Report No. K-TRAN: KSU-09-2 ▪ FINAL REPORT ▪ September 2013

# Investigation of Aged Hot-Mix Asphalt Pavements

Jeremiah Thomas
Farhana Rahman
Mustaque Hossain, Ph.D., P.E.
*Kansas State University*

A cooperative transportation research program between
Kansas Department of Transportation,
Kansas State University Transportation Center, and
The University of Kansas

Kansas Department of Transportation

This page intentionally left blank.

| | | |
|---|---|---|
| **1 Report No.**<br>K-TRAN: KSU-09-2 | **2 Government Accession No.** | **3 Recipient Catalog No.** |
| **4 Title and Subtitle**<br>Investigation of Aged Hot-Mix Asphalt Pavements | | **5 Report Date**<br>September 2013 |
| | | **6 Performing Organization Code** |
| **7 Author(s)**<br>Jeremiah Thomas; Farhana Rahman; and Mustaque Hossain, Ph.D., P.E. | | **8 Performing Organization Report No.** |
| **9 Performing Organization Name and Address**<br>Department of Civil Engineering<br>Kansas State University Transportation Center<br>2118 Fiedler Hall<br>Manhattan, Kansas 66506 | | **10 Work Unit No. (TRAIS)** |
| | | **11 Contract or Grant No.**<br>C1819 |
| **12 Sponsoring Agency Name and Address**<br>Kansas Department of Transportation<br>Bureau of Research<br>2300 SW Van Buren<br>Topeka, Kansas 66611-1195 | | **13 Type of Report and Period Covered**<br>Final Report<br>April 2009–December 2012 |
| | | **14 Sponsoring Agency Code**<br>RE-0487-01 |
| **15 Supplementary Notes**<br>For more information write to address in block 9. | | |


Over the lifetime of an asphalt concrete (AC) pavement, the roadway requires periodic resurfacing and rehabilitation to provide acceptable performance. The most popular resurfacing method is an asphalt overlay over the existing roadway. In the design of asphalt overlays, the thickness is related to the structural strength of the existing pavement. As the layers are overlaid their structural characteristics change due to aging of asphalt. However, currently there is no method to determine the effect of aging on the strength of existing pavement layers.

This study examined structural characterization of six pavement test sections in Kansas using three different test methods: Falling Weight Deflectometer (FWD), Portable Seismic Property Analyzer (PSPA), and Indirect Tensile (IDT) tests. The results were analyzed to determine how the modulus of an AC pavement layer changes over time.

The results indicate that as the AC pavement ages, its modulus decreases due to pavement deterioration. The most prominent cause for AC pavement deterioration was observed to be stripping. Two of the test sections on US-169 and K-4 showed little signs of stripping and had a minimal reduction or even an increase in AC moduli.

The analyzed results from different test methods for moduli were inconclusive as far as any correlation among the methods is concerned. While the correlation between various test methods studied was mostly consistent for a particular roadway, no universal correlation was found for all pavement sections tested.

Fatigue test results show that older pavement layers have a higher propensity for fatigue failure than the newer layers. However, some older pavement layers showed excellent fatigue life. Fatigue results correlated well with the condition of the cores as assessed by visual observation.


| | | | |
|---|---|---|---|
| **17 Key Words**<br>Hot-Mix Asphalt, Pavement, Asphalt Concrete, Falling Weight Deflectometer, Portable Seismic Property Analyzer, Indirect Tensile Test | | **18 Distribution Statement**<br>No restrictions. This document is available to the public through the National Technical Information Service www.ntis.gov. | |
| **19 Security Classification (of this report)**<br>Unclassified | **20 Security Classification (of this page)**<br>Unclassified | **21 No. of pages**<br>105 | **22 Price** |

Form DOT F 1700.7 (8-72)

# Investigation of Aged Hot-Mix Asphalt Pavements

Final Report

Prepared by

Jeremiah Thomas
Farhana Rahman
Mustaque Hossain, Ph.D., P.E.

Kansas State University Transportation Center

A Report on Research Sponsored by

THE KANSAS DEPARTMENT OF TRANSPORTATION
TOPEKA, KANSAS

and

KANSAS STATE UNIVERSITY TRANSPORTATION CENTER
MANHATTAN, KANSAS

September 2013

# PREFACE

The Kansas Department of Transportation's (KDOT) Kansas Transportation Research and New-Developments (K-TRAN) Research Program funded this research project. It is an ongoing, cooperative and comprehensive research program addressing transportation needs of the state of Kansas utilizing academic and research resources from KDOT, Kansas State University and the University of Kansas. Transportation professionals in KDOT and the universities jointly develop the projects included in the research program.

# NOTICE

The authors and the state of Kansas do not endorse products or manufacturers. Trade and manufacturers names appear herein solely because they are considered essential to the object of this report.

This information is available in alternative accessible formats. To obtain an alternative format, contact the Office of Transportation Information, Kansas Department of Transportation, 700 SW Harrison, Topeka, Kansas 66603-3754 or phone (785) 296-3585 (Voice) (TDD).

# DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or the policies of the state of Kansas. This report does not constitute a standard, specification or regulation.

# Abstract

Over the lifetime of an asphalt concrete (AC) pavement, the roadway requires periodic resurfacing and rehabilitation to provide acceptable performance. The most popular resurfacing method is an asphalt overlay over the existing roadway. In the design of asphalt overlays, the thickness is related to the structural strength of the existing pavement. As the layers are overlaid their structural characteristics change due to aging of asphalt. However, currently there is no method to determine the effect of aging on the strength of existing pavement layers.

This study examined structural characterization of six pavement test sections in Kansas using three different test methods: Falling Weight Deflectometer (FWD), Portable Seismic Property Analyzer (PSPA), and Indirect Tensile (IDT) tests. The results were analyzed to determine how the modulus of an AC pavement layer changes over time.

The results indicate that as the AC pavement ages, its modulus decreases due to pavement deterioration. The most prominent cause for AC pavement deterioration was observed to be stripping. Two of the test sections on US-169 and K-4 showed little signs of stripping and had a minimal reduction or even an increase in AC moduli.

The analyzed results from different test methods for moduli were inconclusive as far as any correlation among the methods is concerned. While the correlation between various test methods studied was mostly consistent for a particular roadway, no universal correlation was found for all pavement sections tested.

Fatigue test results show that older pavement layers have a higher propensity for fatigue failure than the newer layers. However, some older pavement layers showed excellent fatigue life. Fatigue results correlated well with the condition of the cores as assessed by visual observation.

# List of Abbreviations

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| AC | Asphalt Concrete |
| ASTM | American Society for Testing and Materials |
| C.V. | Coefficient of Variation |
| FWD | Falling Weight Deflectometer |
| HMA | Hot-Mix Asphalt |
| IDT Test | Indirect Tensile Test |
| KDOT | Kansas Department of Transportation |
| LVDT | Linear Variable Differential Transformer |
| M-EPDG | Mechanical-Empirical Pavement Design Guide |
| NDT | Nondestructive Test |
| PSPA | Portable Seismic Property Analyzer |
| St. Dev. | Standard Deviation |

# Table of Contents

# List of Tables

# List of Figures

# Acknowledgements

The authors to take this opportunity to thank the Kansas Department of Transportation (KDOT) for providing funding for this study under the Kansas Transportation and New Developments (K-TRAN) program. We are thankful to Dr. Stefan Romanoschi for his advice on testing procedures and equipment operation. Special thanks are due to Dr. Chandra Manandhar, Ms. Quinn Stenzel, and Ms. Haritha Musty for their assistance in laboratory testing and data back calculation.

We also appreciate Mr. Curtis Eichman and the crew at the KDOT Materials and Research Laboratory for providing the FWD deflection testing.

# Chapter 1: Introduction

## 1.1 Background

Approximately 89% of state roadways in Kansas are asphalt-surfaced. The typical designed performance period of a hot-mix asphalt (HMA) pavement for new construction or reconstruction as per the Kansas Department of Transportation (KDOT) is 12 years. At this time, the pavement is designed to be rehabilitated with an asphalt overlay.

Currently, the flexible pavement design using the 1993 AASHTO Design Guide allows the year 12 and year 22 overlays' thicknesses to be determined by each state agency. AASHTO (1993*)* describes a method for calculating effective structural number (SN) ($SN_{eff}$) of existing flexible pavements based on condition survey data. The structural layer coefficients for the surface and the base layers are assigned according to the severity of distresses at the pavement surface. Equation 1.1 has been recommended by AASHTO (1993) to calculate SN.

$$SN = \sum m_i \times a_i \times h_i \qquad \textbf{Equation 1.1}$$

Where:

$a_i$ = structural coefficient of layer $i$;

$h_i$ = layer thickness of layer $i$ (in); and

$m_i$ = drainage coefficient, applied only to the granular materials in the base and sub-base layers.

The layer coefficients describe the contribution of each material to the performance of the pavement structure. They were derived from stress and strain calculations in a multilayered pavement system and correlated with performance on the basis of the AASHTO Road Test results (Van Til et al. 1972). Typical values for structural layer coefficients for different pavement materials have been given by Yoder and Witczak (1975) and Paterson (1987). AASHTO (1993) has also recommended calculating SN using nondestructive test (NDT) (deflection test) results.

In the last two decades, KDOT has been doing a 30-year analysis of alternate surface designs that includes at least one major rehabilitation strategy. However, within the last few years

KDOT has increased the analysis period to 40 years. KDOT sponsored this research project to gain a deeper understanding of pavement characteristics after aging to allow for more efficient overlay designs in the future for the longer analysis periods.

## 1.2 Problem Statement

The design and, therefore, the performance of an AC pavement, are based on the initial properties of new aggregates and binder in the AC mix. However, traffic loading and the environment cause the pavement to deteriorate, and the initial properties of the AC mix change. Throughout the life of an AC pavement, resurfacing and rehabilitation are required to keep the pavement in service. The thickness of an asphalt overlay is related to the structural strength of the existing pavement. Therefore, the designer is faced with determining the structural characteristics of the aged AC layers. Currently KDOT uses the structural layer coefficient of the existing layers of AC pavements in the overlay design process. For new pavement design, all asphalt layers (surface, binder and base) are considered as one layer and the layer coefficient of the top one-third of the AC thickness is taken as 0.42. The remaining thickness will then have a layer coefficient of 0.34. When this pavement gets overlaid, the surface layer will then have a coefficient of 0.34 and the base layer coefficient will be 0.24. For future overlays, the respective layer coefficients will be decreased by 0.8. This algorithm loosely follows the recommendations by the 1972 Interim AASHTO Pavement Design Guide. Now the layer coefficient value for the AC layer can be determined using the following equation given by Ullidz (1987):

$$a_1 = 0.40*\log(E / (3000 \text{ MPa})) + 0.44, \quad 0.20 < a_1 < 0.44 \qquad \textbf{Equation 1.2}$$

The equation shows that the layer coefficient of the AC layer is directly related to the elastic moduli of that layer. Thus a decrease in layer coefficient would happen due to a decrease in HMA/AC layer modulus. KDOT is expecting that results from this project would support this hypothesis.

Again, in the newly released Mechanical-Empirical Pavement Design Guide (M-EPDG), prediction of pavement response and performance must take into account the fundamental properties of the layer materials (NCHRP, 2004). Among these, the most important property of an HMA pavement is the dynamic modulus. In the overlay analysis of an HMA pavement, the modulus of the existing pavement is characterized by a damaged modulus that represents the condition at the time of the overly rehabilitation. However, according to the M-EPDG, the laboratory dynamic modulus tests are not needed for measuring the in-place modulus because the test must be performed on intact, but age-hardened specimens. In fact, the M-EPDG contends that the resulting modulus values will likely be higher than those for new HMA mixtures. Thus, the M-EPDG recommends that the modulus be determined from the deflection basin tests, such as the Falling Weight Deflectometer (FWD) test. However, no correlation between the laboratory dynamic modulus of HMA mixes and the back calculated HMA pavement modulus has been established to date. Therefore, there is a need to understand how the aged HMA properties affect future pavement performance.

## 1.3 Objectives of Study

This study was expected to analyze asphalt concrete (AC) mixes from six in-service pavements in Kansas. Three different test methods were used in this study: Falling Weight Deflectometer (FWD), Portable Seismic Property Analyzer (PSPA), and Indirect Tensile (IDT) test. The results will determine how the modulus of aged AC mixes changes with time. The primary goals of this study were:

1. To determine how AC pavement layer modulus changes over its lifetime;
2. To develop a correlation between moduli obtained from FWD, PSPA, and IDT tests; and
3. To investigate the fatigue properties of the aged asphalt layer materials.

## 1.4 Report Outline

This report is divided into six chapters. Chapter 1 provides the introduction to the project and the problem statement. It also briefly describes the objective and scope of the research project. Chapter 2 provides a summary of information available on the tests performed as well as data analyses conducted. Chapter 3 presents information on the selected test sites and data collection methods. Chapter 4 provides the data analysis, while Chapter 5 presents the results of the research. Finally, Chapter 6 summarizes the findings of the research work in the form of conclusions drawn and lists recommendations.

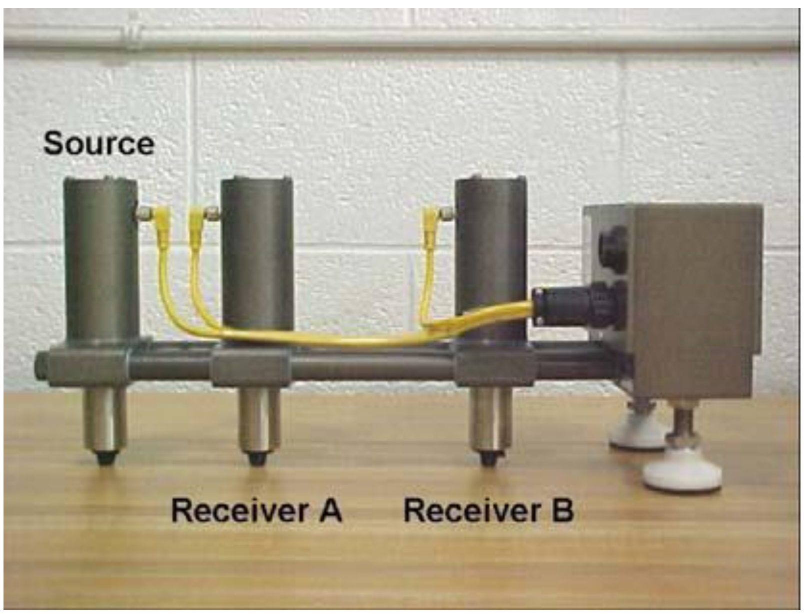
# Chapter 2: Literature Review

## 2.1 Falling Weight Deflectometer Testing

Non-destructive testing (NDT) has become a widely used method for determining the modulus of asphalt concrete (AC) pavements and is accepted by most state highway agencies as a standard practice. The Falling Weight Deflectometer (FWD), the most developed NDT, applies heavy loads to the pavement and measures the surface deflection to simulate actual truck traffic wheel loading (Hoffman and Thompson, 1982).

## 2.2 Portable Seismic Property Analyzer Testing

Another NDT used to gather information at the site was using a portable seismic property analyzer (PSPA). The PSPA is a handheld device that consists of a control module, source, and two receivers, as shown in Figure 2.1. The source produces high frequency waves in the pavement which are measured by the receivers. The receivers then measure the surface (Rayleigh) waves because they contain about 2/3 of the seismic energy making them the easiest waves to measure (Celaya et al. 2006).




(Source: Celaya et al. 2006)

**FIGURE 0.1**
**Portable Seismic Property Analyzer**

The computer software interprets the data collected by the receivers using the Ultrasonic Surface Wave (USW) method and calculates the modulus of the pavement (Celaya et al. 2006). The software calculates the Young's modulus (E) based on the Rayleigh wave velocity ($V_R$) through Equation 2.1.

$$E = 2(1+v)*\rho\left[V_R(1.13-0.16*v)\right]^2$$ **Equation 2.1**

Where, $v$ is Poisson's ratio, and $\rho$ is the density of the material (Celaya et al. 2006).

## 2.3 Modulus Back-Calculation

The output from FWD testing includes temperature, load, and deflection. To obtain the modulus of the pavement from this data, it must be back-calculated using an analysis program. There are many back-calculation programs available including EVERCALC, MODCOMP5, MODULUS, BISDEF, CHEVDEF, ELSDEF, MICHBACK, and ELMOD (Gedafa et al. 2009). Research has shown EVERCALC has consistent results for most pavement types (Gedafa et al. 2009); therefore EVERCALC was used for the analysis.

EVERCALC was designed by the Washington State Department of Transportation using WESLEA as the response analysis program. WESLEA is used to compute the stresses, strains, and deflections in each pavement layer (Van Cauwelaert et al. 1989).

EVERCALC has several features that make it useful for back-calculating pavement moduli. The program is capable of analyzing up to five layers, up to ten FWD sensors and twelve drops per station, and a stiff layer (layer where there is zero deflection) (WSDOT 2005).

EVERCALC starts with seed moduli to perform an iterative analysis until the calculated moduli forms a deflection basin closest to the FWD measured deflection basin. The iterative analysis is completed when the root-mean-square (RMS) (Equation 2.2) is minimized (WSDOT 2005).

$$\text{RMS}\ (\%) = 100\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{d_{ei}-d_{mi}}{d_{mi}}\right)^2}$$ **Equation 2.2**

One potential problem with back-calculation is, it does not have a unique solution for given surface deflections (Mikhail et al. 1999). There could be several different combinations of asphalt, base, and subgrade that will result in similar deflections. To minimize the solutions, the seed moduli and range should limit the back-calculation results to only include reasonable solutions.

## 2.4 Temperature Correction

To be able to compare data from different testing methods, the modulus from each method must be corrected to the same conditions. The most important environmental condition affecting the deflection and back-calculated moduli of asphalt concrete (AC) pavements is the temperature (Park and Kim 1997). There are two steps to correct the modulus of an AC pavement: calculate the mid-depth temperature of the pavement layer and adjusting the pavement modulus based on the mid-depth temperature (Gedafa et al. 2009).

One method of calculating the pavement temperature is using the BELLS equation. The BELLS equation was developed using measured pavement temperatures from the Strategic Highway Research Program's (SHRP) Long Term Pavement Performance (LTPP) data base to predict the one-third depth temperature of AC pavements (Inge and Kim 1995). For FWD testing where the pavement is typically shaded for less than one minute, the BELLS3 equation (Equation 2.2) was developed (FHWA 2000).

$$T_d = 0.95 + 0.892T_s + \left(\log(d) - 1.25\right)\left[1.83\sin\left(2\pi\frac{A}{18}\right) - 0.448T_s + 0.621T_{avg}\right] + 0.042T_s\sin\left(2\pi\frac{B}{18}\right)$$

**Equation 2.3**

Where,

$T_d$ = pavement temperature at layer mid-depth (°C),

$T_s$ = infrared surface temperature (°C),

$T_{avg}$ = average of high and low air temperatures on the day before testing (°C), and

$d$ = layer mid-depth (mm).

$A$ and $B$ are computed as follows:

$$A = \begin{cases} t_d + 9.5 & \text{if} \quad 0 \le t_d < 5 \\ -4.5 & \text{if} \quad 5 \le t_d < 11 \\ t_d - 15.5 & \text{if} \quad 11 \le t_d < 24 \end{cases} \qquad B = \begin{cases} t_d + 9.5 & \text{if} \quad 0 \le t_d < 3 \\ -4.5 & \text{if} \quad 3 \le t_d < 9 \\ t_d - 15.5 & \text{if} \quad 9 \le t_d < 24 \end{cases}$$

Where,

$t_d$ = time of day (decimal hours).

