EVALUATING MOISTURE SUSCEPTIBILITY OF ASPHALT MIXES

Elizabeth Rae Hunter and Khaled Ksaibati
Department Civil and Architectural Engineering
University of Wyoming
P.O. Box 3295
Laramie, WY 82071-3295

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Abstract

This research project utilized laboratory evaluations to study effects of freeze-thaw cycling on the tensile strength of eight Hot Mix Asphalt mixtures and to determine if the Georgia Loaded Wheel Tester could be utilized to measure moisture susceptibility of Hot Mix Asphalt mixtures. The evaluation involved eight Hot Mix Asphalt Mixtures from combinations of two aggregate types and four asphalt-additive-aging possibilities. Laboratory testing was accomplished in the first phase with the production of 2.5 by 4 inch cores that were freeze-thaw cycled and tested for their indirect tensile strength following Wyoming modified AASHTO T283. The second phase was accomplished using 3 by 6 inch cores that were conditioned and tested for rutting using the Georgia Loaded Wheel Tester. Finally, a statistical analysis was performed to determine if performance of the various mixtures was significantly different in groups of asphalt types and to determine if the Georgia Loaded Wheel Tester was a viable measurement tool for moisture susceptibility.

Elizabeth R. Hunter and Dr. Khaled Ksaibati
University of Wyoming
Laramie, Wyoming

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CHAPTER 1

INTRODUCTION

Background

Moisture damage of asphalt cement pavement is a problem that more than one-half of the State Highway agencies are experiencing [Lottman, White, Frith 1988]. This damage is known commonly as stripping. The dominant failure mode is separation of the asphalt coating from the aggregate. An alternate mode gaining acceptance is the loss of cohesion of the asphalt cement [Parker and Gharaybeh 1988]. The most serious consequence of stripping is loss of strength and integrity of the pavement. Stripping can take many surface forms during its progression. However, stripping in a particular area may be quite severe before any surface indicators are evident. Surface indicators may include rutting, shoving, and/or cracking.

Many test methods have been developed and applied in the past to predict moisture susceptibility of asphalt mixes. The developed tests can be classified into two categories: qualitative tests and quantitative strength tests. The Boiling Water Test (ASTM D3625) and Static-Immersion Test (AASHTO T182) are qualitative tests, while the Lottman Test (NCHRP 246), Tunnicliff and Root Conditioning (NCHRP 274), Modified Lottman Test (AASHTO T283), Texas Freeze-Thaw Pedestal Test, and Immersion-Compression Test (AASHTO T165) are quantitative strength tests [Roberts, Kandhal, Brown, Lee, Kennedy 1996]. The strength tests allow numerical comparisons to be made between HMA mixtures.

Problem Statement

The problems addressed in this research are two-fold. In many of the methods developed for moisture susceptibility testing, freeze-thaw cycling is performed in some form on the cores. In most cases freeze-thaw cycling of the cores is limited to one cycle. The effects of many freeze-thaw cycles on mechanical properties and strength of the Hot Mix Asphalt (HMA) mixtures are not well known.

The Georgia Loaded Wheel Tester (GLWT) was developed to predict rutting potential of HMA mixtures. In comparison to other loaded wheel testers, such as the Hamburg Wheel Tracking Device, the GLWT is inexpensive at $11,000. The Hamburg Wheel Tracking Device is capable of measuring the rutting and moisture susceptibility of a HMA mix. The ability of the GLWT to predict moisture damage has yet to be studied.

Objective of Research

The principle objectives of this research are to:

1. investigate moisture susceptibility of asphalt mixes,
2. evaluate the effect of various numbers of freeze-thaw cycles on the mechanical properties of asphalt, and
3. determine if the Georgia Loaded Wheel Tester can be used to test for moisture induced damage.

Thesis Organization

Chapter 2 of this report is a literature review of moisture susceptibility, stripping, existing techniques for limiting moisture effects, testing methods for moisture susceptibility, and the GLWT. Chapter 3 discusses the design of this experiment and explains the procedures used. The data collected throughout this research project is discussed in chapter 4 and can be found in Appendix B through Appendix E. Chapter 5 describes analysis of the laboratory test results. Chapter 6 presents conclusions from this research and recommendations for further research.

CHAPTER 2

LITERATURE REVIEW

Introduction

The moisture effect on physical properties and mechanical behavior of asphalt paving mixtures has been known for many years. Numerous empirical or semi-empirical test methods, such as the Lottman Laboratory Test, Tunnicliff and Root Test, Boiling Water Test, and Hamburg Wheel Tracing Device, have been developed to predict moisture damage on asphalt mixtures. These test methods attempted to simulate the moisture damage that would occur in the field.

Parker and Gharaybeh [1988] evaluated testing procedures for their ability to asses stripping potential. Tensile strength ratios (TSR) were used to measure the stripping potential of various Hot Mix Asphalt (HMA) mixtures. Limiting Tensile Strength Ratio (TSR) values of 0.7 and 0.8 were used simultaneously for comparison. The conclusion from Parker and Gharaybeh's research was that Indirect Tensile Test did not distinctly differentiate stripping and non-stripping aggregate combinations. The supported reason for this was that the reported stripping performance of an aggregate might not be valid for all mixture types. Parker and Gharaybeh felt that TSR values were perhaps a valid indicator of stripping performance.

Coplantz and Newcomb [1988] conducted moisture sensitivity tests on field prepared mixtures. Coplantz and Newcomb's goal was to compare the methods used. The testing method varied conditioning of the samples. The conditionings that were used include the following:

1. saturating the samples;
2. saturating, then performing one freeze-thaw cycle;
3. saturating, then performing multiple freeze-thaw cycles.

Resilient modulus and indirect tensile strength values were used to make a comparison. Coplantz and Newcomb found that vacuum saturation without freeze-thaw cycling is not severe enough to damage the mixtures. Also, as the number of freeze-thaw cycles was increased, the amount of water-induced damage to the cores increased.

This chapter will discuss the effects moisture has on HMA mixtures and some of the methods used to control the amount of moisture damage. Testing procedures commonly used in the past will be discussed, as well as accepted uses for the Georgia Loaded Wheel Tester (GLWT).

Moisture Susceptibility

Moisture susceptibility is an HMA mixture's tendency toward stripping [Construction of Hot Mix Asphalt Pavements 1998, Roberts et al. 1996]. Stripping is the loss of bond between the asphalt and aggregate. To combat moisture susceptibility, proper mix design is essential. However, if a mix is properly designed, but not compacted correctly, it still may be susceptible to moisture damage. Therefore, an HMA design should be tested in a situation where moisture does infiltrate air voids of the mixture. For this reason many tests are performed at 7 percent air voids.[Roberts et al. 1996] The final step in the Superpave mix design procedure is an evaluation of the moisture sensitivity of a mix. AASHTO T-283 is used and will be discussed in more detail in chapter III. A TSR value of less than 80 percent is considered to be moisture susceptible. In other cases 70 percent is used [Parker and Gharaybeh 1987].

Stripping

Loss of the integrity of a HMA mix through weakening of the bond between the aggregate and asphalt cement is known as stripping. When a weakening in the bond occurs, loss of strength of the HMA can be sudden. Stripping usually begins in the bottom of the HMA layer, then travels upward. A typical situation is a gradual loss of strength over a period of years, which causes rutting and shoving to develop in the wheel path. Many times, stripping is difficult to identify because surface indicators may take years to show. Also, many surface indicators are possible and may include: rutting, shoving, corrugations, raveling, and cracking. It is necessary to look at the cross-section of the HMA mix to identify stripping.

In some cases of stripping, a HMA mix has lost so much adhesion between the aggregate and asphalt that a core cannot be removed in one piece. [Kennedy, McGennis, and Roberts 1983; Roberts et al. 1996].

There are many possible causes of stripping and inadequate surface drainage or sub-surface drainage is a primary contributor. There are many ways in which moisture can enter the HMA pavement layers: capillary action from the water table, run off from the road surface, and seepage from surrounding areas are a few examples. If adequate drainage is not present, air voids in the HMA may become saturated with moisture, thereby increasing pressure and weakening the bond. [Roberts et al. 1996]

Most mix designs specify an air void content of 3 to 5 percent. When the air void content is below 5 percent, HMA materials have been shown to be almost impervious to water. During construction, compaction control is not always good and high air void contents are a result. If an air void content is above 8 percent, water can readily seep into the material. Excessive dust coating on an aggregate can inhibit coating by asphalt and provide channels for water to penetrate. Other contributing factors to stripping may include the use of open-graded asphalt friction; coarse, inadequate drying of aggregate; weak aggregate; overlays on deteriorated concrete pavements; waterproofing membranes; and seal coats [Roberts et al. 1996].

Techniques for Limiting Moisture Susceptibility

When subject to moisture, water-sensitive pavements may suffer accelerated damage leading to a reduced pavement life. If asphalt pavement does suffer from water sensitivity, serious distresses may occur. As a result, the asphalt pavement reduces in performance and increases in maintenance costs. To alleviate or control this problem, various liquid or solid anti-stripping additives have been developed, which can be used to promote adhesion between asphalt and aggregate. Anderson and Dukatz [1982] reviewed the effects of commercially available anti-stripping additives on the physical properties of asphalt cement. Anderson and Dukatz's experimental studies of the physical and compositional properties of asphalt cement with anti-stripping additives demonstrated that anti-stripping additives tend to soften asphalt, reduce temperature susceptibility, and improve the aging characteristics of asphalt cement. Also, Anderson and Dukatz stated that the effect of an anti-stripping additive is asphalt specific.

Anti-Stripping Agents

Anti-stripping agents may be necessary if a particular mix design has been shown to be susceptible to moisture-induced damage. Liquid anti-stripping agents and lime additives are among the most commonly used types of anti-stripping agents. However, if an additive is used when it is not needed or if it is used incorrectly, adverse affects may occur, including an increased economic cost and early maintenance and/or rehabilitation [Tunnicliff and Root 1984].

Liquid Anti-Stripping Agents

Liquid anti-stripping agents are chemical compounds that contain amines. Most anti-stripping agents reduce surface tension between the asphalt and aggregate in a mixture [Tunnicliff et al. 1984]. When surface tension is reduced, increased adhesion of the asphalt to the aggregate is promoted. Thus, most liquid anti-stripping agents are surface-active agents [Roberts et al. 1996].

An economical method of mixing the liquid anti-stripping agent with the asphalt is by heating the asphalt to a liquid state. However, a more successful method of adding the additive is to apply it directly to the aggregate prior to the addition of the binder [Kennedy, Roberts, Lee 1983]. It is important that the liquid anti-stripping agent is heat stable. The liquid asphalt commonly is mixed with the liquid anti-stripping agent prior to adding aggregate to the mix [Roberts et al. 1996].

Lime Additives

The anti-stripping mechanism of lime additives is not well understood. However, lime additives are an accepted method of minimizing moisture susceptibility of a mix. The general practice is to add 1 to 1.5 percent lime by dry weight of aggregate to the mix. If an aggregate has more fines present, it may be necessary to use more lime additive due to the increased surface area of the aggregate. Three forms of lime are used: hydrated lime ($Ca(OH)^2$), quick lime (CaO), and Dolomitic limes (both types S and N) [Roberts et al. 1996].

Several methods exist for adding lime to mixtures. Dry hydrated lime is added prior to the asphalt cement. Georgia DOT adds the dry hydrated lime immediately before the asphalt cement is added [Roberts et al. 1996]. However, there is a problem maintaining the coverage until the asphalt cement is added. Using hydrated lime slurry will increase the amount of water needed and the fuel costs of production. Adding dry hydrated lime to wet aggregate has the same results as hydrated lime slurry. Hot (quicklime) slurry is equivalent in cost to hydrated lime, but when slaked, there is a 25 percent higher hydrated lime yield. Also, the elevated temperature during slaking helps to evaporate some of the added moisture [Roberts et. al 1996].

To evaluate the properties of bituminous mixtures containing hydrated lime, Mohammad, Abadie, Gokmen and Puppala [2000] studied TSR values, rutting and resilient modulus. Mohammad, Abadie, Gokmen and Puppala found that if the hydrated lime was added as a mineral filler, the permanent deformation and fatigue endurance improved. Also, test results illustrated that adding lime increased the tensile strength of HMA mixtures. Field and laboratory testing conducted by Kennedy and Anagnos [A Field Evaluation of Techniques for Treating Asphalt Mixtures with Lime 1984] found that dry lime and lime slurry improved moisture resistance. However, lime slurry had a better performance than dry lime. Adding the lime in a drum mix plant was ineffective because much of the lime was lost before mixing with the asphalt. Washing the aggregate before it was used, reduced the moisture resistance of mixture.

Aggregate Pre-Treatment

Different pre-treatments have been shown to improve the adhesion between asphalt and aggregate. Examples of pretreatment include: preheating to evaporate water vapor, weathering, washing to remove surface coatings, and crushing. It also has been shown that aggregates pre-coated with asphalt or recycled materials are better at resisting moisture damage than are virgin materials [Kennedy, Roberts, Lee 1983]. However, an alternate solution that works well is to avoid using rhyolite and siliceous material [Construction, 1998].

Testing Methods for Moisture Susceptibility

Existing methods that test for moisture susceptibility of asphalt mixes include: Boiling Water Test, Texas Boiling Water Test, Static Immersion Test, Lottman Test, Tunnicliff and Root Conditioning, Modified Lottman Test, Immersion Compression Test, Hamburg Wheel Tracking Device, and Texas Freeze-Thaw Pedestal Test. The following section describes each of these methods in detail.

Boiling Water Test

The Boiling Water Test (ASTM D3625) is a subjective test for the effects that moisture has on a particular HMA mix. It is used primarily as an initia l screening test of a HMA mix. However, some agencies use the Boiling Water Test to identify the presence of the anti-stripping agent during production. In this capacity, the boiling water test serves as a measurement of quality control. [Roberts et al. 1996]

For the Boiling Water Test, loose HMA mix is added to boiling water. The mix is allowed to remain in the boiling water for 10 minutes. Moisture damage is measured by observing the loose HMA in the water. The percentage of the total visible area of the aggregate that retained its original coating of asphalt cement is rated as either above or below 95 percent. It is difficult to determine the amount of stripping that occurs of fine aggregate because fine aggregates are difficult to see. This testing method tends to work better when using liquid anti-stripping agents [Roberts et al. 1996].

Yoon and Tarrer [1988] investigated the measurable relationship of aggregate properties to the stripping propensity of a mix of aggregate and asphalt cement. Yoon and Tarrer used the Boiling Water Test in their experimental design. By conducting the Boiling Water Test using different pH levels, Yoon and Tarrer determined that effectiveness of some additives is sensitive to the pH of water that has been in contact with the aggregate surface. Yoon and Tarrer found that there was no relationship between physical properties, such as pore volume and surface area, of an aggregate and the stripping propensity of that aggregate. However, chemical and electrochemical properties affected stripping propensity of the aggregate.

Texas Boiling Water Test

The Texas Boiling Water Test (TBWT) is a visual rating of the extent of stripping after the mixture is boiled. Asphalt cement is heated at 325°F (103°C) for 24 hours to 26 hours. One hundred grams or 300 grams of unwashed aggregate is heated at the same temperature for 1 to 1.5 hours. The aggregate and asphalt are mixed and are allowed to cool for two hours. A 1,000 ml beaker is filled half-way with distilled water and boiled. The mixture is placed in boiling water for 10 minutes. Asphalt cement that is floating is skimmed off the top. The water is cooled to room temperature and then poured off. The mixture is emptied onto a paper towel and graded. A three-person panel grades the mixture at that time and again the next day, once the mixture has had the opportunity to dry. A mixture that retains 65 percent to 75 percent of the asphalt cement is favorable for use in the field [Kennedy , Roberts, Lee 1983].

Static Immersion Test

A second type of subjective test is the Static Immersion Test (AASHTO T-182). An HMA mix sample is immersed in a distilled water bath at 77°F (25°C). The mix is left in the water bath for 16 to 18 hours. Similar to the Boiling Water Test, the percentage of total visible area that remains coated with asphalt cement is estimated as above or below 95 percent [Standard Specifications for Transportation Materials and Methods of Sampling and Testing 1995].

Lottman Test

The Lottman Laboratory Test predicts the susceptibility of asphalt concrete mixtures to moisture-damage. The test was piloted by Lottman [1982] at the University of Idaho. The Lottman Test is well known and is described in NCHRP Project 192. The laboratory procedure that was developed was field tested in NCHRP 246. Results from the study concluded that the ranking of test sections due to visual stripping moisture damage was similar to the rankings obtained from the strength ratios.

Nine specimens are used in the laboratory procedure. They are compacted to field air void content. The nine cores are split into three groups. Group one is the control group in which there is no conditioning done. In the second group the cores are vacuum saturated with water for 30 minutes at 660 mmHg. Group two reflects field performance of the HMA mix for the first four years of life. The third group also is vacuum saturated, but then the cores are put through a freeze-thaw cycle. Group three cores are frozen at 0°F (-18°C) for 15 hours. Then they are thawed at 140°F (60°C) for 24 hours. Group three is designed to reflect field performance from the fourth to the twelfth year [Lottman 1982; Roberts et al. 1996].

The Resilient Modulus (M_R) Test and/or the Indirect Tensile Strength Test (ITS) are performed on each core after the prescribed conditioning has been completed. These tests can be performed at either 55°F (13°C) or 73°F (23°C). ITS is determined using a loading rate of 0.065 in/min. The retained tensile strength (TSR) is calculated for the cores in groups two and three. The TSR is equivalent to the ITS of the conditioned specimens divided by the ITS of the control specimens. The equations will be discussed further in chapter III. It is recommended that a TSR be greater than 0.7. However, field cores have shown visual stripping when the TSR was 0.8. [Lottman 1982, Roberts et al. 1996]

Tunnicliff and Root Conditioning

Tunnicliff and Root Conditioning (NCHRP 274) is a strength test that utilizes ITS. Six specimens are produced with air voids between 6 and 8 percent. The six samples are split into two groups of three. The first group is the control group without any conditioning. The second group is vacuum saturated at 28.6 in. HG for five minutes. Saturation limits for the specimens are 55 to 80 percent. After saturation, group two cores are placed in a 140°F (60°C) water bath for 24 hours. The ITS Test is performed at 77°F (25°C) with a loading rate of 2 in/min. The minimum acceptable TSR used is 0.7 to 0.8 [Tunnicliff et al. 1984].

Modified Lottman Test

AASHTO accepted the Modified Lottman Test (AASHTO T-283) in 1985. It is a combination of the Lottman Test, and the Tunnicliff and Root Test. Six specimens are produced with air voids between six percent and eight percent. The higher percentage of air voids helps to accelerate moisture damage on the cores. Two groups of three specimens are used. The first group is the control group. The second group is saturated between 55 and 80 percent with water and is placed in the freezer (0°F or –18°C) for 16 to 18 hours. The frozen cores then are moved to a water bath at 140°F (60°C) for 24 hours. After conditioning, the Resilient Modulus Test and/or ITS Test are performed. The ITS Test is performed at 77°F (25°C) with a loading rate of 2 in/min.[Standard Specifications 1995] The minimum acceptable TSR used is 0.7 [Roberts et al. 1996].

Immersion-Compression Test

The Immersion-Compression Test (AASHTO T-165) utilizes six cores. Each core is four inches in diameter and four inches in height. The cores are compacted with a double plunger at 3,000 psi for two minutes. An air void content of 6 percent is attained. The six cores are split into two groups. The first group is a control group. The second group is conditioned in a water bath at 120°F (49°C) for four days or at 140°F (60°C) for one day.

After conditioning, the unconfined compressive strength of each core is found. A testing temperature of 77°F (25°C) and a loading rate of 0.2 in/min are used. The retained compressive strength is calculated. A retained strength of 70 percent is specified by many agencies [Roberts et al. 1996].

The Immersion-Compression Test has produced retained strengths close to 100 percent even when stripping is visually evident in the cores. Thus, this test is not sensitive enough to measure damage induced by moisture. This problem was attributed to the internal pore water pressure that develops [Roberts et al. 1996].

Hamburg Wheel Tracking Device

The Hamburg Wheel Tracking Device (HWTD) was developed in the 1970s by Esso A.G. of Hamburg, Germany [Romero and Stuart 1998]. A similar device was already developed in Britain, but it utilized a rubber tire instead of a steel tire. The HWTD measures the combined effects of rutting and moisture on HMA mixtures. A steel wheel rolls across the surface of an asphalt cement slab immersed in hot water [Romero and Stuart 1998]. The HWTD is capable of testing two slabs at one time. The steel wheels move concurrently through a crank connected to a flywheel. This type of movement produces a varying velocity that is maximized at the center of the slab. [Izzo and Tahmoressi 1999]

The slabs are 320mm (12.6in.) long by 260 mm (10.2 in.) wide. The thickness of the slabs are 40 mm, 80 mm, or 120 mm (1.6, 3.2, 4.7 in.). During the test, the slabs are secured with plaster-of-paris in a steel container and are rested on a steel platform. Figure 2.1 is an illustration of a HWTD. The steel wheel has a diameter of 203.5 mm (8 in.) and a width of 47 mm (1.8 in.). A fixed load of 685 N is applied at a rate of 53±2 wheel passes per minute. The contact area of the wheel increases as the rut depth increases. Thus, the contact stress is variable. The average contact stress is 203.5 MPa. A slab undergoes 20,000 passes or until 20 mm of deformation occurs. The temperature of the hot water bath can vary from 25°C to 70°C (77-158°F). A linear variable differential transducer measures the depth of the rut continuously with an accuracy of 0.01 mm [Izzo et al.1999]. The testing takes approximately 6.5 hours. [Aschenbrener 1995, Izzo et al. 1999, Romero et al. 1998]

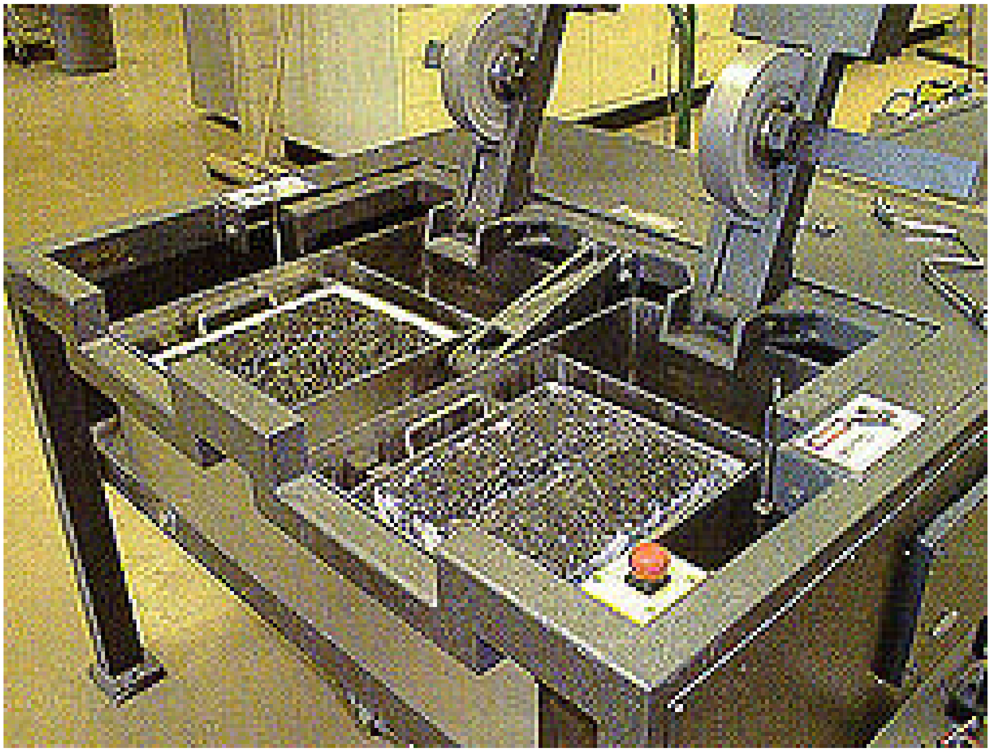

Figure 2.1 Hamburg Wheel Tracking Device [Romero et al. 1998].

Figure 2.2 is a sample of data obtained from running the HWTD [Aschenbrener 1995]. Three points are identified on the curve; creep slope, stripping slope, and stripping inflection point. The creep slope occurs before the onset of stripping, and is the inverse of the rate of deformation in the linear region of the deformation curve. This portion of the curve is where rutting occurs due to plastic flow. The stripping is related to the severity of damage due to moisture. It is the inverse of the rate of deformation in the linear region after the onset of stripping to the end of the test. The stripping inflection point is related to the resistance of the HMA tested to the effects of moisture. This point is measured as the number of passes at the intersection of the creep slope and stripping slope [Aschenbrener 1995; Miller 1995; Mohammad, Abadie, Gokmen, Pappala 2000].

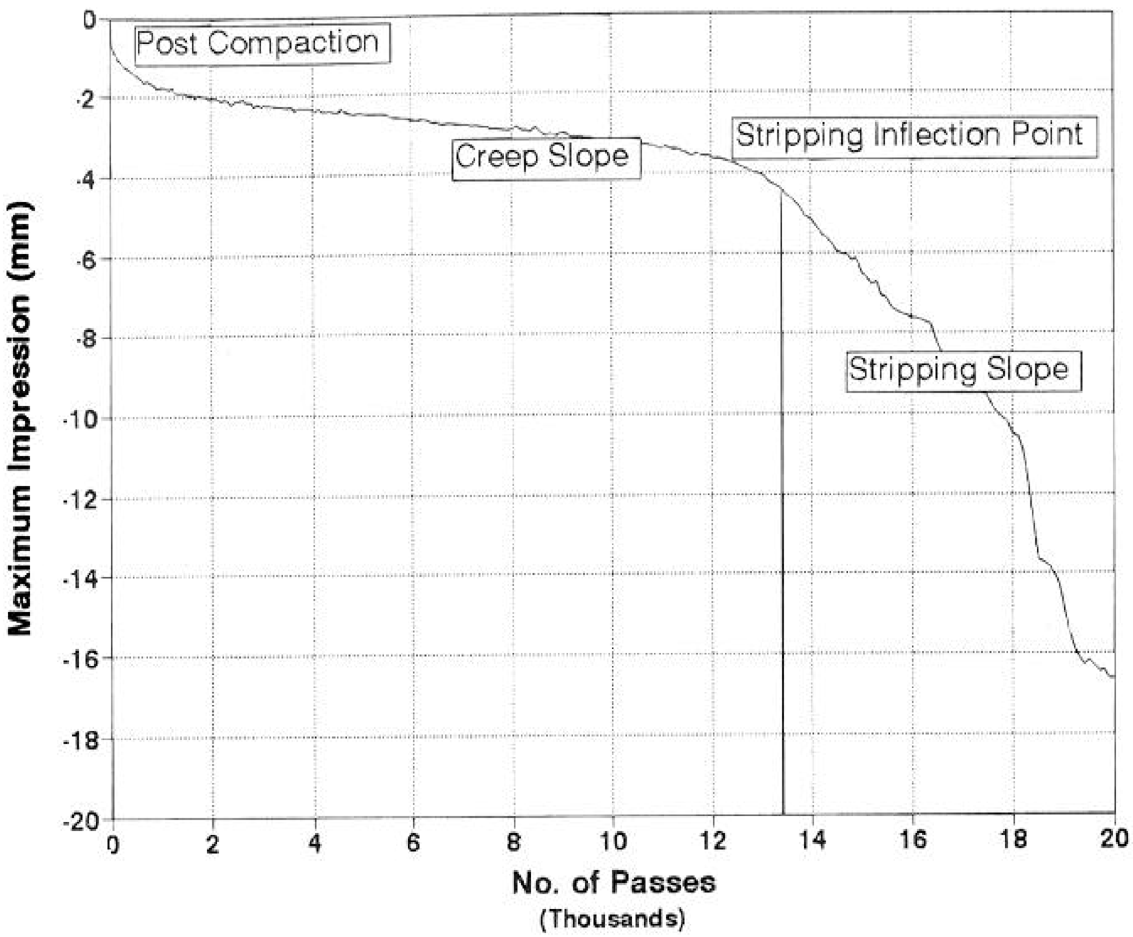

Figure 2.2 **Results from Hamburg Wheel Tracking Device** [Aschenbrener 1995]

The city of Hamburg specifies a rut depth less than 4 mm after 20,000 passes for use. Colorado specifies a rut depth of less than 10 mm after 20,000 passes [Stuart and Izzo 1995]. Results from the HWTD have been used in two capacities by the state of Colorado. The HWTD was used to improve quality of a HMA placed in 1993. Also, I-25 at Longmont, Colo., was bid using test results of the HWTD as an incentive payment. Tim Aschenbrener [1995] found that results from the HWTD are sensitive to aggregate properties such as clay content, high dust to asphalt ratios, and dust coating on the aggregate.

