NATIONAL COOPERATIVE
HIGHWAY RESEARCH PROGRAM REPORT **246**

PREDICTING MOISTURE-INDUCED DAMAGE TO ASPHALTIC CONCRETE

FIELD EVALUATION

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT 246

PREDICTING MOISTURE-INDUCED DAMAGE TO ASPHALTIC CONCRETE

FIELD EVALUATION

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Moscow, Idaho

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:
PAVEMENT DESIGN AND PERFORMANCE
BITUMINOUS MATERIALS AND MIXES
MINERAL AGGREGATES
(HIGHWAY TRANSPORTATION)
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TRANSPORTATION RESEARCH BOARD
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MAY 1982

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry: its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

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The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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FOREWORD

By Staff
Transportation
Research Board

This report contains the findings of the field evaluation phase of a study on moisture-induced damage (stripping) of asphaltic concrete pavements. A tentative test system for predicting moisture-damage was developed under a previous phase of the study and the findings were published as *NCHRP Report 192*. General verification of the prediction test system is described in this report. Because of the field verification, the prediction method is suitable for implementation. Materials engineers, research engineers, and others interested in improving the performance of asphaltic concrete pavements will find the report of interest and value.

Moisture is often the major factor associated with the deterioration of asphaltic concrete pavements. The most serious consequence of the adverse action of moisture is the loss of adhesion between the aggregate and asphalt cement, commonly called "stripping," resulting in substantial reduction in the cohesive strength of the asphaltic concrete mixture.

The aggregate-asphalt adhesion properties of a mixture are very complex, involving the mineral composition and surface characteristics of both the coarse and fine aggregate and the many characteristics of the particular asphalt cement. The present state of the art is not adequate to permit the determination in the presence of moisture of the adhesion properties of a given aggregate-asphalt mixture. Consequently, most tests that have been used involve visual evaluation of aggregate-asphalt mixtures in the presence of water. The objective of this study was development and verification of an empirical test system that would simulate in the laboratory the type of moisture damage experienced in asphaltic concrete pavements and thus be useful for predicting the extent of such moisture damage that should ultimately be expected in the field when a pavement is built with a specific aggregate-asphalt mixture.

The University of Idaho researchers developed and pilot tested a system for predicting moisture-induced damage to asphaltic concrete during the first phase of this study. The results were published as *NCHRP Report 192*, "Predicting Moisture-Induced Damage to Asphaltic Concrete." The test system consists of the preparation of laboratory specimens, using the specific aggregate-asphalt mixture under investigation, moisture and temperature conditioning, followed by split tensile strength testing. A portion of the specimens is tested without being subjected to moisture and temperature conditioning. The ratio of the tensile strength of the conditioned versus unconditioned specimens provides a prediction of anticipated moisture damage for the specific mixture. The field evaluation phase of the study described in this report involved the use of the test system to predict ultimate moisture-induced damage for 8 test sections of new pavement being built in 7 states in various climatic regions of the United States followed by the collection and testing of field cores from these pavements over a 5-year period. The preparation of the specimens, laboratory conditioning, and testing for predicting moisture-induced damage, and the extraction and testing of pavement cores subsequent to construction of the pavements, was all done by the 6 cooperating state highway agencies and the FHWA Western Direct Federal Division. Data analysis was conducted by the University of Idaho researchers.

Verification of the test system was accomplished. After 5 years of service, ranking of the pavement sections in terms of visual evidence of stripping and strength ratios of cores removed from the pavements was very similar to the predicted ranking produced by the laboratory test system prior to construction. Surface deterioration of the pavements was not as extreme after 5 years of exposure to traffic and environmental factors as might have been indicated by the ultimate moisture damage predictions. However, the condition of the pavement cores indicates that the pavement surface deterioration predicted by the test will eventually develop. The test method appears to give reasonable predictive levels in the field and is sensitive to mixture variables. The test procedure can be conducted in the laboratories of highway agencies and should be used by such agencies to determine suitable strength ratio values for the selection and use of aggregate-asphalt mixtures to serve local traffic and environmental conditions.

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ACKNOWLEDGMENTS

The research reported herein was performed under NCHRP Project 4-8(3). Overall coordination of the study was the responsibility of the University of Idaho; Robert P. Lottman was principal investigator. Pavement test section construction, predictive moisture testing, and subsequent periodic testing of field cores were performed by seven highway agencies: Arizona, Colorado, FHWA Region 10 (Western Direct Federal Division), Georgia, Idaho, Montana, and Virginia. The laboratory and field data received by the agencies form the basis of this report. Materials and research personnel at these agencies were responsible for initiating and performing the related work and evaluations. Their continued cooperation and steadfastness have been gratefully appreciated throughout the 5-year field evaluation study.

PREDICTING MOISTURE-INDUCED DAMAGE TO ASPHALTIC CONCRETE

FIELD EVALUATION

SUMMARY

A laboratory test method for the prediction of moisture damage in dense-graded asphaltic concrete mixtures was developed in the Phase I study of NCHRP Project 4-8(3) and is described in *NCHRP Report 192*. The method consists of obtaining ratios of tensile splitting strength and resilient modulus using compacted laboratory specimens subjected to vacuum saturation and to freeze-plus-warm-water-soak accelerated moisture conditioning. The ratios are used to predict short-term and long-term moisture-induced damage representative of field conditions.

The primary objective of the Phase I study was the development of a laboratory test method that would predict levels of moisture damage similar to that which would occur in the field. Specific objectives were to: (1) develop a practical laboratory system, simulative of field conditions but using accelerated conditioning based on known research and experience, for quantitatively predicting the magnitude and rate of progression of moisture damage in asphaltic concrete; (2) assess the effectiveness of the test system through a pilot evaluation using information and materials from in-place pavements; and (3) prepare a plan for a Phase II field evaluation study to test the predictive capabilities of the laboratory method against actual pavement performance.

Once the general format of the test system was established in the beginning of Phase I, different moisture-conditioning processes were applied to laboratory specimens following vacuum saturation, and predictive capabilities judged by comparing responses of the treated specimens with those of companion vacuum-saturated cores when subjected to the indirect tensile test, and by comparing microstructures as observed through scanning electron microscopy and by low-power microscopy. Numerous moisture-conditioning procedures to follow vacuum saturation were examined in the initial phase of the work; procedures that appeared to be the most promising were evaluated more exhaustively through the remainder of Phase I. In an initial series of tests, 6 pavements, varying in age from 2 to 10 years, in 3 states, were represented in the study. When results appeared promising, the study was expanded to 17 pavements, varying in age from 2 to 12 years, in 14 states. Pavements showing various levels of moisture damage, as well as pavements showing no visible signs of damage, were included in the study.

The moisture-damage test system that was selected for Phase II as having the greatest potential for success includes the following steps:

1. Compaction of a series of standard, 4-in diameter laboratory specimens prepared of the same materials and to the same voids as the pavement to be constructed.
2. Exposure of two-thirds of the specimens to vacuum saturation.
3. Exposure of one-half of the vacuum-saturated specimens to further moisture conditioning of one cycle of freeze-plus-140 F water soaking.
4. Testing of all specimens in the indirect tension mode at a specified loading rate and temperature.

5. Computation of tensile strength (and modulus if desired).
6. Prediction of moisture damage using tensile-strength (and modulus) ratios, for which the tensile strength (and modulus) of dry specimens are reference bases for the ratios.

Results from the Phase II, 5-year field evaluation portion of the study, are presented in this report. The purpose of the study was to examine the predictive capabilities of the test method and to determine if the predictive ratios and observed stripping were reasonably representative of pavement conditions in the field.

Seven participating highway agencies selected 8 test sections of new pavements being constructed between 1975 and 1977 with aggregates that had a history of moisture damage when incorporated into asphaltic concrete mixtures. The agencies performed the test method using laboratory specimens to predict short-term and long-term damage for the lowest asphaltic concrete layer of the pavements. Predictive ratios for short-term damage ranged from 0.45 to 1.05 and for long-term damage from 0 to 0.80, which indicated that a variety of moisture-susceptible mixtures existed in the test sections. Subsequently, the agencies drilled cores from the pavements at periodic intervals to determine the extent of moisture damage and to compare the resultant data with the predictions. Predictive ratios and associated stripping of laboratory specimens were compared to the field ratios and visible stripping of the cores. The following is a summary of the results and their implications.

Predictive ratios for short-term damage were reached at 4 years of pavement age, or before. During this period the pavement's asphaltic concrete became "stiffened" because of aging, and it was common to find field ratios greater than 1.0. After this initial period, stripping was observed and the field ratios decreased below 1.0.

At the end of the study, the field ratios decreased to low values for the pavements in which substantial stripping was predicted. However, the field ratios remained numerically higher than the long-term predicted ratios for the pavements with moderate stripping. The decreasing trend of the field ratios appears proportional to these predictive ratios, and the associated differences in the ultimate moisture damage of the pavement now seem established. It is probable that field ratios will more nearly match the predicted ratios in a few years.

The main conclusions that can be drawn from the results of testing laboratory specimens and field cores are as follows:

1. The coarse aggregate or fine aggregate stripping observed in the field cores is similar to the predicted stripping, although the field stripping is somewhat less severe.
2. The ranking of the pavement test sections due to moisture damage when using the lowest values of field ratios is similar to the predicted ranking when using long-term ratios.

Evaluation of other variables incorporated in the study showed that:

3. Although moisture damage predictions using laboratory specimens generally have lower ratios than predictions using cores drilled from the pavements immediately after paving, the use of ratios from laboratory specimens is practical for moisture damage predictions.
4. Specimen curing times greater than 1 or 2 days in the laboratory did not

appreciably increase values of predicted ratios or decrease predicted stripping to the extent practical to warrant a test method change.

5. Some of the pavements have more moisture damage in the wheelpath; others have more moisture damage in between the wheelpath.

6. The rate of moisture damage increase (rate of decrease of field ratio values) appears proportional to the amount of heavy traffic. No correlation could be established for climate (temperature extremes and precipitation) at the various pavement locations.

The agencies estimated the decrease of their pavement's layer coefficient due to the moisture damage by using established methods and experience. The decreases were found to be related to the severity of stripping observed for the pavement cores and were roughly proportional to the tensile-strength ratios of the cores at the end of the study. Implications from this project point out the possibilities of using a future method, requiring more research, for the calculation of layer coefficients from fatigue-life ratios that have been correlated with tensile-strength field ratios. The fatigue-life ratios (fatigue decrease referenced to dry asphaltic concrete) would be determined by laboratory tests using the moisture conditioning procedure of the test method.

It is also suggested that additional field cores be tested in the 8 pavement test sections in FY '83 or FY '84 for the purpose of determining if the predicted, long-term moisture damage has occurred to produce numerically matching ratios (predicted vs. field). A worthwhile, follow-up field evaluation Phase III study, similar to but smaller in scope than the NCHRP 4-8(3) Phase II study, could be established with the seven current participating agencies to accomplish this objective.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

PROBLEM STATEMENT AND RESEARCH OBJECTIVE

The phenomenon of adhesion between asphalt cement and aggregates in asphaltic concrete is very complex and not clearly understood at this time. The loss of bond (stripping) because of the presence of moisture between the asphalt and the aggregate is a problem in many areas of the country and is severe from the standpoint of highway pavement performance in some instances. Although the problem is influenced by many factors, such as asphalt characteristics, aggregate properties, mix design, construction procedures, environmental conditions, and traffic, the vast amount of experience in the field indicates that the presence of moisture in combination with the other factors is most critical with regard to the phenomenon of adhesion between the asphalt cement and the aggregates.

Ultimately, identification must be made of the aggregate properties and the asphalt cement characteristics that affect adhesion. This knowledge is basic to the development of techniques that are needed for optimizing the choice of materials or for specifying appropriate corrective measures where loss of bond is likely to be a problem. However, the accomplishment of these ultimate objectives requires fundamental studies that are time consuming and necessitate the development of test methods for correlating the findings with field performance.

Research conducted under NCHRP Project 4-8(3), "Predicting Moisture-Induced Damage to Asphaltic Concrete," has provided both a tentative test method for predicting the susceptibility of asphaltic concrete mixtures to moisture damage and a general plan for a comprehensive field evaluation of the method. The essential findings from Phase I are included in *NCHRP Report 192*, "Predicting Moisture-Induced Damage to Asphaltic Concrete" (*1*).

The objective of the field evaluation study (Phase II) is to provide verifications of the test method tentatively proposed in Phase I. The study includes 5 years of field data evaluation for most of the pavement test sections.

In order to develop a more "real life" situation and, at the same time, provide a wider range of experience with the test method, cooperative arrangements were made in six state highway agencies and Region 10 of the Federal Highway Administration to perform the field and laboratory testing using test pavements constructed between 1975 and 1977. The University of Idaho coordinated the research, performed the data analysis and correlation studies, and had responsibility for report preparation.

PREDICTIVE TEST METHOD

Before reporting on the Phase II research approach and its findings, the laboratory test method for predicting moisture-induced damage to dense-graded asphaltic concrete, developed in Phase I and used in the Phase II study, is summarized here to provide background information. (A detailed description of the test method is included in Appendix A).

In the Phase I study, a number of cores were tested from 3- to 12-year-old moisture-damaged pavements in the United States. These results were compared to the damage resulting from several modifications of accelerated moisture conditioning using laboratory-compacted specimens with aggregate and asphalt types similar to those incorporated in the pavements. A close field match was observed with the application of the freeze-plus-warm-water-soak conditioning procedure to vacuum-saturated specimens.

The accelerated conditioning induces internal tensile stress to the asphaltic concrete mixture structure through the development of internal water pressures on void fissures of the asphalt–fines matrix and at the asphalt–aggregate interfaces. The pressures are produced prior to and by ice formation, and by the differential thermal expansion stresses between water and asphaltic concrete mixture when the frozen, saturated mixture is subjected to the warm-water bath. In addition, the warm-water bath allows for emulsification to take place if the asphalt used in the mixture has this potential. Another result of the conditioning is that it seems to test the durability of the aggregates in the mixture, tending to break down the weaker, porous ones similar to that which has been observed with weak aggregates in asphaltic concrete pavement mixtures subjected to moisture.

The moisture conditioning procedure and testing use common laboratory equipment. The saturation and testing portion of the test method can be used to monitor pavement damage by testing cores drilled from the asphaltic concrete layer under investigation. The evaluation of the effectiveness of antistripping additives and treatments is also a potential application of the test method.

The five main steps of the test method are as follows:

1. Nine 4-in. diameter by 2.5-in. thick specimens are made from mixtures of aggregate and asphalt materials to be used in the pavement and compacted to the expected field permeable voids.

2. After 1 or 2 days of room temperature "curing," the specimens are divided into three sets of three specimens each. One set is selected for the dry test, the second set for the vacuum-saturation test, and the third set for the accelerated conditioning test (vacuum saturation followed by freeze-plus-warm-water soak). (Permeable voids can also be measured during the vacuum-saturation procedure for the second and third sets). Vacuum saturation consists of immersing the specimens in jars filled with distilled water, pulling a 26-in. Hg vacuum for 30 min, and keeping the submerged specimens in the jars for an additional 30 min at atmospheric pressure.

3. The first (dry) and second (vacuum-saturation) sets are submerged in a water bath at the mechanical test temperature for 3 hours. Dry specimens are maintained dry (e.g. placed in watertight jars in the bath). Resilient modulus is measured first at 55 F (or at room temperature) using the Schmidt or Chevron procedure (*4*). The tensile splitting strength, using the same specimens, is measured at 55 F using a vertical deformation rate of 0.065 in. per min (*2*). Average values for each set are calculated. Visual stripping of the two interior faces of each split specimen is also recorded.

4. To apply accelerated conditioning, each wet specimen of the third set, after vacuum saturation, is tightly wrapped in thin plastic. Each wrapped specimen is placed in a heavy-duty plastic bag with about 3 mil of distilled water, sealed, and immediately placed in a 0 to 10 F freezer for 15 hours. The wrapped, frozen specimens are then quickly submerged in a 140 F water bath for 3 min. The unfrozen wrappings are rapidly removed, and the specimens are quickly replaced in the 140 F bath for 24 hours. The warm, wet specimens are then submerged in a cooler, water bath (set at the desired mechanical test temperature) for 3 to 5 hours prior to testing according to step 3.

5. Two resilient modulus ratios and two tensile splitting strength ratios are calculated from the average test values. Ratios less than 1.0 reflect moisture damage. One ratio is the vacuum saturation-to-dry value. The vacuum-saturation ratio is considered to be a "short-term" ratio that simulates moisture damage in the asphaltic concrete when the pavement approaches saturation in the field. The accelerated conditioning-to-dry ratio is considered to be an ultimate long-term, moisture-damage measurement, occurring in the asphaltic concrete (after the saturation effects) due to the forces of environment and traffic. This ratio is almost always less than the vacuum-saturation ratio, and severe stripping is almost always associated with very low ratios.

RESEARCH APPROACH

Eight 1,000-ft asphaltic concrete pavement test sections were evaluated periodically for approximately 5 years in this study. The sections consisted of portions of pavements constructed in 1975 through 1977 by Arizona, Colorado, FHWA-Region 10, Idaho, Georgia, Montana, and Virginia highway agencies. (Note: Testing was performed by Region 10 of the Federal Highway Administration. Shortly thereafter, this agency was renamed Western Direct Federal Division. All references in this report to FHWA Region 10 refer to Western Direct Federal Division.) A variety of climatic regions and mixtures were represented in the test program. Aggregates were generally chosen that had a history of moisture damage when incorporated into asphaltic concrete pavement. Pertinent information including location, thicknesses, and a general materials description of the pavement test sections is given in Table 1.

Each highway agency performed the (Phase I) test method, as previously described, to obtain ratios for predicting moisture-damage for their respective test sections. Laboratory specimens were fabricated from aggregates and asphalts similar to the materials used in the lowest asphaltic concrete layer of their respective pavements, and permeable voids were representative of the void content found in the cores initially drilled from the pavements after paving. Specimens were compacted by the agency methods (kneading, drop

TABLE 1. PAVEMENT TEST SECTIONS.

STATE/ AGENCY	ROUTE	YEAR PAVED AND INITIAL CORING DATE	PAVEMENT LAYER THICKNESSES	PERIODIC CORES AND LABORATORY MIX MATCHING	MIX AGGREGATES AND ASPHALT
Arizona	Green Valley, I-19	1975 (Oct.)	7.5 in.[a] asph. conc. 10 in. selected subbase	Lower 2.5 in. of asph. conc.	Santa Cruz river gravels asphalt cement (no additives)
Colorado	Arapahoe Rd., S.R. 88	1976 (Jun.)	1.5 in. asph. conc. wearing 2 in. asph. conc. leveling 7 in. asph. conc. base (3/4 in max. agg. size)	Lower 2.5 in. of asph. conc. base	Morrison cr. stone - coarse agg. Platte River (Littleton) - fine agg. asphalt cement (no additives)
FHWA Region 10	West Entrance Crater Lake N.P.	1975 (Nov.)	2 in. asph. conc. 10 in. cr. stone base	2 in. of asph. conc.	Pole Creek stockpile, Klamath County, w/14% blend sand asphalt cement (no additives)
Georgia	Walton County, U.S. 78	1977 (Mar)	1.5 in. asph. conc. wearing 2 in. asph. conc. leveling 7 in. asph. conc. base (3/4 in. max agg. size)	Lower 2.5 in. of asph. conc. base	granite gneiss asphalt cement w/.5% additive all layers
Georgia	Walton County, U.S. 78	1977 (Mar)	1.5 in. asph. conc. wearing 2 in. asph. conc. leveling 7 in. asph. conc. base (3/4-in. max agg. size)	Lower 2.5 in. of asph. conc. base	granite gneiss asphalt cement w/.5% additive in wearing and leveling and top 3 in. of asph. conc. base only. Lower 4 in. of base without additive.
Idaho	Whitebird, US 95	1975 (Nov.)	3.6 in. asph. conc. 8.4 in. cr. stone base	Lower 2.5 in. of asph. conc.	Salmon River gravels asphalt cement mix additive: 1% hydrated lime
Montana	Divide North, I-15	1976(Jul.)	4.8 in. asph. conc. 16.8 in. cr. stone base	Lower 2.5 in. of asph. conc.	bench gravels asphalt cement (no additives)
Virginia	Greenwood Dr. Portsmouth I-264	1976 (May)	1.5 in. asph. conc. wearing 5.5 in. asph. conc. base (1 in. max size) 6 in. compacted agg.-sand 6 in. cement stabil. subgrade	Lower 2.5 in. of asph. conc. base	granites - coarse agg. natural sand asphalt cement (no additives)

Note: a. 1 in. = 2.54 cm.

hammer, etc). In addition, each agency performed the test method and predicted ratios of moisture damage for the initially drilled cores from the lowest asphaltic concrete layer of each pavement section. Prediction variables also included laboratory specimen and initial core storage time at room temperature as well as reduced specimen voids, when feasible.

Mean values and standard deviation for the tensile strength and modulus were calculated by mechanical testing sets of 4 laboratory specimens or initial cores for each moisture stage of dry, vacuum saturation, and accelerated conditioning. Coefficients of variation were calculated and reported.

Ratios of cores from the lowest asphaltic concrete layer of each pavement section were also obtained periodically throughout the study. The field ratios were calculated using vacuum saturation only. (Over a period of time, the natural environmental forces produce an accelerated conditioning equivalency on their own and thus would be "built-in" with the measurement of the field vacuum-saturation ratio). One-half of each set of periodic cores was desiccated in the laboratory to obtain the reference dry base for the field ratios. Wheelpath and between-wheelpath locations were evaluated independently to determine the effects of traffic. Two sets of 8 cores each were drilled for each of the locations and for each measurement period. Measurement periods were every 4 months for the first 2 years and every 6 months (spring and fall) thereafter. The total measurement period was approximately 5 years for 6 of the 8 pavement test sections and 4 years for the two Georgia sections because paving was completed in 1977 instead of in the previous year.

Each highway agency recorded the standard deviation and mean value of the tensile strength and resilient modulus for each half-set of the periodic field cores. Each half-set consisted of 4 cores, either desiccated dry (approx. constant weight) or vacuum saturated, for a total of 8 cores per set. Thus, 2 coefficients of variation were calculated for each set, producing 4 coefficients of variation per two sets: wheelpath and between wheelpath, for each measurement period.

The highway agencies were also requested to record traffic, air temperature, and precipitation at their test section locations. Pavement surface distress and layer coefficients due to the moisture damage were to be noted as well as visual stripping of the periodic cores.

The research objective was to compare the predicted tensile strength and modulus ratios with the field ratios. If the field ratio trend and associated stripping most nearly matched the predicted ratio levels at the end of the study, there would be a good indication that the test method reasonably predicted the occurrence of moisture damage in the pavements.

CHAPTER TWO

FINDINGS

The findings of tensile (splitting) strength ratios are discussed in this chapter; summary graphs and tables are included. Resilient modulus ratios have similar trends. More detailed graphs of predictions and field ratios as well as tables of test data are given in Appendixes B through I for each highway agency's test section.

MOISTURE DAMAGE PREDICTIONS

Tensile strength ratios for unaged laboratory specimens are shown in Figures 1 through 4. Predictive short-term ratios plotted vertically at the left of the pavement age scale represent vacuum saturation, and predictive long-term ratios plotted vertically on the right of the pavement age scale represent accelerated conditioning.

The short-term predictions have higher ratios than those for the long-term predictions. This is to be expected. In some cases, the short-term predictions have ratios that are greater than 1.00. This means that the tensile strength of saturated specimen sets is greater than that of dry sets. This implies that better performance should be experienced in the early life of the pavement in the wet state. Six of the mixtures showed slight stripping after vacuum saturation.

