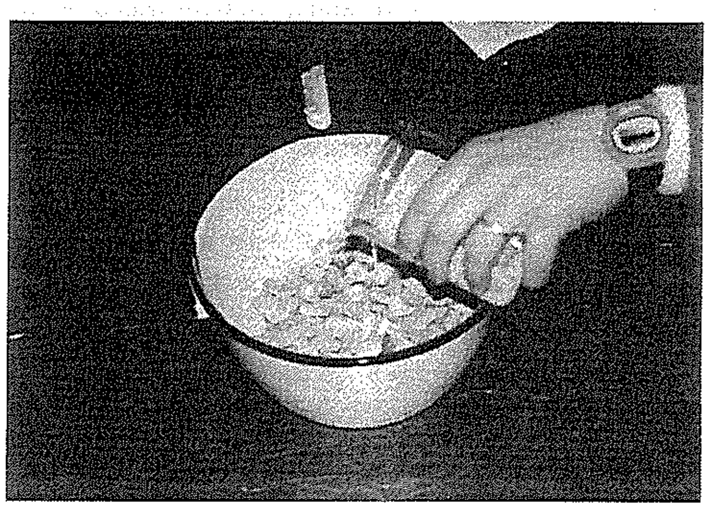


Figure 8. Application of the lime slurry

After the slurry was emptied onto the aggregate, the aggregate was mixed thoroughly to ensure the proper coating of the aggregate with the lime. The prepared aggregate mixture was then emptied into the small aggregate drawers, (figure 9) placed in the oven (figure 10), dried overnight at 375°F (191°C), and mixed with hot asphalt cement the following day.

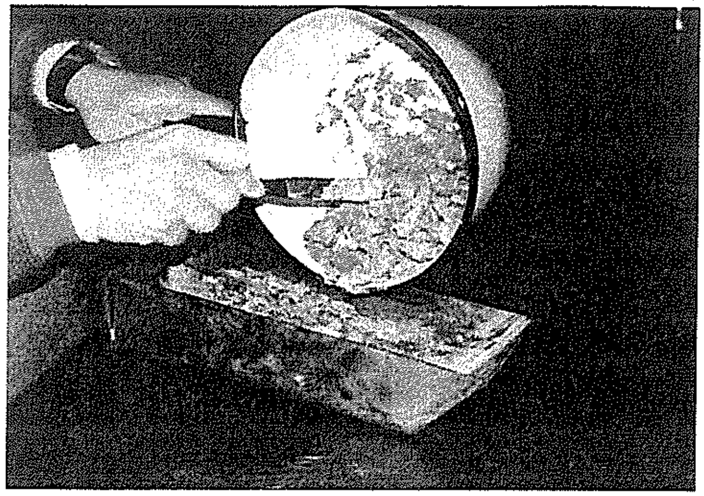


Figure 9. Aggregate and slurry mix if emptied into drawer

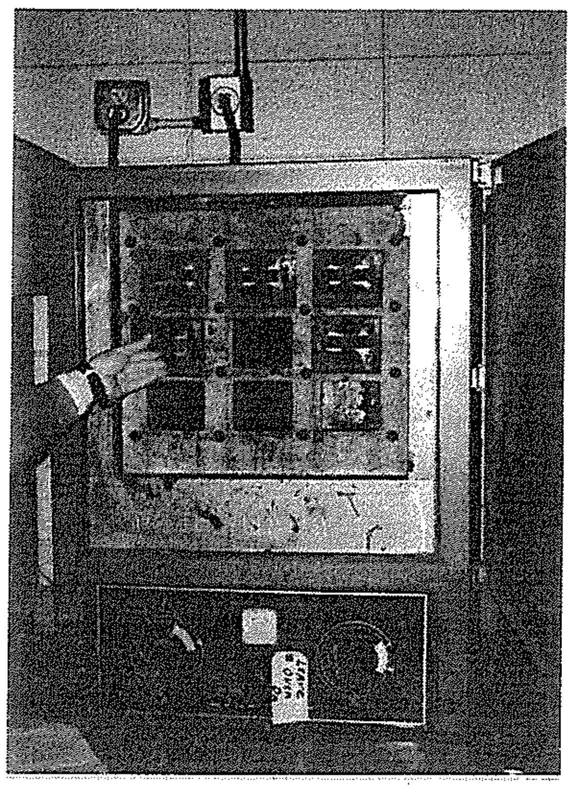


Figure 10. Aggregate oven

The Compaction of the Limestone Specimens

The asphaltic concrete specimens made with the limestone mixture were compacted with a 10-pound Marshall hammer applying 75 blows on each side of the 4-inch (10.16 cm) specimen. The targeted and actual air voids achieved with this compaction method for the selected test sample groups are given in table 7. The air voids of each individual sample used in the testing procedures are given with the limestone test results in appendix A.

The Compaction of the Gravel Specimens

For the compaction of a 4-inch (10.16 cm) asphaltic concrete specimen made with the gravel mixture in this study, the Gyratory Testing Machine (GTM) was used because the targeted air void range could not be achieved by using the Marshall hammer. A constant load of 5000 pounds (22240 N) was applied that converted to a hydraulic (RAM) pressure of 210 psi. The desired sample (roller pressure) for this reading was 105 psi. The initial gyratory (machine) angle was 1 degree, and the compaction temperature was 284°F (140°C). The number of revolutions to achieve adequate compaction were determined by calculating the unit mass of the total mix at every 50 revolutions according to the formula below:

$$\text{Unit Mass Total Mix GTM} = \frac{\text{Weight in grams} \times C_1}{\text{Height in inches}} \qquad (1)$$

where the constant $C_1 = 0.303$ for a 4-inch mold.

The compaction was assumed to be complete when the unit mass change equaled 0.5 lb/ft^3/50 revolutions. For this gravel mix the number of revolutions for good compaction was set at 250. As aforementioned, the targeted and actual air voids for the gravel mix sample groups are provided in table 7. The individual sample air voids are given with the gravel test results in appendix B. The average Gyratory Shear Index (GSI) from the GTM for each of the four gravel mixes is given in Appendix C.

Table 7
Percent air void levels by test type

	ITS			CRPI			CRPA			MR			FAT		
Target Air Void	4 ± 0.5														
Mix Type	**Avg**	**St.D**	**C.V.**	**Avg**	**St.D**	**C.V.**	**Avg**	**St.D**	**C.V.**	**Avg**	**St.D**	**C.V.**	**Avg**	**St.D**	**C.V.**
SAC30N	3.9	0.27	7.11	3.9	0.31	7.96	3.8	0.27	7.11	3.8	0.10	2.63	3.7	0.15	4.09
SAC30L	4.0	0.34	8.61	4.0	0.37	9.25	4.1	0.33	8.03	4.0	0.30	7.50	4.0	0.36	9.01
SPMACN	4.0	0.23	5.82	4.0	0.25	6.23	4.0	0.27	6.89	4.1	0.20	4.88	4.1	0.20	4.88
SPMACL	4.1	0.28	6.82	4.1	0.35	8.66	4.1	0.34	8.40	4.0	0.15	3.85	4.1	0.32	7.78
GAC30N	4.0	0.28	6.95	4.1	0.23	5.66	4.1	0.32	7.75	4.0	0.30	7.50	4.0	0.35	8.71
GAC30L	3.8	0.23	5.87	3.9	0.23	5.87	3.9	0.31	7.88	3.9	0.10	2.56	3.9	0.31	7.90
GPMACN	4.0	0.26	6.57	4.0	0.28	6.95	4.1	0.33	7.90	3.8	0.20	5.26	4.1	0.30	7.32
GPMACL	4.0	0.36	9.04	4.0	0.33	8.24	4.0	0.33	8.24	4.0	0.12	2.86	4.1	0.10	2.44

ITS: Indirect Tensile Strength Test
CRPI: Indirect Tensile Creep Test
CRPA: Uniaxial Creep Test
MR: Indirect Tensile Resilient Modulus Test
FAT: Indirect Tensile Fatigue Test
Avg: Average Air Void Level (%)
St.D: Standard Deviation
C.V.: Coefficient of Variance (%)

Specimen Preparation Equipment

The specimens were prepared using a standard Marshall hammer and a U.S. Army Corps of Engineers Gyratory Testing Machine (GTM).

The GTM, Model 8A/6B/4C/1, was manufactured by the Engineering Developments Company, Inc. of Vicksburg, Mississippi. It is a machine that can be used for compaction as well as strain and simple shear testing of soils, base course materials, and asphaltic concrete paving mixtures. The GTM produces specimens using a kneading compaction process, which is believed to have stress-strain properties that are more representative of field compaction conditions. The machine can be set up to compact 4-inch (10.16 cm), 6-inch (15.24 cm), and 8-inch (20.32 cm) specimens. Figure 11 presents the GTM that was used for compaction procedures in this study.

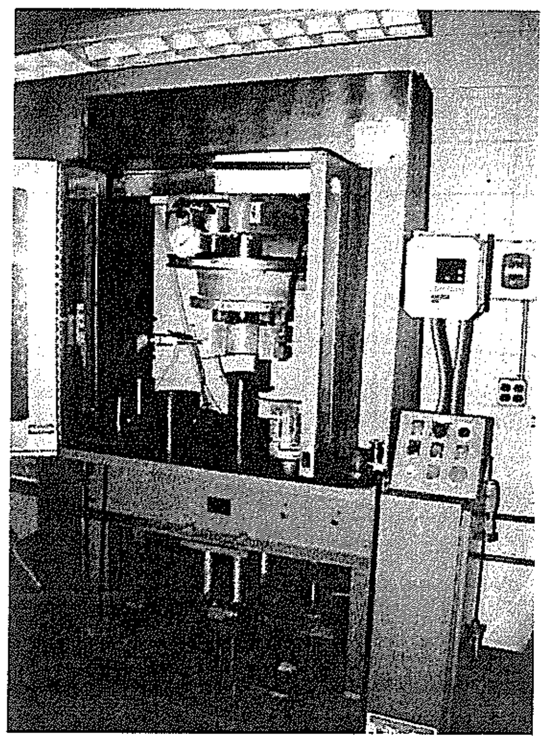


Figure 11. The U.S. Army Corps of Engineers Gyratory Testing Machine (GTM)

Specimen Conditioning Procedure

Since the tests had to be performed at one or more testing temperatures [(40°F (5°C), 77°F (25°C), and 104°F (40°C)], the specimens had to be conditioned to the temperatures set forth by the testing procedures. For the 40°F (5°C) testing the samples were kept in a temperature-controlled refrigerator for the required time period. The 77°F (25°C) testing samples were kept at room temperature, and for the 104°F (40°C) testing the samples were placed and kept in a temperature-controlled oven for the required conditioning period.

At the time of testing, the conditioned samples were then placed in the temperature chamber of the MTS as previously described.

Test Procedures

Indirect Tensile Strength and Strain Test

The indirect tensile strength and strain test was conducted at 77°F (25°C) and 104°F (40°C) in accordance with the American Association of State Highway and Transportation Officials (AASHTO), T 245-82. At the average temperature of 77°F (25°C), this test is a relative measure of the tensile properties of the mix that are related to the fatigue endurance characteristics.

In this test, specimens were loaded to failure at a 2 inch per minute (5.08 cm/minute) deformation rate. The load to failure and the horizontal and vertical deformations were monitored and recorded. Figure 12 shows a typical relationship between the compressive load and the deformation. The indirect tensile strength, S_T, was calculated as:

$$S_T = \frac{2 * P_{ULT}}{\pi * t * D} \quad (2)$$

where,

S_T = indirect tensile strength, psi (or MPa),
P_{ULT} = ultimate applied load to failure, lbf (or N),
t = thickness of specimen, inch (or mm), and
D = diameter of specimen, inch (or mm).

The indirect tensile strength was reported together with the load to failure and the percent tensile strain, which was calculated as follows:

$$TS = 0.52 * H * 100 \quad (3)$$

where,

TS = percent tensile strain, and
H = horizontal deformation at failure in inches.

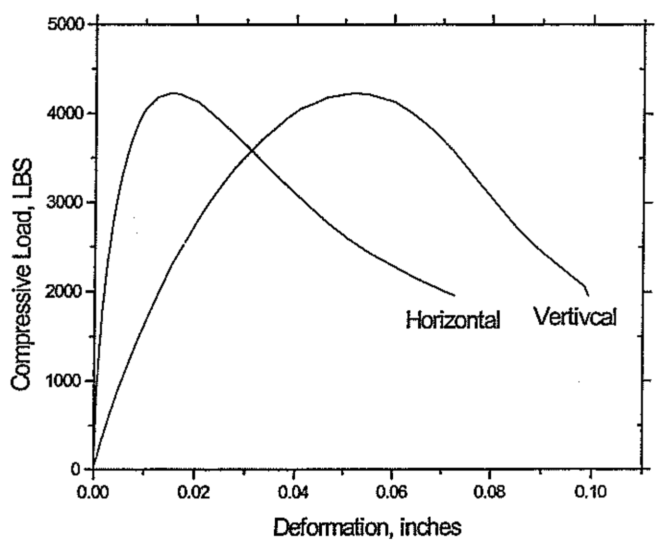


Figure 12
Typical relationship of compressive load to deformation for the indirect tensile strength and strain test *[10]*

Indirect Tensile Resilient Modulus Test

The indirect tensile resilient modulus test provides the resilient behavior of the HMAC over a range of temperatures and loads. The resilient behavior of a mix gives a measure of the mixture's stiffness. High values for the resilient modulus (M_R) at low temperatures can lead to thermal cracking if the indirect tensile strain of the mixture is low.

The testing temperatures used for this test were 40°F (5°C), 77°F (25°C) and 104°F (40°C), and the tests were conducted according to ASTM D4123 with the following modifications *[3, 4, 10]*:

1) The test specimens were seated with a sustained load of 20 pounds (89 N). Cyclic haversine loads of 15, 10, and 5 percents of the average indirect tensile strength (S_T) at 77°F (25°C) were applied to the specimens at 40°F (5°C), 77°F (25°C) and 104°F (40°C), respectively. The two vertical deformations were monitored independently. If these measurements exceeded the tolerance level of 10 percent, further adjustment to the loading device was made. The average of the two vertical deformations was the used in the data analysis (figure 13).

2) The specimen was conditioned by continuously monitoring the deformation until the deformation rate was almost constant. The conditioning was then halted, and the transducers were rezeroed.

3) A haversine waveform load, as described in step 1, was applied on a repetitive basis with a load frequency of two cycles per second with a 0.1 second loading time and a 0.4 second relaxation period, (figure 14).

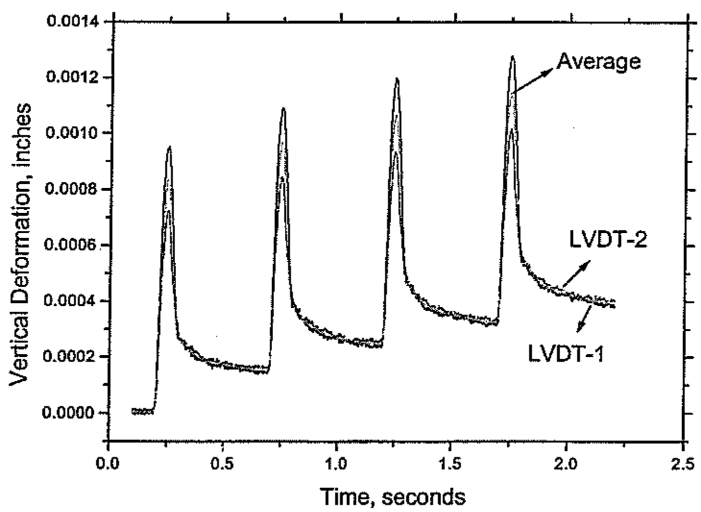


Figure 13
Typical vertical deformation verses time diagram for the indirect tensile resilient modulus test *[10]*

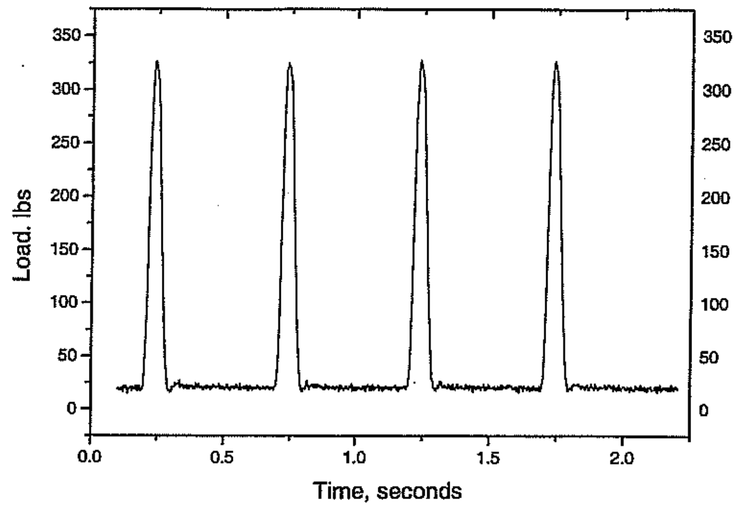


Figure 14
Typical load verses time diagram for the indirect tensile resilient modulus test *[10]*

4) The computation of the instantaneous and total resilient moduli was accomplished through these steps:

   i) The load and vertical and horizontal deformation curves over the two cycles were digitized. From these curves, the instantaneous and total recoverable horizontal and vertical deformation were determined *[11]*. The data at the beginning of the relaxation period were used to compute the instantaneous properties, whereas the data at the end of the relaxation period were used to compute the total properties as follows:

$$M_{RI} = \frac{P*(\mu_I + 0.27)}{t*\Delta H_I} \tag{4}$$

$$M_{RT} = \frac{P*(\mu_T + 0.27)}{t*\Delta H_T} \tag{5}$$

$$\mu_I = 3.59*\frac{\Delta H_I}{\Delta V_I} - 0.27 \tag{6}$$

$$\mu_T = 3.59*\frac{\Delta H_T}{\Delta V_T} \tag{7}$$

where,

M_{RI} = instant resilient modulus, psi (MPa),
M_{RT} = total resilient modulus, psi (MPa),
μ_I = instantaneous Poisson's ratio,
μ_T = total Poisson's ratio,
P = repeated load, lbf (N),
t = specimen thickness, inch (mm)
ΔH_I = instantaneous recoverable horizontal deformation, inch (mm),
ΔH_T = total recoverable horizontal deformation, inch (mm),
ΔV_I = instantaneous recoverable vertical deformation, inch (mm),
ΔV_T = total recoverable vertical deformation, inch (mm),

ii) From these instantaneous and total moduli values the average resilient moduli, M_R, (for both instantaneous and total) were calculated as:

$$M_R = \frac{\sum_{i=1}^{4} M_{R(i)}}{4} \quad (8)$$

ii) The average Poisson's ratio, on the other hand, was calculated as:

$$\mu = \frac{\sum_{i=1}^{4} \mu_{(i)}}{4} \quad (9)$$

Following steps one through four, each specimen was tested at each of the three temperatures, respectively, for minimum permanent damage. The individual specimen was tested in its initial position and then in a 45 degree rotated position. The results were then averaged.

Indirect Tensile Creep Test

The creep test evaluates the rutting potential of asphaltic concrete mixtures by using the creep slope and the time to failure characteristics. The test was conducted at 77°F (25°C) and 104°F (40°C) while a compressive load of 250 pounds (1112 N) was applied on the test specimen. The load and vertical and horizontal deformations were recorded continuously through the data acquisition methods.

After obtaining the creep modulus, C(t), the log of the creep modulus was plotted against the log of the time to sample failure. A typical plot is illustrated in figure 15. From this plot, the creep slope of the calculated indirect tensile creep stiffness (modulus) and the time to failure were obtained and later used in the statistical analysis.

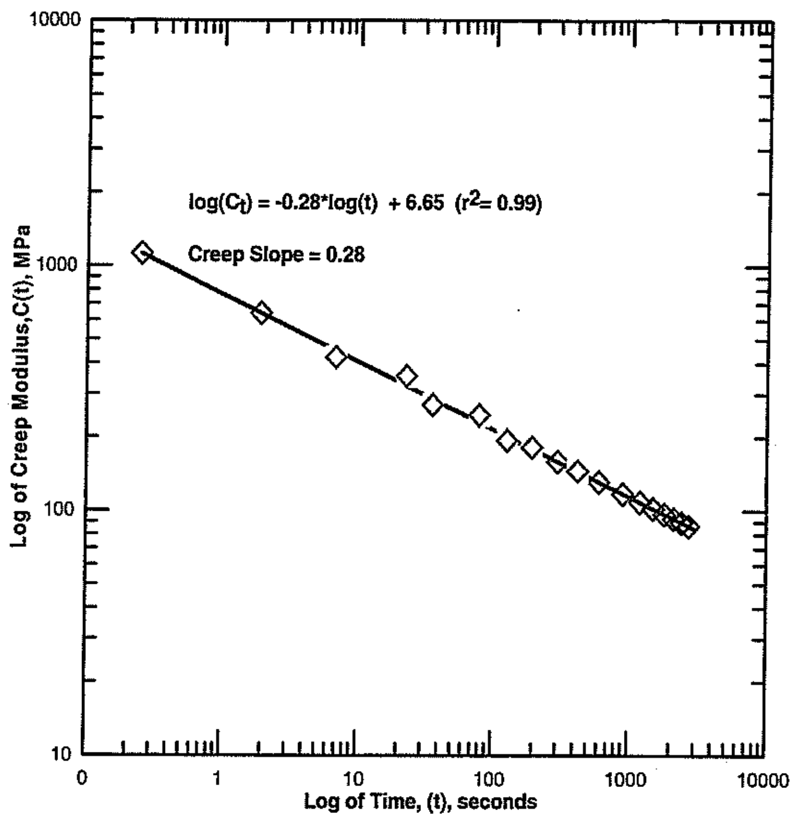


Figure 15
Typical plot of indirect tensile creep data

Uniaxial Creep Test

The uniaxial creep test is used in the determination of creep characteristics (creep slope, permanent strain, and total strain) in axial unconfined compression mode. With these characteristics, HMACs can be evaluated for their rutting potential. The uniaxial creep test was conducted at a temperature of 104°F (40°C) according to the Test Method Tex-231-F *[5]*. The load and vertical deformation of the specimens were monitored and recorded. A plot of the load and deformation is given in figure 16. For each specimen, permanent strain, slope, and creep stiffness were reported.

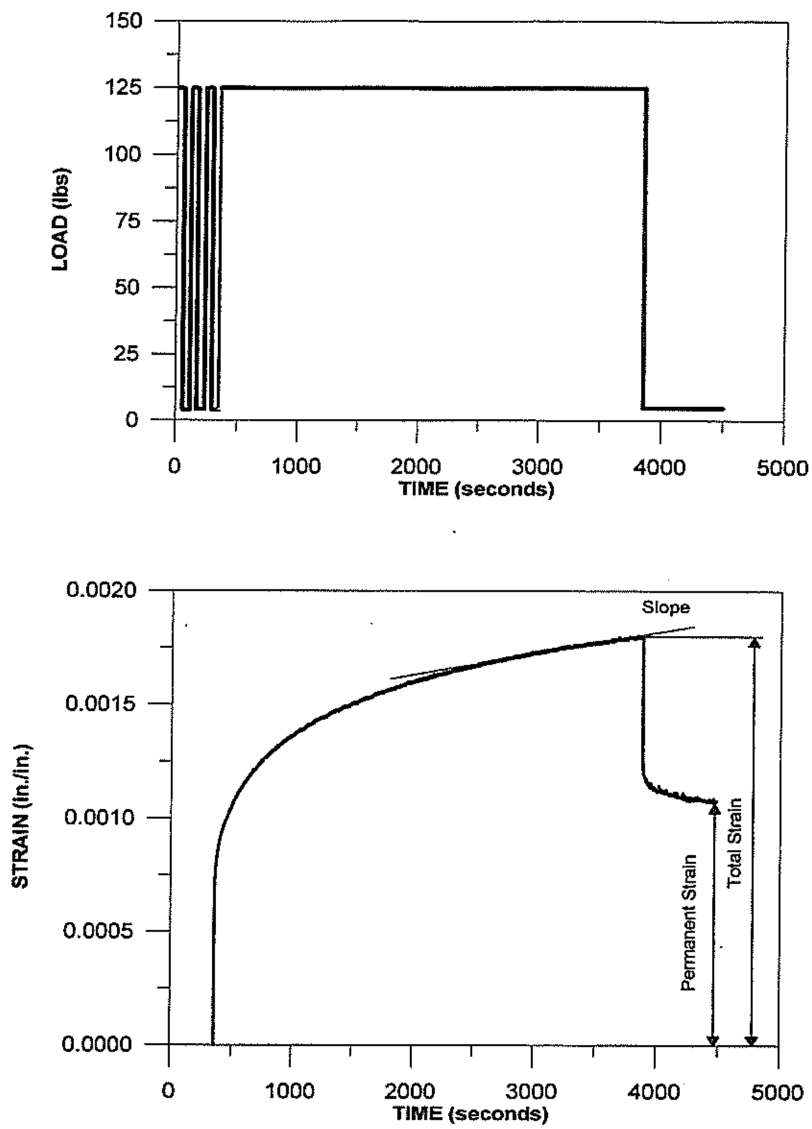


Figure 16

Load vs. time with corresponding strain vs. time graphs for uniaxial creep data

The Wheel Tracking Test

While the wheel tracking test is not a fundamental test, this empirical procedure was used to provide relativity to the fundamental engineering properties.

The Test Procedure. The test is considered a torture test because of the severe test conditions including a testing period of approximately six hours during which the slabs being tested are submerged in a 122°F (50°C) water bath *[6]*. The duplicate slabs are tested under moving steel wheels, 8-inch (204 mm) diameter by 1.85-inch (47 mm) width. The wheels, providing a load of 158 pounds (705 N) each, move at a rate of 50 passes per minute with a maximum velocity of 1.1 ft/sec (34 cm/sec) at the center of the sample *[7]*. This loading results in a cycle of approximately 0.1 seconds loading and 0.9 seconds relaxation *[6]*. A computer with each wheel pass acquires the test data. For the measurement of the vertical deformation, LVDTs, located at the center of the slabs, are used. Each sample is loaded with 20,000 wheel passes or until the rut depth reaches 20 mm.

The Indices for Data Analysis. The following four indices (figure 17) are used to quantify the results *[6]*:

1) Post-Compaction Consolidation: The slabs are usually not fully compacted during specimen fabrication; therefore, the steel wheel consolidates the mix early in the test. This leads to rapid deformation of the specimen, but this rate of deformation slows down after about 1,000 passes. Because the steel wheel creates such a great compaction on the specimen, the deformation at 1,000 passes is called Post-Compaction Consolidation. A low post-compaction consolidation value (reported in mm) is desirable, because this indicates that the compaction during laboratory fabrication was near optimum.

2) Creep Slope: The creep slope is the inverse of the rate of deformation in the linear region of the deformation curve. The linear region is the region after post-compaction effects have ended and before stripping begins. The creep slope value is reported in passes per mm. The larger the value, the more energy is needed to deform the mix. As a result, the slower the rate of permanent deformation, the less sensitive the mix is to rutting.

3) Stripping Slope: The stripping slope is the inverse of the rate of deformation in the linear region of the deformation curve from the beginning of stripping until the end of the test. The stripping slope is reported in passes per mm. The stripping slope involves the severity of moisture damage, and, for this reason, a higher number of passes for each millimeter of impression from stripping is the desired value.

4) Stripping Inflection Point: The stripping inflection point (reported in number of passes) is the number of passes at the intersection of the creep slope and the stripping slope. The stripping inflection point relates the resistance of the mixture to

moisture damage. A high value for this index is desired. The higher the value for the stripping inflection point, the more energy is needed to cause stripping and thus, the less sensitive the mix is to stripping.

The specification in Hamburg, Germany, is a rut depth of less than 4 millimeters after 20,000 passes. Colorado has the only specification for the HWTD test results in the United States. It considers the Hamburg specification to be too severe for its pavements and, instead, uses a rut depth of 10 millimeters after 20,000 passes *[7]*.