Texas Freeze-Thaw Pedestal Test

The Texas Freeze-Thaw Pedestal Test (TFTPT) is conducted on a HMA mix with uniform aggregate sizes. Since a uniform aggregate size is used, the effects of mechanical properties of the aggregate are minimized in the test. Thus, effects of bonding are maximized. To perform the test, the asphalt and aggregate are mixed using the Texas Mixture Design Procedure. After initial mixing, the mixture is reheated and is mixed two additional times.

A cylindrical mold is used to form the specimen, which has a height of 19.05 mm (0.75 in.) and a 41.3 mm (1.6 in.) diameter. A constant load of 27.6 kN (6200 lbs) is applied for 20 minutes. The specimen is cured at ambient temperature for three days. Thermal cycling is performed on the specimen. The specimen is placed on a stress pedestal in a jar and covered with 12.7 mm (0.5 in.) of distilled water. It is cycled through –12°C (-10°F) for 12 hours then 12 hours at 49°C (120°F). The number of freeze thaw cycles to induce cracking indicates moisture susceptibility of the HMA. Kennedy, Roberts, and Lee found that mixes susceptible to moisture survived less than 10 cycles. Mixtures that were not susceptible to moisture survived more than 20 cycles [Kennedy, Roberts, Lee 1983; Kennedy and Anagnos Modified Test 1984].

Georgia Loaded Wheel Tester

The Georgia Loaded Wheel Tester (GLWT) was developed by the Georgia Department of Transportation. Development of the GLWT included comparisons of the creep tests and the repeated load triaxial test with data obtained from GLWT testing. These comparisons were used to evaluate the GLWT ability to produce results in line with rutting in the field [Collins, Watson, Campbel 1995]. The GLWT measures the rutting susceptibility of a HMA mix by rolling a steel wheel across the top of a pressurized hose placed on top of an asphalt beam. The hose is made of stiff 29 mm diameter rubber. The wheel travels at a rate of 33 cycles or 67 passes per minute. Steel plates confine the beams that are used. The machine has a temperature-controlled compartment.

Previous experimentation done at the University of Wyoming by Tyler Miller [1995] developed a process of utilizing 6 in. (150 mm) diameter cores in the GLWT. The cores were placed in a concrete frame and centered in the GLWT. Figure 2.3 shows an example of the concrete frame. Miller confirmed a testing temperature of 115°F (46°C) for Wyoming. Also, Miller correlated rut depths produced in the GLWT with field rutting in Wyoming.

Figure 2.3 Georgia Loaded Wheel Tester Concrete and Steel Frame.

In 1996 Collins, Shami, and Lai developed a gyratory sample mold that could be used in the GLWT. The GLWT that was used had three wheel testers that ran simultaneously. The mold that was developed was made of high density polyethylene. Their results indicated that the GLWT could be used in conjunction with Superpave Level 1 mix design to develop mix designs with low susceptibility to rutting.

The projected use of the GLWT was as an inexpensive proof tester. Watson, Johnson, and Jared [1997] found that some HMA mixes that fell outside the Superpave restricted zone performed well in the

GLWT. Therefore, to prevent economical mixes from being rejected, mixes should be tested even if they fall into the restricted zone. In 1997, Shami, Lai, D'Angelo, and Harmen developed a temperature effect model to be used with the GLWT. With this model, rutting susceptibility can be tested at one temperature for different environments.

Chapter Summary

Stripping is a serious and costly problem for many DOTs. Over the years many testing procedures have been developed to predict moisture susceptibility of an HMA mixture. Two types of testing have been developed: strength and subjective. Of the strength tests, those that use TSR data have been widely tested and accepted. Since the GLWT is a less expensive piece of equipment than the Hamburg Wheel Tracking Device, it would be beneficial if a testing procedure could be developed that uses the GLWT to test for moisture susceptibility.

CHAPTER 3

DESIGN OF EXPERIMENT AND TESTING PROCEDURES

Introduction

The experiment was split into two phases. The goal of phase I was to evaluate effects of various freeze-thaw cycles on the strength of Hot Mix Asphalt (HMA) mixtures. This was achieved by selecting eight HMA mixtures and then developing a testing procedure to condition and test the tensile strength of the cores. Wyoming modified AASHTO T-283 was followed in the production, cycling, and testing of the cores.

The second phase of the experiment was to evaluate ability of the Georgia Loaded Wheel Tester (GLWT) to predict the moisture susceptibility of HMA mixtures. Three of the eight mixtures from phase one were used for this testing. Cores were produced at 4 percent and 7 percent air voids for each of the mixtures. The cores were then conditioned and tested in the GLWT. This chapter details design of the experimental procedures used to conduct phase I and phase II of this experiment.

Evaluation of the Effects of Various Freeze -Thaw Cycles on HMA Strength

This section describes in detail the experimental procedure, including sample preparation, the freeze-thaw cycling, the Resilient Modulus testing, and the Indirect Tensile testing as used in phase I. During the sample preparation for phase I, the density of each type of asphalt used was tested by standard test method ASTM D70-82. The Rice Test was performed on each mixture using theoretical maximum specific density method AASHTO T209-94. Finally, each group of samples was produced using the Gyratory compactor. After the samples cool to ambient temperature, the bulk specific gravity of each core was measured using AASHTO T-166. For each of the eight HMA mixtures, freeze-thaw cycling varying from 0-1-2-4-6-8-10-15 cycles was attempted. Each cycle consists of freezing the sample for 16 to 18 hours and then thawing the samples in a 140°F (60°C) water bath for 24 hours. If a sample failed during cycling, no additional testing was required. After a prescribed number of freeze-thaw cycles, the samples were dried in an environmental chamber at 77°F (25°C) for 24 hours before performing the Resilient Modulus Test. The Resilient Modulus Test is non-destructive and is performed using an Instron machine. The samples then were fractured while performing the Indirect Tensile Test. Once fractured, samples were given to Western Research Institute for chemical analysis.

A total of 128 cores were needed for phase I. Sixteen samples were produced for each of the eight mixtures at 7 percent air voids. It took one week to produce a core and condition it through one freeze-thaw cycle. For the samples from a mixture type to be conditioned for 15 freeze-thaw cycles and tested, it took a little more than one month. That conditioning was timed such that a majority of the testing occurred between seven in the morning and 11 at night. Due to the availability of equipment, six months were needed to complete the conditioning and testing of the eight mixtures.

Aggregate

Classification of the aggregates normally is accomplished by the size of the aggregate. Three common groups are coarse aggregate, fine aggregates, or mineral fillers. Generally aggregates for HMA are required to be resistant to abrasion, sound, clean, and hydrophobic [Roberts et al. 1991]. In this study, granite aggregate was taken from stockpiles at Granite Canyon Quarry in Wyoming, and limestone was obtained from the North Rawlins Quarry in Wyoming. The corresponding physical characteristics of each type of aggregate were obtained from WYDOT. Therefore, physical characteristic tests of the aggregates were not performed at the University of Wyoming.

Gradation is one of the more important properties of an aggregate. It affects the stability and the durability of the HMA mixes. Therefore, gradation is a primary consideration in asphalt mix design. Gradation is usually determined by sieve analysis. Sieve analysis involves passing the material through a series of sieves stacked with progressively smaller openings from top to bottom, and then weighing the material retained on each sieve. The gradation normally is expressed as total percent passing various sieve sizes.

It is unlikely that a single natural or quarried material will meet the specifications necessary. Two or more aggregates of different gradations are typically blended to meet specification limits. It is often more economical to combine naturally occurring and processed materials to meet specifications than to use all processed materials [Roberts et al. 1991]. The nature of particle size distribution can be examined by graphically representing the gradation by a cumulative percent passing on a semi-log scale. Wyoming DOT provided the combination proportions for the aggregates used. Both mix formulas came from WYDOT projects that were constructed in the state. Limestone was used for construction of Curtis Street in Laramie, Wyo. For the limestone, a 53/47 percent aggregate blend was made using aggregates of different gradation from the same source. The granite was a combination of three aggregates from Granite Canyon Quarry at 15/32/53 percent split. The gradation of the aggregates can be seen in Table 3.1 and Table 3.2.

Table 3.1 Sieve Analysis of Limestone Aggregate used in Experiment.

Sieve Size	Percent Passing		
	Aggregates		Aggregate Blend
	- # 4	+ # 4	
1”	100	100	100
¾”	100	99	99
½”	100	67	83
3/8”	100	38	67
# 4	100	0	47
# 8	59	0	28
# 16	35	0	16
# 30	22	0	10
# 50	15	0	7
# 100	11	0	5
# 200	8.7	0	4.1

Table 3.2 Sieve Analysis of Granite Aggregate used in Experiment.

Sieve Size	Percent Passing			
	Aggregates			Aggregate Blend
	+# 4	Med.	- #4	
¾”	100	100	100	100
½”	57	100	100	94
3/8”	22	81	100	82
# 4	3	8	74	42
# 8	1	3	54	30
# 16	1	2	40	22
# 30	1	2	30	16
# 50	1	1	22	12
# 100	1	1	16	9
# 200	0.5	0.8	10.8	6.1

Asphalt Cement

Asphalt cement generally is obtained from distillation of crude petroleum using different refining techniques. At ambient temperatures asphalt cement is a semi-solid material that must be heated to mix with an aggregate. Asphalt is a strong, durable cement with excellent adhesive and waterproofing characteristics. In Phase I of this study, four asphalt-additive-aging combinations were tested: AC-10, aged AC-10, lime added to AC-10, and AC-10 plus model compound dodecanophenone. Phase II used only the first two types of asphalt. The experimental designs of the mixtures can be seen in Figure 3.1 and Figure 3.2.

The primary asphalt used in this research is AC-10 which was provided by Western Research Institute (WRI). The asphalt was SHRP asphalt AAB-1. A complete description of the asphalt characteristics can be seen in Table 3.3 and Table 3.4. Cores were produced by aging the mixture at 212°F (100°C) for 20 hours to produce a second asphalt combination. Lime at 1 percent by weight was added to the primary asphalt to produce a third asphalt. Dodecanophenone was added to the AC-10 at 1 percent by weight to produce a fourth asphalt.

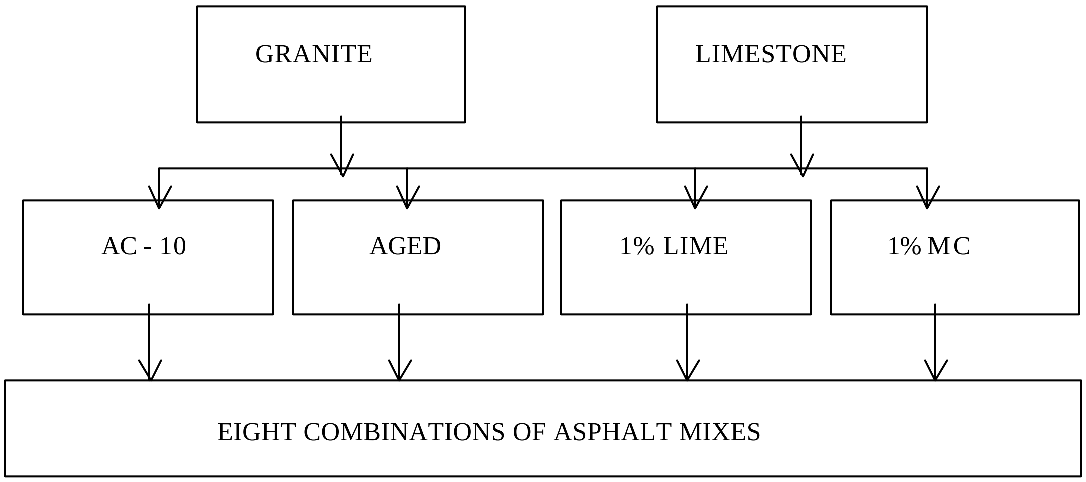

Figure 3.1 Mixture Design Combinations for Phase I.

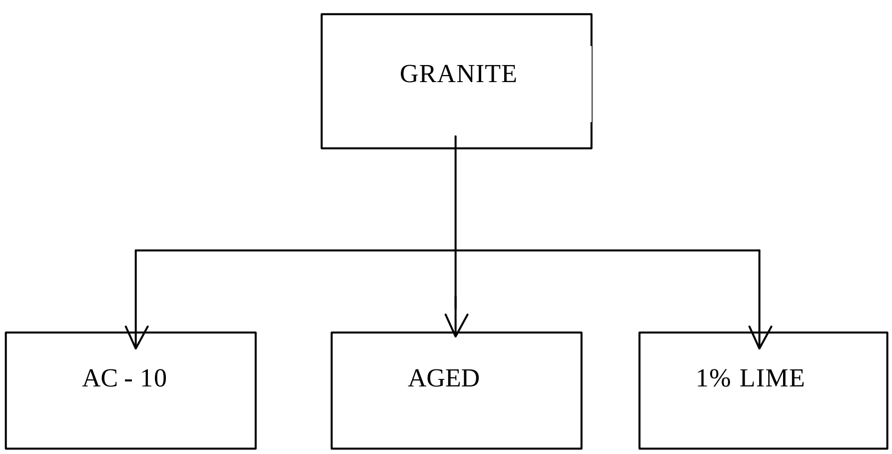

Figure 3.2 Mixture Design Combinations for Phase II.

Table 3.3 Primary Asphalt Characteristics.

Vis./Pen Grade	AC-10
SHRP PG Grade	PG58-22
Viscosity 140°F, poise	1029
Viscosity 275°F, cSt	289
Penetration, 0.1 mm (77°F, 100g, 5s)	98
Penetration, 0.1 mm (39.2°F, 100g, 5s)	6
Ductility, cm (39.2°F, 1cm/min)	40.1
Softening point (R&B), °F	118

Table 3.4 Primary Asphalt Components.

Component Analysis, %	
Asphaltenes (n-heptane)	17.3
Asphaltenes (iso-octane)	2
Polar aromatic	38.3
Napthene Aromatic	33.4
Saturates	8.6
Elemental Analysis	
C, %	82.3
H, %	10.6
O, %	0.8
Nitrogen, %	0.54
Sulfur, %	4.7
Vanadium, ppm	220
Nickel, Fe, ppm	56
Fe, ppm	16

Specific Gravity Test Procedure (ASTM D70-82)

The standard test method for specific gravity and density of asphalt cement is described in detail in ASTM D70-82. The test method requires a 600-mL Griffin low-form beaker and 2-3 pycnometers. Four weights will be obtained in the test: the pycnometer, the pycnometer with water, the pycnometer with asphalt, and the pycnometer plus asphalt and water.

Calculate the specific gravity of asphalt as follows:

$$\text{Specific gravity} = \frac{(C - A)}{[(B - A) - (D - C)]}$$

Where,

A = weight of the dry pycnometer,

B = weight of the pycnometer filled with distilled water,

C = weight of the pycnometer filled with asphalt,

D = weight of the pycnometer, asphalt and distilled water.

Theoretical Maximum Specific Gravity (AASHTO T209-94)

AASHTO T209-94 was used to determine the theoretical maximum specific gravity and density of each pavement mixture. The density is used to calculate values for percent air voids in the compacted asphalt cores. The following equation was used with the procedure,

$$\text{Specific gravity} = \frac{B - A}{B - A + D - C}$$

Where,

A = Mass of the flask,

B = Mass of the flask with oven-dry sample in air,

C = Mass of the flask filled with sample and water at 77^0F (25^0C),

D = Mass of the flask filled with water at 77^0F (25^0C),

and the theoretical maximum specific density is equivalent to the specific gravity multiplied by the unit weight of water (62.4 lb/ft^2).

Production of Cores

In this study, all cores were compacted using the gyratory compactor. The Troxler Gyratory Compactor is an integral part of the mix design and testing phases of Superpave, as illustrated in Figure 3.3. The Gyratory Compactor compacts an asphalt specimen by applying a force of 600 kPa to the mix while gyrating the mold at an angle of 1.25^o. The height of the specimen is monitored continually. The Gyratory Compactor operates by compacting the asphalt mixture with a fixed pressure while gyrating the mold at a fixed angle, simulating the actions of a roller compactor in the field.

Figure 3.3 Troxler Gyratory Compactor.

A quantity of HMA sufficient to achieve a 2.5 in specimen height is placed between specimen papers in the heated cylindrical mold. The mold has an inner diameter of 100 mm (4 in.) and a loose lower puck. The mold is then placed in the Gyratory Compactor and the ram is lowered to apply a fixed pressure of 600 kPa to the mix. The mold is tilted to 1.25^{o} while the upper puck and lower puck remain parallel to each other and perpendicular to the original axis of the cylinder. While maintaining the pressure and preventing the mold from rotating, the mold is gyrated at 1.25^{o} about the original central axis at 30 rpm. As the specimen compacts, its height is measured after each gyration and displayed to the nearest 0.1mm. The Troxler Gyratory Compactor can be used to prepare specimens with 7 percent and 4 percent air voids by utilizing the Gyrate-To-Height feature.

Each of the eight mixtures used in this experiment were heated to a mixing temperature before the asphalt and aggregate were combined. The mixture was placed in an oven for two hours to reach the compaction temperature. Once the compaction temperature was reached, enough mixture was placed in a mold to produce a 2.5 in. by 4 in. core then compacted in the Gyratory compactor. The full procedure followed to produce the cores can be found in Appendix A.

Percent Air Voids

To obtain the percent air void of every sample, AASHTO T-166 was used. This test determines the bulk specific gravity of each core by first calculating the percent of water that is absorbed:

$$\frac{C-A}{C-B} \times 100 = \%\text{Water absorbed}$$

If the percent of water absorbed is less than 2 percent, then the bulk specific gravity can be calculated with the following equation:

$$\text{S.G.} = \frac{A}{C-B}$$

The density = S.G. $\times$ 62.4 lb/ft^3

Where,

A = Mass of core in air,

B = Mass of core in water,

C = Saturated surface dry mass in air.

The percent air voids in the compacted bituminous paving mixture can be calculated as follows:

$$\text{Percent air voids} = 100 \quad (1 - \frac{A}{B})$$

Where,

A = bulk specific gravity (T-166),

B = theoretical maximum specific gravity (T-209).

Saturation and Freeze-Thaw Cycling

As described in Wyoming Modified AASHTO T-283, this method determines the resistance of a compacted mixture to moisture induced damage. Compacted asphalt cores are subjected to a freeze-thaw conditioning process. The resistance to moisture damage of an asphalt mixture can be used to characterize its suitability for use as a paving material. This process also may be used to compare various binders, modifiers, HMA mixes, and additives.

Cores that are to be subjected to freeze-thaw cycling first must be saturated to between 55 and 80 percent of capacity. The cores are placed in a vacuum container filled with distilled water. A vacuum pressure is applied for a duration sufficient to provide the specified saturation level. The cores remain in the water without the vacuum for five minutes. Once the core is removed from the vacuum container, the bulk specific gravity of the cores is determined using the original dry weight of the core. The percent saturation is determined first by multiplying the volume obtained by the total air voids. Next, divide the amount of water absorbed by the previous product and then state as a percent.

In this study, each specimen was wrapped in saran wrap, then placed in a zip-lock bag before the freeze-thaw cycles were performed. Each cycle consisted of freezing the sample for 16 to 18 hours then thawing the samples in a 140°F (60°C) water bath for 24 hours. After a predefined number of cycles, the samples are moved to the environmental chamber at 77^{0}F (25°C) for 24 hours.

Resilient Modulus Test

The Resilient Modulus Test was performed using an Instron machine. The test uses repeated load Indirect Tensile Test techniques to determine resilient modulus values (M_r). The Instron machine can apply a repeated cyclic stress of fixed magnitude, duration (0.1s), and cycle duration (1.0s) to the test specimen. During testing, the specimen was subjected to a dynamic cyclic stress (90 percent of total load) and a constant stress (10 percent of total load). The instantaneous horizontal deformation response of the specimen was measured and used to calculate an instantaneous resilient modulus (M_{Ri}). The analysis in this report will not include this portion of the data collection and its analysis.

Indirect Tensile Test

The indirect tensile test measures change in tensile strength resulting from effects of saturation and accelerated water conditioning of compacted HMA in the laboratory. The results may be used to predict long-term stripping susceptibility of bituminous mixtures and to evaluate liquid anti-stripping additives, which are added to the asphalt cement. The numerical indices of retained indirect tensile properties are obtained by comparing the retained indirect properties of conditioned laboratory specimens with the similar properties of dry specimens.

The indirect tensile test was performed on a Soiltest machine, as shown in Figure 3.4 with steel loading strips that have concave surfaces. Before the indirect tensile strength was measured, the control specimens were wrapped in a zip-lock bag and then placed in a 77^0F (25°C) water bath for a minimum of two hours. The cycled specimens were placed directly in the water bath for two hours before the test was performed.

Figure 3.4 Soiltest Indirect Tensile Machine .

The numerical index or the resistance of asphalt mixtures to the detrimental effect of water can be expressed as the ratio of the original strength retained after freeze-thaw conditioning. The TSR value will be used in Phase I and Phase II of the experiment. The TSR normally is calculated as follows:

$$\text{Tensile Strength Ratio (TSR)} = \frac{T_2}{T_1}$$

Where:

T_1 = average tension of dry subset,

T_2 = average tension of conditioned subset.

Utilizing the Georgia Loaded Wheel Tester to Test for Moisture Susceptibility

The second phase of this study involves the Georgia Loaded Wheel Tester. Cores were produced utilizing the same mix designs from phase I and then were tested in the GLWT. The rutting that occurred will be analyzed to determine if the GLWT can be used to test for moisture susceptibility. Thirty-six cores were tested in phase II of this research. Testing for each core took approximately four hours in the GLWT. The time needed for conditioning of the cores is in addition to the eight hours.

Selection of Aggregate

The Wyoming Department of Transportation Materials Testing Laboratory provided various gradation summaries that have been used in the state. Two types of aggregate initially were chosen for this research as described in section 3.2.1. For testing in the GLWT, the granite aggregate was chosen because it is more moisture susceptible than limestone.

The aggregate was obtained from Granite Canyon Quarry. The final aggregate was a combination of 15 percent three-fourths inch rock, 32 percent one-half inch rock, and 53 percent crushed fines. Material particles are 5.3 percent flat and 2.9 percent elongated. The mix design specified 5.7 percent asphalt content.

Selection of Asphalt

For phase II, only two of the additives were chosen for use. The AC-10 asphalt and the AC-10 plus lime asphalt at 4 percent and 7 percent air voids. At the time phase II was started the model compound had not been tested through phase I. Therefore, it was eliminated from phase II. The AC-10 was used in aged and in un-aged cores.

Once the asphalt and aggregate were chosen for this experiment, it was necessary to identify the theoretical maximum specific gravity for each mixture as well as the specific gravity for each asphalt. AASHTO T209-94 was the test method used for the theoretical maximum specific gravity for each mixture as detailed in section 3.2.4. The specific gravity for each asphalt was found using ASTM D70-82 as detailed in section 3.2.3.

Mixing and Compaction of Specimens

Cores were produced using granite aggregate and one of the three asphalt types provided by WRI. Cores for this study were 15.2 cm (6 in.) in diameter and have a height of 7.6 cm (3 in.). Previous testing at the University of Wyoming developed a procedure for using cores of this size in the GLWT (Miller, 1995). To achieve this sample size at the appropriate air voids, the mixing and the compaction procedure described in section 3.2.5 was used.

Freeze-Thaw Cycling

Cycling for the samples follows Wyoming Modified AASHTO T-283 described in section 3.2.7. Samples were to be exposed to 0, 1, or 2 cycles. Samples that were not cycled were used as the control group for that set. Two cycles were chosen because from Phase I it was found that the granite aggregate showed moisture damage/tensile failure after being cycled two times. After initial testing was conducted it was found that three cycles would be difficult to achieve and still be able to run the cores through the GLWT. Therefore, the test consisted of cores that went through 0 and 1 cycle. Group one cores are used as control samples that are not conditioned. Group two cores are saturated prior to being placed in the GLWT. Group three cores are saturated and then cycled one time. Figure 3.5 details the cycling used in the experiment.

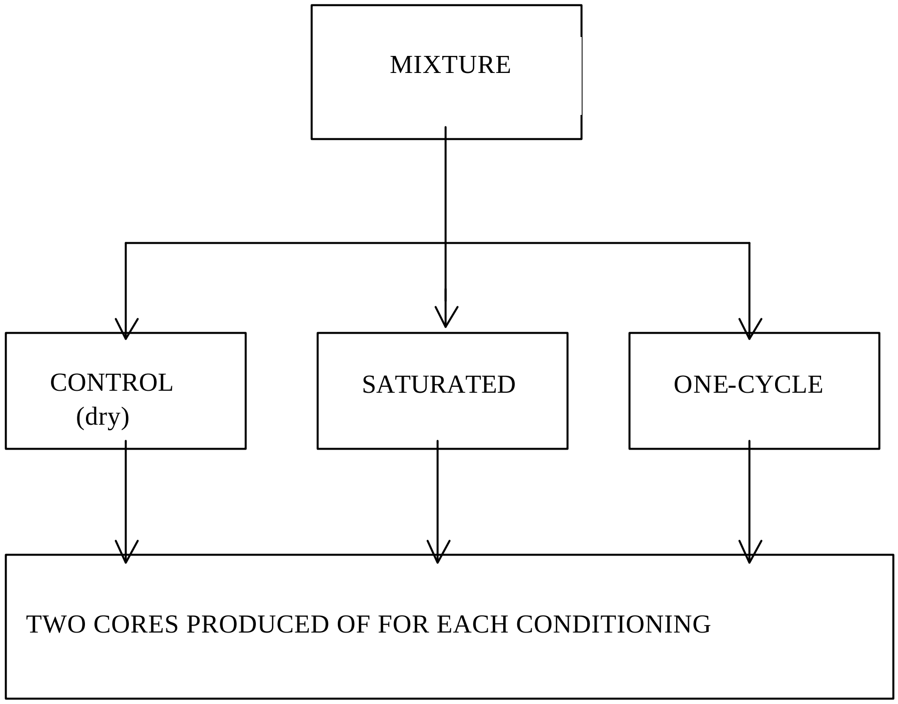

Figure 3.5 Conditioning Design for Phase II Cores.

Saturation Procedure

The cores in group two and group three were saturated from 55 percent to 80 percent with water. Cores in group two were heated in the GLWT for four hours at 115°F (46°C) prior to being saturated. They were then placed in a swim cap, as shown in Figure 3.6, to hold moisture in the core during testing in the GLWT. Cores from group three were saturated and were conditioned as described in section 3.2.7. When the cores from group three were removed from the 140°F (60°C) water bath, they were placed in a swim cap. Prior to being placed in a swim cap, the level of saturation of each core was measured.