The modulus is then adjusted using Equation 2.3 which was developed using deflections from intact locations. This equation is very useful because it can be used to correct the modulus of an AC pavement for any temperature (Gedafa et al. 2009).

$$E_{T_w} = \frac{E_{T_d}}{\left[ \left(1.8T_w + 32\right)^{2.4462} \left(1.8T_d + 32\right)^{-2.4462} \right]}$$

**Equation 2.4**

Where,

$E_{T_w}$ = adjusted modulus at $T_w$ (MPa),

$E_{T_d}$ = measured modulus at $T_c$ (MPa),

$T_w$ = temperature the modulus is adjusted to (°C), and

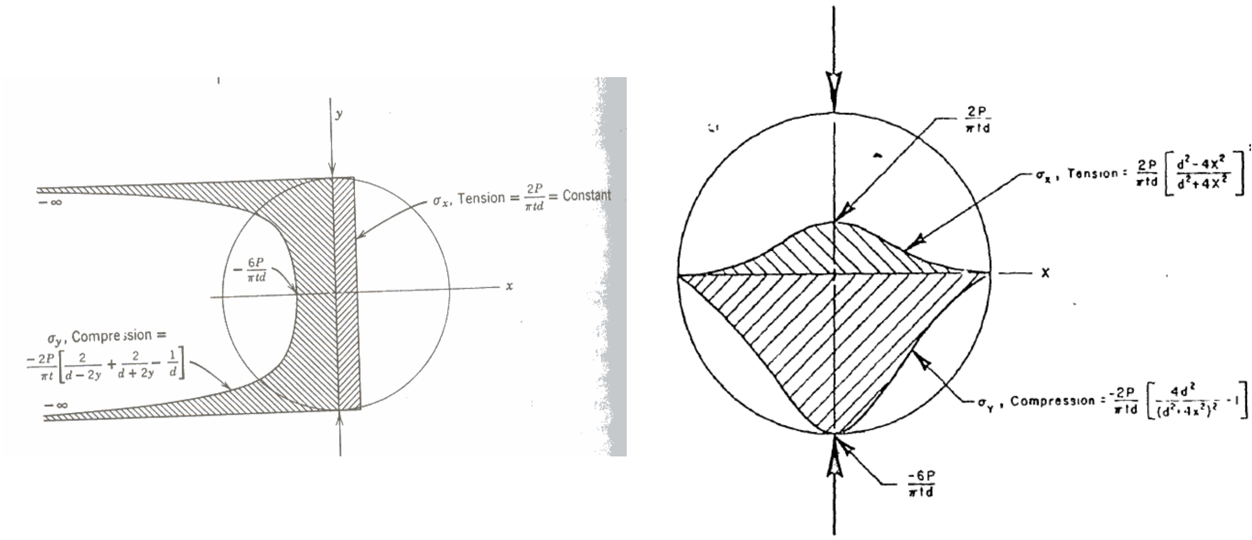
$T_d$ = mid-depth temperature at the time of data collection (°C).

## 2.5 Indirect Tension Resilient Modulus Testing

The indirect tension (IDT) test is designed to simulate the tensile forces that develop in the asphalt concrete (AC) pavement under traffic loading (Zaniewski and Mamlouk 1999). The test is conducted by applying a compressive force to the vertical axis of a cylindrical specimen which causes a tensile force in the horizontal axis (Figure 2.2).

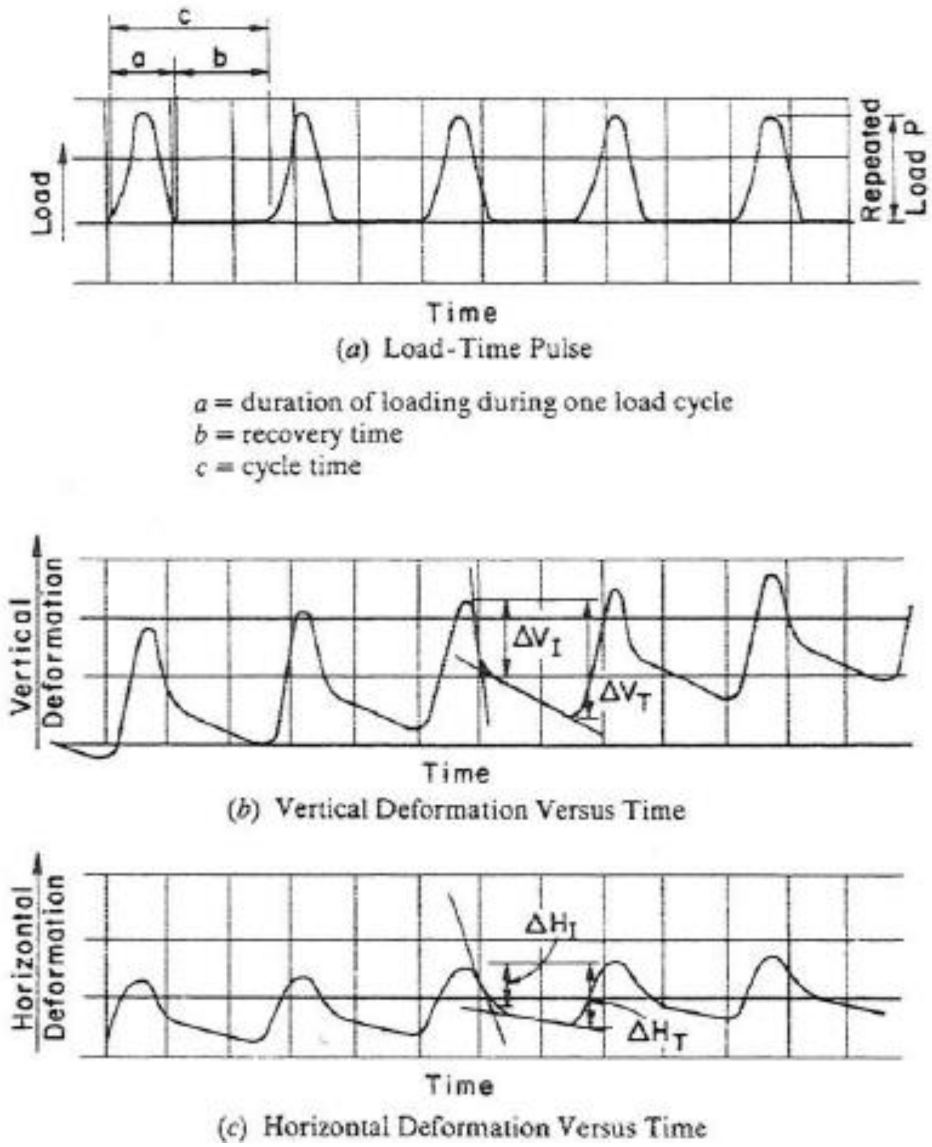
Tests are often ran with 100 preconditioning cycles before the 5 test cycles are applied to the specimen (Romanoschi and Metcalf 1999; Loulizi et al. 2007). The cyclic load is typically applied with a 0.1 sec load period and a rest period of 0.9 sec (AASHTO 2000). Both the vertical and horizontal deformations peak when the load is applied to the specimen. After the load is removed, there is a rapid deformation recovery called the initial deformation recovery, shown as $\Delta V_I$ and $\Delta H_I$ in Figure 2.3 (b and c). There is also a long term deformation recovery during the rest period. The difference in the peak deformation and the deformation at the end of the rest period is called the total deformation recovery, shown as $\Delta V_T$ and $\Delta H_T$ in Figure 2.3 (b and c). For calculations, the Poisson's ratio is often assumed to be 0.35 (Pavement).

After the test is ran once on each specimen, the specimen is rotated 90°, and the test is repeated on the other axis (ASTM 1983). Then, results for the two orientations are averaged to better represent the material characteristics. The test is also commonly ran at multiple temperatures, typically 41°, 77°, and 104°F, to discover how the strength of the AC changes with temperature (Materials).




(Source: Frocht 1957)

**FIGURE 0.2**
**Forces along the Vertical and Horizontal Axes during IDT Testing**




(Source: ASTM 1983)

**FIGURE 2.3**
**IDT Cyclic Loading and Deflection**

## 2.6 Correlation between Laboratory and Back-Calculated Moduli

Several studies have been conducted in the past to find a correlation between in situ and laboratory tests. This is because nondestructive tests are preferred to destructive tests because they do not affect the integrity of the pavement (Romanoschi and Metcalf 1999), but design guides are based on laboratory results. In situ tests are also more efficient and cost effective because of conducting the test and analyzing the results are low (Romanoschi and Metcalf 1999).

There are some environmental and material that could result in an inconsistent correlation between test methods. The most likely cause of the inconsistency is moisture content (Mikhail et al. 1999). The moisture content in a laboratory specimen is very low, but this is rarely the case for a roadway. Other variations between test methods could also be caused by disturbance during sampling and a different aggregate orientation during laboratory testing (Mikhail et al. 1999).

While most studies have been unable to find a correlation between field and laboratory testing (Geldmacher et al. 1957; Akram et al. 1992; Daleiden et al. 1994; Mikhail et al. 1999; Loulizi et al. 2007), a couple studies have shown promising results. One study found the temperature versus modulus curve is very similar for FWD and laboratory tests (Parker 1991). Another study shows a consistent linear relationship between PSPA, FWD, and laboratory dynamic modulus testing when the moduli are corrected for load frequency (Oh et al. 2011), but the tests were all conducted on the same pavement so the results may not be applicable to other pavements.

## 2.7 Fatigue Testing

A variety of methods have been developed for fatigue testing of HMA pavements. Generally, fatigue testing methods can be classified into several categories as summarized by Matthews and Monismith (1993):

a) Simple flexure,
b) Supported flexure,
c) Direct axial,
d) Diametral,
e) Triaxial,
f) Fracture tests, and
g) Wheel-track tests.

These methods employ either bending of beam specimens or creep and fracture of cylindrical specimens. In flexural beam tests, third-point, center-point loading, and cantilever beam with rotating bending are usually used. In other tests, cylindrical specimens are employed.

In this study, direct axial test was selected since the specimens for these tests from materials in a specific layer can be prepared from the cores.

Direct axial test, also called uni-axial test, can be divided into two categories: tension, and tension/compression, based on the forms of loading. This test method was performed by the Transport and Road Research Laboratory (TRRL) of the United Kingdom without stress reversal using a loading frequency of 25 HZ, a duration of 40 milliseconds, and rest periods varying from 0 to 1 sec. Kunst et al. (1991) performed uni-axial tensile tests at frequencies of 1 and 0.1 Hz using haversine loading in the controlled-strain mode. Specimens were prismoidal with 75 mm (3 in.) square cross sections and 225 mm (9 in.) lengths. In the tensile/compressive uni-axial test by the TRRL, loading frequencies were 16.7 and 25 Hz. The TRRL uni-axial tests found the following (Tangella et al. 1990):

- Short rest periods have an important effect on the fatigue life;
- The fatigue life depends largely on the test temperature;
- The effect of load form is not very great, and
- Pure compressive cyclic loading gives the largest fatigue life.

In direct tension tests, specimens are 75 mm in diameter and 150 mm in height made with the Superpave Gyratory Compactor (Brown et al. 1999). The steel end plates are glued to the specimen. Axial deformation measurements are taken at $90^{o}$ Degree intervals over the middle 100 mm of the specimen using loose-core LVDTs. Load applied in the axial direction is measured with a load cell. Axial stress and strain are determined from the following equations:

$$\sigma = P/A$$ **Equation 2.7 (a)**

$$\varepsilon = \Delta L/L$$ **Equation 2.7 (b)**

Where,

$\sigma$ = axial stress;

P = axial load;

A = cross-sectional are of the cylindrical specimen;

$\varepsilon$ = axial strain;

$\Delta$ = deformation; and

L = gage length.

A closed-loop servo-hydraulic loading frame with a temperature control chamber can be used for this test. Typical loading patterns include the constant crosshead rate monotonic test, constant crosshead amplitude cyclic test and constant stress amplitude cyclic test. The constant crosshead amplitude cyclic test ensures the constant amplitude of the crosshead movement, but results in changes of the strain and stress amplitudes due to changes in the compliance of the specimen as it is damaged under loading. Thus this test is in a mixed mode (neither stress nor strain). The stress and strain measurements from the direct tension test can be used to develop the conventional fatigue relationships (Brown et al. 1999).

# Chapter 3: Test Sections and Data Collection

## 3.1 Project Locations and Pavement Characteristics

Six test roadways were selected for this study based on several pavement characteristics: pavement age, pavement depth, number of overlays, type of roadway, and location in state. The test sites are listed in Table 3.1. Each roadway was required to be a minimum of 30 years old to signify the pavement is at the end of its design life. The maximum depth of the pavements was 24 inches to ensure samples could be obtained from the roadways. Each pavement was also required to have had at least two overlays over its lifetime. Finally, a variety of roadway types (US Interstates, US highways, Kansas highways) and locations across the state were chosen so the selected roadways would be a good representative of the pavements in Kansas. Due to these factors, I-70 in Trego County, US-56 in Stevens County, US-59 in Neosho County, US-169 in Miami County, K-4 in Jefferson County, and K-141 in Ellsworth County were chosen for this study, as shown in Figure 3.1. The thickness history for each test roadway is shown in Figure 3.2.

**TABLE 3.1**
**Summary of Selected Sites**

| Route | I-70 | US-56 | US-59 | US-169 | K-4 | K-141 |
|---|---|---|---|---|---|---|
| County | Trego | Stevens | Neosho | Miami | Jefferson | Ellsworth |
| State Mile Post | 122 - 124 | 44 - 46 | 36 - 38 | 131 - 133 | 348 - 350 | 6 - 8 |
| Lane Direction | West | East | North | South | North | North |
| Typical Thickness (in) | 18.1 | 18 | 17.5 | 20.5 | 16.8 | 12.6 |
| Year of Original Construction | 1960 | 1968 | 1960 | 1973 | 1965 | 1962 |

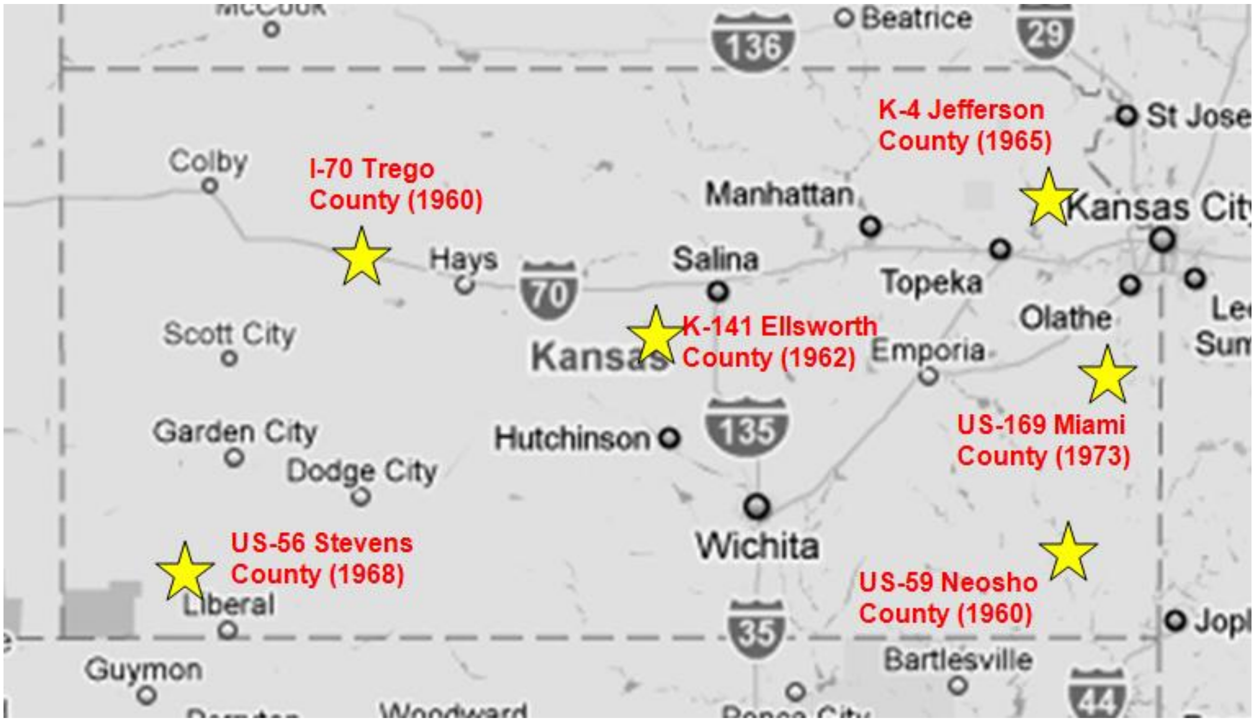
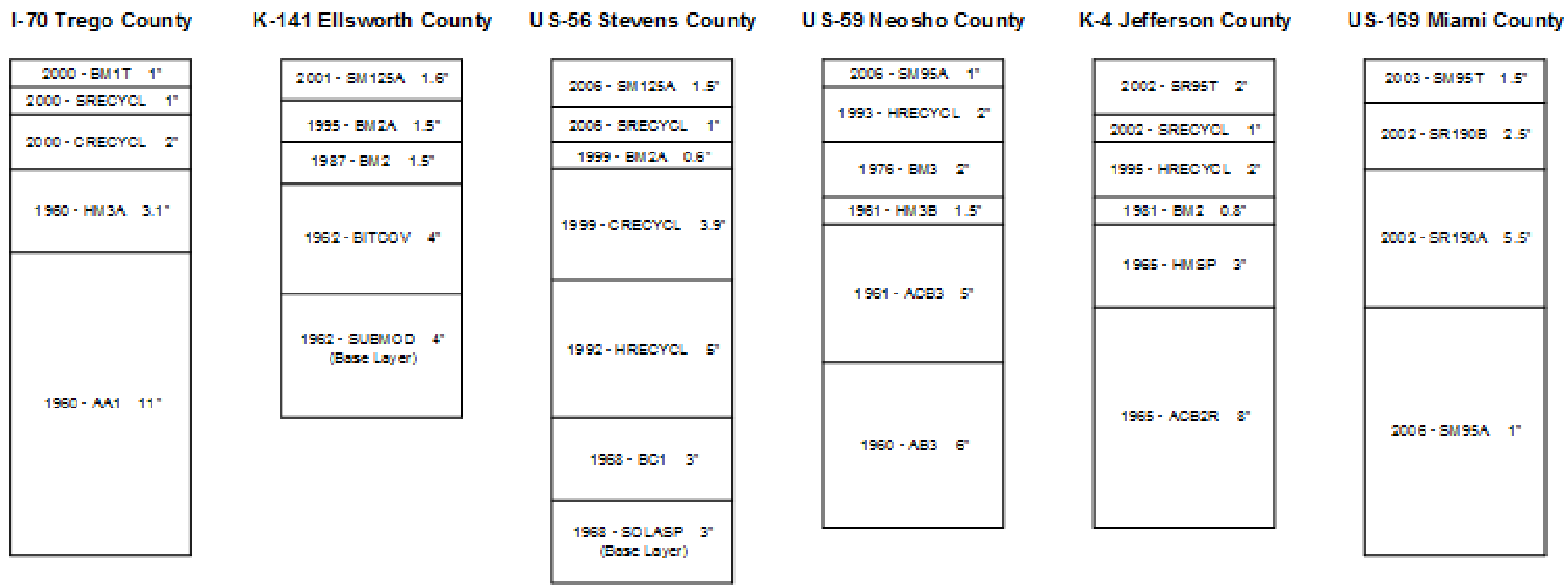



**FIGURE 3.1**
**Project Locations in Kansas**




**Note: AA1: Aggregate Asphalt Grading 1; AB: Aggregate Binder, Limestone; AB3: Aggregate Binder, Limestone; ACB2R: Asphaltic Concrete Base Grading 2 Revised, 50%-75% Limestone, 25%-50% Sand; ACB3: Asphaltic Concrete Base Grading 3, 50%-100% Limestone; BC1: Bituminous Construction Grading 1, 15% Sand; BITCOV: Bituminous Cover, Old Wearing Course; BM1T Bituminous Mix with Combined Aggregates, 30% Crushed Material, 15% Natural Sand; BM2: Bituminous Mix with Mixed Aggregates, 50% Crushed Material; 15% Sand; BM2A: Bituminous Mat Grading 2, Coarse; BM3:Bituminous Mix, Chat; CRECYCL: Cold Recycle Pavement; HM3A: Mixed Asphalt, 50%-100% Crushed Stone; HM3B: Mixed Asphalt, Crushed Gravel; HMSP: Hot-Mix Asphalt Special for Project; HRECYCL: Hot Recycle Pavement;. SM95A: Superpave Mix (9.5 mm Nominal Maximum Aggregate Size, Above Maximum Density); SM95T: Superpave Mix (9.5 mm Nominal Maximum Aggregate Size, Friction Course Mix); SM125A: Superpave Mix (12.5 mm Nominal Maximum Aggregate Size, Above Maximum Density Line); SOLASP: Soil Asphalt or In-place Stabilization; SR95T: Superpave Recycle Mix (9.5 mm Nominal Maximum Aggregate Size, Friction Course Mix); SR190A: Superpave Recycle Mix (19.0 mm Nominal Maximum Aggregate Size, Above Maximum Density Line); SR190B: Superpave Recycle Mix (19.0 mm Nominal Maximum Aggregate Size, Below Maximum Density)SRECYL: Surface Recycle Pavement (Heater Scarifier)**

**FIGURE 3.2**
**Pavement History for Each Test Section**

## 3.2 Data Collection

### *3.2.1 Falling Weight Deflectometer*

A Dynatest 8000, shown in Figure 3.3, was used to obtain FWD deflection data for each of the test sections. FWD data was collected along the outer wheel path and was typically taken at 50 ft intervals. At each test station, six FWD drops were conducted at loads of 9,000 lbs and 12,000 lbs for the first and last three drops, respectively. Seven deflection sensors were used with the first being at the center of the loading plate and the others at a radial distance of 8, 12, 18, 24, 36, and 60 inches.