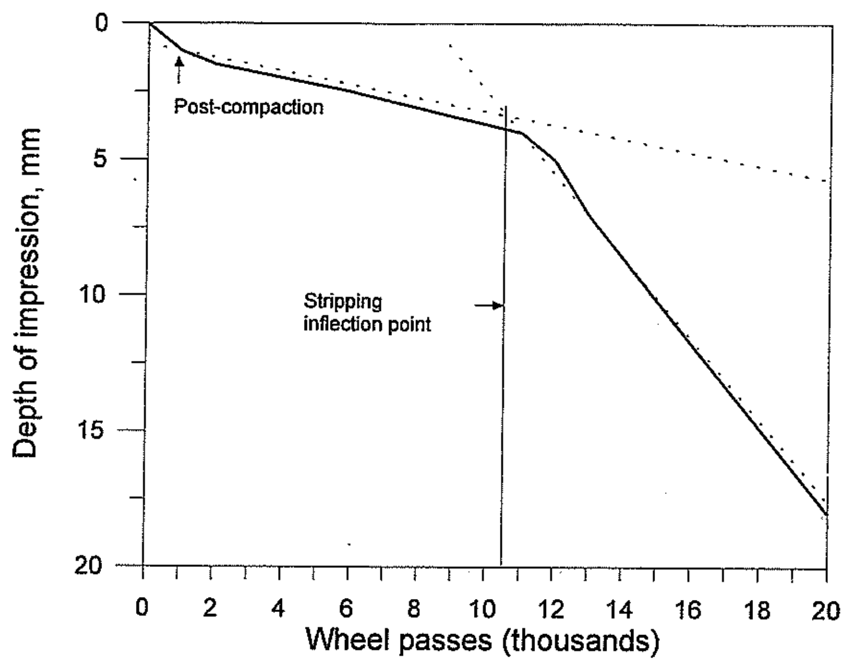


Figure 17
Data analysis indices for the wheel tracking test *[6]*

Indirect Tensile Fatigue Test

The test was conducted at 77°F (25°C) to evaluate the fatigue resistance of the HMAC specimens. The fatigue resistance of a mix is a relative indicator of the pavement design life and can be determined using the fatigue slope and the number of cycles to failure. The specimens were seated with a sustained load of 20 pounds (89 N) and a cyclic haversine load (figure 18) of 10 percent of the average indirect tensile strength (S_T) at 77°F (25°C) was applied. This load was applied on a repetitive basis with a load frequency of 2 cycles per second with a 0.1 second loading time and a 0.4 second relaxation period. The horizontal deformations were monitored throughout the duration of the test, and the test was terminated when the horizontal deformation reached 0.1 inch (0.254 cm) or at sample failure. Sample failure was identified *[12]* as the value at which there was a relatively small difference in the number of cycles between the point where a dramatic increase in horizontal deformation accrued and the point where the horizontal deformation equaled 0.1 inch (0.254 cm).

In order to obtain the slope of the fatigue curve, the log of the permanent horizontal deformation was plotted against the log of the number of cycles to sample failure. A typical fatigue data plot is given in figure 19.

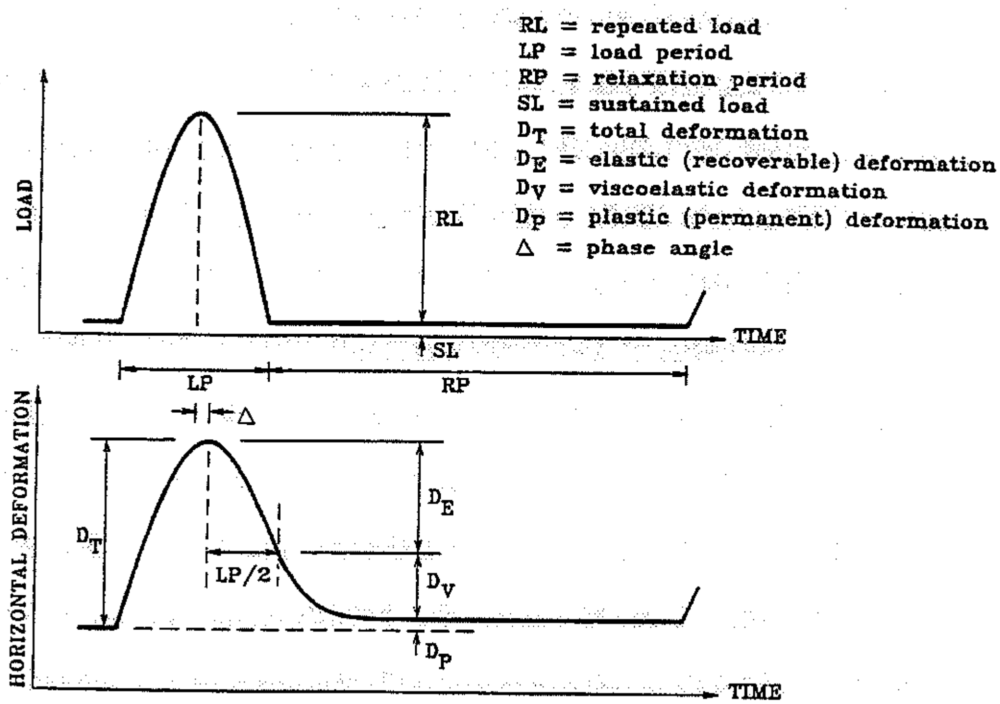


Figure 18
One load and deformation cycle for the indirect tensile fatigue test

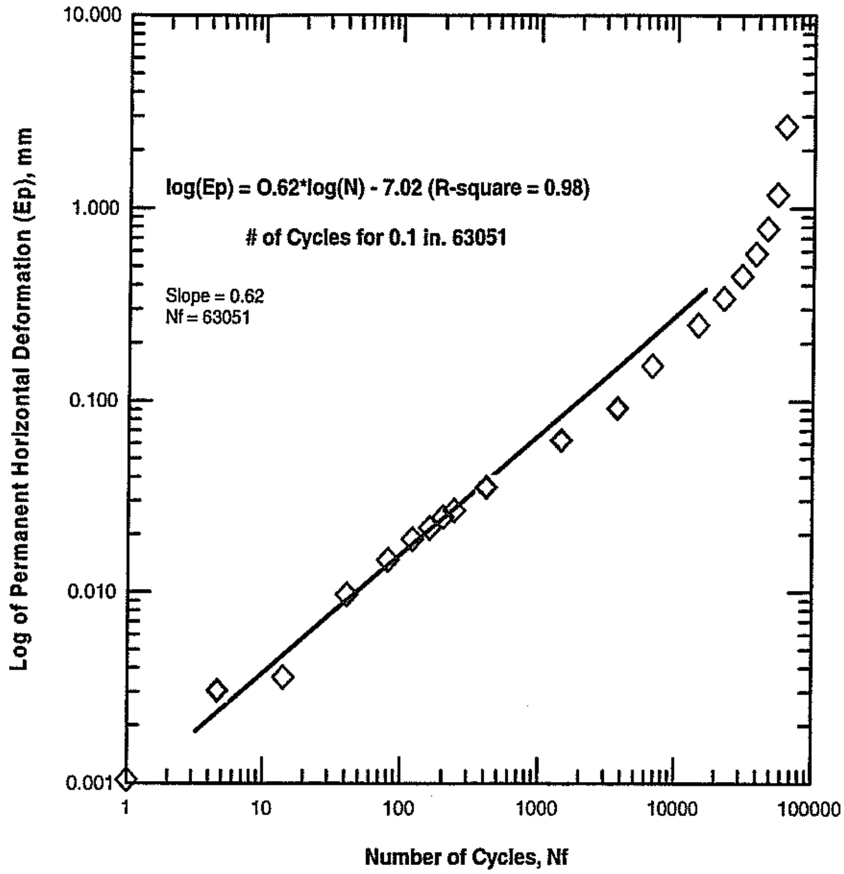


Figure 19
Typical plot of indirect tensile fatigue data

DISCUSSION OF RESULTS

A summary of the fundamental engineering properties and HWTD test results is presented in figures 20 through 41. The test results, reported by individual samples for each of the five fundamental tests, are enclosed in appendix A for the limestone mixes and in appendix B for the gravel mixes. The Statistical Analysis System (SAS) from the SAS Institute, Inc. was used to analyze the test results using the analysis of variance (ANOVA) procedure. A five percent risk level was the basis for the multiple comparison procedure of the least significant differences (LSD). The statistical groupings and rankings obtained from this analysis are presented in tables 8 through 30 for the limestone and gravel mixes. The tables containing the groupings resulting from this analysis present the mean and standard deviation reported by mixture type. The group column contains the results of the statistical grouping reported with the letters A, B, C, and D. The letter A was assigned to the highest mean followed by the other letters in appropriate order. A double or triple letter designation such as A/B or A/B/C indicates that in the analysis the difference in means was not distinct. On the other hand, the tables presenting the rankings contain the means of the test results and the assigned rankings. The numbers assigned for the rankings are 1 through 8 of which 1 was assigned to the mix with the most desirable results and 8 was assigned to the mix with the least desirable results. Therefore, ranking of number 1 was sometimes assigned to the lowest mean value and sometimes to the highest mean value, and the numbers that followed were assigned accordingly. The ranking designations are briefly detailed with each test description.

Indirect Tensile Strength and Strain Test (ITS)

The influence of hydrated lime on the indirect tensile strength and strain of the asphaltic concrete mixtures is presented in figures 20 through 25. The results of the statistical analysis follow these figures in tables 8 through 10.

In the Indirect Tensile Strength and Strain test, high indirect tensile strength and strain values at failure are desirable properties for stiff mixtures. For the ITS test performed at 77°F (25°C), the addition of hydrated lime (figures 20 and 21) increased the strength for SPMACL and GAC30L. At 104°F (40°C), figures 22 and 23 show that lime increased the strength for SAC30L and SPMACL as well as for GAC30L and GPMACL. The statistical results in tables 8 and 9 exhibit the significance of the increase in stiffness at both temperatures. The addition of hydrated lime shows a greater effect on the strength of the mixtures at the higher testing temperature. This may be due to the fact that at higher temperatures, the viscosity of the binder decreases, causing the mixture to lose its strength. The addition of hydrated lime, however, causes the fine lime particles to absorb some of the asphaltic components, which thereby forms a mastic and increases the viscosity of the binder. This effect was more significant in the gravel mixes than in the mixtures containing stone.

For the indirect tensile strain at failure, figures 24 and 25 show that the addition of hydrated lime increased strain for SAC30L, SPMACL, GAC30L, and GPMACL only at 104°F (40°C); however, tables 8 and 9 show that this increase was significant only for GPMACL. These results prove that the effect of the lime addition was more visible at the higher temperature.

Based on the indirect tensile strength and strain results obtained from the ITS test, the eight mixtures that were evaluated in this study were statistically ranked and grouped as presented in table 10. In the statistical rankings, the numbers 1 through 8 are assigned to the mix types with 1 indicating the highest mean value for the indirect tensile strength and strain results and 8 indicating the lowest. This table shows that, overall, the gravel mixes with lime (GAC30L and especially GPMACL) had significantly higher strength and strain values. These higher strength and strain values may be due to the fact that the limestone mixtures may have had some lime dust already on the aggregate, which made the hydrated lime seem to not have as great of an effect as great as on the gravel mixtures. The lime worked better with the PAC-40HG than with the AC-30 at 104°F (40°C).

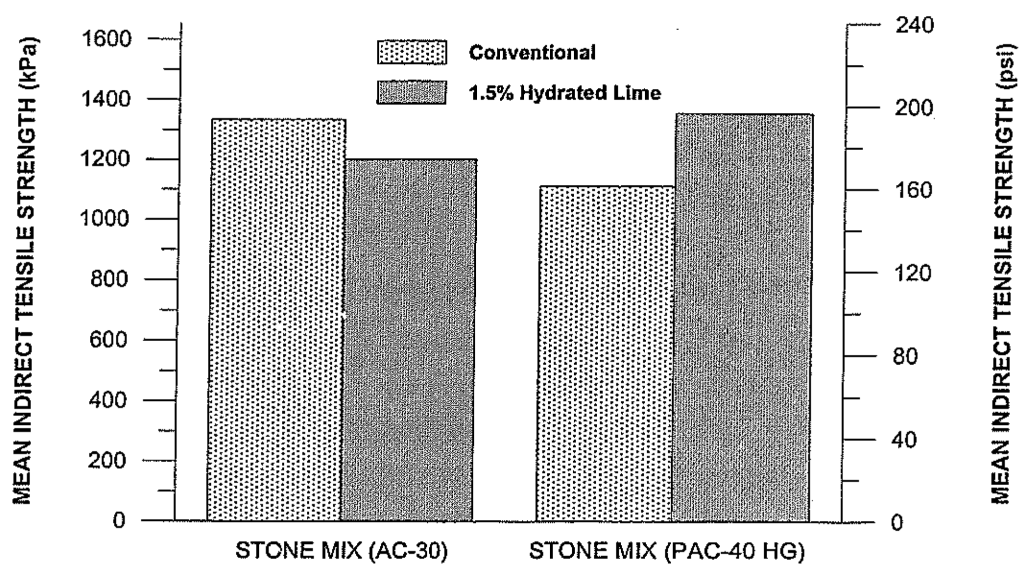


Figure 20
Indirect tensile strength test results at 77°F (25°C) - limestone

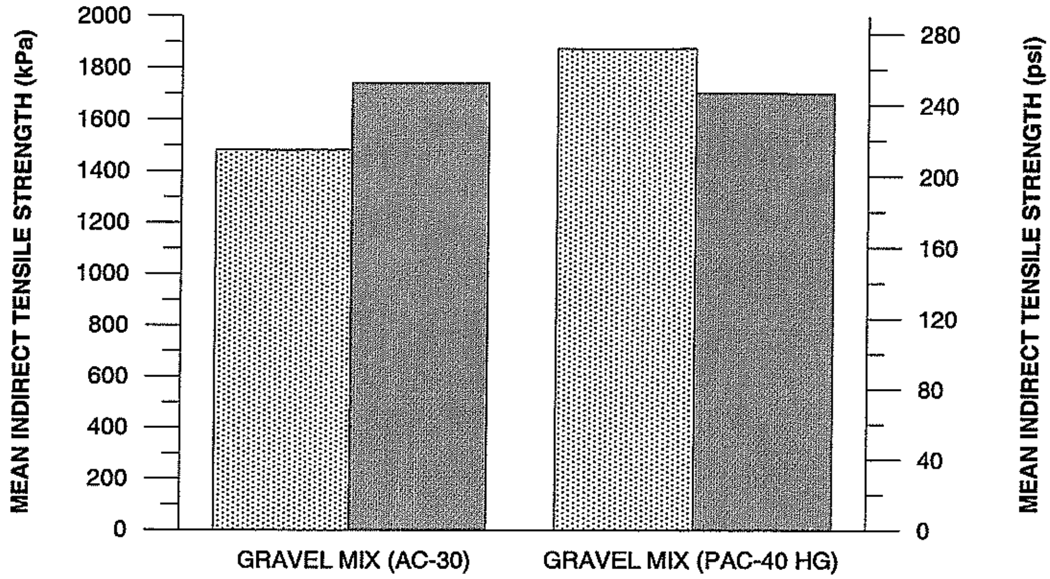


Figure 21
Indirect tensile strength test results at 77°F (25°C) - gravel

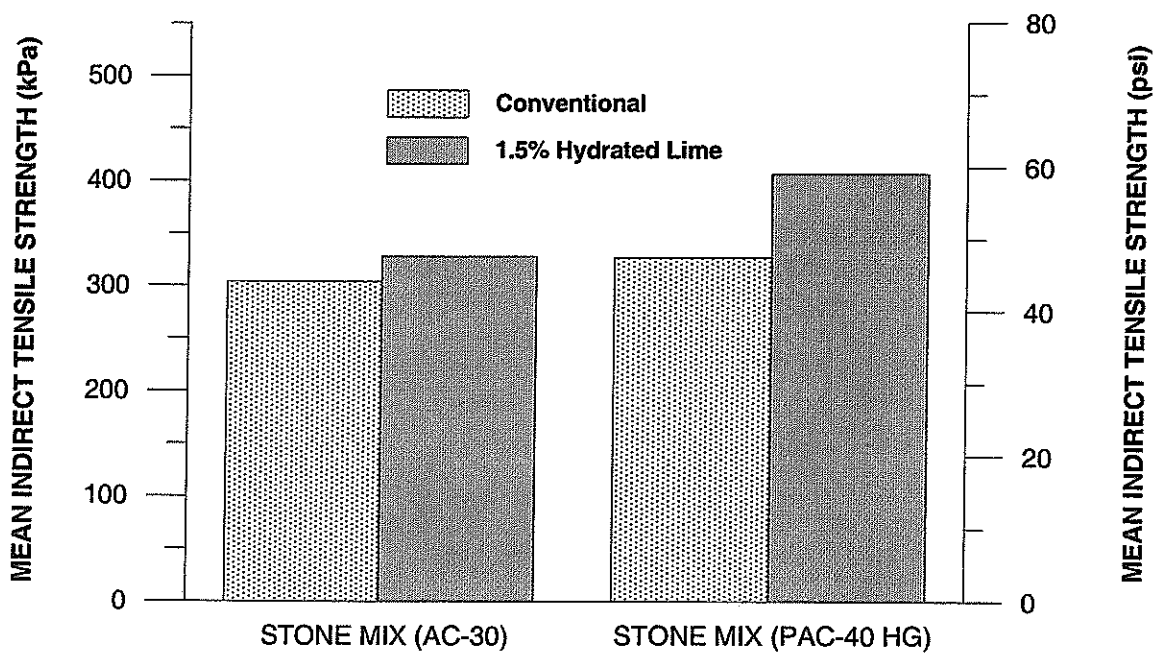


Figure 22
Indirect tensile strength test results at 104°F (40°C) – limestone

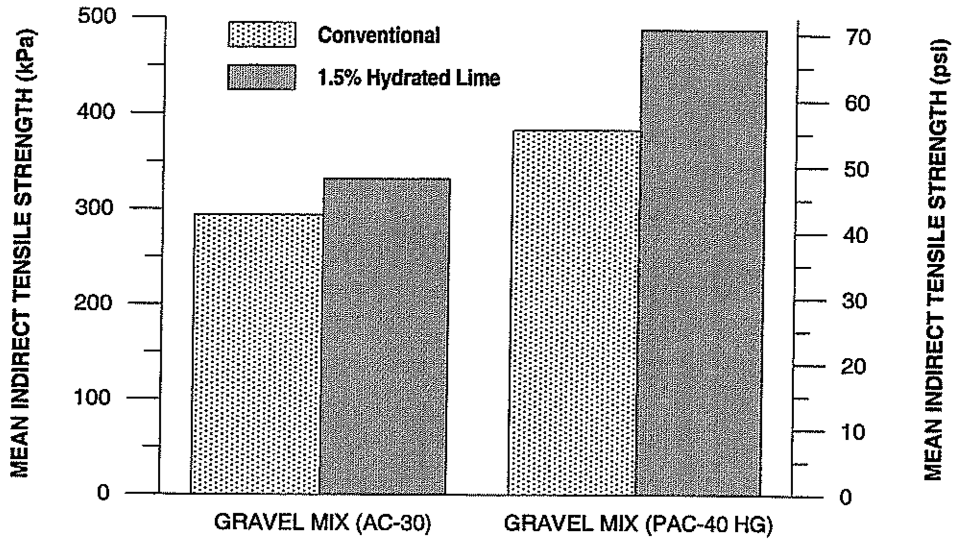


Figure 23

Indirect tensile strength test results at 104°F (40°C) – gravel

Table 8

Statistical grouping of indirect tensile strength test results – limestone mix

Temp	**25°C**			**40°C**			**25°C**			**40°C**		
Property	**Tensile strength**			**Tensile strength**			**Tensile strain**			**Tensile strain**		
Mix Type	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
SAC30N	1334	50	A	304	40	B	0.65	0.02	C	0.72	0.08	B
SAC30L	1202	21	B	328	18	B	0.60	0.06	C	0.73	0.03	B
SPMACN	1111	43	B	327	34	B	0.97	0.10	A	0.92	0.13	A
SPMACL	1354	73	A	401	17	A	0.81	0.03	B	1.00	0.04	A

ITS: Indirect Tensile Strength (kPa)
TS: Tensile Strain (%)
St.D: Standard Deviation
Group: Statistical Grouping (columns with same letters indicate no significant difference)

Table 9

Statistical grouping of indirect tensile strength test results – gravel mix

Temp	**25°C**			**40°C**			**25°C**			**40°C**		
Property	**Tensile strength**			**Tensile strength**			**Tensile strain**			**Tensile strain**		
Mix Type	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
GAC30N	1483	83	C	294	15	D	0.94	0.11	B	1.01	0.09	B
GAC30L	1743	94	B	332	6	C	0.61	0.03	C	1.02	0.10	B
GPMACN	1874	3	A	383	11	B	1.12	0.06	A	1.16	0.05	A/B
GPMACL	1703	45	B	488	33	A	1.06	0.07	A/B	1.28	0.15	A

ITS: Indirect Tensile Strength (kPa)
TS: Tensile Strain (%)
St.D: Standard Deviation
Group: Statistical Grouping (columns with same letters indicate no significant difference)

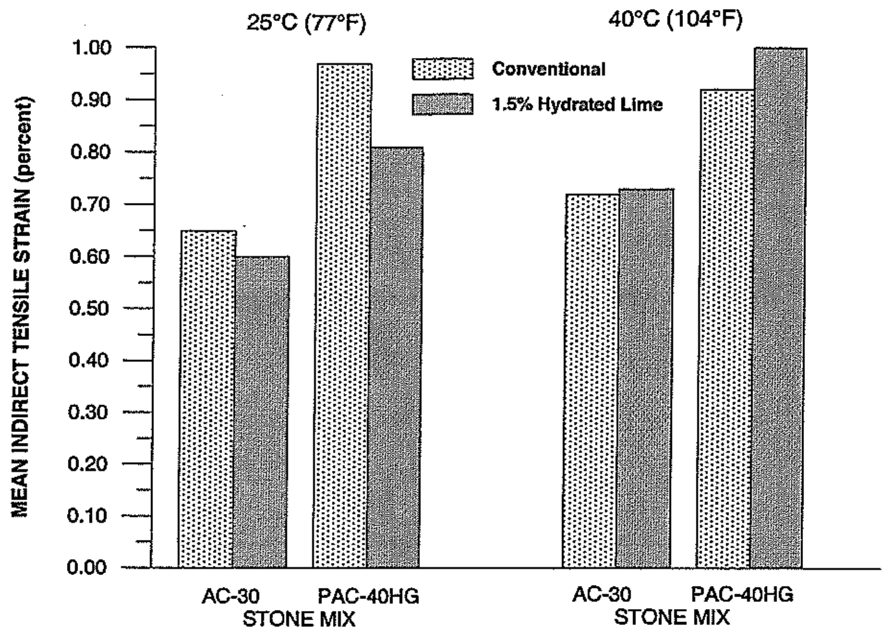


Figure 24
Indirect tensile strain results – limestone

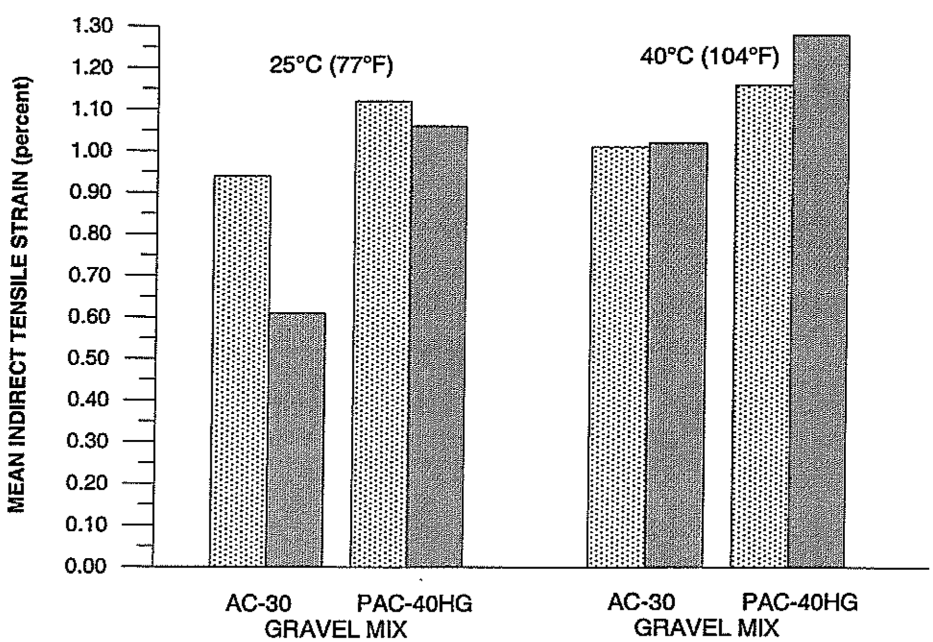


Figure 25
Indirect tensile strain results – gravel

Table 10
Statistical ranking and grouping of indirect tensile strength and strain test results

	Ranking/grouping based on tensile strength (kPa)						Ranking/grouping based on tensile strain (%)					
	77°F (25°C)			104°F (40°C)			77°F (25°C)			104°F (40°C)		
Mixture Type	Mean	Rank	Group	Mean	Rank	Group	Mean	Rank	Group	Mean	Rank	Group
SAC30N	1334	6	D	304	7	C	0.65	6	E	0.72	8	D
SAC30L	1202	7	E	328	5	C	0.60	8	E	0.73	7	D
SPMACN	1111	8	E	327	6	C	0.97	3	B/C	0.92	6	C
SPMACL	1354	5	D	401	2	B	0.81	5	D	1.00	5	C
GAC30N	1483	4	C	294	8	C	0.94	4	C	1.01	4	C
GAC30L	1743	2	B	332	4	C	0.61	7	E	1.02	3	C
GPMACN	1874	1	A	383	3	B	1.12	1	A	1.16	2	B
GPMACL	1703	3	B	488	1	A	1.06	2	A/B	1.28	1	A

Rank: Statistical ranking (1 assigned to most desirable property, 8 assigned to least desirable property in column)
Group: Statistical grouping (columns with same letters indicate no significant difference)

Indirect Tensile Resilient Modulus Test

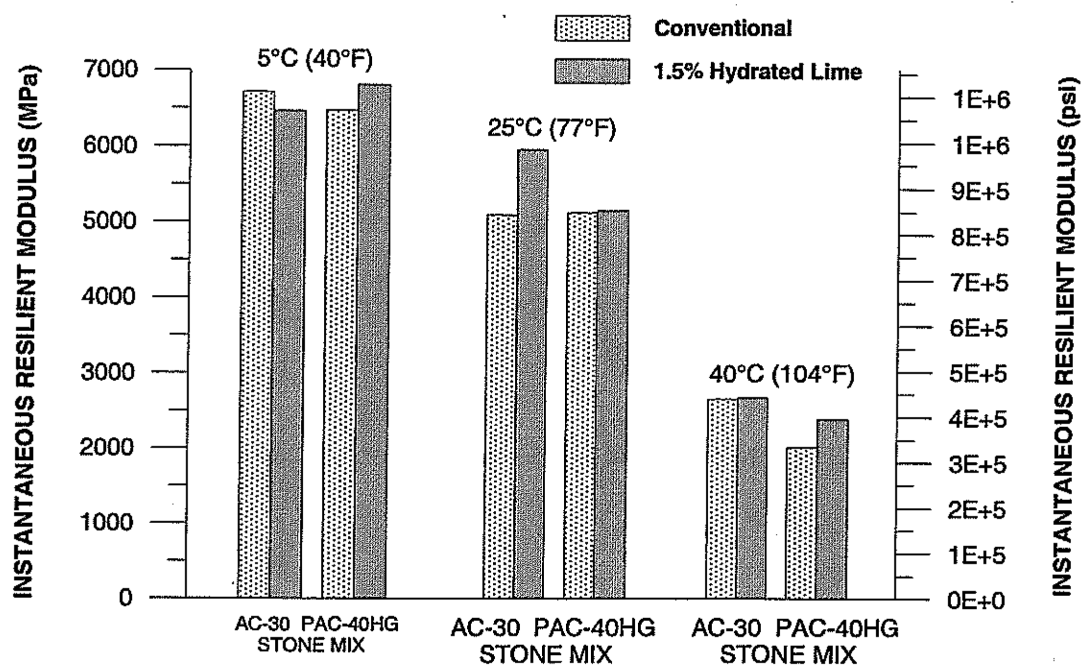
The graphs with the results for the indirect tensile resilient modulus test are given in figures 26 through 29 followed by the statistical groupings in tables 11 through 14. The statistical rankings/groupings of all eight mixture types are presented in tables 15 through 18.
Figures 26 through 29 show that, overall, the instantaneous and total resilient modulus (M_R) values of all eight mixtures decreased and that Poisson's ratio (μ-values) increased as the testing temperatures increased. This result was expected since HMACs are known to be stiffer at lower temperatures.