In comparison with the short-term ratios, the long-term ratios produced by the accelerated conditioning have lower values and reflect greater differences between the pavement mixtures. For instance, long-term ratios for the Idaho mixture are 0.80, resulting in a prediction for the Idaho pavement section of 20 percent maximum reduction of cohesive mechanical properties due to moisture damage. In contrast, the long-term ratios for the Georgia mixtures are 0, resulting in a prediction of 100 percent reduction of cohesive mechanical properties. In between these two mixtures are the long-term ratios for the mixtures of the other pavement sections. Thus a wide range of long-term moisture damage prediction was established by accelerated conditioning and seemed to give a good basis for the test method evaluation.

Stripping was observed in all mixtures subjected to accelerated conditioning with the exception of the Idaho mixture. Generally the severity of stripping was inversely proportional to the long-term ratios, as expected.

Although there are exceptions, the following trends were observed for all the laboratory specimen and initial (zero age) pavement core test data:

1. Ratios using the zero-age pavement cores are somewhat higher than the ratios using laboratory specimens. This implies that the paving process accounts for some build-up of interfacial adhesion, aggregate orientation, and other factors which, in the main, impart more moisture resistance in the pavement, at least initially. It is also recognized that laboratory compaction methods do not always give a perfect match to the compacted mixture characteristics of a pavement. No significant differences could be assigned to the compaction method used for laboratory specimens (e.g., kneading vs. drop hammer).
2. Increased storage time of laboratory specimens and zero-aged pavement cores appears to impart more moisture resistance and gives higher long-term predictive ratios, but the effect is generally obscured due to test variability. However, their short-term predictive ratios are generally high, sometimes greater than 1.0.
3. The laboratory specimens containing reduced voids (usually 50 to 75 percent of the voids of the zero-age pavement cores and "standard" laboratory specimens) impart more moisture resistance and, hence, generally give higher predictive ratios.

It appears that ratios obtained from unaged laboratory specimens (1 to 2 days aging only), compacted to the expected permeable voids for the lowest asphaltic concrete layer in the pavements, predict moisture damage characteristics and levels unique for each of the 8 mixtures and are the most practical way of predicting damage.

Coefficients of variation for the mechanical testing of sets of laboratory specimens averaged 10 percent for tensile strength and 14 percent for resilient modulus. The range of coefficient of variation for all the highway agencies was 7.3 percent to 19.5 percent for tensile strength and 6.8 percent to 20.5 percent for resilient modulus. This suggests that predictive ratios, although quantitative, are not precise because of the specimen-mixture variations and testing variations; rather, the ratios should be viewed as levels of moisture damage.

FIELD MEASUREMENT AND TRENDS

Ratios obtained from the pavement core tests are represented as solid or dashed lines in Figures 1 through 4. The lines are drawn through plotted ratios calculated for each periodic core set tested throughout the pavement evaluation time. The field ratios were calculated after desiccating a core set to constant weight and subsequently vacuum saturating one-half of the core set. Figures 1 through 4 show the lower of the field ratios, occurring either at wheelpath (wp) or at between-wheelpath (bwp) locations. (The graphs in Appendixes B through I show field ratios for both locations.)

Arrows in the figures represent a "minimum" ratio for the final field measurement. It is calculated from the last core set using immediate vacuum saturation (one-half of the core set was immediately saturated and tested) and from the highest dry strength calculated for a core set during the years of measurement. It represents maximum damage (wheelpath or between-wheelpath locations). This ratio was calculated when it was noticed after a few years that the dry strength

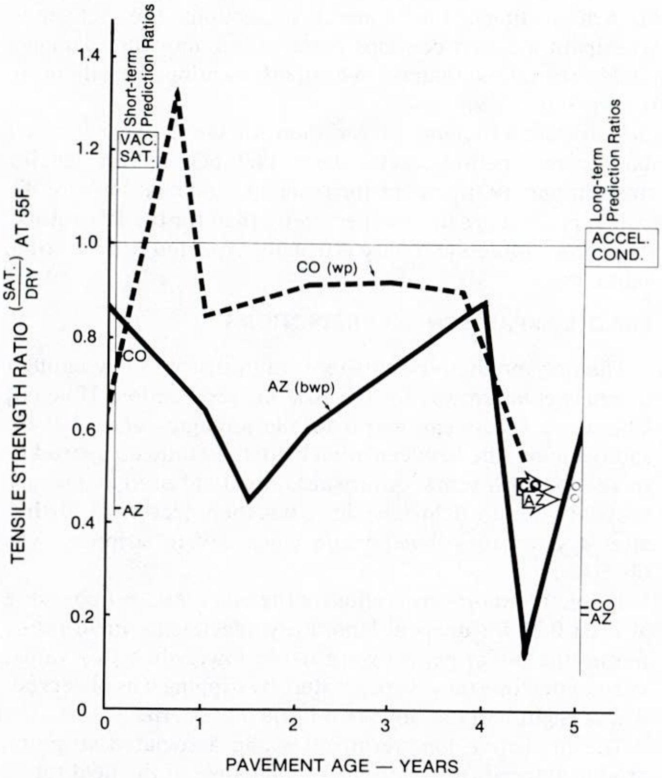

Figure 1. Arizona and Colorado test sections—summary of predictive and field tensile strength ratios at 55 F.

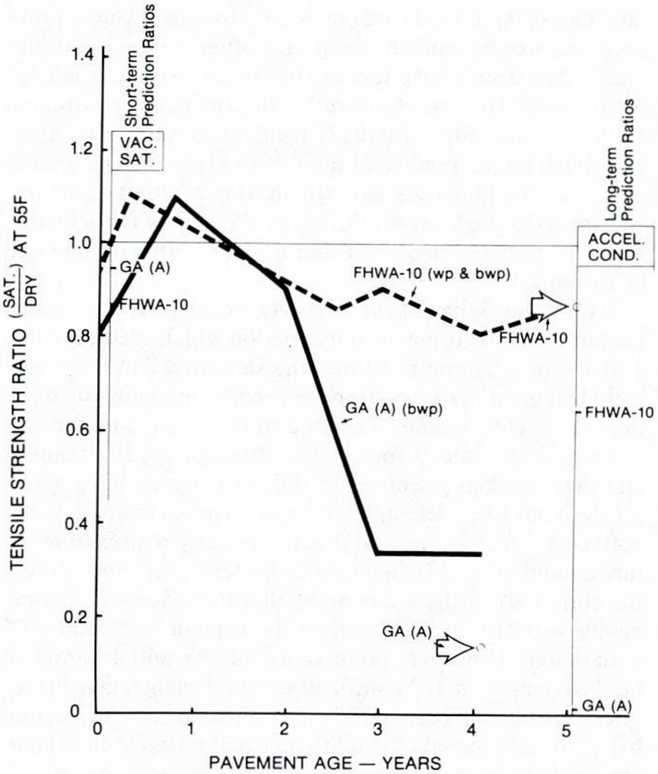

Figure 2. FHWA Region 10 and Georgia (A) test sections—summary of predictive and field tensile strength ratios at 55 F.

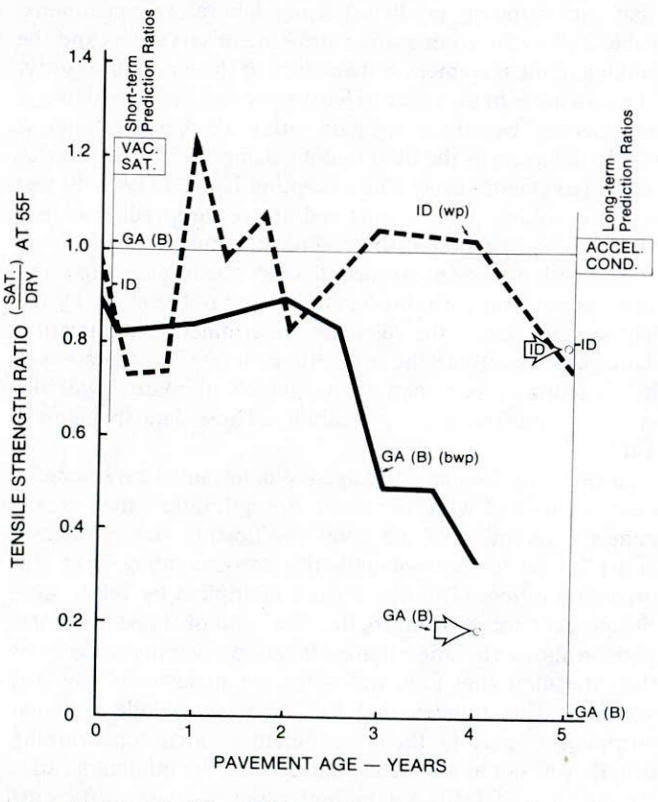

Figure 3. Georgia (B) and Idaho test sections—summary of predictive and field tensile strength ratios at 55 F.

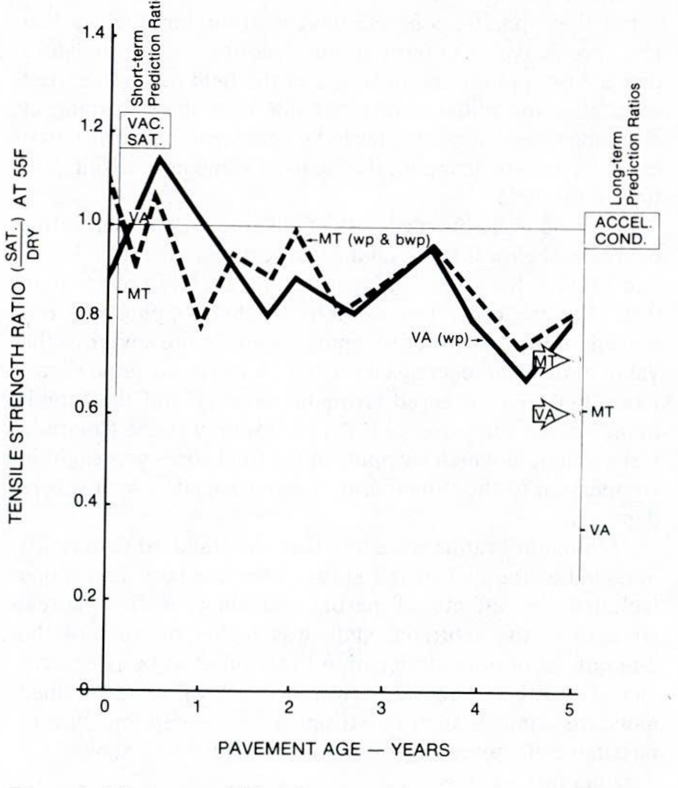

Figure 4. Montana and Virginia test sections—summary of predictive and field tensile strength ratios at 55 F.

(and modulus) of field cores increased to a peak value, probably because of asphalt aging and other interactive influences, then decreased afterward because of moisture damage or stripping. The use of this ratio after the peak dry strength value provides for a calculation of ratios similar to those calculated by the predictive ratio methodology. (The predictive ratio method uses average maximum strength of dry specimens as the basis for the ratios. One of the participating highway agencies suggested that the use of this ratio would be realistic.)

Six of the 8 pavement sections developed field ratios greater than 1.0 during the initial period which seemed to last 1 to 4 years. During this time, the saturated cores sporadically had greater strength (and especially modulus) than the dry cores. This was not predicted from the short-term ratios of unaged laboratory specimens, although aged specimens and zero-age pavement cores did, in general, have ratios greater than 1.0. There appears to be an initial strengthening-stiffening effect in the field due to the early phases of moisture conditioning. Limited laboratory tests performed during the early part of the study show that the viscosity of some paving asphalts increases when the asphalt is "saturated" with water. However, predictions for the initial period of field pavements may be difficult to make using unaged laboratory specimens because of the complexities of interaction between early moisture conditioning and repeated field loading, asphalt aging, and aggregate surface properties.

The field conditioning effect and partial rehealing due to moisture and environmental changes appear to be more responsible than test variability for the erratic, zig-zag periodic ratio patterns shown in the figures. The zig-zag patterns caused difficult tracking of the ratio trends, especially during the first 3 years.

For the asphaltic concrete pavement mixtures which had low, predictive long-term ratios denoting severe moisture damage (stripping), the decrease of the field ratios occurred soon after the initial period. At this time the beginning of stripping was observed, later to be accompanied in the worst cases by severe stripping that caused some core disintegration in the field.

Stripping was observed in the field cores when their ratios decreased below 0.80 for all the test sections except for Idaho and FHWA 10, whose ratios remained slightly greater than 0.80. For the other test sections, slight stripping was observed for the 0.80 ratio; stripping became more severe as the value of the ratio decreased further. A relatively good correlation between observed stripping severity and the "minimum" ratios was observed. An exception was the Colorado test section, in which stripping in the final cores was slight in comparison to the "minimum" ratio associated with severe damage.

"Minimum" ratios were less than the standard field ratios obtained at the end of the study. The standard field ratios included the effects of partial rehealing of field cores; strength at the saturated state was higher because of the 2-month laboratory desiccation time found to be necessary and at the dry state was lower because of some retained moisture damage such as stripping. An exception, due to possible field rehealing between 4.5 and 5 years, was the Arizona test section.

The field ratios do not show a moisture damage bias for wheelpath or between-wheelpath locations when comparing all test sections. For some test sections the between-wheelpath location contains more severe moisture damage (and lower ratios) than the wheelpath location; for others, it is reversed.

Average coefficients of variation for the testing of pavement cores (periodic sets) were 14.7 percent for tensile strength and 19.0 percent for resilient modulus, and are 47 and 36 percent greater, respectively, than for the laboratory specimens. More variability is usually expected when testing field cores.

FIELD COMPARISON TO PREDICTIONS

The only predictive short-term ratio that was low enough to cause concern was for the Arizona test section. Unaged, laboratory specimens had a tensile strength ratio of 0.42. Interestingly, the between-wheelpath field ratio decreased to this ratio at 1.5 years. Afterwards, the field ratio increased, probably due to field rehealing, but then decreased further after 4 years to a lower value when severe stripping was observed.

Predictive short-term ratios for the other test sections were at least 0.75 for unaged, laboratory specimens. Field ratios during the initial period were never lower than this value; most of the time they were greater. If stripping was observed, it was slight and did not seem to be a concern.

The predictive long-term ratios and associated stripping produced trends that were more indicative of the field ratios and observed stripping at the end of the study. The field ratio for the Idaho test section was practically identical to the predictive ratio. The field ratios for the other test sections were about one-third greater than the predictive ratios. The observed stripping in the field cores was about one-third less than the stripping predicted using laboratory specimens. Table 2 gives the comparative stripping observations and the ranking of the pavement test sections at the end of the study. The ranking is in the order of least-to-worst moisture damage as measured by tensile strength ratios. Predicted ranking is nearly the same as the field ranking using "minimum" ratios of the pavement cores. The exception is the FHWA 10 test section ranking, which remained above the predicted, top-ranked Idaho section at the end of the study.

Although pavement surface distress due to moisture damage was not firmly established at the end of the study by the highway agencies, the agencies determined that moisture damage (stripping) in the asphaltic concrete layer decreased its structural layer coefficient—which ultimately will decrease the pavement's serviceability. These data are given in Table 3.

In order to compare the agency-determined layer coefficients in Table 3 with the tensile strength ratios, the percent cohesive retention of the layer coefficients was calculated and is given in Table 4 with the corresponding field and predicted ratios. (The ratios were multiplied by 100 to give the percent retained strength). The end-of-the-study comparison shows that the retained layer coefficients are greater than the minimum field ratios for the majority of the test sections. This implies that the agencies include a visual stripping as part of their coefficient estimation; stripping usually was not as severe as indicated by the minimum ratio. On the basis of Table 4 data, high retained layer coefficients are associated with no more than very slight stripping and with field ratios equal to greater than 0.80.

TABLE 2. MOISTURE DAMAGE RANKING OF TEST SECTIONS.

Predicted at Start of Study Laboratory Specimens			Field at End of Study Pavement Cores		
(Long-Term Ratios^1.)		(Stripping)	(Minimum Ratios)		(Stripping)
			FHWA 10	(0.88)	Slight
ID	(0.82)	Very Slight			
			ID	(0.80)	Very Slight
FHWA 10	(0.63)	Slight to Moderate			
MT	(0.62)	Moderate			
			MT	(0.72)	Slight to Moderate
			VA	(0.51)	Severe (coarse agg.)
VA	(0.35)	Severe (coarse agg.)			
			CO	(0.50)	Slight
CO	(0.22)	Severe	AZ	(0.48)	Moderate to Severe
AZ	(0.21)	Severe			
			GA(B)	(0.20)	Moderate to Very Severe
GA(A)	(0)	Very Severe	BA(A)	(0.15)	Moderate to Very Severe
GA(B)	(0)	Very Severe			

Note: 1. Tensile strength ratios from test method's accelerated conditioning of unaged laboratory specimens.

TABLE 3. ESTIMATED LAYER COEFFICIENTS FOR MOISTURE-DAMAGED ASPHALTIC CONCRETE.

Agency	Original or Design Coeff.	Coeff. if 100% Moisture Damaged^1.	Coeff. at End of Study^2.	Anticipated Coeff. for Long-Term^2.
AZ	0.39	0.15	0.25	0.20
CO	0.44	0.14	0.40	0.36
FHWA 10	0.28	0.14	0.28	0.20
GA(A)	0.30	0.20	0.25	0.22
GA(B)	0.30	0.20	0.25	0.22
ID^3	2.0	1.0	2.0	2.0
MT	0.40	0.12	0.30	0.18
VA	1.0	0.35	0.75	0.75

Notes: 1. Highway agencies assumed the asphalt concrete layer will become noncohesive, equivalent to gravel.

2. Based on visual stripping or a combination of visual stripping and mechanical tests. VA would assign higher coefficients if based on retained core stiffness, only.

3. ID uses gravel equivalency basis.

TABLE 4. COMPARISON OF COHESIVE RETENTION OF LAYER COEFFICIENT TO PREDICTED AND FINAL FIELD RATIOS.

	Percent Retention of Original Coefficient^1 as a Cohesive Layer		Percent Retained Tensile Strength (Ratio X 100)	
Agency	End of Study	Long-Term	Lowest at End of Study	Laboratory Specimen Long-Term Prediction
AZ	42	21	48	22
CO	87	73	50	22
FHWA 10	100	43	90	65
GA(A)	50	20	16	0
GA(B)	50	20	16	0
ID	100	100	80	82
MT	64	21	72	60
VA	62	62	62	36

Note: 1. Percent retention if equal to 100 minus the following ratio expressed as a percentage: the highway agency-estimated decrease of coefficient at end of study (or at the long-term) divided by the difference of coefficient between the original and 100-percent moisture damage values. The coefficient values used are listed previously in Table 3.

Estimated long-term retained layer coefficients are lower than initial values and predicted long-term ratios are also lower than initial values. However, the relative reduction is less for the estimated layer coefficient values. This implies that there is some agency optimism as to how far the pavements will ultimately degrade as compared to predictions. A further evaluation of field cores would need to be made a few years from now to verify if a close, numerical match exists between retained layer coefficients and predictive long-term ratios. If a close match exists, the predictive long-term ratios could be used to assign layer coefficients for pavement rehabilitation requirements.

EFFECT OF VARIABLES

Compaction and aging variables for laboratory specimens did not significantly change overall predictions and field results. Although aging of laboratory specimens appeared to impart more moisture resistance and provide higher predictive ratios, the comparison to overall levels of field moisture damage observed at the end of the study was not significantly different in most cases. The data, however, show that the aging of laboratory specimens seems to be helpful if precise matching of ratios is required.

Reduced voids occurred in only two pavement sections (ID and MT) for the tested, lowest asphaltic concrete layer.

Even though the field voids reduced about 50 percent for these two sections, the predictive long-term ratios were practically the same for the reduced and nonreduced voids. Voids in the other test sections did not reduce. For asphaltic concrete layers that are low in the pavement structure, the data show that predictions based on specimens that have voids lower than the expected permeable voids after paving may not be needed.

Traffic and climatic data are given in Table 5 for each of the test sections. Field ratios at the end of the study that remained at a high level category relative to predictive long-term ratios seemed to be associated with a low number of cumulated 18-kip single-axle equivalents (e.g., FHWA 10 and VA). The FHWA 10 test section has practically negligible traffic on it. On the other hand, test sections having the highest traffic also had the more rapid field ratio decreases to the moderate and lower level categories of damage (e.g., AZ and GA). The traffic influence on the rate of ratio decrease during the last year or two of the field study appears to be dominant over precipitation and temperature extreme differences. Each test section had its own combination of traffic and climatic factors, and the separation of these variables for a controlled determination of their effects was not possible in this study.

TABLE 5. SUMMARY OF TRAFFIC AND CLIMATIC DATA.

	One-Way 18-kip-Single-Axle-Equiv.		Monthly Air Temp. °F		
Agency	Equivs/yr	Est Total	Ave. Low	Ave. High	Ave. Annual Precip. in.
AZ	80,000	398,000	40	101	15
CO	55,000	258,000	15	90	12
FHWA 10	1	5	15	66	56
GA	101,000	405,000	31	82	46
ID	34,000	173,000	19	91	13
MT	17,600	88,000	7	78	14
VA	5,000	26,000	22	88	38

Notes: 1. Georgia data represent 4 years of observation; data for other agencies represent approximately 5 years of observation.

CHAPTER THREE

INTERPRETATION, APPRAISAL, APPLICATION

TEST METHOD PREDICTIONS

The performing of the NCHRP 4-8(3) test method by the participating highway agencies for the purpose of predicting short-term and long-term moisture damage in their test sections was accomplished at the completion of paving, early in the study. Most of the agencies had no prior experience with the method, leading one to recognize that more precise predictions could now be achieved because of the 5-year background of testing. However, the agency personnel readily adapted to the test method, and the predictions (ratio) should be used as levels of damage rather than precise numbers. Evaluation of visual signs of stripping is also valuable as a supplemental measure.

Long-term prediction ratios obtained from the accelerated moisture conditioning ranged from 0 to 0.8+ for the tensile splitting strength and resilient modulus tests. Some mixtures had ratios in between, indicating that a range of moisture-susceptible pavements was evaluated. The agencies which experienced very low predictive ratios (e.g., less than 0.45) were very hesitant to use the mixtures in other pavements without a change of materials or without antistripping treatments. Agencies which had middle-range predicted damage ratios of 0.45 to 0.70 were less certain about their mixtures' long-term field performance, although more specific viewpoints were noted in one or two cases where the field cores showed stripping and associated ratio decreases at the end of the study. Therefore, predictive credibility interacts with end-result experience.

As the amount of visual stripping increased with the obtaining of low ratios, the visual effects aided the acceptance of the ratios calculated by the mechanical tests. Exposing the tensile splitting test specimens to observe stripping was done easily in the test method.

The mechanical test procedure favored by the agencies was the tensile splitting test. It was easy to perform and visualize what was happening. The resilient modulus test appeared more difficult to perform; some agencies experienced initial problems in equipment and procedure. However, the majority of the agencies proceeded with resilient modulus testing and became proficient. Test variability was slightly higher for the resilient modulus testing.

Shortening the time to perform the test method was a concern of some of the agencies. A possible suggestion is to shorten the freezing time from 15 h to 3 or 4 h in the accelerated conditioning part of the method. In some instances this may be practical, providing the time is adequate to completely freeze the specimen. The current test method consists of a 5-day procedure:

Day 1. Make mixtures; over night oven cure (optional).
Day 2. Compact mixtures; cure specimens at room temperature; select 3 specimen sets.
Day 3. Vacuum saturate one specimen set; test the dry set and the vacuum-saturated set; vacuum saturate the third specimen set and freeze overnight.
Day 4. Remove the third set from freezer and place in 140 F water bath.
Day 5. Remove the third set from 140 F bath and test after cooling.

Thus, besides the possibility of reducing the freeze time, the following times could also be reduced: oven mixture cure, specimen cure, 140 F water bath soaking. This would reduce the overall time by a day or a day-and-a-half. However, it should be cautioned that adequate adhesion time should be developed as well as adequate moisture damage mechanism time. This can only be verified with carefully obtained laboratory data for a wide variety of mixtures and treatments.