**FIGURE 3.3**
**Dynatest 8000 FWD Tester**

### *3.2.2 Portable Seismic Property Analyzer*

PSPA tests were typically conducted at 600 ft intervals located at the 250 ft station of FWD testing. The PSPA is used to measure extremely small surface deflections, so any additional vibration in the pavement from vehicle or pedestrian traffic will cause inaccurate readings. To be sure the results were accurate, tests were repeated until three consecutive consistent readings were recorded. PSPA tests were conducted at three points within five feet of each core location to increase the number of data readings and accuracy of the test.

## 3.3 Resilient Modulus Testing

To allow for laboratory testing of the full pavement depth, samples were obtained by taking cores of the roadways. Cores were typically taken at 600 ft intervals located at the 250 ft station of FWD testing using a diamond tipped circular coring bit (Figure 3.4). The portable drill was not powerful enough for the deep pavement and large six inch diameter cores; therefore a trailer mounted drill was used for the remaining projects.

(a) Portable Drill (b) Trailer Mounted Drill

**FIGURE 3.4**
**Pavement Coring Drills**

The six inch cores were then cut into approximately 3.125 inch (80 mm) thick specimens so each asphalt layer could be tested individually (some asphalt layers were too thin and were combined for one test specimen). When possible, the cut was made between layers. Table 3.2 shows the number of specimens obtained from each AC layer.

Each specimen was tested in the laboratory for resilient modulus by performing the indirect tension (IDT) test on them using an IPC Global UTM-25 machine. The testing procedure followed was the AASHTO TP31-94 with a TP-9 setup (Figure 3.5). The TP-9 setup has a horizontal and vertical linear variable differential transformers (LVDT) epoxied to each face of the specimen to measure the deflection in each direction due to a compressive load applied along the vertical axis. The deflections from the two horizontal LVDTs and two vertical LVDTs were averaged to calculate the mean modulus, standard deviation, and coefficient of variation.

**TABLE 3.2 Number of Specimens per AC Layer**

| I-70 Trego County | | | US-56 Stevens County | | | US-59 Neosho County | | |
|---|---|---|---|---|---|---|---|---|
| Layer | Year | Number of Specimens | Layer | Year | Number of Specimens | Layer | Year | Number of Specimens |
| BM1T, SRECYL | 2000 | 9 | SM125A, SRECYL | 2006 | 10 | SM95A, HRECYL | 1993 | 10 |
| CRECYL | 2000 | 12 | BM2A, CRECYL | 1999 | 10 | BM3, HM3B | 1976 | 9 |
| HM3A | 1960 | 11 | HRECYL | 1992 | 10 | ACB3 | 1961 | 10 |
| AA1 | 1960 | 0 | BC1 | 1968 | 9 | AB3 | 1960 | 10 |

| US-169 Miami County | | | K-4 Jefferson County | | | K-141 Ellsworth County | | |
|---|---|---|---|---|---|---|---|---|
| Layer | Year | Number of Specimens | Layer | Year | Number of Specimens | Layer | Year | Number of Specimens |
| SM95T, SR190B | 2002 | 10 | SR95T, SRECYL | 2002 | 7 | SM125A, BM2A | 1995 | 10 |
| SR-190A | 2002 | 10 | HRECYL, BM2 | 1995 | 8 | BM2 | 1987 | 6 |
| ACB3 | 1973 | 37 | HMSP | 1965 | 10 | BITCOV | 1962 | 5 |
| | | | ACB2R | 1965 | 9 | | | |

**FIGURE 3.5**
**AASHTO TP-9 Setup**

Loading strips, which can be seen at the top and bottom of the specimen in Figure 3.5, are used to transfer the applied load to the specimen. The loading strips have the same curvature as the specimen to allow for a good contact surface. Only five preconditioning cycles and five test cycles were applied to the specimens to find the resilient modulus because fatigue testing will be performed on the specimens in a later study. Figure 2.3 in chapter 2 shows the typical loading cycle and resulting deformations of IDT test. The peak load is 6 kN (1350 lbs) with a 0.1 second loading period and 2.9 second rest period. This has been changed from the TP31-94 procedure of 0.1 second loading and 0.9 second rest periods because the testing machine needed a longer rest period to apply the specified load correctly. The effect of changing the length of the rest period is unknown, but it is likely insignificant (Huang et al. 2004). Calculations can be based off either the initial or total deformation recovery. For this research, the total deformation recovery was used. The typical total deformation recovery was 0.079 to 0.197 mils with a maximum of 0.590 mils, and most of the recovery was during the initial deformation recovery period. For the specimen with the largest total deformation recovery, approximately 0.024 mils of deformation recovery occurred during the final 2.6 seconds of the rest period. Therefore, the length of the rest period did not have a large influence on the moduli of the specimens. Tests were performed at only one temperature (20°C) since the results are going to be compared to other testing methods and temperature sensitivity will not be considered in this study. After testing the specimens along one axis, they were turned 90° and tested again along the other axis to receive a more representative average modulus (ASTM 1983).

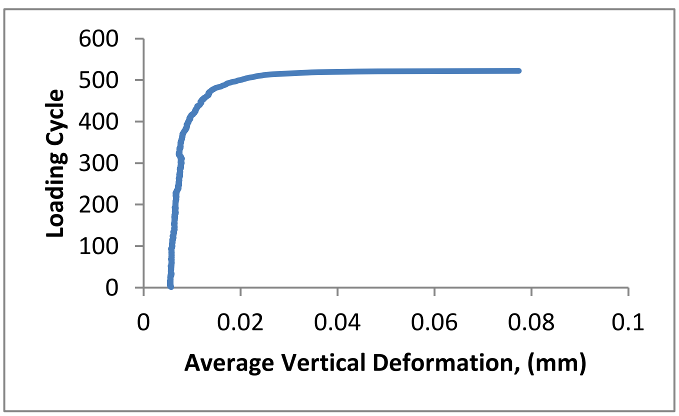
### 3.4 Direct Tension Fatigue Testing

To allow for laboratory fatigue testing of the full pavement depth, the resilient modulus test samples were used. After the resilient modulus testing, each six-inch diameter samples were cored to get three to four two-inch diameter samples.

Each specimen was tested in the laboratory for fatigue by performing repetitive direct tension (DT) tests using an IPC Global UTM-25 machine. The test set up is shown in Figure 3.6.

**FIGURE 3.6**
**Direct Testing**
**Fatigue Test Set Up**

The setup has two vertical linear variable differential transformers (LVDT) epoxied to the side of the specimen to measure the deflection due to a tension load applied along the vertical axis. The deflections from the two vertical LVDTs were used to calculate the average strain. For successful tests, seven preconditioning cycles or test cycles were applied before the specimens failed. Figure 3.7 (a & b) shows the typical loading cycle verses resulting deformations and the failed sample on core 3, K-141 route. The peak load is 1 kN (224.8 lbs) with a 0.1 second loading period and 2.9 second rest period. For this research, the total deformation recovery was used. Tests were performed at only one temperature (20°C) since temperature sensitivity will not be considered in this study.




(a)


(b)

**FIGURE 3.7**
**Direct Tension Test Output (a) Loading Cycle versus Average Vertical Deformation, and (b) Failed Sample**

# Chapter 4: Data Analysis

## 4.1 Modulus Back-Calculation

Each test roadway was divided into ten sections approximately 600 ft in length. In each section, eleven Falling Weight Deflectometer (FWD) tests were typically run at 50 ft intervals. A pavement core was taken at approximately the middle of each test section, shown in Tables 4.1-4.6.

As explained above, the back-calculation was performed with EVERCALC. Results were calculated from the 9,000 lb FWD deflections. Most of the roadways were analyzed as a two layer system: asphalt pavement and subgrade. US-56 and K-141 also had the addition of a subgrade modification layer. Some of the stations required a stiff layer at varying depths to minimize the back-calculated deflection error. A stiff layer is a layer at which there is zero deflection often caused by bedrock or a water table.

## 4.2 Portable Seismic Property Analyzer Analysis

As mentioned in Chapter 3, PSPA tests were conducted at each core location. Due to equipment problems, there is no PSPA data for K-4. The results for the other five test roadways are listed in Tables 4.7-4.11.

The standard deviation and coefficient of variation are high for the PSPA results because tests were run at three different spots within five feet of each core location. Although the data was consistent for each spot, there were variations between the three spots causing a large deviation at many of the core locations.

**TABLE 4.1**
**PSPA Results for I-70 in Trego County**

| Core Number | Avg | St. Dev | C.V. | Temp Corr Modulus |
|---|---|---|---|---|
| 1 | 678.9 | 52.55 | 7.74 | 1327.8 |
| 2 | 1184.4 | 190.66 | 16.10 | 2001.4 |
| 3 | 241.4 | 48.33 | 20.02 | 458.4 |
| 4 | 197.8 | 8.70 | 4.40 | 365.9 |
| 5 | 285.0 | 140.34 | 49.24 | 569.9 |
| 6 | 183.5 | 37.64 | 20.51 | 390.2 |
| 7 | 161.1 | 9.61 | 5.97 | 345.9 |
| 8 | 197.8 | 10.03 | 5.07 | 457.3 |
| 9 | 177.2 | 29.49 | 16.64 | 407.2 |
| 10 | 178.3 | 36.66 | 20.56 | 443.1 |

**TABLE 4.2**
**PSPA Results for US-56 in Stevens County**

| Core Number | Avg | St. Dev | C.V. | Temp Corr Modulus |
|---|---|---|---|---|
| 1 | 1838.2 | 67.05 | 3.65 | 3580.2 |
| 2 | 1534.0 | 255.57 | 16.66 | 2775.9 |
| 3 | 1717.8 | 189.52 | 11.03 | 3337.7 |
| 4 | 1543.0 | 265.58 | 17.21 | 3170.2 |
| 5 | 1690.0 | 251.63 | 14.89 | 3735.3 |
| 6 | 1234.4 | 145.70 | 11.80 | 2912.4 |
| 7 | 1746.4 | 168.95 | 9.67 | 4298.5 |
| 8 | 1633.0 | 172.37 | 10.56 | 4197.8 |
| 9 | 1492.0 | 27.81 | 1.86 | 3314.0 |
| 10 | 1461.8 | 472.33 | 32.31 | 3320.3 |

**TABLE 4.3**
**PSPA Results for US-59 in Neosho County**

| Core Number | Avg | St. Dev | C.V. | Temp Corr Modulus |
|---|---|---|---|---|
| 1 | 690.0 | 197.78 | 28.66 | 917.3 |
| 2 | 727.3 | 520.67 | 71.59 | 555.0 |
| 3 | 810.0 | 585.68 | 72.31 | 615.5 |
| 4 | 953.3 | 414.37 | 43.47 | 727.8 |
| 5 | 1281.1 | 198.02 | 15.46 | 963.4 |
| 6 | 864.2 | 328.15 | 37.97 | 658.0 |
| 7 | 1116.7 | 206.09 | 18.46 | 877.4 |
| 8 | 624.2 | 312.46 | 50.06 | 486.4 |
| 9 | 962.0 | 55.54 | 5.77 | 758.0 |
| 10 | 1201.0 | 190.17 | 15.83 | 959.1 |

**TABLE 4.4**
**PSPA Results for US-169 in Miami County**

| Core Number | Avg | St. Dev | C.V. | Temp Corr Modulus |
|---|---|---|---|---|
| 1 | 1090.0 | 80.83 | 7.42 | 1645.1 |
| 2 | 2524.2 | 724.00 | 28.68 | 3997.7 |
| 3 | 1976.7 | 1501.07 | 75.94 | 3320.1 |
| 4 | 2311.4 | 1509.95 | 65.33 | 3938.9 |
| 5 | 1774.2 | 1198.62 | 67.56 | 3767.1 |
| 6 | 4784.4 | 1675.54 | 35.02 | 10906.3 |
| 7 | 4123.3 | 172.43 | 4.18 | 10122.9 |
| 8 | 3460.0 | 1507.85 | 43.58 | 8813.3 |
| 9 | 2041.7 | 1217.40 | 59.63 | 5092.1 |
| 10 | 2080.0 | 1369.32 | 65.83 | 5322.7 |

**TABLE 4.5**
**PSPA Results for K-141 in Ellsworth County**

| Core Number | Avg | St. Dev | C.V. | Temp Corr Modulus |
|---|---|---|---|---|
| 1 | 1195.6 | 357.57 | 29.91 | 2631.7 |
| 2 | 1307.8 | 85.26 | 6.52 | 2720.5 |
| 3 | 1253.3 | 22.36 | 1.78 | 2921.2 |
| 4 | 1191.3 | 105.28 | 8.84 | 2764.2 |
| 5 | 1223.6 | 99.53 | 8.13 | 3416.5 |
| 6 | 1227.0 | 39.17 | 3.19 | 3171.4 |
| 7 | 1310.0 | 71.86 | 5.49 | 3528.7 |
| 8 | 1262.2 | 153.44 | 12.16 | 3397.4 |
| 9 | 1147.0 | 153.12 | 13.35 | 3311.6 |
| 10 | 1012.0 | 155.55 | 15.37 | 2804.0 |

## 4.3 Temperature Correction

As previously mentioned, the FWD and PSPA calculated moduli were corrected for temperature. The pavement temperatures were corrected to 20°C, the same as the IDT testing temperature, using Equations 2.3 and 2.4 so the moduli can be directly compared. The results of the temperature corrected moduli are shown in Tables 4.6-4.11.

## 4.4 Indirect Tension Test Analysis

As mentioned previously, each core was cut into test specimens approximately 3.125 inches (80 mm) thick. When possible, at least one specimen was made for each asphalt concrete (AC) layer. Some AC layers were too thin to obtain a specimen from, so it was necessary to combine two layers in one specimen. Other AC layers could not be tested because they were too degraded to obtain a quality specimen from.

Indirect Tension (IDT) Testing was performed twice on each test specimen. After the first test, the specimen was rotated 90° and the test was repeated. The two test results were then averaged to determine the modulus of the specimen.

The specimen modulus was calculated from the IDT test results using Equation 4.1. The value of Poisson's ratio was assumed to be 0.35.

$$E_T = \frac{P(\nu + 0.27)}{t\Delta H_T}$$ **Equation 4.1**

Where,

$E_T$ = total resilient modulus of elasticity (MPa),

$P$ = cyclic load (N),

$\nu$ = Poisson's ratio,

$t$ = thickness of specimen (mm), and

$\Delta H_T$ = total recoverable horizontal deformation (mm).

After the moduli was calculated for each AC layer, the results were condensed to obtain one equivalent modulus for the core (Equation 4.2) so the IDT results could be compared to the FWD and PSPA results.

$$E_{equivalent} = \frac{\sum (M_r \times d)}{\sum d}$$ **Equation 4.2**

Tables 4.6-4.11 and Figures 4.1-4.6 show that the modulus of most AC layers reduces linearly with age. This is expected because the AC deteriorates due to the loading and environmental factors. The most common type of pavement deterioration observed was stripping. Stripping was seen in AC layers with both large and small aggregates, but AC with small aggregates showed the greatest amount of stripping. US-169 and K-4 (Tables 4.9-4.10 and Figures 4.4-4.5) do not follow pattern because the pavement cores showed little to no deterioration even in the bottom layers. US-169 even showed an increase in modulus with age. This was likely caused by the AC being compacted by traffic loading and the samples showing no deterioration.

**TABLE 4.6**
**IDT Year Analysis for I-70 in Trego County**

| Layer | Year | Mr avg (ksi) | St. Dev. | Variance | High Mr | Low Mr |
|---|---|---|---|---|---|---|
| BM1T, SRECYL | 2000 | 3002 | 812 | 27.1 | 4,648 | 2,115 |
| CRECYL | 2000 | 2722 | 338 | 12.4 | 3,196 | 2,049 |
| HM3A | 1960 | 2037 | 520 | 25.5 | 2,872 | 1,312 |

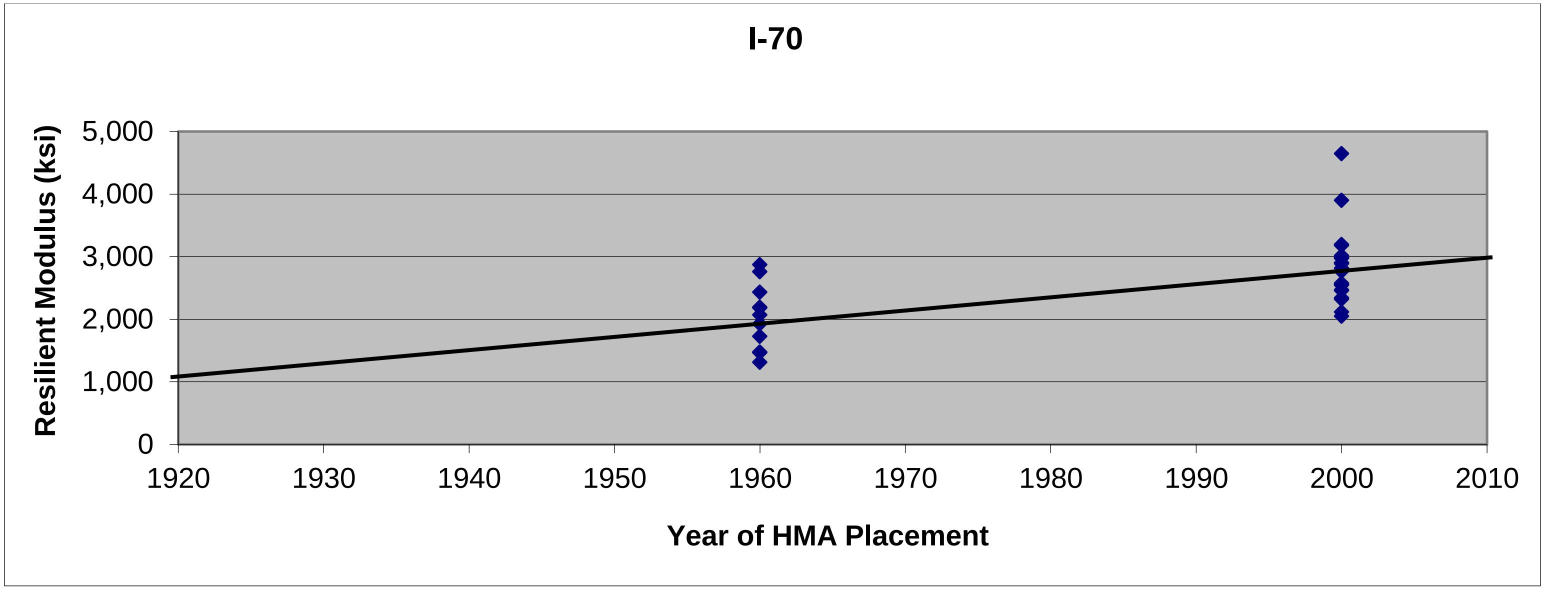



**FIGURE 4.1**
**IDT Year Analysis for I-70**

**TABLE 4.1**
**IDT Year Analysis for US-56 in Stevens County**

| Layer | Year | Mr avg (ksi) | St. Dev. | Variance | High Mr | Low Mr |
|---|---|---|---|---|---|---|
| SM125A, SRECYL | 2006 | 2193 | 232 | 10.6 | 2,516 | 1,815 |
| BM2A | 1999 | 2081 | 418 | 20.1 | 2,731 | 1,481 |
| CRECYL | 1999 | 1861 | 287 | 15.4 | 2,283 | 1,364 |
| HRECYL | 1992 | 1109 | 338 | 30.5 | 1,604 | 577 |