The addition of hydrated lime increases the instantaneous M_R values (figure 26) for SPMACL at 40°F (5°C), SAC30L at 77°F (25°C), and SPMACL at 104°F (40°C). Table 11 indicates that these increases in the instantaneous M_R were significant at 77°F (25°C) and 104°F (40°C). The instantaneous μ-values increased as the temperature increased; however, the increases for the mixtures with added lime exhibited no significant difference. The instantaneous M_R values for the gravel mixtures with added lime, GAC30L, and GPMACL showed significantly higher values at all three testing temperatures as can be seen from figure 27 and table 12. Although there is an increase in μ-values with increasing temperatures, this increase is not significantly different for the lime mixtures.

For the total resilient modulus and μ-values, the results in figure 28 show that the addition of hydrated lime increased the total M_R for SPMACL at 40°F (5°C) and 104°F (40°C) and for SAC30L at 77°F (25°C). While increases for SPMACL were not significant, the increase in total resilient modulus for SAC30L was significantly high. The total Poisson's ratio increased as the testing temperatures increased; however, they showed no significant change in the mixes at the three temperatures as can be seen in table 13. Figure 29 shows the higher total M_R values for the gravel mixes with lime, GAC30L and GPMACL, at all three temperatures. The increase in these modulus values was significantly high as can be seen from table 14. The higher values indicate that the lime did increase the stiffness of the asphaltic concrete mix. The μ-values for the total resilient modulus did not show a significant change with the addition of hydrated lime. Overall, these values followed an upward trend with increasing temperatures.

The statistical rankings and groupings are given in tables 15 through 18 with a rank number of 1 assigned to the highest and 8 to the lowest mean values for the resilient moduli and μ-values. Both the rankings and groupings indicated that the hydrated lime modified mixes for both aggregate types had higher instantaneous resilient modulus values. At higher temperatures, [77°F (25°C) and 104°F (40°C)] these values were higher for GAC30L and GPMACL. Again, the μ-values did not show a specific trend other than a general increase related to increasing testing temperature. The rankings based on the total resilient modulus values, table 17, show that the addition of hydrated lime increased the total resilient modulus values for both stone and gravel mixes. However, GAC30L and GPMACL had higher total resilient modulus values at all three temperatures than did the stone mix. The μ-values, again, showed no trend other than an increase with the temperature increase.

The results of the groupings and rankings of the instantaneous and total resilient modulus values and Poisson's ratio for the limestone and gravel mixtures indicate that the addition of hydrated lime increased the resilient behavior of the mixes. This increase was more significant for the gravel mixes, GAC30L and GPMACL, demonstrating that the filler worked better with gravel than with the limestone. GPMACL had the most significant increase in instantaneous and total resilient modulus values (tables 15 and 17) of all mixes.



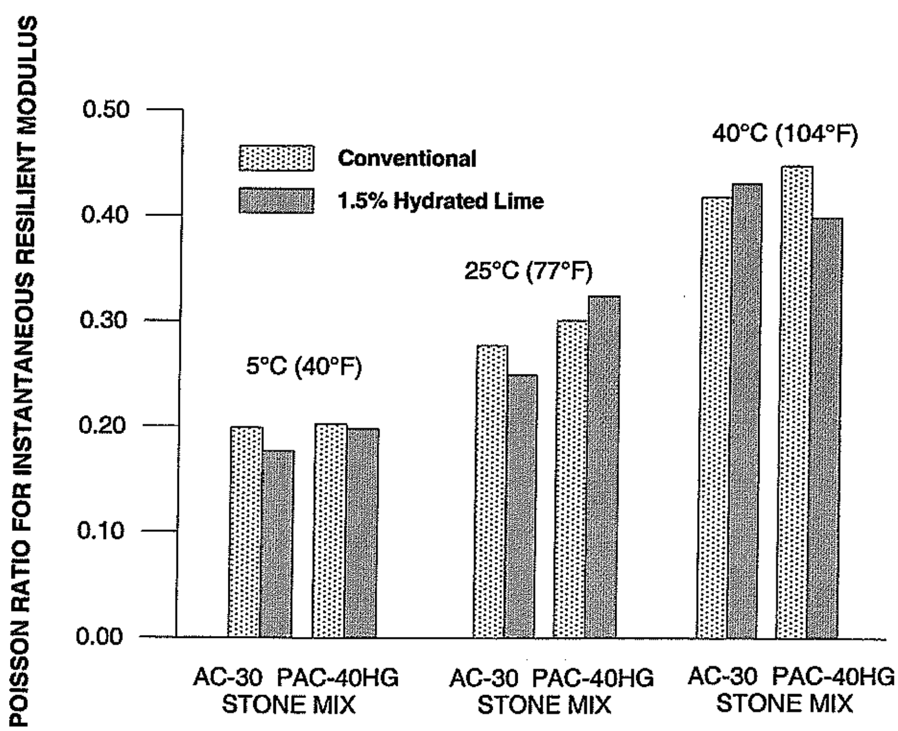


Figure 26
Indirect tensile resilient modulus test results (instantaneous)-limestone

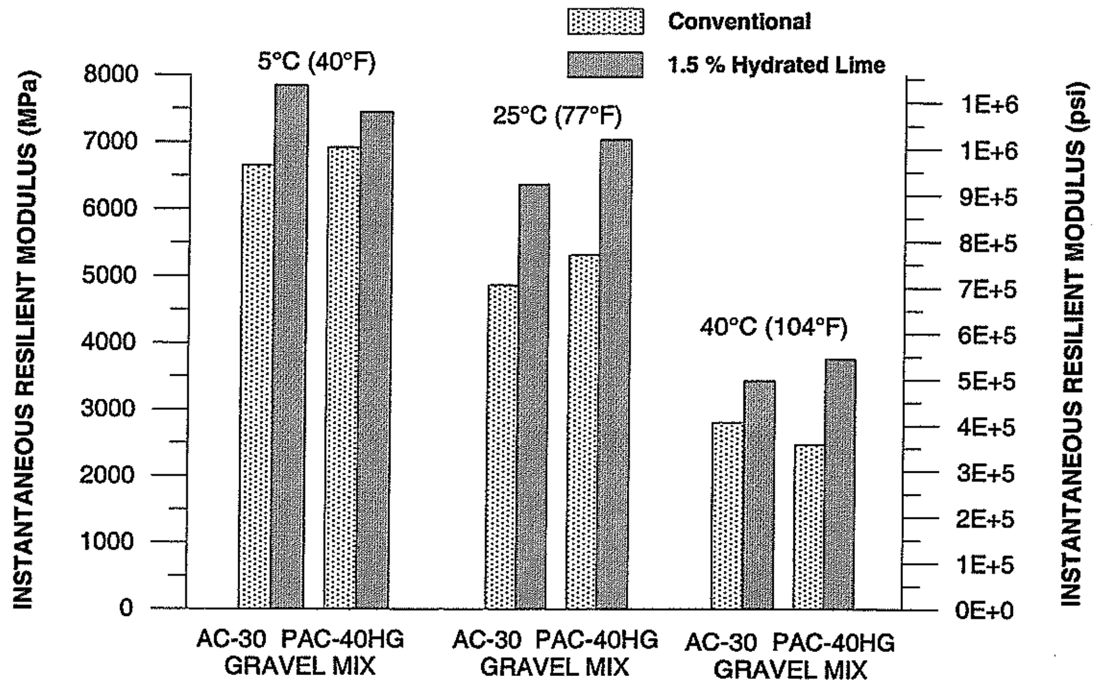
Table 11

Statistical grouping of indirect tensile resilient modulus test results (instantaneous) – limestone mix

Temp.	5°C			25°C			40°C		
Property	MRI			MRI			MRI		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
SAC30N	6714	700	A	5091	322	B	2653	226	A
SAC30L	6466	712	A	5953	193	A	2676	150	A
SPMACN	6471	453	A	5121	499	B	2010	122	C
SPMACL	6809	521	A	5147	313	B	2387	141	B
Temp.	**5°C**			**25°C**			**40°C**		
Property	**MUI**			**MUI**			**MUI**		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
SAC30N	0.199	0.082	A	0.275	0.025	B	0.418	0.025	A/B
SAC30L	0.177	0.045	A	0.301	0.037	A/B	0.431	0.050	A/B
SPMACN	0.202	0.041	A	0.319	0.019	A	0.448	0.031	A
SPMACL	0.198	0.042	A	0.325	0.014	A	0.399	0.020	B

MRI: Instantaneous Resilient Modulus (Mpa)
MUI: O-Value for Instantaneous Resilient Modulus

St.D: Standard Deviation
Group: Statistical Grouping (columns with same letters indicate no significant difference)



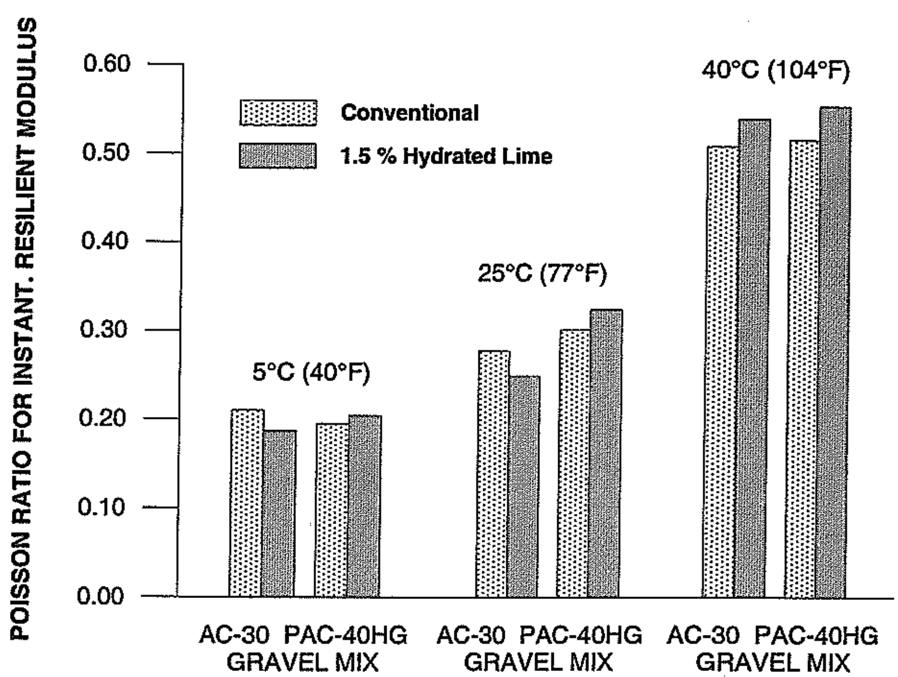


Figure 27

Indirect tensile resilient modulus test results (instantaneous)-gravel

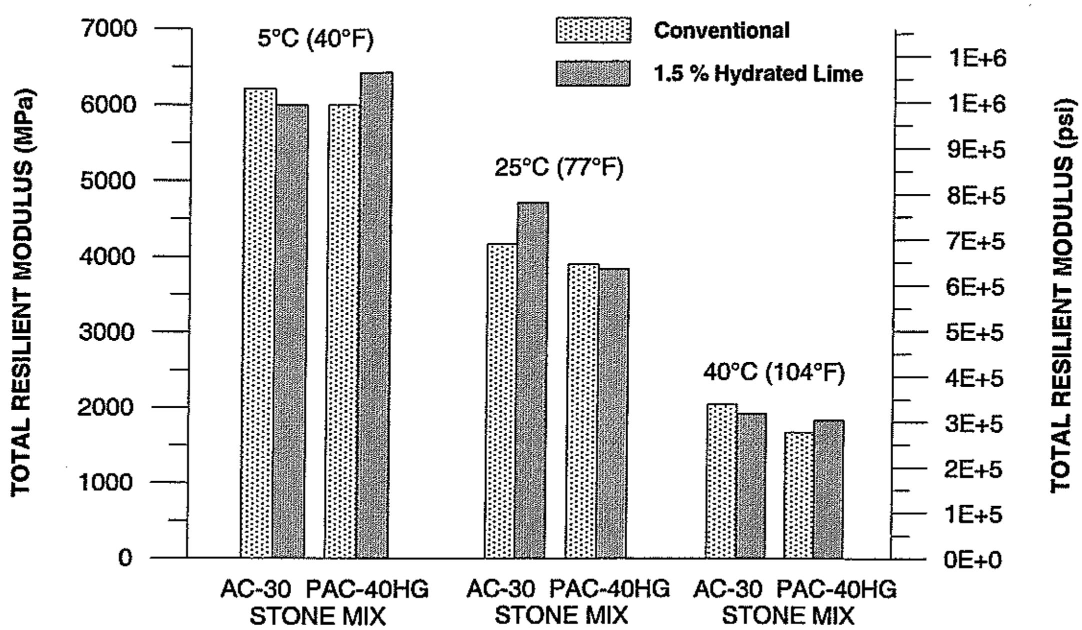
Table 12

Statistical grouping of indirect tensile resilient modulus test results (total) – limestone mix

Temp.	5°C			25°C			40°C		
Property	**MRT**			**MRT**			**MRT**		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
SAC30N	6219	608	A	4175	233	B	2044	178	A
SAC30L	6005	805	A	4721	157	A	1929	86	A/B
SPMACN	6003	456	A	3902	395	B	1677	54	C
SPMACL	6432	487	A	3844	171	B	1838	91	B

Temp.	5°C			25°C			40°C		
Property	**MUT**			**MUT**			**MUT**		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
SAC30N	0.188	0.064	A/B	0.271	0.035	B	0.449	0.041	A
SAC30L	0.141	0.048	B	0.305	0.034	A/B	0.451	0.041	A
SPMACN	0.205	0.039	A	0.312	0.028	A	0.448	0.027	A
SPMACL	0.212	0.032	A	0.301	0.020	A/B	0.433	0.029	A

MRT: Total Resilient Modulus (Mpa)
MUT: O-Value for Total Resilient Modulus
St.D: Standard Deviation
Group: Statistical Grouping (columns with same letters indicate no significant difference)



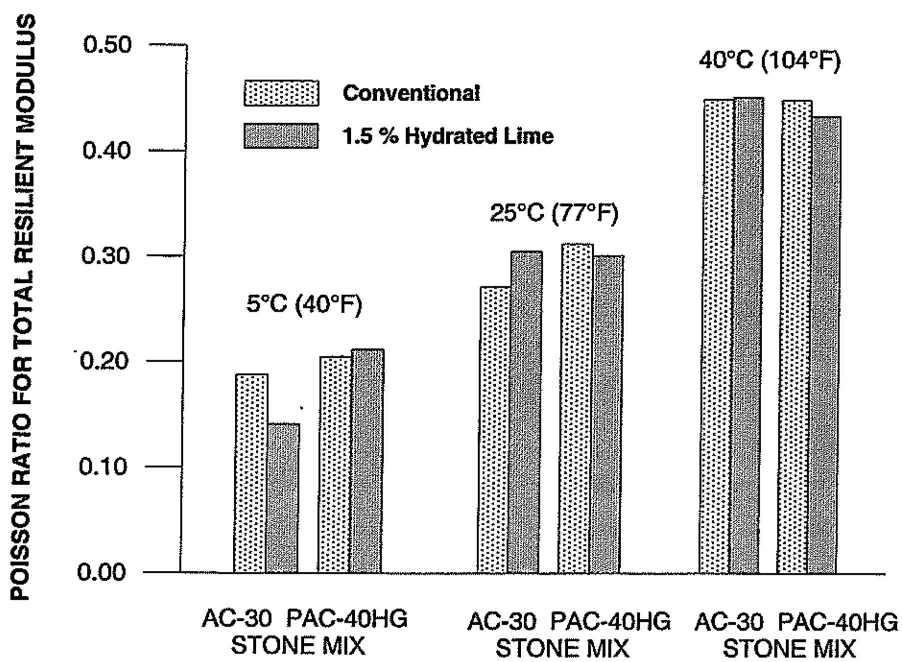


Figure 28

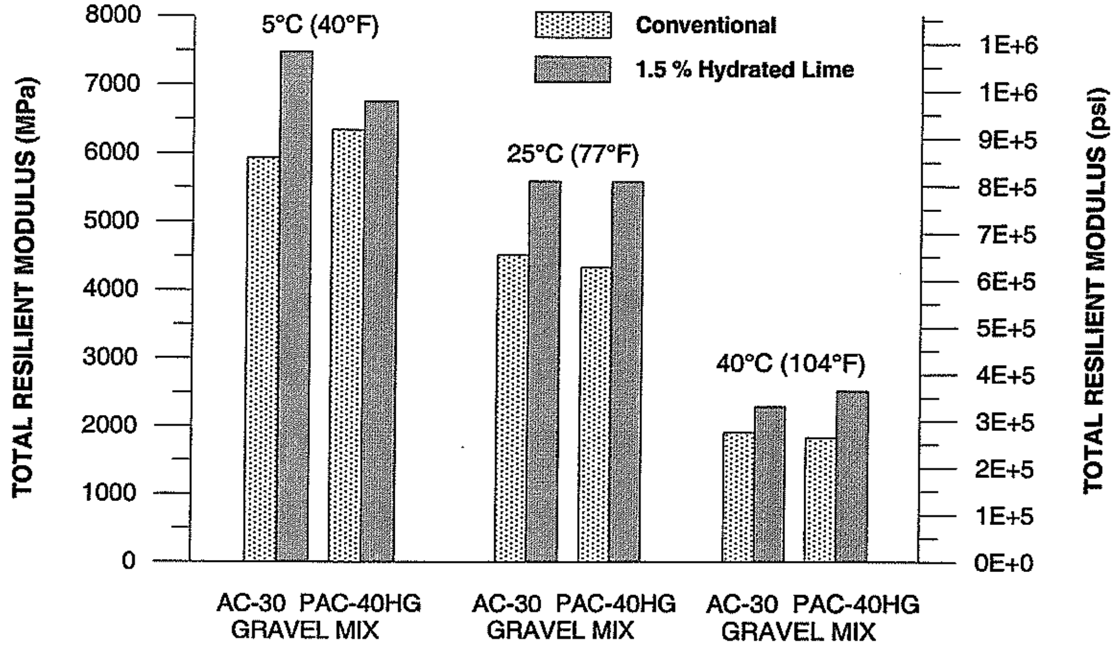
Indirect tensile resilient modulus test results (total) – limestone

Table 13

Statistical grouping of indirect tensile resilient modulus test results (instantaneous) – gravel mix

Temp.	**5°C**			**25°C**			**40°C**		
Property	**MRI**			**MRI**			**MRI**		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
GAC30N	6654	379	B	4864	579	B	2810	154	B
GAC30L	7852	1386	A	6372	933	A	3430	264	A
GPMACN	6922	612	A/B	5312	123	B	2477	235	B
GPMACL	7448	552	A/B	7034	341	A	3763	373	A
Temp.	**5°C**			**25°C**			**40°C**		
Property	**MUI**			**MUI**			**MUI**		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
GAC30N	0.210	0.018	A	0.277	0.043	A/B	0.508	0.093	A
GAC30L	0.187	0.106	A	0.249	0.062	B	0.539	0.100	A
GPMACN	0.195	0.027	A	0.301	0.032	A	0.515	0.097	A
GPMACL	0.204	0.043	A	0.324	0.020	A	0.553	0.076	A

MRI: Instantaneous Resilient Modulus (Mpa)
MUI: Ο-Value for Instantaneous Resilient Modulus
St.D: Standard Deviation
Group: Statistical Grouping (columns with same letters indicate no significant difference)



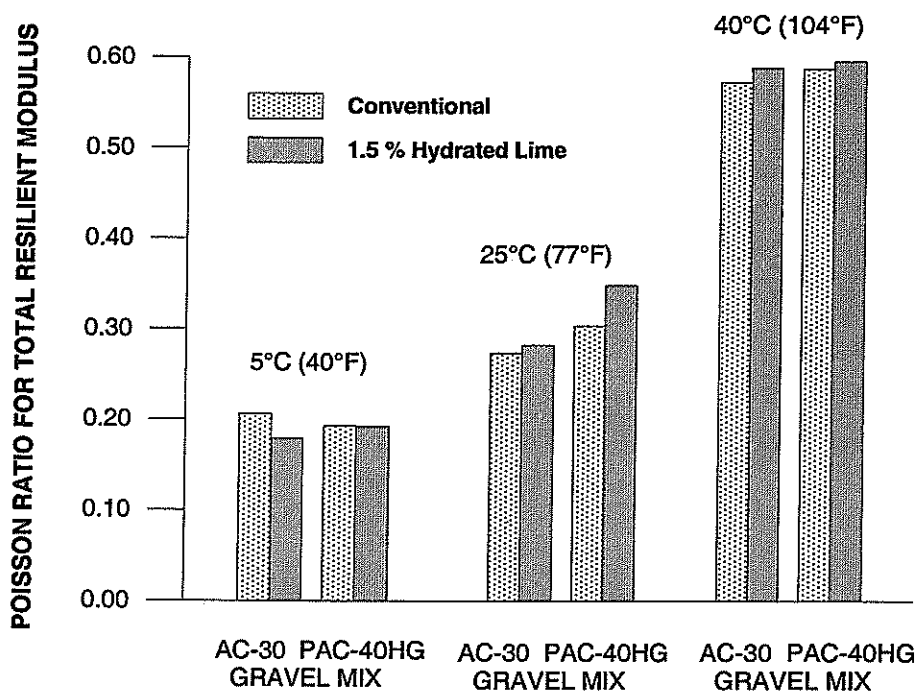


Figure 29

Indirect tensile resilient modulus test results (total) – gravel

Table 14

Statistical grouping of indirect tensile resilient modulus test results (total) – gravel mix

Temp.	**5°C**			**25°C**			**40°C**		
Property	**MRT**			**MRT**			**MRT**		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
GAC30N	5935	323	B	4508	579	B	1899	162	C
GAC30L	7483	1242	A	5586	631	A	2284	174	B
GPMACN	6341	506	B	4326	139	B	1830	93	C
GPMACL	6765	450	A/B	5585	284	A	2519	176	A
Temp.	**5°C**			**25°C**			**40°C**		
Property	**MUT**			**MUT**			**MUT**		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
GAC30N	0.206	0.036	A	0.273	0.036	B	0.572	0.113	A
GAC30L	0.179	0.089	A	0.282	0.051	A/B	0.588	0.077	A
GPMACN	0.193	0.030	A	0.303	0.055	A/B	0.587	0.121	A
GPMACL	0.192	0.030	A	0.348	0.058	A	0.595	0.065	A

MRT: Total Resilient Modulus (Mpa)
MUT: O-Value for Total Resilient Modulus
St.D: Standard Deviation
Group: Statistical Grouping (columns with same letters indicate no significant difference)

Table 15

Statistical ranking and grouping of indirect tensile resilient modulus test results (instantaneous M_R)

Mixture Type	Ranking/Grouping Based on Instantaneous M_R (MPa)								
	40°F (5°C)			77°F (25°C)			104°F (40°C)		
	Mean	Rank	Group	Mean	Rank	Group	Mean	Rank	Group
SAC30N	6714	5	B/C	5091	7	C	2653	5	C/D/E
SAC30L	6466	8	C	5953	3	B	2676	4	C/D
SPMACN	6471	7	C	5121	6	C	2010	8	F
SPMACL	6809	4	B/C	5147	5	C	2387	7	E
GAC30N	6654	6	B/C	4864	8	C	2810	3	C
GAC30L	7852	1	A	6372	2	B	3430	2	B
GPMACN	6922	3	B/C	5312	4	C	2477	6	D/E
GPMACL	7448	2	A/B	7034	1	A	3763	1	A

Rank: Statistical ranking (1 assigned to most desirable property, 8 assigned to least desirable property in column)
Group: Statistical grouping (columns with same letters indicate no significant difference)

Table 16

Statistical ranking and grouping of indirect tensile resilient modulus test results (instantaneous μ-value)

Mixture Type	Ranking/Grouping Based on Instantaneous μ-Value								
	40°F (5°C)			77°F (25°C)			104°F (40°C)		
	Mean	Rank	Group	Mean	Rank	Group	Mean	Rank	Group
SAC30N	0.199	3	A/B	0.275	2	B/C	0.418	2	C
SAC30L	0.177	1	B	0.301	5	A/B	0.431	3	B/C
SPMACN	0.202	6	A/B	0.319	6	A/B	0.448	4	B/C
SPMACL	0.198	8	A/B	0.325	8	A	0.399	1	C
GAC30N	0.210	7	A	0.277	3	B/C	0.508	5	A/B
GAC30L	0.187	2	A/B	0.249	1	C	0.539	7	A
GPMACN	0.195	4	A/B	0.301	4	A/B	0.515	6	A/B
GPMACL	0.204	5	A/B	0.324	7	A	0.553	8	A

Rank: Statistical ranking (1 assigned to most desirable property, 8 assigned to least desirable property in column)
Group: Statistical grouping (columns with same letters indicate no significant difference)

Table 17

Statistical ranking and grouping of indirect tensile resilient modulus test results (total M_R)

	Ranking/Grouping Based on Total M_R (MPa)								
	40°F (5°C)			77°F (25°C)			104°F (40°C)		
Mixture Type	Mean	Rank	Group	Mean	Rank	Group	Mean	Rank	Group
SAC30N	6219	5	B	4175	6	C/D/E	2044	3	C
SAC30L	6005	6	B	4721	3	B	1929	4	C/D
SPMACN	6003	7	B	3902	7	D/E	1677	8	E
SPMACL	6432	3	B	3844	8	E	1838	6	D/E
GAC30N	5935	8	B	4508	4	B/C	1899	5	C/D
GAC30L	7483	1	A	5586	1	A	2284	2	B
GPMACN	6341	4	B	4326	5	B/C/D	1830	7	D/E
GPMACL	6765	2	A/B	5585	2	A	2519	1	A

Rank: Statistical ranking (1 assigned to most desirable property, 8 assigned to least desirable property in column)
Group: Statistical grouping (columns with same letters indicate no significant difference)

Table 18

Statistical ranking and grouping of indirect tensile resilient modulus test results (total μ-value)

Mixture Type	Ranking/Grouping Based on Total μ-Value								
	40°F (5°C)			77°F (25°C)			104°F (40°C)		
	Mean	Rank	Group	Mean	Rank	Group	Mean	Rank	Group
SAC30N	0.188	3	A/B	0.271	1	B	0.449	3	B
SAC30L	0.141	1	B	0.305	6	A/B	0.451	4	B
SPMACN	0.205	6	A	0.312	7	A/B	0.448	2	B
SPMACL	0.212	8	A	0.301	4	A/B	0.433	1	B
GAC30N	0.206	7	A	0.273	2	B	0.572	5	A
GAC30L	0.179	2	A/B	0.282	3	B	0.588	7	A
GPMACN	0.193	5	A/B	0.303	5	A/B	0.587	6	A
GPMACL	0.192	4	A/B	0.348	8	A	0.595	8	A

Rank: Statistical ranking (1 assigned to most desirable property, 8 assigned to least desirable property in column)
Group: Statistical grouping (columns with same letters indicate no significant difference)

Indirect Tensile Creep Test

The indirect tensile creep test is one of the series of tests (indirect tensile creep test, uniaxial creep test, and HWTD test) that can be used to evaluate the rutting potential of the asphaltic concrete mixes. The effect of hydrated lime on the indirect tensile creep slope and time-to-failure of the limestone and gravel mixes are presented in figures 30 and 31 and tables 12 and 21. In this test, a low creep slope value and a long time to failure are desirable properties of high performance HMACs. Such mixes are less susceptible to rutting.