FIELD EVALUATION OF MOISTURE DAMAGE

If the 8 asphaltic concrete pavement test sections used in the study are representative of most pavements in the United States, the field conditioning or stiffening effect, brought about by the interaction of early moisture influences, repeated loading, and asphalt aging factors, will be observed during the first few years. Ratios of vacuum-saturated field cores to those of dry cores should remain high during this time. It is suspected, however, that if rapid asphalt "emulsification" occurs for some pavements (not included in this study), the field stiffening effect will be minimal, if any, and the rapid decrease of field ratios will result.

The field conditioning or stiffening effect usually produced field ratios greater than 1.0 in a more or less zig-zag pattern during the early pavement age. Short-term predictions from vacuum saturation of aged cores initially drilled from the pavement after paving and laboratory specimens also produced ratios greater than 1.0. However, several months for laboratory curing of specimens are required, the need of which is questionable at this time, especially if one is considering long-term damage. The short-term predictions should be viewed from these field observations as the detection of very serious early life problems. For the purpose of this application unaged specimens can be used.

The initial period of high field ratios is associated with the increasing magnitude of tensile strength and resilient modulus, especially for the pavements whose long-term moisture damage was predicted to be not extremely severe. Thereafter, the mechanical properties of the field cores will decline if stripping or other types of moisture damage occur. This began at 1 to 4 years of pavement age in this study. Although field ratios then decreased, the magnitudes of the mechanical properties of most of the cores remained greater than those of the cores obtained initially after paving.

Consequently, field moisture damage could be viewed as consisting of two measurement criteria: (1) saturation-to-dry ratios of cores for moisture sensitivity, and (2) retention of mechanical property magnitude (tensile strength or modulus).

The approach to use mechanical property retention for field data should be done with caution. This criterion, if used, should be evaluated with respect to fatigue-life retention to be practical. Even though the field conditioning (stiffening) effect is not fully compensated for by moisture damage in the field, resulting in high tensile strength or modulus, the mixture's fatigue life could actually be decreased especially if stripping is observed. Until more is known about fatigue-life changes due to saturation and stripping under field moisture conditioning and asphalt aging, it is recommended that the field ratios from cores be used as the primary measure of moisture damage.

On the other hand, the criterion of a minimum tensile strength for laboratory specimens subjected to the test method, for both dry and moisture-conditioned stages, appears to be practical and can be used to supplement the laboratory ratios and visual stripping by ruling out basically poor, low-strength mixtures for pavements even if their ratios are high. This is similar to what some agencies have incorporated in the immersion compression test to supplement the index of retained strength.

Slight stripping was noticed in the field cores when their ratios reduced to 0.80. As the ratios decreased further, more severe stripping was observed. Each mixture possessed its own unique stripping characteristic, which is to be expected. The ratios generally seemed to be greater than what one would estimate from coarse aggregate stripping alone. The fine aggregate and asphalt mastic apparently maintains a structured continuity in the mixtures for most of the cases of coarse aggregate stripping and thus retains a good deal of the dry tensile strength and modulus after saturation. Severe stripping involved both coarse and fine aggregate. When this happened the ratios were lower and came closer in agreement with the visual stripping effects. Mixtures from other studies might show different strength ratio–visual stripping relationships.

The comparison of predictive ratios to field ratios caused problems because the method of core testing and calculation did not technically match the predictive test method. The predictive test method reference basis for ratios is the mechanical properties for relatively fresh, dry laboratory specimens. Field cores, after a period of time, do not possess these conditions because of asphalt aging and the practical inability to thoroughly desiccate them. Although the calculation of periodic, running ratios was used throughout the study, they were thought to be on the high side. Immediate saturation of the field cores and "minimum" ratios were therefore calculated to provide additional comparative ratios at the end of the study. Their use seems to be technically better for comparison to the predictive long-term ratios. In the future, it is recommended that immediate saturation of field cores be used to obtain field ratios. Maximum "dry" core mechanical properties, found at the end of the field conditioning period, should be used for the reference basis thereafter with immediate vacuum saturated core sets.

Stripping and other forms of moisture damage reduce the cohesion of asphaltic concrete. The agency-estimated reduction of layer strength coefficient for the respective pavement test sections was derived based on this premise. A main factor was the amount of visual stripping in the field cores at the end of the study. Long-term estimates were essentially based on experienced protractions of current stripping observations. Consequently, some agencies estimated lower and higher numerical layer coefficients (changed to percent cohesive retention of coefficient) as compared to tensile strength ratios. There is an overall proportionality between the two, however, and it may not be too unreasonable to use the tensile strength ratio of field cores to estimate the existing layer coefficient. To do this, the tensile strength ratio of field cores (calculated from the immediate saturation ratio) would be multiplied by 100 to change to percent and equated to the percent cohesive retention of the layer coefficient. Both the original coefficient and the untreated gravel or crushed stone coefficient would also have to be known. For example, suppose an existing, moisture-damaged pavement is to be assessed for an overlay and the overlay thickness is to be determined by the current structural capacity of the pavement layers. Suppose also that the current tensile strength ratio of field cores is 0.60 and that the original and gravel layer coefficients are 0.44 and 0.14, respectively. Then,

$$0.60 \times 100 = 100 - \frac{100 \times \text{decrease of layer coefficient}}{0.44 - 0.14}$$

Thus, decrease of layer coefficient = 0.12 and the existing layer coefficient for the asphaltic concrete is: 0.44 − 0.12 = 0.32.

The existing coefficient could be adjusted based on the amount of stripping observed. The adjustment could make the coefficient lower if the remaining bending-strain fatigue life is considered (see Chapter Four).

So far, the field data show that the predictive long-term ratios should be viewed as levels of ultimate damage. For most of the pavements the field ratios numerically remain above the predictive ratios at the end of the study. Several more years of field data would be needed to make another numerical assessment of how closely the predictive ratios were reached. The best that can be determined right now is that the field ratio trend seems to be one of approaching the predictive ratios. The field ratios, the associated stripping, and the layer coefficients determined at the end of the study rank the pavement test sections approximately the same as the ranking predicted by the long-term ratios and stripping produced by the accelerated conditioning of the test method.

LOCATION VARIABLES

In the study twice as many cores were drilled as for an "ordinary operation" in order to evaluate independently the moisture damage in wheelpaths and between wheelpaths. Unfortunately, there were no specific trends at the end of the study—some pavements had more damage in wheel-paths, others had more damage between wheelpaths, and in one or two pavements there was no difference. The testing of cores from the lowest portion of the asphaltic concrete layer probably had something to do with it. If moisture damage builds-up more rapidly in the lowest layer, as observed in many pavements, the added influence of wheel loading at the pavement surface is probably attenuated or spread out underneath the pavements. For future pavement damage evaluation, one might consider the drilling of cores with representative, combined sampling in and between wheelpaths for a given periodic core set, especially if testing the lowest asphaltic concrete layer for the thicker pavements. This would minimize the number of cores to be drilled.

Heavy traffic volume, however, does have its effect. Both the Arizona and Georgia pavements had more 18-kip single-axle equivalents than the other pavements, and their field ratios decreased rapidly. On the other hand, the FHWA 10 and Virginia pavements had much lower traffic, and their field ratios decreased at much lower rates. It appears, then, that heavy traffic will decrease the field time to reach the maximum moisture damage predicted by the test method.

Locations of high precipitation and wide temperature extremes were expected to decrease the field time to reach predicted damage. This effect could not be verified in the study. Perhaps this effect was obscured because of such other variables as different asphaltic concrete mixtures and traffic.

The results of the study show that ultimate or long-term moisture damage is primarily influenced by asphalt mixture variables (aggregates, asphalt, and voids) as long as field conditions provide for moisture entry. This can occur in "dry" as well as "wet" climates because the lowest asphaltic concrete layer absorbs moisture in its various forms from the subgrade and stores it. Heavy traffic volume appears to increase the rate of damage more effectively than climatic extremes of precipitation and temperature.

CHAPTER FOUR

CONCLUSIONS AND SUGGESTED RESEARCH

CONCLUSIONS

At the end of the 5-year study, the main conclusions that can be drawn from the testing of laboratory specimens and field cores are as follows.

The ranking of the 8 pavement test sections due to visual stripping moisture damage is similar to the predicted ranking using the long-term strength ratios. Predicted stripping in coarse or fine aggregate is similar to the stripping in saturated field cores, and long-term ratios provided predicted damage levels equivalent to the levels determined by "minimum" field ratios.

Evaluation of other variables incorporated in the study showed that: (1) moisture damage predictive ratios from pavement cores drilled during early pavement age are slightly greater than those from laboratory specimens, but the use of laboratory specimens appears practical for predictive purposes; (2) specimen curing time in the laboratory before moisture conditioning did not appreciably increase predictive ratios to warrant a test method change; (3) lower field ratios did not always occur in the wheelpath—about one-half of the test sections showed lower field ratios in between the wheelpaths; and (4) the rate of moisture damage increase (decrease of field ratios) appears proportional to heavy traffic volume, and no correlation could be established for climate (temperature extremes and precipitation).

PERFORMING THE TEST METHOD

With a minimum of experience, the performing of the test method becomes relatively easy. It was found by highway agency personnel that the test method can readily be incorporated into their overall asphaltic concrete test methodology in the laboratory. Specimens are of conventional size (4 in. diameter by 2.5 in. thick) and are compacted by the same method used for determining design asphalt content. Moisture conditioning requires the use of conventional laboratory equipment. The tensile splitting test requires a deformation-rate-control compression testing machine that is commonly used in the laboratories.

The test method's specific procedures for vacuum saturation and accelerated conditioning should be followed. They have been evaluated over the past 15 years and have been found to correlate with field experiences.

There are now good reasons for highway agencies to use the test method and to weigh its advantages over other test methods. The highway agencies report that the test method gives high moisture sensitivity between different mixtures and they believe that similar differences of moisture sensitivity also occur in the field.

APPLYING THE TEST METHOD

The purpose of the test method is to reproduce the moisture damage that will occur in a dense-graded asphaltic concrete mixture for a pavement. If extensive damage is predicted, the asphaltic concrete should be either redesigned, treated, or replaced. No less consideration is given to any building material that is to be used outdoors in a harsh environment. Acceptable ratios calculated from the test method should be specified conservatively. Evidence shows that stripping of mixtures is detected at ratios as high as 0.80 from the test method's accelerated conditioning and from field cores. However, some highway agencies view acceptable test method ratios of 0.80 as too high; others believe the 0.80 acceptable ratio is about right.

The increased use of marginal aggregates, greater asphalt varieties, and lower mixing temperatures with higher moisture contents appears to make field mixtures more moisture sensitive than in the past. Lower mixing temperatures and higher moisture contents are not widely used in bituminous laboratories at present. Perhaps, then, the minimum, acceptable test method ratio should be greater than 0.80 to ensure good performance in the field.

The obtaining of an acceptable ratio above 0.80 can be a difficult assignment. There is practical evidence from other studies that the use of liquid antistripping additives of the correct type and dosage or the use of other treatments, such as portland cement or hydrated lime and slurry, incrementally increases the ratios of untreated, stripping-type mixtures. However, the requirement of a high, acceptable ratio should provide a performance target for antistripping products and treatments. The treatments can be evaluated quantitatively by dividing the tensile strength of the accelerated conditioned treated mixtures by the tensile strength of the dry (or accelerated conditioned) untreated mixture.

The desirable test specimen size and the diametral testing used in the test method have overall advantages to highway agencies. Incorporated as an addition to their design asphalt content procedure, moisture damage can be assessed and antistripping treatments can be evaluated. The test data are in the engineering unit form of tensile strength (stress) and resilient modulus (stress/strain). These data can then be directly applied to mechanistic pavement designs and related evaluation approaches to make go or no-go decision on the apparent fatigue life decrease due to moisture damage versus the cost of antistripping treatments. In addition, the laboratory specimens can be exposed to the test method's moisture conditioning and diametral fatigue tests performed to obtain fatigue curves for use in the mechanistic approaches. Asphaltic concrete fatigue curves should not be based only on dry mixtures for this purpose.

In the absence of fatigue curves that reflect damage due to moisture conditions, the short-term and long-term ratios predicted by the test method can be used to estimate the decrease of pavement design layer coefficients for the asphaltic concrete. The basis for the decrease would be loss of cohesion. A ratio of 1 denotes new, undamaged asphaltic concrete and the respective layer coefficient is used. For the other extreme, a ratio of 0 denotes 100 percent stripping (complete moisture damage) and the respective coefficient for untreated aggregate is used. Layer coefficients can be assigned to asphaltic concrete mixtures with ratios between these extremes. Unfortunately, the field time for the layer coefficient loss to occur is variable. The evidence from this study shows that short-term ratios (vacuum saturation) can occur up to 4 years of pavement age and long-term ratios occur after that, most probably from 4 years to 12 years depending on heavy traffic volume and other factors not presently correlated.

FIELD MEASUREMENT

As mentioned previously, the measurement of moisture damage from field cores was a new approach and consequently produced unforseen testing technique problems that had to be solved toward the end of the study. However, the data were helpful to the highway agencies and provided insight to the meaning of testing cores, evaluating the data, and obtaining a moisture damage profile for each test section as the pavement became older. Future moisture-damage field monitoring should be based on the following:

1. If one-time cores are obtained so that there is no knowledge of the maximum dry strength and modulus peak that has occurred, the "moisture damage ratios" should be calculated from the immediate vacuum saturation of one-half of

the core set and from the desiccation (dried to constant weight) of the other half of the core set.

2. If periodic cores are obtained, starting no less than a year after paving, it is possible to obtain the approximate maximum dry strength and modulus peak. Using the immediate vacuum saturation value for a subsequent, periodic core set with the maximum dry strength, and modulus obtained previously during the pavement aging process, more accurate moisture damage ratios can be calculated.

3. After performing the modulus and tensile strength tests on cores, it is also helpful to split open the cores completely and record the observed stripping.

4. The decrease of pavement layer coefficients due to moisture damage should be calculated using the field ratios and observed stripping. The coefficients should probably be less than indicated by the field core ratios because of the greater, apparent decrease of cohesive fatigue life that has occurred. Highway agencies may want to develop a correlation with the field core ratios that includes the reduced fatigue life factor. Long-term layer coefficients could be predicted by the ratios and stripping resulting from the test method's accelerated conditioning.

5. The field evidence shows that cores from badly stripped pavements can produce moderately good ratios because the drilling process provides the laboratory with integral cores so that they can be tested. The cores that have disintegrated during drilling are not tested, because, sometimes, their rubble is not delivered to the laboratory. In order to eliminate this problem, it is suggested that the disintegrated cores be given a strength and modulus value of 0 and their number averaged in with the strength and modulus values of the testable cores. Thus, the calculated ratios should more closely represent the pavement's overall moisture damage "ratio."

EXTENSION OF FIELD EVALUATION PHASE

Approximately 5 years of moisture-damage-related data have been collected and analyzed for the 8 pavement test sections of this study. The predicted moderate-to-severe moisture-susceptible asphaltic concrete layers in these sections are showing distress, although their field ratios remain numerically above the predicted ratios. The participating highway agencies generally agree that the damage will increase over the next few years. It will be advantageous to evaluate further the test sections in a few years from now in order to obtain final data for comparison to the predictions.

It is recommended that a small NCHRP study (e.g. Phase III of NCHRP 4-8(3)) be funded in FY '83 or '84 for this purpose. Some additional funds from FHWA, coordinated through the NCHRP study to the participating agencies, will assist their research budget for the required core drilling and testing. Cores could be obtained in the spring of 1984, for example, with the study's start-up in the fall of 1983. Some of the participating agencies have expressed a great deal of interest in this. An organization should be selected to coordinate the data and relate it to the NCHRP 4-8(3) Phase II study.

OTHER RESEARCH

Advantages to performing additional research of moisture-damaged asphaltic concrete have been implied indirectly in this report. The important project objectives are listed in the following:

1. Needed is the application of the test method's moisture conditioning stages of vacuum saturation and accelerated conditioning to asphaltic concrete to determine their effects on fatigue life. These data will provide a correlation for obtaining specification-type acceptable test method ratios and will be of great help to the highway agencies.

2. There are indications from the field and from laboratory fatigue tests that asphaltic concrete "dry" performance is improved, perhaps temporarily, by the inclusion of moisture if only saturation is induced and the test method ratio is greater than 1.0. If this is true, practical pavement longevity benefits can be accrued before the onset of stripping, if it does occur.

3. The basis for the calculation of the decrease of layer coefficients due to moisture damage needs to be developed quantitatively for national practical considerations. A fatigue ratio correlation mentioned previously under item 1 can be used in conjunction with joint experience from participating highway agencies. More accurate assessments and "field timing" of existing, moisture-damaged pavements will aid pavement rehabilitation design and overlay thickness determination. This will provide for the separation of layer coefficient reduction due to moisture damage and due to traffic-associated conventional fatigue cracking. The resulting method would be less complex and should be more precise.

4. An in-depth field evaluation study is needed to determine the long-term effectiveness of antistripping treatments. Highway agencies have performed the NCHRP 4-8(3) test method on various mixtures with different additives, dosages, and treatments resulting in a wide range of conclusions. Improvements range from significant to insignificant. Also, some agencies require blanket use of antistripping additives and there is concern about the long-term cost effectiveness. Although the effectiveness of treatments is predicted by the test method, there may be construction and aging factors in the field which reduce their effectiveness. A well-planned and monitored field evaluation study over a period of years should provide the data needed. If it is found that the long-term effectiveness decreases and if the mechanism of field factors can be found from the study, the NCHRP 4-8(3) test method can be altered by the addition of an accelerated field aging mechanism to better predict long-term additive effectiveness. If, however, the current test method's prediction of effectiveness is accurate for all practical purposes, it would provide immediate credibility for the use of the test method in the laboratories of highway agencies and of additive manufacturers.

REFERENCES

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APPENDIX A

PREDICTIVE MOISTURE DAMAGE TEST METHOD USED IN NCHRP PROJECT 4-8(3)

EFFECT OF WATER-RELATED CONDITIONING ON INDIRECT TENSILE PROPERTIES OF COMPACTED BITUMINOUS MIXTURES

1. Scope

1.1 This method covers measurement of the change of diametral tensile strength and diametral (tensile) resilient modulus resulting from the effects of saturation and accelerated water conditioning of compacted bituminous mixtures. Internal water pressures in the mixtures are produced by vacuum saturation followed by a freeze and warm-water soaking cycle. Numerical indices of retained indirect tensile properties are obtained by comparing the retained indirect properties of saturated and accelerated water-conditioned laboratory specimens with the similar properties of dry specimens.

2. Apparatus

2.1 Two automatically controlled water baths will be required for immersing the specimens. The baths will be of sufficient size to permit total immersion of the test specimens. They will be so designed and equipped to permit accurate and uniform control of the immersion temperature. One bath is provided for bringing the immersed specimens to the temperature of 140 ± 3.6 F (60 ± 2C) for the warm-water-soak portion of the specimen conditioning. The second bath is provided for bringing the immersed specimens to either the selected test temperature of 55 ± 1.85 F (12.8 ± 1C) or of 73 ± 1.8 F (22.8 ± 1C) for the indirect tensile testing. The baths will be constructed of or lined with stainless steel or other nonreactive material. The water in the baths will be either distilled or otherwise treated to eliminate electrolytes; and the baths will be emptied, cleaned, and refilled with fresh water for each series of tests.

2.2 One automatically controlled freezer will be required for freezing the specimens. The freezer will be of sufficient size to permit total containment of the test specimens. It will be so designed and equipped to permit accurate and uniform control of its air temperature. The freezer is required to bring the specimens to the selected temperature of −0.4 ± 3.6 F (−18 ±2C) for the freeze portion of specimen accelerated conditioning.

2.3 One vacuum pump with capacity to pull at least 26 in. (66 cm) of mercury will be required to water-saturate the test specimens. Accessory equipment will include: Pyrex or equivalent vacuum jars of at least 6 in. (15 cm) diameter and 8 in. (20 cm) high with smooth fired edges, a donut-shaped gasket made of rubber-type sponge, a stiff metal round plate greater than 6 in. (15 cm) diameter with suitable vacuum hose receptacle and hole bored through the plate thickness, vacuum hose attached to receptacle fitting and vacuum pump, and a 6-in. (15-cm) diameter screen-type or highly porous specimen spacer seat approximately 0.25 in. (1 cm) high.

2.4 A compressive testing machine as described in accordance with Method D 1074, but having the controlled deformation rate capability of 0.065 in. per min (0.165 cm per min).

2.5 Mark III or Mark IV Resilient Modulus Apparatus manufactured by Retsina Co., El Cerrito, CA 94530, or equivalent.

2.6 A balance and a room-temperature water bath with suitable accessory equipment will be required for weighing the test specimens in air and in water (saturated specimens only) in order to determine their densities, the amount of absorption, and permeable voids. This apparatus is similar to that required for Method D2762, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens.

2.7 A supply of plastic film for wrapping and heavy-duty leak-proof plastic bags will be required to wrap and enclose the saturated specimens for preventing moisture loss during handling and freezing. Also, several metal jars of at least 4 in. (10.2 cm) diameter and at least 6 in. (15 cm) high will be required for bringing dry specimens to test temperature without water intrusion into the dry specimens in the water bath.

3. Test Specimens

3.1 At least nine, duplicate 4-in. (102-mm) diameter by 2.5-in. (63.5-mm) high cylindrical test specimens of the same mixture will be made for each test. The procedures described in either Method D1559, Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus, or Method D1561, Test for Compaction of Test Specimens of Bituminous Mixtures by Means of California Keading Compactor, or Method D3387, Test for Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine, will be followed in preparing the loose mixtures and in molding and curing the test specimens.

4. Grouping, Vacuum Saturation, and Determination of Bulk Density and Permeable Voids of Test Specimens

4.1 Allow each set of nine test specimens to cool at room temperature for at least 24 hours after completion of specimen fabrication described in Methods D1559, D1561, and D3387. Label each specimen with waterproof identification and obtain the dry weight of each specimen to the nearest 0.1 g.

4.2 Randomly select a subset, I, of three specimens from the set of nine test specimens. Maintain subset I specimens in a dry condition. Place subset I specimens in metallic jars and then place the jars in a water bath at the selected mechanical test temperature (refer to section 6 for information on the selection of mechanical test temperature) of 55 ± 1.8 F (12.8 ± 1 C) or 73 ± 1.8 F (22.8 ± 1 C) for 5 hours maintaining the top rim of the jars above the water level of the bath. Place an insulating stuffing in the top of the jars, making contact with the top specimen's surface and with the jar walls, then proceed with the mechanical testing of subset I as described in sections 6–9.

4.3 The six remaining test specimens will be vacuum saturated as follows. Place a porous spacer seat on the bottom of a vacuum jar and then place one or more of the specimens, depending on jar height, flat in the jar using another porous spacer seat between the specimens. Put distilled water, or water treated to eliminate electrolytes, at 73 F (22.8 C) in the jar to about 1 in. (2.5 cm) above the upper specimen's surface. Place a dampened donut gasket and a stiff metallic plate on top of the jar. Attach a vacuum hose from vacuum pump. Apply a vacuum of 26 in. (66 cm) of mercury to the jars for a duration of 30 min., gently agitating the jar wall. Remove the vacuum and leave the six specimens submerged in the jars at atmospheric pressure for 30 minutes.

4.4 Remove each of the six specimens from the vacuum jars, quickly surface dry the specimens by towel blotting, and weigh immediately in air and then weigh submerged in room-temperature water at approximately 73 F (22.8 C). Immediately after weighing each submerged specimen, return the specimens to the water-filled vacuum jars and submerge each specimen temporarily under the water at atmospheric pressure.

4.5 Calculate the bulk density and permeable voids of each of the six vacuum-saturated test specimens as follows:

$$\text{Bulk density} = \frac{AD}{B - C} \tag{A-1}$$

$$\text{Permeable voids, \%} = \frac{100\,(B - A)}{B - C} \tag{A-2}$$

where:

A = weight of dry specimen in air, g;

B = weight of surface-dry (blotted) vacuum-saturated specimen in air, g;

C = weight of vacuum saturated specimen submerged in water, g; and

D = density of water at 73F (22.8C), g/cc.