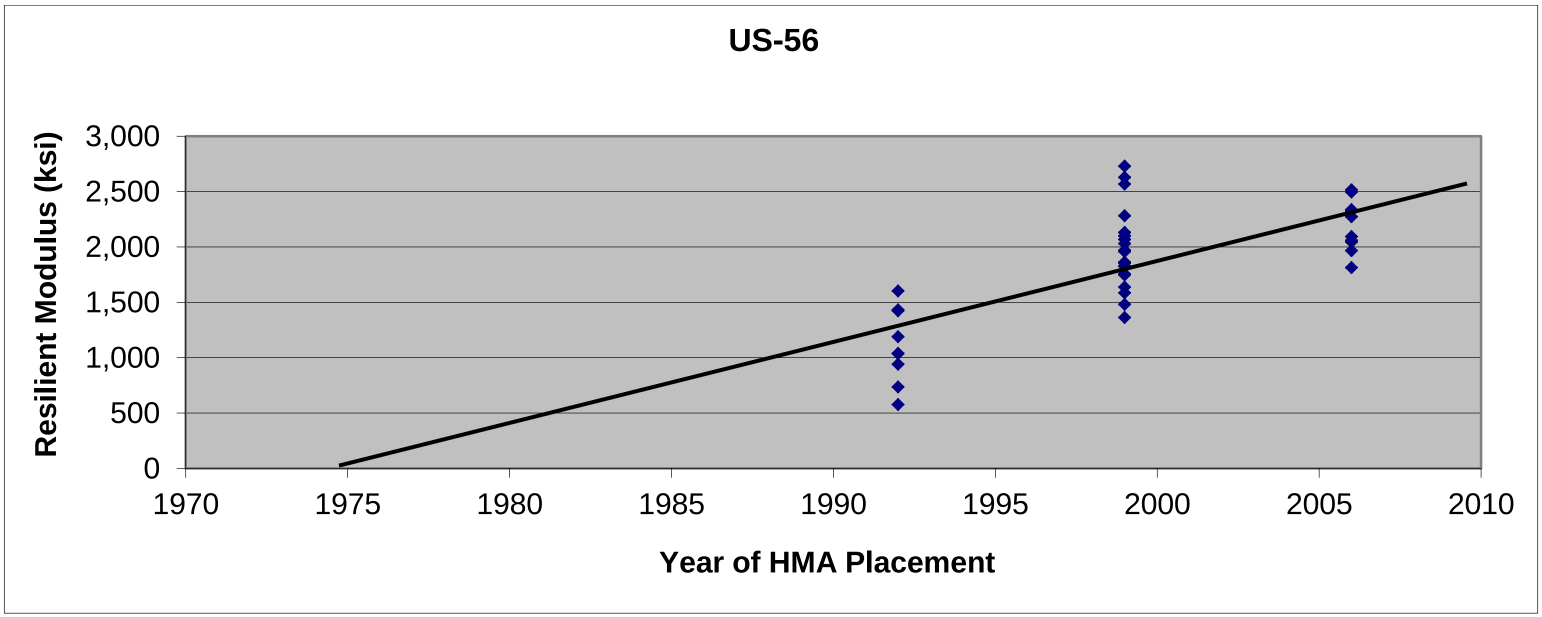



**FIGURE 4.2**
**IDT Year Analysis for US-56**

**TABLE 4.8**
**IDT Year Analysis for US-59 in Stevens County**

| Layer | Year | Mr avg (ksi) | St. Dev. | Variance | High Mr | Low Mr |
|---|---|---|---|---|---|---|
| SM95A, HRECYLCL | 1993 | 2,037 | 343.3064 | 16.84973 | 2,648 | 1,430 |
| BM3, HM3B | 1976 | 1,466 | 451.4568 | 30.79718 | 2,588 | 964 |
| ACB3 | 1961 | 827 | 184.8897 | 22.3576 | 1,193 | 574 |
| AB3 | 1960 | 964 | 378.0586 | 39.22402 | 1,537 | 495 |

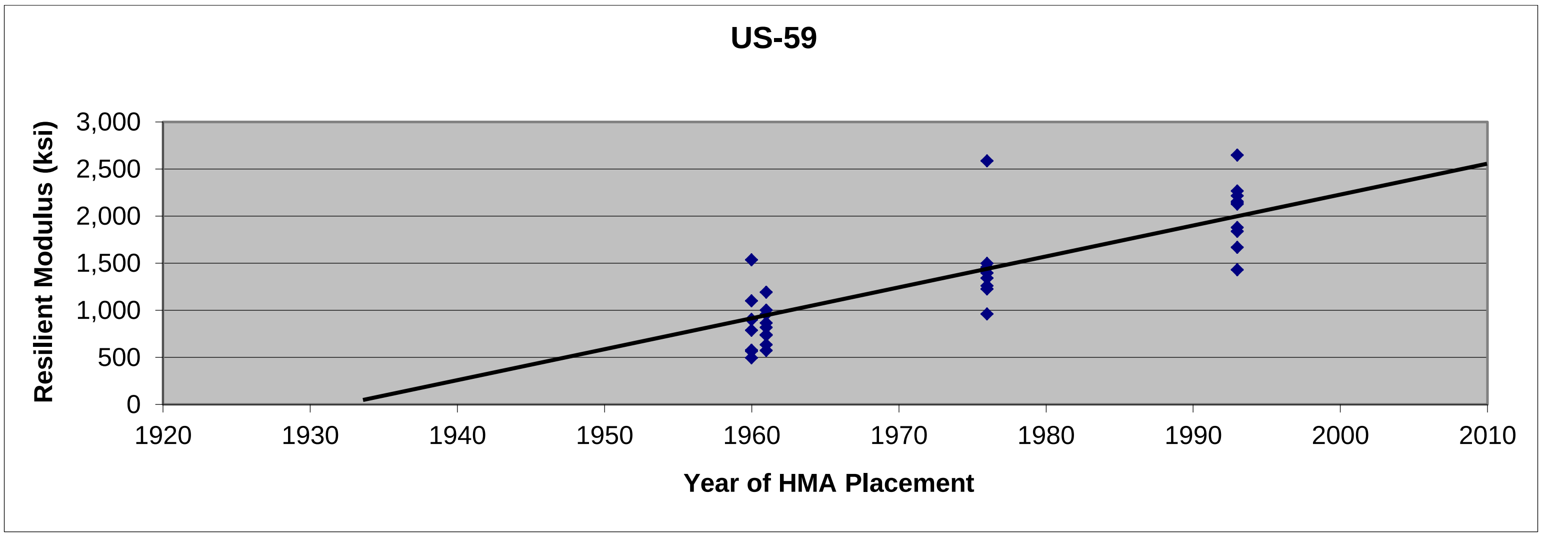



**FIGURE 4.3**
**IDT Year Analysis for US-59**

**TABLE 4.9**
**IDT Year Analysis for US-169 in Miami County**

| Layer | Year | Mr avg (ksi) | St. Dev. | Variance | High Mr | Low Mr |
|---|---|---|---|---|---|---|
| SM-9.5T, SR-19B | 2002 | 2784 | 1269 | 45.6 | 4,531 | 1,133 |
| SR-19A | 2002 | 3034 | 1616 | 53.3 | 6,187 | 1,042 |
| ACB3 | 1973 | 4345 | 1972 | 45.4 | 7,849 | 1,768 |

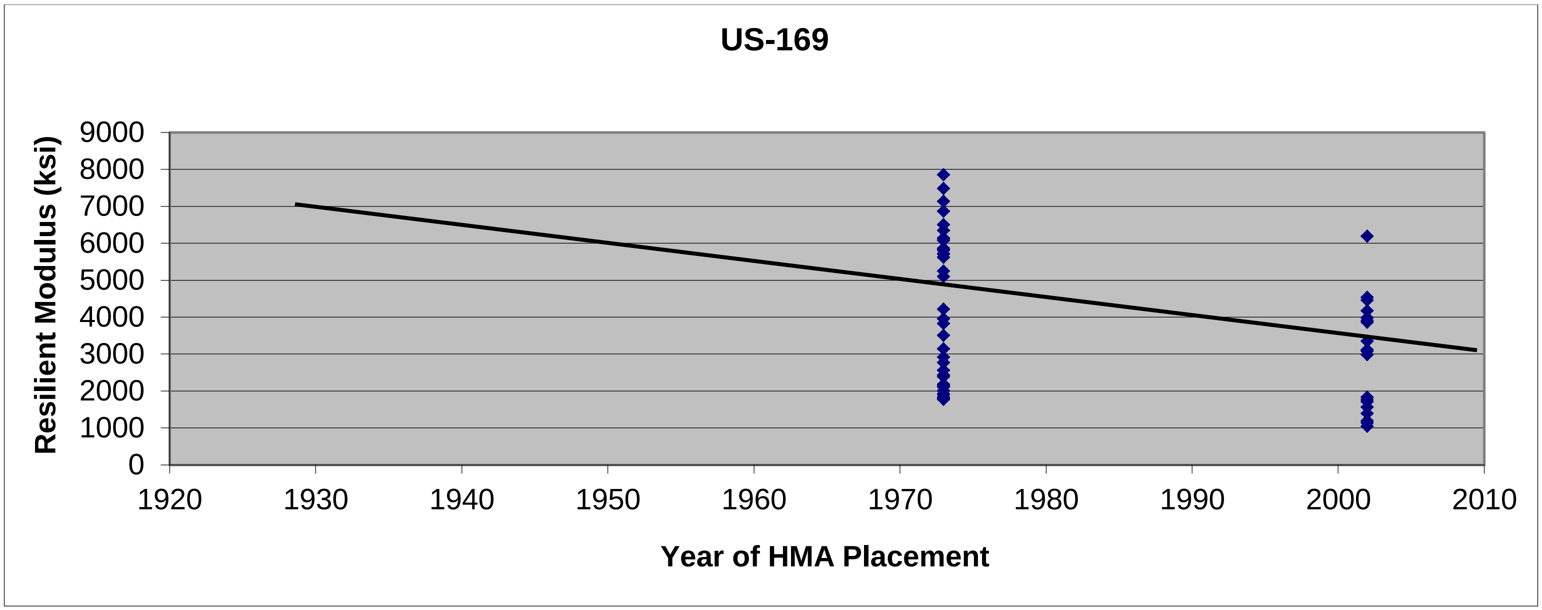



**FIGURE 4.4**
**IDT Year Analysis for US-169**

**TABLE 0.10**
**IDT Year Analysis for K-4 in Jefferson County**

| Layer | Year | Mr avg (ksi) | St. Dev. | Variance | High Mr | Low Mr |
|---|---|---|---|---|---|---|
| SR95T, SRECYCL | 2002 | 2,800 | 490 | 17.5 | 3,739 | 2,257 |
| HRECYCL, BM2 | 1995 | 2,380 | 553 | 23.2 | 3,080 | 1,340 |
| HMSP | 1965 | 2,201 | 398 | 18.1 | 2,704 | 1,241 |
| ACB2R | 1965 | 2,527 | 457 | 18.1 | 3,408 | 1,985 |

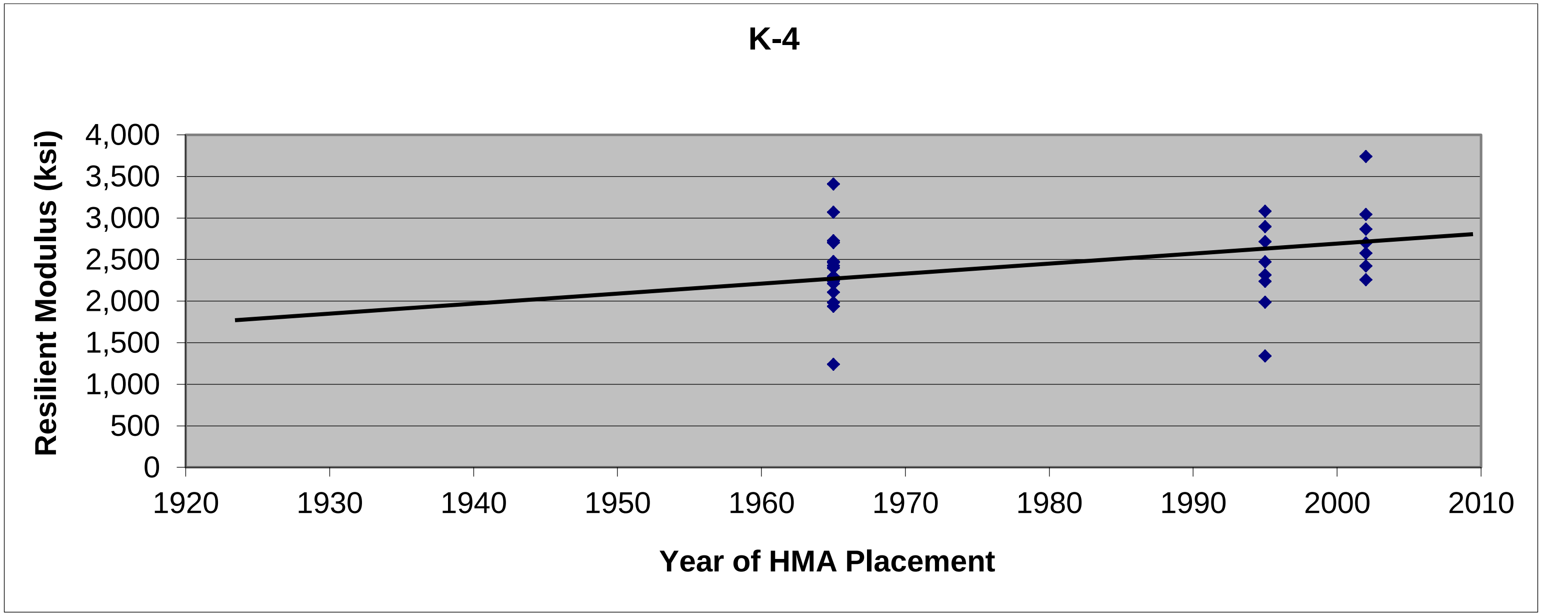



**FIGURE 4.5**
**IDT Year Analysis for K-4**

**TABLE 4.11**
**IDT Year Analysis for K-141 in Ellsworth County**

| Layer | Year | Mr avg (ksi) | St. Dev. | Variance | High Mr | Low Mr |
|---|---|---|---|---|---|---|
| SM125A, BM2A | 1987 | 1,571 | 694 | 44.2 | 2,579 | 653 |
| BM2 | 1995 | 2,544 | 616 | 24.2 | 3,219 | 1,469 |
| BITCOV | 1995 | 2,893 | 343 | 11.8 | 3,410 | 2,589 |

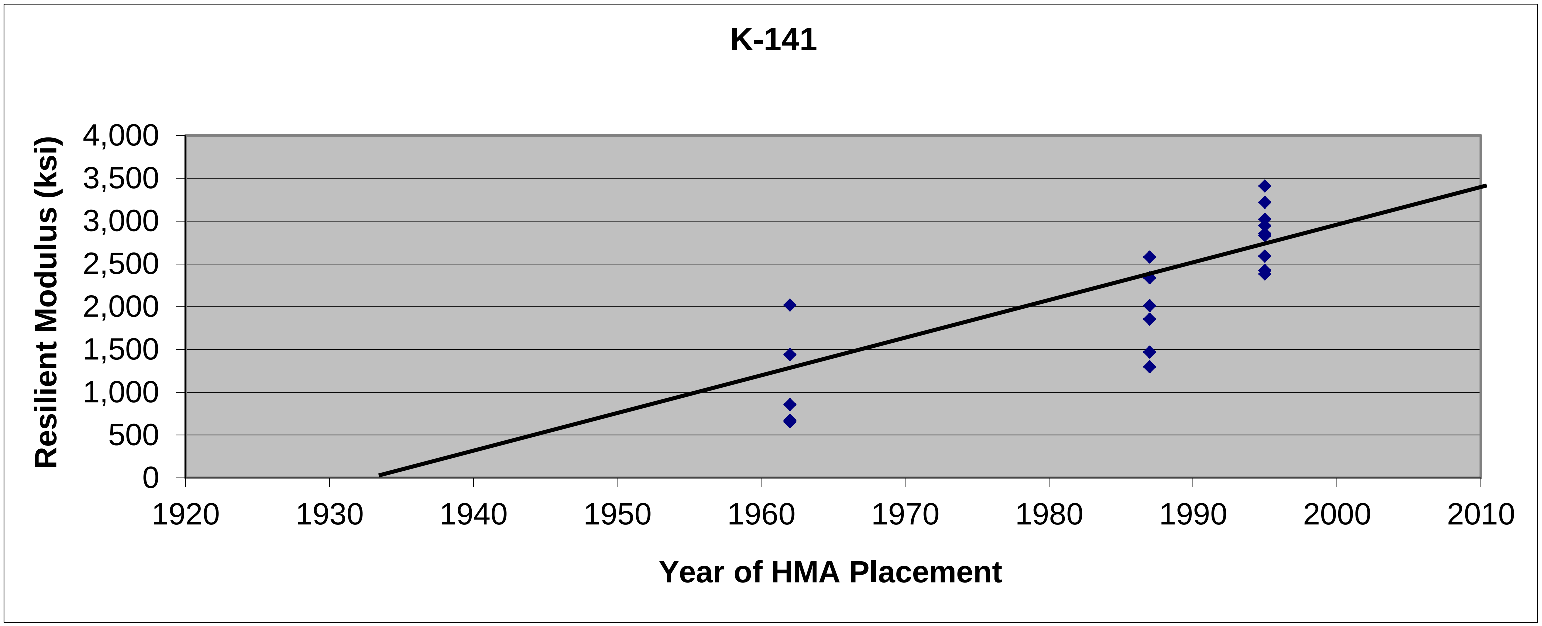



**FIGURE 4.6**
**IDT Year Analysis for K-141**

### 4.5 Structural Layer Coefficients of Aged HMA Layers

The correlation between layer coefficient and layer resilient modulus is approximately linear for HMA with a resilient modulus greater than 200 ksi, as shown in figure 4.7. Based on this, the layer coefficient for each layer of the test sections was calculated. The surface layer of each test section was assumed to have a layer coefficient of 0.42 since the layer is fairly new. The lower AC layer coefficients were determined by developing an equation based on the linear portion of the chart in figure 4.7. If the linear portion of the line is extrapolated, the intercept with the y-axis is at approximately 0.22 for the structural coefficient (at a resilient modulus value of 0 ksi). Based on these assumptions, the equation for the structural coefficient of each layer was calculated using Equation 4.3. Example results from the equation for a few test roadways are shown in Figure 4.8.

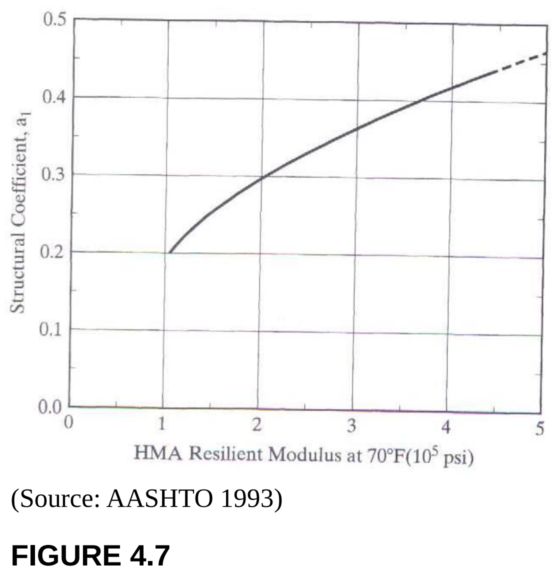
$$a_i = \frac{(0.42 - 0.22)}{Mr_{avg,surface}} * Mr_{avg,i} + 0.22$$ **Equation 4.3**

Where,

$a_i$ = structural coefficient of layer i,

$Mr_{avg,surface}$ = average resilient modulus of surface layer, and

$Mr_{avg,i}$ = average resilient modulus of layer i.




(Source: AASHTO 1993)

**FIGURE 4.7**
**Chart for Estimating Layer Coefficient Based on Resilient Modulus**

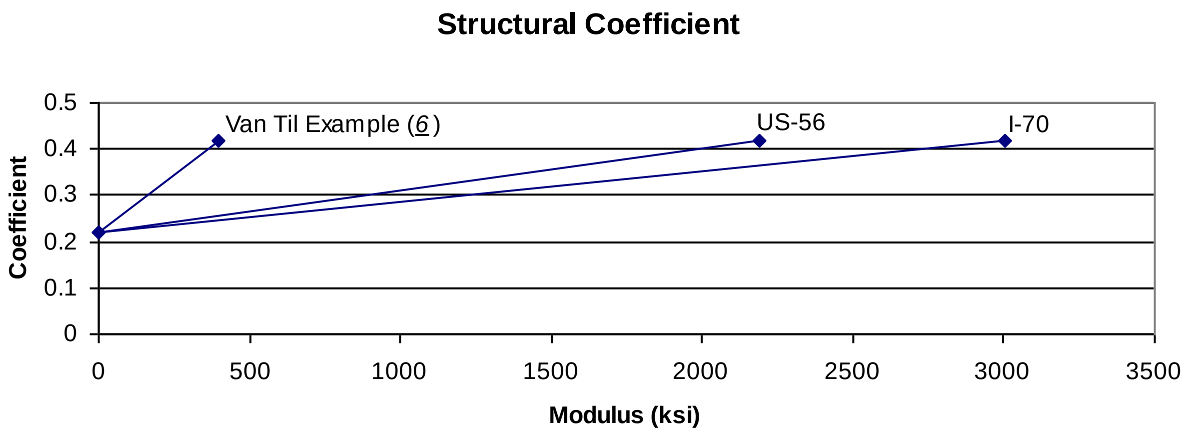



**FIGURE 4.8**
**Examples for Determining Structural Coefficient for Each Layer**

As shown in Table 4.12, the structural coefficients of the layers do not decrease at the rate assumed by KDOT. The actual rate of decline is lower. The fastest rate of decline of structural coefficient was 0.06 for the layers on US-59 and K-141 which is still lower than the 0.08 unit reduction between layers assumed by KDOT.