Figures 30 and 31 and tables 19 and 20 show that, in general, the addition of hydrated lime to the mixes (both limestone and gravel) decreased the creep slope values and increased the time to failure values. Figure 30 and table 19 demonstrate that the decrease in the creep slope and the increase in the time to failure results for SPMACL at 77°F (25°C) and 104°F (40°C) were significantly different from all other limestone mixes. Figure 31 and table 20 show that the creep slopes for GAC30L at 77°F (25°C) and 104°F (40°C) were significantly lower and that the decrease in the creep slope and the increase in the time to failure results for GPMACL at 104°F (40°C) were significant.

The statistical rankings and groupings of the indirect tensile creep test results are presented in table 21. Best performance is indicated by lowest creep slop and greatest time to failure (rank = 1). The rankings show that the addition of hydrated lime to both stone and gravel mixes decreased the creep slope and increased the time to failure. However, the mixes with a combination of polymer asphalt and hydrated lime (SPMACL and GPMACL) were most favorably ranked.

These results indicate that, overall, hydrated lime worked well with both aggregate and asphalt cement types at both testing temperatures. However, the stone and gravel mixes modified with lime and containing PAC-40HG (SPMACL and GPMACL) showed the most improvement in creep properties especially at higher testing temperatures. More improvement was seen in the gravel mixes than for the limestone. This seems to indicate that the polymer modified asphalt and the lime function well in conjunction with gravel aggregate to provide an HMAC that is less susceptible to rutting.

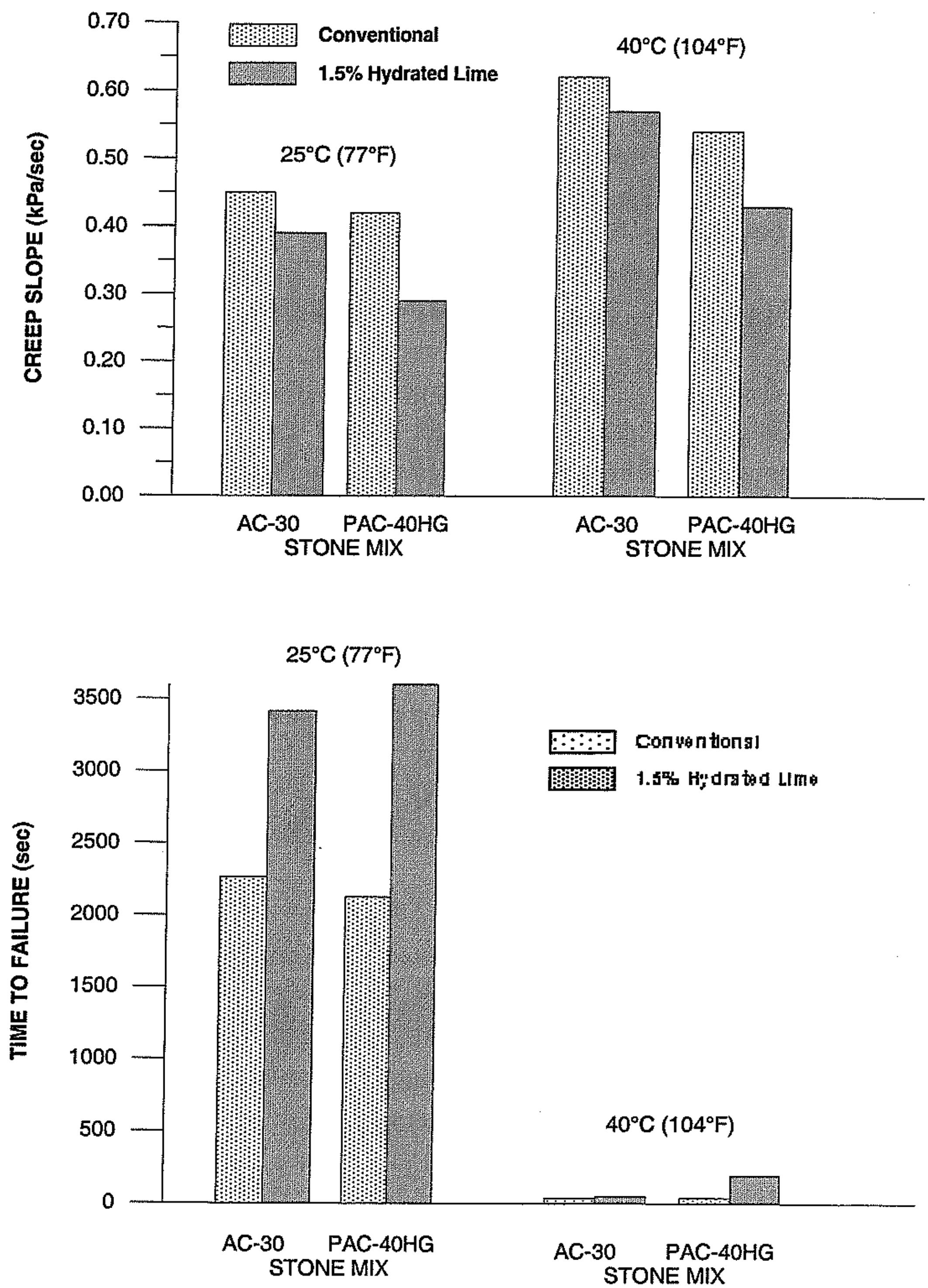


Figure 30

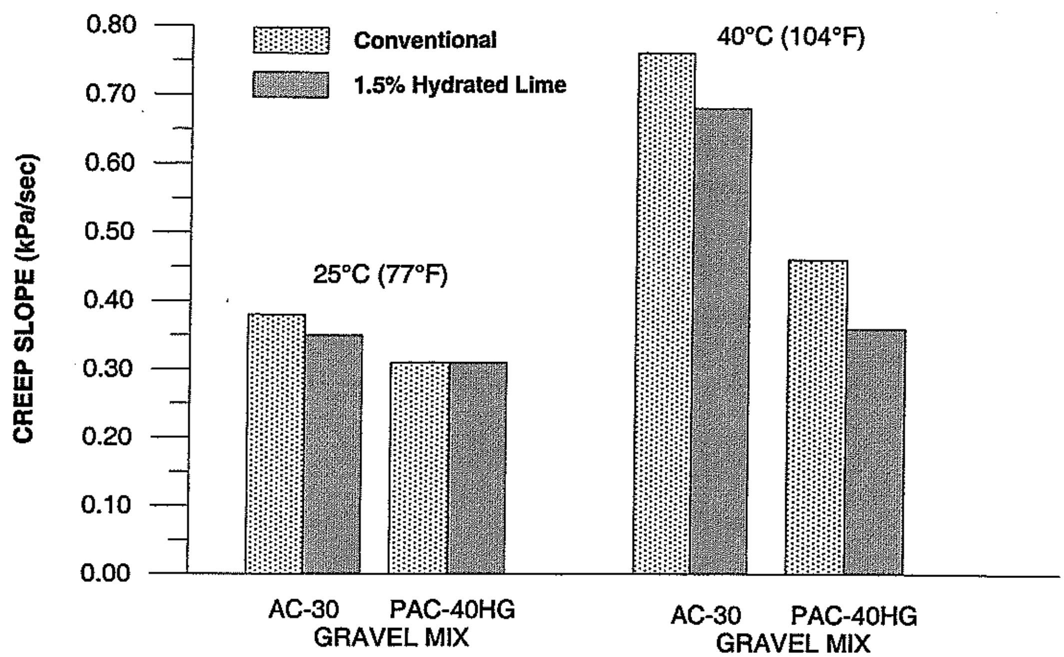
Indirect tensile creep test results - limestone

Table 19

Statistical grouping of indirect tensile creep test results – limestone mix

Temp	**25°C**			**40°C**			**25°C**			**40°C**		
Property	**CS**			**CS**			**TF**			**TF**		
Mix Type	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
SAC30N	0.45	0.02	A	0.62	0.05	A	2264	812	B	37	4	B
SAC30L	0.39	0.03	A	0.57	0.08	A	3414	133	A	49	18	B
SPMACN	0.42	0.04	A	0.54	0.06	A/B	2125	453	B	37	9	B
SPMACL	0.29	0.02	B	0.43	0.02	B	3600	0	A	193	67	A

CS: Creep Slope for Calculated Indirect Tensile Creep Stiffness (kPa/sec)
TF: Time to Failure (sec)
St.D: Standard Deviation
Group: Statistical Grouping (columns with same letters indicate no significant difference)



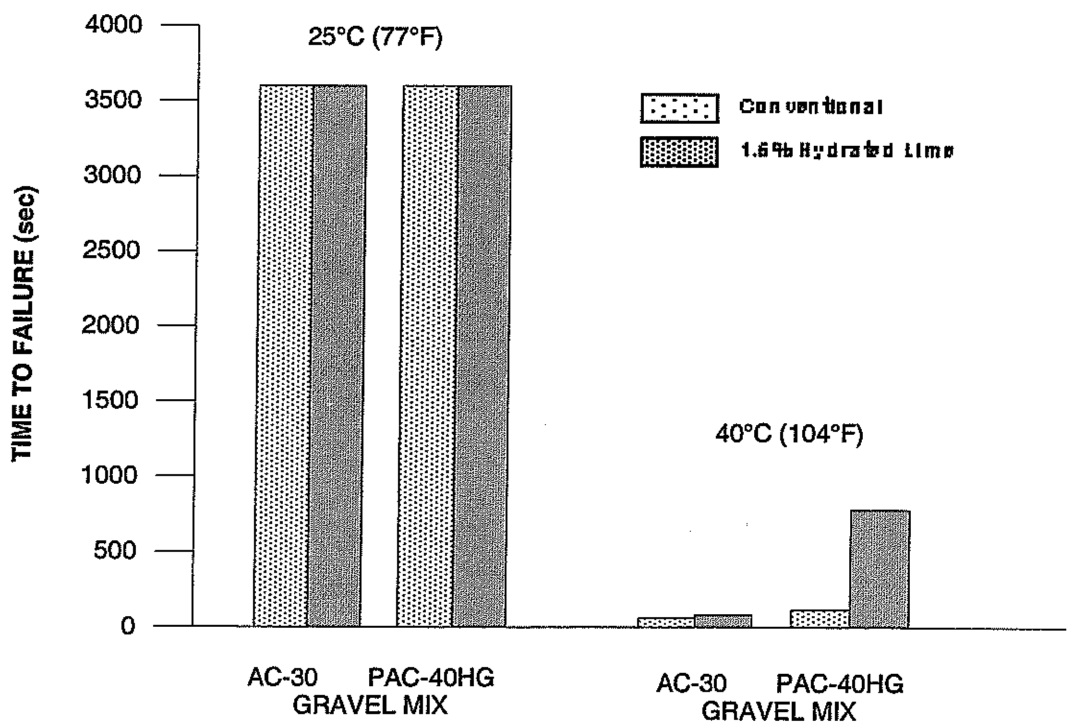


Figure 31

Indirect tensile creep test results - gravel

Table 20

Statistical grouping of indirect tensile creep test results –gravel mix

Temp	**25°C**			**40°C**			**25°C**			**40°C**		
Property	**CS**			**CS**			**TF**			**TF**		
Mix Type	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
GAC30N	0.38	0.03	A	0.76	0.04	A	3600	0	A	59	13	B
GAC30L	0.35	0.01	A/B	0.68	0.03	B	3600	0	A	84	21	B
GPMACN	**0.31**	0.01	B	0.46	0.04	C	3600	0	A	116	21	B
GPMACL	0.31	0.01	B	0.36	0.04	D	3600	0	A	777	245	A

CS: Creep Slope for Calculated Indirect Tensile Creep Stiffness (kPa/sec)
TF: Time to Failure (sec)
St.D: Standard Deviation
Group: Statistical Grouping (columns with same letters indicate no significant difference)

Table 21

Statistical ranking and grouping of indirect tensile creep test results

Mixture Type	Ranking/Grouping Based on Creep Slope (kPa/sec)						Ranking/Grouping Based on Time to Failure (sec)					
	77°F (25°C)			104°F (40°C)			77°F (25°C)			104°F (40°C)		
	Mean	Rank	Group	Mean	Rank	Group	Mean	Rank	Group	Mean	Rank	Group
SAC30N	0.45	8	A	0.62	6	B/C	2264	3	B	37	7	B
SAC30L	0.39	6	B/C	0.57	5	C	3414	2	A	49	6	B
SPMACN	0.42	7	A/B	0.54	4	C/D	2125	4	B	37	8	B
SPMACL	0.29	1	E	0.43	2	E	3600	1	A	193	2	B
GAC30N	0.38	5	B/C	0.76	8	A	3600	1	A	59	5	B
GAC30L	0.35	4	C/D	0.68	7	A/B	3600	1	A	84	4	B
GPMACN	0.31	3	D/E	0.46	3	D/E	3600	1	A	116	3	B
GPMACL	0.31	2	D/E	0.36	1	E	3600	1	A	777	1	A

Rank: Statistical ranking (1 assigned to most desirable property, 8 assigned to least desirable property in column)
Group: Statistical grouping (columns with same letters indicate no significant difference)

Uniaxial Creep Test

The uniaxial creep test results were evaluated based on the creep stiffness, creep slope, and permanent strain of the mixes at 104°F (40°C). For a stiff asphaltic concrete mixture that will resist rutting, a high creep stiffness, a low creep slope, and low permanent strain are the desired properties. Figures 32 through 37 and tables 22 and 23 present the results of this test. The statistical rankings and groupings are presented in table 24. Since this test was taken from the Texas specification for the uniaxial creep test procedure *[5]*, the figures contain a comparison to the Texas specification for the creep slope and stiffness and the permanent strain. These values are:

1) maximum permanent strain = $5x10^{-4}$ in/in or (mm/mm),
2) maximum creep slope = $3.5x10^{-8}$ in/in/sec or (mm/mm/sec), and
3) minimum creep stiffness = 6000 psi or (41.38 MPa).

Figures 32 through 37 show that the addition of hydrated lime has increased the creep stiffness of SAC30L and SPMACL and decreased the creep slope of these mixes. The gravel mixes with lime did not show any improvement either in stiffness or slope. Table 22 indicates that the increases in stiffness and slope for SAC30L and SPMACL were not significant. These figures further indicate that there was an improvement in the permanent strain for SAC30L and SPMACL and that the decrease in the strain for SAC30L was significant. The gravel mixes with lime did not show any improvement in the permanent strain either.

The statistical rankings and groupings presented in table 24 have rank number 1 assigned to the lowest permanent strain, the lowest creep slope, and the highest creep stiffness with the other ranking numbers following accordingly. According to this table, the addition of hydrated lime has improved the properties only of the stone mixes (SAC30L and SPMACL).

When comparing the results to the Texas specification, it can be seen that SAC30N, SAC30L, SPMACN, SPMACL, GAC30N, GAC30L, and GPMACN exceeded the creep stiffness minimum of 6000 psi (41.38 MPa). SAC30L, GAC30N, and GPMACN meet the maximum for the permanent strain. The only mix that meets the creep slope maximum is SAC30L. Under the Texas specification, SAC30L is the only unacceptable mix.

The results of the uniaxial creep test indicate that, although the improvements were not significant, the stone mixes modified with hydrated lime, SAC30L and SPMACL, showed improved properties that were almost identical. On the other hand, the gravel mixes did not show much improvement.

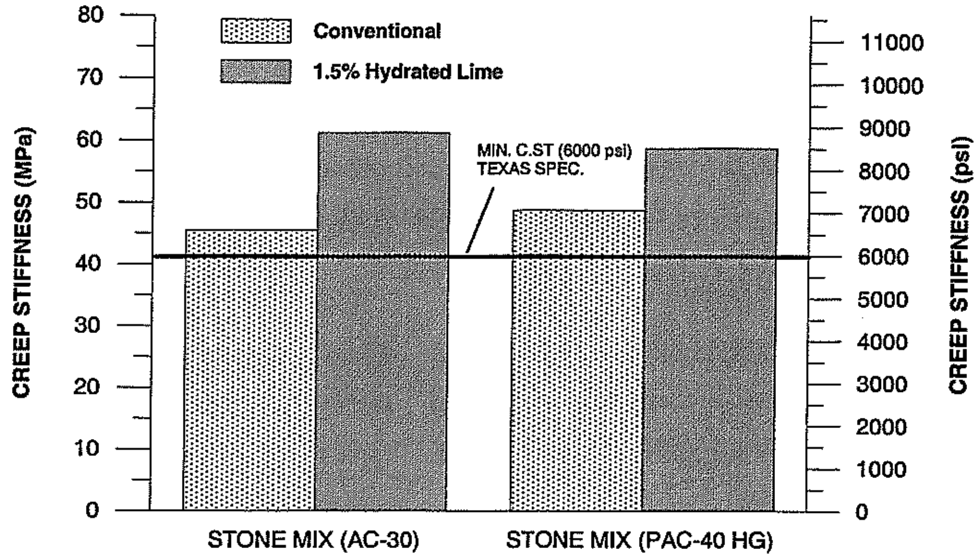


Figure 32
Creep stiffness for uniaxial creep test – limestone

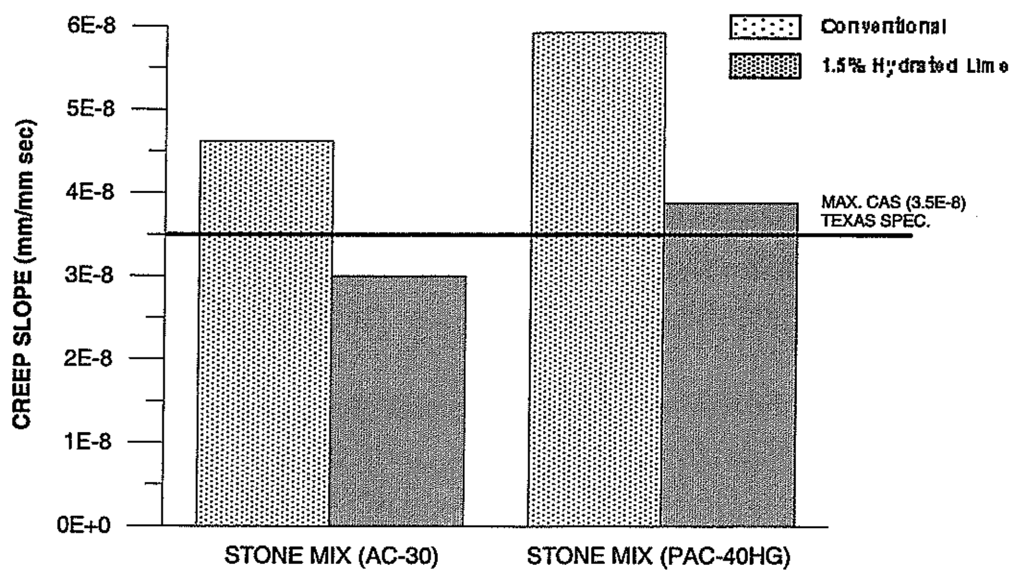


Figure 33
Creep slope for uniaxial creep test - limestone

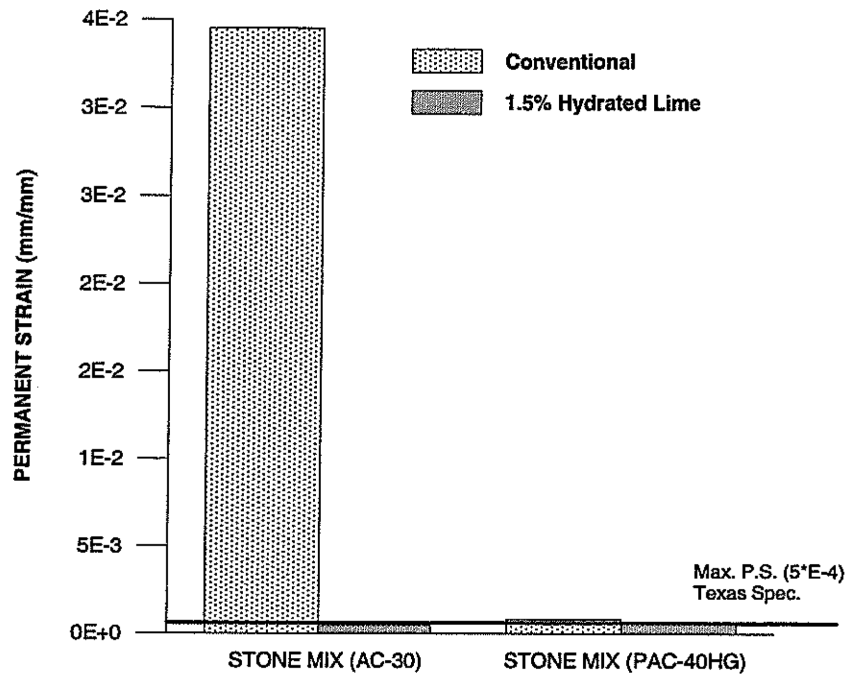


Figure 34

Permanent strain for uniaxial creep test – limestone

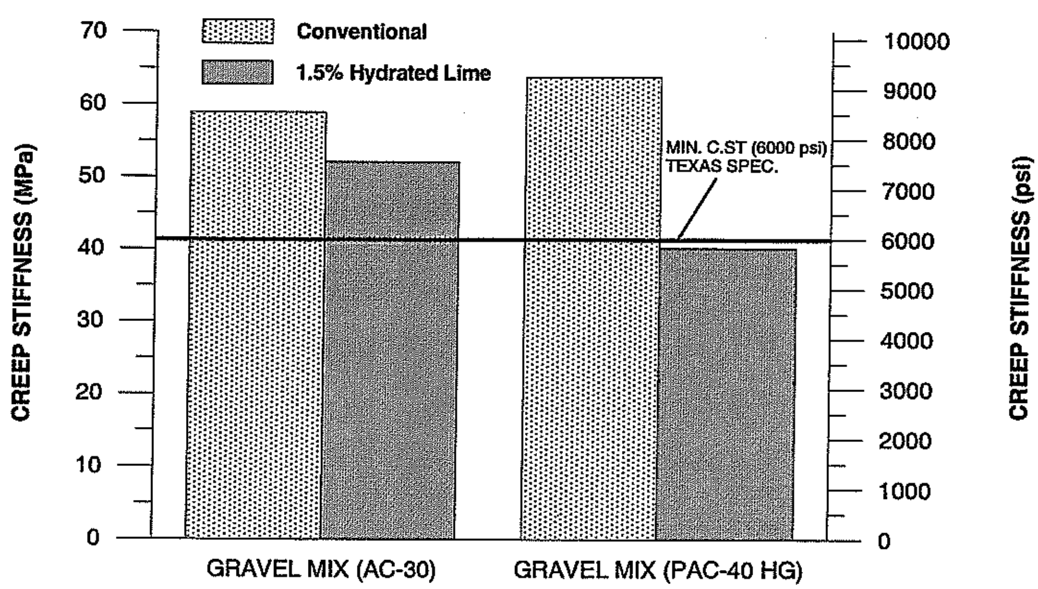


Figure 35

Creep stiffness for uniaxial creep test - gravel

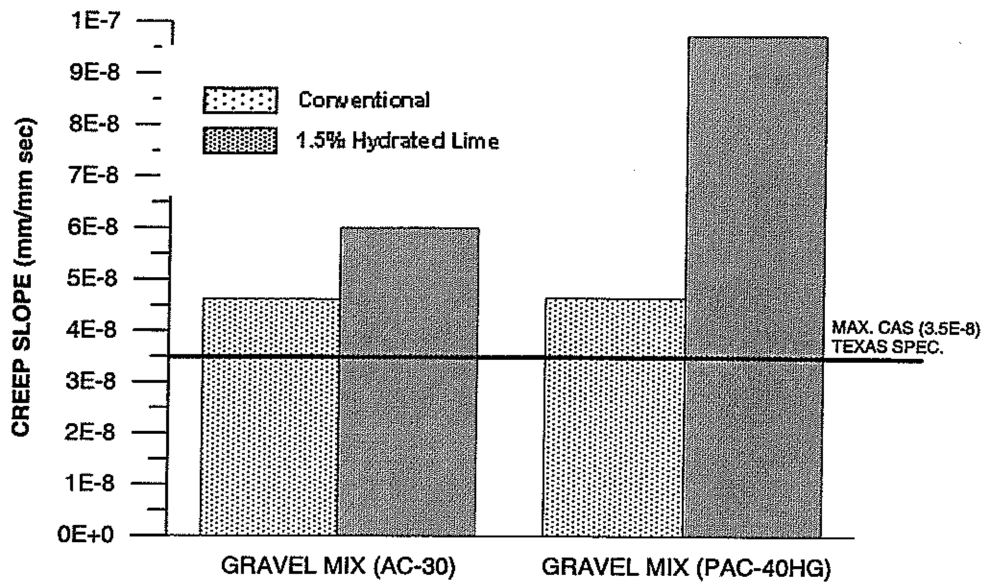


Figure 36
Creep slope for uniaxial creep test – gravel

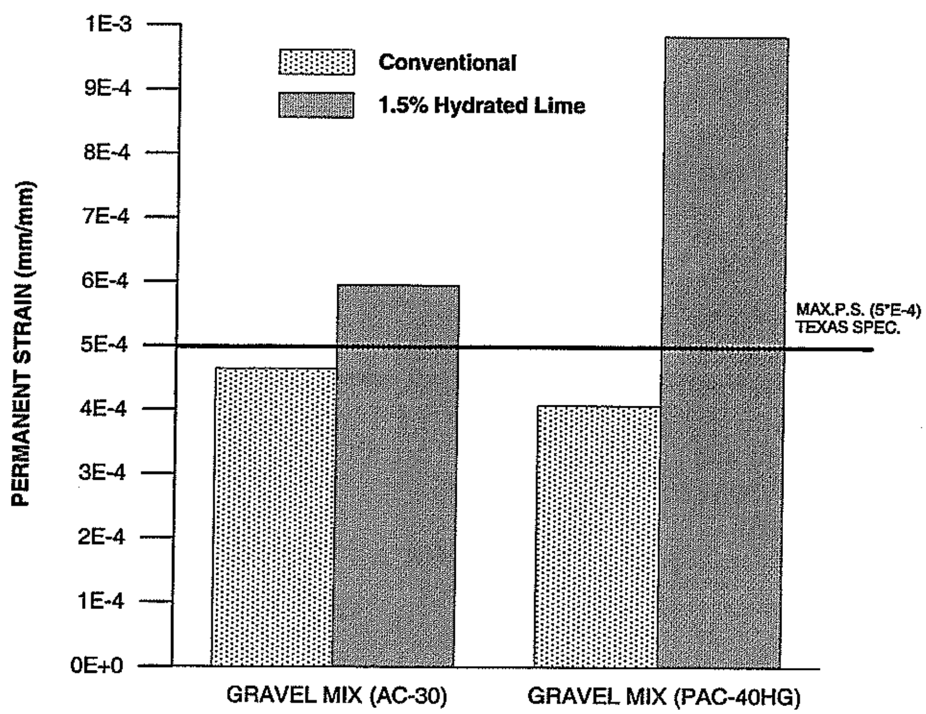


Figure 37
Permanent strain for uniaxial creep test - gravel

Table 22

Statistical groupings of uniaxial creep test results – limestone mix

Temp.	40°C								
Property	PS			CAS			C.ST		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
SAC30N	34.53 E-4	43.57 E-4	A	4.62 E-8	2.69 E-8	A	45.5	6.1	A
SAC30L	4.49 E-4	1.90 E-4	B	3.00 E-8	1.52 E-8	A	61.2	12.8	A
SPMACN	8.10 E-4	0.66 E-4	B	5.92 E-8	1.96 E-8	A	48.7	5.4	A
SPMACL	5.60 E-4	1.85 E-4	B	3.88 E-8	1.33 E-8	A	58.7	13.6	A

PS: Permanent Strain (mm/mm)
CAS: Creep Slope for Uniaxial Creep Stiffness (mm/mm sec)
C.ST: Creep Stiffness (MPa)
St.D: Standard Deviation
Group: Statistical Groupings (columns with same letters indicate no significant difference)

Table 23

Statistical groupings of uniaxial creep test results – gravel mix

Temp.	**40°C**								
Property	**PS**			**CAS**			**C.ST**		
Mix	Mean	St.D.	Group	Mean	St.D.	Group	Mean	St.D.	Group
GAC30N	4.64 E-4	5.78 E-5	B	4.62 E-8	1.42 E-9	B	58.9	8.3	A
GAC30L	5.95 E-4	2.49 E-4	B	6.01 E-8	2.49 E-8	B	52.1	7.8	A
GPMACN	4.07 E-4	3.49 E-5	B	4.64 E-8	3.40 E-9	B	63.8	2.1	A
GPMACL	9.83 E-4	9.41 E-5	A	9.74 E-8	1.10 E-8	A	40.2	1.7	A

PS: Permanent Strain (mm/mm)
CAS: Creep Slope for Uniaxial Creep Stiffness (mm/mm sec)
C.ST: Creep Stiffness (MPa)
St.D: Standard Deviation
Group: Statistical Groupings (columns with same letters indicate no significant difference)

Table 24

Statistical rankings and groupings of uniaxial creep test results

	Ranking/Grouping Based on Permanent Strain (mm/mm)			Ranking/Grouping Based on Uniaxial Creep Slope (mm/mm sec)			Ranking/Grouping Based on Creep Stiffness (MPa)		
	104°F (40°C)								
Mixture Type	Mean	Rank	Group	Mean	Rank	Group	Mean	Rank	Group
SAC30N	34.53 E-4	8	A	4.62 E-8	4	B/C	45.5	7	C/D
SAC30L	4.49 E-4	2	B	3.00 E-8	1	C	61.2	2	A/B
SPMACN	8.10 E-4	6	B	5.92 E-8	6	B/C	48.7	6	B/C/D
SPMACL	5.60 E-4	4	B	3.88 E-8	2	B/C	58.7	4	A/B/C
GAC30N	4.64 E-4	3	B	4.62 E-8	3	B/C	58.9	3	A/B/C
GAC30L	5.95 E-4	5	B	6.01 E-8	7	B	52.1	5	A/B/C/D
GPMACN	4.07 E-4	1	B	4.64 E-8	5	B/C	63.8	1	A
GPMACL	9.83 E-4	7	B	9.74 E-8	8	A	40.2	8	D

Rank: Statistical rankings (1 assigned to most desirable property, 8 assigned to least desirable property in column)
Group: Statistical groupings (columns with same letters indicate no significant difference)

Hamburg Wheel Tracking Device

Factors that affect performance in the Hamburg include the 1) quality of aggregate, 2) asphalt cement stiffness, 3) length of short term aging, 4) refining process or crude oil source of asphalt cement, 5) quantity and type of liquid anti-strip additive or hydrated lime, and 6) compaction temperature *[7]*. The HMACs that were provided to the KOCH MATERIALS lab were evaluated for their rutting and moisture susceptibility.