4.6 Sort and assign each of the six vacuum-saturated test specimens into subsets, II and III, consisting of three specimens each so that the average permeable voids (or average bulk density) is essentially the same in each subset. Immerse subset II specimens into a water bath at the selected mechanical test temperature of 55 ± 1.8 F (12.8 ± 1 C) or 73 ± 1.8 F (22.8 ± 1 C) for 3 hours and then proceed with the mechanical testing of this subset described in sections 6–9. Condition the subset III specimens by using the procedure described in section 5.

5. Accelerated Conditioning Procedure

5.1 Maintain specimen surface dampness and internal saturation, and wrap tightly each of the three specimens of subset III with two layers of plastic film using masking tape to hold the wrapping if necessary. Place each wrapped specimen into a leak-proof plastic bag containing approximately 3 ml of distilled water, and seal the bag with a tie or tape.

5.2 Immerse each of the three individually wrapped and bagged specimens of subset III into an air bath freezer for 15 hours at −0.4 ± 3.6 F (−18 ± 2 C). (If this step begins at 5 p.m., specimens can be removed from the freezer at 8:00 a.m. the following day).

5.3 Remove the three wrapped and bagged specimens of subset III from the freezer and immerse them immediately into a water bath at 140 ± 3.6 F (60 ± 2 C) for 24 hours. (After 3 min of immersion, when specimen surface thaw takes place, rapidly, but carefully, remove the bag and wrapping from the specimens and rapidly reimmerse the specimens in the water bath).

5.4 Carefully remove the three unwrapped specimens of subset III from the water bath, immerse the specimens in a water bath at the selected mechanical test temperature of 55 ± 1.8 F (12.8 ± 1 C) or 73 ± 1.8 F (22.8 ± 1 C) for 3 hours, and proceed with the mechanical testing of this subset as described in sections 6–9.

6. Selection of Mechanical Test Temperature

6.1 The selection of the mechanical test temperature for the nine specimen set is based on the type of mechanical test desired for measurement of the effects of the water-related conditioning. Diametral (tensile) resilient modulus may be performed at either 55 ± 1.8 F (12.8 ± 1 C) or 73 ±1.8 F (22.8 ± 1 C). Diametral tensile strength is performed at 55 ± 1.8 F (12.8 ± 1 C). If low-to-moderate stresses are applied to the specimens in the diametral (tensile) resilient modulus test, this test can be considered nondestructive and the same specimens can be also tested using the diametral tensile strength test, therefor providing additional mechanical properties data. If this is to be done, specimens must be reimmersed in the water bath at selected test temperature for 1 to 2 hours after diametral (tensile) resilient modulus testing prior to the diametral tensile strength testing.

7. Specimen Handling in the Mechanical Testing Procedures

7.1 Each specimen subset shall be tested rapidly following the completion of their respective test-temperature water-bath soak times as prescribed in section 4.2 for subset I, section 4.6 for subset II, and section 5.4 for subset III.

7.2 Remove a subset specimen from the water bath at the test temperature, surface dry by blotting with a towel (necessary for specimens from subsets II and III), measure and record the specimen height (thickness) and identification, and place the specimen with circular ends vertical (specimen on edge) into the appropriate mechanical loading device. Test one specimen at a time, leaving the remaining untested specimens in the water bath. Proceed with testing as rapidly as possible because the mechanical testing will expose the specimen to air temperature which may be different from the test temperature. Test the specimens by either one or both of the procedures described in sections 8 and 9.

8. Test and Calculation Procedure for Diametral (Tensile) Modulus

8.1 Place the transducers of the Resilient Modulus Apparatus on the specimen at test temperature and proceed rapidly with diametral loading at 0.1-sec load duration time, following the procedures described in the instruction manual provided by the manufacturer. Record load and horizontal deformation. Rotate the specimen 90° and repeat.

8.2 Calculate the specimen's diametral resilient modulus for each of the two 90° rotations as follows:

$$M_R = \frac{P(\nu + 0.2734)}{L\,\Delta} \qquad \text{(A-3)}$$

where:

M_R = diametral resilient modulus, psi (k Pa);
P = load magnitude applied to specimen, lb (N);
ν = Poissons ratio of specimen (use 0.35 unless measured specifically);
0.2734 = dimensionless strain integration constant for 4-in. (10.2-cm) diameter specimens;
L = thickness of specimen, in. (cm); and
Δ = horizontal deformation magnitude of specimen, in. (cm).

The average of the two 90° resilient modulus values is calculated for this specimen and test temperature. Return specimen to water bath if a diametral tensile strength test is also to be performed on the same specimen.

8.3 Repeat by testing the two remaining specimens in the subset, and calculate the overall average diametral resilient modulus for the subset of three specimens.

8.4 Repeat procedure and calculations described in sections 8.1–8.4 for the remaining two subsets of three specimens each.

8.5 Proceed to section 10, Calculation.

9. Test and Calculation Procedure for Diametral Tensile Strength

9.1 Place and center a subset specimen at test temperature under the flat loading head of the compression test machine, and proceed quickly with diametral loading at a vertical deformation rate of 0.065 in. per min (0.165 cm per min). The specimen is placed on its edge without support blocks or loading strips). Record the maximum compressive load. Immediately decrease load to zero, remove specimen and measure specimen edge or side flattening to nearest 0.1 in. (0.25 cm). This can be accomplished easily by stroking the top flattened edge (side) with a piece of chalk held lengthwise to delineate the flattened width and then using a scale to measure the average maximum width of the flattened edge. Record this width.

9.2 Replace the specimen in the compression test machine with its original orientation (flattened edges top and bottom) and redeform the specimen at 0.065 in. per min (0.165 cm per min) until a definitive vertical crack appears and opens. Decrease load to zero, remove specimen, and slowly pull apart the two sides of the specimen at the crack. The internal surface may then be observed for stripping and recorded qualitatively.

9.3 Calculate the specimen's diametral tensile strength as follows:

$$S_t = \frac{S_{10} P}{10{,}000\, L} \qquad \text{(A-4)}$$

where:

S_t = diametral tensile strength, psi (k Pa);
S_{10} = maximum tensile stress, psi (k Pa), obtained by calculating: $1591 + 437a - 1889 a^2 + 2854 a^3 - 2474 a^4 + 885 a^5$, where a = flattening width, in., based on a 4 in. (10.2 cm) diameter solid cylinder loaded at 10,000 lb (22 kg) per inch (cm) thickness (note: to calculate S_{10} in SI units, first calculate S_{10} in U.S. customary units of psi using the polynomial constants as shown, with a in inches, then convert psi to k Pa using 1 psi = 6.895 k Pa);
P = maximum compressive load on specimen, lb (N);
10,000 = load constant: 10,000 lb per in. of thickness (17,512 N per cm of thickness); and
L = thickness of specimen, in. (cm).

9.4 Repeat by testing the two remaining specimens in the subset, and calculate the overall average diametral tensile strength for the subset of three specimens.

9.5 Repeat procedure and calculations described in sections 9.1–9.4 for the remaining two subsets of three specimens each.

9.6 Proceed to section 10, Calculation.

10. Calculation

10.1 Calculate the numerical indices of the effects of vacuum saturation and accelerated conditioning as the ratios of the mechanical properties of subsets II and III to the mechanical properties of subset I for the specified test temperature as follows:

$$M_R R_1 = \frac{M_R\,(II)}{M_R\,(I)} \quad \text{and} \quad M_R R_2 = \frac{M_R\,(III)}{M_R\,(I)} \qquad \text{(A-5)}$$

where:

$M_R R_1$ = diametral resilient modulus ratio of saturation;
$M_R R_2$ = diametral resilient modulus ratio of accelerated conditioning;

M_R (I) = average diametral resilient modulus of specimen subset I, psi (k Pa);
M_R (II) = average diametral resilient modulus of specimen subset II, psi (k Pa); and
M_R (III) = average diametral resilient modulus of specimen subset III, psi (k Pa).

$$TSR_1 = \frac{S_t\,(II)}{S_t\,(I)} \text{ and } TSR_2 = \frac{S_t\,(III)}{S_t\,(I)} \qquad \text{(A-6)}$$

where:

TSR_1 = diametral tensile strength ratio of saturation;
TSR_2 = diametral tensile strength ratio of accelerated conditioning;
S_t (I) = average diametral tensile strength of specimen subset I, psi (k Pa);
S_t (II) = average diametral tensile strength of specimen subset II, psi (k Pa); and
S_t (III) = average diametral tensile strength of specimen subset III, psi (k Pa).

Ratios will be reported to the nearest hundredth.

10.2 Ratios may be interpreted as follows. M_RR_1 and TSR_1 are related to short-term pavement performance (e.g., 2–4 yr), and M_RR_2 and TSR_2 are related to long-term pavement performance (e.g., 4 yr or more). Low ratios are associated with the mixture's inability to resist moisture effects.

11. Single-Operator Precision

11.1 The single operator standard deviation has been found to be 14 percent for M_RR and 10 percent for TSR. (These numbers represent, respectively, the (IS) and (D2S) limits as described in ASTM Recommended Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.) Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 40 percent for M_RR and 28 percent for TSR.

APPENDIXES B THROUGH I

TEST SECTION DATA

Test data reported in Appendixes B through I were obtained by the participating highway agencies (Arizona (B), Colorado (C), FHWA-10 (D), Georgia (E,F), Idaho (G), Montana (H), and Virginia, (I)). Figures in the appendixes were constructed at the University of Idaho from the test data. An explanation of the prediction ratio codes used in the figures is based on the following examples:

C-5 = initial pavement cores tested at 5-month storage time;
L-0 = laboratory specimens tested at zero-month storage time;
LR-0 = laboratory specimens at reduced voids tested at zero-month storage time;
SAT = vacuum saturation only; and
COND = vacuum saturation plus accelerated conditioning.

APPENDIX B—ARIZONA TEST SECTION DATA

TABLE B-1. ARIZONA PAVEMENT TEST SECTION—QUANTITATIVE LABORATORY TEST DATA FOR MOISTURE DAMAGE PREDICTIONS.

Tensile Splitting Strength, psi[1]
(Temp. = 55F[2],
Deform. Rate = 0.065 in./min.[3])

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 5.0 %

Laboratory Storage Time, Months

0			8			12			16		
Dry	VS[4]	AC[5]	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
222	97	47	266	179	55	266	127	62	259	131	69

B. Laboratory Fabricated Specimens
@ Reduced Voids = %

Laboratory Storage Time, Months

0											
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC

Test not run; mix voids could not reduce by compaction

C. Initial Pavement Cores
@ Voids = 5.0 %

Laboratory Storage Time, Months

0			8			12			16		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
97	82	39	120	82	49	141	51	41	145	108	52

Resilient Modulus, 10^3 psi[1]
(Pulse Load Time = 0.10 s)

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 5.0 %

Laboratory Storage Time, Months

	0			8			12			16		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	765	473	292	1231	1064	612	1192	855	615	1158	884	515
Temp. = 55F[2]												

B. Laboratory Fabricated Specimens
@ Reduced Voids = %

Laboratory Storage Time, Months

	0											
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]												
Temp. = 55F[2]												

Test not run; mix voids could not reduce by compaction

C. Initial Pavement Cores
@ Voids = 5.0 %

Laboratory Storage Time, Months

	0			8			12			16		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	407	343	290	424	422	369				579	562	349
Temp. = 55F[2]												

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in./min. = 0.00275 cm/s
4. vacuum saturated
5. accelerated conditioned

TABLE B-2. ARIZONA PAVEMENT TEST SECTION—VISUAL STRIPPING OF PREDICTIVE LABORATORY SPECIMENS AND INITIAL PAVEMENT CORES AFTER MOISTURE CONDITIONING.

Specimen or Core Condition	Laboratory Fabricated Specimens @ Initial Pavt. Core Voids = 5.0%	Laboratory Fabricated Specimens @ Reduced Voids =5.0%	Initial Pavement Cores @ Voids =5.0%
Vacuum Saturated	Slight Stripping (same for all storage times)	Test not run; mix voids could not reduce	Slight Stripping (same for all storage times)
Accelerated Conditioned	Severe Stripping (same for all storage times)	Test not run; mix voids could not reduce	Severe Stripping (same for all storage times)

TABLE B-3. ARIZONA PAVEMENT TEST SECTION—QUANTITATIVE PERIODIC CORE TEST DATA.

	Tensile Splitting Strength, psi[1.] (Temp. = 55F[2.], Deform. Rate = 0.065 in./min)				Resilient Modulus, 10^3 psi[1.] (Temp. = 73F[2.], Pulse Load Time = 0.10 s)				Resilient Modulus, 10^3 psi[1.] (Temp. = 55F[2.] Pulse Load Time = 0.10 s)			
Month	Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path	
	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.
0	97	82	97	82	407	343	407	343	Test not programmed due to early startup			
4												
7	137	87	118	81	318	310	288	312				
12	165	115	137	94	425	473	373	413				
18	148	140	143	65	418	531	284	363				
20												
23	172	98	132	74	442	464	413	367				
30	163	107	107	68	684	649	427	375				
36												
42												
48	140	125	125	116	Malfunction of M_R equipment							
55	222	212	100	13	"		"					
62	140	118	142	77	"		"					
62i[4]	140	109	not run		"		"					

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in/min. = 0.00275 cm/s
4. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous values).

TABLE B-4. ARIZONA PAVEMENT TEST SECTION—VISUAL STRIPPING OF PERIODIC CORES AFTER VACUUM SATURATION.

Month	Stripping Observation
0	Not discernible
4	Not discernible
7	Slight Stripping
12	Slight Stripping
18	Slight Stripping
20	
23	Slight Stripping
30	
36	
42	
48	
55	Slight-to-moderate stripping; some severe stripping between wheelpaths. (High % of cores disintegrated when drilled).
62	Moderate stripping; some severe stripping between wheelpaths. (Core disintegrated when drilled).
62i[1]	Moderate-severe stripping; some severe stripping between wheelpaths.

Notes: 1. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous observations).

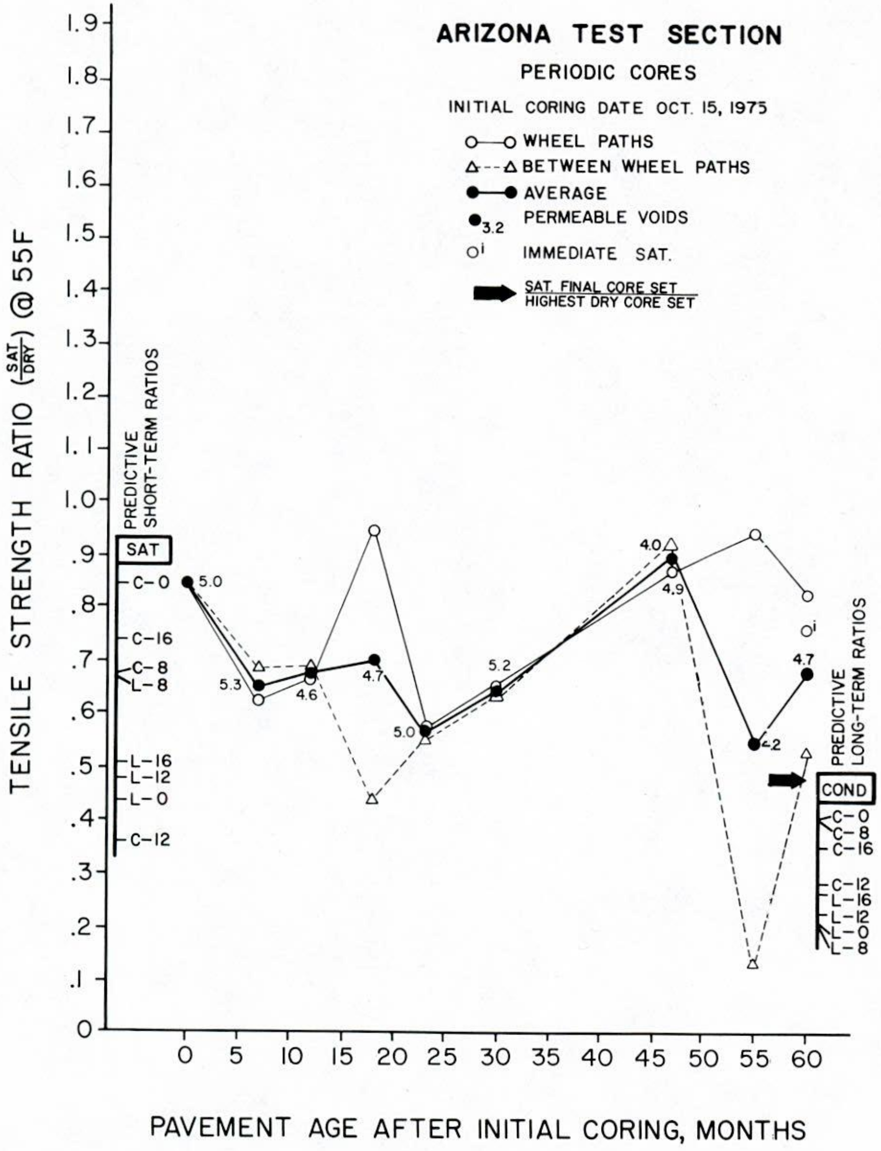

Figure B-1. Arizona test section—predictive and field tensile strength ratios at 55 F.

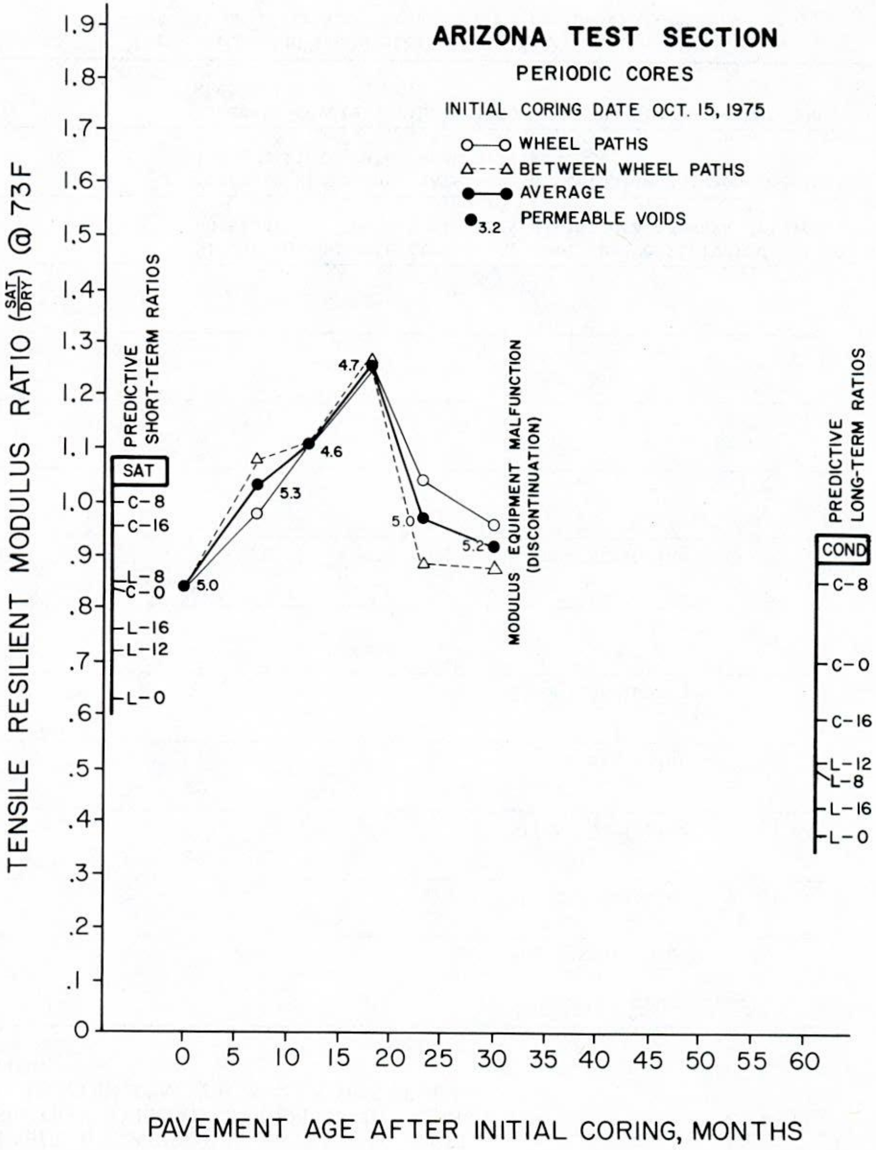

Figure B-2. Arizona test section—predictive and field resilient modulus ratios at 73 F.

APPENDIX C—COLORADO TEST SECTION DATA

TABLE C-1. COLORADO PAVEMENT TEST SECTION—QUANTITATIVE LABORATORY TEST DATA FOR MOISTURE DAMAGE PREDICTIONS.

Tensile Splitting Strength, psi[1]
(Temp. = 55F[2],
Deform. Rate = 0.065 in./min.[3])

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids =9.1 %

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS[4]	AC[5]	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
41	32	9	53	36	12	56	39	11	58	44	12

B. Laboratory Fabricated Specimens
@ Reduced Voids =6.1 %

Laboratory Storage Time, Months

0									10		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
65	55	16							91	69	18

C. Initial Pavement Cores
@ Voids =9.1 %

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
36	24	16	46	37	17	50	47	18	44	51	18

Resilient Modulus, 10^3 psi[1]
(Pulse Load Time = 0.10 s)

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids =9.1 %

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	322	215	63	284	259	90	403	278	85	265	288	101
Temp. = 55F[2]	940	693	186	1205	723	268	1212	793	233	1271	979	298

B. Laboratory Fabricated Specimens
@ Reduced Voids =6.1 %

Laboratory Storage Time, Months

	0									10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	474	335	111							499	529	147
Temp. = 55F[2]	1281	1046	303							1999	1563	447

C. Initial Pavement Cores
@ Voids =9.1 %

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	127	144	83	214	201	110	318	267	133	227	303	121
Temp. = 55F[2]	475	456	196	955	616	355	1083	828	436	796	862	332

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in./min. = 0.00275 cm/s
4. vacuum saturated
5. accelerated conditioned

TABLE C-2. COLORADO PAVEMENT TEST SECTION—VISUAL STRIPPING OF PREDICTIVE LABORATORY SPECIMENS AND INITIAL PAVEMENT CORES AFTER MOISTURE CONDITIONING.

Specimen or Core Condition	Laboratory Fabricated Specimens @ Initial Pavt. Core Voids = 9.1%	Laboratory Fabricated Specimens @ Reduced Voids =6.1%	Initial Pavement Cores @ Voids =9.1%
Vacuum Saturated	Slight Stripping (same for all storate times)	Slight Stripping (same for all storage times)	No discernible stripping (same for all storage times)
Accelerated Conditioned	Severe Stripping (same for all storage times)	Severe Stripping (same for all storage times)	Severe Stripping (same for all storage times)

TABLE C-3. COLORADO PAVEMENT TEST SECTION—QUANTITATIVE PERIODIC CORES TEST DATA.