Figure 3.6 Typical Core in a Swim Cap.

Georgia Loaded Wheel Tester

The GLWT at the University of Wyoming can be seen in Figure 3.7. The GLWT was heated to a temperature of 115°F (46°C) for testing. The hose is a double ply rubber hose inflated to a pressure of 100 psi. The pressure is maintained during the entire testing procedure. The cores are placed in a concrete mold, shown in Figure 3.8, to maintain stability during the test. Also, the molds allow circular specimens to be used instead of beams.

Figure 3.7 University of Wyoming GLWT.

Figure 3.8 Concrete Core Mold.

The GLWT protocol calls for 8,000 cycles to be applied to each core. Measurements of the rut depth were made at the end of 1,000, 4,000, and 8,000 cycles. Figure 3.9 shows the measurement device used. The measurement device has three spin rods located along a bar. Measurements were taken at the center point of the core, two inches left of center and two inches right of center.

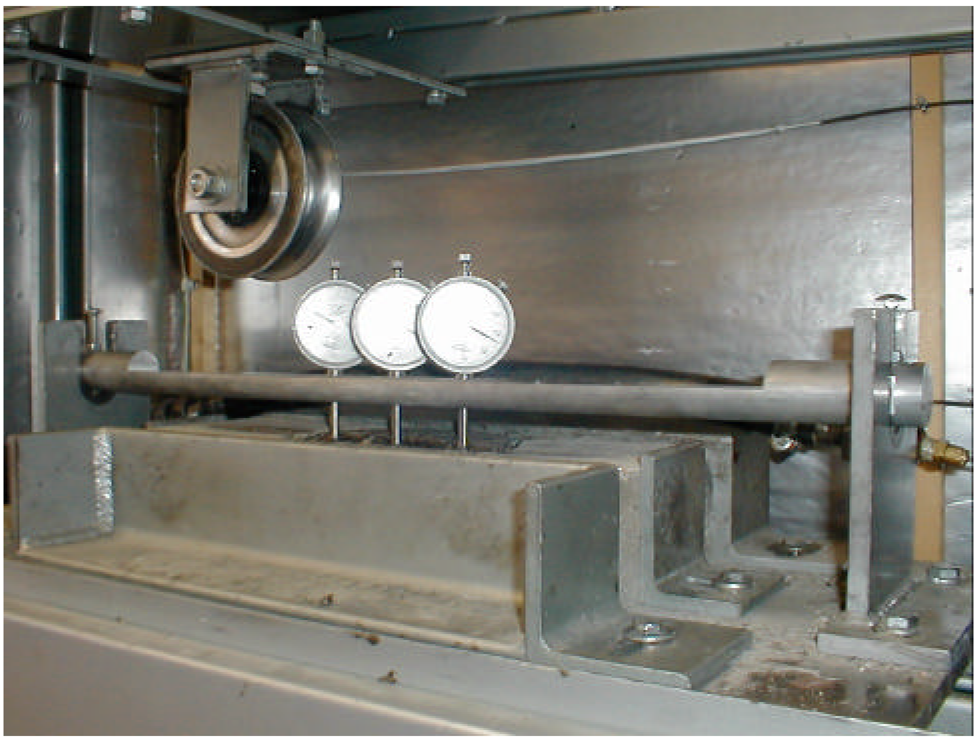

Figure 3.9 Rut Depth Measuring Device.

Once the cores were conditioned, they were placed in the GLWT. Cores in group one were placed in the machine for four hours before testing began. Group two cores were warmed for four hours, saturated, then tested. Group three cores were saturated, one freeze-thaw cycle, then tested.

Chapter Summary

This chapter explained testing procedures and the experimental design used for this study. During evaluation of the freeze-thaw cycles on strength of the HMA mixtures, 16 cores were tested for each mixture. Of those 16 cores for each group, only those cores that maintained integrity were tested for their tensile strength. Evaluation of the GLWT utilized identical cycling and production procedures to those used in the first phase of the study. Data were collected for both phases. The data collection will be discussed in the following chapter.

CHAPTER 4

DATA COLLECTION

Introduction

Laboratory evaluations were used in this experiment. The laboratory evaluations for phase I and phase II of the experiment were conducted at the University of Wyoming. Phase I involved the production of samples from eight mixtures using the gyratory compactor, testing of those samples was conducted using an Instron machine and a Soiltest machine. Phase II involved the production of samples from three mixtures at two different air void contents. Testing of these samples was conducted in the Georgia Loaded Wheel Tester (GLWT). The purpose of these tests was to compare the mechanical properties of asphalt mixtures and to develop a method of measuring the amount of moisture damage to expected using the GLWT.

Materials

The materials used in this procedure were acquired from various sources. The mix designs were provided by WYDOT for both aggregate sources. The limestone aggregate was obtained from the North Rawlins Quarry in Wyoming. Figure 4.1 shows the gradation of the limestone used in comparison to the QC/QA specification for WYDOT aggregates.

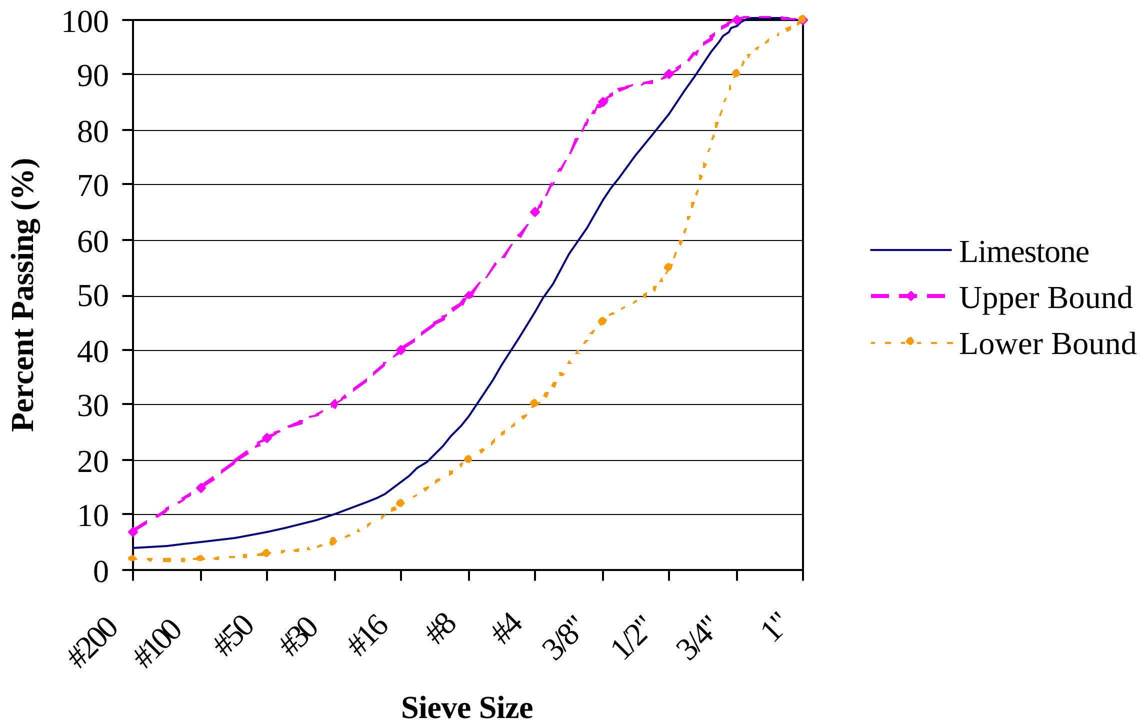

Figure 4.1 Limestone Gradation with Respect to WYDOT Specifications.

The granite aggregate was provided by Granite Canyon Quarry, which is located west of Cheyenne. Granite aggregate was taken from stockpiles at the quarry during the early spring of 2001. The aggregate was oven dried for 24 hours prior to testing. Figure 4.2 shows the relationship of the granite gradation to specifications utilized by WYDOT.

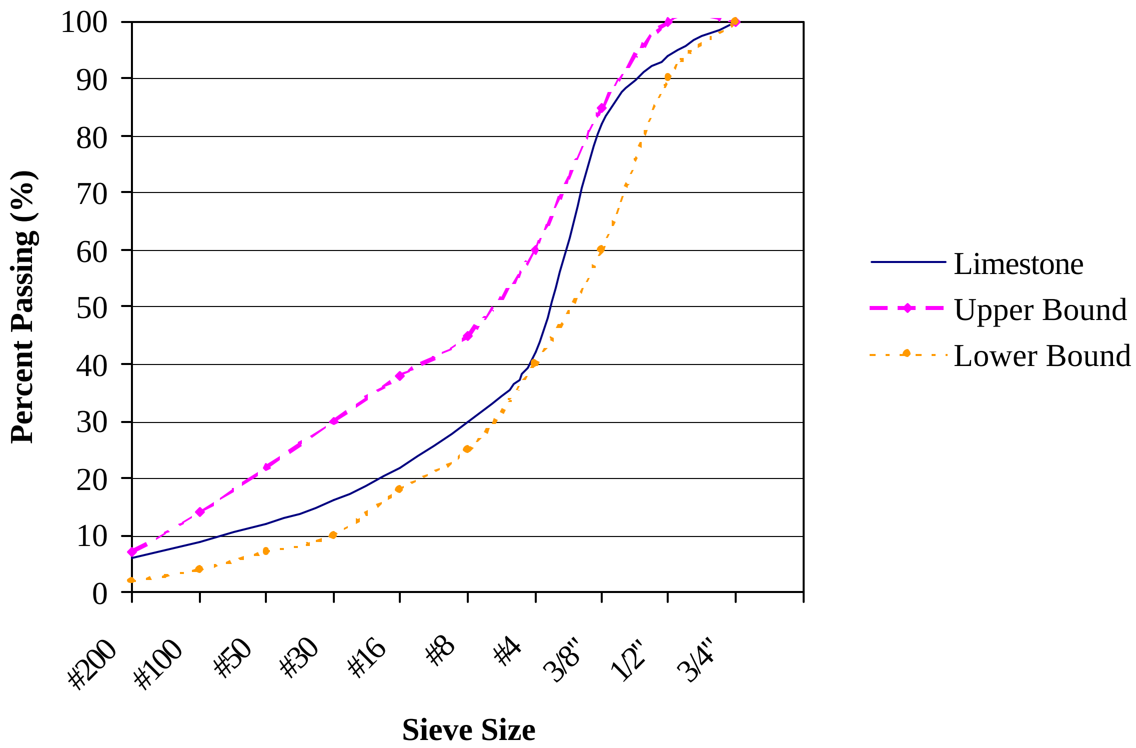

Figure 4.2 Granite Gradation with Respect to WYDOT Specifications.

Asphalt and asphalt mixtures were provided by Western Research Institute. Three asphalts that were provided are: AC-10, AC-10 plus lime, AC-10 plus dodecanophenone. It was necessary to perform only a few tests on the asphalts before production of the cores for evaluation.

Asphalt

The asphalt provided by WRI was AC-10, PG grade 58-22. Many of the properties were provided by WRI and are detailed in Table 3.3 and Table 3.4. However, it was necessary to determine specific gravity for each asphalt to determine the amount of each mixture needed to produce cores at 7 percent air voids and at the correct size. ASTM D70-82 as described in section 3.2.3 was utilized to determine the specific gravity of each asphalt type. Table 4.1 shows the specific gravity as determined by ASTM D70-82 for the three asphalts used.

Table 4.1 Specific Gravity of Asphalts.

Asphalt Type	Specific Gravity
AC - 10	1.03
AC – 10 + Lime	1.14
AC – 10 + Model Compound	1.04

Mixtures

For phase I, eight mixtures were used. Of these eight mixtures, only three were used in phase II. Each mixture was produced using the mix design provided by WYDOT. Mixtures composed of the limestone aggregate were produced with 5.5 percent asphalt. The granite aggregate mixtures used 5.7 percent asphalt. The theoretical maximum specific gravity and the maximum density were needed for each mixture type to determine the percent air voids of compacted specimens. AASHTO T209-94 was used as described in section 3.2.4 to determine the theoretical maximum specific gravity and to determine the maximum density shown in Table 4.2.

Table 4.2 Theoretical Maximum Specific Gravity and Maximum Density for Mixtures.

Mixture Type	Theoretical Maximum Specific Gravity	Maximum Density
Limestone + AC-10	2.45	152.9
Limestone + AC-10 (AGED)	2.45	152.9
Limestone + AC-10 + Lime	2.46	153.4
Limestone + AC-10 + Model Compound	2.45	153.7
Granite + AC-10	2.45	152.8
Granite + AC-10 (AGED)	2.45	152.8
Granite + AC-10 + Lime	2.44	152.4
Granite + AC-10 + Model Compound	2.44	152.3

Production of Cores

Using the Gyratory Compactor, samples were produced for phase I and phase II. A total of 128 cores were tested in phase I of the research. Phase I samples were to have 7 percent air voids and a 4 in. diameter by 2.5 in. height. A total of 36 cores were tested in phase II of the research. Phase II samples were 6 in. diameter by 3 in. height at 4 and 7 percent air voids.

Phase I Cores

Phase I samples were produced in batches of 10 cores. Once compacted in the Gyratory Compactor, the percent air voids of each core were determined using AASHTO T-166 as described in section 3.2.6. Twenty-four hours after determining the percent air voids for each core, the height and the diameter were measured. The data for the cores of phase I are summarized in Appendix B. All of the cores listed were not used in the procedure. Some of the cores were not within the air void limits and the others were extra.

Phase II Cores

The cores for phase II were produced as needed in batches of four or less. Once compacted in the Gyratory Compactor, the percent air voids of each core were determined using AASHTO T-166 as described in section 3.2.6. The data for each of the cores used in Phase II are given in Appendix C.

Indirect Tensile Test

The Indirect Tensile Test as described in section 3.2.9 was performed on each core in Phase I. After the Resilient Modulus Test was performed on each core, they were placed in a 77°F (25°C) water bath for two hours. Steel loading strips were used in the Soiltest machine to test the cores. A typical sample after being fractured in the Soiltest machine is shown on Figure 4.3. Table 4.3 shows the tensile strength ratio (TSR) values for the cores tested by mixture type and number of freeze-thaw cycles. Figure 4.4 shows the indirect tensile strength values obtained for limestone plus AC-10 samples. The indirect tensile strength values for the remainder of the cores tested are summarized in Appendix D.

Figure 4.3 A Fractured Soiltest Core.

Table 4.3 Average TSR Values for Cores in Phase I.

Mixture Type	Number of Freeze Thaw Cycles								
	0	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**15**
Limestone + AC-10	100	86	79	60	50	46	53	---	---
Limestone + AC-10 (Aged)	100	96	93	88	69	62	76	62	---
Limestone + AC-10 + Lime	100	90	90	92	85	76	89	---	81
Limestone + AC-10 + Model Compound	100	84	86	54	44	46	---	---	---
Granite + AC-10	100	80	52	46	---	---	---	---	---
Granite + AC-10 (Aged)	100	84	59	---	---	---	---	---	---
Granite + AC-10 + Lime	100	97	96	80	99	82	93	---	85
Granite + AC-10 + Model Compound	100	94	64	---	---	---	---	---	---

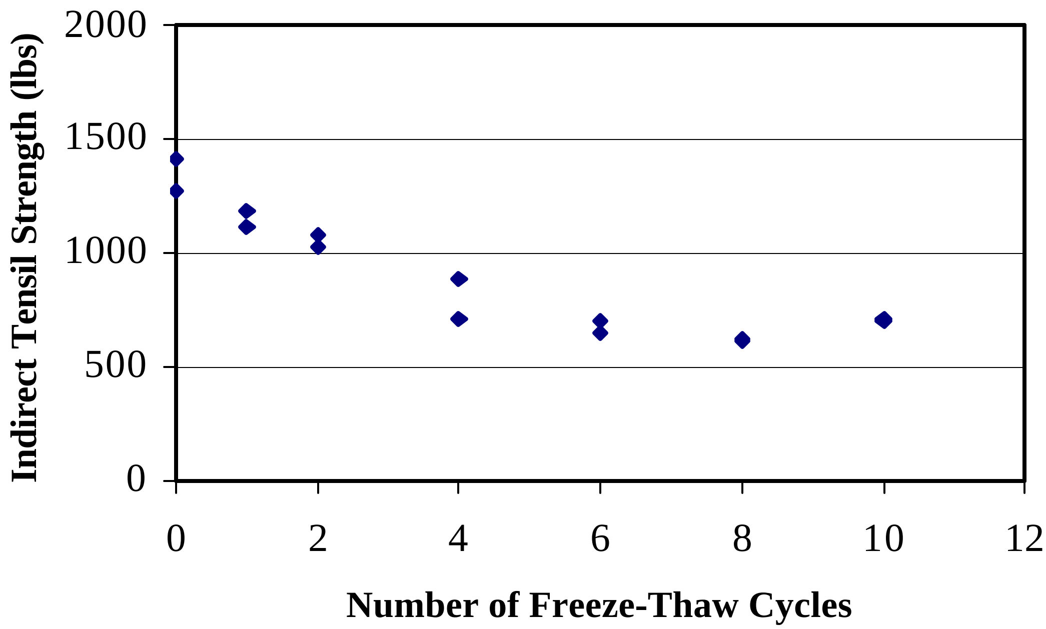

Figure 4.4 Indirect Tensile Strength for Limestone Plus AC-10.

Georgia Loaded Wheel Test

The cores from Phase II were tested for rut depth in the GLWT. The rut depth was measured after 1,000, 4,000 and 8,000 cycles in the GLWT for each core. Table 4.4 summarizes rut depths measured after 8,000 cycles for each core. The measured rut depths for each core are shown in Appendix C. Cores were heated in the GLWT for four hours before the test was run for the control and saturated cores. Cores exposed to one freeze thaw cycle were saturated and cycled before being tested in the GLWT. A typical core after testing in the GLWT is shown in Figure 4.5. The percent saturation for the cores that were cycled initially was measured to confirm that it was between 55 percent and 80 percent. The percent saturation also was measured after performing the GLWT for the first few cores that were tested. However, amounts of mixture separated from the core effected the percent saturation calculation. The percent saturation of the core after the GLWT was no longer collected after this trend was noticed.

Figure 4.5 A Typical Core after Testing in the GLWT.

Table 4.4 Measured Rut Depths After 8,000 Cycles.

Core #	Conditioning	Percent Air Voids	Asphalt Type	Average Rut Depth (in.)	Rut Depth (in.)		
					LOC	Center	ROC
7	0	7	AC-10	0.239	0.276	0.2695	0.1715
8	0	7	AC-10	0.221	0.2495	0.2825	0.1315
12	Sat.	7	AC-10	0.210	0.205	0.203	0.2225
13	Sat.	7	AC-10	0.179	0.19	0.205	0.141
23	1	7	AC-10	0.257	0.194	0.215	0.361
24	1	7	AC-10	0.263	0.345	0.202	0.241
25	0	7	Aged	0.141	0.138	0.143	0.1425
27	0	7	Aged	0.110	0.1075	0.092	0.1305
29	1	7	Aged	0.196	0.2165	0.1605	0.2115
30	1	7	Aged	0.201	0.287	0.1405	0.175
31	Sat.	7	Aged	0.221	0.195	0.2215	0.2455
32	0	4	AC-10	0.148	0.174	0.129	0.1405
34	Sat.	4	AC-10	0.099	0.078	0.095	0.123
37	1	4	AC-10	0.089	0.137	0.044	0.0865
38	0	4	Aged	0.073	0.082	0.048	0.0875
39	0	4	Aged	0.072	0.0735	0.0635	0.079
40	Sat.	4	Aged	0.061	0.0575	0.0503	0.0745
41	Sat.	4	Aged	0.079	0.0915	0.059	0.087
42	1	4	Aged	0.077	0.1155	0.057	0.0595
43	1	4	Aged	0.068	0.059	0.05	0.0945
44	Sat.	7	Aged	0.188	0.201	0.165	0.1965
50	0	4	Lime	0.171	0.186	0.1645	0.1635
51	0	4	Lime	0.208	0.1995	0.199	0.224
52	0	7	Lime	0.300	0.304	0.341	0.256
54	Sat.	4	Lime	0.225	0.193	0.225	0.256
55	Sat.	4	Lime	0.168	0.187	0.1475	0.168
56	1	4	Lime	0.143	0.1565	0.147	0.125
57	1	4	Lime	0.187	0.214	0.175	0.173
59	Sat.	7	Lime	0.272	0.257	0.269	0.289
60	1	7	Lime	0.237	0.208	0.239	0.2625
61	1	7	Lime	0.246	0.273	0.279	0.187
62	1	4	AC-10	0.134	0.143	0.142	0.116
63	0	4	AC-10	0.118	0.0615	0.1545	0.1375
64	Sat.	4	AC-10	0.113	0.143	0.09	0.107
66	Sat.	7	AC-10	0.191	0.193	0.1905	0.1895
67	0	7	AC-10	0.324	0.2655	0.3815	0.3245

Visual observations were made of the cores during the GLWT. Cores that were saturated would lose material on the hose of the GLWT. Material would rub off or would crumble off depending on the mixture type and the air void content. Cores that were at 7 percent air voids would tend to crumble under these conditions. Also, they would have deeper ruts on the left of center reading and the right of center reading than the center of the core reading.

Chapter Summary

In this chapter, data collection procedures and the results were presented. In Phase I the TSR values were used to evaluate the performance of eight mixtures with respect to moisture damage. In Phase II, the Georgia Loaded Wheel Tester was used to predict moisture resistance of three mixtures. In the following chapter, a statistical analysis of the results is performed.

CHAPTER 5

ANALYSIS OF DATA

Introduction

Following the laboratory procedures and data collection described in the previous chapters, a statistical analysis was performed on tensile strength ratio (TSR) results from phase I and the Georgia Loaded Wheel Tester (GLWT) results from phase II. The analysis for phase I was performed using linear regression. Phase II analysis was performed using an Analysis of Variance (ANOVA) assisted by Interaction Plots.

This chapter describes the statistical analysis used to evaluate data from phase I and phase II of this research. Complete sets of analysis can be found in Appendix D through Appendix G. Analyses were performed using MINITAB release 13.

Statistical Analysis of Tensile Strength Ratio Data

Initial observation of the graphs in Appendix E of the TSR results indicates that the strength of each of the mixtures decreases as the number of cycles is increased. A summary of the TSR values was given in Table 4.3. The failure point for TSR used in this analysis was 70 percent. Limestone aggregate mixtures with the AC-10 and the AC-10 with model compound reached failure between two and four freeze-thaw cycles. The granite aggregate mixtures with the same asphalt and additive failed after one freeze-thaw cycle. The aged mixture with limestone failed after four freeze-thaw cycles, while the granite aggregate failed after only one cycle. Both mixtures utilizing the lime additive did not reach failure. However, the mixtures with lime additive showed variability in strength, when referencing the indirect tensile strength graphs. The granite aggregate reached failure quite quickly in comparison to the limestone aggregate.

The relationship of the asphalt and additives to performance of the mixtures, with respect to moisture susceptibility, was analyzed. Linear regression was performed on the TSR values obtained from each of the eight mixtures. Minitab was used to calculate the slope of the line for each of the eight mixtures, as well as the standard deviation of regression and the degrees of freedom. Results of the analysis are shown in Appendix F. Table 5.1 summarizes the analysis.

Table 5.1 Linear Regression of TSR Data.

Mixture	Slope	Degree of Freedom	Sd for Regression
Limestone + AC–10	-6.4163	5	12.36
Granite + AC-10	-15.81	2	13.62
Limestone + Aged AC-10	-3.4301	6	7.52
Granite + Aged AC-10	-19.6	1	4.025
Limestone + Lime AC-10	-1.657	6	7.332
Granite + Lime AC-10	-1.2018	6	7.957
Limestone + MC AC-10	-8.2314	4	10.27
Granite + MC AC-10	-15.6	1	10.73

A regression model was developed, which the slope for each mixture was used, but the spread about the line was assumed to be the same for each asphalt type. Regression was forced to give an expected TSR value of 100 percent at 0 cycles. From the linear regression, it is notable that the standard deviation for regression generally is similar for asphalt type pairs. Therefore, mixtures were grouped into four pairs by asphalt type for use in the regression model. The model used is

$$Y = \beta_1 X + \beta_2 XW + \text{error}$$

where $\beta 1$ and $\beta 2$ are components of the slopes of the lines, X is the number of cycles the core endured, and W is a dummy variable indicating the aggregate type. W was defined as either a 1 for limestone aggregate or a 0 for granite aggregate. For limestone aggregate, the equation becomes

$$Y = (\beta_1 + \beta_2)X + \text{error}$$

and for granite aggregate the equation becomes

$$Y = \beta_1 X + \text{error}.$$

Thus, β_2 is the difference measured between the slopes. To determine whether strength decreased at the same rate for granite as for limestone, the null hypothesis is $\beta_2 = 0$ (the slopes are the same), and the alternative is that $\beta_2 \neq 0$. The level of significance used is 0.0125. This is the Bonferroni adjusted significance level to give a simultaneous significance level of 0.05 for all tests. Results of the analysis are shown in Appendix G. Table 5.2 summarizes results from this analysis.

Table 5.2 Linear Regression of TSR Data using the Regression Model.

Asphalt Type	b_1	b_2	T for b_2	Degrees of Freedom	P- value
AC-10	-15.81	9.393	3.23	7	0.0144
Aged AC-10	-19.6	16.17	5.04	7	0.0014
AC-10 + Lime	-1.202	-0.406	-0.79	10	0.4475
AC-10 + MC	-15.6	7.369	1.56	5	0.1796

Regression data for the AC-10 asphalt shows that at a significance level of 0.0125 there is no difference in the slopes of lines for mixtures using this model. This criterion is quite conservative.

However, if the significance level of 0.05 were used it would be judged to be significantly different. The value 3.23 is close to the rejection value of 3.335. Also, the observed difference in slopes (-15.81 versus -6.42) is substantial.

The aged AC-10 has an observed difference in slopes for the limestone and granite aggregates of 16.17. Also, the significance level value of 3.335 is less than the T-value of 5.04. Therefore, these slopes are definitely different.

The lime plus AC-10 pair produced a T-value of -0.79, which is less than 3.038. The difference in slopes for the lime asphalt pair is quite small (-1.202 versus -1.608), indicating that the slopes are the same for this pair.

The group with the model compound and the AC-10 also showed no significant difference in the slopes (1.56 is less than 3.810). The actual size of the difference in slopes (-15.6 versus -8.231) is substantial and failure to note difference may be due to the small sample pool.

From the analysis, it is evident that the aggregate and the asphalt type affect moisture susceptibility of the mixture. The granite aggregate reached failure quickly in comparison to the limestone aggregate. In the case where lime is added to the asphalt, the aggregate type is less of a factor in moisture susceptibility of the mixture.

Statistical Analysis of Georgia Loaded Wheel Tester Data

Data from the GLWT were analyzed using an Analysis of Variance (ANOVA). Three factors, without interacting, were analyzed for their significance. Those three factors are conditioning of the core, air void content of the cores, and the asphalt type. Rut depth was measured in three locations across the top of the core. These three measurements were averaged to give a single response variable for the analysis. Averages were used because saturated cores and cores that were cycled once, developed deeper rut depths on the sides of the core, while the center measurement was consistent with the control cores. A summary of the results is displayed in Table 5.3. The results in Table 5.3 indicate that the amount of air voids and type of asphalt contribute significantly to the performance of the cores in the GLWT. Conditioning of the cores does not contribute to performance of the cores in the GLWT.

Table 5.3 ANOVA Results for GLWT Data.