One exception to the lower rate of structural coefficient reduction was the oldest layer for I-70, AA1. This layer was too deteriorated to obtain a quality specimen. Therefore, the structural coefficient for layer AA1 was assumed to be 0.11, the maximum value typically assumed for unbound sub base layers. This layer was built in 1960. Thus the annual rate of change of layer coefficient of this layer was calculated as (0.42-0.11)/40 or approx. 0.08 units for 10 years exactly as assumed by KDOT. Thus stripped pavements appear to deteriorate at a rate much faster than other non-stripped pavement. Correct estimation of the structural coefficient of existing pavement layers is an important step in designing the thickness of an overlay. For pavements with higher structural coefficients, the required overlay is thinner.


**FIGURE 4.9**
**K-141 Specimen 10-3**

**TABLE 4.12**
**Structural Layer Coefficient for Each AC Layer**

| | Layer | Year | Design Thickness (in) | Mr avg (ksi) | Modulus Range | Percent of Modulus | Structural Coefficient |
|---|---|---|---|---|---|---|---|
| I-70 Trego County | BM1T, SRECYL | 2000 | 2 | 3,002 | 2,115 - 4,648 | 100 | 0.42 |
| | CRECYL | 2000 | 2 | 2,722 | 2,049 - 3,196 | 91 | 0.40 |
| | HM3A | 1960 | 3.1 | 2,037 | 1,312 - 2,872 | 68 | 0.36 |
| | AA1 | 1960 | 11 | N.A. | N.A. | N.A. | 0.11 |
| US-56 Stevens County | SM125A, SRECYL | 2006 | 2.5 | 2,193 | 1,815 - 2,516 | 100 | 0.42 |
| | BM2A, CRECYL | 1999 | 0.6 | 2,081 | 1,481 - 2,731 | 95 | 0.41 |
| | HRECYL | 1992 | 3.9 | 1,861 | 1,364 - 2,283 | 85 | 0.39 |
| | BC1 | 1968 | 5 | 1,109 | 577 – 1,604 | 51 | 0.32 |
| US-59 Neosho County | SM95A, HRECYL | 1993 | 3 | 2,037 | 1,430 - 2,648 | 100 | 0.42 |
| | BM3, HM3B | 1976 | 3.5 | 1,466 | 964 – 2,588 | 72 | 0.36 |
| | ACB3 | 1961 | 5 | 827 | 574 – 1,193 | 41 | 0.30 |
| | AB3 | 1960 | 6 | 964 | 495 – 1,537 | 47 | 0.31 |
| US-169 Miami County | SM95T, SR19B | 2002 | 4 | 2,784 | 1,133 - 4,531 | 100 | 0.42 |
| | SR-19A | 2002 | 5.5 | 3,034 | 1,042 - 6,187 | 109 | 0.44 |
| | ACB3 | 1973 | 11 | 4,345 | 1,768 - 7,849 | 156 | 0.53 |
| K-4 Jefferson County | SR95T, SRECYL | 2002 | 3 | 2,800 | 2,257 - 3,739 | 100 | 0.42 |
| | HRECYL, BM2 | 1995 | 2.8 | 2,380 | 1,340 - 3,080 | 85 | 0.39 |
| | HMSP | 1965 | 3 | 2,495 | 1,985 - 3,408 | 89 | 0.40 |
| | ACB2R | 1965 | 8 | 2,200 | 1,241 - 2,704 | 79 | 0.38 |
| K-141 Ellsworth County | SM125A, BM2A | 1995 | 3.1 | 2,826 | 2,381 - 3,410 | 100 | 0.42 |
| | BM2 | 1987 | 1.5 | 1,924 | 1,297 - 2,579 | 68 | 0.36 |
| | BITCOV | 1962 | 4 | 1,127 | 653 - 2,016 | 40 | 0.30 |

## 4.6 Fatigue Data Analysis

As mentioned previously, each specimen for the resilient modulus test was cored to get three to four samples of two-inch diameter for the fatigue test. These were cut into test specimens approximately 3.125 inches (80 mm) thick. When possible, at least one specimen was made for each asphalt concrete (AC) layer. Some AC layers were too thin to obtain a specimen from, so it was necessary to combine two layers in one specimen. Other AC layers could not be tested because they were too degraded to obtain a quality specimen from.

Indirect Tension (IDT) Testing was performed twice on each test specimen. After the first test, the specimen was rotated 90° and the test was repeated. The two test results were then averaged to determine the modulus of the specimen. The fatigue results were expressed in terms of traditional fatigue relationship shown in Equation 4.4.

$$N_f = k_1 (1/\varepsilon_t)^{k_2}$$ **Equation 4.4**

Where,

$N_f$ = Number of repetitions to failure,

$\varepsilon_t$ = Initial strain and

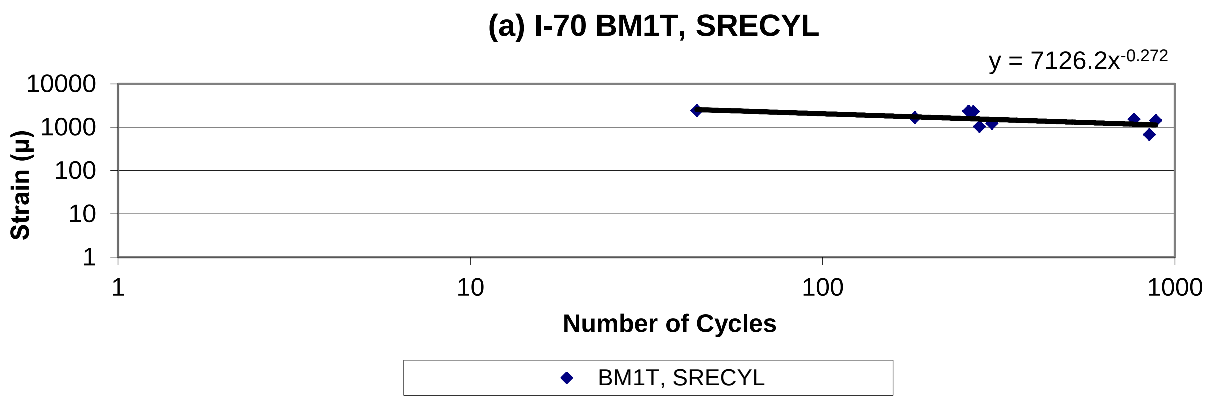
$k_1$ and $k_2$ = Regression constants.

Figures 4.11-4.16 show that the fatigue relationships for different aged mixtures each project. It is to be noted that although a stress-controlled test was done due to different stiffness of the specimens varying initial strains were obtained. Thus the relationships have been expressed in terms of strains. After fatigue tests, the samples were used for determining bulk specific gravities. Then some were used in determination of asphalt content and rest for determining the maximum specific gravities. Thus, binder content and air voids of each layer material were determined.

Table 4.13 shows the summary of fatigue test results for the materials of the all the layers of the projects in this study. The corresponding binder and air contents are also shown. In general, the air voids of the samples are within the expected range (5 to 8%). The older layers have higher binder contents than the range (5%-7%) encountered in the Superpave mixture design in Kansas. Some of the higher binder content might have resulted from the pavement maintenance treatments such as surface recycling, chip seal, etc. In general, higher the value of $k_2$ the more fatigue susceptible the mixture would be. In most cases, the older layers show higher $k_2$ values. However, there is exception to this. The SR-19A mixture on US-169 shows a negative value of $k_2$ that is close to 0. The same is true for the SM-12.5A mixture on US-56. This may indicate that these layers have not undergone much fatigue damage. A visual observation of the core on US-169 (Figure 4.10) confirms this observation. The whole core was intact without any sign of visible distresses.

$k_2$ is also very low for the cold recycled layer (CRECYL) on I-70. The cold recycled involved using fly ash as a binder. This might have contributed to the lower value of $k_2$ for this layer material. In general, $k_2$ value for the newest layer is always low. This may indicate that the newer mixtures are less fatigue susceptible. On the other hand, $k_2$ is always higher for the older layers and increases with age. Thus this may lend support to the practice of KDOT assuming lower structural coefficients to the layers that are being overlaid. However, no definite trend could be established as that had been done for the structural layer coefficients.

**FIGURE 4.10**
**Full-Depth Core on US-169**



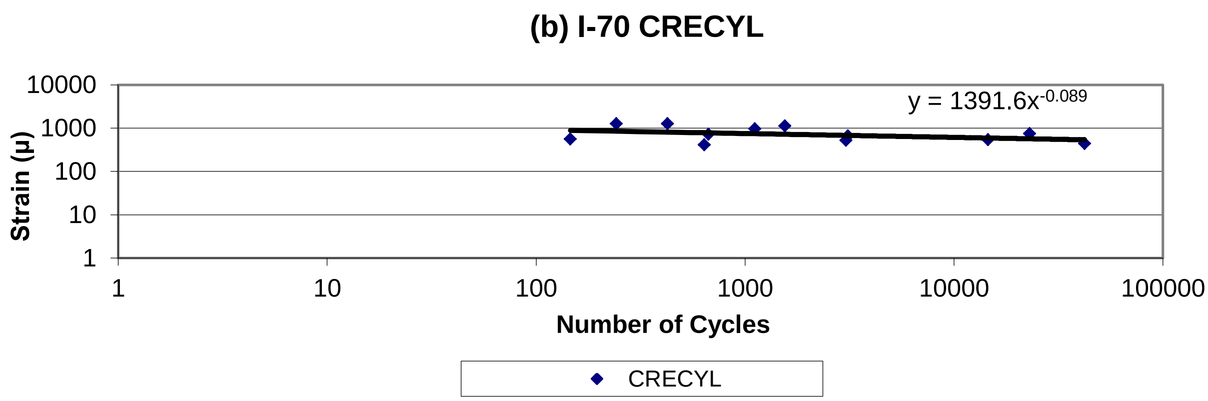
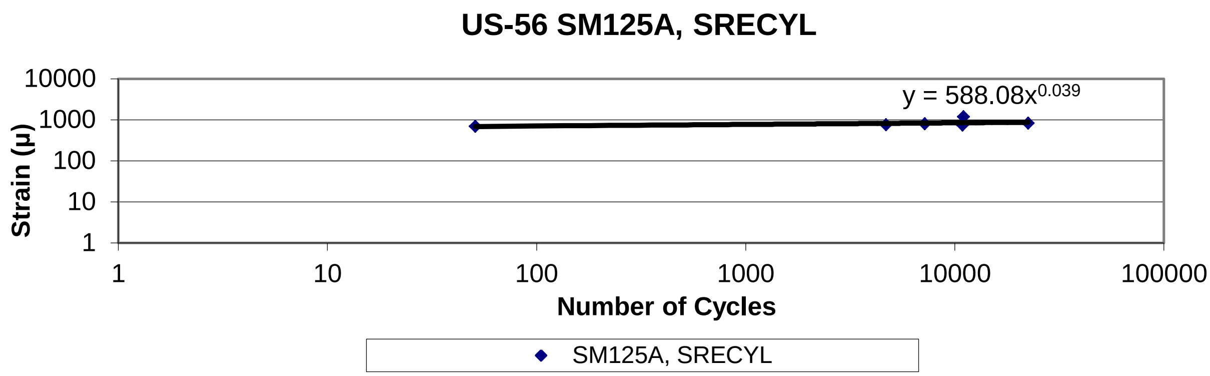
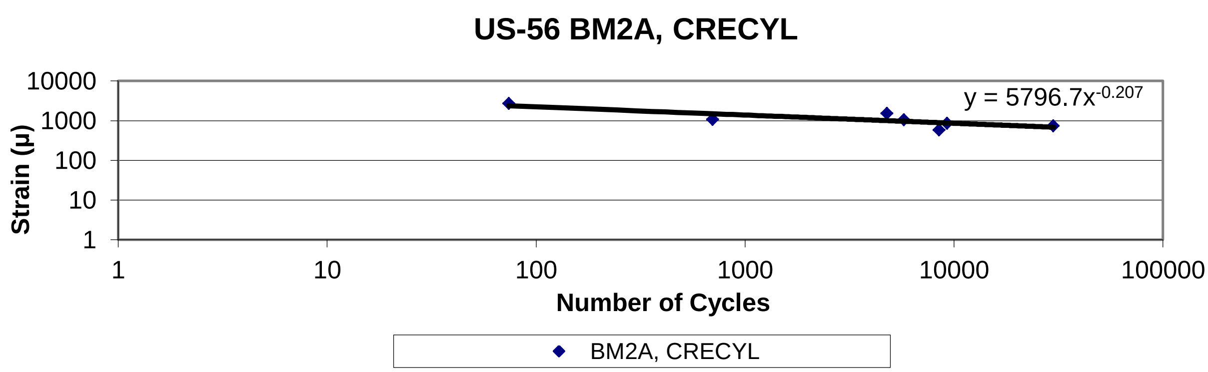
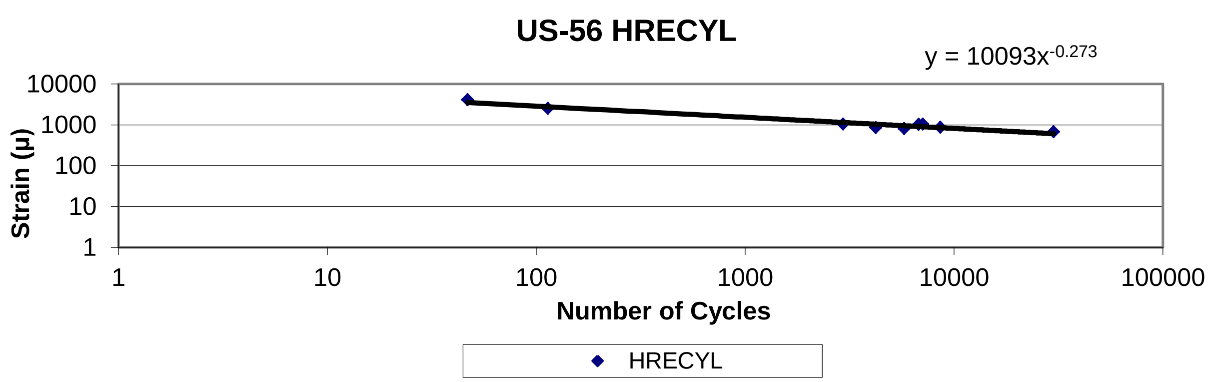




**FIGURE 4.11**
**Fatigue Curves for the Mixtures of I-70**


US-56 SM125A, SRECYL
y = 588.08x^0.039
10000
1000
100
10
1
Strain (μ)
1
10
100
1000
10000
100000
Number of Cycles
SM125A, SRECYL


US-56 BM2A, CRECYL
y = 5796.7x^-0.207
10000
1000
100
10
1
Strain (μ)
1
10
100
1000
10000
100000
Number of Cycles
BM2A, CRECYL


US-56 HRECYL
y = 10093x^-0.273
10000
1000
100
10
1
Strain (μ)
1
10
100
1000
10000
100000
Number of Cycles
HRECYL

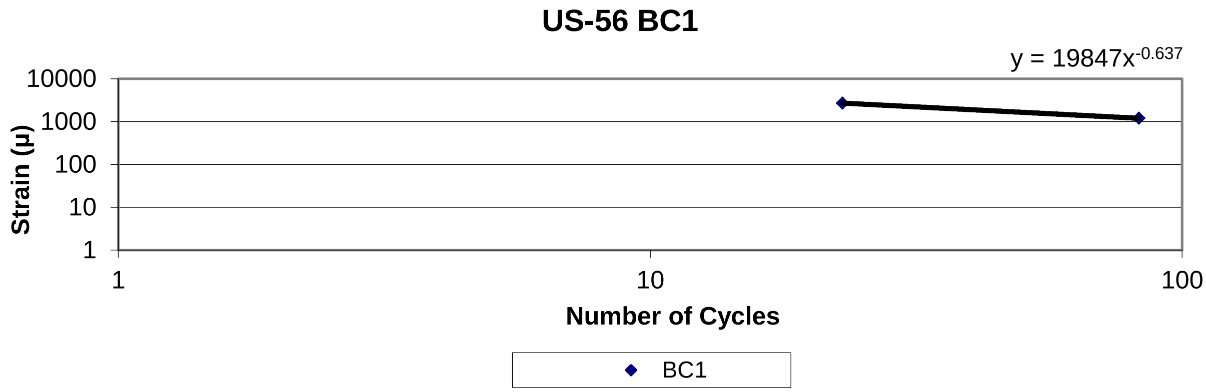
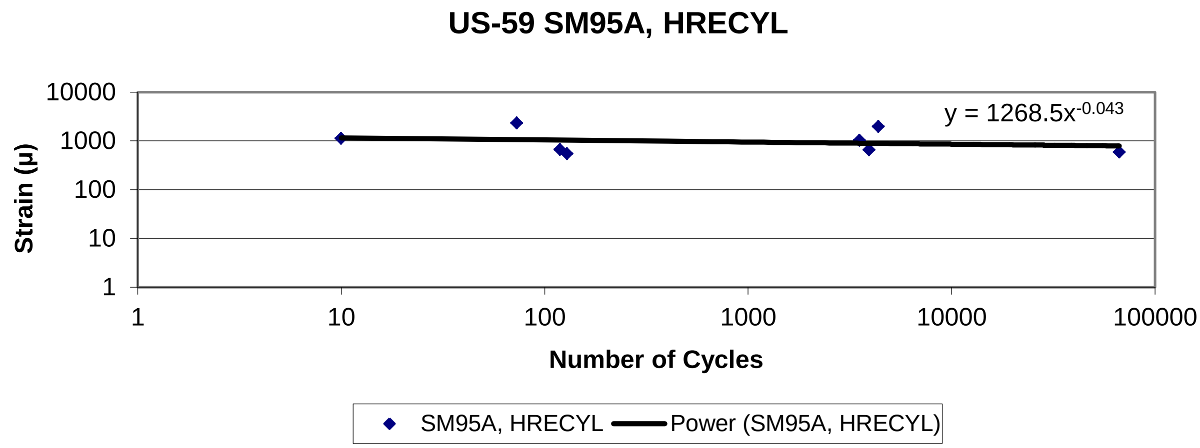