	Tensile Splitting Strength, psi[1.] (Temp. = 55F[2.], Deform. Rate = 0.065 in./min)				Resilient Modulus, 10^3 psi[1.] (Temp. = 73F[2.], Pulse Load Time = 0.10 s)				Resilient Modulus, 10^3 psi[1.] (Temp. = 55F[2.] Pulse Load Time = 0.10 s)			
Month	Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path	
	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.
0	36	24	36	24	127	144	127	144	474	456	475	456
4	53	41	47	37	284	328	260	272	942	642	790	619
8	48	62	34	45	361	386	234	221	892	1065	619	674
12	68	55	63	56	214	261	192	283	1193	941	1081	924
16	65	60	65	66	358	338	357	358	987	1045	1094	1094
20	68	63	61	64	635	551	508	528	1448	1427	1342	1332
24	71	62	71	68	295	378	252	302	1265	1168	1178	996
30	70	72	68	65	527	592	550	486	1353	1375	1570	1295
34	63	52	69	69	404	331	499	441	1438	1160	1742	1595
40	72	73	80	83	448	390	493	467	1428	1373	1451	1564
45	80	73	77	70	462	445	436	481	1590	1436	1528	1492
52	73	63	97	79	490	512	528	570	1504	1587	2134	1730
52i[4]		39		56		267		286		722		1146
58	80	68	92	78	556	443	667	593	1465	1426	1737	1699
58i[4.]		41		71		225		534		539		1521

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in/min. = 0.00275 cm/s
4. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous values).

TABLE C-4. COLORADO PAVEMENT TEST SECTION—VISUAL STRIPPING OF PERIODIC CORES AFTER VACUUM SATURATION.

Month	Stripping Observation
0	Not discernible
4	Not discernible
8	Slight Stripping
12	Slight Stripping
16	Slight Stripping
20	Slight Stripping
24	Slight Stripping
30	Slight Stripping
34	Slight Stripping
40	Slight Stripping
46	Slight Stripping
52	Slight Stripping
52i[1]	Slight Stripping
60	Slight Stripping
60i[1].	Slight Stripping

Notes: 1. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous observations).

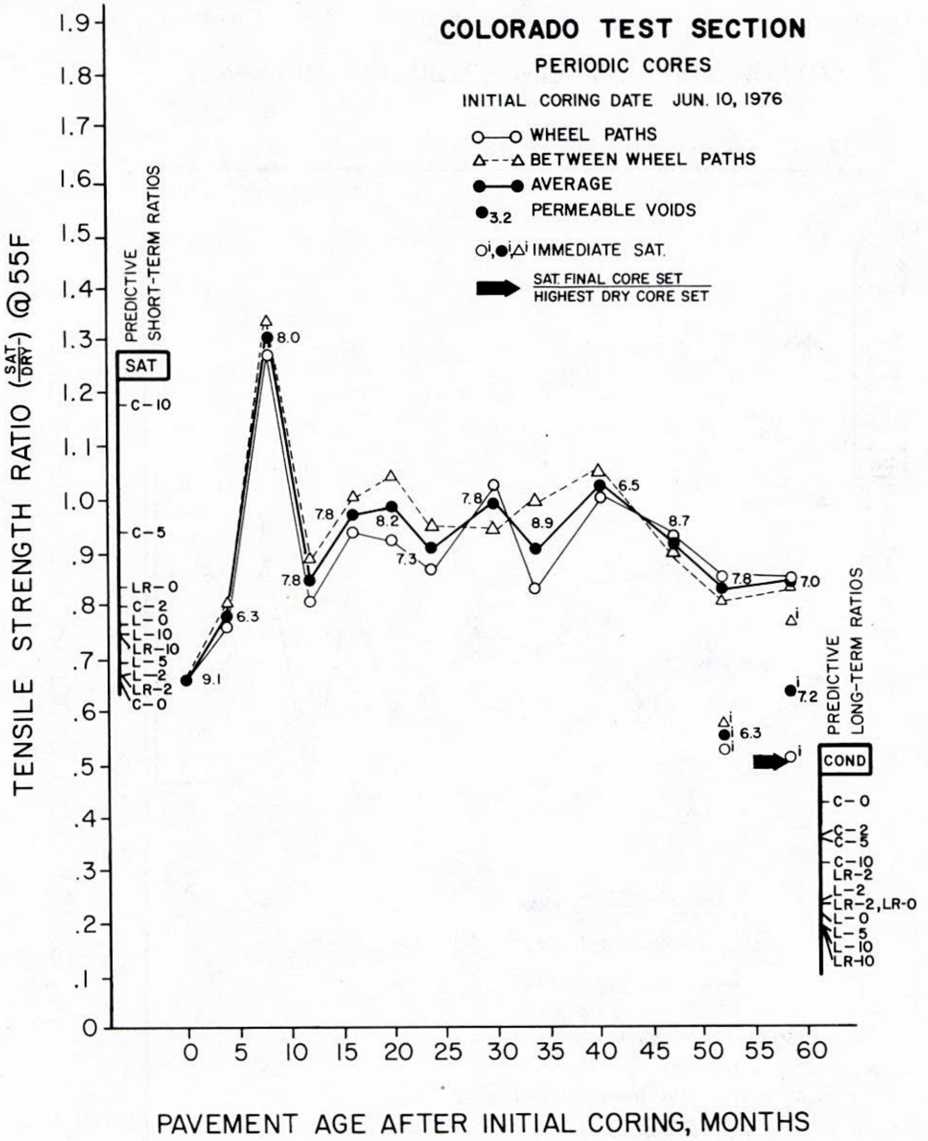

Figure C-1. Colorado test section—predictive and field tensile strength ratios at 55 F.

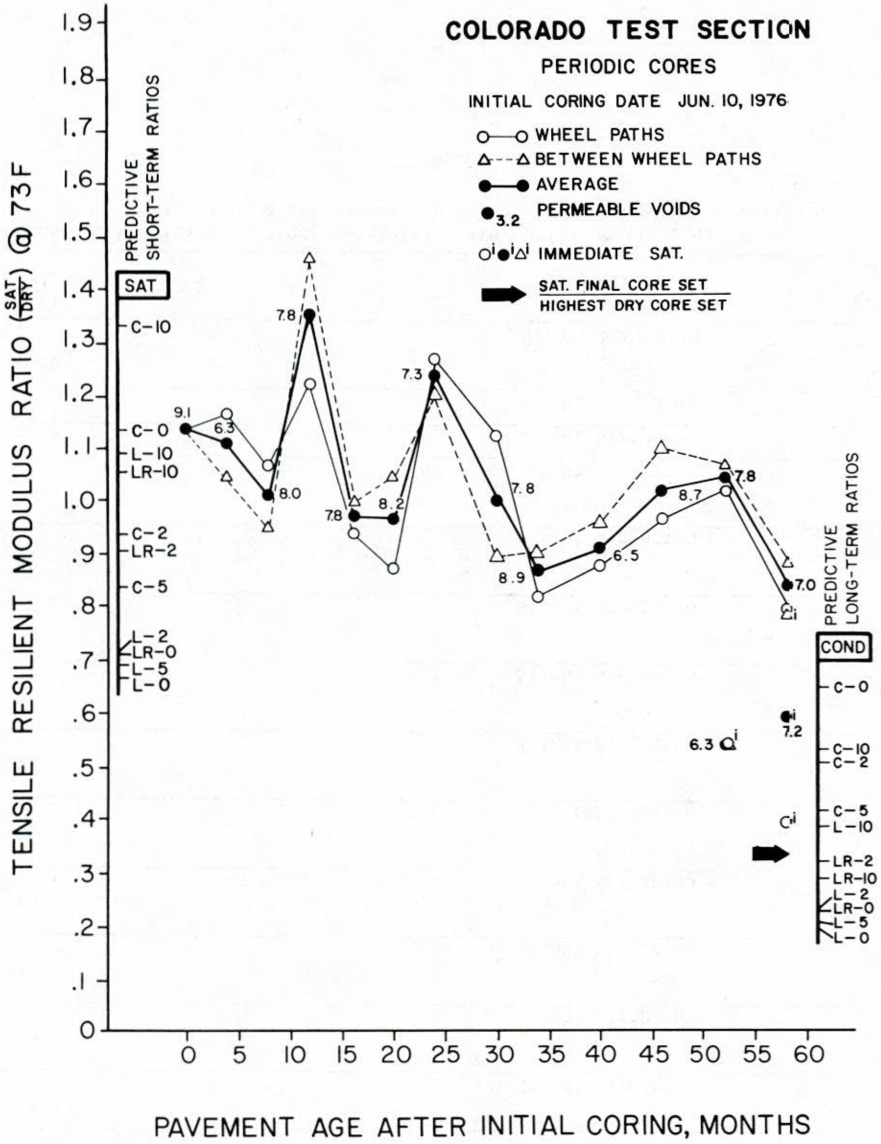

Figure C-2. Colorado test section—predictive and field resilient modulus ratios at 73 F.

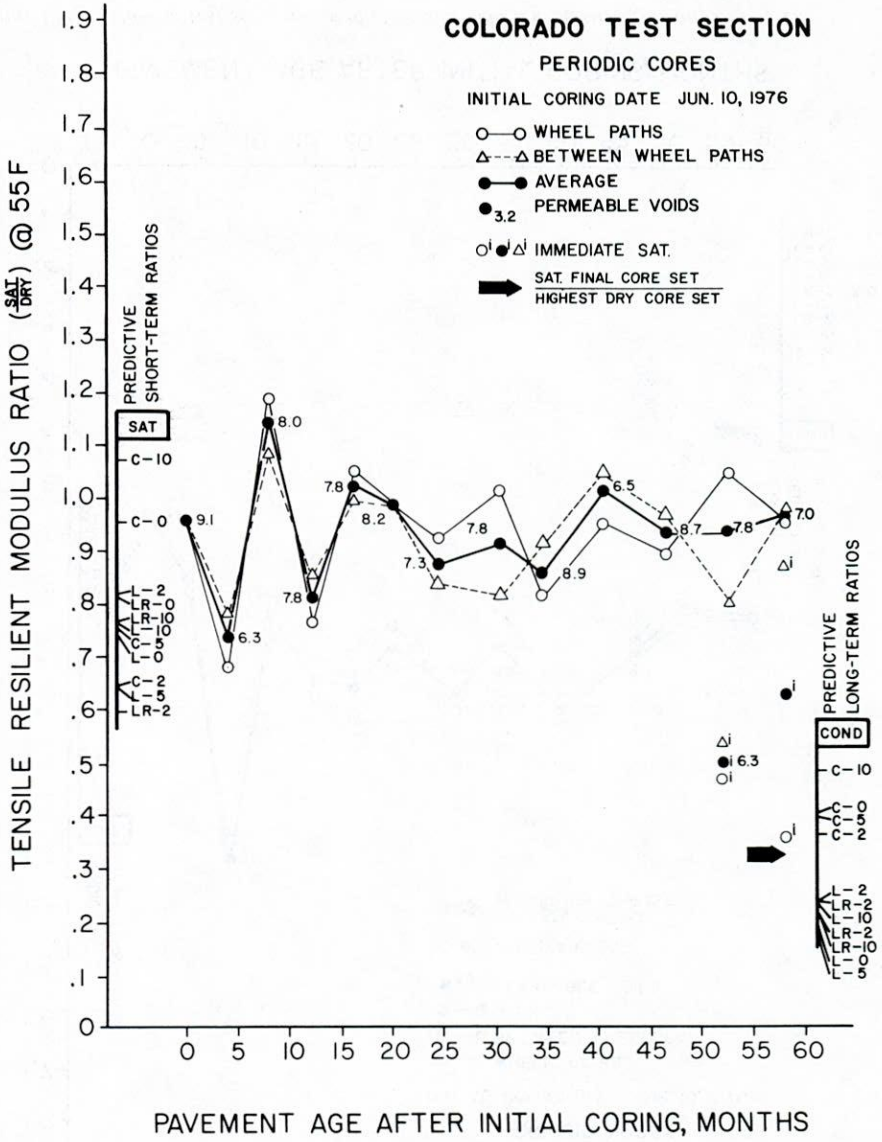

Figure C-3. Colorado test section—predictive and field resilient modulus ratios at 55 F.

APPENDIX D—FHWA-10 TEST SECTION DATA (WESTERN DIRECT FEDERAL DIVISION)

TABLE D-1. FHWA REGION 10 PAVEMENT TEST SECTION—QUANTITATIVE LABORATORY TEST DATA FOR MOISTURE DAMAGE PREDICTIONS.

Tensile Splitting Strength, psi[1]
(Temp. = 55F[2],
Deform. Rate = 0.065 in./min.[3])

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 10.0 %

Laboratory Storage Time, Months

0			2								
Dry	VS[4]	AC[5]	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
135	118	85	109	112							

B. Laboratory Fabricated Specimens
@ Reduced Voids = 7.0 %

Laboratory Storage Time, Months

0											
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
162	131										

C. Initial Pavement Cores
@ Voids = 10.0%

Laboratory Storage Time, Months

0			2								
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
74	70	46	73	80	32						

Resilient Modulus, 10^3 psi[1]
(Pulse Load Time = 0.10 s)

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 10.0%

Laboratory Storage Time, Months

	0			2								
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	450	401	317	420	462							
Temp. = 55F[2]	1688	1489	1146	1550	1314							

B. Laboratory Fabricated Specimens
@ Reduced Voids = 7.0 %

Laboratory Storage Time, Months

	0											
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	553	464										
Temp. = 55F[2]	1642	1590										

C. Initial Pavement Cores
@ Voids = 10.0%

Laboratory Storage Time, Months

	0			2								
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	279	284	189	375	303	147						
Temp. = 55F[2]	997	1023	720	958	930	516						

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in./min. = 0.00275 cm/s
4. vacuum saturated
5. accelerated conditioned

TABLE D-2. FHWA REGION 10 PAVEMENT TEST SECTION—VISUAL STRIPPING OF PREDICTIVE LABORATORY SPECIMENS AND INITIAL PAVEMENT CORES AFTER MOISTURE CONDITIONING.

Specimen or Core Condition	Laboratory Fabricated Specimens @ Initial Pavt. Core Voids = 10.0%	Laboratory Fabricated Specimens @ Reduced Voids = 7.0%	Initial Pavement Cores @ Voids = 10.0%
Vacuum Saturated	No discernible stripping (same for all storage times)	No discernible stripping (same for all storage times)	No discernible stripping (same for all storage times)
Accelerated Conditioned	Light to moderate stripping (same for all storage times)	Light to moderate stripping (same for all storage times)	Light to moderate stripping (same for all storage times)

TABLE D-3. FHWA REGION 10 PAVEMENT TEST SECTION—QUANTITATIVE PERIODIC CORE TEST DATA.

	Tensile Splitting Strength, psi[1] (Temp. = 55F[2], Deform. Rate = 0.065 in./min)				Resilient Modulus, 10^3 psi[1] (Temp. = 73F[2], Pulse Load Time = 0.10 s)				Resilient Modulus, 10^3 psi[1] (Temp. = 55F[2], Pulse Load Time = 0.10 s)			
	Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path	
Month	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.
0	74	70	74	70	279	284	279	284	997	1023	997	1023
3	54	65	58	65	165	246	178	243	629	816	651	743
8												
12												
16												
20												
24												
30	136	119	142	130	669	490	679	496	2069	1340	1268	1292
36	133	125	133	149	643	597	615	673	1807	1507	1548	1651
42	156	144	166	166	745	654	798	685	1802	1755	2209	1797
48	139	130	155	127	726	733	779	652	2028	1938	2159	1740
54	144	145	135	144	736	691	712	658	1839	1567	1685	1587
60	171	155	157	155	950	837	769	826	2220	2110	1994	2002
60i[4]	171	163	157	147	950	789	769	603	2220	2107	1994	2230

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in/min. = 0.00275 cm/s
4. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous values).

TABLE D-4. FHWA REGION 10 PAVEMENT TEST SECTION—VISUAL STRIPPING OF PERIODIC CORES AFTER VACUUM SATURATION.

Month	Stripping Observation
0	Not discernible
3	Not discernible
8	Not discernible
12	Not discernible
16	Not discernible
20	Not discernible
24	Not discernible
30	Not discernible
36	Not discernible
42	Not discernible
48	Not discernible
54	Not discernible
60	Slight Stripping
60i[1]	Slight Stripping

Notes: 1. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous observations).

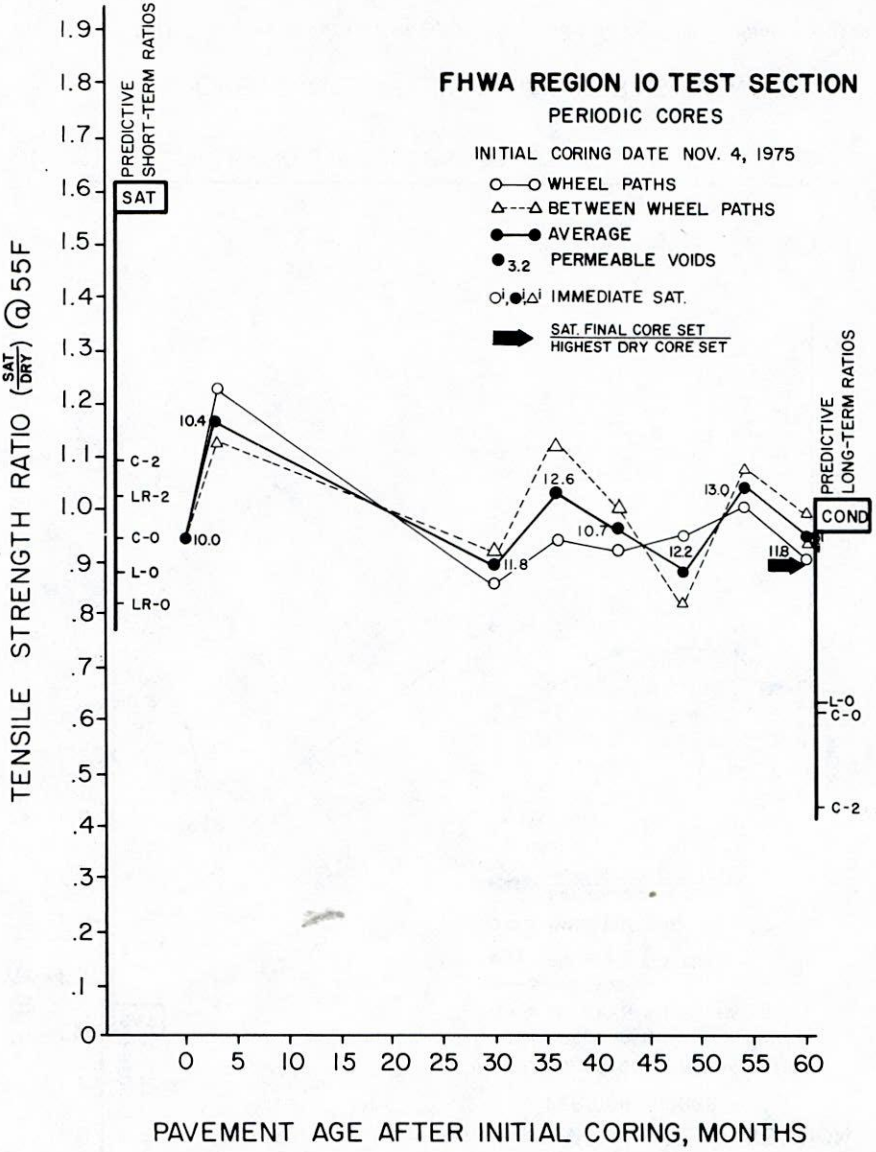

Figure D-1. FHWA Region 10 test section—predictive and field tensile strength ratios at 55 F.

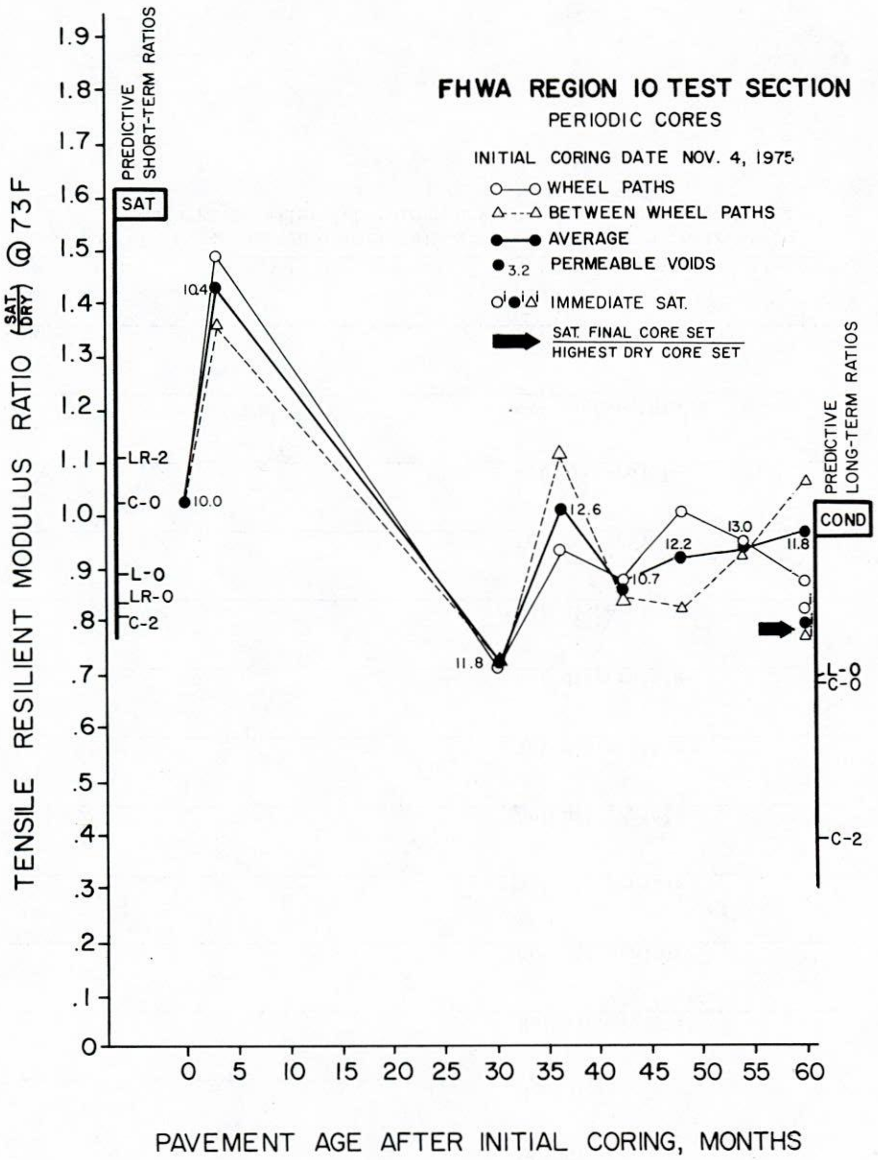

Figure D-2. FHWA Region 10 test section—predictive and field resilient modulus ratios at 73 F.