Source	Degrees of Freedom	F	p-value
Conditioning	2	0.27	0.766
Air Voids	1	81.76	0.000
Asphalt Type	2	24.68	0.000
Error	30	---	---

Interaction Plots for Georgia Loaded Wheel Tester Data

Several interaction diagrams were utilized. It was not evident from the ANOVA alone whether conditioning was significant to performance of the cores because of the possibility of interactions. The interaction plot shown in Figure 5.1 illustrates the mean rut depth after 8,000 cycles in the GLWT verses asphalt type and the percent air voids. For the cores produced at 4 percent air voids, there is no significant difference in the amount of rutting for different conditionings. At 7 percent air voids with aged asphalt, the control cores did not rut as much as did the other cores. Otherwise the cores with 7 percent air voids performed with variable results. The 7 percent cores with aged asphalt performed in a manner that was expected. This expectation was due to rapid failure of the granite aggregates in the TSR testing and because the conditioned cores were expected to rut more significantly than the control cores. However, for the AC-10 and the AC-10 plus lime the control cores suffered slightly more rutting than the conditioned cores.

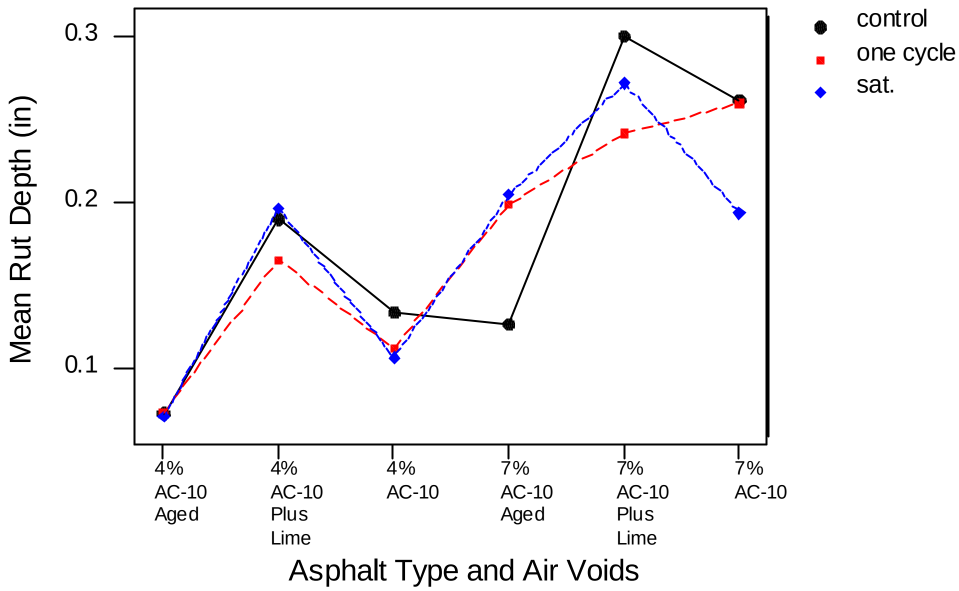

Figure 5.1 Interaction Plot of Rut Depth Means versus Percent Air Voids and Asphalt Type for the Different Conditionings.

A second interaction plot is shown in Figure 5.2. This interaction plot shows mean rut depth versus the percent air voids for different conditionings. It verifies that the cores with 7 percent air voids developed a higher mean rut depth than the cores at 4 percent air voids. Overall, after one freeze-thaw cycle the cores at 7 percent air voids performed worse than did the cores at 4 percent air voids.

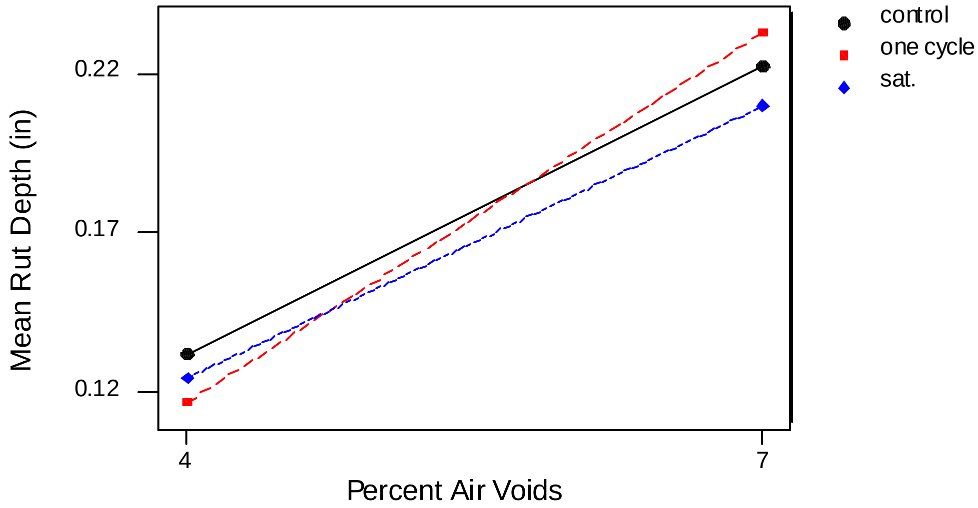

Figure 5.2 Interaction Plot of Rut Depth Means versus the Percent Air Voids for the Different Conditionings.

The interaction plot shown in Figure 5.3 was developed using data for the AC-10 cores and the Aged AC-10 cores. Cores with lime were omitted because of problems with data quality and confusion in interpretation. At 4 percent air voids conditioning of the core contributed less to the amount of rutting experienced by the Aged cores than the AC-10 cores. The 7 percent data indicates that the control and one-cycle cores reacted similarly to the 4 percent cores but with more variable results. While the saturated core performance at 7 percent air voids was approximately the same for aged and un-aged types.

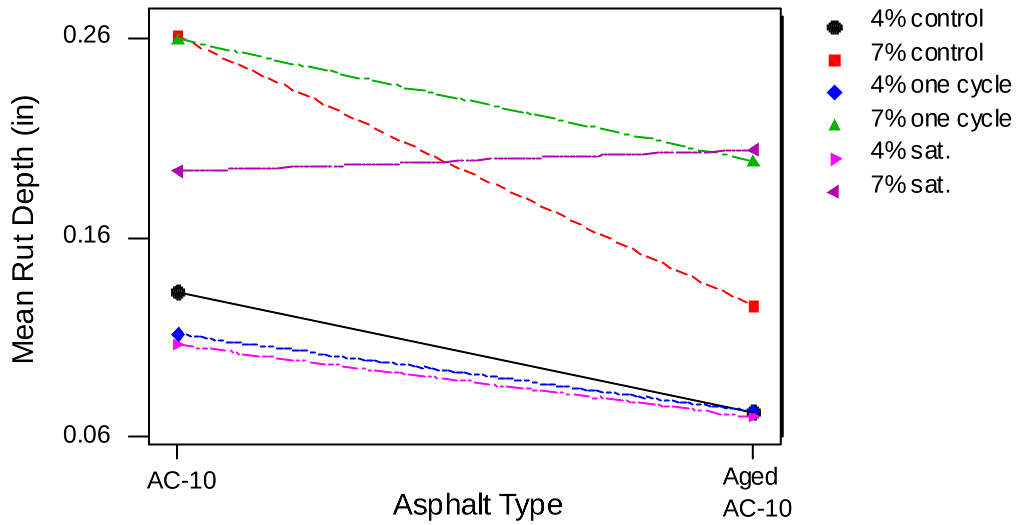

Figure 5.3 Interaction Plot of Rut Depth Means versus Asphalt Type for the Combined Air Void and Conditioning Treatments.

In cases where the conditioned cores suffered less rutting than the control cores, questions arise. A poor aggregate was utilized in production of the cores for the GLWT. Therefore, failure was expected to be attained by these cores after one freeze-thaw cycle. A possible explanation for performance of the conditioned cores in the GLWT may be the added pore water pressure maintained in the conditioned cores during testing. Water was kept in the core by a water cap causing pressure acting against the pressure of the hose on the core. Also, variability in the amount of saturation of the cores may have caused variation in the performance of saturated cores, and the cores that were subject to one freeze-thaw cycle.

During testing, observations were made of the cores and pressurized hose in the GLWT. Cores that were conditioned tended to have pieces of aggregate separate from the compacted core. Also, after removing cores from the 140°F (60°C) water bath during the freeze-thaw cycle, the cores would be soft and would deform and/or lose pieces of aggregate from the edges. During the GLWT of the conditioned cores, material from the cores would deposit on the pressurized hose.

Chapter Summary

A statistical analysis was performed on the TSR and GLWT test results. The analysis was to determine how TSR values varied after freeze-thaw cycling and if the GLWT could be used to predict moisture susceptibility of HMA.

The statistical analysis performed on the TSR data found that two of the four asphalt mixtures displayed a significantly different slope variation between limestone and granite. The two asphalt mixtures that displayed similar variations about the slope were the AC-10 plus lime and the AC-10 plus model compound. Two that showed a difference were the AC-10 and the aged AC-10. Note, however, that the AC-10 plus model compound data were fairly sparse, and actual differences could well exist. Therefore, both the asphalt additive and the aggregate type affected moisture susceptibility of the mixtures.

The analysis performed on the GLWT results found that the percent air voids and the asphalt type affected performance of the mixture in the GLWT. The conditioning only affected the performance of the 7 percent aged AC-10 mixture. From the Analysis of Variance and the Interaction Plots, it is evident that the 4 percent air void mixtures sustained less rutting than did the 7 percent air void mixtures. Also, the aged AC-10 mixtures generally sustained less rutting than did the AC-10 mixtures. The type of conditioning did not matter for the 4 percent air voids, and its effect, if any, was ambiguous, for 7 percent air voids.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Summary

This research project utilized laboratory evaluations to study the effects of freeze-thaw cycling on the tensile strength of eight Hot Mix Asphalt (HMA) mixtures and to determine if the Georgia Loaded Wheel Tester (GLWT) could be used to measure moisture susceptibility of HMA mixtures. The evaluation involved eight HMA mixtures from combinations of two aggregate types and four asphalt-additive-aging possibilities. Laboratory testing was accomplished in the first phase with the production of 2.5 in. by 4 in. cores cycled and tested for their indirect tensile strength. The second phase was accomplished using 3- by 6-inch cores that were conditioned and tested for rutting using the GLWT. Finally, a statistical analysis was performed to determine if performance of the various mixtures was significantly different in groups of asphalt types and to determine if the GLWT was a viable measurement tool for moisture susceptibility.

Conclusions

Based on observations and testing performed in this study, the following conclusions were made:

1. The cores were conditioned using a freeze-thaw procedure. After the freeze–thaw conditioning was performed, tensile strength of the eight HMA mixtures decreased.
2. The tensile strength of the cores produced using the granite aggregate reached failure within four freeze-thaw cycles. Cores produced with the limestone aggregate took significantly more cycles to reach failure. Thus, tensile strength of the granite aggregate reached failure more rapidly than the limestone aggregate.

3. The asphalt and the aggregate type were shown to have an effect on the moisture susceptibility of the HMA mixtures. Mixtures produced using the lime additive showed less of an effect due to the aggregate type than did the other HMA mixtures.
4. The second phase of testing indicated that the 4 percent air void mixtures sustained less rutting than did 7 percent air void mixtures. The percent air voids and the asphalt type affected performance of the cores in the GLWT. Conditioning of the cores did not contribute significantly to performance of the cores in the GLWT.
5. No evidence suggested that saturating and freeze-thaw conditionings affected performance of the cores in the GLWT. Therefore, testing the cores in a saturated state confined in a swim cap was not an effective method for measuring for moisture damage.

Recommendations

1. Cores with the lime additive should be produced and then tested again for their indirect tensile strength. Testing should be performed to make sure the additive was distributed equally between the cores. This is due to the lack of a consistent downward trend in the TSR data.
2. Further research should be performed to study effectiveness of the GLWT at measuring moisture susceptibility. The testing procedure that was utilized was not effective. Therefore, a testing procedure that addresses saturation of the cores should be designed.
3. Once a procedure is found that can evaluate the moisture susceptibility of HMA using the GLWT, the experimental design should make a comparison between HMA mixtures in the field and the laboratory produced cores to check effectiveness of the procedure.

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APPENDIX A

Core Production Procedure

The following are detailed steps followed in the production of the cores.

1. Weigh out aggregate for 5-10 specimens,
2. Place aggregate and asphalt in 275°F (135°C) oven for 2 hours.
3. Remove the hot aggregate, place it on a scale, and add the proper weight of asphalt cement to obtain the desired asphalt content.
4. Mix asphalt cement and aggregate until all the aggregate is evenly coated.
5. Place mixtures in separate containers to cure at ambient temperature for 2 hours.
6. Place in 140°F (60°C) oven for 16 hours.
7. Increase oven temperature to 275°F (135°C) for 2 hours; meanwhile preheat the mold and lower puck.
8. Switch on the Gyrator Compactor and preheat it for five minutes.
9. Check the parameters of the Gyrator Compactor to comply with the desired specimen height.
10. Place a paper disc into an assembled, preheated Gyrator mold and pour in loose HMA. Spade the mixture with a heated spatula to level. Place another paper disc on the top of the mixture in the mold.
11. Place the mold filled with HMA into the Gyratory Compactor.
12. Compact the HMA into a core.
13. Remove the paper filters from the top and bottom of the specimens. Cool the specimens and extrude from the mold using a jack. Place identification marks on each specimen with an alphanumeric code using a grease pencil.
14. Allow specimens to sit at ambient temperature for 2 hours.
15. Determine the bulk specific gravity for each specimen.
16. Let specimens stand at ambient temperature for 24 hours.
17. Measure height in 4 difference places and diameter in 3 different places on each specimen.

APPENDIX B

Phase I Core Data

Core #	Aggregate Type	Asphalt Type	# of Gyrations	Bulk Density	Max. Density	Density	Percent Air Voids	Avg. Height (mm)	Avg. Diameter (mm)
14	Granite	AC-10	46	2.34	145.74	95.37	4.63	---	---
14	Granite	AC-10	46	2.34	145.74	95.37	4.63	---	---
15	Granite	AC-10	32	2.32	144.69	94.69	5.31	---	---
15	Granite	AC-10	32	2.32	144.69	94.69	5.31	---	---
16	Granite	AC-10	46	2.35	146.55	95.90	4.10	---	---
16	Granite	AC-10	46	2.35	146.55	95.90	4.10	---	---
17	Granite	AC-10	35	2.33	145.31	95.09	4.91	---	---
17	Granite	AC-10	35	2.33	145.31	95.09	4.91	---	---
20	Limestone	AC-10	31	2.28	142.50	93.21	6.79	64.1	100.0
21	Limestone	AC-10	29	2.31	143.86	94.11	5.89	64.1	99.9
22	Limestone	AC-10	31	2.29	143.00	93.54	6.46	64.1	100.0
23	Limestone	AC-10	32	2.30	143.80	94.07	5.93	64.1	100.0
24	Limestone	AC-10	30	2.27	141.93	92.84	7.16	64.0	100.0
25	Limestone	AC-10	33	2.29	142.99	93.53	6.47	64.0	100.0
26	Limestone	AC-10	30	2.27	141.93	92.84	7.16	64.0	100.0
27	Limestone	AC-10	37	2.26	141.29	92.42	7.58	64.1	100.0
28	Limestone	AC-10	29	2.24	139.50	91.25	8.75	64.5	100.0
29	Limestone	AC-10	34	2.30	143.50	93.87	6.13	64.0	100.0
30	Limestone	AC-10	29	2.28	142.01	92.90	7.10	64.1	100.0
31	Limestone	AC-10	33	2.28	142.14	92.98	7.02	64.2	100.0
32	Limestone	AC-10	36	2.29	143.07	93.59	6.41	64.1	100.0
33	Limestone	AC-10	36	2.27	141.63	92.65	7.35	64.0	100.1
34	Limestone	AC-10	37	2.27	141.72	92.71	7.29	64.1	100.0
35	Limestone	AC-10	37	2.28	142.29	93.08	6.92	64.3	100.0
36	Limestone	AC-10	33	2.28	142.16	92.99	7.01	64.0	100.0
37	Limestone	AC-10	33	2.26	140.89	92.16	7.84	64.1	100.0
38	Limestone	AC-10	31	2.28	142.54	93.24	6.76	64.0	100.0
39	Limestone	AC-10	31	2.27	141.61	92.63	7.37	64.1	100.0
40	Limestone	AC-10	32	2.28	142.35	93.12	6.88	64.0	100.0
41	Limestone	AC-10	34	2.28	142.38	93.14	6.86	64.2	100.0
42	Limestone	AC-10	39	2.29	142.75	93.38	6.62	64.0	100.0
43	Limestone	AC-10	32	2.29	142.71	93.35	6.65	64.0	100.0
44	Limestone	AC-10	37	2.28	142.05	92.92	7.08	63.5	100.1
45	Limestone	AC-10	34	2.28	142.35	93.12	6.88	63.5	100.4
46	Limestone	AC-10	35	2.28	142.07	92.93	7.07	63.6	100.0

47	Limestone	AC-10	49	2.31	144.36	94.43	5.57	63.6	100.0
48	Limestone	AC-10	33	2.27	141.78	92.75	7.25	63.8	100.0
50	Granite	AC-10	22	2.26	141.28	92.45	7.55	64.0	100.0
50	Granite	AC-10	22	2.26	141.28	92.45	7.55	64.0	100.0
51	Granite	AC-10	20	2.27	141.49	92.59	7.41	63.8	100.0
51	Granite	AC-10	20	2.27	141.49	92.59	7.41	63.8	100.0
52	Granite	AC-10	23	2.27	141.64	92.69	7.31	64.3	100.0
52	Granite	AC-10	23	2.27	141.64	92.69	7.31	64.3	100.0
53	Granite	AC-10	27	2.28	142.55	93.29	6.71	64.0	100.0
53	Granite	AC-10	27	2.28	142.55	93.29	6.71	64.0	100.0
54	Granite	AC-10	24	2.28	142.13	93.01	6.99	64.1	100.1
54	Granite	AC-10	24	2.28	142.13	93.01	6.99	64.1	100.1
55	Granite	AC-10	21	2.26	141.25	92.43	7.57	64.0	100.0
55	Granite	AC-10	21	2.26	141.25	92.43	7.57	64.0	100.0
56	Granite	AC-10	27	2.27	141.73	92.75	7.25	64.1	100.0
56	Granite	AC-10	27	2.27	141.73	92.75	7.25	64.1	100.0
57	Granite	AC-10	23	2.28	142.45	93.22	6.78	64.0	100.0
57	Granite	AC-10	23	2.28	142.45	93.22	6.78	64.0	100.0
58	Granite	AC-10	23	2.26	141.08	92.32	7.68	64.0	99.9
58	Granite	AC-10	23	2.26	141.08	92.32	7.68	64.0	99.9
59	Granite	AC-10	27	2.28	142.35	93.15	6.85	64.0	100.0
59	Granite	AC-10	27	2.28	142.35	93.15	6.85	64.0	100.0
60	Granite	AC-10	26	2.28	142.32	93.14	6.86	64.1	100.0
60	Granite	AC-10	26	2.28	142.32	93.14	6.86	64.1	100.0
61	Granite	AC-10	24	2.29	142.98	93.57	6.43	64.1	100.0
61	Granite	AC-10	24	2.29	142.98	93.57	6.43	64.1	100.0
62	Granite	AC-10	29	2.29	142.66	93.36	6.64	64.0	100.0
62	Granite	AC-10	29	2.29	142.66	93.36	6.64	64.0	100.0
63	Granite	AC-10	26	2.32	144.62	94.64	5.36	64.1	100.0
63	Granite	AC-10	26	2.32	144.62	94.64	5.36	64.1	100.0
64	Granite	AC-10	31	2.30	143.83	94.12	5.88	64.0	100.0
64	Granite	AC-10	31	2.30	143.83	94.12	5.88	64.0	100.0
65	Granite	AC-10	27	2.27	141.60	92.67	7.33	64.0	100.0
65	Granite	AC-10	27	2.27	141.60	92.67	7.33	64.0	100.0
66	Granite	AC-10	25	2.31	144.19	94.36	5.64	64.0	100.0
66	Granite	AC-10	25	2.31	144.19	94.36	5.64	64.0	100.0
67	Granite	AC-10	27	2.29	142.97	93.56	6.44	64.0	100.0
67	Granite	AC-10	27	2.29	142.97	93.56	6.44	64.0	100.0
68	Granite	AC-10	27	2.27	141.85	92.83	7.17	64.0	100.0

68	Granite	AC-10	27	2.27	141.85	92.83	7.17	64.0	100.0
69	Granite	AC-10	23	2.29	142.64	93.34	6.66	64.1	100.0
69	Granite	AC-10	23	2.29	142.64	93.34	6.66	64.1	100.0
70	Granite	AC-10	23	2.29	142.79	93.44	6.56	64.1	100.0
70	Granite	AC-10	23	2.29	142.79	93.44	6.56	64.1	100.0
71	Granite	AC-10	23	2.29	142.63	93.34	6.66	64.0	100.0
71	Granite	AC-10	23	2.29	142.63	93.34	6.66	64.0	100.0
72	Granite	AC-10	24	2.29	142.90	93.51	6.49	64.1	100.0
72	Granite	AC-10	24	2.29	142.90	93.51	6.49	64.1	100.0
73	Granite	AC-10	24	2.27	141.63	92.68	7.32	64.0	100.0
73	Granite	AC-10	24	2.27	141.63	92.68	7.32	64.0	100.0
74	Granite	AC-10	26	2.28	142.33	93.14	6.86	64.0	100.0
74	Granite	AC-10	26	2.28	142.33	93.14	6.86	64.0	100.0
75	Granite	AC-10	24	2.29	142.95	93.55	6.45	64.0	100.0
75	Granite	AC-10	24	2.29	142.95	93.55	6.45	64.0	100.0
76	Granite	AC-10	27	2.28	142.25	93.09	6.91	64.0	100.0
76	Granite	AC-10	27	2.28	142.25	93.09	6.91	64.0	100.0
108	Limestone	Aged	35	2.22	138.54	90.63	9.37	64.1	101.7
109	Limestone	Aged	31	2.27	141.50	92.56	7.44	63.8	100.3
110	Limestone	Aged	33	2.27	141.94	92.84	7.16	63.9	100.3
111	Limestone	Aged	34	2.28	142.40	93.15	6.85	64.0	100.1
112	Limestone	Aged	33	2.28	142.41	93.16	6.84	63.6	100.0
113	Limestone	Aged	34	2.29	142.76	93.39	6.61	63.7	100.0
114	Limestone	Aged	33	2.29	143.19	93.66	6.34	63.5	100.0
115	Limestone	Aged	41	2.29	143.17	93.65	6.35	63.6	100.0
116	Limestone	Aged	37	2.30	143.59	93.93	6.07	63.5	100.0
117	Limestone	Aged	28	2.26	140.98	92.22	7.78	64.1	101.7
118	Limestone	Aged	33	2.27	141.45	92.52	7.48	63.8	100.3
119	Limestone	Aged	34	2.27	141.34	92.46	7.54	63.9	100.3
120	Limestone	Aged	32	2.27	141.64	92.65	7.35	64.0	100.1
121	Limestone	Aged	29	2.26	141.24	92.39	7.61	63.6	100.0
122	Limestone	Aged	31	2.28	142.26	93.06	6.94	63.7	100.0
123	Limestone	Aged	31	2.27	141.74	92.72	7.28	63.5	100.0
124	Limestone	Aged	32	2.27	141.66	92.66	7.34	63.5	100.0
125	Limestone	Aged	37	2.27	141.47	92.54	7.46	63.5	100.0
126	Limestone	Aged	36	2.26	141.06	92.27	7.73	64.0	100.0
127	Limestone	Aged	33	2.26	140.73	92.06	7.94	64.2	100.0
128	Limestone	Aged	34	2.24	139.92	91.53	8.47	64.3	100.0
129	Limestone	Aged	34	2.26	140.79	92.09	7.91	64.0	100.1

130	Limestone	Aged	34	2.25	140.69	92.03	7.97	64.0	100.0
131	Limestone	Aged	33	2.27	141.45	92.53	7.47	64.0	100.0
132	Limestone	Aged	35	2.29	142.62	93.30	6.70	64.0	100.0
133	Limestone	Aged	35	2.26	140.74	92.07	7.93	64.1	100.1
134	Limestone	Aged	32	2.27	141.43	92.51	7.49	64.0	100.0
135	Limestone	Aged	35	2.28	142.21	93.02	6.98	63.9	100.0
200	Granite	Lime	18	2.30	143.34	94.07	5.93	63.8	100.0
200	Granite	Lime	18	2.30	143.34	94.07	5.93	63.8	100.0
201	Granite	Lime	17	2.31	144.02	94.52	5.48	63.9	100.0
201	Granite	Lime	17	2.31	144.02	94.52	5.48	63.9	100.0
202	Granite	Lime	20	2.30	143.56	94.21	5.79	64.0	100.0
202	Granite	Lime	20	2.30	143.56	94.21	5.79	64.0	100.0
203	Granite	Lime	23	2.31	144.20	94.64	5.36	63.9	100.0
203	Granite	Lime	23	2.31	144.20	94.64	5.36	63.9	100.0
204	Granite	Lime	19	2.30	143.56	94.21	5.79	63.9	100.0
204	Granite	Lime	19	2.30	143.56	94.21	5.79	63.9	100.0
205	Granite	Lime	14	2.28	142.31	93.40	6.60	63.5	100.0
205	Granite	Lime	14	2.28	142.31	93.40	6.60	63.5	100.0
206	Granite	Lime	18	2.29	142.82	93.73	6.27	63.9	100.0
206	Granite	Lime	18	2.29	142.82	93.73	6.27	63.9	100.0
207	Granite	Lime	14	2.27	141.66	92.97	7.03	63.9	100.0
207	Granite	Lime	14	2.27	141.66	92.97	7.03	63.9	100.0
208	Granite	Lime	18	2.29	142.83	93.74	6.26	63.9	100.0
208	Granite	Lime	18	2.29	142.83	93.74	6.26	63.9	100.0
209	Granite	Lime	14	2.28	142.18	93.31	6.69	63.8	100.0
209	Granite	Lime	14	2.28	142.18	93.31	6.69	63.8	100.0
210	Granite	Lime	16	2.29	143.20	93.98	6.02	64.0	100.0
210	Granite	Lime	16	2.29	143.20	93.98	6.02	64.0	100.0
211	Granite	Lime	13	2.27	141.79	93.05	6.95	63.8	100.0
211	Granite	Lime	13	2.27	141.79	93.05	6.95	63.8	100.0
212	Granite	Lime	14	2.29	142.71	93.65	6.35	64.0	100.0
212	Granite	Lime	14	2.29	142.71	93.65	6.35	64.0	100.0
213	Granite	Lime	18	2.30	143.54	94.20	5.80	63.8	100.0
213	Granite	Lime	18	2.30	143.54	94.20	5.80	63.8	100.0
214	Granite	Lime	16	2.28	142.28	93.37	6.63	63.8	100.0
214	Granite	Lime	16	2.28	142.28	93.37	6.63	63.8	100.0
215	Granite	Lime	48	2.38	148.24	97.28	2.72	63.9	100.0
215	Granite	Lime	48	2.38	148.24	97.28	2.72	63.9	100.0
216	Granite	Lime	16	2.29	143.18	93.97	6.03	63.9	100.0