**FIGURE 4.12**
**Fatigue Curves for the Mixtures of US-56**



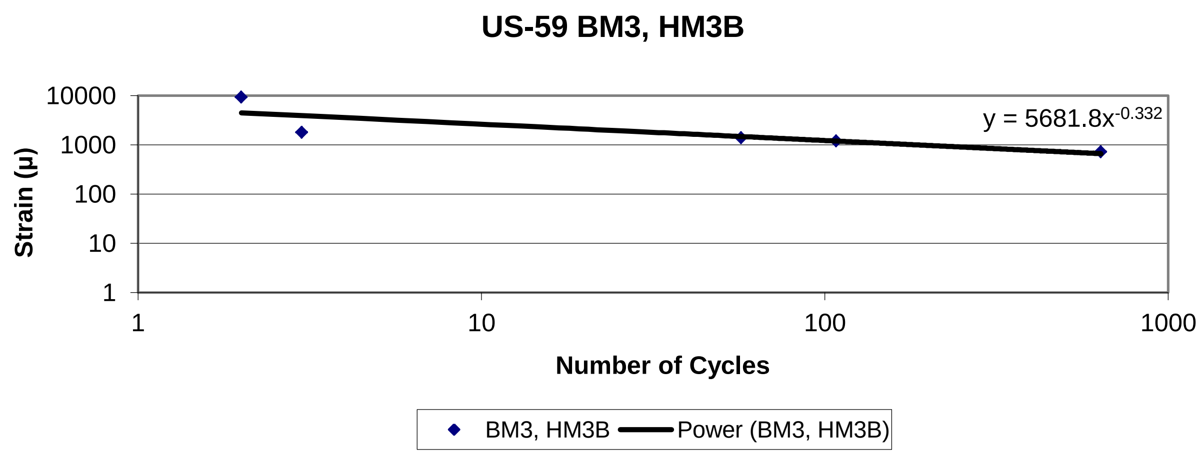




**FIGURE 4.13**
**Fatigue Curves for the Mixtures of US-59**

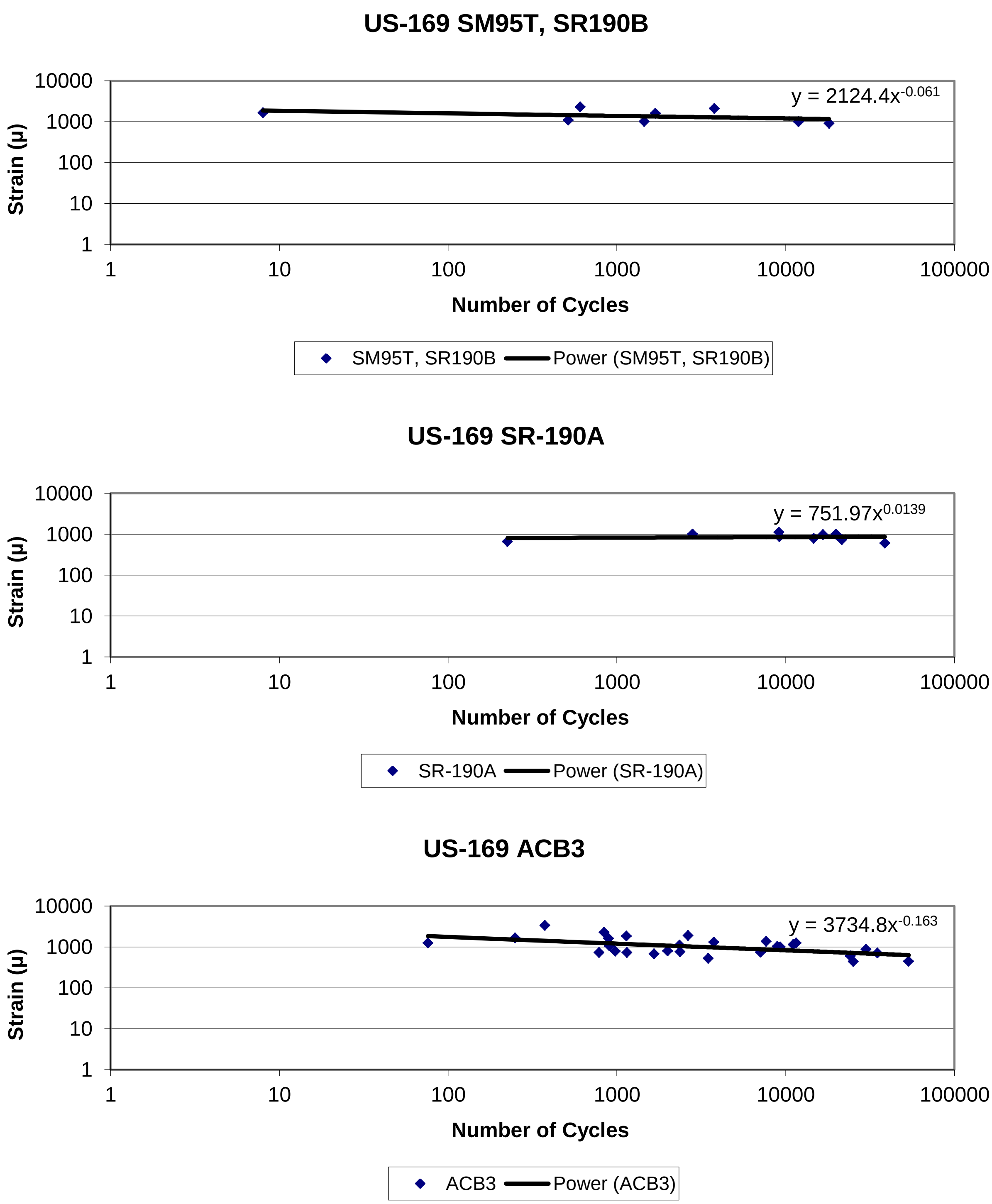



**FIGURE 4.14**
**Fatigue Curves for the Mixtures of US-169**

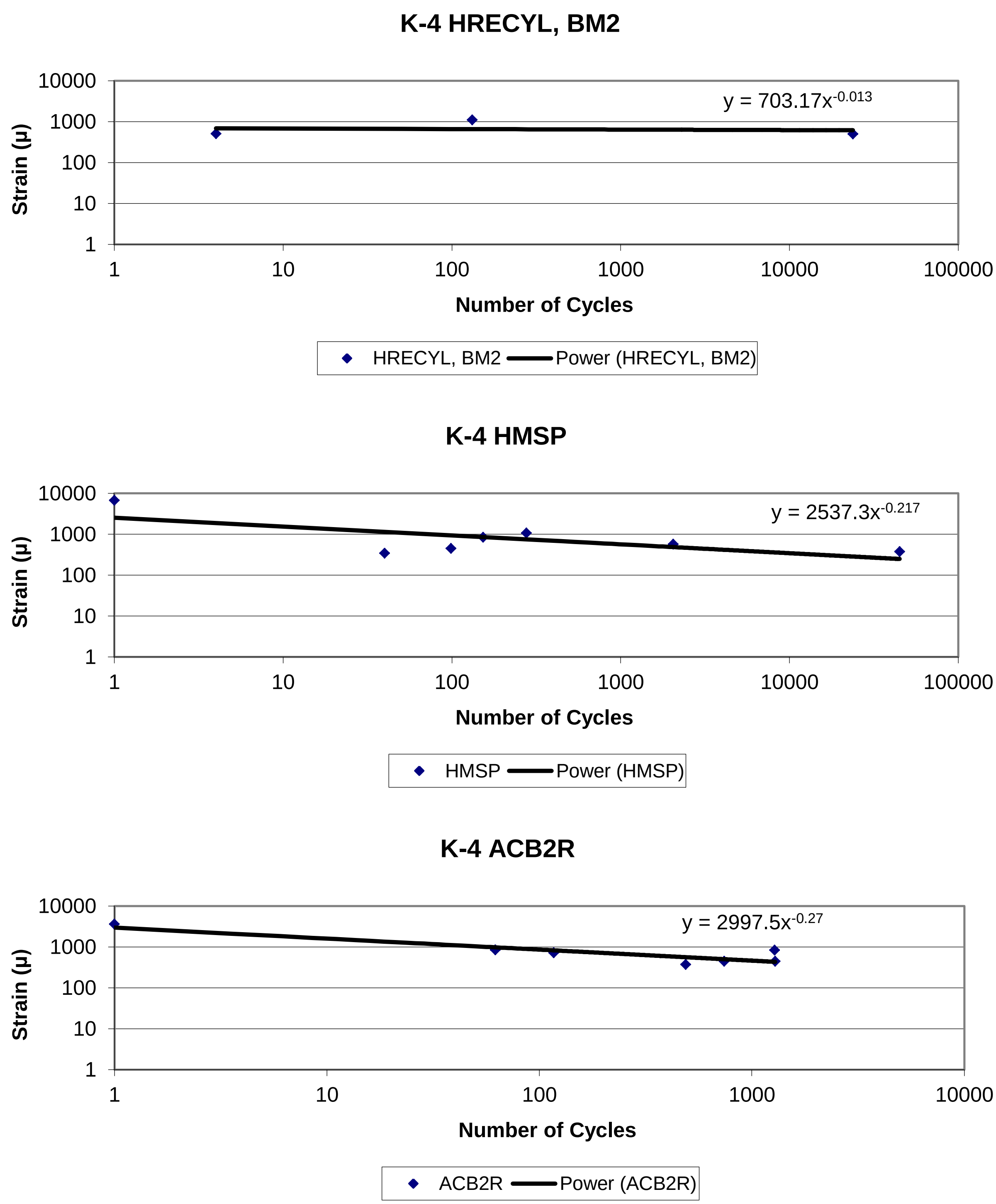



**FIGURE 4.15**
**Fatigue Curves for the Mixtures of K-4**

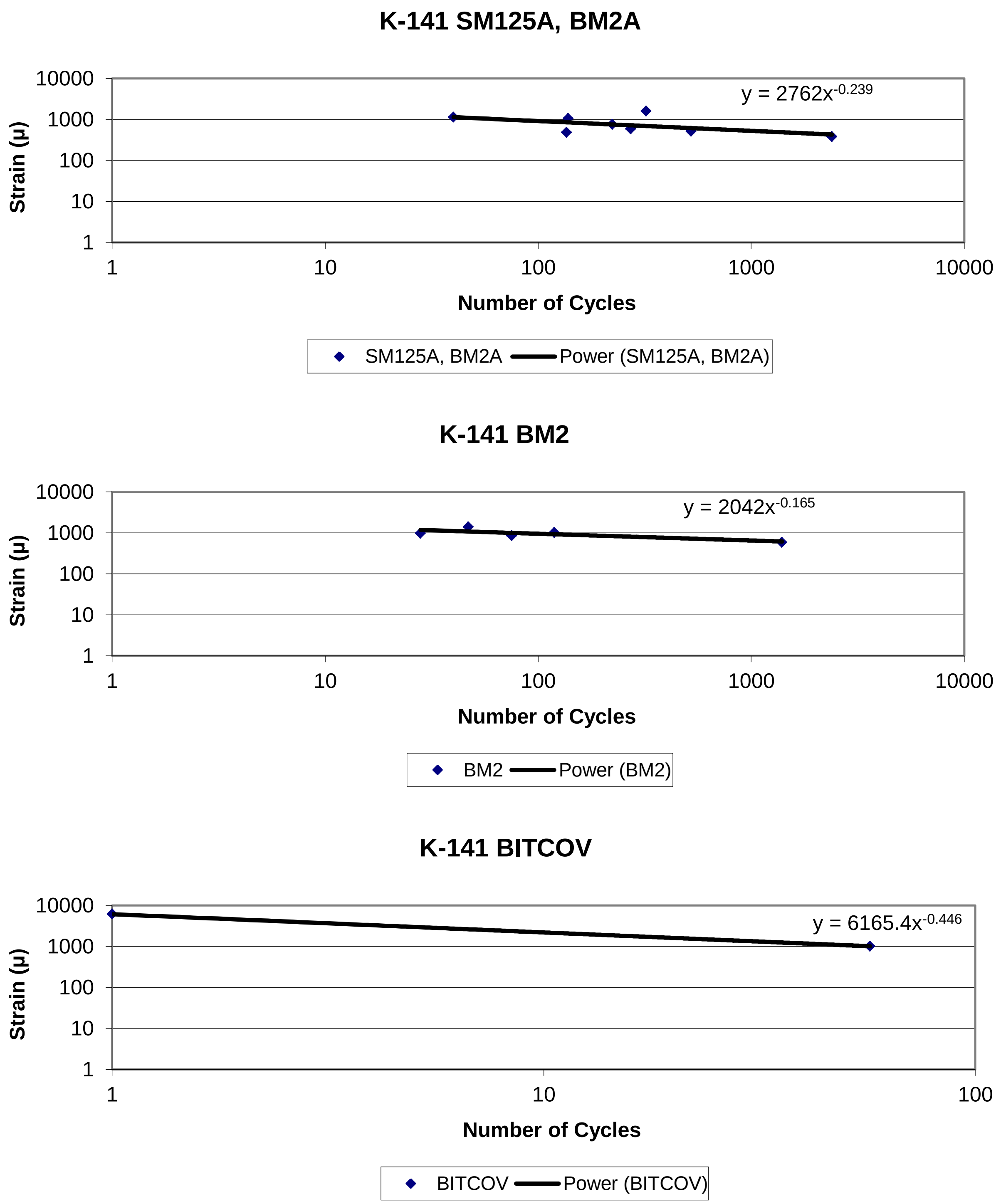



**FIGURE 4.16**
**Fatigue Curves for the Mixtures of K-141**

**TABLE 4.13**
**Summary of Fatigue Test Results**

I-70

| Layer | Year | NMAS (in) | # data points | k1 | k2 | Pb (%) | Pa (%) |
|---|---|---|---|---|---|---|---|
| BM1T, SRECYL | 2000 | 0.75 | 9 | 7126.2 | 0.2717 | 4.68 | 8.12 |
| CRECYL | 2000 | 0.75 | 12 | 1391.6 | 0.0892 | 4.23 | 7.43 |
| HM3A | 1960 | 1 | 0 | | | 6.53 | |

US-56

| Layer | Year | NMAS (in) | # data points | k1 | k2 | Pb (%) | Pa (%) |
|---|---|---|---|---|---|---|---|
| SM125A, SRECYL | 2006 | 0.5 | 6 | 588.08 | -0.039 | 5.01 | 5.88 |
| BM2A, CRECYL | 1999 | 0.5 | 7 | 5796.7 | 0.2068 | 5.64 | 4.56 |
| HRECYL | 1992 | 0.75 | 9 | 10093 | 0.2726 | 5.64 | 5.43 |
| BC1 | 1968 | 0.75 | 2 | 19847 | 0.637 | 5.68 | 8.55 |

US-59

| Layer | Year | NMAS (in) | # data points | k1 | k2 | Pb (%) | Pa (%) |
|---|---|---|---|---|---|---|---|
| SM95A, HRECYL | 1993 | | 10 | 1481.3 | 0.0617 | 6.12 | 6.60 |
| BM3, HM3B | 1976 | | 5 | 5681.8 | 0.332 | 6.39 | 6.08 |
| ACB3 | 1961 | | 0 | | | 5.81 | |
| AB3 | 1960 | | 1 | | | 5.93 | 7.90 |

US-169

| Layer | Year | NMAS (in) | # data points | k1 | k2 | Pb (%) | Pa (%) |
|---|---|---|---|---|---|---|---|
| SM95T, SR190B | 2002 | 0.75 | 8 | 2124.4 | 0.0611 | 6.51 | 7.09 |
| SR-190A | 2002 | 0.75 | 9 | 751.97 | -0.0139 | 5.94 | 7.73 |
| ACB3 | 1973 | 0.75 | 28 | 3734.8 | 0.1627 | 5.86 | 3.24 |

K-4

| Layer | Year | NMAS (in) | # data points | k1 | k2 | Pb (%) | Pa (%) |
|---|---|---|---|---|---|---|---|
| SR95T, SRECYL | 2002 | | 3 | 1263.5 | 0.0834 | 5.91 | 7.37 |
| HRECYL, BM2 | 1995 | | 3 | 703.17 | 0.0125 | 6.63 | 5.33 |
| HMSP | 1965 | | 7 | 2537.3 | 0.2166 | 6.35 | 5.01 |
| ACB2R | 1965 | | 7 | 2997.5 | 0.2695 | 6.89 | 6.94 |

K-141

| Layer | Year | NMAS (in) | # data points | k1 | k2 | Pb (%) | Pa (%) |
|---|---|---|---|---|---|---|---|
| SM125A, BM2A | 1995 | 0.5 | 8 | 2762 | 0.239 | 5.11 | 6.09 |
| BM2 | 1987 | 0.5 | 6 | 1881.2 | 0.1498 | 5.87 | 6.33 |
| BITCOV | 1962 | 0.5 | 2 | 6165.4 | 0.446 | 5.69 | 7.75 |

# Chapter 5: Results and Analysis

## 5.1 Test Method Comparison

The moduli from each testing method (FWD, PSPA, and IDT) were directly analyzed to discover if there is a relationship between the different methods. Unfortunately, no consistent correlation emerges.

Results for US-169 had a very high variation in the PSPA modulus likely caused by user error with the equipment. I-70 also had a very significant difference in PSPA readings for cores 1-1, 1-2, 2-1, and 2-2.