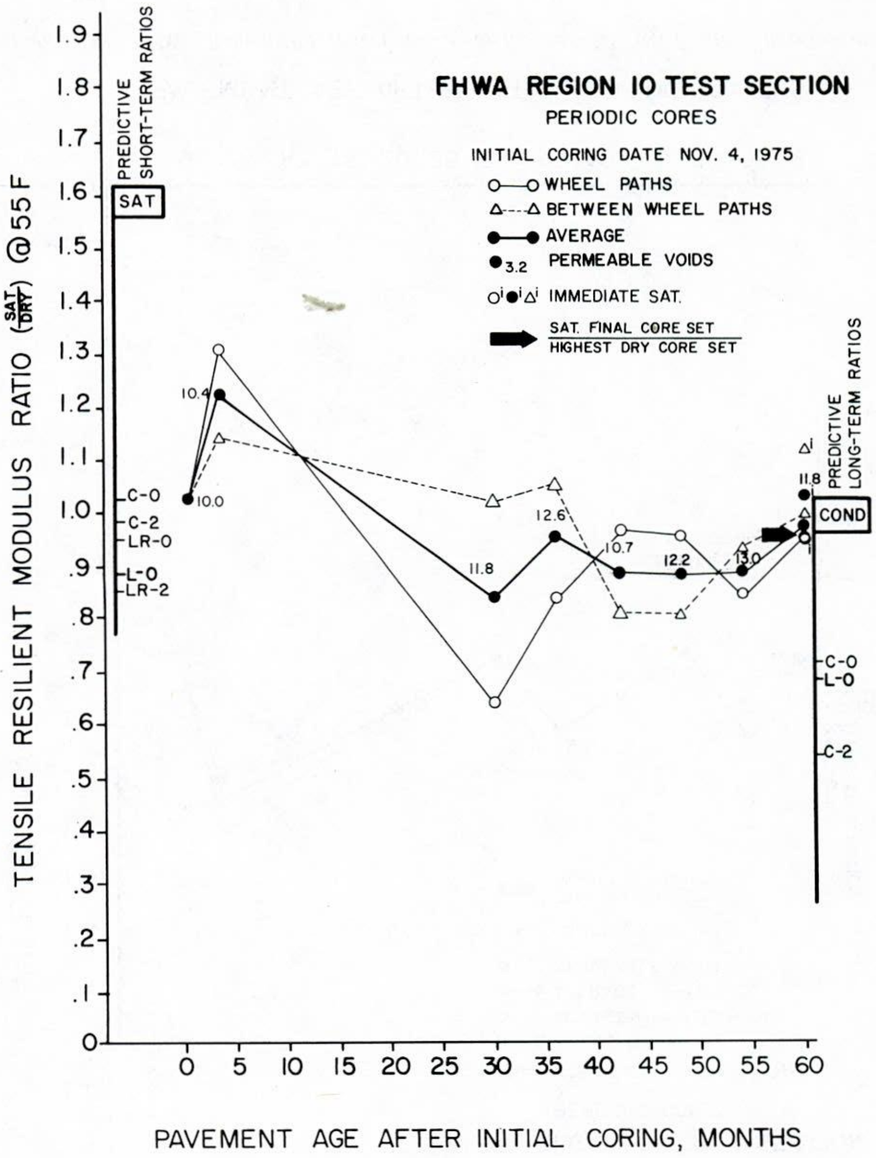

Figure D-3. FHWA Region 10 test section—predictive and field resilient modulus ratios at 55 F.

APPENDIX E—GEORGIA (A) TEST SECTION DATA

TABLE E-1. GEORGIA (A) PAVEMENT TEST SECTION—QUANTITATIVE LABORATORY TEST DATA FOR MOISTURE DAMAGE PREDICTIONS.

Tensile Splitting Strength, psi[1]
(Temp. = 55F[2],
Deform. Rate = 0.065 in./min.[3])

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 8.0 %

Laboratory Storage Time, Months

0			2			5					
Dry	VS[4]	AC[5]	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
87	84	0	84	74	0	80	69	0			

B. Laboratory Fabricated Specimens
@ Reduced Voids = %

Laboratory Storage Time, Months

0											
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC

Test not run; mix voids could not reduce by compaction

C. Initial Pavement Cores
@ Voids = 8.0 %

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
59	48	0	46	58	14	56	62	14	78	60	0

Resilient Modulus, 10^3 psi[1]
(Pulse Load Time = 0.10 s)

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 8.0 %

Laboratory Storage Time, Months

	0											
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	236	190	0	288	385	0	282	202	0			
Temp. = 55F[2]	456	379	0	645	576	0						

B. Laboratory Fabricated Specimens
@ Reduced Voids = %

Laboratory Storage Time, Months

	0											
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]												
Temp. = 55F[2]												

Test not run; mix voids could not reduce by compaction

C. Initial Pavement Cores
@ Voids = 8.0%

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	149	123	0	115	173	30	119	114	23	138	152	0
Temp. = 55F[2]	246	324	0	219	224	45	251	289	46	299	295	0

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in./min. = 0.00275 cm/s
4. vacuum saturated
5. accelerated conditioned

TABLE E.2. GEORGIA (A) PAVEMENT TEST SECTION—VISUAL STRIPPING OF PREDICTIVE LABORATORY SPECIMENS AND INITIAL PAVEMENT CORES AFTER MOISTURE CONDITIONING.

Specimen or Core Condition	Laboratory Fabricated Specimens @ Initial Pavt. Core Voids= 8.0%	Laboratory Fabricated Specimens @ Reduced Voids = %	Initial Pavement Cores @ Voids =8.0%
Vacuum Saturated	Slight Stripping (same for all storage times)	Test not run; mix voids could not reduce	Slight Stripping (same for all storage times)
Accelerated Conditioned	Severe Stripping and specimen disintegration (same for all storage times)	Test not run; mix voids could not reduce	Severe stripping and core disintegration (same for all storage times)

TABLE E-3. GEORGIA (A) PAVEMENT TEST SECTION—QUANTITATIVE PERIODIC CORE TEST DATA.

	Tensile Splitting Strength, psi[1] (Temp. = 55F[2], Deform. Rate = 0.065 in./min)				Resilient Modulus, 10^3 psi[1] (Temp. = 73F[2], Pulse Load Time = 0.10 s)				Resilient Modulus, 10^3 psi[1] (Temp. = 55F[2] Pulse Load Time = 0.10 s)			
Month	Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path	
	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.
0	59	48	59	48	149	123	149	123	246	324	246	324
4	99	91	76	87	170	194	136	136	511	560	360	501
8	63	83	71	78	217	348	302	302	346	498	575	654
12	74	66	71	63	411	399	286	216	850	726	1107	697
15	100	91	93	85	154	125	139	135	294	225	271	191
20	76	71	78	77	221	309	220	325	220	336	219	358
24	254	241	228	213	243	243	248	246	375	347	365	362
30	106	91	94	55	120	106	115	91	202	190	195	189
36	116	57	114	41	Malfunction of M_R equipment							
42	108	45	116	48	475	233	516	325	802	337	775	457
48	85	48	80	32	282	198	220	101	455	221	403	192
48i[1]	85	52	80	30	282	142	220	122	455	186	403	190
60												
60i[4]												

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in/min. = 0.00275 cm/s
4. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous values).

TABLE E-4. GEORGIA (A) PAVEMENT TEST SECTION—VISUAL STRIPPING OF PERIODIC CORES AFTER VACUUM SATURATION.

Month	Stripping Observation
0	Not discernible
4	Slight Stripping
8	Slight Stripping
12	Slight Stripping
15	Slight Stripping
20	Slight Stripping
24	Slight Stripping
30	Severe Stripping Some cores disintegrating
36	Severe Stripping Some cores disintegrating
42	Severe Stripping Some cores disintegrating
48	Moderate-light stripping, some cores disintegrating. Some cores show rehealing - (dry weather)
48[1]	Moderate-light stripping, some cores disintegrating. Some cores show rehealing - (dry weather).

Notes: 1. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous observations).

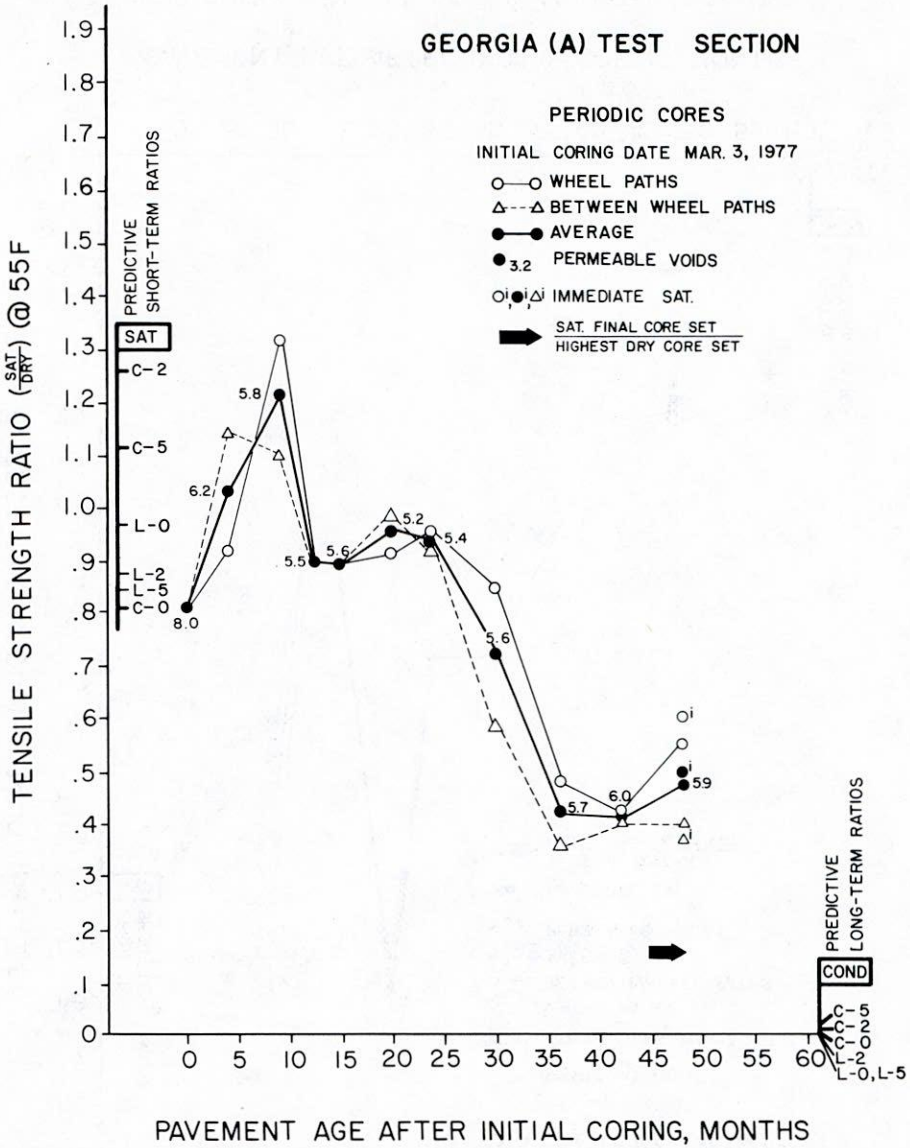

Figure E-1. Georgia (A) test section—predictive and field tensile strength ratios at 55 F.

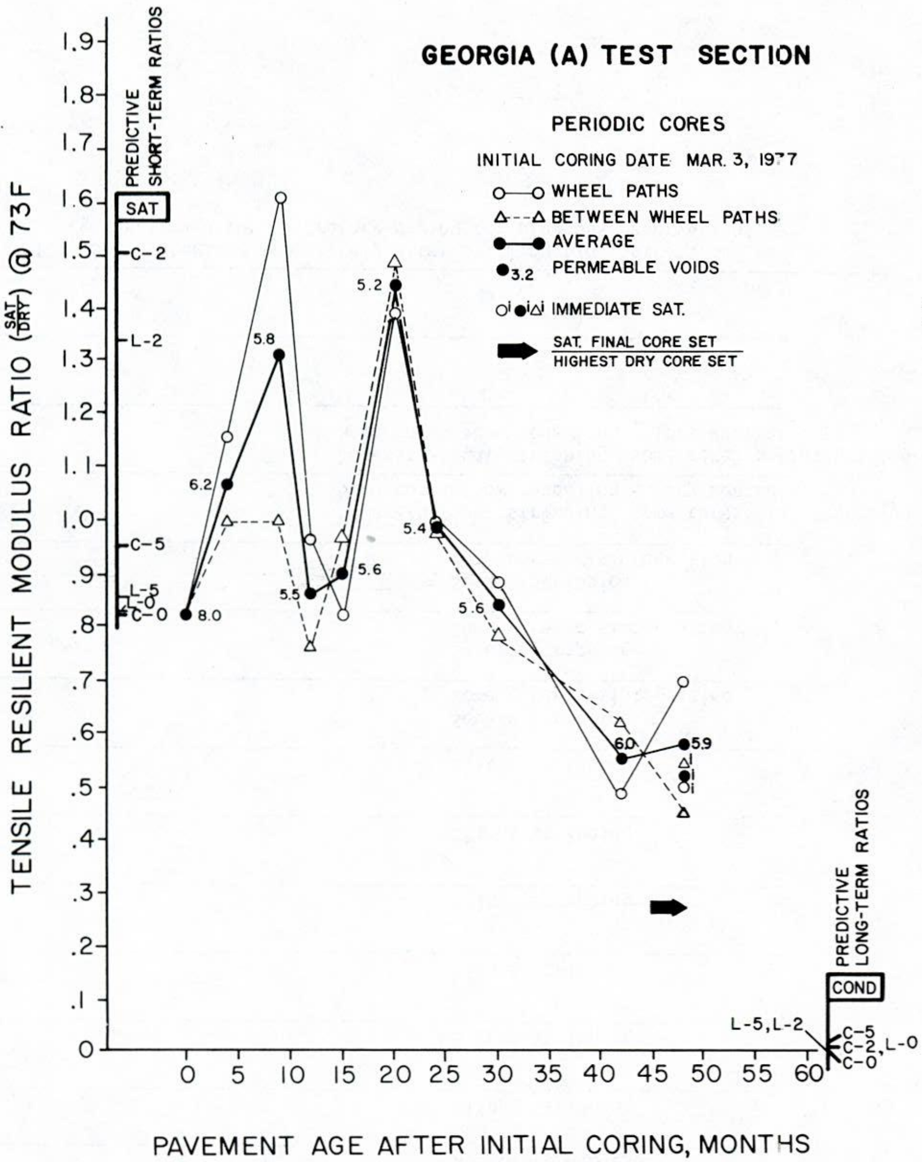

Figure E-2. Georgia (A) test section—predictive and field resilient modulus ratios at 73 F.

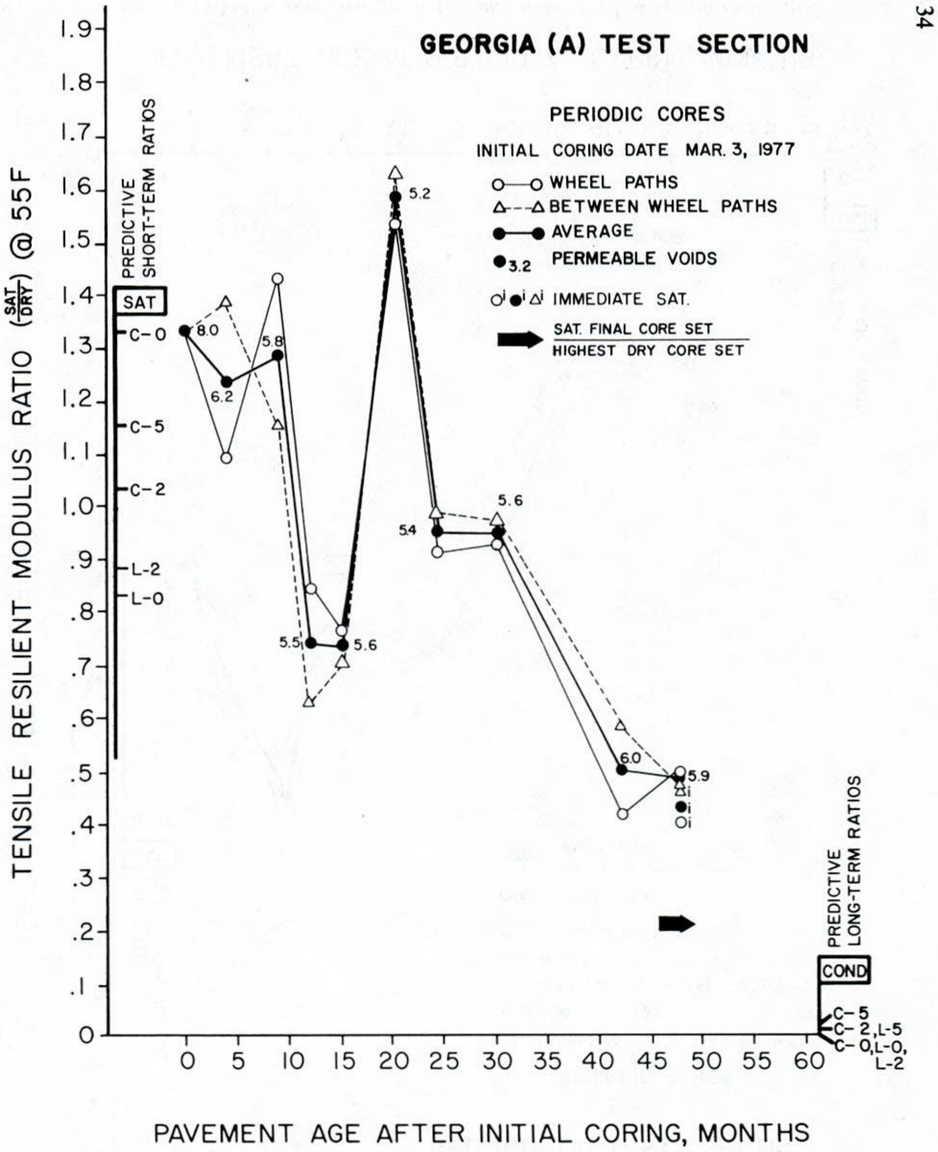

Figure E-3. Georgia (A) test section—predictive and field resilient modulus ratios at 55 F.

APPENDIX F—GEORGIA (B) TEST SECTION DATA

TABLE F-1. GEORGIA (B) PAVEMENT TEST SECTION—QUANTITATIVE LABORATORY TEST DATA FOR MOISTURE DAMAGE PREDICTIONS.

Tensile Splitting Strength, psi[1.]
(Temp. = 55F[2.],
Deform. Rate = 0.065 in./min.[3.])

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 7.1 %

Laboratory Storage Time, Months

0			2			5					
Dry	VS[4.]	AC[5.]	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
85	87	0	85	69	0	79	72	0			

B. Laboratory Fabricated Specimens
@ Reduced Voids = %

Laboratory Storage Time, Months

0											
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC

Test not run; mix voids could not reduce by compaction

C. Initial Pavement Cores
@ Voids = 7.1%

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
110	99	0	56	68	32	100	65	46	94	50	0

Resilient Modulus, 10^3 psi[1.]
(Pulse Load Time = 0.10 s)

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 7.1 %

Laboratory Storage Time, Months

	0			2			5					
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2.]	288	224	0	369	265	0	470	428	0			
Temp. = 55F[2.]	375	390	0	792	748	0						

B. Laboratory Fabricated Specimens
@ Reduced Voids = %

Laboratory Storage Time, Months

	0											
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2.]												
Temp. = 55F[2.]												

Test not run; mix voids could not reduce by compaction

C. Initial Pavement Cores
@ Voids = 7.1%

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2.]	205	134	0	221	268	81	193	160	121	216	204	0
Temp. = 55F[2.]	788	316	0	204	213	132	416	377	222	499	445	0

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in./min. = 0.00275 cm/s
4. vacuum saturated
5. accelerated conditioned

TABLE F-2. GEORGIA (B) PAVEMENT TEST SECTION—VISUAL STRIPPING OF PREDICTIVE LABORATORY SPECIMENS AND INITIAL PAVEMENT CORES AFTER MOISTURE CONDITIONING.

Specimen or Core Condition	Laboratory Fabricated Specimens @ Initial Pavt. Core Voids= 7.1%	Laboratory Fabricated Specimens @ Reduced Voids = %	Initial Pavement Cores @ Voids =7.1%
Vacuum Saturated	Slight stripping (same for all storage times)	Test not run; mix voids could not reduce	Slight stripping (same for all storage times)
Accelerated Conditioned	Severe stripping and specimen disintegration (same for all storage times)	Test not run; mix voids could not reduce	Severe stripping and core disintegration (same for all storage times)

TABLE F-3. GEORGIA (B) PAVEMENT TEST SECTION—QUANTITATIVE PERIODIC CORE TEST DATA.

	Tensile Splitting Strength, psi[1] (Temp. = 55F[2], Deform. Rate = 0.065 in./min)				Resilient Modulus, 10^3 psi[1] (Temp. = 73F[2], Pulse Load Time = 0.10 s)				Resilient Modulus, 10^3 psi[1] (Temp. = 55F[2] Pulse Load Time = 0.10 s)			
Month	Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path	
	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.
0	110	99	110	99	205	134	205	134	788	316	788	316
4	93	85	99	83	196	205	201	179	426	568	577	560
8	62	73	77	70	401	312	354	369	565	530	634	653
12	70	68	73	62	373	309	298	349	647	846	815	1253
15	105	103	105	97	113	157	152	188	163	395	158	194
20	76	78	79	76	225	324	209	317	202	284	214	297
24	222	202	237	211	240	241	240	244	379	365	381	334
30	128	117	119	93	117	905	105	97	199	174	192	160
36	114	57	110	73	Malfunction of M_R equipment							
42	100	98	96	49	536	573	448	215	672	841	679	340
48	83	64	112	48	384	223	340	230	496	313	412	310
48i[4]	83	44	112	40	384	203	340	165	496	229	412	268

Notes: 1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in/min. = 0.00275 cm/s
4. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous values).

TABLE F-4. GEORGIA (B) PAVEMENT TEST SECTION—VISUAL STRIPPING OF PERIODIC CORES AFTER VACUUM SATURATION.

Month	Stripping Observation
0	Not discernible
4	Slight Stripping
8	Slight Stripping
12	Slight Stripping
15	Slight Stripping
20	Slight Stripping
24	Slight Stripping
30	Severe Stripping Some cores disintegrating
36	Severe Stripping Some cores disintegrating
42	Severe Stripping Some cores disintegrating
48	Moderate-light stripping - some cores show rehealing (dry weather). Some cores disintegrating
48[1.]	

Notes: 1. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous observations).

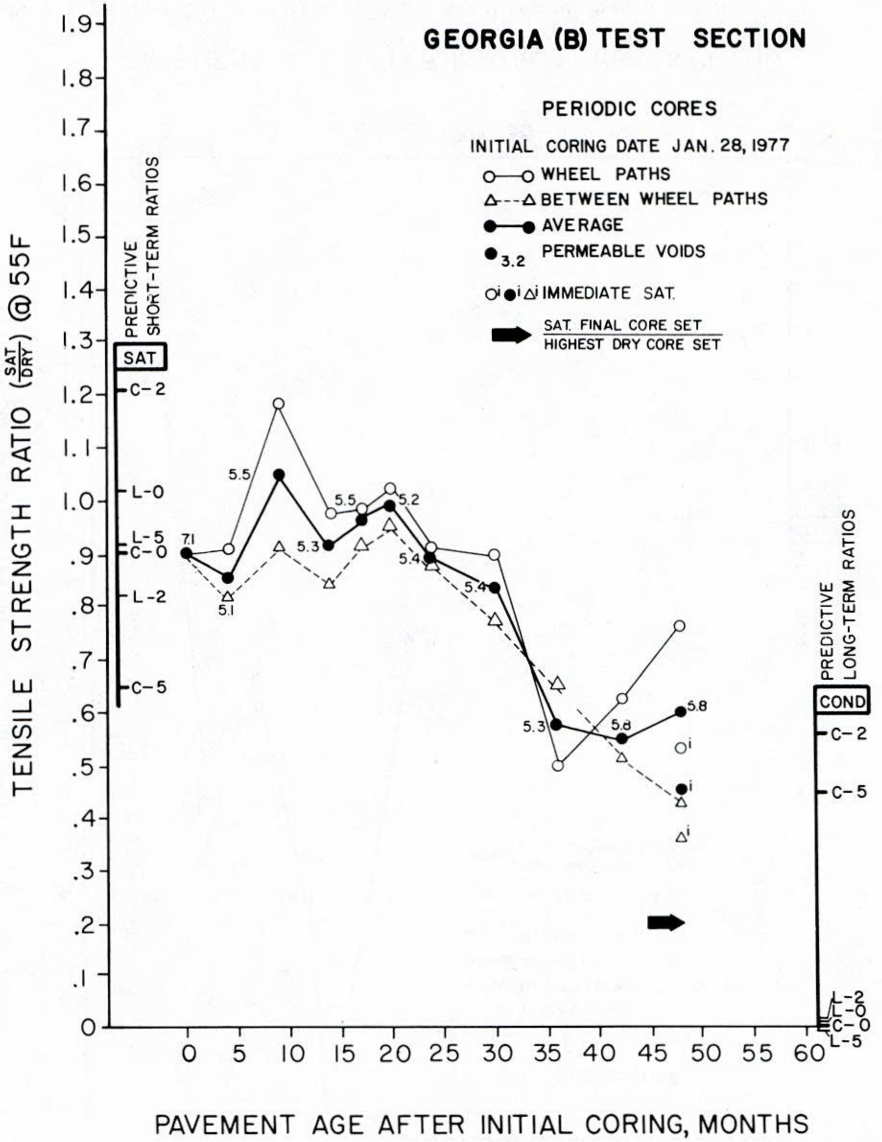

Figure F-1. Georgia (B) test section—predictive and field tensile strength ratios at 55 F.