Table 25 provides the results for the tests conducted on the limestone and gravel mixes. For a rut and strip resistant mix, higher creep slope, steepness of stripping slope values, increased number of passes to a 20 mm rut depth, and higher stripping inflection point values are desirable. The rut depth at 20,000 passes, however, results in low value for the permanent deformation. Figures 38 and 39 have the permanent deformation plotted against the number of wheel passes for these mixes. Table 26 presents the results of the statistical rankings and groupings of the rut characteristics of all eight mixtures. The rank number 1 was assigned to each of the following values: the highest creep slope, the lowest rut depth, and the highest number of passes. The other rank numbers followed respectively.

The results show that the lime modified limestone mixes, SAC30L and SPMACL, showed better properties than the conventional mixes, SAC30N and SPMACN, while all gravel mixes, in general, performed equally well. The results for the gravel mixture are somewhat limited regarding the stripping properties, because there was no onset of stripping during the test period. Also, it is important to note that the deformation curves were still in the linear region of the creep slope during the test period. When evaluating the available test results, it can be observed that the addition of hydrated lime increased the creep slope for SAC30L, SPMACL, and GPMACL and the stripping slope for SAC30L and SPMACL. The lime addition also increased the stripping inflection point and the passes to a 20 mm rut depth for SAC30L and SPMACL. The rut depth at 20,000 passes was, however, lower for SAC30L and SPMACL. This was expected since these two mixes were less rut-susceptible. The rankings indicate that among the stone mixes, SPAMCL had the most desirable rut properties (i.e. high creep slope value, low rut depth, and high number of passes). In addition, SPMACL exhibited a better performance than SAC30L. This may be due to the fact that the PAC-40HG and the lime worked well together, creating a mixture that was less susceptible to rutting and moisture damage. When comparing the test values for SPMACL and GPMACL, the observed creep slope values and the rut depth at 20,000 passes are very close to each other. The creep slope values for SAC30L and GAC30L are also in close proximity to each other. However, the gravel mixes did not show any stripping tendencies and, in general, had lower rut depths. This can lead to the conclusion that the hydrated lime coated the gravel better than the limestone, and in the gravel mixes provide stiffer mixes that contained a moisture barrier.

When comparing the results of the three rut tests (indirect tensile creep test, uniaxial creep test, and the HWTD test), overall, the addition of hydrated lime improved the performance indicators, and the mixes containing the polymer asphalt cement (PAC-40HG) in combination with the hydrated lime showed the most favorable results (table 27). However, the uniaxial creep test results for the gravel mix are not in line with the indirect tensile creep test and HWTD test results for the same mixes, which may be simply a result of the incompatibility of the test set-up with the gravel aggregate. Otherwise, the results of these three rut test are quite similar.

Table 25
Hamburg wheel tracking device test indices for test mixtures

	Limestone Mixtures				Gravel Mixtures			
Test Indices / Air Voids	SAC30N	SAC30L	SPMACN	SPMACL	GAC30N	GAC30L	GPMACN	GPMACL
Air Void Levels (percent)	4.5	3.9	5.4	5.3	6.3	6.1	6.7	5.5
Post Compaction, mm	0.6	1.6	0.9	1.4	1.1	1.2	0.2	1.4
Creep Slope, passes/mm	2,290	9,800	4,110	11,350	18,182	9,756	10,810	11,765
Stripping Slope, passes/mm	385	1,170	820	4,350	NS	NS	NS	NS
Stripping Inflect. Pt, passes	7,385	9,325	9,815	14,290	NS	NS	NS	☆ NS
Rut Depth at 20,000 passes	HR	16.0	11.8	4.1	2.6	3.8	2.2	3.9
Passes to 20 mm	13,700	29,600	23,300	89,000	LR	LR	✧ LR	LR

NS The mixes did not reach the state of stripping for the duration of the test.
HR Sample reached 20 mm rut depth before 20,000 passes.
LR The mixes did not reach a rut depth of 20 mm by the end of the test.

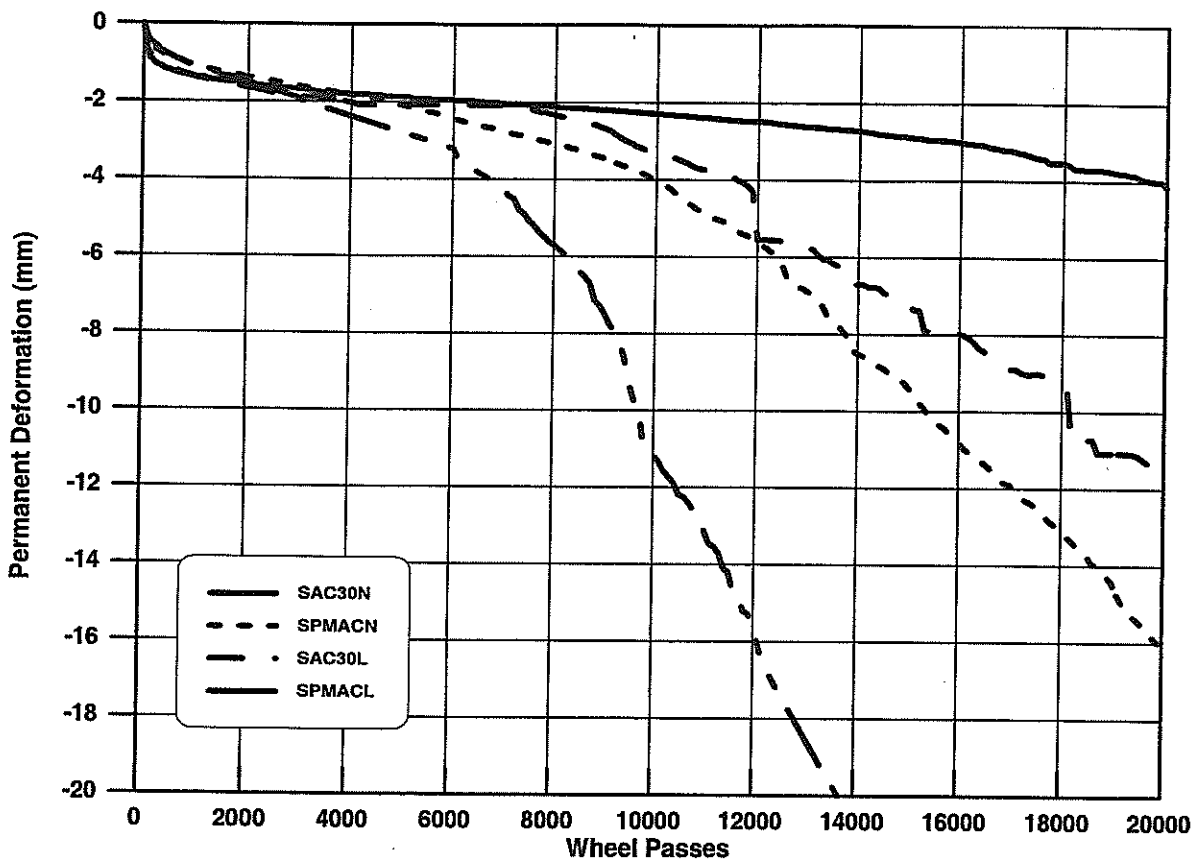


Figure 38
Hamburg wheel tracking test for limestone mix

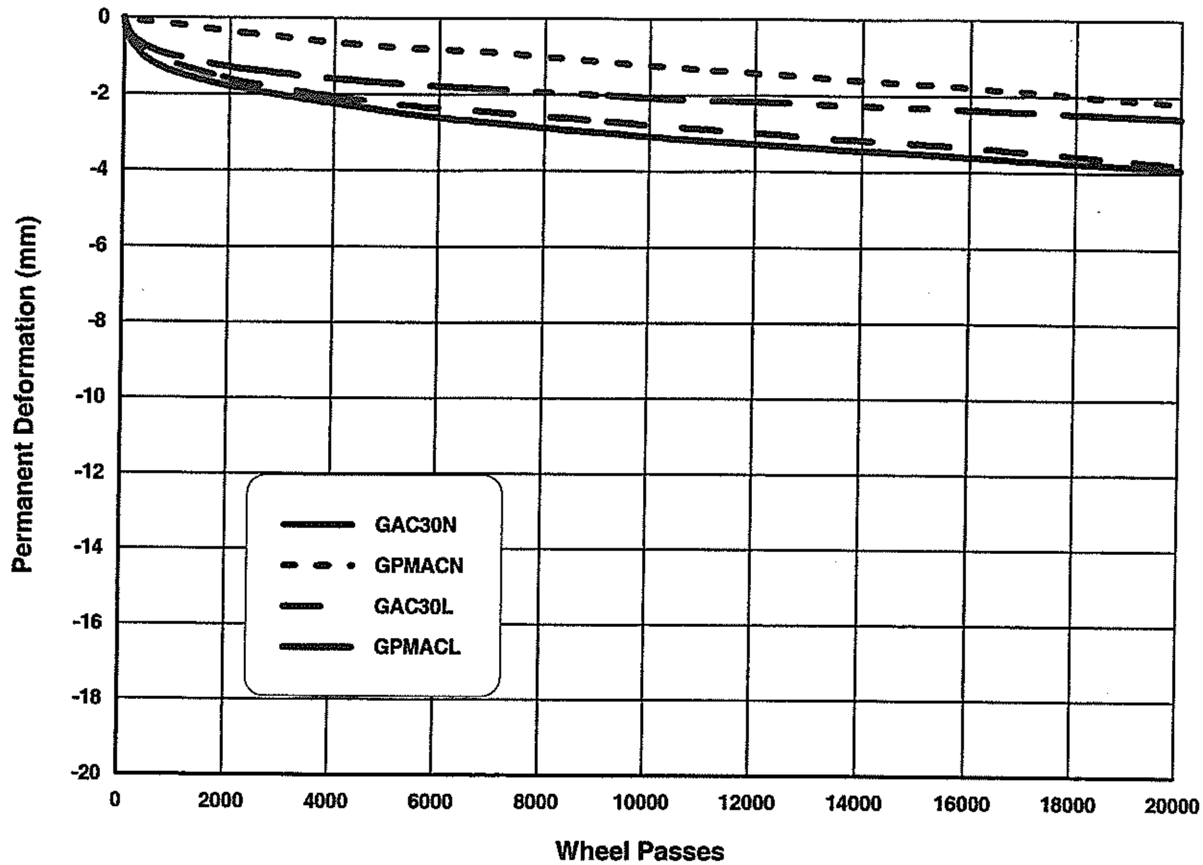


Figure 39
Hamburg wheel tracking test for gravel mix

Table 26

Rankings of HWTD test results

Mixture Type	Ranking Based on Creep Slope (passes/mm)		Ranking Based on Rut Depth at 20,000 Passes (mm)		Ranking Based on Passes to 20 mm	
	122°F (50°C)					
	Mean	Rank	Mean	Rank	Mean	Rank
SAC30N	2,290	8	¤	8	13,700	5
SAC30L	9,800	5	16.0	7	29,600	3
SPMACN	4,110	7	11.8	6	23,300	4
SPMACL	11,350	3	4.1	5	89,000	2
GAC30N	18,182	1	2.6	2	✧	1
GAC30L	9,756	6	3.8	3	✧	1
GPMACN	10,810	4	2.2	1	✧	1
GPMACL	11,765	2	3.9	4	✧	1

¤ Sample reached 20 mm rut depth before 20,000 passes.

✧ The mixes did not reach a rut depth of 20 mm by the end of the test.

Table 27
Statistical rankings and groupings summary of the rut tests

	Indirect Tensile Creep Test								Uniaxial Creep Test						HWTD Test		
	Creep Slope				Time to Failure				P.Strain		C.Slope		C. Stiffness.		CSI	RD.	Pas
	77°F (25°C)		104°F (40°C)		77°F (25°C)		104°F (40°C)		104°F (40°C)						122°F (50°C)		
Mixture Type	R	G	R	G	R	G	R	G	R	G	R	G	R	G	R	R	R
SAC30N	8	A	6	B/C	3	B	7	B	8	A	4	B/C	7	C/D	8	8	5
SAC30L	6	B/C	5	C	2	A	6	B	2	B	1	C	2	A/B	5	7	3
SPMACN	7	A/B	4	C/D	4	B	8	B	6	B	6	B/C	6	B/C/D	7	6	4
SPMACL	1	E	2	E	1	A	2	B	4	B	2	B/C	4	A/B/C	3	5	2
GAC30N	5	A/C	8	A	1	A	5	B	3	B	3	B/C	3	A/B/C	1	2	1
GAC30L	4	C/D	7	A/B	1	A	4	B	5	B	7	B	5	A/B/C/D	6	3	1
GPMACN	3	D/E	3	D/E	1	A	3	B	1	B	5	B/C	1	A	4	1	1
GPMACL	2	D/E	1	E	1	A	1	A	7	B	8	A	8	D	2	4	1

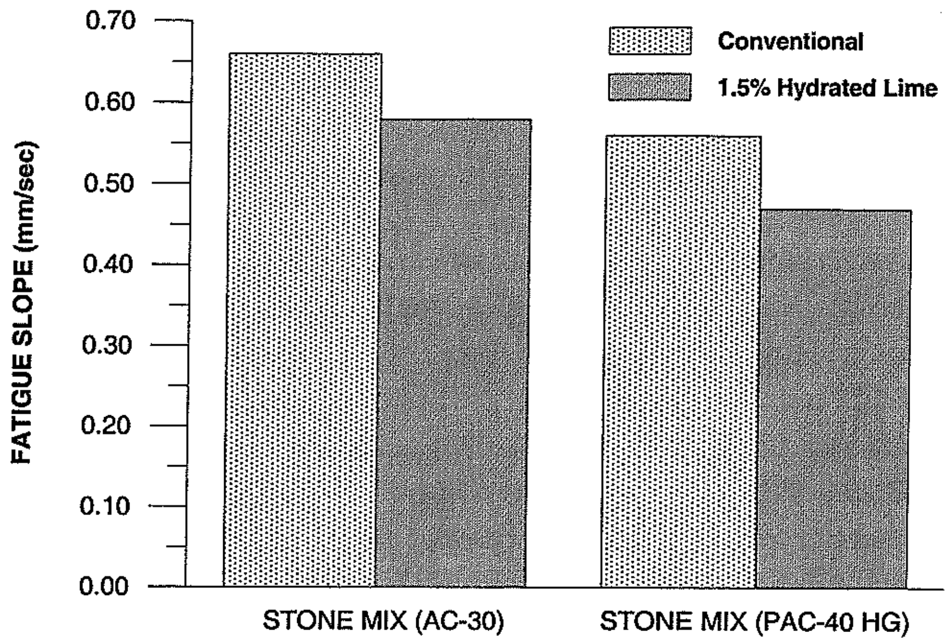
R: Rank - Statistical ranking (1 assigned to most desirable property, 8 assigned to least desirable property in column)
G: Group - Statistical grouping (columns with same letters indicate no significant difference)
P.Strain: Permanent stain
C.Slope (CSI): Creep slope
C.Stffness: Creep stiffness
RD.: Rut Depth at 20,000 passes
Pas: Number of passes to reach 20 mm rut depth

Indirect Tensile Fatigue Test

The results of the indirect tensile fatigue test have been summarized in figures 40 and 41 followed by a statistical analysis in tables 28 and 29. Table 30 summarizes the statistical analysis of the fatigue slope and cycles to failure for the various mixtures studied. Table 30 also ranks each mix for best performance (1 = lowest slope and highest number of cycles to failure).

Tables 28 through 30 show that the use of hydrated lime in the mixes improved the values for the fatigue slope of SAC30L, SPMACL, GAC30L, and GPMACL. The slope values for the stone mixes were in close proximity to those of the gravel mixes. The decrease in slopes shown in tables 28 and 29 was significant. The addition of hydrated lime also increased the number of cycles for SAC30L, SPMACL, GAC30L, and GPMACL. This increase was not significant for SAC30L and GAC30L, but was very significant for SPMACL and GPMACL. In general, the number of cycles to failure was higher for the gravel mixes.

The results of the fatigue test indicate that the addition of hydrated lime as a filler increased the fatigue resistance of the mixes. Again, the mixtures containing a combination of hydrated lime and PAC-40HG showed the most improvement in fatigue properties. GPMACL showed the highest endurance to the repeated cyclic loading of the fatigue test.



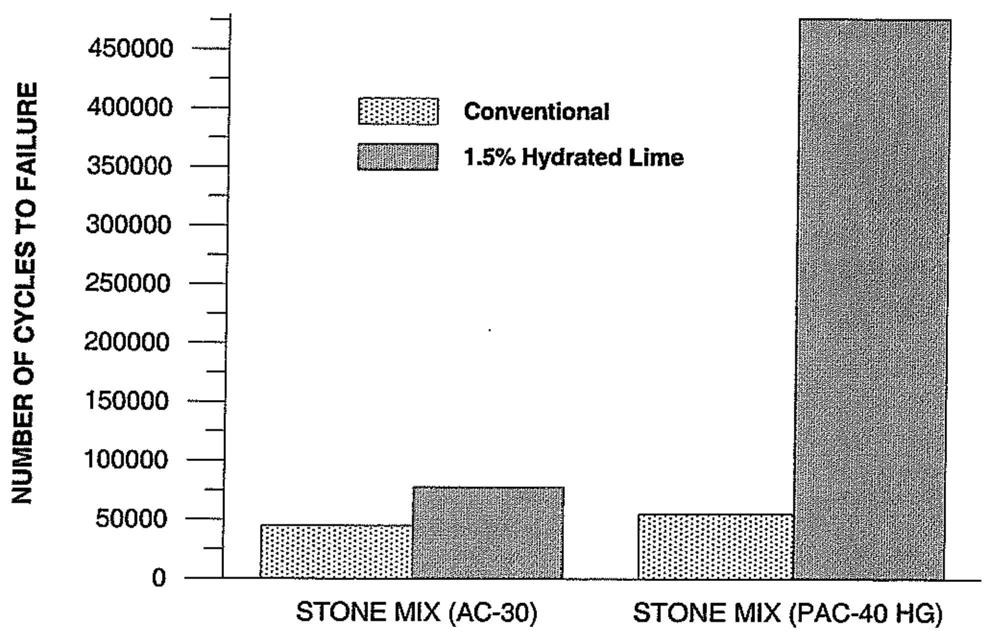
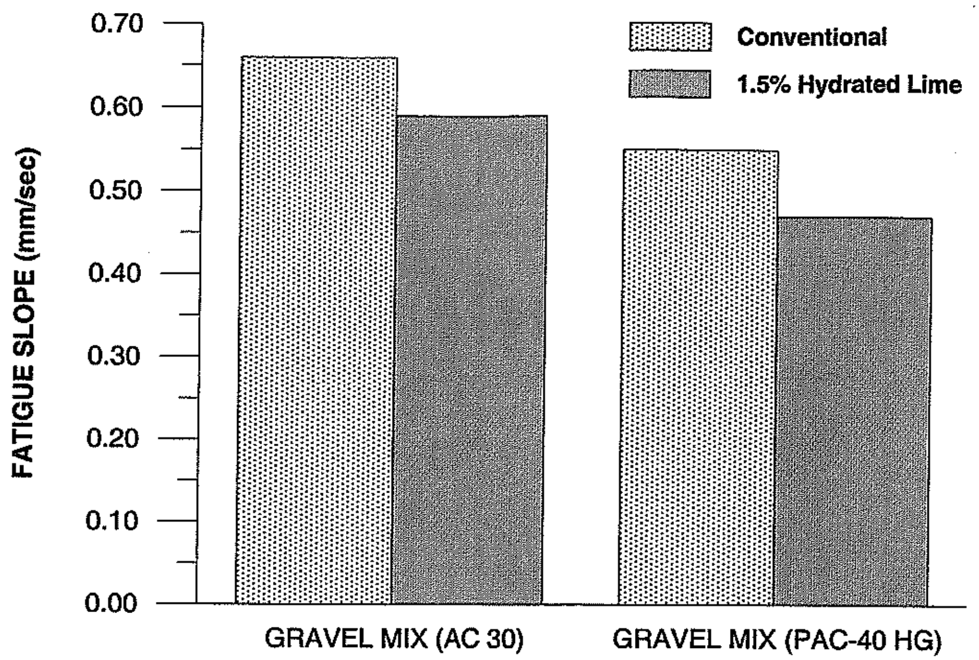


Figure 40
Indirect tensile fatigue test results - limestone



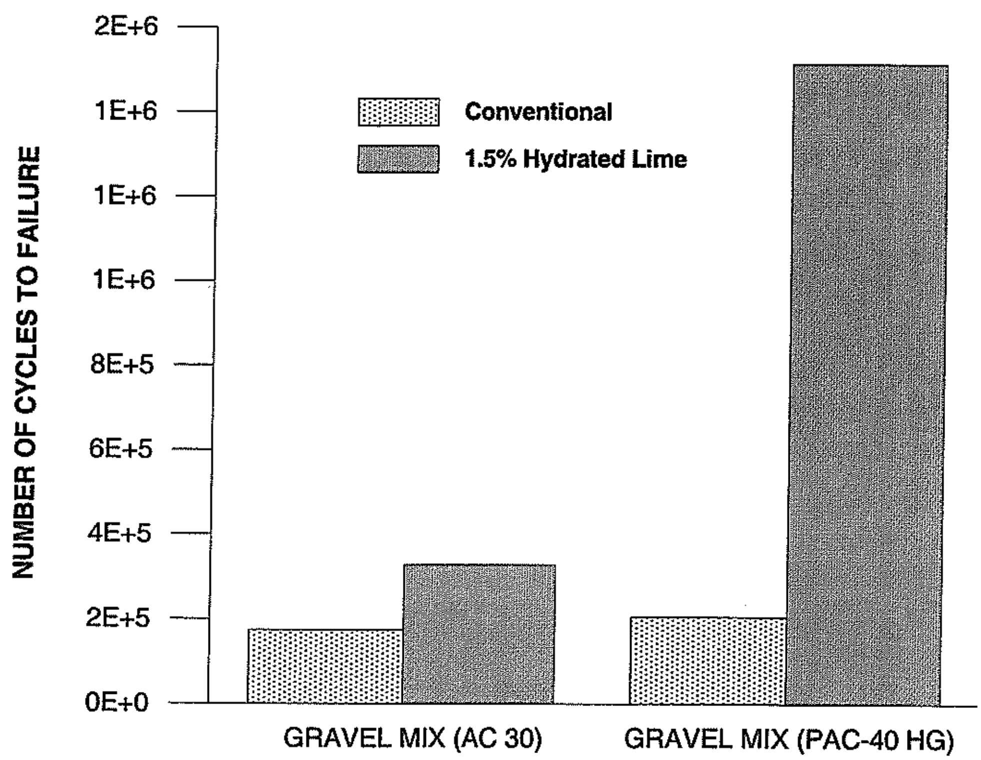


Figure 41
Indirect tensile fatigue test results - gravel

Table 28
Statistical groupings of indirect tensile fatigue test results – limestone mix

Temp.	**25°C**					
Property	**FS**			**N_f**		
Mix Type	Mean	St.D.	Group	Mean	St.D.	Group
SAC30N	0.66	0.04	A	45118	16662	B
SAC30L	0.58	0.04	A/B	77785	31416	B
SPMACN	0.56	0.01	B	54985	10621	B
SPMACL	0.47	0.04	C	476774	224230	A

FS: Fatigue Slope for Permanent Deformation (mm/sec)
N_f: Number of Cycles for Sample to Reach Failure
St.D: Standard Deviation
Group: Statistical Grouping (columns with same letters indicate no significant difference)

Table 29
Statistical groupings of indirect tensile fatigue test results – gravel mix

Temp.	25°C					
Property	FS			N_f		
Mix Type	Mean	St.D.	Group	Mean	St.D.	Group
GAC30N	0.66	0.09	A	173652	92699	B
GAC30L	0.59	0.05	A/B	327185	262549	B
GPMACN	0.55	0.02	A/B	204851	43298	B
GPMACL	0.47	0.06	B	1514986	879209	A

FS: Fatigue Slope for Permanent Deformation (mm/sec)
N_f: Number of Cycles for Sample to Reach Failure
St.D: Standard Deviation
Group: Statistical Grouping (groups with same letters indicate no significant difference)

Table 30

Statistical significance grouping and performance ranking of indirect tensile fatigue test results

	Ranking/Grouping Based on Fatigue Slope (mm/sec)			Ranking/Grouping Based on Number of Cycles to Failure		
	77°F (25°C)					
Mixture Type	Mean	Rank	Group	Mean	Rank	Group
SAC30N	0.66	8	A	45118	8	B
SAC30L	0.58	5	A/B	77785	6	B
SPMACN	0.56	4	A/B/C	54985	7	B
SPMACL	0.47	2	C	476774	2	B
GAC30N	0.66	7	A	173652	5	B
GAC30L	0.59	6	A/B	327185	3	B
GPMACN	0.55	3	B/C	204851	4	B
GPMACL	0.47	1	C	1514986	1	A

Rank: Statistical ranking (1 assigned to most desirable property, 8 assigned to least desirable property in column)
Group: Statistical grouping (columns with same letters indicate no significant difference)

CONCLUSIONS

The fundamental engineering properties of asphaltic concrete mixtures with two different aggregate types, limestone and gravel, and two different asphalt cement types, AC-30 and a polymer modified PAC-40HG, were evaluated using engineering characterization tests (i.e., the indirect tensile strength test, indirect tensile resilient modulus test, indirect tensile and axial creep tests, and indirect tensile fatigue test) and the Hamburg Wheel Tracking Device test. In addition, the results of these tests were statistically grouped and ranked to identify any significant improvement in the fundamental properties. The results of the tests and the statistical analysis have been documented.