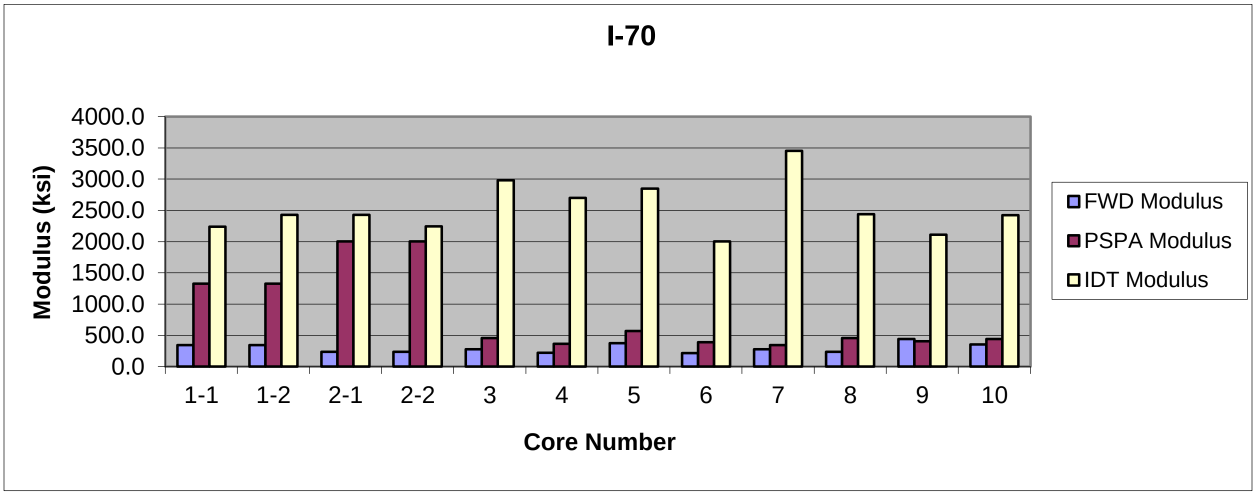



**FIGURE 5.1**
**Modulus Comparison for I-70 in Trego County**

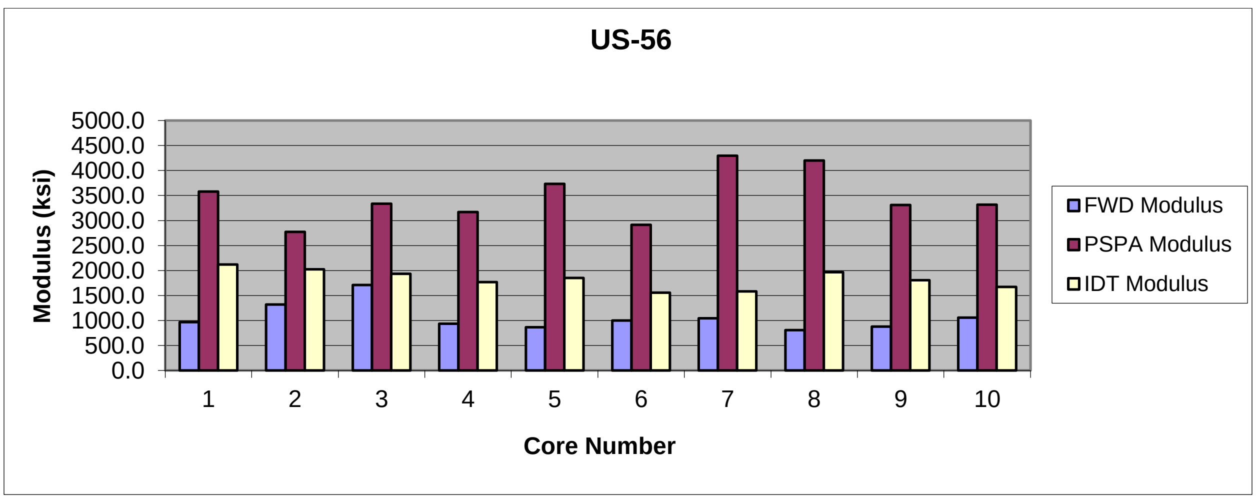



**FIGURE 5.2**
**Modulus Comparison for US-56 in Stevens County**

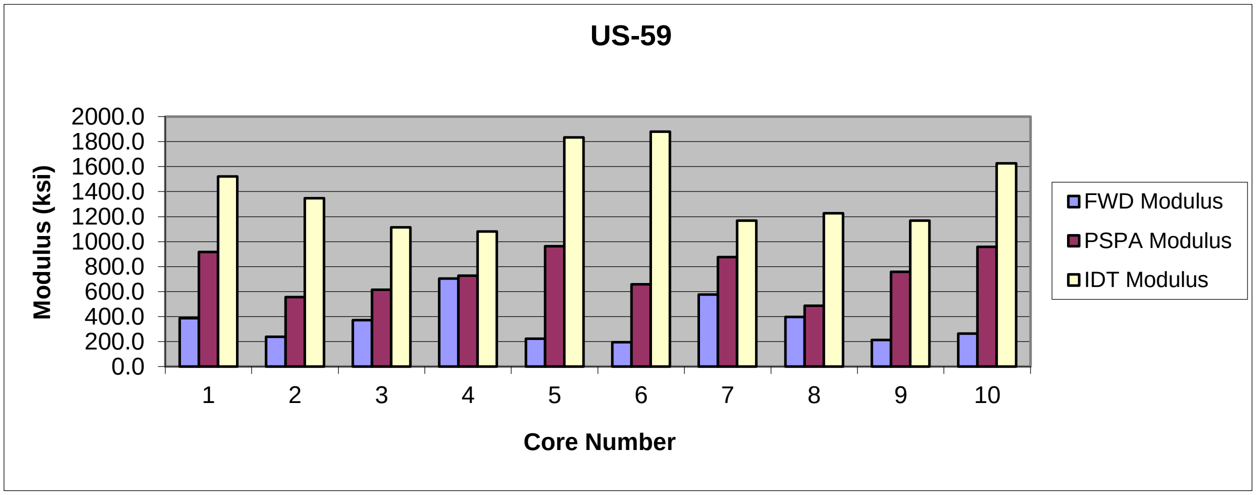



**FIGURE 5.3**
**Modulus Comparison for US-59 in Neosho County**

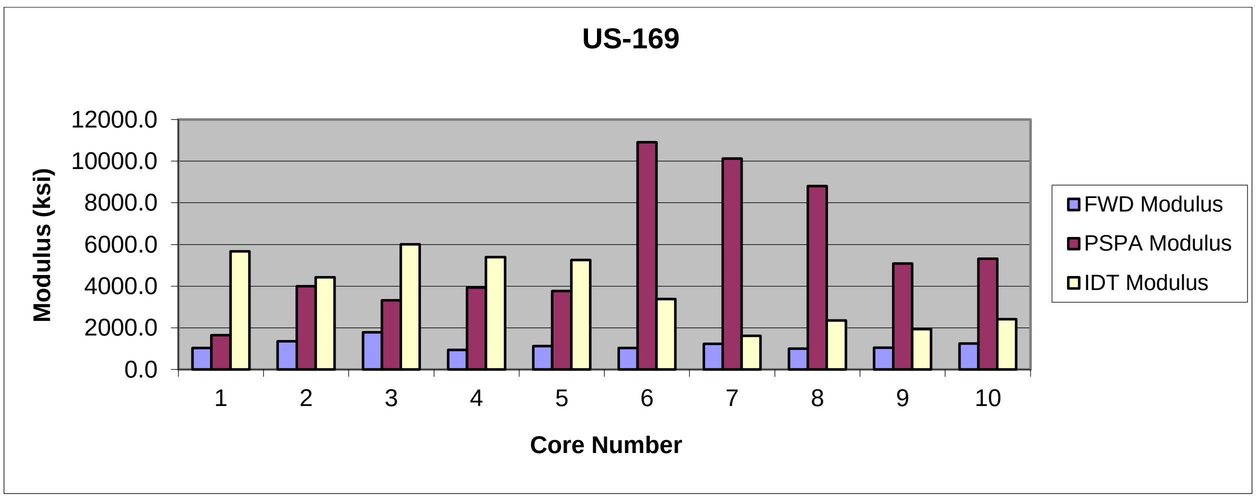



**FIGURE 5.4**
**Modulus Comparison for US-169 in Miami County**

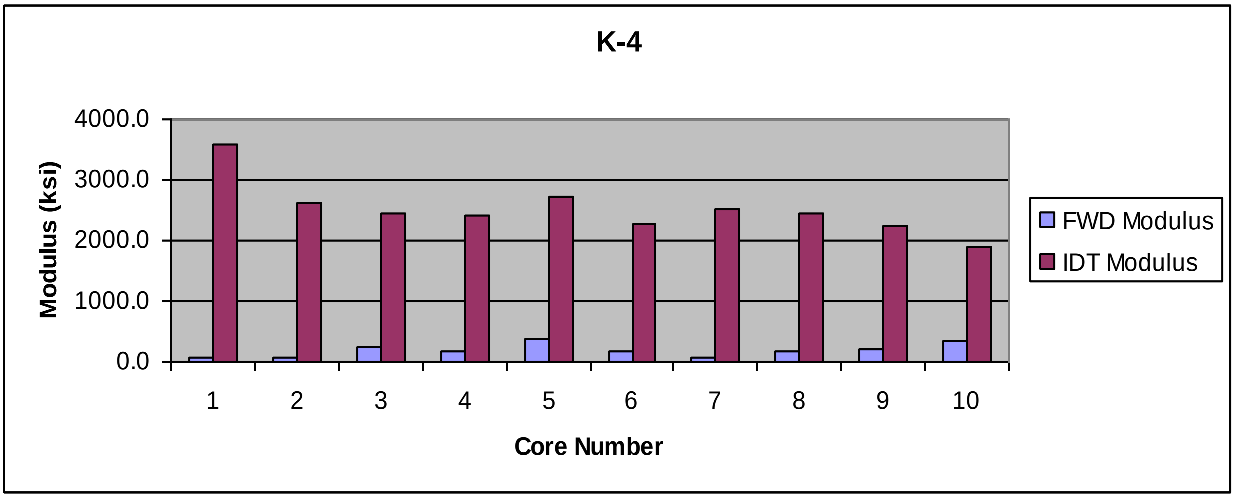



**FIGURE 5.5**
**Modulus Comparison for K-4 in Jefferson County**

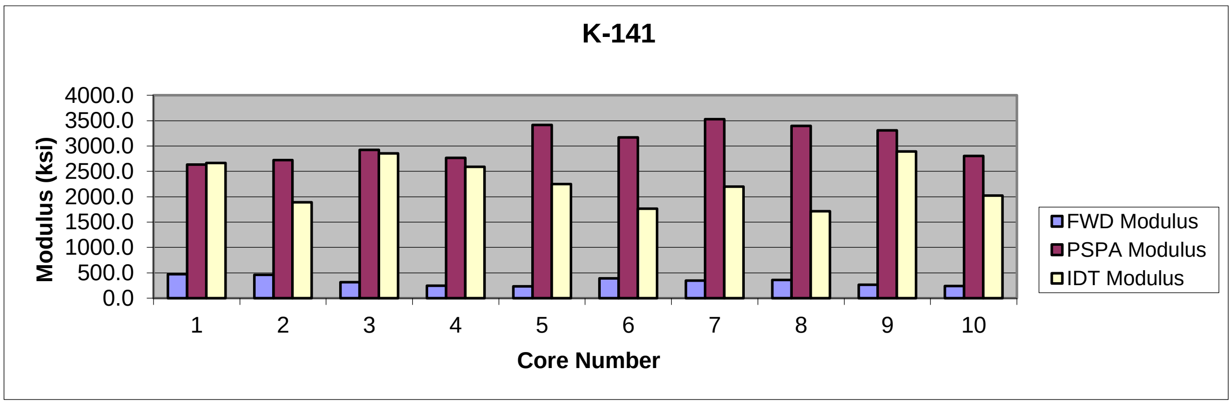



**FIGURE 5.6**
**Modulus Comparison for K-141 in Ellsworth County**

## 5.2 Depth Comparison

Test methods were also analyzed by the depth of the pavement to discover if depth influenced the moduli. Pavement depth was determined by the depth of the core. This could be an inaccurate method of determining the pavement depth if part of the core was too deteriorated to be extracted from the hole.

Most of the data was consistent and independent of pavement depth. US-59, one of the deepest pavements, shows the results for the three test methods possibly converge at higher depths.

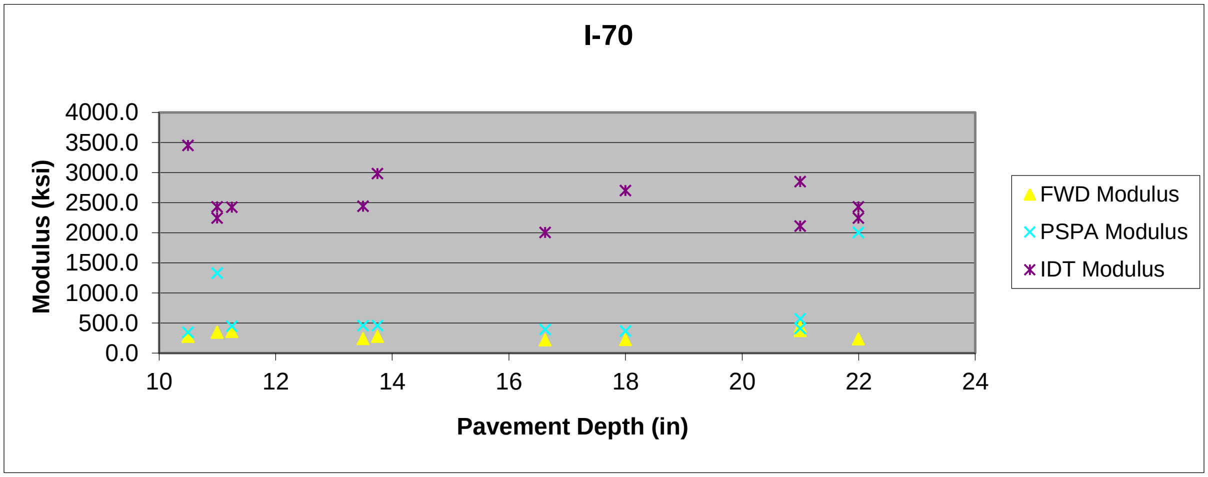



**FIGURE 5.7**
**Modulus Comparison by Depth for I-70 in Trego County**

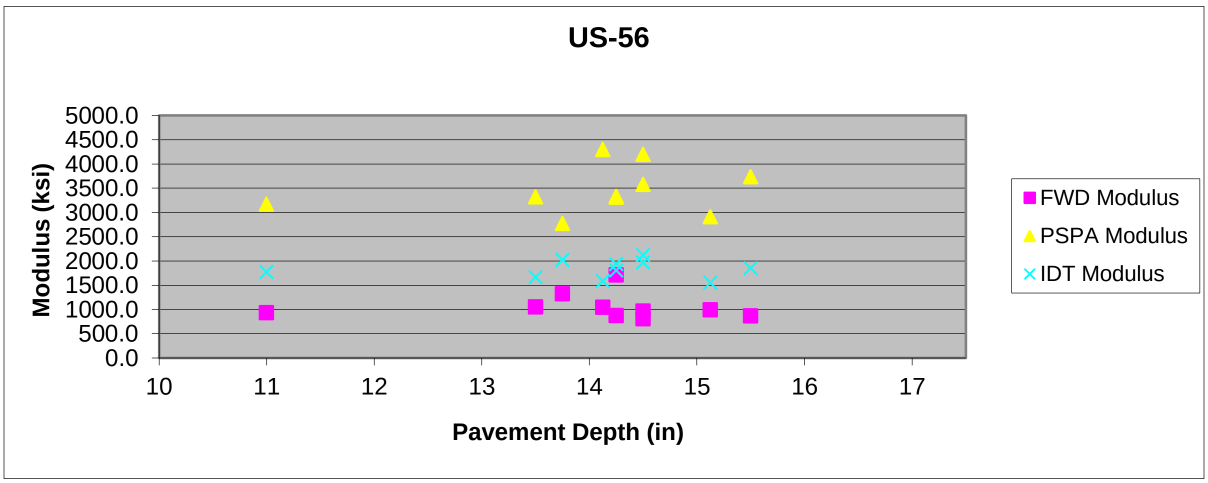



**FIGURE 5.8**
**Modulus Comparison by Depth for US-56 in Stevens County**

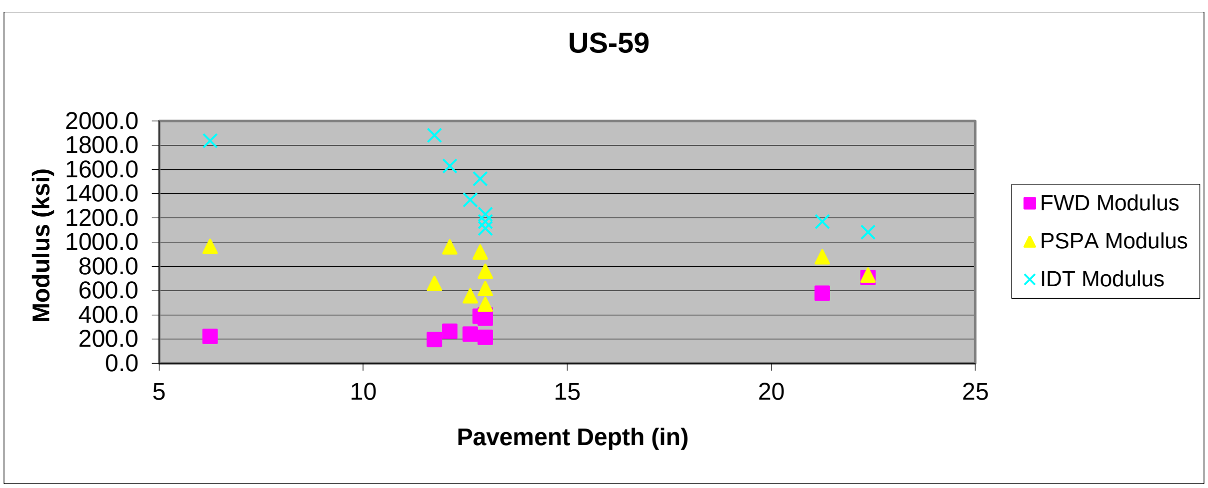



**FIGURE 5.9**
**Modulus Comparison by Depth for US-59 in Neosho County**

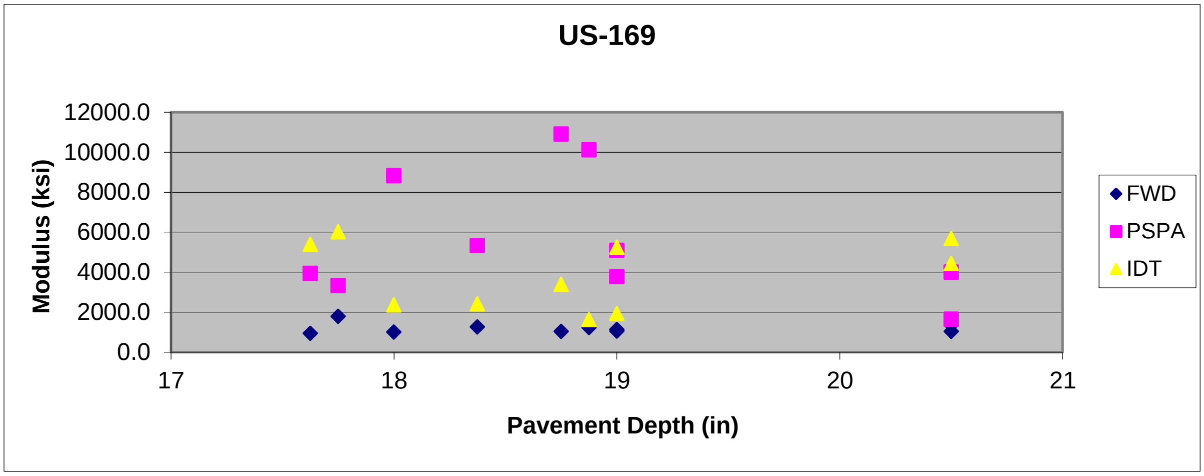



**FIGURE 5.10**
**Modulus Comparison by Depth for US-169 in Miami County**

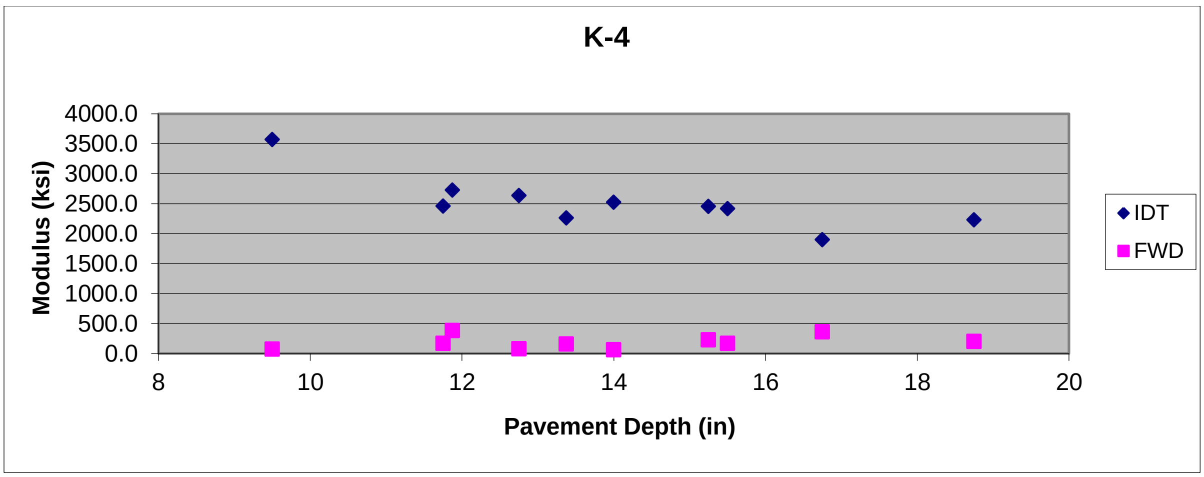



**FIGURE 5.11**
**Modulus Comparison by Depth for K-4 in Jefferson County**

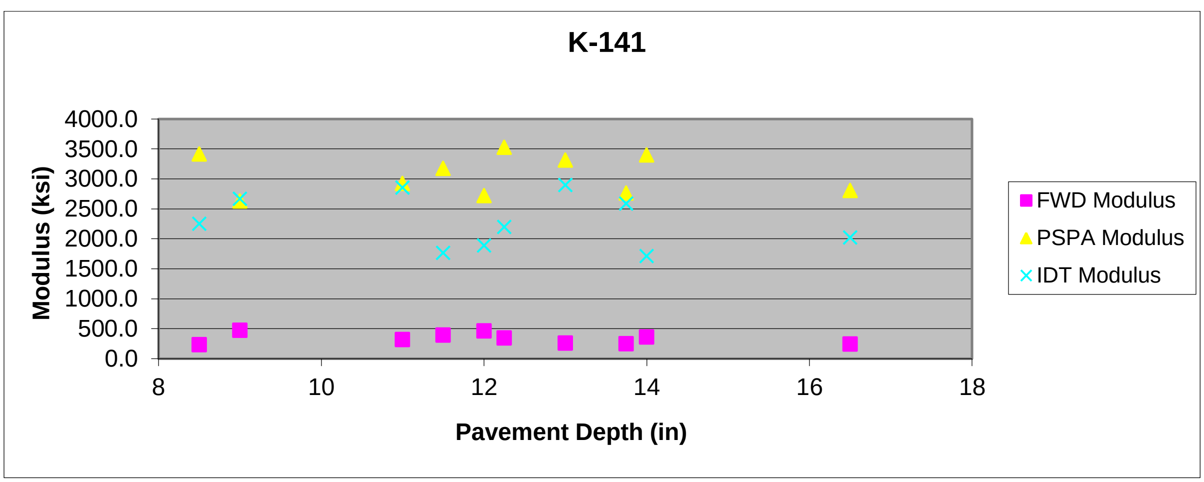



**FIGURE 5.12**
**Modulus Comparison by Depth for K-141 in Ellsworth County**

## 5.3 Fatigue Results Analysis

The fatigue results were also statistically analyzed on a project-by-project basis. The dependent variable was the maximum strain or the strain at failure. The independent variables were the initial strain, resilient modulus (MR), asphalt content (AC), air void (VA) and age of the layer. The statistical analysis software, SAS was used for this purpose. The summary results are shown in Table 5.1. The results show that no consistent, statistically significant factor was identified for all projects. However, all significant factors, such as, initial strain (or resilient modulus for one project), air voids, and asphalt content, are already known to affect the fatigue life of a HMA pavement. This study reconfirms the importance of these factors. As KDOT plans to implement the mechanistic-empirical pavement design process it is strongly recommended that these factors, initial strain, binder content and air voids be strictly controlled during the pavement design, mixture design, and construction process, respectively. For overlays, it is highly recommended that the existing pavement cores be thoroughly studied or any nondestructive method such as Ground Penetrating Radar (GPR) survey be done on the existing pavement to identify layers that are distressed. Also, the use of Falling Weight Deflectometer (FWD) moduli would result in a conservative design for overlays.

**TABLE 5.1**
**Summary of Results of the Statistical Analysis of Fatigue Test Data**

| Project | Response Variable | Independent Variables | p-values | Significance @ α = 0.1 |
|---|---|---|---|---|
| I-70 (whole model is significant @ α = 0.1 p-value = 0.07) | Max. Strain | Initial Strain | 0.0076 | Y |
| | | MR/E* | 0.5416 | N |
| | | AC | 0.1874 | N |
| | | VA | 0.1319 | N |
| K-141 (Overall p-value = 0.7685) | Max. Strain | Initial Strain | 0.6252 | N |
| | | MR/E* | 0.2242 | N |
| | | AC | 0.7613 | N |
| | | VA | 0.9136 | N |
| | | AGE | 0.7877 | N |
| K-4 (Overall p-value = 0.1821) | Max. Strain | Initial Strain | 0.1241 | N |
| | | MR/E* | 0.8798 | N |
| | | AC | 0.2532 | N |
| | | VA | 0.0109 | Y |
| | | AGE | 0.1538 | N |
| US -169 (Overall p-value = 0.4023) | Max. Strain | Initial Strain | 0.1213 | N |
| | | MR/E* | 0.1041 | Y |
| | | AC | 0.3005 | N |
| | | VA | 0.9241 | N |
| | | AGE | 0.7258 | N |
| US-59 (Overall p-value = 0.5565) | Max. Strain | Initial Strain | 0.5466 | N |
| | | MR/E* | 0.1767 | N |
| | | AC | 0.3935 | N |
| | | VA | 0.5981 | N |
| | | AGE | 0.8284 | N |
| US-56 (whole model is significant @ α = 0.1 p-value = 0.083) | Max. Strain | Initial Strain | 0.8920 | N |
| | | MR/E* | 0.4047 | N |
| | | AC | 0.1895 | N |
| | | VA | 0.0111 | Y |
| | | AGE | 0.2957 | N |

# Chapter 6: Conclusions and Recommendations

## 6.1 Conclusions

1. Poor correlation was found between FWD, PSPA, and IDT testing methods. Even though most of the test roadways showed a fairly consistent correlation (or trends) between the tests, there was no consistency between roadways.
2. Pavements with the greatest amount of deterioration showed the largest decline in modulus. The most prominent form of deterioration observed was stripping. Aggregate size had little influence in the amount of stripping.
3. Pavement modulus is independent of the depth of pavement. The moduli showed little variation with a change in depth along the roadway. This may have been impacted by inaccuracy in determining the pavement depth.
4. Fatigue test results show that older pavement layers have a higher propensity for fatigue failure than the newer layers. However, some older pavement layers showed excellent fatigue life.