216	Granite	Lime	16	2.29	143.18	93.97	6.03	63.9	100.0
217	Granite	Lime	15	2.30	143.31	94.05	5.95	64.0	100.0
217	Granite	Lime	15	2.30	143.31	94.05	5.95	64.0	100.0
218	Granite	Lime	17	2.32	144.64	94.92	5.08	63.9	100.0
218	Granite	Lime	17	2.32	144.64	94.92	5.08	63.9	100.0
219	Granite	Lime	12	2.28	142.02	93.21	6.79	64.0	100.0
219	Granite	Lime	12	2.28	142.02	93.21	6.79	64.0	100.0
220	Granite	Lime	15	2.25	140.36	92.11	7.89	63.4	100.0
220	Granite	Lime	15	2.25	140.36	92.11	7.89	63.4	100.0
221	Granite	Lime	14	2.27	141.61	92.94	7.06	63.7	100.0
221	Granite	Lime	14	2.27	141.61	92.94	7.06	63.7	100.0
222	Granite	Lime	15	2.25	140.70	92.34	7.66	63.7	100.0
222	Granite	Lime	15	2.25	140.70	92.34	7.66	63.7	100.0
223	Granite	Lime	15	2.28	142.05	93.22	6.78	63.9	100.0
223	Granite	Lime	15	2.28	142.05	93.22	6.78	63.9	100.0
224	Granite	Lime	17	2.27	141.88	93.11	6.89	63.9	100.0
224	Granite	Lime	17	2.27	141.88	93.11	6.89	63.9	100.0
225	Granite	Lime	16	2.28	142.24	93.35	6.65	64.0	100.0
225	Granite	Lime	16	2.28	142.24	93.35	6.65	64.0	100.0
226	Granite	Lime	16	2.29	143.18	93.97	6.03	63.9	100.0
226	Granite	Lime	16	2.29	143.18	93.97	6.03	63.9	100.0
227	Granite	Lime	13	2.28	142.04	93.22	6.78	63.9	100.0
227	Granite	Lime	13	2.28	142.04	93.22	6.78	63.9	100.0
228	Granite	Lime	18	2.27	141.66	92.97	7.03	64.0	100.0
228	Granite	Lime	18	2.27	141.66	92.97	7.03	64.0	100.0
229	Granite	Lime	23	2.29	143.09	93.91	6.09	63.4	100.0
229	Granite	Lime	23	2.29	143.09	93.91	6.09	63.4	100.0
260	Limestone	Lime	24	2.26	140.76	91.74	8.26	63.9	100.0
261	Limestone	Lime	23	2.25	140.12	91.32	8.68	63.9	100.1
262	Limestone	Lime	27	2.28	142.40	92.81	7.19	64.0	100.0
263	Limestone	Lime	27	2.29	142.77	93.05	6.95	64.0	100.0
265	Limestone	Lime	35	2.28	142.38	92.79	7.21	63.9	100.0
266	Limestone	Lime	34	2.29	142.68	92.99	7.01	63.9	100.0
268	Limestone	Lime	26	2.29	142.80	93.07	6.93	63.9	100.0
269	Limestone	Lime	33	2.28	142.41	92.81	7.19	64.0	100.0
270	Limestone	Lime	31	2.30	143.66	93.63	6.37	64.0	100.0
271	Limestone	Lime	39	2.30	143.82	93.73	6.27	64.0	100.0
272	Limestone	Lime	38	2.30	143.81	93.73	6.27	64.0	100.0
273	Limestone	Lime	36	2.30	143.79	93.71	6.29	64.0	100.0

274	Limestone	Lime	32	2.30	143.48	93.51	6.49	64.0	100.0
275	Limestone	Lime	23	2.27	141.43	92.17	7.83	64.0	100.0
276	Limestone	Lime	27	2.27	141.81	92.42	7.58	64.0	100.0
277	Limestone	Lime	34	2.27	141.86	92.46	7.54	64.0	100.0
278	Limestone	Lime	30	2.27	141.71	92.35	7.65	64.0	100.0
279	Limestone	Lime	32	2.27	141.87	92.46	7.54	64.0	100.0
280	Limestone	Lime	33	2.29	143.00	93.20	6.80	64.0	100.0
281	Limestone	Lime	31	2.29	142.73	93.02	6.98	64.0	100.0
282	Limestone	Lime	30	2.29	143.15	93.29	6.71	63.9	100.0
283	Limestone	Lime	29	2.30	143.54	93.55	6.45	63.9	100.0
284	Limestone	Lime	31	2.28	142.58	92.93	7.07	63.9	100.1
300	Granite	MC	22	2.27	141.94	93.20	6.80	63.8	100.1
300	Granite	MC	22	2.27	141.94	93.20	6.80	63.8	100.1
301	Granite	MC	23	2.26	140.97	92.57	7.43	63.5	100.0
301	Granite	MC	23	2.26	140.97	92.57	7.43	63.5	100.0
302	Granite	MC	24	2.26	141.32	92.79	7.21	63.9	99.8
302	Granite	MC	24	2.26	141.32	92.79	7.21	63.9	99.8
303	Granite	MC	22	2.26	140.93	92.54	7.46	63.6	100.0
303	Granite	MC	22	2.26	140.93	92.54	7.46	63.6	100.0
304	Granite	MC	22	2.27	141.63	93.00	7.00	63.6	99.9
304	Granite	MC	22	2.27	141.63	93.00	7.00	63.6	99.9
305	Granite	MC	22	2.28	142.06	93.28	6.72	63.6	100.2
305	Granite	MC	22	2.28	142.06	93.28	6.72	63.6	100.2
306	Granite	MC	20	2.26	140.75	92.42	7.58	63.9	101.3
306	Granite	MC	20	2.26	140.75	92.42	7.58	63.9	101.3
307	Granite	MC	20	2.28	142.13	93.33	6.67	63.6	100.0
307	Granite	MC	20	2.28	142.13	93.33	6.67	63.6	100.0
308	Granite	MC	23	2.28	142.05	93.28	6.72	63.8	100.6
308	Granite	MC	23	2.28	142.05	93.28	6.72	63.8	100.6
309	Granite	MC	25	2.28	142.54	93.60	6.40	63.4	100.0
309	Granite	MC	25	2.28	142.54	93.60	6.40	63.4	100.0
310	Granite	MC	21	2.27	141.77	93.09	6.91	63.5	100.1
310	Granite	MC	21	2.27	141.77	93.09	6.91	63.5	100.1
311	Granite	MC	18	2.26	141.15	92.68	7.32	63.5	100.0
311	Granite	MC	18	2.26	141.15	92.68	7.32	63.5	100.0
312	Granite	MC	23	2.29	142.76	93.74	6.26	63.2	100.0
312	Granite	MC	23	2.29	142.76	93.74	6.26	63.2	100.0
313	Granite	MC	24	2.28	142.40	93.50	6.50	63.5	100.0
313	Granite	MC	24	2.28	142.40	93.50	6.50	63.5	100.0

314	Granite	MC	21	2.29	142.71	93.71	6.29	63.4	100.0
314	Granite	MC	21	2.29	142.71	93.71	6.29	63.4	100.0
315	Granite	MC	21	2.27	141.86	93.15	6.85	63.5	100.1
315	Granite	MC	21	2.27	141.86	93.15	6.85	63.5	100.1
316	Granite	MC	24	2.29	143.03	93.92	6.08	63.6	100.2
316	Granite	MC	24	2.29	143.03	93.92	6.08	63.6	100.2
317	Granite	MC	20	2.30	143.57	94.27	5.73	63.5	99.9
317	Granite	MC	20	2.30	143.57	94.27	5.73	63.5	99.9
318	Granite	MC	17	2.29	143.02	93.91	6.09	63.5	100.3
318	Granite	MC	17	2.29	143.02	93.91	6.09	63.5	100.3
319	Granite	MC	25	2.31	143.98	94.54	5.46	63.6	100.0
319	Granite	MC	25	2.31	143.98	94.54	5.46	63.6	100.0
350	Limestone	MC	37	2.23	139.29	90.62	9.38	63.6	100.0
351	Limestone	MC	50	2.30	143.63	93.44	6.56	63.9	99.8
352	Limestone	MC	48	2.28	141.99	92.37	7.63	63.9	100.0
353	Limestone	MC	55	2.25	140.26	91.25	8.75	63.7	100.1
354	Limestone	MC	35	2.24	139.76	90.92	9.08	63.9	100.1
355	Limestone	MC	42	2.29	142.83	92.92	7.08	63.5	99.9
356	Limestone	MC	42	2.28	142.26	92.55	7.45	63.5	100.1
357	Limestone	MC	45	2.25	140.47	91.38	8.62	63.5	100.0
358	Limestone	MC	37	2.27	141.92	92.33	7.67	63.5	100.0
359	Limestone	MC	43	2.27	141.65	92.15	7.85	63.5	100.2
360	Limestone	MC	42	2.25	140.10	91.14	8.86	---	---
361	Limestone	MC	38	2.25	140.45	91.37	8.63	---	---
362	Limestone	MC	37	2.28	142.12	92.46	7.54	63.5	100.1
363	Limestone	MC	39	2.26	140.76	91.58	8.42	---	---
364	Limestone	MC	40	2.27	141.53	92.08	7.92	63.5	100.0
365	Limestone	MC	42	2.27	141.37	91.97	8.03	---	---
366	Limestone	MC	47	2.29	143.20	93.16	6.84	63.5	100.1
367	Limestone	MC	37	2.28	142.31	92.58	7.42	63.5	100.1
368	Limestone	MC	46	2.29	142.99	93.03	6.97	63.5	100.0
369	Limestone	MC	36	2.26	141.03	91.75	8.25	---	---
370	Limestone	MC	40	2.28	142.06	92.42	7.58	63.6	100.2
371	Limestone	MC	36	2.27	141.77	92.23	7.77	63.6	100.1
372	Limestone	MC	37	2.26	140.91	91.67	8.33	63.5	100.2
373	Limestone	MC	37	2.27	141.95	92.35	7.65	63.8	100.0
374	Limestone	MC	45	2.28	142.35	92.61	7.39	63.7	100.2
375	Limestone	MC	42	2.28	142.18	92.50	7.50	63.7	100.1
376	Limestone	MC	43	2.28	142.56	92.75	7.25	64.0	100.1

377	Limestone	MC	39	2.27	141.56	92.09	7.91	64.0	100.0
379	Limestone	MC	41	2.28	142.35	92.61	7.39	63.5	100.0

APPENDIX C

Phase II Core Data and GLWT Data

Core #:: 5
Designation: AC-10
Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 7/10/01
Compaction Procedure:
30 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.4475
B = 6.527
C = 3.675
Gmb = A/(B-C) = 2.26

Density = Gmb * 62.4 = 141.07
Air Voids = 7.7%

Rice Wt.: 152.81
Group: sat

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4475	---	6.4475
Weight in Water (B)	3.7665	---	3.708
SSD Weight (D)	6.6245	---	6.5885
Volume (d-b)=E	2.858	---	2.8805
ABS (d-a)=F	0.177	---	0.141
Saturation F/ (E*voids)	80.6%	---	63.7%

Testing Date: 7/14/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.527	0.552	0.58	0	0	0
1000	0.449	0.47	0.488	0.078	0.082	0.092
4000	0.402	0.441	0.449	0.125	0.111	0.131
8000	0.307	0.416	0.427	0.22	0.136	0.153

Core #:: 6
Designation: AC-10
Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 7/10/01
Compaction Procedure:
38 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.4575
B = 6.529
C = 3.6865
Gmb = A/(B-C) = 2.27

Density = Gmb * 62.4 = 141.76
Air Voids = 7.2%

Rice Wt.: 152.81
Group: sat

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4575	---	6.4575
Weight in Water (B)	3.7615	---	3.697
SSD Weight (D)	6.6025	---	6.581
Volume (d-b)=E	2.841	---	2.884
ABS (d-a)=F	0.145	---	0.1235
Saturation F/ (E*voids)	70.6%	---	59.2%

Testing Date: 7/14/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.515	0.562	0.571	0	0	0
1000	0.429	0.484	0.506	0.086	0.078	0.065
4000	0.376	0.438	0.474	0.139	0.124	0.097
8000	0.321	0.38	0.436	0.194	0.182	0.135

Core #:: 7
Designation: AC-10
Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 7/10/01
Compaction Procedure:
31 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.4685
B = 6.547
C = 3.693
Gmb = A/(B-C) = 2.27

Density = Gmb * 62.4 = 141.43
Air Voids = 7.4%

Rice Wt.: 152.81
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 7/15/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.491	0.5185	0.507	0	0	0
1000	0.375	0.4435	0.432	0.116	0.075	0.075
4000	0.3105	0.353	0.3755	0.1805	0.1655	0.1315
8000	0.215	0.249	0.3355	0.276	0.2695	0.1715

Core #:: 8
Designation: AC-10
Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 7/12/01
Compaction Procedure:
31 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.4595
B = 6.5255
C = 3.686
Gmb = A/(B-C) = 2.27

Density = Gmb * 62.4 = 141.95
Air Voids = 7.1%

Rice Wt.: 152.81
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 7/15/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.509	0.534	0.527	0	0	0
1000	0.383	0.427	0.462	0.126	0.107	0.065
4000	0.319	0.329	0.42	0.19	0.205	0.107
8000	0.2595	0.2515	0.3955	0.2495	0.2825	0.1315

Core #::	9
Designation:	AC-10
Mix Design:	1

Compaction Date: 7/12/01
Compaction Procedure:
28 gyrations
using gyratory compactor.

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Initial Gmb Calculations

A =	6.4575
B =	6.532
C =	3.6885
Gmb = A/(B-C) =	2.27
Density = Gmb * 62.4 =	141.71
Air Voids =	7.3%
Rice Wt.:	152.81
Group:	sat

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4575	---	6.4575
Weight in Water (B)	3.7835	---	3.712
SSD Weight (D)	6.633	---	6.5975
Volume (d-b)=E	2.8495	---	2.8855
ABS (d-a)=F	0.1755	---	0.14
Saturation F/ (E*voids)	84.8%	---	66.8%

Testing Date: 7/17/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.5305	0.57	0.571	0	0	0
1000	0.452	0.406	0.49	0.0785	0.164	0.081
4000	0.4	0.437	0.446	0.1305	0.133	0.125
8000	0.354	0.377	0.413	0.1765	0.193	0.158

Core #:: 10
Designation: AC-10
Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 7/12/01
Compaction Procedure:
33 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.465
B = 6.5345
C = 3.6985
Gmb = A/(B-C) = 2.28

Density = Gmb * 62.4 = 142.25
Air Voids = 6.9%

Rice Wt.: 152.81
Group: sat

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.465	---	6.465
Weight in Water (B)	3.776	---	3.708
SSD Weight (D)	6.625	---	6.59
Volume (d-b)=E	2.849	---	2.882
ABS (d-a)=F	0.16	---	0.125
Saturation F/ (E*voids)	81.2%	---	62.7%

Testing Date: 7/17/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.527	0.563	0.568	0	0	0
1000	0.4565	0.469	0.514	0.0705	0.094	0.054
4000	0.401	0.415	0.459	0.126	0.148	0.109
8000	0.36	0.391	0.413	0.167	0.172	0.155

Core #:: 11
Designation: AC-10
Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 7/12/01
Compaction Procedure:
32 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.45
B = 6.531
C = 3.6905
Gmb = A/(B-C) = 2.27

Density = Gmb * 62.4 = 141.69
Air Voids = 7.3%

Rice Wt.: 152.81
Group: *sat

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.45	---	6.45
Weight in Water (B)	3.7695	---	3.698
SSD Weight (D)	6.629	---	6.5955
Volume (d-b)=E	2.8595	---	2.8975
ABS (d-a)=F	0.179	---	0.1455
Saturation F/ (E*voids)	86.0%	---	69.0%

Testing Date: 7/18/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.5495	0.589	0.609	0	0	0
1000	0.446	0.482	0.5	0.1035	0.107	0.109
4000	0.398	0.424	0.448	0.1515	0.165	0.161
8000	0.351	0.342	0.396	0.1985	0.247	0.213

Core #:: 12
Designation: AC-10
Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 7/13/01
Compaction Procedure:
29 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.454
B = 6.5335
C = 3.686
Gmb = A/(B-C) = 2.27

Density = Gmb * 62.4 = 141.43
Air Voids = 7.4%

Rice Wt.: 152.81
Group: *sat

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.454	---	6.454
Weight in Water (B)	3.736	---	3.6845
SSD Weight (D)	6.5985	---	6.5795
Volume (d-b)=E	2.8625	---	2.895
ABS (d-a)=F	0.1445	---	0.1255
Saturation F/ (E*voids)	67.8%	---	58.2%

Testing Date: 7/18/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.5105	0.577	0.5965	0	0	0
1000	0.424	0.4803	0.489	0.0865	0.0967	0.1075
4000	0.343	0.421	0.428	0.1675	0.156	0.1685
8000	0.3055	0.374	0.374	0.205	0.203	0.2225

Core #:: 13

Designation: AC-10

Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 7/13/01

Compaction Procedure:

28 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.4625

B = 6.53

C = 3.68

Gmb = A/(B-C) = 2.27

Density = Gmb * 62.4 = 141.49

Air Voids = 7.4%

Rice Wt.: 152.81

Group: *sat

	Initial	**After Cycling**	**After GLWT**
Weight in Air (A)	6.4625	---	6.4625
Weight in Water (B)	3.7365	---	3.683
SSD Weight (D)	6.5965	---	6.5795
Volume (d-b)=E	2.86	---	2.8965
ABS (d-a)=F	0.134	---	0.117
Saturation F/ (E*voids)	63.3%	---	54.5%

Testing Date: 7/19/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.538	0.571	0.574	0	0	0
1000	0.444	0.496	0.5115	0.094	0.075	0.0625
4000	0.389	0.419	0.4665	0.149	0.152	0.1075
8000	0.348	0.366	0.433	0.19	0.205	0.141

Core #:: 14
Designation: AC-10
Mix Design: 1

Compaction Date: 7/13/01
Compaction Procedure:
32 gyrations
using gyratory compactor.

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Initial Gmb Calculations

A = 6.448
B = 6.531
C = 3.699
Gmb = A/(B-C) = 2.28

Density = Gmb * 62.4 = 142.07
Air Voids = 7.0%

Rice Wt.: 152.81
Group: *sat

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.448	---	6.448
Weight in Water (B)	3.7415	---	3.671
SSD Weight (D)	6.6035	---	6.573
Volume (d-b)=E	2.862	---	2.902
ABS (d-a)=F	0.1555	---	0.125
Saturation F/ (E*voids)	77.3%	---	61.3%

Testing Date: 7/20/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.512	0.577	0.5905	0	0	0
1000	0.3775	0.466	0.5025	0.1345	0.111	0.088
4000	0.324	0.3875	0.4565	0.188	0.1895	0.134
8000	0.283	0.3295	0.408	0.229	0.2475	0.1825

Core #:: 16

Designation: AC-10

Mix Design: 2

Compaction Date: 7/20/01

Compaction Procedure:

52 gyrations

using gyratory compactor.

Sieve	% Retained	Weight (lbs)
Pan	12	0.7594
No. 50	4	0.2531
No. 30	6	0.3797
No. 16	8	0.5063
No. 8	10	0.6328
No. 4	42	2.6579
3/8 in.	12	0.7594
1/2 in.	6	0.3797
3/4 in.	0	0.0000
	Sub total:	**6.3283**
AC -10	5.70%	**0.3825**
Total		**6.7108**

Initial Gmb Calculations

A = 6.6685

B = 6.7075

C = 3.834

Gmb = A/(B-C) = 2.32

Density = Gmb * 62.4 = 144.81

Air Voids = 5.2%

Rice Wt.: 152.81

Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 7/25/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.548	0.55	0.535	0	0	0
1000	0.414	0.457	0.47	0.134	0.093	0.065
4000	0.359	0.412	0.439	0.189	0.138	0.096
8000	0.319	0.371	0.416	0.229	0.179	0.119

Core #:: 17
Designation: AC-10
Mix Design: 2

Sieve	% Retained	Weight (lbs)
Pan	12	0.7594
No. 50	4	0.2531
No. 30	6	0.3797
No. 16	8	0.5063
No. 8	10	0.6328
No. 4	42	2.6579
3/8 in.	12	0.7594
1/2 in.	6	0.3797
3/4 in.	0	0.0000
	Sub total:	**6.3283**
AC -10	5.70%	**0.3825**
Total		**6.7108**

Compaction Date: 7/20/01
Compaction Procedure:
67 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.677
B = 6.723
C = 3.84
Gmb = A/(B-C) = 2.32

Density = Gmb * 62.4 = 144.52
Air Voids = 5.4%

Rice Wt.: 152.81
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 7/25/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.485	0.531	0.4805	0	0	0
1000	0.4285	0.492	0.435	0.0565	0.039	0.0455
4000	0.379	0.452	0.42	0.106	0.079	0.0605
8000	0.327	0.4	0.401	0.158	0.131	0.0795

Core #:: 23

Designation: AC-10

Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 8/28/01

Compaction Procedure:

24 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.476

B = 6.5595

C = 3.7215

Gmb = A/(B-C) = 2.28

Density = Gmb * 62.4 = 142.39

Air Voids = **6.8%**

Rice Wt.: 152.81

Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.476	6.476	6.476
Weight in Water (B)	3.7495	3.7465	3.709
SSD Weight (D)	6.5865	6.6075	6.5975
Volume (d-b)=E	2.837	2.861	2.8885
ABS (d-a)=F	0.1105	0.1315	0.1215
Saturation F/ (E*voids)	57.1%	67.4%	61.7%

Testing Date: 9/7/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.548	0.574	0.5725	0	0	0
1000	0.408	0.495	0.2945	0.14	0.079	0.278
4000	0.406	0.4565	0.261	0.142	0.1175	0.3115
8000	0.354	0.359	0.2115	0.194	0.215	0.361

Core #:: 24
Designation: AC-10
Mix Design: 1

Compaction Date: 8/28/01
Compaction Procedure:
21 gyrations
using gyratory compactor.

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Initial Gmb Calculations

A = 6.471
B = 6.535
C = 3.714
Gmb = A/(B-C) = 2.29

Density = Gmb * 62.4 = 143.14
Air Voids = **6.3%**

Rice Wt.: 152.81
Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.471	6.471	6.471
Weight in Water (B)	3.752	3.745	3.7135
SSD Weight (D)	6.588	6.5945	6.5765
Volume (d-b)=E	2.836	2.8495	2.863
ABS (d-a)=F	0.117	0.1235	0.1055
Saturation F/ (E*voids)	65.2%	68.5%	58.2%

Testing Date: 9/7/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.535	0.579	0.582	0	0	0
1000	0.372	0.483	0.432	0.163	0.096	0.15
4000	0.221	0.433	0.372	0.314	0.146	0.21
8000	0.19	0.377	0.341	0.345	0.202	0.241

Core #:: 25
Designation: AC-10 Aged
Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 8/29/01
Compaction Procedure:
22 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.47
B = 6.5445
C = 3.726
Gmb = A/(B-C) = 2.30

Density = Gmb * 62.4 = 143.24
Air Voids = 6.3%

Rice Wt.: 152.81
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 9/4/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.492	0.5	0.529	0	0	0
1000	0.445	0.432	0.484	0.047	0.068	0.045
4000	0.394	0.393	0.4415	0.098	0.107	0.0875
8000	0.354	0.357	0.3865	0.138	0.143	0.1425

Core #:: 27

Designation: AC-10 Aged

Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 8/29/01

Compaction Procedure:

25 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.465

B = 6.5315

C = 3.716

Gmb = A/(B-C) = 2.30

Density = Gmb * 62.4 = 143.28

Air Voids = 6.2%

Rice Wt.: 152.81

Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 9/5/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.487	0.518	0.5175	0	0	0
1000	0.452	0.48	0.462	0.035	0.038	0.0555
4000	0.423	0.4525	0.4255	0.064	0.0655	0.092
8000	0.3795	0.426	0.387	0.1075	0.092	0.1305

Core #:: 29

Designation: AC-10 Aged

Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 8/29/01

Compaction Procedure:

29 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.487

B = 6.554

C = 3.725

Gmb = A/(B-C) = 2.29

Density = Gmb * 62.4 = 143.09

Air Voids = **6.4%**

Rice Wt.: 152.81

Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.487	6.487	6.487
Weight in Water (B)	3.79	3.76	3.7245
SSD Weight (D)	6.599	6.631	6.5895
Volume (d-b)=E	2.809	2.871	2.865
ABS (d-a)=F	0.112	0.144	0.1025
Saturation F/ (E*voids)	62.6%	78.8%	56.2%

Testing Date: 9/8/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.5545	0.574	0.562	0	0	0
1000	0.411	0.514	0.468	0.1435	0.06	0.094
4000	0.357	0.474	0.3975	0.1975	0.1	0.1645
8000	0.338	0.4135	0.3505	0.2165	0.1605	0.2115

Core #:: 30

Designation: AC-10 Aged

Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 8/29/01

Compaction Procedure:

30 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.477

B = 6.5575

C = 3.731

Gmb = A/(B-C) = 2.29

Density = Gmb * 62.4 = 142.99

Air Voids = **6.4%**

Rice Wt.: 152.81

Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.477	6.477	6.477
Weight in Water (B)	3.781	3.754	3.716
SSD Weight (D)	6.6005	6.6105	6.5525
Volume (d-b)=E	2.8195	2.8565	2.8365
ABS (d-a)=F	0.1235	0.1335	0.0755
Saturation F/ (E*voids)	68.2%	72.7%	41.4%

Testing Date: 9/8/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.51	0.583	0.599	0	0	0
1000	0.413	0.504	0.511	0.097	0.079	0.088
4000	0.261	0.472	0.46	0.249	0.111	0.139
8000	0.223	0.4425	0.424	0.287	0.1405	0.175

Core #:: 31

Designation: AC-10 Aged

Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 9/11/01

Compaction Procedure:

23 gyrations using gyratory compactor.

Initial Gmb Calculations

A = 6.4345

B = 6.508

C = 3.704

Gmb = A/(B-C) = 2.29

Density = Gmb * 62.4 = 143.19

Air Voids = 6.3%

Rice Wt.: 152.81

Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4345	---	---
Weight in Water (B)	3.741	---	---
SSD Weight (D)	6.5525	---	---
Volume (d-b)=E	2.8115	---	---
ABS (d-a)=F	0.118	---	---
Saturation F/ (E*voids)	66.7%	---	---

Testing Date: 9/12/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.535	0.5805	0.579	0	0	0
1000	0.4675	0.501	0.463	0.0675	0.0795	0.116
4000	0.4135	0.442	0.403	0.1215	0.1385	0.176
8000	0.34	0.359	0.3335	0.195	0.2215	0.2455

Core #:: 32
Designation: AC-10
Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 9/7/01
Compaction Procedure:
75 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.82
B = 6.835
C = 3.962
Gmb = A/(B-C) = 2.37

Density = Gmb * 62.4 = 148.13
Air Voids = 3.1%

Rice Wt.: 152.81
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 9/9/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.543	0.55	0.549	0	0	0
1000	0.4445	0.486	0.4785	0.0985	0.064	0.0705
4000	0.406	0.44	0.442	0.137	0.11	0.107
8000	0.369	0.421	0.4085	0.174	0.129	0.1405

Core #:: 33
Designation: AC-10
Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 9/7/01
Compaction Procedure:
83 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.819
B = 6.846
C = 3.9755
Gmb = A/(B-C) = 2.38

Density = Gmb * 62.4 = 148.23
Air Voids = 3.0%

Rice Wt.: 152.81
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 9/10/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.494	0.5345	0.534	0	0	0
1000	0.419	0.497	0.473	0.075	0.0375	0.061
4000	0.379	0.481	0.451	0.115	0.0535	0.083
8000	0.35	0.4715	0.427	0.144	0.063	0.107

Core #:: 34
Designation: AC-10
Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 9/7/01
Compaction Procedure:
81 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.818
B = 6.8455
C = 3.975
Gmb = A/(B-C) = 2.38

Density = Gmb * 62.4 = 148.21
Air Voids = 3.0%

Rice Wt.: 152.81
Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.818	---	---
Weight in Water (B)	4.018	---	---
SSD Weight (D)	6.8795	---	---
Volume (d-b)=E	2.8615	---	---
ABS (d-a)=F	0.0615	---	---
Saturation F/ (E*voids)	71.4%	---	---

Testing Date: 9/10/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.539	0.567	0.543	0	0	0
1000	0.49	0.51	0.4795	0.049	0.057	0.0635
4000	0.465	0.4852	0.434	0.074	0.0818	0.109
8000	0.461	0.472	0.42	0.078	0.095	0.123

Core #:: 37

Designation: AC-10

Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 9/7/01

Compaction Procedure:

--- gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.8245

B = 6.857

C = 3.9705

Gmb = A/(B-C) = 2.36

Density = Gmb * 62.4 = 147.53

Air Voids = **3.5%**

Rice Wt.: 152.81

Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.8245	6.8245	---
Weight in Water (B)	4.011	4.002	---
SSD Weight (D)	6.8855	6.902	---
Volume (d-b)=E	2.8745	2.9	---
ABS (d-a)=F	0.061	0.0775	---
Saturation F/ (E*voids)	61.4%	77.3%	---

Testing Date: 9/11/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.505	0.548	0.556	0	0	0
1000	0.427	0.522	0.512	0.078	0.026	0.044
4000	0.392	0.51	0.4895	0.113	0.038	0.0665
8000	0.368	0.504	0.4695	0.137	0.044	0.0865

Core #:: 38
Designation: AC-10 Aged
Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 9/11/01
Compaction Procedure:
88 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.8035
B = 6.8365
C = 3.965
Gmb = A/(B-C) = 2.37

Density = Gmb * 62.4 = 147.85
Air Voids = 3.2%

Rice Wt.: 152.81
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 9/14/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.484	0.537	0.545	0	0	0
1000	0.4295	0.509	0.491	0.0545	0.028	0.054
4000	0.4125	0.498	0.473	0.0715	0.039	0.072
8000	0.402	0.489	0.4575	0.082	0.048	0.0875

Core #:: 39
Designation: AC-10 Aged
Mix Design: 3

Compaction Date: 9/11/01
Compaction Procedure:
92 gyrations
using gyratory compactor.