Overall, the mixtures in which lime was added did show improved properties, proving that the hydrated lime does provide stronger adhesion between the aggregate and the binder. This improvement was particularly apparent in tests performed at higher temperatures. The mixtures containing the combination of hydrated lime and the polymer modified asphalt cement (PAC-40HG) showed the most improvement. This can be attributed to the fact that the hydrated lime provides a stronger bond between the aggregate and binder and that the polymer modified binder adds elasticity to this bond. This type of asphalt cement mixture would have the desired stiffness to withstand the loads and the desired elasticity to accumulate only minimal permanent deformation; therefore, the hydrated lime mixtures will provide higher rut resistance.

The following observations can be drawn from the data and analysis:

1) For both the limestone mixes and the gravel mixes, the hydrated lime provided an increase in the tensile strength at 104°F (40°C). The strength values of the four gravel mixes were higher at 77°F (25°C) than those of the limestone mixes, while at 104°F (40°C) the strength values were similar.

2) For the gravel mixes with hydrated lime (GAC30L and GPMACL), the total resilient modulus values were higher at all three temperatures, whereas for the limestone mix no trend was observed.

3) The limestone and the gravel mixes with the lime filler (SAC30L, SPMACL, GAC30L, and GPMACL) showed improvement in the indirect tensile creep slope at

77°F (25°C) and 104°F (40°C). The decrease in the slope values was more significant at the higher temperatures.

4) For the uniaxial creep test, only the lime-modified mixes of the limestone mix (SAC30L and SPMACL) showed such improved properties as creep slope and creep stiffness.

5) The fatigue properties for the lime modified mixes of both aggregate types (SAC30L, SPMACL, GAC30L, and GPMACL) showed an improvement with a lower fatigue slope and higher number of cycles to failure. However, the most significant fatigue endurance was noted for the lime-modified mixes with PAC-40HG (GAC30L and GPMACL).

6) When comparing the results of the fundamental test with the HWTD results for the limestone mixtures, it is observed that both results include improved resistance to permanent deformation of the mixtures with the hydrated lime additive.

RECOMMENDATIONS

The objective of this research was to investigate whether hydrated lime used as a mineral filler would improve the fundamental engineering properties of the studied HMACs. The results of this research are expected to aid in predicting improvement in the performance of pavements that are constructed with HMACs containing the lime filler.

The study has shown that there is a change in the fundamental properties of the mixtures under laboratory conditions. The next step is to evaluate the lime modified mixes in the field by constructing test lanes with those mixes. Such tests could support and strengthen the laboratory findings and could provide help in the development of specifications concerning the use of hydrated lime as a mineral filler in Louisiana asphaltic concrete pavements.

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APPENDIX A

Test Data for the Limestone Mixtures

Table A1
Lime study: indirect tensile strength test data
Date: 3/7/95

77°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Stone Mix AC 30 (4.7%)	5 (3.6)	2.407	4.016	3066	2.09	0.04786	0.013079	0.68	201.9
	13 (4.3)	2.427	4.010	2884	1.79	0.03997	0.012315	0.64	188.7
	15 (3.9)	2.452	4.010	2939	1.99	0.04552	0.012232	0.64	190.3
	AVG. (3.9)	2.429	4.012	2963	1.96	0.04445	0.012542	0.65	193.6
	STD.	0.023	0.003	93	0.15	0.00405	0.000467	0.02	7.2
	%CV	0.93	0.09	3.15	7.81	9.11	3.72	3.72	3.74

104°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Stone Mix AC 30 (4.7%)	16 (4.0)	2.453	4.003	744	1.29	0.02938	0.013994	0.73	48.2
	18 (3.6)	2.415	4.011	709	1.19	0.02668	0.012278	0.64	46.6
	20 (3.7)	2.401	4.046	573	1.59	0.03851	0.015431	0.80	37.6
	AVG. (3.8)	2.423	4.020	675	1.36	0.03152	0.013901	0.72	44.1
	STD.	0.027	0.023	90	0.21	0.00620	0.001579	0.08	5.8
	%CV	1.11	0.57	13.38	15.34	19.66	11.36	11.36	13.04

Mix Type: Type of asphalt mixture used
A.V.: % Air Voids
Briq #: Asphalt briquette #
STD: Standard Deviation
%CV: Coefficient of Variation
Height: Thickness of the specimen, in inches

Diameter: Diameter of the specimen, in inches
Load: Load at failure of the specimen, in pounds
Time: Time taken for failure of the specimen, in seconds
Ver. Defm.: Average vertical deformation of specimen at failure, in inches
Hor. Defm.: Average horizontal deformation of specimen at failure, in inches
Ten. Stn. Tensile strain of the specimen at failure, in percent
I.T.S.: Horizontal tensile stress at center of specimen, in psi

Table A2
Lime study: indirect tensile strength test data
Date: 3/7/95

77°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Stone Mix AC 30 (4.6%) with 1.5% Hydrated Lime	8 (4.2)	2.460	3.996	2695	1.69	0.03741	0.011379	0.59	174.5
	9 (4.3)	2.468	3.995	2747	1.70	0.03735	0.010325	0.54	177.4
	13 (3.6)	2.462	3.994	2646	2.09	0.04875	0.012754	0.66	171.3
	AVG. (3.9)	2.463	3.995	2696	1.83	0.04117	0.011486	0.60	174.4
	STD.	0.004	0.001	51	0.23	0.00657	0.001218	0.06	3.0
	%CV	0.17	0.03	1.87	12.49	15.95	10.60	10.60	1.74

104°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Stone Mix AC 30 (4.6%) with 1.5% Hydrated Lime	11 (4.2)	2.467	3.993	765	1.29	0.02938	0.014449	0.75	49.4
	27 (3.5)	2.449	3.993	686	1.29	0.02964	0.013291	0.69	44.7
	37 (4.1)	2.482	3.996	760	1.29	0.02930	0.014283	0.74	48.8
	AVG. (4.0)	2.466	3.994	737	1.29	0.02944	0.014008	0.73	47.6
	STD.	0.017	0.002	44	0.00	0.00018	0.000626	0.03	2.6
	%CV	0.67	0.04	6.00	0.00	0.60	4.47	4.47	5.44

Mix Type: Type of asphalt mixture used
A.V.: % Air Voids
Briq #: Asphalt briquette #
STD: Standard Deviation
%CV: Coefficient of Variation
Height: Thickness of the specimen, in inches

Diameter: Diameter of the specimen, in inches
Load: Load at failure of the specimen, in pounds
Time: Time taken for failure of the specimen, in seconds
Ver. Defm.: Average vertical deformation of specimen at failure, in inches
Hor. Defm.: Average horizontal deformation of specimen at failure, in inches
Ten. Stn. Tensile strain of the specimen at failure, in percent
I.T.S.: Horizontal tensile stress at center of specimen, in psi

Table A3
Lime study: indirect tensile strength test data
Date: 4/21/95

77°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Stone Mix PAC-40 HG (4.7%)	10 (3.8)	2.487	4.000	2613	2.29	0.05374	0.019513	1.01	167.2
	11 (3.9)	2.451	3.992	2379	2.29	0.05421	0.020030	1.04	154.8
	17 (4.4)	2.467	3.997	2503	2.09	0.04811	0.016309	0.85	161.6
	AVG. (4.0)	2.468	3.996	2498	2.22	0.05202	0.018617	0.97	161.2
	STD.	0.018	0.004	117	0.12	0.00339	0.002016	0.10	6.2
	%CV	0.73	0.10	4.69	5.19	6.52	10.83	10.83	3.86

104°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Stone Mix PAC-40 HG (4.7%)	15 (3.9)	2.389	4.049	640	1.94	0.04486	0.019926	1.04	42.1
	21 (4.1)	2.468	4.003	757	1.56	0.03471	0.018195	0.95	48.8
	32 (3.8)	2.391	4.050	785	1.57	0.03489	0.015002	0.78	51.6
	AVG. (3.9)	2.416	4.034	727	1.69	0.03815	0.017708	0.92	47.5
	STD.	0.045	0.027	77	0.22	0.00581	0.002498	0.13	4.9
	%CV	1.86	0.67	10.58	12.81	15.23	14.11	14.11	10.25

Mix Type: Type of asphalt mixture used
A.V.: % Air Voids
Briq #: Asphalt briquette #
STD: Standard Deviation
%CV: Coefficient of Variation
Height: Thickness of the specimen, in inches

Diameter: Diameter of the specimen, in inches
Load: Load at failure of the specimen, in pounds
Time: Time taken for failure of the specimen, in seconds
Ver. Defm.: Average vertical deformation of specimen at failure, in inches
Hor. Defm.: Average horizontal deformation of specimen at failure, in inches
Ten. Stn. Tensile strain of the specimen at failure, in percent
I.T.S.: Horizontal tensile stress at center of specimen, in psi

Table A4
Lime study: indirect tensile strength test data
Date: 3/21/95

77°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Stone Mix PAC-40 HG (4.6%) 1.5% Hydrated Lime	5 (4.4)	2.479	3.995	2894	2.09	0.04724	0.015441	0.80	186.0
	14 (3.8)	2.433	4.008	3175	2.09	0.04691	0.015219	0.79	207.3
	16 (4.1)	2.452	4.011	3030	2.21	0.05014	0.016232	0.84	196.1
	AVG. (4.1)	2.455	4.005	3033	2.13	0.04810	0.015631	0.81	196.5
	STD.	0.023	0.009	141	0.07	0.00178	0.000532	0.03	10.6
	%CV	0.94	0.21	4.63	3.25	3.70	3.41	3.41	5.41

104°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Stone Mix PAC-40 HG (4.6%) 1.5% Hydrated Lime	3 (4.3)	2.480	3.992	927	1.69	0.03963	0.018790	0.98	59.6
	4 (4.2)	2.468	3.995	870	1.69	0.03999	0.020169	1.05	56.2
	30 (3.7)	2.440	4.002	937	1.59	0.03698	0.018666	0.97	61.1
	AVG. (4.1)	2.463	3.996	911	1.66	0.03887	0.019208	1.00	59.0
	STD.	0.021	0.005	36	0.06	0.00164	0.000834	0.04	2.5
	%CV	0.83	0.13	3.97	3.49	4.23	4.34	4.34	4.28

Mix Type: Type of asphalt mixture used
A.V.: % Air Voids
Briq #: Asphalt briquette #
STD: Standard Deviation
%CV: Coefficient of Variation
Height: Thickness of the specimen, in inches

Diameter: Diameter of the specimen, in inches
Load: Load at failure of the specimen, in pounds
Time: Time taken for failure of the specimen, in seconds
Ver. Defm.: Average vertical deformation of specimen at failure, in inches
Hor. Defm.: Average horizontal deformation of specimen at failure, in inches
Ten. Stn. Tensile strain of the specimen at failure, in percent
I.T.S.: Horizontal tensile stress at center of specimen, in psi

Table A5
Lime study: indirect tensile creep test results
Date: 3/14/1995

77°F, CALCULATEDμ

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.7%)	1 (4.4)	95365	30625	17908	13144	-0.44	12.31
	6 (3.7)	81606	26943	13355	6215	-0.48	12.22
	25 (3.9)	92558	31401	19150	14237	-0.42	12.28
	AVG (4.0)	89843	29656	16804	11199	-0.45	12.27
	STD	5936	1945	2491	3552	0.02	0.04
	%CV	6.61	6.56	14.82	31.72	5.58	0.30

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.6%) with 1.5% Hydrated Lime	4 (4.2)	82431	27375	16492	12735	-0.41	12.12
	32 (3.5)	74846	25162	15438	11936	-0.35	11.75
	25 (4.2)	89585	31281	19063	14381	-0.41	12.23
	AVG (4.0)	82287	27939	16998	13017	-0.39	12.03
	STD	6018	2530	1522	1018	0.03	0.21
	%CV	7.31	9.05	8.96	7.82	7.25	1.71

Table A6
Lime study: indirect tensile creep test results
Date: 3/14/1995

104°F, CALCULATEDμ

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.7%)	3 (3.7)	28603	-	-	-	-0.57	11.18
	8 (4.0)	24903	-	-	-	-0.68	11.21
	12 (3.6)	29770	-	-	-	-0.61	11.28
	AVG (3.8)	27759	0	0	0	-0.62	11.22
	STD	2075	0	0	0	0.05	0.04
	%CV	7.47	0.00	0.00	0.00	7.33	0.37

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.6%) with 1.5% Hydrated Lime	3 (4.3)	25575	-	-	-	-0.58	11.03
	18 (4.1)	22556	-	-	-	-0.67	11.07
	30 (3.5)	25426	-	-	-	-0.47	10.95
	AVG (4.0)	24519	0	0	0	-0.57	11.02
	STD	1389	0	0	0	0.08	0.05
	%CV	5.67	0.00	0.00	0.00	14.26	0.45

Table A7
Lime study: indirect tensile creep test results
Date: 3/14/1995

77°F, CALCULATEDμ

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix PAC-40 HG (4.7%)	13 (4.0)	83863	29344	16130	10926	-0.44	12.20
	23 (3.7)	51955	21326	13489	10318	-0.36	11.58
	31 (4.4)	78896	27767	14385	9109	-0.45	12.17
	AVG (4.0)	71571	26146	14668	10118	-0.42	11.98
	STD	14018	3468	1097	755	0.04	0.29
	% CV	19.59	13.27	7.48	7.46	9.67	2.38

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix PAC-40 HG (4.6%) 1.5% Hydrated Lime	2 (4.5)	103090	38761	24796	20078	-0.32	12.07
	21 (4.0)	71003	29867	20245	16870	-0.28	11.63
	35 (3.7)	66512	30045	20635	16751	-0.28	11.59
	AVG (4.1)	80202	32891	21892	17900	-0.29	11.76
	STD	16288	4151	2060	1541	0.02	0.22
	%CV	20.31	12.62	9.41	8.61	6.43	1.85

Table A8
Lime study: indirect tensile creep test results
Date: 3/14/1995

104°F, CALCULATEDμ

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix PAC-40 HG (4.7%)	16 (3.8)	15234	-	-	-	-0.62	10.55
	19 (4.1)	23823	-	-	-	-0.49	10.83
	33 (3.9)	25971	-	-	-	-0.50	10.96
	AVG (3.9)	21676	0	0	0	-0.54	10.78
	STD	4639	0	0	0	0.06	0.17
	% CV	21.40	0.00	0.00	0.00	11.01	1.59

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix PAC-40 HG (4.6%) 1.5% Hydrated Lime	24 (4.2)	35495	10991	-	-	-0.45	11.30
	25 (4.3)	31671	11532	-	-	-0.40	11.08
	26 (3.6)	59034	10267	-	-	-0.45	11.07
	AVG (4.0)	42067	10930	0	0	-0.43	11.15
	STD	12099	518	0	0	0.02	0.11
	%CV	28.76	4.74	0.00	0.00	5.44	0.95

Table A9
Lime study: indirect tensile creep test results
Date: 3/14/1995

77°F, ASSUMEDμ (0.35)

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.7%)	1 (4.4)	70505	16134	7153	4332	-0.64	12.51
	6 (3.7)	56071	11896	4028	1170	-0.72	12.37
	25 (3.9)	85094	18824	8463	5074	-0.66	12.76
	AVG (4.0)	70557	15618	6548	3525	-0.67	12.55
	STD	11849	2852	1860	1693	0.03	0.16
	% CV	16.79	18.26	28.41	48.02	5.05	1.29

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.6%) with 1.5% Hydrated Lime	4 (4.2)	72406	16660	7419	4767	-0.64	12.55
	32 (3.5)	56066	13163	6431	4452	-0.52	11.87
	25 (4.2)	63650	14510	6655	4276	-0.62	12.36
	AVG (4.0)	64041	14778	6835	4498	-0.59	12.26
	STD	6676	1440	423	203	0.05	0.29
	%CV	10.43	9.75	6.19	4.52	8.85	2.34

Table A10
Lime study: indirect tensile creep test results
Date: 3/14/1995

104°F, ASSUMEDμ (0.35)

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.7%)	3 (3.7)	9033	-	-	-	-0.80	10.38
	8 (4.0)	8958	-	-	-	-1.01	10.67
	12 (3.6)	9890	-	-	-	-0.88	10.59
	AVG (3.8)	9294	0	0	0	-0.90	10.55
	STD	423	0	0	0	0.09	0.12
	% CV	4.55	0.00	0.00	0.00	9.65	1.16

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.6%) with 1.5% Hydrated Lime	3 (4.3)	8771	-	-	-	-0.83	10.38
	18 (4.1)	7207	-	-	-	-0.96	10.36
	30 (3.5)	9144	-	-	-	-0.65	10.23
	AVG (4.1)	8374	0	0	0	-0.81	10.32
	STD	839	0	0	0	0.13	0.07
	%CV	10.02	0.00	0.00	0.00	15.63	0.64

Table A11
Lime study: indirect tensile creep test results
Date: 3/14/1995

77°F, ASSUMEDμ (0.35)

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.7%)	13 (4.0)	49128	12262	4853	2618	-0.65	12.16
	23 (3.7)	49790	12950	5612	3444	-0.61	12.12
	31 (4.4)	48062	11405	4196	2090	-0.66	12.12
	AVG (4.0)	48993	12206	4887	2717	-0.64	12.13
	STD	712	632	579	557	0.02	0.02
	% CV	1.45	5.18	11.84	20.51	3.38	0.16

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix AC 30 (4.6%) with 1.5% Hydrated Lime	2 (4.5)	71203	19683	10333	7514	-0.45	11.97
	21 (4.0)	53140	16486	9238	6935	-0.40	11.58
	35 (3.7)	43680	13510	7521	5451	-0.42	11.44
	AVG (4.1)	56008	16560	9031	6633	-0.42	11.66
	STD	11418	2521	1157	869	0.02	0.22
	%CV	20.39	15.22	12.82	13.10	4.85	1.92

Table A12
Lime study: indirect tensile creep test results
Date: 3/14/1995

104°F, ASSUMEDμ (0.35)

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix PAC-40 HG (4.7%)	16 (3.8)	6123	-	-	-	-1.02	10.21
	19 (4.1)	7811	-	-	-	-0.74	10.11
	33 (3.9)	8194	-	-	-	-0.73	10.16
	AVG (3.9)	7376	0	0	0	-0.83	10.16
	STD	900	0	0	0	0.13	0.04
	% CV	12.20	0.00	0.00	0.00	16.19	0.40

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Stone Mix PAC-40 HG (4.6%) 1.5% Hydrated Lime	24 (4.2)	13398	2460	-	-	-0.64	10.66
	25 (4.3)	13541	2873	-	-	-0.61	10.61
	26 (3.6)	4990	1393	-	-	-0.61	10.31
	AVG (4.0)	10643	2242	0	0	-0.62	10.53
	STD	3998	624	0	0	0.01	0.15
	%CV	37.56	27.81	0.00	0.00	2.28	1.47

Table A13
Type 3, binder course (stone mix, 4.7% AC 30)
Resilient modulus test data
May 11, 1995

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	1051111	986235	0.305	0.261	1141536	1156511
23 (3.9)	960911	887772	0.105	0.124	1596799	1442878
24 (3.8)	880696	824174	0.226	0.208	1111051	1081768
AVG (3.8)	964239	899394	0.212	0.198	1283129	1227052
STD	69611	66670	0.082	0.056	222147	155632
%CV	7.22	7.41	38.80	28.54	17.31	12.68

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	1149226	1047288	0.299	0.265	1294178	1234978
23 (3.9)	957106	875475	0.123	0.095	1517860	1498167
24 (3.8)	847318	794731	0.138	0.177	1327615	1103673
AVG (3.8)	984550	905831	0.187	0.179	1379884	1278939
STD	124772	105317	0.060	0.069	98514	164024
%CV	12.67	11.63	42.68	38.78	7.14	12.83

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	762276	631978	0.276	0.205	876565	834034
23 (3.9)	806342	639125	0.272	0.292	940565	708473
24 (3.8)	699363	558428	0.250	0.310	840817	597958
AVG (3.8)	755994	609844	0.266	0.269	885982	713488
STD	43899	36473	0.011	0.046	41263	96443
%CV	5.81	5.98	4.30	17.04	4.66	13.52

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	781285	639846	0.318	0.272	824465	743707
23 (3.9)	702294	600930	0.291	0.295	782057	663010
24 (3.8)	681974	565112	0.245	0.250	829166	675563
AVG (3.8)	721851	601963	0.285	0.272	811896	693193
STD	42837	30519	0.030	0.018	21186	36257
%CV	5.93	5.07	10.59	6.75	2.61	5.23

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	423227	328584	0.416	0.496	383747	266353
23 (3.9)	383449	301783	0.471	0.490	322946	246931
24 (3.8)	349326	263493	0.406	0.407	320099	242124
AVG (3.8)	385334	297953	0.431	0.464	342264	251803
STD	30199	26711	0.029	0.041	29356	10474
%CV	7.84	8.96	6.63	8.75	8.58	4.16

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	434396	330332	0.401	0.406	411397	303412
23 (3.9)	361772	275285	0.393	0.410	338848	254507
24 (3.8)	357817	280913	0.422	0.482	320519	232109
AVG (3.8)	384662	295510	0.405	0.433	356921	263343
STD	35205	24730	0.012	0.035	39240	29772
%CV	9.15	8.37	3.02	8.07	10.99	11.31

Table A14
Type 3, binder course (stone mix, 4.6% AC 30, 1.5% hydrated lime)
Resilient modulus test data
May 11, 1995

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	929215	729789	0.147	0.090	1392291	1287448
23 (3.7)	1070562	1020129	0.220	0.165	1376929	1471491
24 (4.3)	913983	874280	0.147	0.138	1366897	1335767
AVG (4.0)	971253	874733	0.171	0.131	1378706	1364902
STD	70497	118531	0.034	0.031	10443	77908
%CV	7.26	13.55	20.09	23.68	0.76	5.71

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	1016688	973890	0.227	0.211	1276426	1266622
23 (3.7)	739932	708291	0.110	0.070	1207120	1302497
24 (4.3)	960542	922703	0.213	0.169	1233944	1323861
AVG (4.0)	905721	868295	0.183	0.150	1289163	1297660
STD	119450	115053	0.052	0.059	28435	23617
%CV	13.19	13.25	28.46	39.41	2.30	1.82

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	895482	714957	0.277	0.297	1016090	805793
23 (3.7)	834231	667292	0.308	0.318	925753	708700
24 (4.3)	888314	696547	0.358	0.339	884475	712006
AVG (4.0)	872676	692932	0.314	0.318	942106	742166
STD	27342	19626	0.033	0.017	54962	45011
%CV	3.13	2.83	10.62	5.39	5.83	6.06

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	891406	706173	0.291	0.328	1005722	742318
23 (3.7)	844211	676433	0.328	0.310	881267	724411
24 (4.3)	830561	649631	0.242	0.235	1017673	800174
AVG (4.0)	855383	677412	0.287	0.291	968221	755634
STD	26068	23094	0.035	0.040	61679	32332
%CV	3.05	3.41	12.27	13.84	6.37	4.28

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	411862	303764	0.493	0.442	334779	270159
23 (3.7)	368521	266255	0.427	0.488	342401	220109
24 (4.3)	364432	277543	0.368	0.407	355700	254173
AVG (4.0)	381605	282521	0.429	0.446	344293	248147
STD	21460	15712	0.051	0.033	8645	20872
%CV	5.62	5.56	11.89	7.44	2.51	8.41

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	376614	285221	0.371	0.393	370641	267976
23 (3.7)	385588	267815	0.492	0.509	313359	213636
24 (4.3)	422989	279225	0.435	0.464	376399	237975
AVG (4.0)	395064	277420	0.433	0.455	353466	239862
STD	20083	7220	0.049	0.048	28457	22224
%CV	5.08	2.60	11.42	10.49	8.05	9.27

Table A15
Type 3, binder course (stone mix, 4.7% PAC-40 HG)
Resilient modulus test data
May 11, 1995

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	1030537	967147	0.246	0.250	1245070	1164877
34 (3.9)	934241	842997	0.201	0.235	1245451	1039702
35 (4.1)	982497	913525	0.187	0.188	1352641	1257284
AVG (4.1)	982425	907890	0.211	0.224	1281054	1153954
STD	39313	50840	0.025	0.026	50620	89163
%CV	4.00	5.60	11.91	11.77	3.95	7.73

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	837002	783677	0.123	0.130	1330682	1240075
34 (3.9)	876149	802816	0.244	0.225	1052380	1006861
35 (4.1)	974648	917488	0.209	0.199	1263666	1227620
AVG (4.1)	895933	834660	0.192	0.185	1215576	1158185
STD	57909	59087	0.051	0.040	118596	107123
%CV	6.46	7.08	26.48	21.71	9.76	9.25

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	783678	606696	0.323	0.269	827313	704656
34 (3.9)	691817	500203	0.300	0.291	751908	554474
35 (4.1)	627084	498681	0.294	0.297	695137	547057
AVG (4.1)	700860	535193	0.306	0.286	758119	602062
STD	64248	50564	0.012	0.012	54139	72608
%CV	9.17	9.45	4.09	4.23	7.14	12.06

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	859890	661965	0.348	0.345	866676	673572
34 (3.9)	746957	568210	0.314	0.344	800800	573921
35 (4.1)	749928	562337	0.334	0.327	776966	585388
AVG (4.1)	785592	597504	0.332	0.339	814814	610960
STD	52551	45644	0.014	0.008	37941	44520
%CV	6.69	7.64	4.20	2.44	4.66	7.29

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	305881	244758	0.416	0.474	278366	206713
34 (3.9)	288671	239240	0.495	0.472	234268	200428
35 (4.1)	274889	236994	0.410	0.427	251431	213971
AVG (4.1)	289814	240331	0.440	0.458	254688	207037
STD	12678	3262	0.039	0.022	18150	5534
%CV	4.37	1.36	8.80	4.74	7.13	2.67

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	322875	260040	0.477	0.477	270826	216482
34 (3.9)	273033	238239	0.439	0.408	239067	218303
35 (4.1)	284920	240930	0.451	0.431	249975	216011
AVG (4.1)	293609	246403	0.456	0.439	253289	216932
STD	21255	9705	0.016	0.029	13176	988
%CV	7.24	3.94	3.48	6.54	5.20	0.46

Table A16
Type 3, binder course (stone mix, 4.6% PAC-40, 1.5% hydrated lime)
Resilient modulus test data
May 11, 1995

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	1066201	1001288	0.212	0.197	1387139	1330441
27 (4.1)	953290	909515	0.165	0.209	1363655	1193630
36 (3.8)	1007995	950684	0.261	0.264	1181050	1117486
AVG (4.0)	1009162	953829	0.213	0.223	1310615	1213852
STD	46103	37532	0.039	0.029	92116	88107
%CV	4.57	3.93	18.43	13.06	7.03	7.26

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	838083	789359	0.131	0.160	1304684	1141547
27 (4.1)	1022699	963504	0.229	0.230	1274501	1215747
36 (3.8)	1041519	986407	0.188	0.210	1413446	1280835
AVG (4.0)	967434	913090	0.183	0.200	1330877	1212710
STD	91787	87989	0.040	0.029	59671	56905
%CV	9.49	9.64	22.00	14.72	4.48	4.69

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	800963	595499	0.334	0.277	827774	685970
27 (4.1)	671571	525098	0.313	0.339	722333	539576
36 (3.8)	750903	537631	0.298	0.304	824577	581326
AVG (4.0)	741146	552743	0.315	0.307	791561	602291
STD	53273	30663	0.015	0.025	48969	61576
%CV	7.19	5.55	4.69	8.28	6.19	10.22

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	758530	584668	0.329	0.292	788662	649553
27 (4.1)	708005	549228	0.333	0.284	740888	615650
36 (3.8)	792408	554961	0.340	0.310	806819	594534
AVG (4.0)	752981	562952	0.334	0.295	778790	619912
STD	34680	15533	0.005	0.011	27807	22663
%CV	4.61	2.76	1.36	3.68	3.57	3.66

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	329989	270522	0.402	0.390	305528	255676
27 (4.1)	333689	253256	0.436	0.459	295261	216541
36 (3.8)	332114	260671	0.372	0.416	322945	237212
AVG (4.0)	331931	261483	0.403	0.422	307911	236476
STD	1516	7072	0.026	0.028	11427	15985
%CV	0.46	2.70	6.48	6.75	3.71	6.76