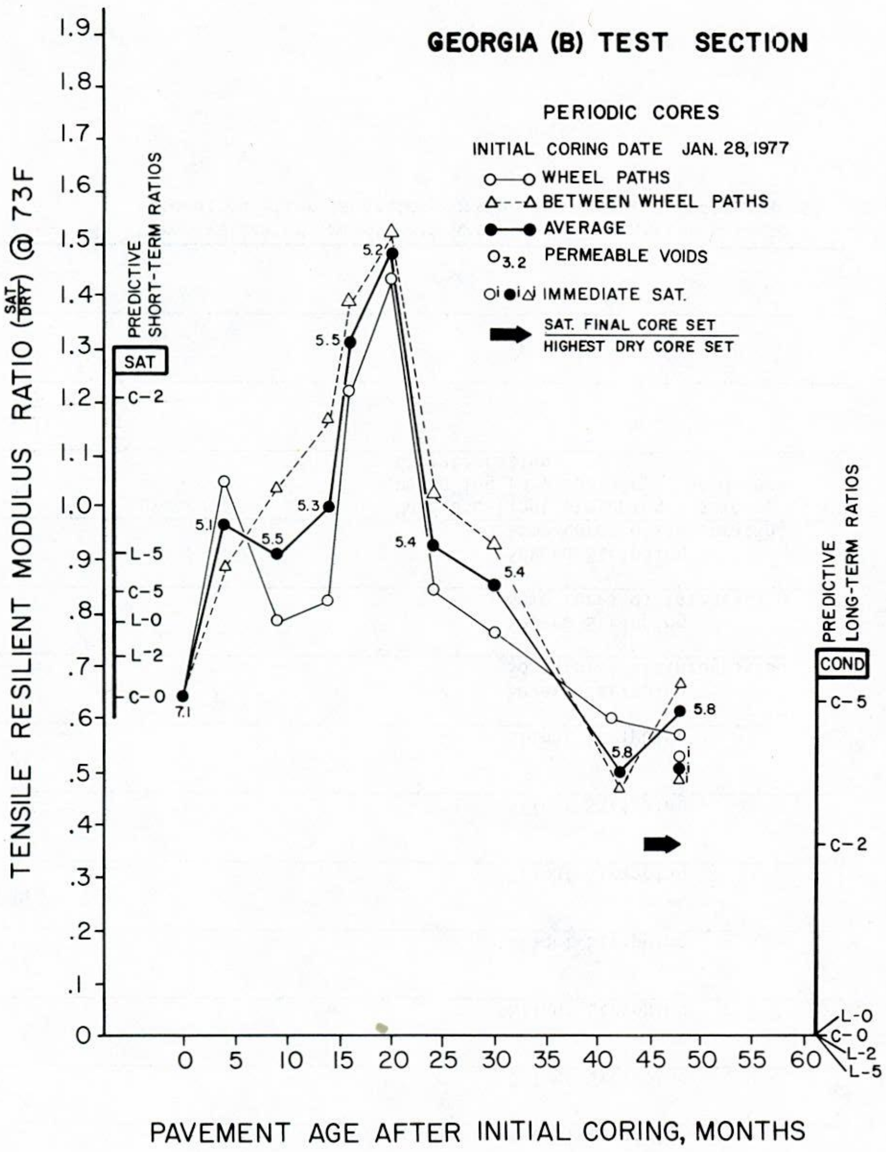

Figure F-2. Georgia (B) test section—predictive and field resilient modulus ratios at 73 F.

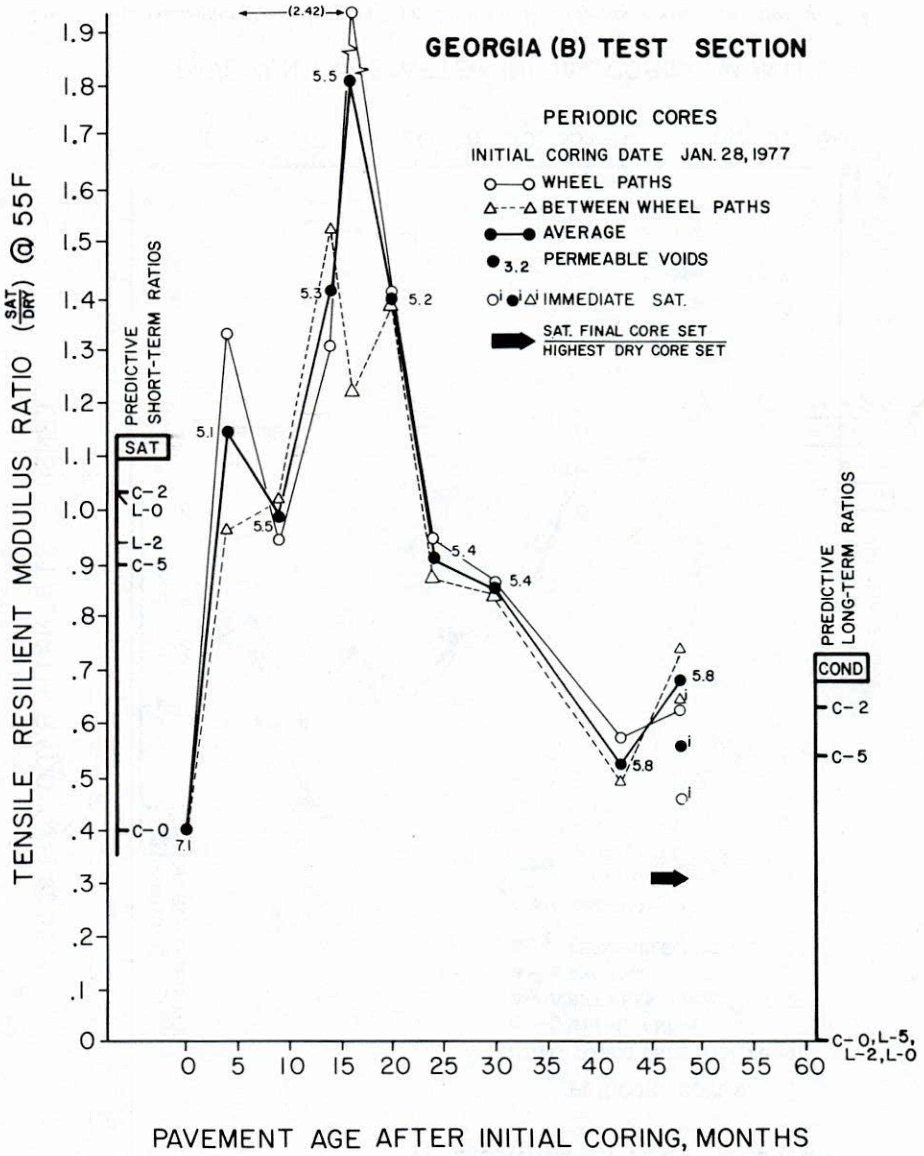

Figure F-3. Georgia (B) test section—predictive and field resilient modulus ratios at 55 F.

APPENDIX G—IDAHO TEST SECTION DATA

TABLE G-1. IDAHO PAVEMENT TEST SECTION—QUANTITATIVE LABORATORY TEST DATA FOR MOISURE DAMAGE PREDICTIONS.

Tensile Splitting Strength, psi[1]
(Temp. = 55F[2],
Deform. Rate = 0.065 in./min.[3])

A. Laboratory Fabricated Specimens @ Initial Pavt. Core Voids = 3.2 %

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS[4]	AC[5]	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
83	75	68	83	78	72	109	94	83	124	104	97

B. Laboratory Fabricated Specimens @ Reduced Voids = 1.8%

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
103	90	86	96	99	89	117	103	103	121	125	104

C. Initial Pavement Cores @ Voids = 3.2%

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
52	51	47	78	56	55	87	75	67	93	84	66

Resilient Modulus, 10^3 psi[1]
(Pulse Load Time = 0.10 s)

A. Laboratory Fabricated Specimens @ Initial Pavt. Core Voids = 3.2 %

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	294	267	287	270	251	253	344	259	231	391	207	272
Temp. = 55F[2]												

B. Laboratory Fabricated Specimens @ Reduced Voids = 1.8%

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	402	383	349	320	357	317	362	327	316	438	388	349
Temp. = 55F[2]												

C. Initial Pavement Cores @ Voids = 3.2%

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	167	153	146	184	131	137	226	209	201	264	245	182
Temp. = 55F[2]												

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in./min. = 0.00275 cm/s
4. vacuum saturated
5. accelerated conditioned

TABLE G-2. IDAHO PAVEMENT TEST SECTION—VISUAL STRIPPING OF PREDICTIVE LABORATORY SPECIMENS AND INITIAL PAVEMENT CORES AFTER MOISTURE CONDITIONING.

Specimen or Core Condition	Laboratory Fabricated Specimens @ Initial Pavt. Core Voids= 3.2%	Laboratory Fabricated Specimens @ Reduced Voids =1.8%	Initial Pavement Cores @ Voids =3.2%
Vacuum Saturated	No discernible stripping (same for all storage times)	No discernible stripping (same for all storage times)	No discernible stripping (same for all storage times)
Accelerated Conditioned	Very slight stripping (same for all storage times)	Very slight stripping (same for all storage times)	Very slight stripping (same for all storage times)

TABLE G-3. IDAHO PAVEMENT TEST SECTION—QUANTITATIVE PERIODIC CORE TEST DATA.

	Tensile Splitting Strength, psi[1] (Temp. = 55F[2], Deform. Rate = 0.065 in./min)				Resilient Modulus, 10^3 psi[1] (Temp. = 73F[2], Pulse Load Time = 0.10 s)				Resilient Modulus, 10^3 psi[1] (Temp. = 55F[2], Pulse Load Time = 0.10 s)			
Month	Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path	
	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.
0	52	51	52	51	167	153	167	153	Test not programmed due to early startup			
4	81	60	76	64	174	134	183	161				
8	94	82	99	73	180	174	182	138				
12	69	80	65	78	204	181	176	164				
16	65	69	68	67	218	180	200	169				
20												
24	81	67	76	69	212	212	145	194				
30	62	68	64	58	261	202	235	196				
36	91	96	92	105	282	269	246	195				
42	68	65	64	62	214	202	220	223				
48	76	80	69	73	254	238	190	225				
54	95	93	99	86	241	195	241	201				
60	124	101	103	89	235	276	223	216				
60i[4]	124	79	103	80	(M_R test not programmed for 60i)							

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in/min. = 0.00275 cm/s
4. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous values).

TABLE G-4. IDAHO PAVEMENT TEST SECTION—VISUAL STRIPPING OF PERIODIC CORES AFTER VACUUM SATURATION.

Month	Stripping Observation
0	Not discernible
4	Not discernible
8	Not discernible
12	Not discernible
16	Not discernible
20	Not discernible
24	Not discernible
30	Not discernible
36	Very slight stripping
42	Very slight stripping
48	Very slight stripping
54	Very slight stripping
60	Very slight stripping
60i[1.]	Very slight stripping

Notes: 1. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous observations).

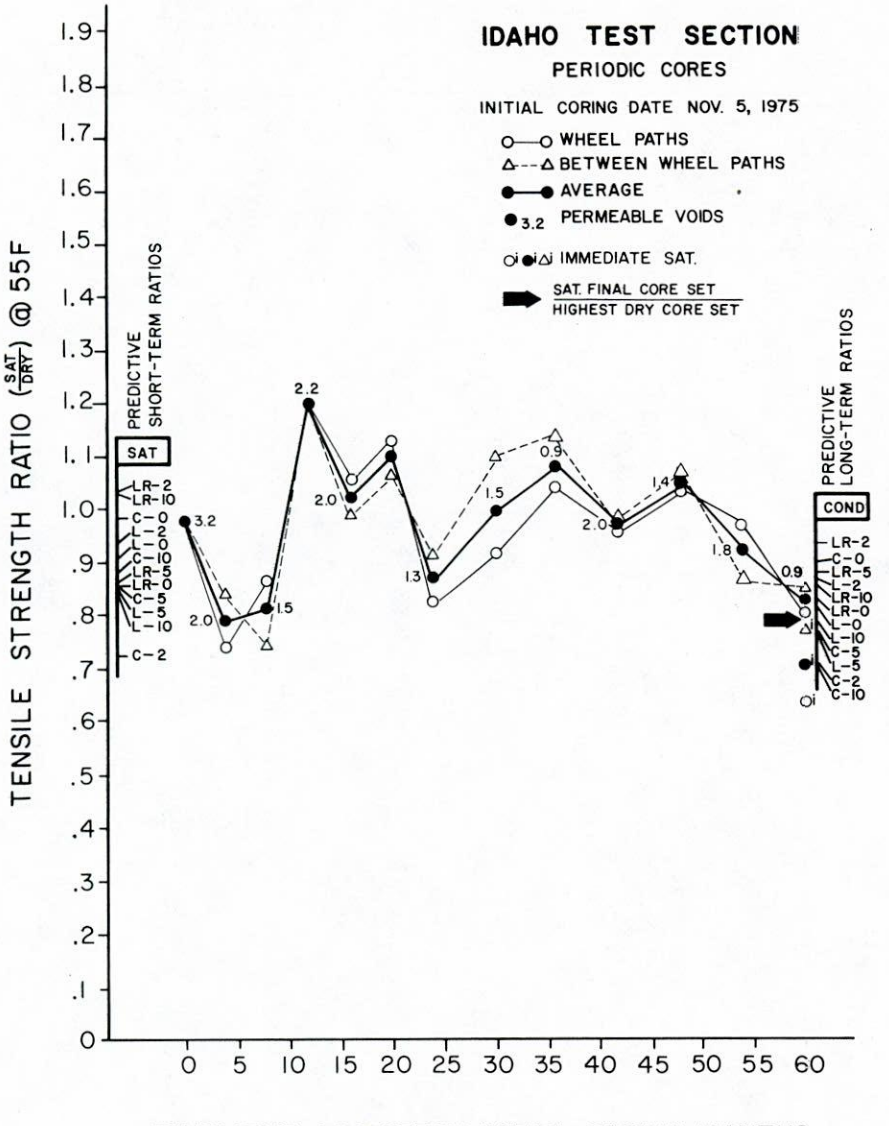

Figure G-1. Idaho test section—predictive and field tensile strength ratios at 55 F.

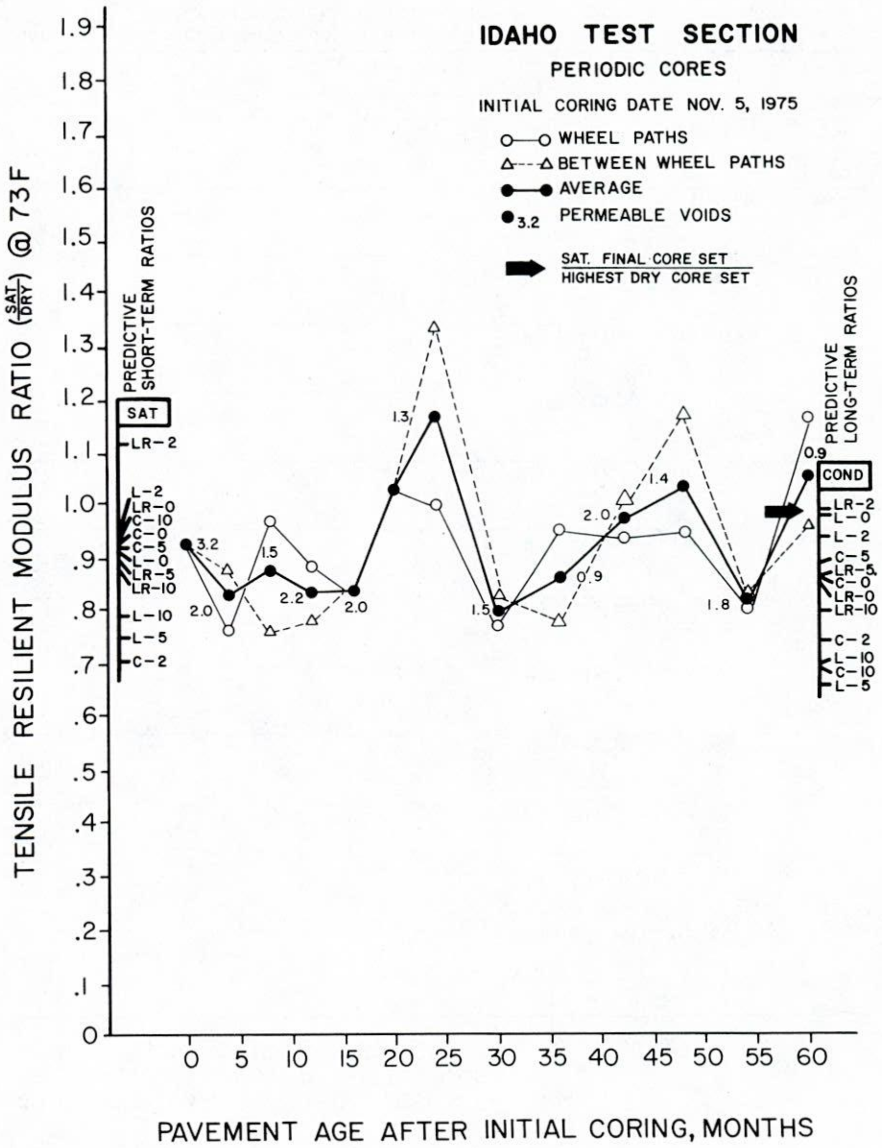

Figure G-2. Idaho test section—predictive and field resilient modulus ratios at 73 F.

APPENDIX H—MONTANA TEST SECTION DATA

TABLE H-1. MONTANA PAVEMENT TEST SECTION—QUANTITATIVE LABORATORY TEST DATA FOR MOISTURE DAMAGE PREDICTIONS.

Tensile Splitting Strength, psi[1]
(Temp. = 55F[2],
Deform. Rate = 0.065 in./min.[3])

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 4.3 %

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS[4]	AC[5]	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
74	61	44	70	51	32	77	52	37	74	62	32

B. Laboratory Fabricated Specimens
@ Reduced Voids = 2.2%

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
66	50	38	89	71	58	86	79	52	86	82	67

C. Initial Pavement Cores
@ Voids = 4.3%

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
47	51	40	61	54	25	78	76	48	81	72	48

Resilient Modulus, 10^3 psi[1]
(Pulse Load Time = 0.10 s)

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 4.3 %

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	159	128	106	198	121	78	213	174	145	283	274	140
Temp. = 55F[2]	785	648	471	960	538	307				1128	1187	510

B. Laboratory Fabricated Specimens
@ Reduced Voids = 2.2%

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	150	89	89	189	141	142	246	254	176	302	266	241
Temp. = 55F[2]	855	501	415	955	767	584				1264	1287	709

C. Initial Pavement Cores
@ Voids = 4.3 %

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	99	97	121	127	117	94	175	151	128	197	142	149
Temp. = 55F[2]				599	493	314	788	702	574	728	424	458

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in./min. = 0.00275 cm/s
4. vacuum saturated
5. accelerated conditioned

TABLE H-2. MONTANA PAVEMENT TEST SECTION—VISUAL STRIPPING OF PREDICTIVE LABORATORY SPECIMENS AND INITIAL PAVEMENT CORES AFTER MOISTURE CONDITIONING.

Specimen or Core Condition	Laboratory Fabricated Specimens @ Initial Pavt. Core Voids = 4.3%	Laboratory Fabricated Specimens @ Reduced Voids =2.2%	Initial Pavement Cores @ Voids =4.3%
Vacuum Saturated	Slight stripping (same for all storage times)	Slight stripping (same for all storage times)	Slight stripping (same for all storage times)
Accelerated Conditioned	Moderate stripping (same for all storage times)	Moderate stripping (same for all storage times)	Moderate stripping (same for all storage times)

TABLE H-3. . MONTANA PAVEMENT TEST SECTION—QUANTITATIVE PERIODIC CORE TEST DATA.

Month	Tensile Splitting Strength, psi[1.] (Temp. = 55F[2.], Deform. Rate = 0.065 in./min)				Resilient Modulus, 10^3 psi[1.] (Temp. = 73F[2.], Pulse Load Time = 0.10 s)				Resilient Modulus, 10^3 psi[1.] (Temp. = 55F[2.] Pulse Load Time = 0.10 s)			
	Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path	
	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.
0	47	51	47	51	99	97	99	97	(Not programmed for month 0)			
4	66	59	57	51	108	117	98	94	609	581	524	533
9	51	55	46	46	139	105	109	131	580	506	560	689
12	67	53	68	54	162	111	158	114	627	390	665	410
16	66	66	67	63	(M_R 73°F not run at Month 16)				887	642	844	680
20	67	59	58	62	184	184	176	171	673	777	642	646
24	51	52	54	59	136	105	144	126	571	398	506	515
30	58	56	66	53	148	153	135	150	745	710	685	568
36	59	52	50	55	222	171	196	140	874	723	763	571
42	70	69	74	72	145	168	146	137	634	816	673	557
51	70	65	75	56	239	207	245	181	899	745	953	632
51i[4.]	70	52	75	66	239	126	245	174	899	458	953	676
56	59	53	62	53	222	160	180	127	836	629	734	559
56i[4.]	59	64	62	62	222	119	180	110	836	445	734	481

Notes: 1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in/min. = 0.00275 cm/s
4. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous values).

TABLE H-4. MONTANA PAVEMENT TEST SECTION—VISUAL STRIPPING OF PERIODIC CORES AFTER VACUUM SATURATION.

Month	Stripping Observation
0	Not discernible
4	Slight Stripping
9	Slight Stripping
12	Slight Stripping
16	Slight Stripping
20	Slight Stripping
24	Slight Stripping
30	Slight Stripping
36	Slight Stripping
42	Slight Stripping
48	-
51	Slight stripping most cores; One core had severe stripping
56	Slight stripping most cores; moderate stripping remainder of cores
56i[1]	Slight stripping most cores; moderate stripping remainder of cores

Notes: 1. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous observations).