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Initial Gmb Calculations

A = 6.798
B = 6.828
C = 3.961
Gmb = A/(B-C) = 2.37

Density = Gmb * 62.4 = 147.96
Air Voids = 3.2%

Rice Wt.: 152.81
Group: 0

	Initial	**After Cycling**	**After GLWT**
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 9/15/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.486	0.525	0.524	0	0	0
1000	0.439	0.486	0.476	0.047	0.039	0.048
4000	0.4305	0.478	0.459	0.0555	0.047	0.065
8000	0.4125	0.4615	0.445	0.0735	0.0635	0.079

Core #:: 40
Designation: AC-10 Aged
Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 9/11/01
Compaction Procedure:
76 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.7655
B = 6.796
C = 3.9325
Gmb = A/(B-C) = 2.36

Density = Gmb * 62.4 = 147.43
Air Voids = 3.5%

Rice Wt.: 152.81
Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.7655	---	---
Weight in Water (B)	3.989	---	---
SSD Weight (D)	6.845	---	---
Volume (d-b)=E	2.856	---	---
ABS (d-a)=F	0.0795	---	---
Saturation F/ (E*voids)	79.1%	---	---

Testing Date: 9/15/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.5065	0.5603	0.5785	0	0	0
1000	0.476	0.533	0.537	0.0305	0.0273	0.0415
4000	0.4585	0.514	0.515	0.048	0.0463	0.0635
8000	0.449	0.51	0.504	0.0575	0.0503	0.0745

Core #:: 41

Designation: AC-10 Aged

Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 9/11/01

Compaction Procedure:

75 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.751

B = 6.791

C = 3.933

Gmb = A/(B-C) = 2.36

Density = Gmb * 62.4 = 147.40

Air Voids = 3.5%

Rice Wt.: 152.81

Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.751	---	---
Weight in Water (B)	3.967	---	---
SSD Weight (D)	6.83	---	---
Volume (d-b)=E	2.863	---	---
ABS (d-a)=F	0.079	---	---
Saturation F/ (E*voids)	77.9%	---	---

Testing Date: 9/17/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.538	0.567	0.5545	0	0	0
1000	0.495	0.541	0.513	0.043	0.026	0.0415
4000	0.457	0.522	0.481	0.081	0.045	0.0735
8000	0.4465	0.508	0.4675	0.0915	0.059	0.087

Core #:: 42
Designation: AC-10 Aged
Mix Design: 3

Compaction Date: 9/11/01
Compaction Procedure:
90 gyrations
using gyratory compactor.

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Initial Gmb Calculations
A = 6.7845
B = 6.8235
C = 3.9535
Gmb = A/(B-C) = 2.36

Density = Gmb * 62.4 = 147.51
Air Voids = 3.5%

Rice Wt.: 152.81
Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.7845	6.7845	---
Weight in Water (B)	3.986	3.974	---
SSD Weight (D)	6.855	6.855	---
Volume (d-b)=E	2.869	2.881	---
ABS (d-a)=F	0.0705	0.0705	---
Saturation F/ (E*voids)	70.8%	70.5%	---

Testing Date: 9/16/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.545	0.569	0.5545	0	0	0
1000	0.465	0.533	0.512	0.08	0.036	0.0425
4000	0.43	0.512	0.503	0.115	0.057	0.0515
8000	0.4295	0.512	0.495	0.1155	0.057	0.0595

Core #:: 43
Designation: AC-10 Aged
Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 9/11/01
Compaction Procedure:
114 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.7825
B = 6.818
C = 3.9535
Gmb = A/(B-C) = 2.37

Density = Gmb * 62.4 = 147.75
Air Voids = 3.3%

Rice Wt.: 152.81
Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.7825	6.7825	---
Weight in Water (B)	3.989	3.984	---
SSD Weight (D)	6.853	6.861	---
Volume (d-b)=E	2.864	2.877	---
ABS (d-a)=F	0.0705	0.0785	---
Saturation F/ (E*voids)	74.3%	82.4%	---

Testing Date: 9/16/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.539	0.559	0.575	0	0	0
1000	0.5	0.518	0.512	0.039	0.041	0.063
4000	0.486	0.513	0.491	0.053	0.046	0.084
8000	0.48	0.509	0.4805	0.059	0.05	0.0945

Core #:: 44

Designation: AC-10 Aged

Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 9/11/01

Compaction Procedure:

24 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.4445

B = 6.5135

C = 3.7185

Gmb = A/(B-C) = 2.31

Density = Gmb * 62.4 = 143.88

Air Voids = 6.5%

Rice Wt.: 153.81

Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4445	---	---
Weight in Water (B)	3.742	---	---
SSD Weight (D)	6.5515	---	---
Volume (d-b)=E	2.8095	---	---
ABS (d-a)=F	0.107	---	---
Saturation F/ (E*voids)	59.0%	---	---

Testing Date: 9/12/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.5	0.557	0.579	0	0	0
1000	0.435	0.474	0.4805	0.065	0.083	0.0985
4000	0.334	0.4135	0.405	0.166	0.1435	0.174
8000	0.299	0.392	0.3825	0.201	0.165	0.1965

Core #:: 50
Designation: AC-10 Lime
Mix Design: 4

Sieve	% Retained	Weight (lbs)
Pan	12	0.7447
No. 50	4	0.2482
No. 30	6	0.3724
No. 16	8	0.4965
No. 8	10	0.6206
No. 4	42	2.6066
3/8 in.	12	0.7447
1/2 in.	6	0.3724
3/4 in.	0	0.0000
	Sub total:	**6.2062**
AC -10	5.70%	**0.4761**
Total		**6.6823**

Compaction Date: 9/18/01
Compaction Procedure:
25 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.6515
B = 6.6775
C = 3.8215
Gmb = A/(B-C) = 2.33

Density = Gmb * 62.4 = 145.33
Air Voids = 4.6%

Rice Wt.: 152.37
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 10/1/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.465	0.5245	0.5275	0	0	0
1000	0.3775	0.456	0.474	0.0875	0.0685	0.0535
4000	0.322	0.419	0.415	0.143	0.1055	0.1125
8000	0.279	0.36	0.364	0.186	0.1645	0.1635

Core #:: 51

Designation: AC-10 Lime

Mix Design: 4

Sieve	% Retained	Weight (lbs)
Pan	12	0.7447
No. 50	4	0.2482
No. 30	6	0.3724
No. 16	8	0.4965
No. 8	10	0.6206
No. 4	42	2.6066
3/8 in.	12	0.7447
1/2 in.	6	0.3724
3/4 in.	0	0.0000
	Sub total:	**6.2062**
AC -10	5.70%	**0.4761**
Total		**6.6823**

Compaction Date: 9/18/01

Compaction Procedure:

27 gyrations

using gyratory compactor.

Initial Gmb Calculations:

A = 6.6215

B = 6.653

C = 3.8015

Gmb = A/(B-C) = 2.32

Density = Gmb * 62.4 = 144.90

Air Voids = 4.9%

Rice Wt.: 152.37

Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 10/1/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.4885	0.514	0.51	0	0	0
1000	0.382	0.4185	0.3875	0.1065	0.0955	0.1225
4000	0.311	0.3505	0.321	0.1775	0.1635	0.189
8000	0.289	0.315	0.286	0.1995	0.199	0.224

Core #:: 52
Designation: AC-10 Lime
Mix Design: 5

Sieve	% Retained	Weight (lbs)
Pan	12	0.7215
No. 50	4	0.2405
No. 30	6	0.3607
No. 16	8	0.4810
No. 8	10	0.6012
No. 4	42	2.5251
3/8 in.	12	0.7215
1/2 in.	6	0.3607
3/4 in.	0	0.0000
	Sub total:	**6.0122**
AC -10	5.70%	**0.4612**
Total		**6.4734**

Compaction Date: 9/18/01
Compaction Procedure:
15 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.439
B = 6.4855
C = 3.671
Gmb = A/(B-C) = 2.29

Density = Gmb * 62.4 = 142.76
Air Voids = 6.3%

Rice Wt.: 152.37
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 10/2/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.516	0.538	0.49	0	0	0
1000	0.342	0.412	0.3785	0.174	0.126	0.1115
4000	0.277	0.313	0.315	0.239	0.225	0.175
8000	0.212	0.197	0.234	0.304	0.341	0.256

Core #:: 53

Designation: AC-10 Lime

Mix Design: 5

Sieve	% Retained	Weight (lbs)
Pan	12	0.7215
No. 50	4	0.2405
No. 30	6	0.3607
No. 16	8	0.4810
No. 8	10	0.6012
No. 4	42	2.5251
3/8 in.	12	0.7215
1/2 in.	6	0.3607
3/4 in.	0	0.0000
	Sub total:	**6.0122**
AC -10	5.70%	**0.4612**
Total		**6.4734**

Compaction Date: 9/18/01

Compaction Procedure:

18 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.461

B = 6.508

C = 3.6835

Gmb = A/(B-C) = 2.29

Density = Gmb * 62.4 = 142.74

Air Voids = 6.3%

Rice Wt.: 152.37

Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 10/2/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.486	0.518	0.515	0	0	0
1000	0.37	0.439	0.379	0.116	0.079	0.136
4000	0.306	0.377	0.312	0.18	0.141	0.203
8000	0.256	0.311	0.2865	0.23	0.207	0.2285

Core #:: 54
Designation: AC-10 Lime
Mix Design: 4

Sieve	% Retained	Weight (lbs)
Pan	12	0.7447
No. 50	4	0.2482
No. 30	6	0.3724
No. 16	8	0.4965
No. 8	10	0.6206
No. 4	42	2.6066
3/8 in.	12	0.7447
1/2 in.	6	0.3724
3/4 in.	0	0.0000
	Sub total:	6.2062
AC -10	5.70%	0.4761
Total		**6.6823**

Compaction Date: 9/21/01
Compaction Procedure:
28 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.649
B = 6.6795
C = 3.8225
Gmb = A/(B-C) = 2.33

Density = Gmb * 62.4 = 145.22
Air Voids = 4.7%

Rice Wt.: 152.37
Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.649	---	---
Weight in Water (B)	3.877	---	---
SSD Weight (D)	6.7265	---	---
Volume (d-b)=E	2.8495	---	---
ABS (d-a)=F	0.0775	---	---
Saturation F/ (E*voids)	57.9%	---	---

Testing Date: 10/2/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.515	0.565	0.563	0	0	0
1000	0.408	0.474	0.46	0.107	0.091	0.103
4000	0.353	0.3935	0.354	0.162	0.1715	0.209
8000	0.322	0.34	0.307	0.193	0.225	0.256

Core #:: 55

Designation: AC-10 Lime

Mix Design: 4

Sieve	% Retained	Weight (lbs)
Pan	12	0.7447
No. 50	4	0.2482
No. 30	6	0.3724
No. 16	8	0.4965
No. 8	10	0.6206
No. 4	42	2.6066
3/8 in.	12	0.7447
1/2 in.	6	0.3724
3/4 in.	0	0.0000
	Sub total:	**6.2062**
AC -10	5.70%	**0.4761**
Total		**6.6823**

Compaction Date: 9/21/01

Compaction Procedure:

27 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.6405

B = 6.6745

C = 3.8125

Gmb = A/(B-C) = 2.32

Density = Gmb * 62.4 = 144.78

Air Voids = 5.0%

Rice Wt.: 152.37

Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.6405	---	---
Weight in Water (B)	3.885	---	---
SSD Weight (D)	6.7375	---	---
Volume (d-b)=E	2.8525	---	---
ABS (d-a)=F	0.097	---	---
Saturation F/ (E*voids)	68.2%	---	---

Testing Date: 10/3/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.505	0.579	0.564	0	0	0
1000	0.41	0.513	0.4715	0.095	0.066	0.0925
4000	0.351	0.481	0.432	0.154	0.098	0.132
8000	0.318	0.4315	0.396	0.187	0.1475	0.168

Core #:: 56
Designation: AC-10 Lime
Mix Design: 4

Sieve	% Retained	Weight (lbs)
Pan	12	0.7447
No. 50	4	0.2482
No. 30	6	0.3724
No. 16	8	0.4965
No. 8	10	0.6206
No. 4	42	2.6066
3/8 in.	12	0.7447
1/2 in.	6	0.3724
3/4 in.	0	0.0000
	Sub total:	**6.2062**
AC -10	5.70%	**0.4761**
Total		**6.6823**

Compaction Date: 9/21/01
Compaction Procedure:
33 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.6555
B = 6.686
C = 3.8355
Gmb = A/(B-C) = 2.33

Density = Gmb * 62.4 = 145.69
Air Voids = 4.4%

Rice Wt.: 152.37
Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.6555	6.6555	---
Weight in Water (B)	3.876	3.867	---
SSD Weight (D)	6.73	6.73	---
Volume (d-b)=E	2.854	2.863	---
ABS (d-a)=F	0.0745	0.0745	---
Saturation F/ (E*voids)	59.5%	59.4%	---

Testing Date: 10/4/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.528	0.563	0.543	0	0	0
1000	0.404	0.475	0.474	0.124	0.088	0.069
4000	0.3825	0.442	0.456	0.1455	0.121	0.087
8000	0.3715	0.416	0.418	0.1565	0.147	0.125

Core #:: 57
Designation: AC-10 Lime
Mix Design: 4

Sieve	% Retained	Weight (lbs)
Pan	12	0.7447
No. 50	4	0.2482
No. 30	6	0.3724
No. 16	8	0.4965
No. 8	10	0.6206
No. 4	42	2.6066
3/8 in.	12	0.7447
1/2 in.	6	0.3724
3/4 in.	0	0.0000
	Sub total:	**6.2062**
AC -10	5.70%	**0.4761**
Total		**6.6823**

Compaction Date: 9/21/01
Compaction Procedure:
57 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.611
B = 6.6485
C = 3.799
Gmb = A/(B-C) = 2.32

Density = Gmb * 62.4 = 144.77
Air Voids = 5.0%

Rice Wt.: 152.37
Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.611	6.611	---
Weight in Water (B)	3.8565	3.833	---
SSD Weight (D)	6.6965	6.7085	---
Volume (d-b)=E	2.84	2.8755	---
ABS (d-a)=F	0.0855	0.0975	---
Saturation F/ (E*voids)	60.3%	68.0%	---

Testing Date: 10/4/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.539	0.584	0.584	0	0	0
1000	0.415	0.488	0.489	0.124	0.096	0.095
4000	0.366	0.447	0.451	0.173	0.137	0.133
8000	0.325	0.409	0.411	0.214	0.175	0.173

Core #:: 58

Designation: AC-10 Lime

Mix Design: 5

Compaction Date: 9/21/01

Compaction Procedure:

27 gyrations

using gyratory compactor.

Sieve	% Retained	Weight (lbs)
Pan	12	0.7215
No. 50	4	0.2405
No. 30	6	0.3607
No. 16	8	0.4810
No. 8	10	0.6012
No. 4	42	2.5251
3/8 in.	12	0.7215
1/2 in.	6	0.3607
3/4 in.	0	0.0000
	Sub total:	**6.0122**
AC -10	5.70%	**0.4612**
Total		**6.4734**

Initial Gmb Calculations

A = 6.4285

B = 6.4955

C = 3.677

Gmb = A/(B-C) = 2.28

Density = Gmb * 62.4 = 142.32

Air Voids = 6.6%

Rice Wt.: 152.37

Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4285	---	---
Weight in Water (B)	3.7515	---	---
SSD Weight (D)	6.5705	---	---
Volume (d-b)=E	2.819	---	---
ABS (d-a)=F	0.142	---	---
Saturation F/ (E*voids)	76.4%	---	---

Testing Date: 10/3/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.503	0.5045	0.503	0	0	0
1000	0.429	0.466	0.433	0.074	0.0385	0.07
4000	0.36	0.44	0.373	0.143	0.0645	0.13
8000	0.316	0.397	0.325	0.187	0.1075	0.178

Core #:: 59
Designation: AC-10 Lime
Mix Design: 5

Compaction Date: 9/21/01
Compaction Procedure:
23 gyrations
using gyratory compactor.

Sieve	% Retained	Weight (lbs)
Pan	12	0.7215
No. 50	4	0.2405
No. 30	6	0.3607
No. 16	8	0.4810
No. 8	10	0.6012
No. 4	42	2.5251
3/8 in.	12	0.7215
1/2 in.	6	0.3607
3/4 in.	0	0.0000
	Sub total:	**6.0122**
AC -10	5.70%	**0.4612**
Total		**6.4734**

Initial Gmb Calculations

A = 6.4225
B = 6.4835
C = 3.667
Gmb = A/(B-C) = 2.28

Density = Gmb * 62.4 = 142.29
Air Voids = 6.6%

Rice Wt.: 152.37
Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4225	---	---
Weight in Water (B)	3.7055	---	---
SSD Weight (D)	6.5315	---	---
Volume (d-b)=E	2.826	---	---
ABS (d-a)=F	0.109	---	---
Saturation F/ (E*voids)	58.3%	---	---

Testing Date: 10/8/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.549	0.578	0.586	0	0	0
1000	0.452	0.492	0.475	0.097	0.086	0.111
4000	0.373	0.411	0.376	0.176	0.167	0.21
8000	0.292	0.309	0.297	0.257	0.269	0.289

Core #:: 60
Designation: AC-10 Lime
Mix Design: 5

Sieve	% Retained	Weight (lbs)
Pan	12	0.7215
No. 50	4	0.2405
No. 30	6	0.3607
No. 16	8	0.4810
No. 8	10	0.6012
No. 4	42	2.5251
3/8 in.	12	0.7215
1/2 in.	6	0.3607
3/4 in.	0	0.0000
	Sub total:	**6.0122**
AC -10	5.70%	**0.4612**
Total		**6.4734**

Compaction Date: 9/21/01
Compaction Procedure:
28 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.4365
B = 6.4975
C = 3.6735
Gmb = A/(B-C) = 2.28

Density = Gmb * 62.4 = 142.22
Air Voids = 6.7%

Rice Wt.: 152.37
Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4365	6.4365	---
Weight in Water (B)	3.729	3.718	---
SSD Weight (D)	6.559	6.564	---
Volume (d-b)=E	2.83	2.846	---
ABS (d-a)=F	0.1225	0.1275	---
Saturation F/ (E*voids)	65.0%	67.2%	---

Testing Date: 10/5/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.521	0.58	0.5795	0	0	0
1000	0.391	0.469	0.421	0.13	0.111	0.1585
4000	0.35	0.419	0.366	0.171	0.161	0.2135
8000	0.313	0.341	0.317	0.208	0.239	0.2625

Core #:: 61

Designation: AC-10 Lime

Mix Design: 5

Sieve	% Retained	Weight (lbs)
Pan	12	0.7215
No. 50	4	0.2405
No. 30	6	0.3607
No. 16	8	0.4810
No. 8	10	0.6012
No. 4	42	2.5251
3/8 in.	12	0.7215
1/2 in.	6	0.3607
3/4 in.	0	0.0000
	Sub total:	**6.0122**
AC -10	5.70%	**0.4612**
Total		**6.4734**

Compaction Date: 9/21/01

Compaction Procedure:

23 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.4495

B = 6.51

C = 3.6885

Gmb = A/(B-C) = 2.29

Density = Gmb * 62.4 = 142.64

Air Voids = 6.4%

Rice Wt.: 152.37

Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4495	6.4495	---
Weight in Water (B)	3.7315	3.713	---
SSD Weight (D)	6.5615	6.557	---
Volume (d-b)=E	2.83	2.844	---
ABS (d-a)=F	0.112	0.1075	---
Saturation F/ (E*voids)	61.9%	59.1%	---

Testing Date: 10/5/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.521	0.567	0.557	0	0	0
1000	0.3825	0.449	0.459	0.1385	0.118	0.098
4000	0.299	0.369	0.403	0.222	0.198	0.154
8000	0.248	0.288	0.37	0.273	0.279	0.187

Core #:: 62
Designation: AC-10
Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 10/3/01
Compaction Procedure:
82 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.783
B = 6.8185
C = 3.946
Gmb = A/(B-C) = 2.36

Density = Gmb * 62.4 = 147.35
Air Voids = 3.6%

Rice Wt.: 152.81
Group: 1

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.783	6.783	---
Weight in Water (B)	3.9755	3.9685	---
SSD Weight (D)	6.85	6.864	---
Volume (d-b)=E	2.8745	2.8955	---
ABS (d-a)=F	0.067	0.081	---
Saturation F/ (E*voids)	65.2%	78.3%	---

Testing Date: 10/10/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.472	0.567	0.58	0	0	0
1000	0.361	0.489	0.51	0.111	0.078	0.07
4000	0.336	0.464	0.4945	0.136	0.103	0.0855
8000	0.329	0.425	0.464	0.143	0.142	0.116

Core #:: 63
Designation: AC-10
Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 10/3/01
Compaction Procedure:
62 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.722
B = 6.762
C = 3.894
Gmb = A/(B-C) = 2.34

Density = Gmb * 62.4 = 146.25
Air Voids = 4.3%

Rice Wt.: 152.81
Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 10/9/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.4805	0.533	0.5365	0	0	0
1000	0.4005	0.476	0.466	0.08	0.057	0.0705
4000	0.426	0.441	0.432	0.0545	0.092	0.1045
8000	0.419	0.3785	0.399	0.0615	0.1545	0.1375

Core #:: 64

Designation: AC-10

Mix Design: 3

Sieve	% Retained	Weight (lbs)
Pan	12	0.7762
No. 50	4	0.2587
No. 30	6	0.3881
No. 16	8	0.5175
No. 8	10	0.6469
No. 4	42	2.7168
3/8 in.	12	0.7762
1/2 in.	6	0.3881
3/4 in.	0	0.0000
	Sub total:	**6.4685**
AC -10	5.70%	**0.3910**
Total		**6.8595**

Compaction Date: 10/3/01

Compaction Procedure:

67 gyrations

using gyratory compactor.

Initial Gmb Calculations

A = 6.776

B = 6.81

C = 3.9435

Gmb = A/(B-C) = 2.36

Density = Gmb * 62.4 = 147.50

Air Voids = 3.5%

Rice Wt.: 152.81

Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.776	---	---
Weight in Water (B)	3.983	---	---
SSD Weight (D)	6.847	---	---
Volume (d-b)=E	2.864	---	---
ABS (d-a)=F	0.071	---	---
Saturation F/ (E*voids)	71.4%	---	---

Testing Date: 10/9/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.511	0.564	0.5695	0	0	0
1000	0.4275	0.524	0.51	0.0835	0.04	0.0595
4000	0.3875	0.488	0.472	0.1235	0.076	0.0975
8000	0.368	0.474	0.4625	0.143	0.09	0.107

Core #:: 66
Designation: AC-10 Lime
Mix Design: 5

Sieve	% Retained	Weight (lbs)
Pan	12	0.7215
No. 50	4	0.2405
No. 30	6	0.3607
No. 16	8	0.4810
No. 8	10	0.6012
No. 4	42	2.5251
3/8 in.	12	0.7215
1/2 in.	6	0.3607
3/4 in.	0	0.0000
	Sub total:	**6.0122**
AC -10	5.70%	**0.4612**
Total		**6.4734**

Compaction Date: 10/19/01
Compaction Procedure:
22 gyrations
using gyratory compactor.

Initial Gmb Calculations

A = 6.4335
B = 6.5035
C = 3.69
Gmb = A/(B-C) = 2.29

Density = Gmb * 62.4 = 142.69
Air Voids = 6.4%

Rice Wt.: 152.37
Group: sat*

	Initial	After Cycling	After GLWT
Weight in Air (A)	6.4335	---	---
Weight in Water (B)	3.7495	---	---
SSD Weight (D)	6.565	---	---
Volume (d-b)=E	2.8155	---	---
ABS (d-a)=F	0.1315	---	---
Saturation F/ (E*voids)	73.5%	---	---

Testing Date: 10/21/01
Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.5195	0.566	0.6095	0	0	0
1000	0.444	0.4845	0.519	0.0755	0.0815	0.0905
4000	0.376	0.4405	0.4765	0.1435	0.1255	0.133
8000	0.3265	0.3755	0.42	0.193	0.1905	0.1895

Core #:: 67

Designation: AC-10 Lime

Mix Design: 5

Sieve	% Retained	Weight (lbs)
Pan	12	0.7215
No. 50	4	0.2405
No. 30	6	0.3607
No. 16	8	0.4810
No. 8	10	0.6012
No. 4	42	2.5251
3/8 in.	12	0.7215
1/2 in.	6	0.3607
3/4 in.	0	0.0000
	Sub total:	**6.0122**
AC -10	5.70%	**0.4612**
Total		**6.4734**

Compaction Date: 10/19/01

Compaction Procedure:

15 gyrations

using gyratory compactor.

Initial Gmb Calculations:

A = 6.3775

B = 6.46

C = 3.629

Gmb = A/(B-C) = 2.25

Density = Gmb * 62.4 = 140.57

Air Voids = 7.7%

Rice Wt.: 152.37

Group: 0

	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

Testing Date: 10/2/01

Testing Temperature: 115 F

Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.4895	0.5365	0.5445	0	0	0
1000	0.397	0.431	0.4315	0.0925	0.1055	0.113
4000	0.31	0.294	0.3255	0.1795	0.2425	0.219
8000	0.224	0.155	0.22	0.2655	0.3815	0.3245

Core #:: 68
Designation: AC-10
Mix Design: 1

Sieve	% Retained	Weight (lbs)
Pan	12	0.7357
No. 50	4	0.2452
No. 30	6	0.3678
No. 16	8	0.4904
No. 8	10	0.6131
No. 4	42	2.5748
3/8 in.	12	0.7357
1/2 in.	6	0.3678
3/4 in.	0	0.0000
	Sub total:	**6.1306**
AC -10	5.70%	**0.3706**
Total		**6.5011**

Compaction Date: 10/19/01
Compaction Procedure:
21 gyrations
using gyratory compactor.