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	388543	285833	0.404	0.477	357278	238497
27 (4.1)	339837	250303	0.383	0.434	322012	220601
36 (3.8)	354125	280243	0.399	0.420	330154	253116
AVG (4.0)	360835	272126	0.395	0.444	336481	237405
STD	20442	15599	0.009	0.024	15076	13297
%CV	5.67	5.73	2.27	5.47	4.48	5.60

Table A17
Type 3, binder course (stone mix, 4.7% AC 30)
Resilient modulus test data (in Mpa)
May 11, 1995

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	7242	6795	0.305	0.261	7865	7968
23 (3.9)	6621	6117	0.105	0.124	11002	9941
24 (3.8)	6068	5679	0.226	0.208	7655	7453
AVG (3.8)	6644	6197	0.212	0.198	8841	8454
STD	480	459	0.082	0.056	1531	1072
%CV	7.22	7.41	38.80	28.54	17.31	12.68

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	7918	7216	0.299	0.265	8917	8509
23 (3.9)	6594	6032	0.123	0.095	10458	10322
24 (3.8)	5838	5476	0.138	0.177	9147	7604
AVG (3.8)	6784	6241	0.187	0.179	9507	8812
STD	860	726	0.080	0.069	679	1130
%CV	12.67	11.63	42.68	38.78	7.14	12.83

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	5252	4354	0.276	0.205	6040	5746
23 (3.9)	5556	4404	0.272	0.292	6480	4881
24 (3.8)	4819	3848	0.250	0.310	5793	4120
AVG (3.8)	5209	4202	0.266	0.269	6104	4916
STD	302	251	0.011	0.046	284	664
%CV	5.81	5.98	4.30	17.04	4.66	13.52

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	5383	4409	0.318	0.272	5681	5124
23 (3.9)	4839	4140	0.291	0.295	5388	4550
24 (3.8)	4699	3894	0.245	0.250	5713	4655
AVG (3.8)	4974	4148	0.285	0.272	5594	4776
STD	295	210	0.030	0.018	146	250
%CV	5.93	5.07	10.59	6.75	2.61	5.23

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	2916	2264	0.416	0.496	2644	1835
23 (3.9)	2642	2079	0.471	0.490	2225	1701
24 (3.8)	2407	1815	0.406	0.407	2205	1668
AVG (3.8)	2655	2063	0.431	0.464	2358	1735
STD	208	184	0.029	0.041	202	72
%CV	7.84	8.96	6.63	8.75	8.58	4.16

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
9 (3.7)	2993	2276	0.401	0.406	2834	2091
23 (3.9)	2493	1897	0.393	0.410	2335	1754
24 (3.8)	2465	1935	0.422	0.482	2208	1599
AVG (3.8)	2650	2036	0.405	0.433	2459	1814
STD	243	170	0.012	0.035	270	205
%CV	9.15	8.37	3.02	8.07	10.98	11.31

Table A18
Type 3, binder course (stone mix, 4.6% AC 30, 1.5% hydrated lime)
Resilient modulus test data (in Mpa)
May 11, 1995

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	6402	5028	0.147	0.090	9593	8871
23 (3.7)	7376	7029	0.220	0.165	9487	10139
24 (4.3)	6297	6024	0.147	0.138	9418	9203
AVG (4.0)	6692	6027	0.171	0.131	9499	9404
STD	486	817	0.034	0.031	72	537
%CV	7.26	13.55	20.09	23.68	0.76	5.71

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	7005	6710	0.227	0.211	8795	8727
23 (3.7)	5098	4880	0.110	0.070	8317	8974
24 (4.3)	6618	6357	0.213	0.169	8502	9121
AVG (4.0)	6240	5983	0.183	0.150	8538	8941
STD	823	793	0.052	0.059	197	163
%CV	13.19	13.25	28.46	39.41	2.30	1.82

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	6170	4926	0.277	0.297	7001	5552
23 (3.7)	5748	4598	0.308	0.318	6378	4883
24 (4.3)	6120	4799	0.358	0.339	6097	4906
AVG (4.0)	6013	4774	0.314	0.318	6491	5114
STD	188	135	0.033	0.017	379	310
%CV	3.13	2.83	10.62	5.39	5.83	6.06

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	6142	4866	0.291	0.328	6929	5115
23 (3.7)	5817	4661	0.328	0.310	6072	4991
24 (4.3)	5723	4476	0.242	0.235	7012	5513
AVG (4.0)	5894	4667	0.287	0.291	6671	5206
STD	180	159	0.035	0.040	425	223
%CV	3.05	3.41	12.27	13.84	6.37	4.28

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	2838	2093	0.493	0.442	2307	1861
23 (3.7)	2539	1834	0.427	0.488	2359	1517
24 (4.3)	2511	1912	0.368	0.407	2451	1751
AVG (4.0)	2629	1947	0.429	0.446	2372	1710
STD	148	108	0.051	0.033	60	144
%CV	5.62	5.56	11.89	7.44	2.51	8.41

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	2595	1965	0.371	0.393	2554	1846
23 (3.7)	2657	1845	0.492	0.509	2159	1472
24 (4.3)	2914	1924	0.435	0.464	2593	1640
AVG (4.0)	2722	1911	0.433	0.455	2435	1653
STD	138	50	0.050	0.048	196	153
%CV	5.08	2.60	11.45	10.49	8.05	9.27

Table A19
Type 3, binder course (stone mix, 4.7% PAC-40 HG)
Resilient modulus test data (in Mpa)
May 11, 1995

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	7100	6664	0.246	0.250	8579	8026
34 (3.9)	6437	5808	0.201	0.235	8581	7164
35 (4.1)	6769	6294	0.187	0.188	9320	8663
AVG (4.1)	6769	6255	0.211	0.224	8826	7951
STD	271	350	0.025	0.026	349	614
%CV	4.00	5.60	11.91	11.77	3.95	7.73

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	5767	5400	0.123	0.130	9168	8544
34 (3.9)	6037	5531	0.244	0.225	7251	6937
35 (4.1)	6715	6321	0.209	0.199	8707	8458
AVG (4.1)	6173	5751	0.192	0.185	8375	7980
STD	399	407	0.051	0.040	817	738
%CV	6.46	7.08	26.48	21.71	9.76	9.25

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	5400	4180	0.323	0.269	5700	4855
34 (3.9)	4767	3446	0.300	0.291	5181	3820
35 (4.1)	4321	3436	0.294	0.297	4789	3769
AVG (4.1)	4829	3687	0.306	0.286	5223	4148
STD	443	348	0.012	0.012	373	500
%CV	9.17	9.45	4.09	4.23	7.14	12.06

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	5925	4561	0.348	0.345	5971	4641
34 (3.9)	5147	3915	0.314	0.344	5518	3954
35 (4.1)	5167	3875	0.334	0.327	5353	4033
AVG (4.1)	5413	4117	0.332	0.339	5614	4210
STD	362	314	0.014	0.008	261	307
%CV	6.69	7.64	4.20	2.44	4.66	7.29

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	2108	1686	0.416	0.474	1918	1424
34 (3.9)	1989	1648	0.495	0.472	1614	1381
35 (4.1)	1894	1633	0.410	0.427	1732	1474
AVG (4.1)	1997	1656	0.440	0.458	1755	1426
STD	87	22	0.039	0.022	125	38
%CV	4.37	1.36	8.80	4.74	7.13	2.67

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
24 (4.3)	2225	1792	0.477	0.477	1866	1492
34 (3.9)	1881	1641	0.439	0.408	1647	1504
35 (4.1)	1963	1660	0.451	4.31	1722	1488
AVG (4.1)	2023	1698	0.456	0.439	1745	1495
STD	146	67	0.016	0.029	91	7
%CV	7.24	3.94	3.48	6.54	5.20	0.46

Table A20
Type 3, binder course (stone mix, 4.6% PAC-40, 1.5% hydrated lime)
Resilient modulus test data (in Mpa)
May 11, 1995

0 Degrees

40°F ASSUMED μ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	7346	6899	0.212	0.197	9557	9167
27 (4.1)	6568	6267	0.165	0.209	9396	8224
36 (3.8)	6945	6550	0.261	0.264	8137	7699
AVG (4.0)	6953	6572	0.213	0.223	9030	8363
STD	318	259	0.039	0.029	635	607
%CV	4.57	3.93	18.43	13.06	7.03	7.26

45 Degrees

40°F ASSUMED μ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	5774	5439	0.131	0.160	8989	7865
27 (4.1)	7046	6639	0.229	0.230	8781	8376
36 (3.8)	7176	6796	0.188	0.210	9739	8825
AVG (4.0)	6666	6291	0.183	0.200	9170	8356
STD	632	606	0.040	0.029	411	392
%CV	9.49	9.64	22.00	14.72	4.48	4.69

0 Degrees

77°F ASSUMED μ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	5519	4103	0.334	0.277	5703	4726
27 (4.1)	4627	3618	0.313	0.339	4977	3718
36 (3.8)	5174	3704	0.298	0.304	5681	4005
AVG (4.0)	5106	3808	0.315	0.307	5454	4150
STD	367	211	0.015	0.025	337	424
%CV	7.19	5.55	4.69	8.28	6.19	10.22

45 Degrees

77°F ASSUMED μ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	5226	4028	0.329	0.292	5434	4475
27 (4.1)	4878	3784	0.333	0.284	5105	4242
36 (3.8)	5460	3824	0.340	0.310	5559	4096
AVG (4.0)	5188	3879	0.334	0.295	5366	4271
STD	239	107	0.005	0.011	192	156
%CV	4.61	2.76	1.36	3.68	3.57	3.66

0 Degrees

104°F ASSUMED μ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	2274	1864	0.402	0.390	2105	1762
27 (4.1)	2299	1745	0.436	0.459	2034	1492
36 (3.8)	2288	1796	0.372	0.416	2225	1634
AVG (4.0)	2287	1802	0.403	0.422	2122	1629
STD	10	49	0.026	0.028	79	110
%CV	0.46	2.70	6.48	6.75	3.71	6.76

45 Degrees

104°F ASSUMED μ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
12 (4.0)	2677	1969	0.404	0.477	2462	1643
27 (4.1)	2341	1725	0.383	0.434	2219	1520
36 (3.8)	2440	1931	0.399	0.420	2275	1744
AVG (4.0)	2486	1875	0.395	0.444	2318	1636
STD	141	107	0.009	0.024	104	92
%CV	5.67	5.73	2.27	5.47	4.48	5.60

Table A21
Lime study: uniaxial creep analysis test results
Date: 12/14/95

104°F

Mix Type	Briq. # (A.V.)	Permanent Strain	Total Strain	Creep Slope	Intercept	Creep Stiffness
Stone Mix AC 30 (4.7%)	14 (3.6)	8.480E –03	1.611E –03	4.37E –08	0.001450	6207
	19 (4.0)	1.111E –03	1.672E –03	7.43E –08	0.001369	5981
	21 (3.5)	7.691E –04	1.312E –03	2.06E –08	0.001231	7622
	AVG (3.7)	3.453E –03	1.532E –03	4.62E –08	0.001350	6603
	STD	4.357E –03	1.927E –04	2.69E –08	0.000111	889
	%CV	126.15	12.58	58.31	8.20	13.47

Mix Type	Briq. # (A.V.)	Permanent Strain	Total Strain	Creep Slope	Intercept	Creep Stiffness
Stone Mix AC 30 (4.6%) with 1.5% Hydrated Lime	6 (4.3)	4.747E –04	1.227E –03	1.27E –08	0.001177	8150
	15 (4.2)	6.256E –04	1.332E –03	4.11E –08	0.001178	7508
	29 (3.5)	2.474E –04	9.091E –04	3.63E –08	0.000901	11000
	AVG (4.1)	4.492E –04	1.156E –03	3.00E –08	0.001085	8886
	STD	1.904E –04	2.202E –04	1.52E –08	0.000160	1859
	%CV	42.38	19.05	50.62	14.71	20.92

Mix Type	Briq. # (A.V.)	Permanent Strain	Total Strain	Creep Slope	Intercept	Creep Stiffness
Stone Mix PAC 40 HG (4.7%)	18 (3.8)	8.417E –04	1.485E –03	5.88E –08	0.001264	6734
	25 (3.9)	7.343E –04	1.257E –03	3.98E –08	0.000110	7955
	27 (4.1)	8.542E –04	1.534E –03	7.90E –08	0.001235	6502
	AVG (3.9)	8.101E –04	1.425E –03	5.92E –08	0.000870	7064
	STD	6.591E –04	1.478E –04	1.96E –08	0.000658	781
	%CV	8.14	10.37	33.11	75.65	11.05

Mix Type	Briq. # (A.V.)	Permanent Strain	Total Strain	Creep Slope	Intercept	Creep Stiffness
Stone Mix PAC 40 HG (4.6%) 1.5% Hydrated Lime	13 (3.5)	7.658E –04	1.601E –03	5.41E –08	0.001387	6246
	23 (4.4)	4.064E –04	1.014E –03	3.23E –08	0.000891	9862
	32 (4.2)	5.073E –04	1.061E –03	3.01E –08	0.000946	9425
	AVG (4.0)	5.598E –04	1.225E –03	3.88E –08	0.001075	8511
	STD	1.854E –04	3.262E –04	1.33E –08	0.000272	1974
	%CV	33.11	26.62	34.16	25.30	23.19

Table A22
Lime study: indirect tensile fatigue test results
Date: 3/28/96

Permanent Deformation

Mix Type	Briq. # (A.V.)	Slope	Intercept	Cycles To Failure
Stone Mix AC 30 (4.7%)	4 (3.9)	0.71	-10.54	27052
	10 (3.7)	0.66	-10.31	41051
	22 (3.6)	0.62	-10.40	67252
	AVG (3.7)	0.66	-10.42	45118
	STD	0.04	0.09	16662
	%CV	5.55	0.91	37

Mix Type	Briq. # (A.V.)	Slope	Intercept	Cycles To Failure
Stone Mix AC 30 (4.6%) with 1.5% Hydrated Lime	5 (4.1)	0.62	-10.52	63051
	28 (3.6)	0.52	-9.41	121451
	36 (4.3)	0.61	-10.00	48852
	AVG (4.0)	0.58	-9.89	77785
	STD	0.04	0.35	31416
	%CV	7.71	3.56	40

Mix Type	Briq. # (A.V.)	Slope	Intercept	Cycles To Failure
Stone Mix PAC-40 HG (4.7%)	3 (4.3)	0.55	-9.18	61052
	8 (4.1)	0.56	-9.35	63852
	28 (3.9)	0.57	-9.45	40052
	AVG (4.1)	0.56	-9.33	54985
	STD	0.01	0.11	10621
	%CV	1.46	1.20	19

Mix Type	Briq. # (A.V.)	Slope	Intercept	Cycles To Failure
Stone Mix PAC-40 HG (4.6%) 1.5% Hydrated Lime	28 (3.9)	0.42	-9.58	615619
	31 (4.5)	0.48	-10.11	654252
	34 (4.0)	0.52	-9.52	160451
	AVG (4.1)	0.47	-9.74	476774
	STD	0.04	0.27	224230
	%CV	8.68	2.72	47

APPENDIX B

Test Data for the Gravel Mixtures

Table B1
Lime study: indirect tensile strength test data
Date: 11/20/95

77°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Gravel Mix AC 30 (5.8%)	6 (3.8)	2.526	3.996	3278	2.39	0.05533	0.020345	1.06	206.7
	21 (4.1)	2.536	4.002	3339	2.29	0.05256	0.017472	0.91	209.4
	24 (4.5)	2.517	3.997	3616	2.09	0.04659	0.016418	0.85	228.8
	AVG. (4.1)	2.526	3.998	3411	2.26	0.05149	0.018078	0.94	215.0
	STD.	0.010	0.003	180	0.15	0.00447	0.002033	0.11	12.0
	%CV	0.38	0.08	5.28	6.77	8.67	11.24	11.24	5.60

104°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Gravel Mix AC 30 (5.8%)	23 (4.0)	2.524	3.998	660	1.70	0.04078	0.017544	0.91	41.6
	26 (3.7)	2.528	4.000	718	1.89	0.04631	0.021079	1.10	45.2
	30 (4.1)	2.534	4.002	657	1.79	0.04371	0.019751	1.03	41.2
	AVG. (3.9)	2.529	4.000	678	1.79	0304360	0.019458	1.01	42.7
	STD.	0.005	0.002	34	0.10	0.00277	0.001786	0.09	2.2
	%CV	0.20	0.05	5.07	5.30	6.35	9.18	9.18	5.11

Mix Type: Type of asphalt mixture used
A.V.: % Air Voids
Briq #: Asphalt briquette #
STD: Standard Deviation
%CV: Coefficient of Variation
Height: Thickness of the specimen, in inches
Diameter: Diameter of the specimen, in inches
Load: Load at failure of the specimen, in pounds
Time: Time taken for failure of the specimen, in seconds
Ver. Defm.: Average vertical deformation of specimen at failure, in inches
Hor. Defm.: Average horizontal deformation of specimen at failure, in inches
Ten. Stn. Tensile strain of the specimen at failure, in percent
I.T.S.: Horizontal tensile stress at center of specimen, in psi

Table B2
Lime study: indirect tensile strength test data
Date: 11/20/95

77°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Gravel Mix AC 30 (5.0%) 1.5% Hydrated Lime	11 (3.8)	2.507	4.000	3748	2.01	0.04310	0.012392	0.64	237.9
	27 (4.2)	2.505	4.002	4171	1.79	0.03734	0.011653	0.61	264.9
	40 (3.7)	2.510	4.007	4033	1.80	0.03712	0.011203	0.58	255.3
	AVG. (3.9)	2.507	4.003	3984	1.87	0.03919	0.011749	0.61	252.7
	STD.	0.003	0.004	216	0.12	0.00339	0.000600	0.03	13.7
	%CV	0.10	0.09	5.41	6.66	8.66	5.11	5.11	5.40

104°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Gravel Mix AC 30 (5.0%) 1.5% Hydrated Lime	33 (3.7)	2.513	4.003	748	1.89	0.04427	0.020128	1.05	47.3
	36 (3.6)	2.488	4.001	753	1.92	0.04637	0.020981	1.09	48.2
	38 (4.0)	2.473	3.997	763	1.61	0.03789	0.017467	0.91	49.1
	AVG. (3.8)	2.491	4.000	755	1.81	0.04284	0.019525	1.02	48.2
	STD.	0.020	0.003	8	0.17	0.00441	0.001833	0.10	0.9
	%CV	0.81	0.08	1.01	9.46	10.30	9.39	9.39	1.87

Mix Type: Type of asphalt mixture used
A.V.: % Air Voids
Briq #: Asphalt briquette #
STD: Standard Deviation
%CV: Coefficient of Variation
Height: Thickness of the specimen, in inches

Diameter: Diameter of the specimen, in inches
Load: Load at failure of the specimen, in pounds
Time: Time taken for failure of the specimen, in seconds
Ver. Defm.: Average vertical deformation of specimen at failure, in inches
Hor. Defm.: Average horizontal deformation of specimen at failure, in inches
Ten. Stn. Tensile strain of the specimen at failure, in percent
I.T.S.: Horizontal tensile stress at center of specimen, in psi

Table B3
Lime study: indirect tensile strength test data
Date: 11/20/95

77°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Gravel Mix PAC-40 HG (5.2%)	9 (4.1)	2.524	4.002	4321	2.79	0.06467	0.020552	1.07	272.3
	11 (4.4)	2.533	4.000	4317	2.49	0.05657	0.021565	1.12	271.2
	22 (3.7)	2.520	3.998	4302	2.79	0.06464	0.022722	1.18	271.8
	AVG. (4.1)	2.526	4.000	4313	2.69	0.06196	0.021613	1.12	271.8
	STD.	0.007	0.002	10	0.17	0.00467	0.001086	0.06	0.5
	%CV	0.26	0.05	0.23	6.44	7.54	5.02	5.02	0.20

104°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Gravel Mix PAC-40 HG (5.2%)	2 (3.8)	2.514	4.000	853	1.96	0.04374	0.021616	1.12	54.0
	6 (3.9)	2.506	3.998	899	2.10	0.05144	0.023554	1.22	57.1
	28 (4.2)	2.511	4.003	874	1.89	0.04589	0.021968	1.14	55.4
	AVG. (4.0)	2.510	4.000	875	1.98	0.04702	0.022379	1.16	55.5
	STD.	0.004	0.003	23	0.11	0.00397	0.001032	0.05	1.6
	%CV	0.16	0.06	2.63	5.39	8.45	4.61	4.61	2.82

Mix Type: Type of asphalt mixture used
A.V.: % Air Voids
Briq #: Asphalt briquette #
STD: Standard Deviation
%CV: Coefficient of Variation
Height: Thickness of the specimen, in inches

Diameter: Diameter of the specimen, in inches
Load: Load at failure of the specimen, in pounds
Time: Time taken for failure of the specimen, in seconds
Ver. Defm.: Average vertical deformation of specimen at failure, in inches
Hor. Defm.: Average horizontal deformation of specimen at failure, in inches
Ten. Stn. Tensile strain of the specimen at failure, in percent
I.T.S.: Horizontal tensile stress at center of specimen, in psi

Table B4
Lime study: indirect tensile strength test data
Date: 12/13/95

77°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Gravel Mix PAC-40 HG (5.2%) 1.5% Hydrated Lime	1 (3.9)	2.520	4.001	3947	2.30	0.05138	0.018919	0.98	249.2
	11 (3.7)	2.501	4.002	3964	2.41	0.05423	0.020505	1.07	252.1
	13 (4.5)	2.551	4.002	3843	2.29	0.05140	0.021585	1.12	239.6
	AVG. (4.0)	2.524	4.002	3918	2.33	0.05234	0.020336	1.06	247.0
	STD.	0.025	0.001	66	0.07	0.00164	0.001341	0.07	6.5
	%CV	1.00	0.01	1.67	2.85	3.13	6.59	6.59	2.65

104°F

Mix Type	Briq. # (A.V.)	Height	Diameter	Load	Time	Ver. Defm.	Hor. Defm.	Ten. Stn.	I.T.S.
Gravel Mix PAC-40 HG (5.2%) 1.5% Hydrated Lime	3 (3.5)	2.520	4.008	1106	2.09	0.05118	0.025513	1.33	69.7
	5 (4.2)	2.519	3.999	1203	2.29	0.05665	0.026727	1.39	76.0
	7 (4.1)	2.560	3.998	1069	1.89	0.04547	0.021342	1.11	66.5
	AVG. (4.0)	2.533	4.002	1126	2.09	0.05110	0.024527	1.28	70.7
	STD.	0.023	0.006	69	0.20	0.00559	0.002825	0.15	4.8
	%CV	0.92	0.14	6.15	9.57	10.94	11.52	11.52	6.86

Mix Type: Type of asphalt mixture used
A.V.: % Air Voids
Briq #: Asphalt briquette #
STD: Standard Deviation
%CV: Coefficient of Variation
Height: Thickness of the specimen, in inches

Diameter: Diameter of the specimen, in inches
Load: Load at failure of the specimen, in pounds
Time: Time taken for failure of the specimen, in seconds
Ver. Defm.: Average vertical deformation of specimen at failure, in inches
Hor. Defm.: Average horizontal deformation of specimen at failure, in inches
Ten. Stn. Tensile strain of the specimen at failure, in percent
I.T.S.: Horizontal tensile stress at center of specimen, in psi

Table B5
Lime study: indirect tensile creep test results
Date: 11/20/1995

77°F, CALCULATEDμ

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix AC 30 (5.8%)	16 (4.2)	65424	18831	10786	8265	-0.41	11.76
	20 (3.9)	46381	16639	10334	8191	-0.34	11.33
	34 (4.4)	66537	20943	12532	9715	-0.38	11.73
	AVG (4.2)	59447	18804	11217	8724	-0.38	11.61
	STD	9250	1757	948	702	0.03	0.20
	%CV	15.56	9.34	8.45	8.04	7.61	1.69

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix AC 30 (5.0%) 1.5% Hydrated Lime	1 (3.9)	98649	29299	18124	14750	-0.34	11.95
	3 (4.2)	86709	27254	16437	13260	-0.34	11.86
	23 (3.7)	81641	22759	13527	11014	-0.36	11.80
	AVG (3.9)	89000	26437	16029	13008	-0.35	11.87
	STD	7130	2732	1899	1536	0.01	0.06
	%CV	8.01	10.33	11.85	11.80	2.72	0.52

Table B6
Lime study: indirect tensile creep test results
Date: 11/20/1995

104°F, CALCULATEDμ

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix AC 30 (5.8%)	27 (3.9)	11393	-	-	-	-0.81	9.73
	33 (4.4)	19841	-	-	-	-0.77	10.11
	41 (3.9)	22028	-	-	-	-0.71	10.26
	AVG (4.1)	17754	0	0	0	-0.76	10.03
	STD	4586	0	0	0	0.04	0.22
	%CV	25.83	0.00	0.00	0.00	5.38	2.22

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix AC 30 (5.0%) 1.5% Hydrated Lime	25 (3.6)	18581	3848	-	-	-0.63	10.01
	31 (4.0)	18230	-	-	-	-0.70	10.10
	35 (3.7)	16655	-	-	-	-0.70	9.95
	AVG (3.8)	17822	3848	0	0	-0.68	10.02
	STD	838	0	0	0	0.03	0.06
	%CV	4.70	0.00	0.00	0.00	4.88	0.62

Table B7
Lime study: indirect tensile creep test results
Date: 11/20/1995

77°F, CALCULATEDμ

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix PAC-40 HG (5.2%)	5 (4.1)	49977	20174	13030	10518	-0.31	11.34
	20 (3.7)	44759	16068	10074	8058	-0.33	11.26
	34 (4.4)	54472	22264	14461	11868	-0.30	11.40
	AVG (4.1)	49736	19502	12522	10148	-0.31	11.33
	STD	3969	2574	1827	1577	0.01	0.06
	%CV	7.98	13.20	14.59	15.54	3.98	0.51

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix PAC-40 HG (5.2%) 1.5% Hydrated Lime	14 (3.7)	70685	22807	14211	12067	-0.31	11.56
	23 (4.5)	79052	27022	17702	14863	-0.29	11.66
	24 (3.9)	69347	21878	13845	11595	-0.32	11.56
	AVG (4.0)	73028	23902	15253	12842	-0.31	11.59
	STD	4294	2238	1738	1442	0.01	0.05
	%CV	5.88	9.36	11.40	11.23	4.07	0.41

Table B8
Lime study: indirect tensile creep test results
Date: 11/20/1995

104°F, CALCULATEDμ

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix PAC-40 HG (5.2%)	8 (3.8)	17393	3793	-	-	-0.43	10.48
	23 (3.9)	18816	4905	-	-	-0.43	10.57
	24 (4.3)	21096	-	-	-	-0.51	10.79
	AVG (4.0)	19102	4349	0	0	-0.46	10.61
	STD	1525	556	0	0	0.04	0.13
	%CV	7.98	0.00	0.00	0.00	8.26	1.23

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix PAC-40 HG (5.2%) 1.5% Hydrated Lime	8 (3.6)	21372	6678	-	-	-0.41	10.67
	12 (4.2)	22019	9078	5299	3727	-0.33	10.60
	15 (4.1)	19482	7366	3904	-	-0.34	10.46
	AVG (4.0)	20958	7707	4602	3727	-0.36	10.58
	STD	1076	1009	698	0	0.04	0.09
	%CV	5.14	13.09	15.16	0.00	9.89	0.83

Table B9
Lime study: indirect tensile creep test results
Date: 11/20/1995

77°F, ASSUMEDμ (0.35)

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix AC 30 (5.8%)	16 (4.2)	54087	11531	5797	3812	-0.57	11.95
	20 (3.9)	55711	13280	6643	4301	-0.55	11.95
	34 (4.4)	59796	13156	6593	4337	-0.54	11.95
	AVG (4.2)	56531	12656	6344	4150	-0.55	11.95
	STD	2402	797	388	239	0.01	0.00
	%CV	4.25	6.30	6.11	5.77	2.25	0.00