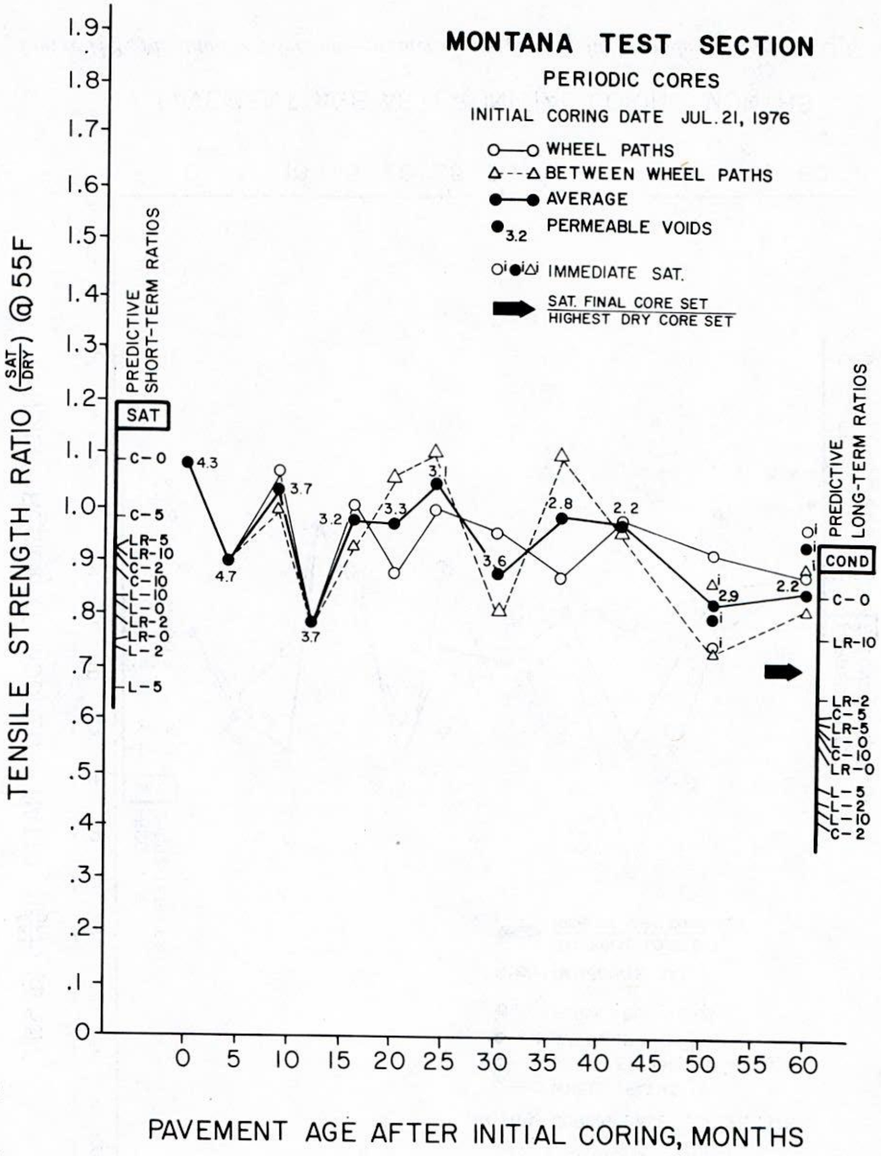

Figure H-1. Montana test section—predictive and field tensile strength ratios at 55 F.

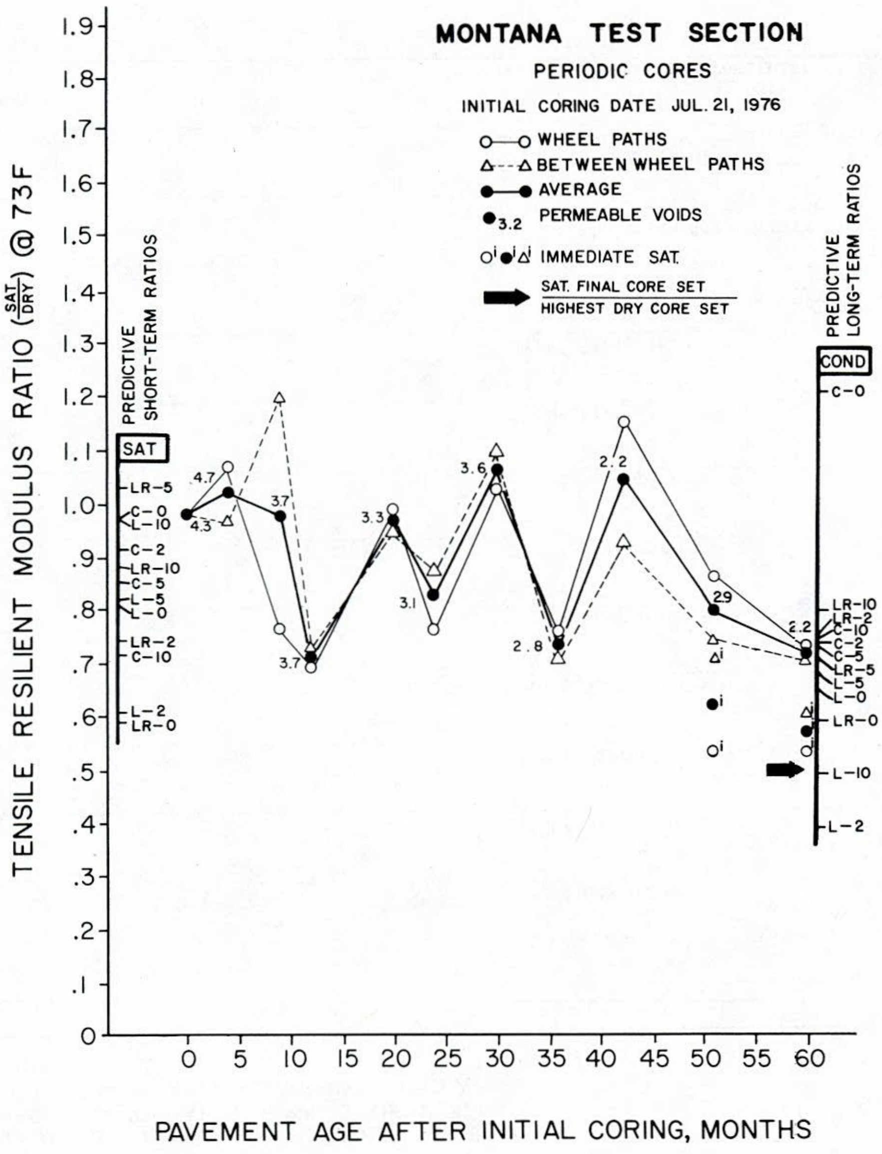

Figure H-2. Montana test section—predictive and field resilient modulus ratios at 73 F.

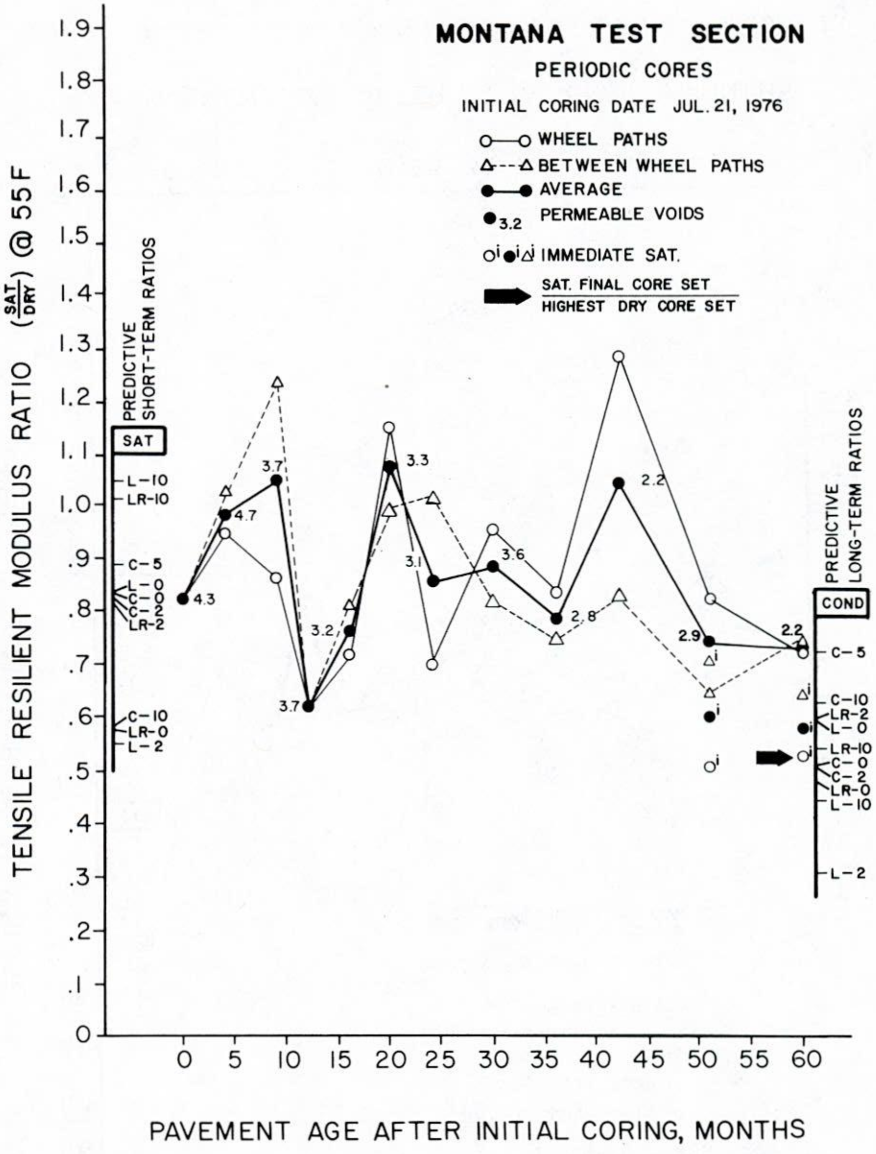

Figure H-3. Montana test section—predictive and field resilient modulus ratios at 55 F.

APPENDIX I—VIRGINIA TEST SECTION DATA

TABLE I-1. VIRGINIA PAVEMENT TEST SECTION—QUANTITATIVE LABORATORY TEST DATA FOR MOISTURE DAMAGE PREDICTIONS.

Tensile Splitting Strength, psi[1]
(Temp. = 55F[2],
Deform. Rate = 0.065 in./min.[3])

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 6.0 %

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS[4]	AC[5]	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
56	56	20	67	77	28	76	78	30	69	71	32

B. Laboratory Fabricated Specimens
@ Reduced Voids = %

Laboratory Storage Time, Months

0											
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC

Test not run; mix voids could not reduce by compaction

C. Initial Pavement Cores
@ Voids = 6.0%

Laboratory Storage Time, Months

0			2			5			10		
Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
47	45	24	51	45	30	50	58	30	65	64	37

Resilient Modulus, 10^3 psi[1]
(Pulse Load Time = 0.10 s)

A. Laboratory Fabricated Specimens
@ Initial Pavt. Core Voids = 6.0 %

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	236	182	51	282	324	115	286	350	118	262	336	144
Temp. = 55F[2]	668	666	227	832	790	325	626	561	323	527	724	394

B. Laboratory Fabricated Specimens
@ Reduced Voids = %

Laboratory Storage Time, Months

	0											
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]												
Temp. = 55F[2]												

Test not run; mix voids could not reduce by compaction

C. Initial Pavement Cores
@ Voids = 6.0 %

Laboratory Storage Time, Months

	0			2			5			10		
	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC	Dry	VS	AC
Temp. = 73F[2]	163	143	79	168	162	91	176	234	105	263	362	139
Temp. = 55F[2]	465	439	262	472	447	307	522	642	332	764	547	454

Notes:
1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in./min. = 0.00275 cm/s
4. vacuum saturated
5. accelerated conditioned

TABLE I-2. VIRGINIA PAVEMENT TEST SECTION—VISUAL STRIPPING OF PREDICTIVE LABORATORY SPECIMENS AND INITIAL PAVEMENT CORES AFTER MOISTURE CONDITIONING.

Specimen or Core Condition	Laboratory Fabricated Specimens @ Initial Pavt. Core Voids = 6.0%	Laboratory Fabricated Specimens @ Reduced Voids =	Initial Pavement Cores @ Voids = 6.0
Vacuum Saturated	Very slight stripping (same for all storage times)	Test not run; mix voids could not reduce	Very slight stripping (same for all storage times)
Accelerated Conditioned	Severe stripping (same for all storage times)	Test not run; mix voids could not reduce	Severe stripping (same for all storage times)

TABLE I-3. VIRGINIA PAVEMENT TEST SECTION—QUANTITATIVE PERIODIC CORE TEST DATA.

	Tensile Splitting Strength, psi$^{1.}$ (Temp. = 55F$^{2.}$, Deform. Rate = 0.065 in./min)				Resilient Modulus, 10^3 psi$^{1.}$ (Temp. = 73F$^{2.}$, Pulse Load Time = 0.10 s)				Resilient Modulus, 10^3 psi$^{1.}$ (Temp. = 55F$^{2.}$ Pulse Load Time = 0.10 s)			
	Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path		Wheel Path		Bet. Wheel Path	
Month	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.	Dry	Vac. Sat.
0	47	45	47	45	163	143	163	143	465	439	465	439
4	60	59	73	65	184	257	213	268	540	650	650	692
8	69	79	78	96	207	293	279	457	527	643	524	979
12	63	69	76	79	225	284	275	340	488	608	688	695
16	82	76	82	88	442	472	400	538	1550	1250	1150	1120
22	76	64	81	84	281	299	277	308	911	873	881	800
24	80	76	77	77	254	280	239	352	963	831	859	1210
30	77	71	62	67	361	441	374	305	1080	1020	850	712
34	67	56	73	78	307	340	284	426	938	694	1010	900
42	77	75	74	73	326	428	322	325	998	893	1040	819
46	71	77	88	72	311	338	394	433	962	932	1120	836
53	71	48	58	58	332	284	292	334	936	616	731	733
58	60	70	71	60	195	354	274	282	568	752	648	642
58i$^{4.}$	60	49	71	58	195	230	274	256	568	496	648	616

Notes: 1. 1 psi = 6.895 kPa
2. 55F = 13C; 73F = 23C
3. 0.065 in/min. = 0.00275 cm/s
4. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous values).

TABLE I-4. VIRGINIA PAVEMENT TEST SECTION—VISUAL STRIPPING OF PERIODIC CORES AFTER VACUUM SATURATION.

Month	Stripping Observation
0	Not discernible
4	Very slight stripping[2]
8	Slight Stripping[2]
12	Moderate Stripping[2]
16	Moderate Stripping[2]
22	Moderate Stripping[2]
24	Moderate Stripping[2]
30	Moderate Stripping[2]
34	Moderate Stripping[2]
42	Moderate Stripping[2]
46	Moderate Stripping[2]
53	Severe Stripping[2]
58	Severe Stripping[2]
58[1]	Severe Stripping[2]

Notes: 1. Cores saturated immediately after drilling (in contrast to saturation after laboratory drying for previous observations).

2. Coarse aggregate stripping only.

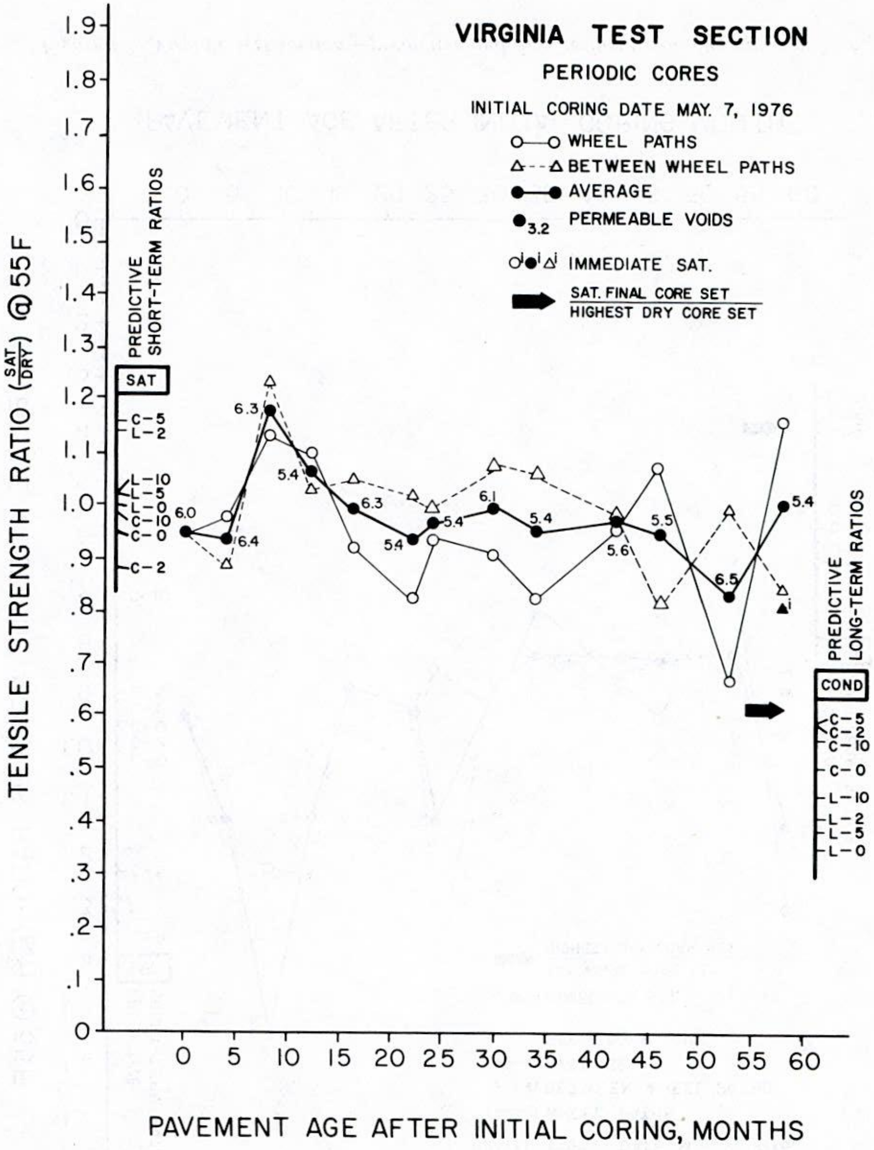

Figure I-1. Virginia test section—predictive and field tensile strength ratios at 55 F.

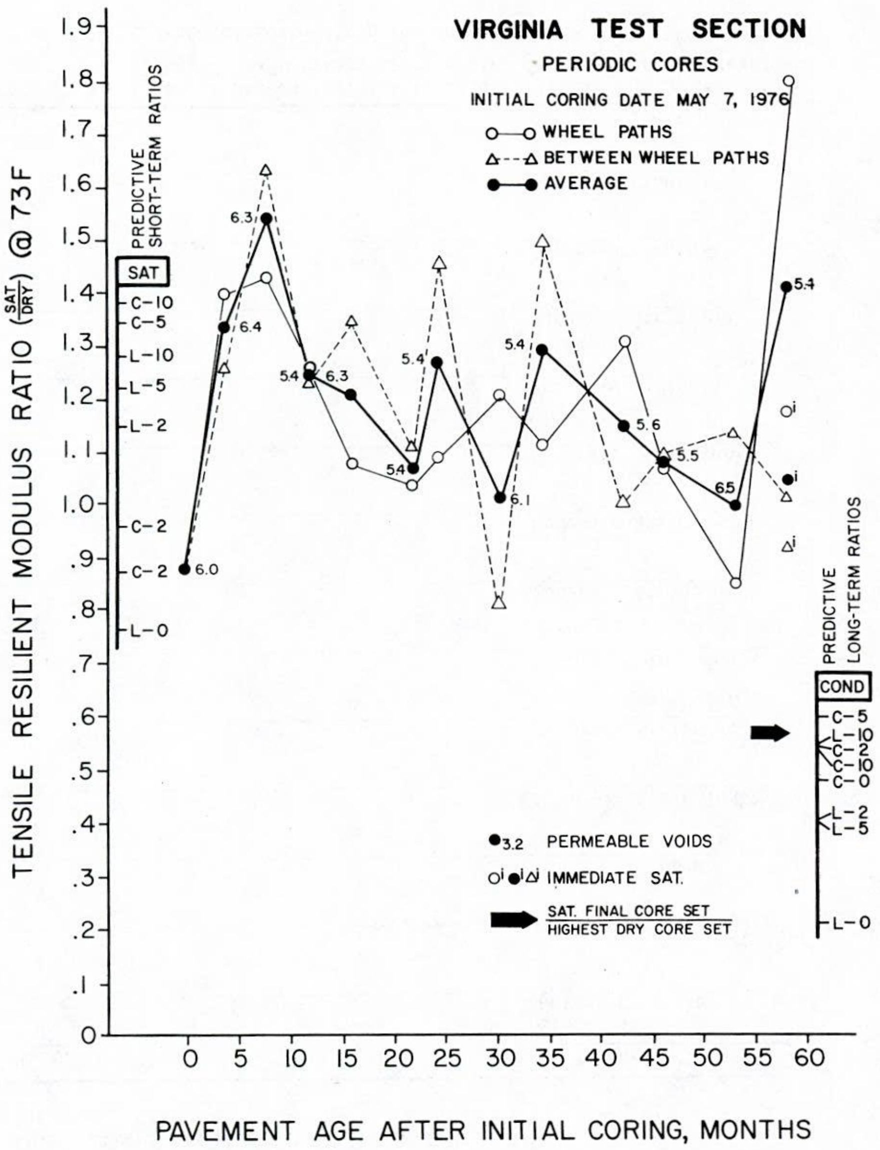

Figure I-2. Virginia test section—predictive and field resilient modulus ratios at 73 F.

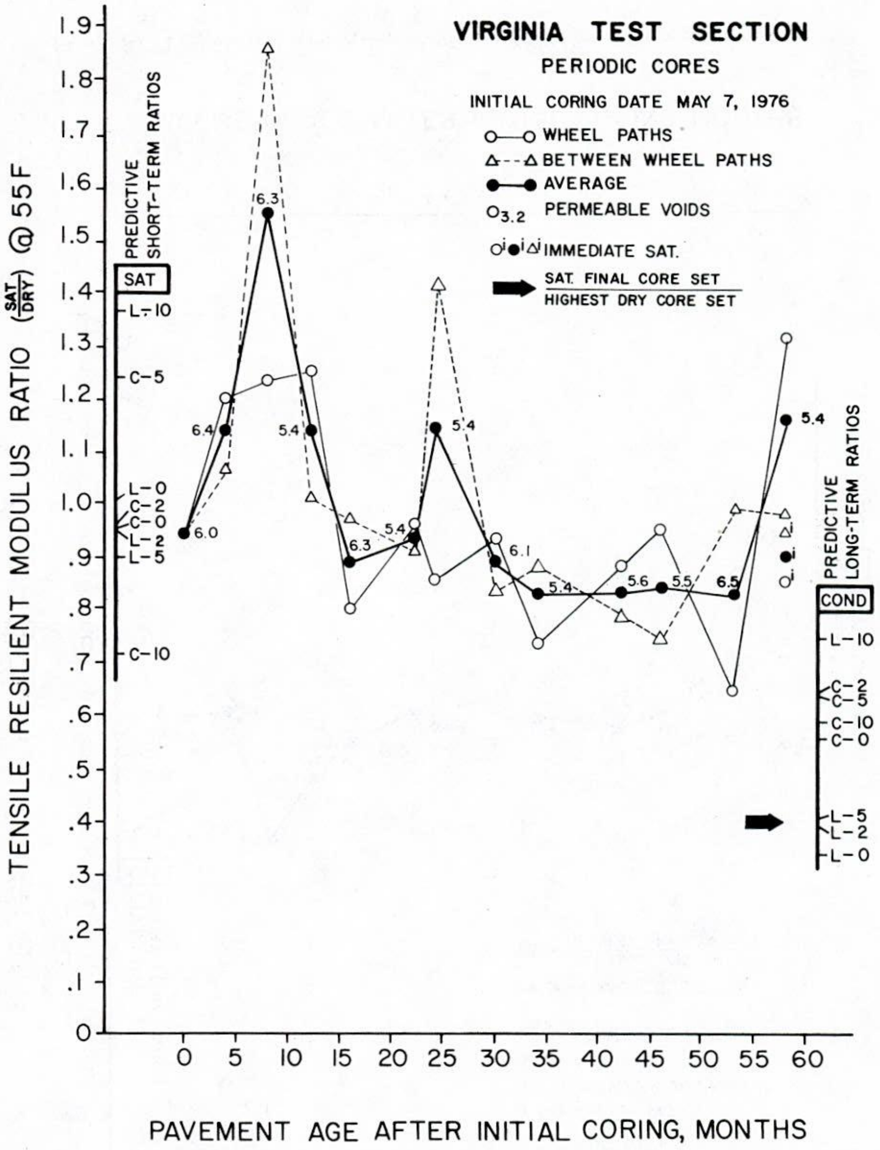

Figure I-3. Virginia test section—predictive and field resilient modulus ratios at 55 F.

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