Initial Gmb Calculations
A = 6.41
B = 6.4895
C = 3.6765
Gmb = A/(B-C) = 2.28

Density = Gmb * 62.4 = 142.19
Air Voids = 6.9%

Rice Wt.: 152.81
Group: 0

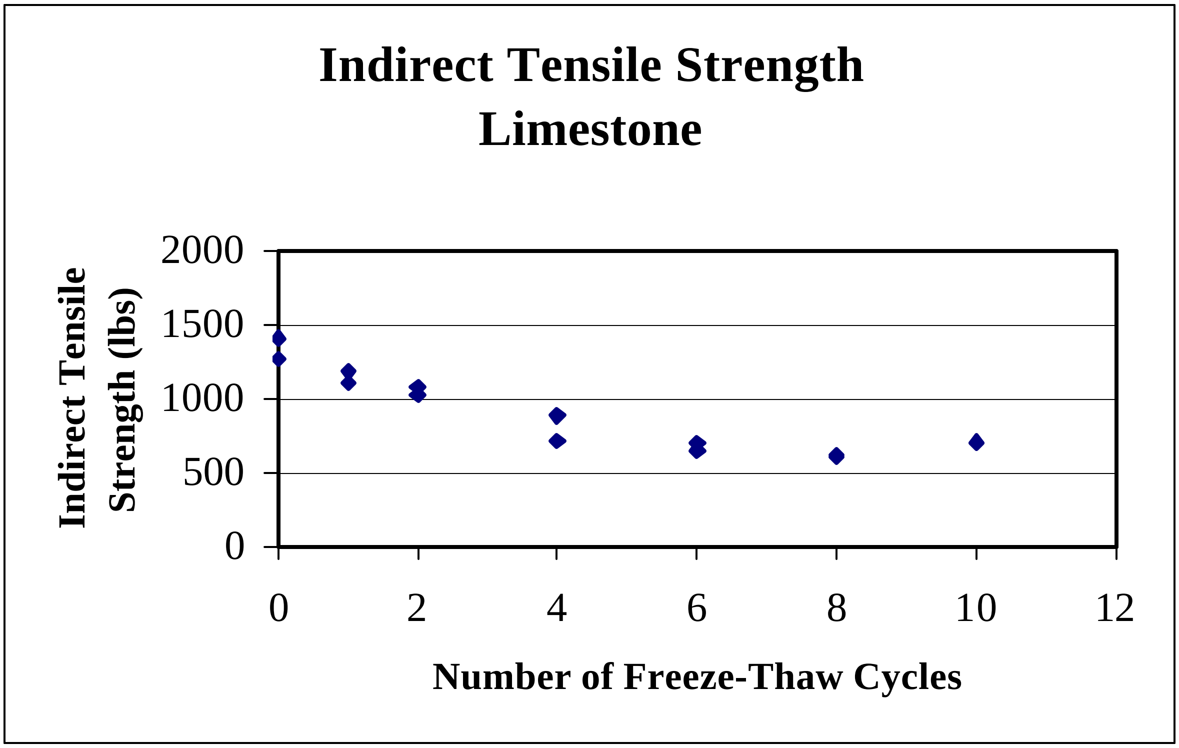
	Initial	After Cycling	After GLWT
Weight in Air (A)	---	---	---
Weight in Water (B)	---	---	---
SSD Weight (D)	---	---	---
Volume (d-b)=E	---	---	---
ABS (d-a)=F	---	---	---
Saturation F/ (E*voids)	---	---	---

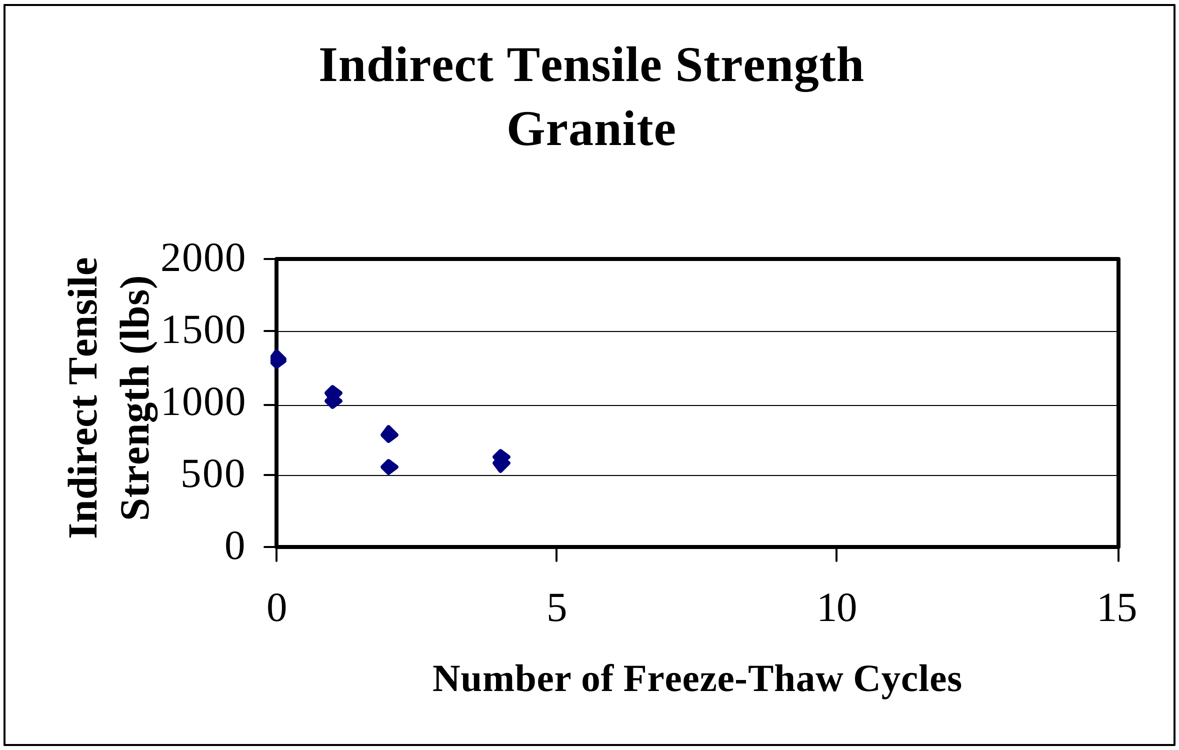
Testing Date: 10/20/01
Testing Temperature: 115 F

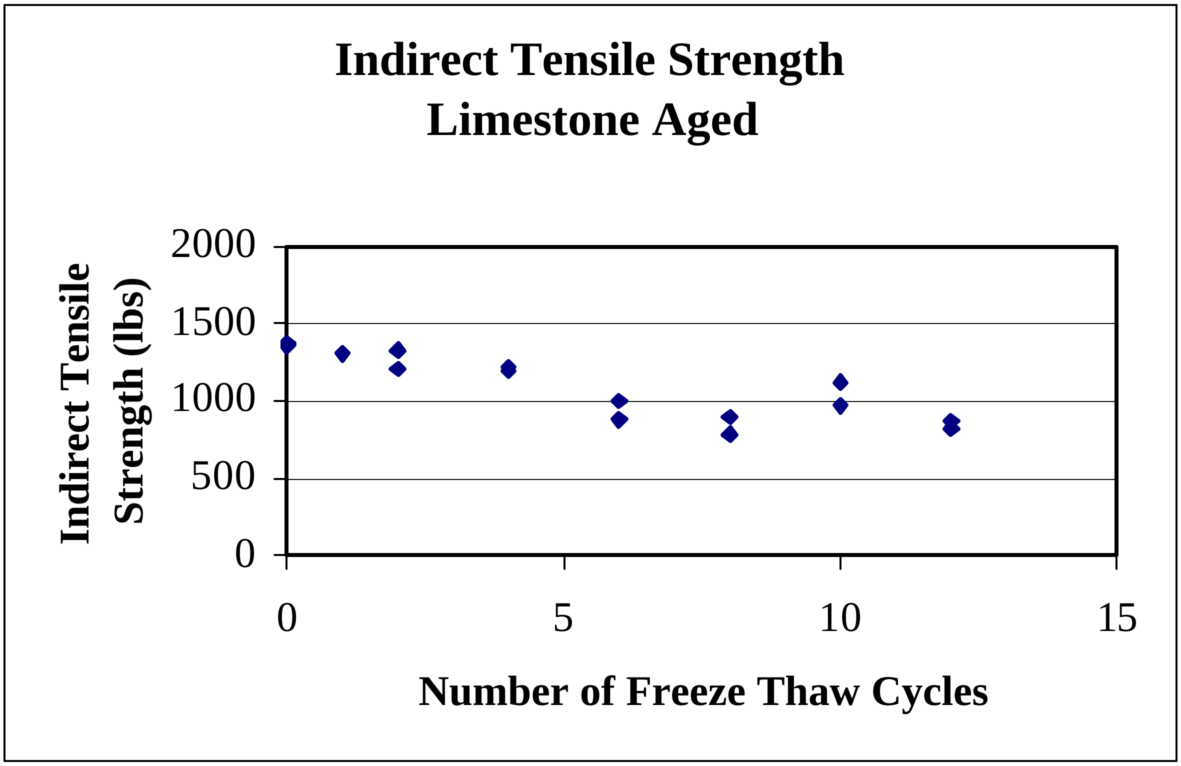
Cycles	Dial Indicator Reading (in)			Rut Depths (in)		
	LOC	Center	ROC	LOC	Center	ROC
0	0.484	0.541	0.546	0	0	0
1000	0.345	0.454	0.3915	0.139	0.087	0.1545
4000	0.2765	0.286	0.234	0.2075	0.255	0.312
8000	0.215	0.142	0.162	0.269	0.399	0.384

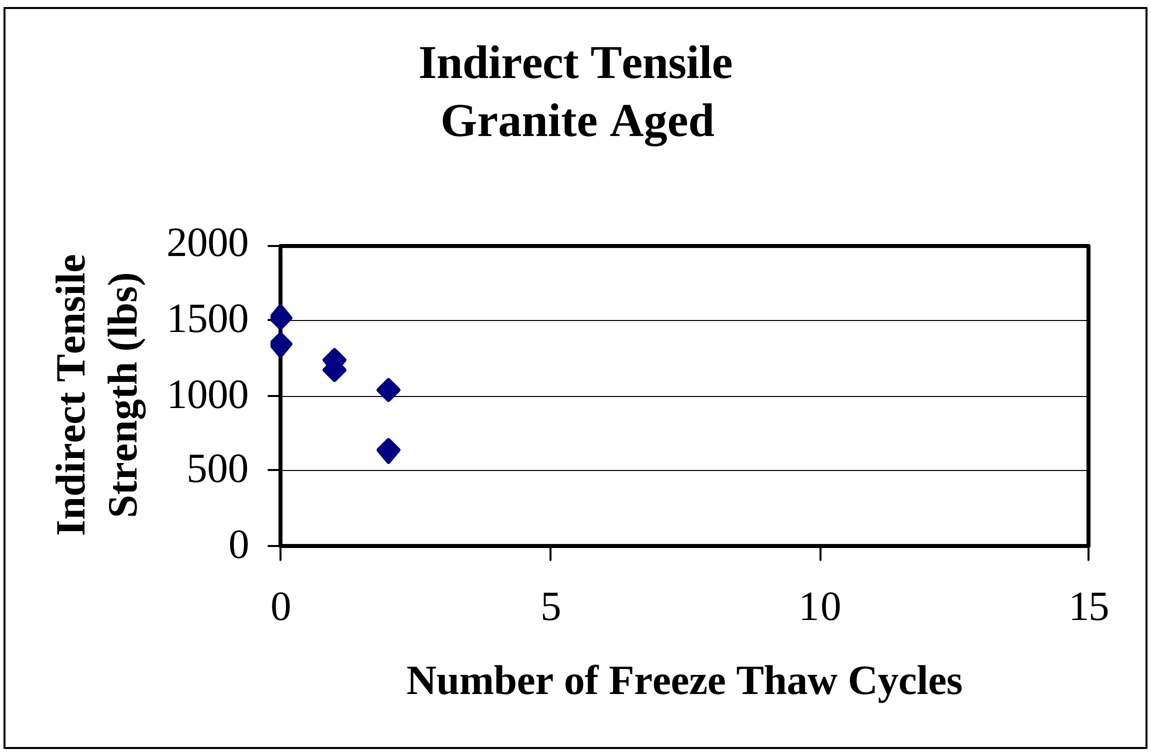
APPENDIX D

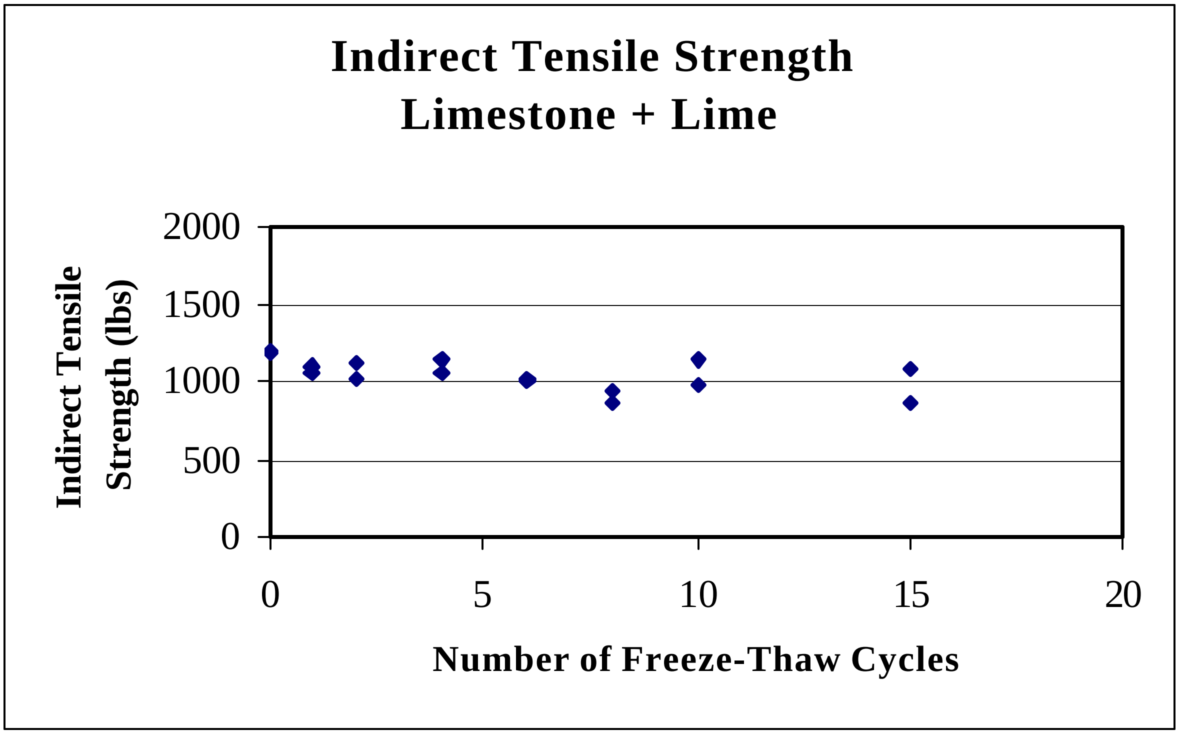
Phase I Indirect Tensile Strength Graphs

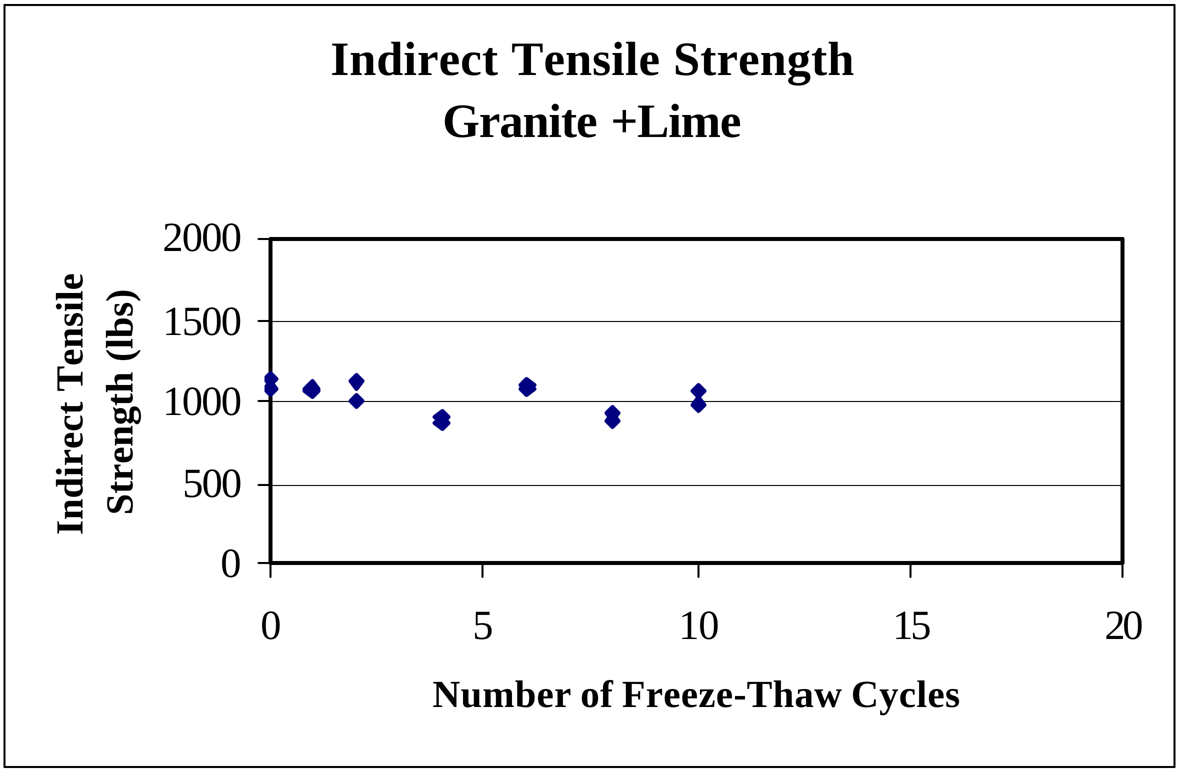

Indirect Tensile Strength
Limestone
Indirect Tensile Strength (lbs)
2000
1500
1000
500
0
0
2
4
6
8
10
12
Number of Freeze-Thaw Cycles

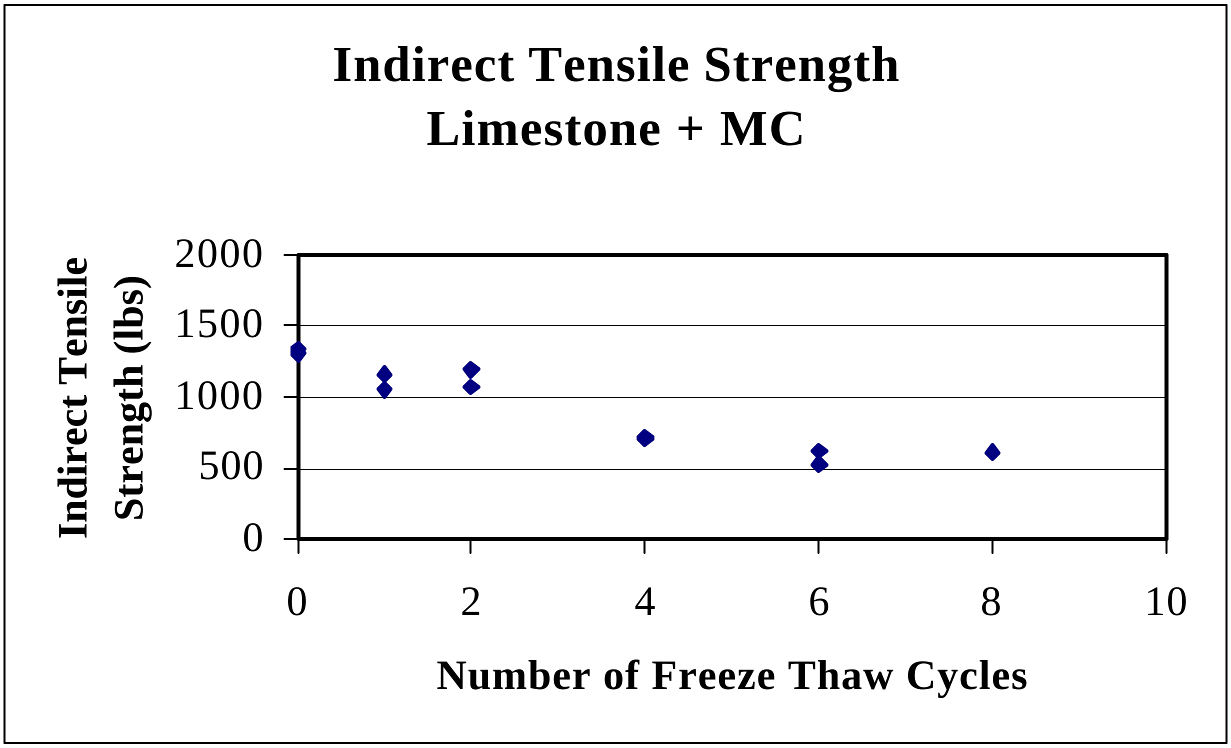

Indirect Tensile Strength
Granite
Indirect Tensile Strength (lbs)
2000
1500
1000
500
0
0
5
10
15
Number of Freeze-Thaw Cycles

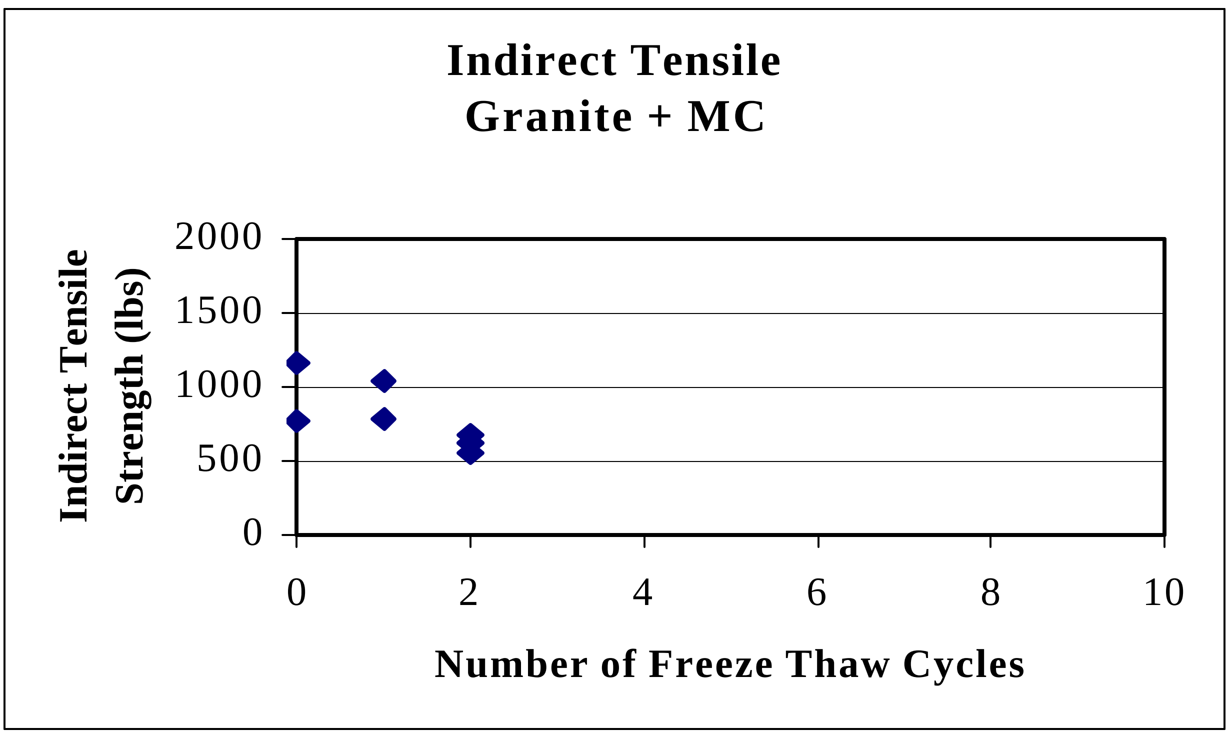

Indirect Tensile Strength
Limestone Aged
Indirect Tensile Strength (lbs)
2000
1500
1000
500
0
0
5
10
15
Number of Freeze Thaw Cycles


Indirect Tensile
Granite Aged
Indirect Tensile Strength (lbs)
2000
1500
1000
500
0
0
5
10
15
Number of Freeze Thaw Cycles


Indirect Tensile Strength
Limestone + Lime
Indirect Tensile Strength (lbs)
2000
1500
1000
500
0
0
5
10
15
20
Number of Freeze-Thaw Cycles

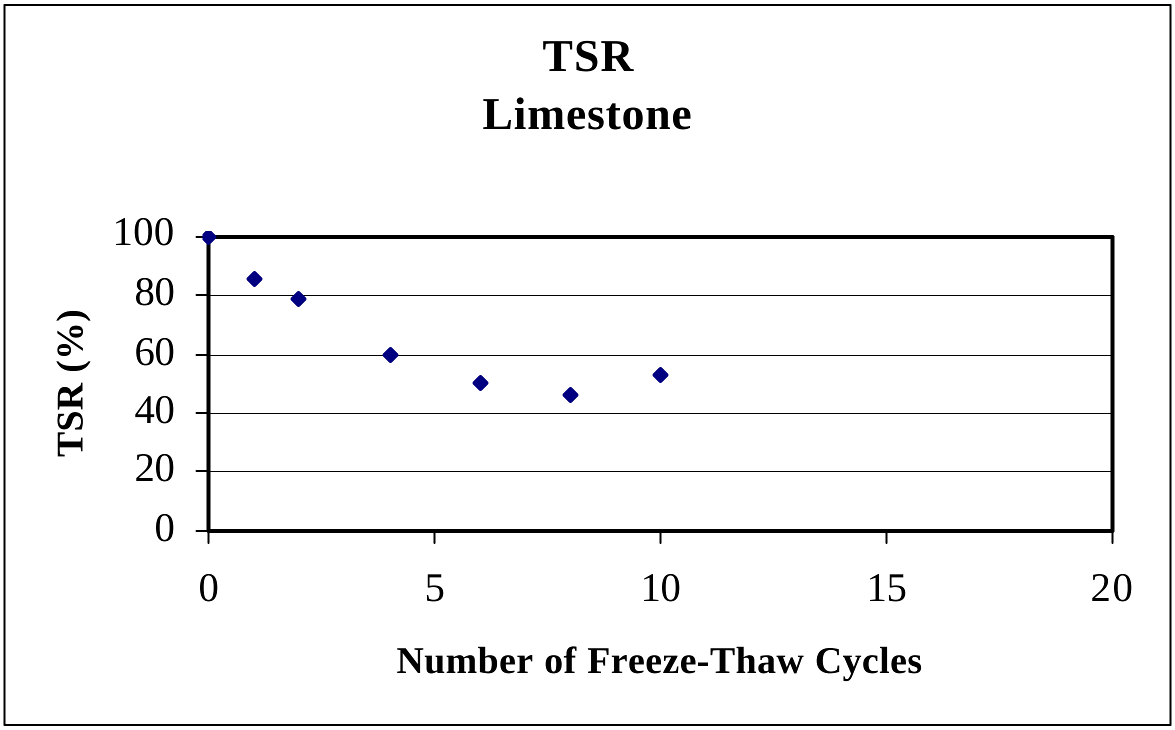

Indirect Tensile Strength
Granite +Lime
Indirect Tensile Strength (lbs)
2000
1500
1000
500
0
0
5
10
15
20
Number of Freeze-Thaw Cycles