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix AC 30 (5.0%) 1.5% Hydrated Lime	1 (3.9)	74528	15827	8862	6744	-0.44	11.83
	3 (4.2)	83019	17401	8890	6550	-0.47	12.03
	23 (3.7)	67819	14147	7339	5407	-0.48	11.84
	AVG (3.9)	75122	15792	8364	6234	-0.46	11.90
	STD	6220	1329	725	590	0.02	0.09
	%CV	8.28	8.41	8.66	9.46	3.67	0.77

Table B10
Lime study: indirect tensile creep test results
Date: 11/20/1995

104°F, ASSUMEDμ (0.35)

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix AC 30 (5.8%)	27 (3.9)	4934	-	-	-	-0.81	9.73
	33 (4.4)	7331	-	-	-	-0.77	10.11
	41 (3.9)	9062	-	-	-	-0.71	10.26
	AVG (4.1)	7109	0	0	0	-0.76	10.03
	STD	1693	0	0	0	0.04	0.22
	%CV	23.81	0.00	0.00	0.00	5.38	2.22

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix AC 30 (5.0%) 1.5% Hydrated Lime	25 (3.6)	7714	702	-	-	-0.63	10.01
	31 (4.0)	7666	-	-	-	-0.70	10.10
	35 (3.7)	6812	-	-	-	-0.70	9.95
	AVG (3.8)	7397	702	0	0	-0.68	10.02
	STD	414	0	0	0	0.03	0.06
	%CV	5.60	0.00	0.00	0.00	4.88	0.62

Table B11
Lime study: indirect tensile creep test results
Date: 11/20/1995

77°F, ASSUMEDμ (0.35)

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix PAC-40 HG (5.2%)	5 (4.1)	53321	14915	7791	5387	-0.47	11.76
	20 (3.7)	38440	10612	5575	3862	-0.48	11.44
	34 (4.4)	45484	13566	7413	5397	-0.44	11.51
	AVG (4.1)	45748	13031	6926	4882	-0.46	11.57
	STD	6078	1797	968	721	0.02	0.14
	%CV	13.29	13.79	13.97	14.77	3.67	1.19

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix PAC-40 HG (5.2%) 1.5% Hydrated Lime	14 (3.7)	52930	14666	8899	7477	-0.34	11.31
	23 (4.5)	53025	15600	9804	7985	-0.34	11.33
	24 (3.9)	43331	11781	7276	5987	-0.35	11.13
	AVG (4.0)	49762	14016	8660	7150	-0.34	11.26
	STD	4548	1626	1046	848	0.00	0.09
	%CV	9.14	11.60	12.08	11.86	1.37	0.80

Table B12
Lime study: indirect tensile creep test results
Date: 11/20/1995

104°F, ASSUMEDμ (0.35)

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix PAC-40 HG (5.2%)	8 (3.8)	7110	743	-	-	-0.62	9.90
	23 (3.9)	8219	1193	-	-	-0.61	10.04
	24 (4.3)	8198	-	-	-	-0.71	10.17
	AVG (4.0)	7842	968	0	0	-0.65	10.04
	STD	518	225	0	0	0.04	0.11
	%CV	6.60	0.00	0.00	0.00	6.95	1.10

MIX TYPE	BRIQ. # (A.V.)	CREEP STIFFNESS (psi)				SLOPE	INTERCEPT
		5 SEC.	100 SEC.	500 SEC.	1000 SEC.		
Gravel Mix PAC-40 HG (5.2%) 1.5% Hydrated Lime	8 (3.6)	9772	2461	-	-	-0.58	10.26
	12 (4.2)	9921	3386	1529	548	-0.48	10.16
	15 (4.1)	9334	2911	1082	-	-0.51	10.11
	AVG (4.0)	9676	2919	1306	548	-0.52	10.18
	STD	249	378	224	0	0.04	0.06
	%CV	2.57	12.94	17.12	0.00	8.01	0.61

Table B13
Type 3, binder course (gravel mix, 5.8% AC 30)
Resilient modulus test data

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	987648	926074	0.231	0.200	1234697	1242646
39 (4.3)	951162	825633	0.235	0.257	1169351	973203
45 (4.0)	905678	801867	0.183	0.218	1240862	1020114
AVG (4.0)	948163	851191	0.216	0.225	1214970	1078654
STD	33531	53832	0.024	0.024	32356	117530
%CV	3.54	6.32	10.92	10.57	2.66	10.90

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	932793	887524	0.198	0.136	1246321	1394809
39 (4.3)	936877	819326	0.208	0.212	1216267	1054890
45 (4.0)	1074849	902663	0.202	0.214	1212618	1116138
AVG (4.0)	981506	869838	0.203	0.187	1225069	1188612
STD	66024	36248	0.004	0.036	15101	147932
%CV	6.73	4.17	2.03	19.38	1.23	12.45

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	659720	608493	0.331	0.310	775086	775295
39 (4.3)	825273	777660	0.244	0.209	913292	769324
45 (4.0)	603796	568346	0.232	0.258	746574	668511
AVG (4.0)	696263	651500	0.269	0.259	811651	737710
STD	94037	90702	0.044	0.041	72808	48992
%CV	13.51	13.92	16.40	15.92	8.97	6.64

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	715156	636846	0.310	0.305	789382	696000
39 (4.3)	801251	757716	0.319	0.301	987305	746769
45 (4.0)	626575	573166	0.228	0.254	779845	679008
AVG (4.0)	714327	655909	0.286	0.287	852177	707259
STD	71314	76539	0.041	0.023	95629	28786
%CV	9.98	11.67	14.33	8.08	11.22	4.07

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	401485	328584	0.409	0.440	366419	247316
39 (4.3)	411828	301783	0.552	0.692	310797	157629
45 (4.0)	378282	269219	0.553	0.657	284972	180662
AVG (4.0)	397188	299862	0.505	0.596	320729	195202
STD	14027	24274	0.068	0.111	33984	38031
%CV	3.53	8.09	13.40	18.69	10.60	19.48

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	410537	261614	0.352	0.414	409377	237307
39 (4.3)	450456	321004	0.601	0.551	320725	242394
45 (4.0)	392024	272882	0.583	0.680	285344	178310
AVG (4.0)	417672	285167	0.512	0.548	338482	219337
STD	24382	25755	0.113	0.109	52170	29085
%CV	5.84	9.03	22.14	19.81	15.41	13.26

Table B14
Type 3, binder course (gravel mix, 5.0% AC 30, 1.5% hydrated lime)
Resilient modulus test data

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	1051263	991457	0.294	0.247	1755409	1589979
19 (4.0)	960429	937925	0.057	0.077	1829512	1680895
37 (3.8)	1379865	1308862	0.225	0.234	1731889	1609595
AVG (3.9)	1130519	1079415	0.192	0.186	1772270	1626823
STD	180172	163709	0.100	0.077	41600	39064
%CV	15.94	15.17	51.84	41.54	2.35	2.40

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	1043411	982523	0.164	0.139	1661930	1508660
19 (4.0)	944600	925260	0.056	0.072	1801227	1678189
37 (3.8)	1451911	1364089	0.327	0.306	1510045	1483808
AVG (3.9)	1146641	1090624	0.182	0.172	167734	1556886
STD	219596	194777	0.111	0.098	118912	86372
%CV	19.15	17.86	61.09	57.10	7.17	5.55

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	820033	738918	0.224	0.269	1031928	851633
19 (4.0)	853378	760049	0.194	0.238	1144357	929961
37 (3.8)	1106191	931798	0.321	0.330	1162447	964798
AVG (3.9)	926534	810255	0.246	0.279	1112911	915464
STD	127764	86376	0.054	0.038	57738	47323
%CV	13.79	10.66	22.00	13.70	5.19	5.17

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	809880	734331	0.210	0.237	1049807	898889
19 (4.0)	831821	749066	0.197	0.248	1104834	908316
37 (3.8)	1121957	945577	0.349	0.371	1127007	915447
AVG (3.9)	921219	809658	0.252	0.285	1093883	907551
STD	142225	96297	0.069	0.061	32454	6781
%CV	15.44	11.89	27.30	21.29	2.97	0.75

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	463348	319693	0.526	0.513	360785	253112
19 (4.0)	500724	343624	0.367	0.501	487119	276185
37 (3.8)	507306	308017	0.609	0.646	357652	241856
AVG (3.9)	490459	323778	0.501	0.553	401852	257051
STD	19358	1481	0.100	0.066	60306	14289
%CV	3.95	4.58	20.05	11.87	15.01	5.56

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	436556	295054	0.560	0.680	326273	193651
19 (4.0)	521725	362997	0.487	0.521	301878	248973
37 (3.8)	554142	357408	0.686	0.667	359273	236412
AVG (3.9)	504141	338486	0.578	0.623	329141	226345
STD	49588	30796	0.082	0.072	23519	23880
%CV	9.84	9.10	14.23	11.58	7.15	10.46

Table B15
Type 3, binder course (gravel mix, 5.2% PAC-40 HG)
Resilient modulus test data

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	887383	821806	0.183	0.193	1215402	1103346
21 (3.8)	1093465	985795	0.212	0.204	1406312	1292489
30 (3.6)	1017869	934776	0.173	0.157	1427980	1358250
AVG (3.8)	999572	914126	0.189	0.185	1349898	1251362
STD	85122	68522	0.017	0.020	95514	108051
%CV	8.52	7.50	8.74	10.87	7.08	8.63

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	920248	850016	0.214	0.233	1180777	1050346
21 (3.8)	1134827	1031735	0.233	0.217	1399410	1318919
30 (3.6)	968176	892530	0.153	0.151	1421342	1318314
AVG (3.8)	1007750	924760	0.200	0.200	1333843	1229193
STD	91962	77608	0.034	0.035	108604	126464
%CV	9.13	8.39	17.06	17.72	8.14	10.29

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	749189	615701	0.321	0.318	786388	649333
21 (3.8)	784438	654860	0.324	0.266	840060	763920
30 (3.6)	801993	641062	0.334	0.394	823510	598721
AVG (3.8)	778540	637208	0.326	0.326	816653	670058
STD	21957	16217	0.006	0.053	22442	69107
%CV	2.82	2.55	1.70	16.12	2.75	10.30

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	766930	626080	0.311	0.344	818831	632609
21 (3.8)	756786	591242	0.252	0.238	901166	727193
30 (3.6)	762070	634644	0.261	0.256	909171	757072
AVG (3.8)	761929	617322	0.275	0.279	876389	705625
STD	4142	18770	0.026	0.046	40831	53051
%CV	0.54	3.04	9.45	16.58	4.66	7.52

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	388824	268458	0.592	0.665	280505	178107
21 (3.8)	344052	253506	0.591	0.704	247836	161307
30 (3.6)	294420	242594	0.344	0.432	298383	215058
AVG (3.8)	342432	254853	0.509	0.600	275575	184824
STD	38557	10602	0.117	0.120	20928	22452
%CV	11.26	4.16	22.92	20.00	7.59	12.15

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	398665	274508	0.592	0.675	377815	260512
21 (3.8)	359662	270066	0.547	0.640	286763	180176
30 (3.6)	369303	282917	0.425	0.404	333502	261796
AVG (3.8)	375877	275830	0.521	0.573	332693	234161
STD	16588	5329	0.071	0.120	37176	38177
%CV	4.41	1.93	13.53	21.00	11.17	16.30

Table B16
Type 3, binder course (gravel mix, 5.2% PAC-40 HG, 1.5% hydrated lime)
Resilient modulus test data

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	985918	907895	0.159	0.182	1426679	1249992
26 (4.1)	1204639	1092016	0.244	0.209	1048131	1000465
32 (3.9)	1090424	968286	0.169	0.145	1540903	1449620
AVG (4.0)	1093660	989399	0.191	0.179	1338571	1233359
STD	89322	76635	0.038	0.026	210600	183744
%CV	8.17	7.75	19.89	14.68	15.73	14.90

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	974692	903523	0.160	0.184	1406604	1236892
26 (4.1)	1091758	1019873	0.269	0.245	1491756	1414162
32 (3.9)	1132272	993524	0.222	0.184	1434608	1358158
AVG (4.0)	1066241	972307	0.217	0.204	1444323	1336404
STD	66814	49813	0.045	0.029	35435	73987
%CV	6.27	5.12	20.57	14.07	2.45	5.54

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	986841	781418	0.294	0.338	1085826	797434
26 (4.1)	1102848	869526	0.314	0.238	1132219	957799
32 (3.9)	950398	757473	0.356	0.429	944877	676789
AVG (4.0)	1013362	802806	0.321	0.335	1054307	810674
STD	65001	48181	0.026	0.078	79663	115103
%CV	6.41	6.00	8.04	23.28	7.56	14.20

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	994683	795861	0.326	0.383	1035089	755082
26 (4.1)	1032349	793973	0.311	0.335	1193141	850010
32 (3.9)	1052301	860761	0.342	0.365	1097368	799769
AVG (4.0)	1026444	816865	0.326	0.361	1108533	801620
STD	23890	31049	0.013	0.020	65006	38776
%CV	2.33	3.80	3.88	5.48	5.86	4.84

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	514454	335386	0.574	0.606	386137	241856
26 (4.1)	491322	370887	0.414	0.500	445652	298521
32 (3.9)	630159	406673	0.633	0.696	433260	261557
AVG (4.0)	545312	870982	0.540	0.601	421683	267311
STD	60735	29103	0.093	0.080	25639	23489
%CV	11.14	7.84	17.12	13.34	6.08	8.79

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	493537	346681	0.636	0.601	338315	246737
26 (4.1)	537773	344615	0.509	0.532	428155	266468
32 (3.9)	606346	387363	0.551	0.636	460018	265293
AVG (4.0)	545885	359553	0.565	0.590	408829	259499
STD	46410	19683	0.053	0.043	51530	9037
%CV	8.50	5.47	9.34	7.33	12.60	3.48

Table B17
Type 3, binder course (gravel mix, 5.8% AC 30)
Resilient modulus test data (in Mpa)

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	6811	6387	0.231	0.200	8515	8570
39 (4.3)	6560	5694	0.235	0.257	8064	6712
45 (4.0)	6246	5530	0.183	0.218	8558	7035
AVG (4.0)	6539	5870	0.216	0.225	8379	7439
STD	231	371	0.024	0.024	223	811
%CV	3.53	6.33	10.92	10.57	2.67	10.90

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	6433	6121	0.198	0.136	8595	9619
39 (4.3)	6461	5651	0.208	0.212	8388	7275
45 (4.0)	7413	6225	0.202	0.214	8363	7698
AVG (4.0)	6769	5999	0.203	0.187	8449	8197
STD	456	250	0.004	0.036	104	1020
%CV	6.73	4.16	2.03	19.38	1.23	12.44

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	4550	4197	0.331	0.310	5345	5347
39 (4.3)	5692	5363	0.244	0.209	6299	5306
45 (4.0)	4164	3920	0.232	0.258	5149	4610
AVG (4.0)	4802	4493	0.269	0.259	5598	5088
STD	649	625	0.044	0.041	502	338
%CV	13.51	13.92	16.40	15.92	8.97	6.65

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	4932	4392	0.310	0.305	5444	4800
39 (4.3)	5526	5226	0.319	0.301	6809	5150
45 (4.0)	4321	3953	0.228	0.254	5378	4683
AVG (4.0)	4926	4524	0.286	0.287	5877	4878
STD	492	528	0.041	0.023	660	198
%CV	9.99	11.67	14.33	8.08	11.22	4.07

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	2769	1952	0.409	0.440	2527	1706
39 (4.3)	2840	1687	0.552	0.692	2143	1087
45 (4.0)	2609	1857	0.553	0.657	1965	1246
AVG (4.0)	2739	1832	0.505	0.596	2212	1346
STD	87	110	0.068	0.111	235	262
%CV	3.53	5.98	13.40	18.69	10.60	19.50

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
10 (3.7)	2831	1804	0.352	0.414	2823	1637
39 (4.3)	3107	2214	0.601	0.551	2212	1672
45 (4.0)	2704	1882	0.583	0.680	1968	1230
AVG (4.0)	2881	1967	0.512	0.548	2334	1513
STD	168	178	0.113	0.109	360	201
%CV	5.84	9.04	22.14	19.81	15.41	13.26

Table B18
Type 3, binder course (gravel mix, 5.0% AC 30, 1.5% hydrated lime) Resilient modulus test data (in Mpa)

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	7250	6838	0.294	0.247	12103	10965
19 (4.0)	6624	6468	0.057	0.077	12617	11592
37 (3.8)	9516	9027	0.225	0.234	11944	11101
AVG (3.9)	7797	7444	0.192	0.186	12221	11219
STD	1242	1129	0.100	0.077	287	269
%CV	15.93	15.17	51.84	41.54	2.35	2.40

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	7196	6776	0.164	0.139	11462	10405
19 (4.0)	6514	6381	0.056	0.072	12422	11574
37 (3.8)	10013	9408	0.327	0.306	10414	10233
AVG (3.9)	7908	7522	0.182	0.172	11433	10737
STD	1515	1344	0.111	0.098	820	596
%CV	19.15	17.86	61.09	57.10	7.17	5.55

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	5655	5096	0.224	0.269	7117	5873
19 (4.0)	5885	5242	0.194	0.238	7842	6414
37 (3.8)	7629	6426	0.321	0.330	8017	6654
AVG (3.9)	6390	5588	0.246	0.279	7659	6314
STD	881	596	0.054	0.038	390	327
%CV	13.79	10.66	22.00	13.70	5.09	5.17

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	5585	5064	0.210	0.237	7240	6199
19 (4.0)	5737	5166	0.197	0.248	7620	6264
37 (3.8)	7738	6512	0.349	0.371	7772	6313
AVG (3.9)	6353	5581	0.252	0.285	7544	6259
STD	981	660	0.069	0.061	224	47
%CV	15.44	11.82	27.30	21.29	2.97	0.75

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	3196	2205	0.526	0.513	2488	1746
19 (4.0)	3453	2370	0.367	0.501	3359	1905
37 (3.8)	3499	2124	0.609	0.646	2467	1668
AVG (3.9)	3383	2233	0.501	0.553	2771	1773
STD	133	102	0.100	0.066	416	99
%CV	9.94	4.58	20.05	11.87	15.00	5.56

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
18 (3.9)	3011	2035	0.560	0.680	2250	1336
19 (4.0)	3598	2503	0.487	0.521	2082	1717
37 (3.8)	9822	2465	0.686	0.667	2478	1630
AVG (3.9)	3477	2334	0.578	0.623	2270	1561
STD	342	212	0.082	0.072	162	163
%CV	9.84	9.09	14.23	11.58	7.15	10.44

Table B19
Type 3, binder course (gravel mix, 5.2% PAC-40 HG)
Resilient modulus test data (in Mpa)

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	6120	5668	0.183	0.193	8382	7609
21 (3.8)	7541	6799	0.212	0.204	9699	8914
30 (3.6)	7020	6447	0.173	0.157	9848	9367
AVG (3.8)	6894	6305	0.189	0.185	9310	8630
STD	587	473	0.017	0.020	659	745
%CV	8.51	7.50	8.74	10.87	7.08	8.64

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	6347	5862	0.214	0.233	8143	7244
21 (3.8)	7826	7115	0.233	0.217	9651	9096
30 (3.6)	6677	6155	0.153	0.151	9802	9092
AVG (3.8)	6950	6377	0.200	0.200	9199	8477
STD	634	535	0.034	0.035	749	872
%CV	9.12	8.39	17.06	17.72	8.14	10.29

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	5167	4246	0.321	0.318	5423	4478
21 (3.8)	5410	4516	0.324	0.266	5794	5268
30 (3.6)	5531	4421	0.334	0.394	5679	4129
AVG (3.8)	5369	4394	0.326	0.326	5632	4625
STD	151	112	0.006	0.053	155	476
%CV	2.82	2.54	1.70	16.12	2.75	10.30

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	5189	4318	0.311	0.344	5647	4363
21 (3.8)	5219	4078	0.252	0.238	6215	5015
30 (3.6)	5256	4377	0.261	0.256	6270	5221
AVG (3.8)	5221	4258	0.275	0.279	6044	4866
STD	27	129	0.026	0.046	282	366
%CV	0.52	3.04	9.45	16.58	4.66	7.52

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	2682	1851	0.592	0.665	1935	1228
21 (3.8)	2373	1748	0.591	0.704	1709	1112
30 (3.6)	2030	1673	0.344	0.432	2058	1483
AVG (3.8)	2362	1757	0.509	0.600	1901	1274
STD	266	73	0.117	0.120	145	155
%CV	11.28	4.15	22.92	20.00	7.60	12.16

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
7 (4.0)	2749	1893	0.592	0.675	2606	1797
21 (3.8)	2480	1863	0.547	0.640	1978	1243
30 (3.6)	2547	1951	0.425	0.404	2300	1805
AVG (3.8)	2592	1902	0.521	0.573	2295	1615
STD	114	37	0.071	0.120	256	263
%CV	4.41	1.92	13.53	21.00	11.17	16.29

Table B20
Type 3, binder course (gravel mix, 5.2% PAC-40 HG, 1.5% hydrated lime)
Resilient modulus test data (in Mpa)

0 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	6799	6261	0.159	0.182	9839	8621
26 (4.1)	8308	7531	0.244	0.209	7228	6900
32 (3.9)	7520	6678	0.169	0.145	10627	9997
AVG (4.0)	7542	6823	0.191	0.179	9231	8506
STD	616	529	0.038	0.026	1453	1267
%CV	8.17	7.75	19.89	14.68	15.74	14.89

45 Degrees

40°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	6722	6231	0.160	0.184	9701	8530
26 (4.1)	7529	7034	0.269	0.245	10288	9753
32 (3.9)	7809	6852	0.222	0.184	9894	9367
AVG (4.0)	7353	6706	0.217	0.204	9961	9217
STD	461	344	0.045	0.029	244	510
%CV	6.27	5.13	20.57	14.07	2.45	5.54

0 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	6806	5389	0.294	0.338	7488	5500
26 (4.1)	7606	5997	0.314	0.238	7808	6606
32 (3.9)	6554	5224	0.356	0.429	6516	4668
AVG (4.0)	6989	5537	0.321	0.335	7271	5591
STD	448	332	0.026	0.078	549	794
%CV	6.42	6.00	8.04	23.28	7.56	14.20

45 Degrees

77°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	6860	5476	0.326	0.383	7139	5207
26 (4.1)	7120	5489	0.311	0.335	8229	5862
32 (3.9)	7257	5936	0.342	0.365	7568	5516
AVG (4.0)	7079	5634	0.326	0.361	7645	5528
STD	165	214	0.013	0.020	448	268
%CV	2.33	3.80	3.88	5.48	5.86	4.84

0 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	3548	2313	0.574	0.606	2663	1688
26 (4.1)	3388	2558	0.414	0.500	3073	2059
32 (3.9)	4346	2805	0.633	0.696	2988	1804
AVG (4.0)	3761	2559	0.540	0.601	2908	1844
STD	419	201	0.093	0.080	177	162
%CV	11.14	7.85	17.12	13.34	6.08	8.79

45 Degrees

104°F ASSUMEDμ = 0.35

Bq # (A.V.)	MRI	MRT	MUI	MUT	MUMRI	MUMRT
20 (4.1)	3404	2391	0.636	0.601	2333	1702
26 (4.1)	3709	2377	0.509	0.532	2953	1838
32 (3.9)	4182	2671	0.551	0.636	3173	1830
AVG (4.0)	3765	2480	0.565	0.590	2820	1790
STD	320	135	0.053	0.043	356	62
%CV	8.50	5.46	9.34	7.33	12.61	3.48

Table B21
Lime study: uniaxial creep analysis test results
Date: 12/14/95

104°F

Mix Type	Briq. # (A.V.)	Permanent Strain	Total Strain	Creep Slope	Intercept	Creep Stiffness
Gravel Mix AC 30 (5.8%)	11 (3.8)	4.404E –04	1.080E –03	4.51E –08	0.000898	9259
	14 (4.5)	4.209E –04	1.085E –03	4.78E –08	0.000900	9217
	25 (4.0)	5.294E –04	1.398E –03	4.57E –08	0.001224	7153
	AVG (4.1)	4.636E –04	1.188E –03	4.62E –08	0.001007	8543
	STD	5.784E –05	1.822E –04	1.42E –09	0.000188	1204
	%CV	12.48	15.34	3.07	18.63	14.09

Mix Type	Briq. # (A.V.)	Permanent Strain	Total Strain	Creep Slope	Intercept	Creep Stiffness
Gravel Mix AC 30 (5.0%) with 1.5% Hydrated Lime	13 (3.7)	7.110E –04	1.517E –03	8.47E –08	0.001191	6592
	22 (3.6)	3.092E –04	1.136E –03	3.49E –08	0.001002	8803
	41 (4.1)	7.633E –04	1.372E –03	6.08E –08	0.001132	7289
	AVG (3.8)	5.945E –04	1.342E –03	6.01E –08	0.001108	7561
	STD	2.485E –04	1.923E –04	2.49E –08	0.000097	1130
	%CV	41.79	14.33	41.42	8.72	14.95

Mix Type	Briq. # (A.V.)	Permanent Strain	Total Strain	Creep Slope	Intercept	Creep Stiffness
Gravel Mix PAC 40 HG (5.2%)	4 (4.4)	3.751E –04	1.111E –03	4.39E –08	0.001012	9009
	18 (4.1)	4.018E –04	1.043E –03	4.51E –08	0.000870	9588
	25 (3.8)	4.443E –04	1.109E –03	5.03E –08	0.000921	9174
	AVG (4.1)	4.071E –04	1.088E –03	4.64E –08	0.000934	9257
	STD	3.490E –05	3.870E –05	3.40E –09	0.000072	298
	%CV	8.57	3.56	7.33	7.70	3.22

Mix Type	Briq. # (A.V.)	Permanent Strain	Total Strain	Creep Slope	Intercept	Creep Stiffness
Gravel Mix PAC 40 HG (5.2%) 1.5% Hydrated Lime	6 (4.2)	1.041E –03	1.742E –03	1.07E –07	0.001321	5741
	17 (4.1)	8.747E –04	1.638E –03	8.54E –08	0.001308	6105
	18 (3.6)	1.034E –03	1.778E –03	9.97E –08	0.001405	5624
	AVG (4.0)	9.832E –04	1.719E –03	9.74E –08	0.001345	5823
	STD	9.406E –05	7.270E –05	1.04E –08	0.000053	251
	%CV	9.57	4.23	11.28	3.92	4.31

Table B22
Lime study: indirect tensile fatigue test results
Date: 4/17/1996

Permanent Deformation

Mix Type	Briq. # (A.V.)	Slope	Intercept	Cycles To Failure
Gravel Mix AC 30 (5.8%)	8 (3.7)	0.54	-9.79	301451
	31 (4.4)	0.76	-12.14	135052
	46 (4.0)	0.67	-10.62	84452
	AVG (4.0)	0.66	-10.85	173652
	STD	0.09	0.97	92699
	%CV	13.75	8.97	53

Mix Type	Briq. # (A.V.)	Slope	Intercept	Cycles To Failure
Gravel Mix AC 30 (5.0%) with 1.5% Hydrated Lime	2 (4.2)	0.57	-10.15	262252
	10 (3.6)	0.65	-9.68	43051
	42 (3.8)	0.54	-10.04	676252
	AVG (3.9)	0.59	-9.96	327185
	STD	0.05	0.20	262549
	%CV	7.91	2.02	80

Mix Type	Briq. # (A.V.)	Slope	Intercept	Cycles To Failure
Gravel Mix PAC-40 HG (5.2%)	13 (4.1)	0.57	-10.26	263651
	26 (3.8)	0.53	-9.28	160651
	29 (4.4)	0.55	-9.75	190252
	AVG (4.1)	0.55	-9.76	204851
	STD	0.02	0.40	43298
	%CV	2.97	4.10	21

Mix Type	Briq. # (A.V.)	Slope	Intercept	Cycles To Failure
Gravel Mix PAC-40 HG (5.2%) 1.5% Hydrated Lime	22 (4.0)	0.43	-9.03	1598052
	25 (4.1)	0.55	-9.82	399051
	29 (4.2)	0.42	-9.39	2547854
	AVG (4.1)	0.47	-9.41	1514986
	STD	0.06	0.32	879209
	%CV	12.66	3.43	58