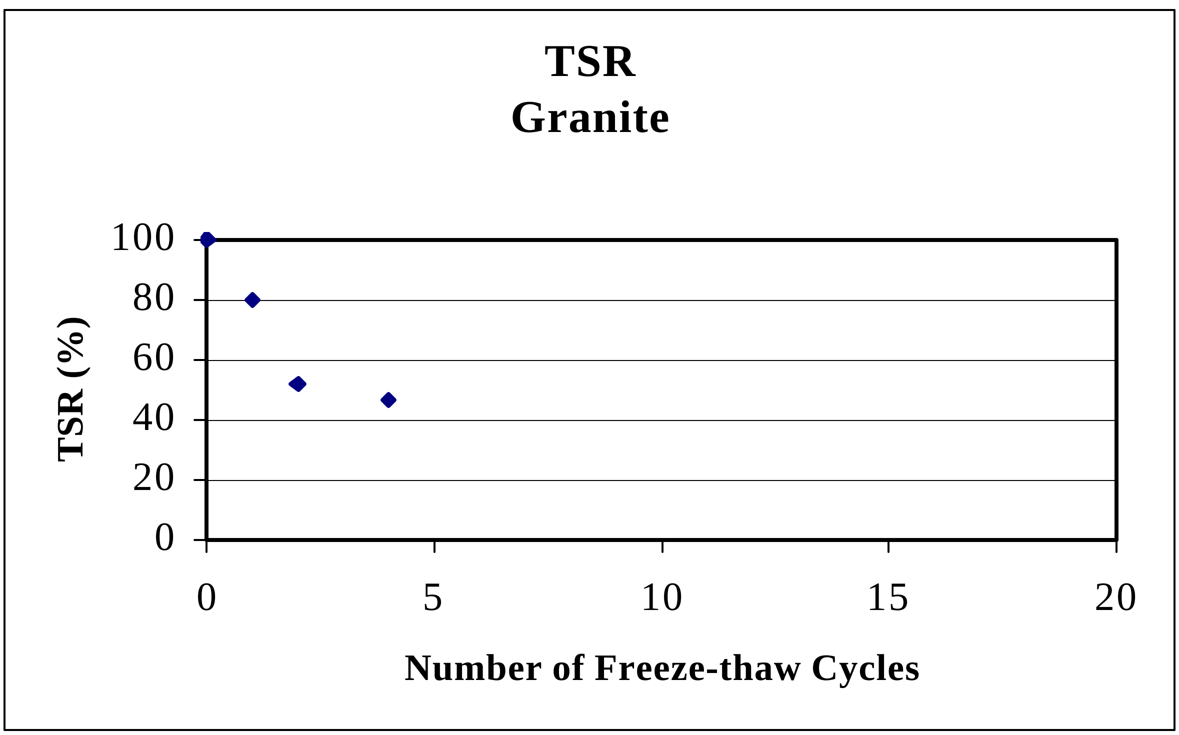

Indirect Tensile Strength
Limestone + MC
Indirect Tensile Strength (lbs)
2000
1500
1000
500
0
0
2
4
6
8
10
Number of Freeze Thaw Cycles

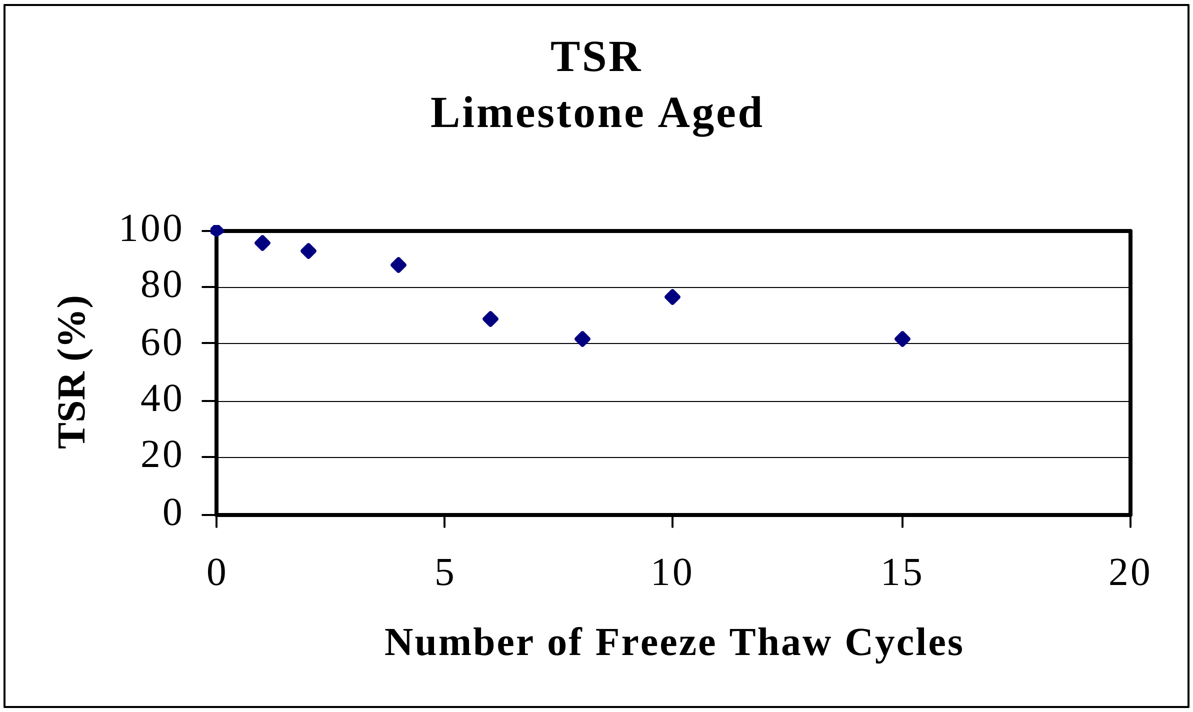

Indirect Tensile
Granite + MC
Indirect Tensile Strength (lbs)
2000
1500
1000
500
0
0
2
4
6
8
10
Number of Freeze Thaw Cycles

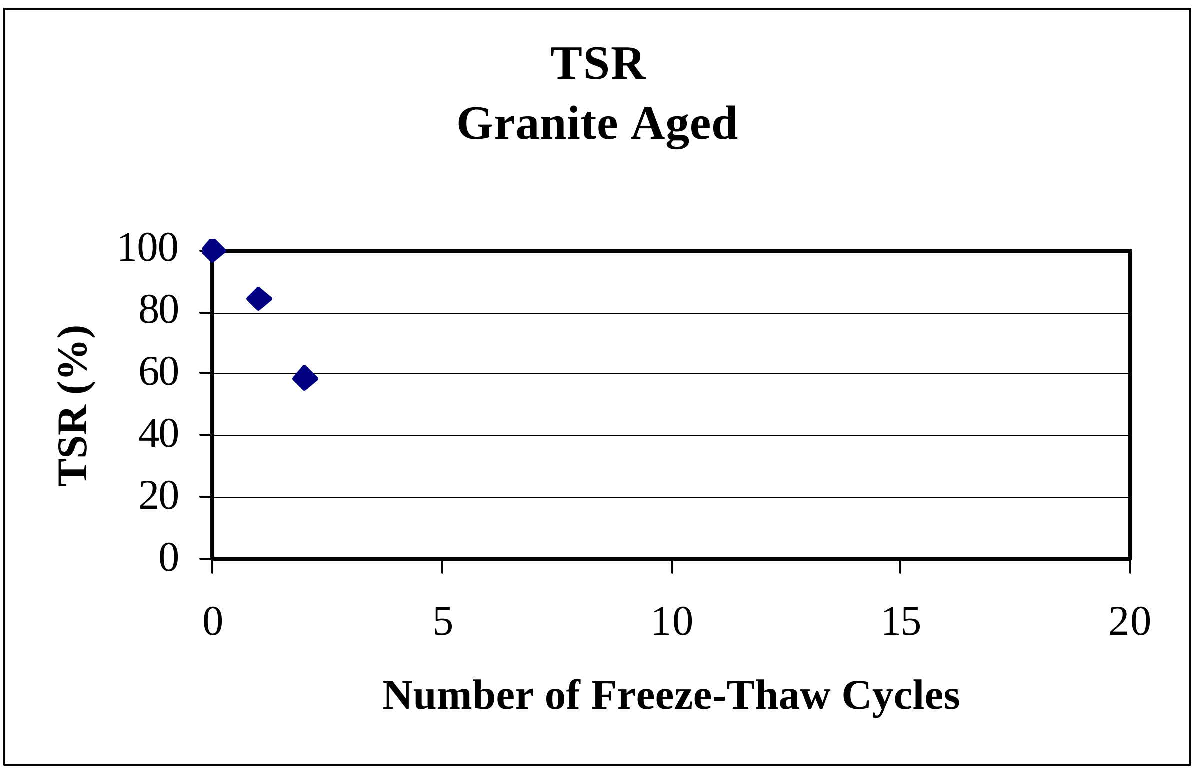
APPENDIX E

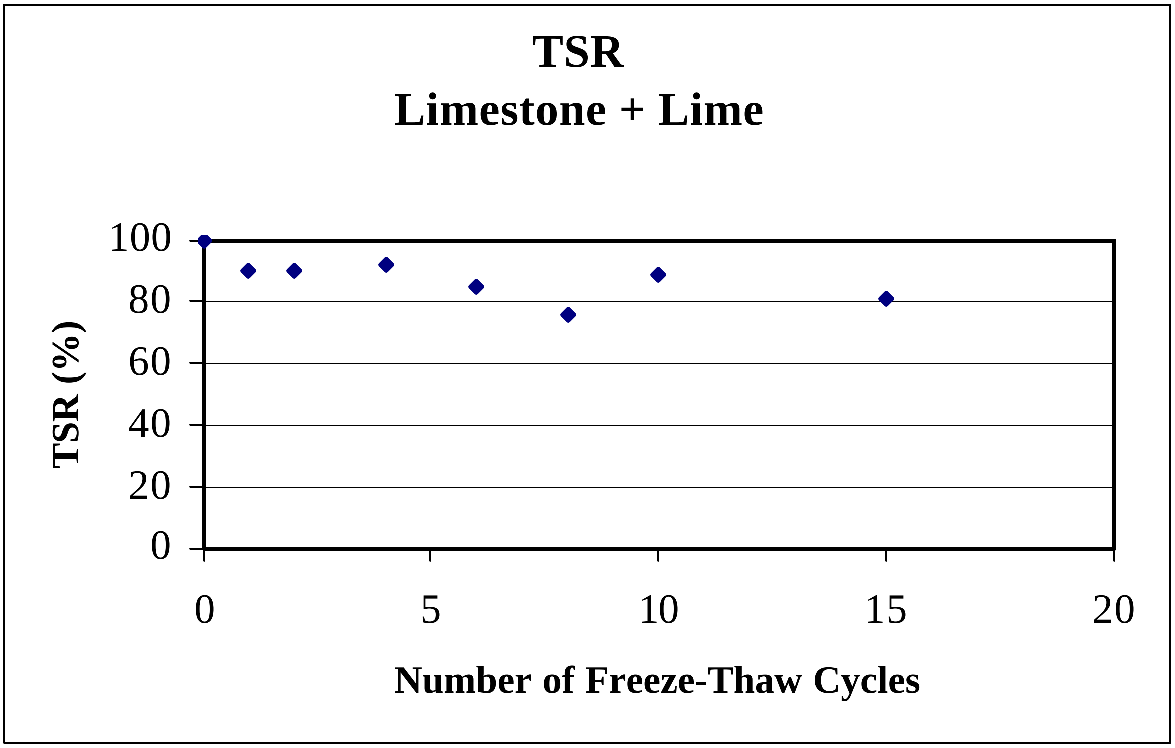
Phase I TSR Graphs

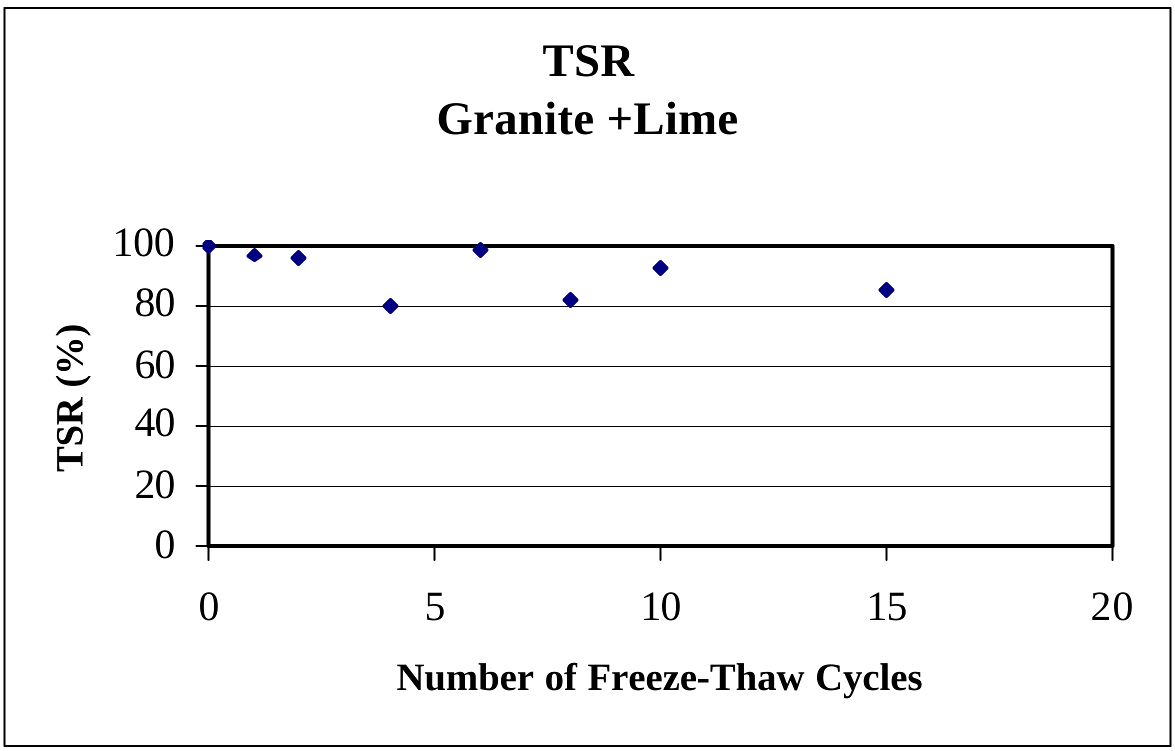

TSR
Limestone
100
80
60
40
20
0
TSR (%)
0
5
10
15
20
Number of Freeze-Thaw Cycles

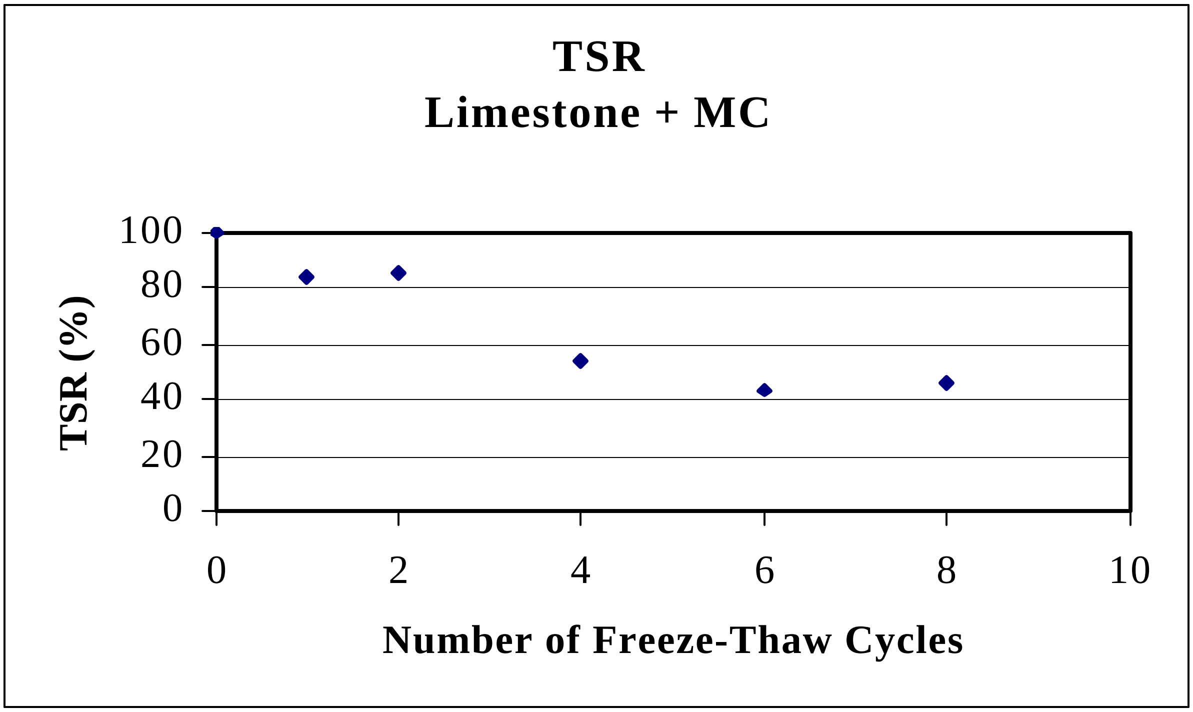

TSR
Granite
100
80
60
40
20
0
TSR (%)
0
5
10
15
20
Number of Freeze-thaw Cycles

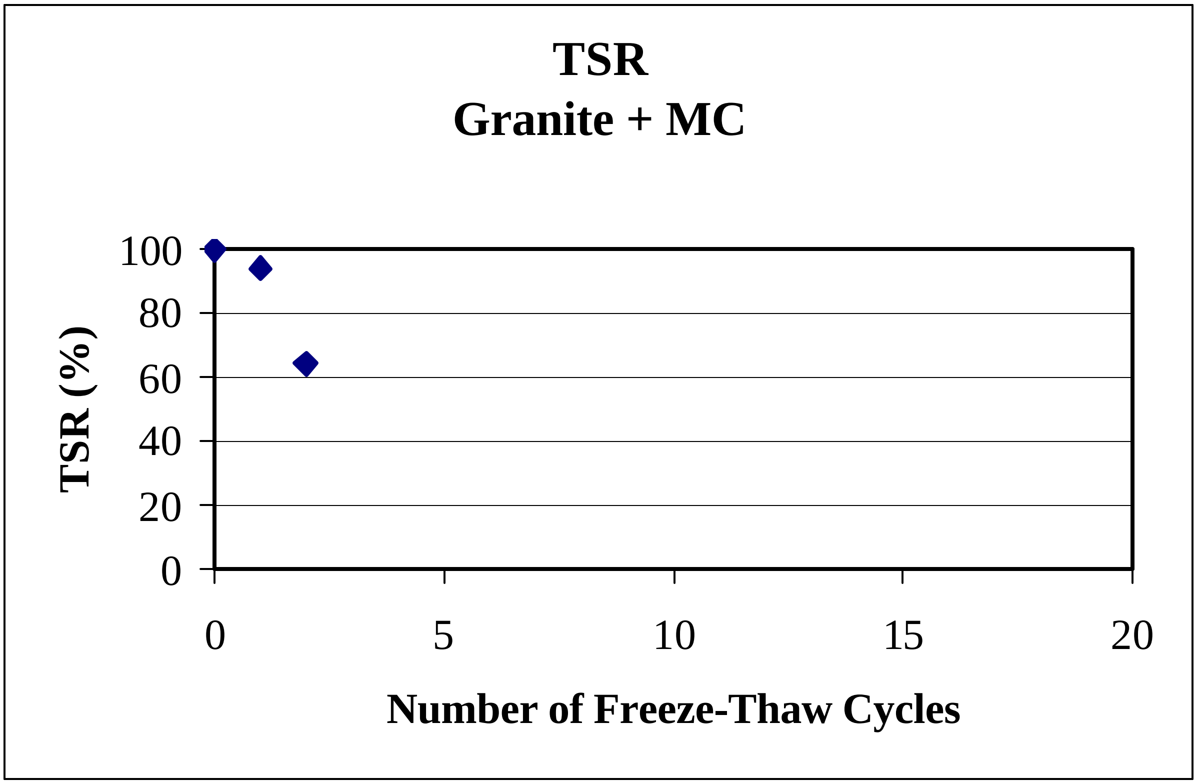

TSR
Limestone Aged
TSR (%)
100
80
60
40
20
0
0
5
10
15
20
Number of Freeze Thaw Cycles


TSR
Granite Aged
TSR (%)
100
80
60
40
20
0
0
5
10
15
20
Number of Freeze-Thaw Cycles


TSR
Limestone + Lime
100
80
60
40
20
0
TSR (%)
0
5
10
15
20
Number of Freeze-Thaw Cycles


TSR
Granite +Lime
100
80
60
40
20
0
TSR (%)
0
5
10
15
20
Number of Freeze-Thaw Cycles


TSR
Limestone + MC
TSR (%)
100
80
60
40
20
0
0
2
4
6
8
10
Number of Freeze-Thaw Cycles


TSR
Granite + MC
TSR (%)
100
80
60
40
20
0
0
5
10
15
20
Number of Freeze-Thaw Cycles

APPENDIX F

Phase I TSR Minitab Analysis I

Regression Analysis: TSR versus Number of Cycles
Limestone + AC-10

The regression equation is
TSR = - 6.42 Cycles

6 cases used 47 cases contain missing values

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-6.4163	0.8313	-7.72	0.001

S = 12.36

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	9098.3	9098.3	59.57	0.001
Residual Error	5	763.7	152.7		
Total	6	9862.0			

Regression Analysis: TSR versus Number of Cycles
Granite + AC-10

The regression equation is
TSR = - 15.8 Cycles

3 cases used 23 cases contain missing values

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-15.810	2.973	-5.32	0.034

S = 13.62

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	5248.8	5248.8	28.28	0.034
Residual Error	2	371.2	185.6		
Total	3	5620.0			

Unusual Observations

Obs	C17	C19	Fit	SE Fit	Residual	St Resid
2	-16.0	*	252.95	47.57	*	* X
3	-41.0	*	648.19	121.89	*	* X

X denotes an observation whose X value gives it large influence.

Regression Analysis: TSR versus Number of Cycles
Limestone + Aged AC-10

The regression equation is
TSR = - 3.43 Cycles

7 cases used 7 cases contain missing values

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-3.4301	0.3937	-8.71	0.000

S = 7.522

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	4294.5	4294.5	75.90	0.000
Residual Error	6	339.5	56.6		
Total	7	4634.0			

Regression Analysis: TSR versus Number of Cycles
Granite + Aged AC-10

The regression equation is
TSR = - 19.6 Cycles

2 cases used 1 cases contain missing values

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-19.600	1.800	-10.89	0.058

S = 4.025

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1920.8	1920.8	118.57	0.058
Residual Error	1	16.2	16.2		
Total	2	1937.0			

Regression Analysis: TSR versus Number of Cycles Limestone + Lime + AC-10

The regression equation is
TSR = - 1.657 Cycles

7 cases used 61 cases contain missing values

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-1.6570	0.3472	-4.77	0.003

S = 7.332

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1224.5	1224.5	22.78	0.003
Residual Error	6	322.5	53.8		
Total	7	1547.0			

Unusual Observations

Obs	C26	C28	Fit	SE Fit	Residual	St Resid
68	15.0	-19.00	-24.85	5.21	5.85	1.13 X

X denotes an observation whose X value gives it large influence.

Regression Analysis: TSR versus Number of Cycles Granite + Lime + AC-10

The regression equation is
TSR = - 1.2018 Cycles

7 cases used 31 cases contain missing values

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-1.2018	0.3768	-3.19	0.019

S = 7.957

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	644.16	644.16	10.18	0.019
Residual Error	6	379.84	63.31		
Total	7	1024.00			

Unusual Observations

Obs	C20	C22	Fit	SE Fit	Residual	St Resid
38	15.0	-15.00	-18.03	5.65	3.03	0.54 X

X denotes an observation whose X value gives it large influence.

Regression Analysis: TSR versus Number of Cycles
Limestone + AC-10 + MC

The regression equation is
TSR = - 8.23 Cycles

5 cases used 85 cases contain missing values

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-8.2314	0.9332	-8.82	0.001

S = 10.27

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	8198.5	8198.5	77.80	0.001
Residual Error	4	421.5	105.4		
Total	5	8620.0			

Regression Analysis: TSR versus Number of Cycles
Granite + AC-10 + MC

The regression equation is
TSR = - 15.6 Cycles

2 cases used 77 cases contain missing values

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-15.600	4.800	-3.25	0.190

S = 10.73

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	1216.8	1216.8	10.56	0.190
Residual Error	1	115.2	115.2		
Total	2	1332.0			

APPENDIX G

Phase I TSR Minitab Analysis II

Regression Analysis: TSR versus Cycles, Adjustment
Limestone and Granite AC-10

The regression equation is
TSR = - 15.8 Cycles + 9.39 Adjustment

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-15.810	2.779	-5.69	0.001
Adjustment	9.393	2.908	3.23	0.014

S = 12.73

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	14347.1	7173.5	44.24	0.000
Residual Error	7	1134.9	162.1		
Total	9	15482.0			

Source	DF	Seq SS
Cycles	1	12655.0
Adjustment	1	1692.1

Unusual Observations

Obs	x	y	Fit	SE Fit	Residual	St Resid
3	4.0	-54.00	-63.24	11.11	9.24	1.49 X

X denotes an observation whose X value gives it large influence.

Regression Analysis: TSR versus Cycles, Adjustment
Limestone and Granite Aged AC-10

The regression equation is
TSR = - 19.6 Cycles + 16.2 Adjustment

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-19.600	3.188	-6.15	0.000
Adjustment	16.170	3.210	5.04	0.001

S = 7.128

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	6215.3	3107.7	61.16	0.000
Residual Error	7	355.7	50.8		
Total	9	6571.0			

Source	DF	Seq SS
Cycles	1	4925.7
Adjustment	1	1289.7

Unusual Observations

Obs	C46	C48	Fit	SE Fit	Residual	St Resid
2	2.0	-41.00	-39.20	6.38	-1.80	-0.56 X

X denotes an observation whose X value gives it large influence.

Regression Analysis: TSR versus Cycles, Adjustment
Limestone and Granite AC-10 + Lime

The regression equation is
TSR = - 1.20 Cycles - 0.406 Adjustment

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-1.2018	0.3628	-3.31	0.008
Adjustment	-0.4059	0.5145	-0.79	0.448

S = 7.661

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	1784.03	892.01	15.20	0.001
Residual Error	10	586.97	58.70		
Total	12	2371.00			

Source	DF	Seq SS
Cycles	1	1747.49
Adjustment	1	36.54

Unusual Observations

Obs	C58	C60	Fit	SE Fit	Residual	St Resid
3	4.0	-20.00	-4.81	1.45	-15.19	-2.02R
7	15.0	-15.00	-18.03	5.44	3.03	0.56 X
12	15.0	-19.00	-24.12	5.47	5.12	0.95 X

R denotes an observation with a large standardized residual
X denotes an observation whose X value gives it large influence.

Regression Analysis: TSR versus Cycles, Adjustment
Limestone and Granite AC-10 + MC

The regression equation is
TSR = - 15.6 Cycles + 7.37 Adjustment

Predictor	Coef	SE Coef	T	P
Noconstant				
Cycles	-15.600	4.633	-3.37	0.020
Adjustment	7.369	4.728	1.56	0.180

S = 10.36

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	9415.3	4707.6	43.86	0.001
Residual Error	5	536.7	107.3		
Total	7	9952.0			

Source	DF	Seq SS
Cycles	1	9154.6
Adjustment	1	260.7