## 6.2 Recommendations

1. Fatigue testing will be performed on the test specimens discussed in this report to determine the remaining service life of each AC layer. Results from these tests will be released in a later report.
2. Further study is recommended to determine if there is a consistent correlation between FWD, PSPA, and IDT testing methods that works for multiple AC pavements. Further study is also recommended on deeper pavements to determine if the depth affects the modulus from the testing methods.
3. As KDOT plans to implement the mechanistic-empirical pavement design process it is strongly recommended that pavement initial strain, mixture binder content and in-situ air voids be strictly controlled during the pavement design, mixture design, and construction process, respectively.
4. For overlays, it is highly recommended that the existing pavement cores be thoroughly studied or any nondestructive method such as Ground Penetrating Radar (GPR) survey be

done on the existing pavement to identify layers that are distressed. Also, the use of Falling Weight Deflectometer (FWD) moduli would result in conservative design.

# References

AASHTO. 1972. *Interim Guide for Design of Pavement Structure*. American Association for State Highway and Transportation Officials, Washington, D.C.

AASHTO. 1993. *AASHTO Guide for Design of Pavement Structures*. American Association of State Highway and Transportation Officials, Washington, D.C.

Akram, T., T. Scullion, R. E. Smith, and E. G. Fernando. 1992. "Estimating Damage Effects of Dual Versus Wide Base Tires with Multidepth Deflectometers." Transportation Research Record 1355, TRB, National Research Council, Washington, D.C., 51–66.

Brown, E. R., M. S. Buchanan, M. A. Anderson, and G. Huber. 1998. *Superpave Gyratory Compaction Guidelines-Executive Summary: Evaluation of the Superpave Gyratory Compaction Procedure-Final Report and Appendix to the Final Report. No. CRP-CD-1*.

Celaya, M., S. Nazarian, M. Zea, and V. Tandon. 2006. *Use of NDT Equipment for Construction Quality Control of Hot Mix Asphalt Pavements*. Research Report 574-1. Center for Transportation Infrastructure Systems, El Paso, TX.

Daleiden, J. F., B. M. Killingsworth, A. L. Simpson, and R. A. Zamora. 1994. "Analysis of Procedures for Establishing In Situ Subgrade Moduli." Transportation Research Record 1462, TRB, National Research Council, Washington, D.C., 102–107.

FHWA. 2000. *Temperature Predictions and Adjustment Factors for Asphalt Pavement*. Publication No. FHWA-RD-98-085, FHWA, Research and Development, McLean, VA.

Frocht, M. M. 1957. *Photoelasticity*, Vol. 2, John Vliley and Sons, NY.

Gedafa, D., M. Hossain, and S. A. Romanoschi. 2009. *Field Verification of KDOT's Superpave Mixture Properties to be used as Inputs in the NCHRP Mechanistic-Empirical Pavement Design Guide*. Kansas Department of Transportation, Topeka, KS.

Geldmacher, R. C., R. L. Anderson, J. W. Dunkin, G. R. Partridge, M. E. Harr, and L. E. Wood. 1957. *Subgrade Support Characteristics as Indicated by Measurements of Deflection and Strain*. Highway Research Board Proceedings.

Hoffman, M. S., and M. R. Thompson. 1982. "A Comparative Study of Selected Non-Destructive Testing Devices." Transportation Research Record 852, TRB, National Research Council, Washington, D.C., 32–42.

Huang, B., L. N. Mohammad, and G. W. Wathugala. 2004. "Application of a Temperature Dependent Viscoplastic Hierarchical Single Surface Model for Asphalt Mixtures." *Journal of Materials in Civil Engineering* 16 (2): 147–154.

Inge, E. H., Jr., and Y. R. Kim. 1995. "Prediction of Effective Asphalt Layer Temperature." Transportation Research Record 1473, TRB, National Research Council, Washington, D.C., 93–100.

Kunst, P., P. C. Hopman, A. C. Pronk, J. Monenaar, and A. A. A. Molenaar. 1991. *Asphalt Research in the Netherlands*. No. VTI Report 372A, Part 4.

Loulizi, A., G. W. Flintsch, and K. McGhee. 2007. "Determination of In-Place Hot Mix Asphalt Layer Modulus for Rehabilitation Projects by a Mechanistic Empirical Procedure." Transportation Research Record 2037(-1), TRB, National Research Council, Washington, D.C., 53–62.

Matthews, J. M., and C. L. Monismith. 1993. "Direct Tension and Simple Stiffness Tests-Tools for the Fatigue Design of Asphalt Concrete Layers." Transportation Research Record 1388, TRB, National Research Council, Washington, D.C., 182–199.

Mikhail, M. Y., S. B. Seeds, S. H. Alavi, and W. C. Ott. 1999. "Evaluation of Laboratory and Back-Calculated Resilient Moduli from the Wes Track Experiment." Transportation Research Record 1687(-1), TRB, National Research Council, Washington, D.C., 55–65.

NCHRP. 2004. "Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures." Final Report for Project 1-37A. Part 1, Chapter 1. Transportation Research Board, National Research Council, Washington, D.C.

Oh, J. H., E. G. Fernando, S. I. Lee, and C. Holzschuher. 2011. "Correlation of Asphalt Concrete Layer Moduli Determined from Laboratory and Nondestructive Field Tests." *Journal of Transportation Engineering* 138 (3): 361–370.

Park, S. W., and Y. R. Kim. 1997. "Temperature Correction of Backcalculated Moduli and Deflections Using Linear Viscoelasticity and Time-Temperature Superposition." Transportation Research Record 1570, TRB, National Research Council, Washington, D.C., 108–117.

Parker Jr, F. 1991. "Estimation of Paving Materials Design Moduli from Falling Weight Deflectometer Measurements." Transportation Research Record 1293, TRB, National Research Council, Washington, D.C., 42–51.

Paterson, W. D. O. 1987. *Road Deterioration and Maintenance Effects. Models for Planning and Management, Highway Design and Maintenance Standards Series*. The Johns Hopkins University Press, Baltimore and London.

Romanoschi, S., and J. B. Metcalf. 1999. "Simple Approach to Estimation of Pavement Structural Capacity." Transportation Research Record 1652 (-1), TRB, National Research Council, Washington, D.C., 198–205.

Tangella, S. R., J. Craus, J. A. Deacon, and C. L. Monismith. 1990. *Summary Report on Fatigue Response of Asphalt Mixtures*. No. SHRP-A-312.

Ullidtz, P. 1987. *Pavement Analysis*. Elsevier, NY, 221–223.

Van Cauwelaert, F. J., D. R. Alexander, T. D. White, and W. R. Barker. 1989. "Multilayer Elastic Program for Backcalculating Layer Moduli in Pavement Evaluation. Nondestructive Testing of Pavements and Backcalculation of Moduli." American Society for Testing and Materials. Baltimore, MD, 171–188.

Van Til, C. J., B. F. McCullough, B. A. Vallerga, and R. G. Hicks. 1972. *Evaluation of AASHO Interim Guide for Design of Pavement Structures*. NCHRP Report 128, Highway Research Board, Washington, D.C.

Washington State Department of Transportation (WSDOT). 2005. Ever Series User's Guide Pavement Analysis Computer Software and Case Studies.

Yoder, E. J., and M. W. Witczak. 1975. *Principles of Pavement Design*. John Wiley and Sons, NY.

Zaniewski, J., and M. Mamlouk. 1999. "Pavement Preventive Maintenance: Key to Quality Highways." Transportation Research Record 1680 (-1), TRB, National Research Council, Washington, D.C., 26–29.

# Appendix A: IDT Results

**TABLE A.1**
**IDT Results for I-70 in Trego County**

| Specimen | Trial No | Modulus by Cycle (ksi) | | | | | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| | | Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | | | |
| 70-1-1-1 | 1 | 2061.0 | 2004.5 | 2058.3 | 2015.3 | 1958.2 | 2019 | 42.5 | 2.10 |
| | 2 | 2177.8 | 2248.1 | 2229.5 | 2176.5 | 2216.4 | 2210 | 31.8 | 1.44 |
| 70-1-2-1 | 1 | 2300.7 | 2341.4 | 2296.2 | 2368.3 | 2465.8 | 2354 | 69.0 | 2.93 |
| | 2 | 2251.1 | 2374.0 | 2194.0 | 2353.8 | 2265.5 | 2288 | 74.9 | 3.27 |
| 70-1-1-2 | 1 | 2825.5 | 2734.9 | 2871.6 | 2730.2 | 2817.4 | 2796 | 61.4 | 2.20 |
| | 2 | 2081.1 | 2158.8 | 2157.7 | 2169.5 | 2144.0 | 2142 | 35.4 | 1.65 |
| 70-1-2-2 | 1 | 2809.2 | 2583.0 | 2593.6 | 2739.6 | 2658.8 | 2677 | 96.8 | 3.62 |
| | 2 | 2769.3 | 2769.8 | 2842.7 | 2873.5 | 3014.5 | 2854 | 100.7 | 3.53 |
| 70-1-3-2 | 1 | 1944.6 | 1957.5 | 2042.4 | 1955.1 | 1927.1 | 1965 | 44.7 | 2.28 |
| | 2 | 2152.9 | 2161.5 | 2112.5 | 2207.8 | 2244.5 | 2176 | 51.2 | 2.35 |
| 70-2-1-1 | 1 | 2633.8 | 2593.9 | 2519.3 | 2468.3 | 2474.9 | 2538 | 73.3 | 2.89 |
| | 2 | 2646.8 | 2576.5 | 2630.8 | 2580.9 | 2613.9 | 2610 | 30.7 | 1.18 |
| 70-2-2-1 | 1 | 3222.3 | 2836.6 | 2939.9 | 2837.0 | 2901.8 | 2947 | 159.8 | 5.42 |
| | 2 | 3513.9 | 3555.4 | 3359.8 | 3414.1 | 3381.2 | 3445 | 85.5 | 2.48 |
| 70-2-3-1 | 1 | 1485.3 | 1470.4 | 1514.3 | 1459.5 | 1444.0 | 1475 | 26.8 | 1.82 |
| | 2 | | | | | | | | |
| 70-2-1-2 | 1 | 3345.8 | 3235.6 | 3276.1 | 3436.9 | 3091.8 | 3277 | 128.8 | 3.93 |
| | 2 | 2487.9 | 2285.9 | 2294.1 | 2417.1 | 2288.3 | 2355 | 92.8 | 3.94 |
| 70-2-2-2 | 1 | 1961.1 | 2087.0 | 2057.9 | 2142.6 | 2202.3 | 2090 | 90.9 | 4.35 |
| | 2 | 2839.4 | 2949.6 | 2732.6 | 2834.5 | 2752.8 | 2822 | 85.9 | 3.04 |
| 70-2-3-2 | 1 | 1428.0 | 1396.5 | 1399.3 | 1378.8 | 1386.3 | 1398 | 18.8 | 1.34 |
| | 2 | 1231.5 | 1267.9 | 1213.9 | 1209.3 | 1205.2 | 1226 | 25.7 | 2.10 |
| 70-3-1 | 1 | 3664.3 | 3470.9 | 3592.9 | 3637.5 | 3344.7 | 3542 | 132.9 | 3.75 |
| | 2 | 2641.6 | 3161.1 | 2728.1 | 2732.3 | 2826.6 | 2818 | 202.7 | 7.19 |
| 70-3-2 | 1 | 3018.2 | 3028.5 | 2884.3 | 2870.0 | 2924.4 | 2945 | 74.3 | 2.52 |
| | 2 | 2791.0 | 2965.8 | 2971.6 | 2713.3 | 2861.7 | 2861 | 111.7 | 3.91 |
| 70-3-3 | 1 | 3801.7 | 3624.3 | 3772.2 | 3931.5 | 3463.9 | 3719 | 179.5 | 4.83 |
| | 2 | 2068.6 | 2045.4 | 2017.1 | 2026.0 | 1973.8 | 2026 | 35.3 | 1.74 |
| 70-4-1 | 1 | 2623.3 | 2634.7 | 2682.9 | 2717.4 | 2652.0 | 2662 | 38.3 | 1.44 |
| | 2 | 3266.6 | 3362.4 | 3184.6 | 3213.2 | 3379.7 | 3281 | 87.3 | 2.66 |
| 70-4-2 | 1 | 3129.9 | 2984.2 | 2760.2 | 3007.4 | 3082.4 | 2993 | 142.5 | 4.76 |
| | 2 | 3136.7 | 3230.6 | 2849.1 | 2749.3 | 2872.0 | 2968 | 205.3 | 6.92 |
| 70-4-3 | 1 | 2403.1 | 2519.5 | 2339.9 | 2453.5 | 2464.7 | 2436 | 67.9 | 2.79 |
| | 2 | 1971.2 | 1937.2 | 1985.0 | 1886.5 | 1965.6 | 1949 | 39.1 | 2.01 |
| 70-5-1 | 1 | 3828.3 | 4219.2 | 3977.3 | 4032.3 | 4087.0 | 4029 | 143.6 | 3.57 |
| | 2 | 3788.2 | 3638.5 | 3865.6 | 3541.8 | 4024.8 | 3772 | 189.6 | 5.03 |
| 70-5-2 | 1 | 3296.5 | 3175.2 | 3322.2 | 2933.3 | 3182.1 | 3182 | 153.9 | 4.84 |
| | 2 | 3053.2 | 2915.0 | 2848.7 | 2713.5 | 2732.1 | 2852 | 139.7 | 4.90 |
| 70-5-3 | 1 | 1698.1 | 1763.0 | 1745.5 | 1699.0 | 1725.5 | 1726 | 28.5 | 1.65 |
| | 2 | 1699.8 | 1748.1 | 1733.8 | 1691.9 | 1746.5 | 1724 | 26.5 | 1.53 |
| 70-6-2 | 1 | 2333.1 | 2414.8 | 2386.6 | 2305.4 | 2165.0 | 2321 | 97.2 | 4.19 |
| | 2 | 2867.1 | 2725.8 | 2767.8 | 2755.5 | 2820.9 | 2787 | 56.3 | 2.02 |
| 70-6-3 | 1 | 1516.3 | 1497.5 | 1466.9 | 1470.5 | 1477.8 | 1486 | 20.8 | 1.40 |
| | 2 | 1478.8 | 1442.9 | 1429.1 | 1450.6 | 1436.0 | 1448 | 19.2 | 1.33 |

## TABLE A.1
## IDT Results for I-70 in Trego County, Continued

| Specimen | Trial No | Modulus by Cycle (ksi) | | | | | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| | | Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | | | |
| 70-7-1 | 1 | 4458.0 | 4713.1 | 4620.3 | 4523.1 | 4924.4 | 4648 | 182.4 | 3.93 |
| | 2 | 3463.9 | 3469.8 | 3510.0 | 3426.6 | 3480.8 | 3470 | 30.1 | 0.87 |
| 70-7-2 | 1 | 2561.4 | 2495.0 | 2469.3 | 2569.7 | 2491.2 | 2517 | 45.2 | 1.80 |
| | 2 | 3345.7 | 3851.3 | 3491.9 | 3759.6 | 3657.3 | 3621 | 203.7 | 5.63 |
| 70-7-3 | 1 | 1953.4 | 1866.4 | 1898.0 | 1889.7 | 1900.6 | 1902 | 31.9 | 1.68 |
| | 2 | 1950.2 | 1917.3 | 1967.2 | 1951.2 | 1910.6 | 1939 | 24.2 | 1.25 |
| 70-8-1 | 1 | 2794.3 | 2776.3 | 2737.3 | 2639.4 | 2759.5 | 2741 | 60.8 | 2.22 |
| | 2 | 2419.6 | 2514.3 | 2585.2 | 2583.7 | 2556.0 | 2532 | 69.0 | 2.72 |
| 70-8-2 | 1 | 2537.0 | 2499.3 | 2552.0 | 2603.3 | 2595.7 | 2557 | 43.0 | 1.68 |
| | 2 | 3746.0 | 3646.5 | 3486.2 | 3476.8 | 3361.6 | 3543 | 152.0 | 4.29 |
| 70-8-3 | 1 | 1318.7 | 1337.7 | 1310.7 | 1304.2 | 1312.5 | 1317 | 12.8 | 0.97 |
| | 2 | 1371.8 | 1354.8 | 1376.8 | 1350.2 | 1369.3 | 1365 | 11.5 | 0.84 |
| 70-9-2 | 1 | 2782.1 | 2781.3 | 2767.2 | 2624.3 | 2710.9 | 2733 | 67.5 | 2.47 |
| | 2 | 2535.7 | 2450.6 | 2471.5 | 2391.7 | 2448.0 | 2459 | 51.8 | 2.11 |
| 70-9-3 | 1 | 1923.5 | 1920.1 | 1899.0 | 1894.4 | 1869.3 | 1901 | 21.9 | 1.15 |
| | 2 | 2914.6 | 2891.7 | 2754.9 | 2818.9 | 2857.9 | 2848 | 63.2 | 2.22 |
| 70-10-2 | 1 | 3029.1 | 2923.6 | 2943.2 | 2898.7 | 2843.7 | 2928 | 67.9 | 2.32 |
| | 2 | 3144.0 | 3185.9 | 3225.6 | 3195.5 | 3102.1 | 3171 | 48.2 | 1.52 |
| 70-10-3 | 1 | 682.7 | 693.7 | 683.4 | 674.9 | 670.8 | 681 | 8.8 | 1.30 |
| | 2 | 851.8 | 822.3 | 816.0 | 820.9 | 794.3 | 821 | 20.5 | 2.50 |

## TABLE A.2
## IDT Results for US-56 in Stevens County

| Specimen | Trial No | Modulus by Cycle (ksi) | | | | | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| | | Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | | | |
| 56-1-1 | 1 | 1942.6 | 1871.4 | 1813.0 | 1818.8 | 1968.1 | 1883 | 70.6 | 3.8 |
| | 2 | 2205.3 | 2262.7 | 2131.8 | 2220.8 | 2229.5 | 2210 | 48.5 | 2.2 |
| 56-1-2 | 1 | 2463.4 | 2615.8 | 2656.3 | 2435.6 | 2580.3 | 2550 | 96.4 | 3.8 |
| | 2 | 2984.1 | 2828.2 | 2789.4 | 2939.7 | 3017.5 | 2912 | 98.9 | 3.4 |
| 56-1-3 | 1 | 1912.9 | 1935.2 | 1854.8 | 1870.3 | 1855.9 | 1886 | 36.3 | 1.9 |
| | 2 | 2650.5 | 2673.3 | 2710.3 | 2702.2 | 2668.5 | 2681 | 24.8 | 0.9 |
| 56-1-4 | 1 | 1725.2 | 1671.5 | 1687.2 | 1653.6 | 1655.8 | 1679 | 29.3 | 1.7 |
| | 2 | 1193.0 | 1156.6 | 1152.9 | 1170.5 | 1172.0 | 1169 | 15.8 | 1.4 |
| 56-2-1 | 1 | 2679.9 | 2738.7 | 2772.8 | 2779.2 | 2754.9 | 2745 | 39.7 | 1.4 |
| | 2 | 2420.9 | 2330.9 | 2174.2 | 2218.0 | 2295.4 | 2288 | 96.7 | 4.2 |
| 56-2-2 | 1 | 2801.9 | 2831.7 | 2828.3 | 2885.8 | 2838.7 | 2837 | 30.5 | 1.1 |
| | 2 | 2520.0 | 2460.4 | 2331.9 | 2443.5 | 2361.5 | 2423 | 76.3 | 3.1 |
| 56-2-3 | 1 | 1862.8 | 1817.2 | 1859.4 | 2023.1 | 1855.5 | 1884 | 80.1 | 4.3 |
| | 2 | 2230.7 | 2370.5 | 2222.1 | 2329.8 | 2117.8 | 2254 | 99.3 | 4.4 |
| 56-2-4 | 1 | 1064.8 | 1045.8 | 1053.9 | 1055.8 | 1040.0 | 1052 | 9.6 | 0.9 |
| | 2 | 856.2 | 837.3 | 841.6 | 812.0 | 809.3 | 831 | 20.1 | 2.4 |
| 56-3-1 | 1 | 2274.9 | 2360.2 | 2254.9 | 2271.0 | 2319.8 | 2296 | 43.1 | 1.9 |
| | 2 | 2500.0 | 2414.0 | 2326.8 | 2276.6 | 2365.1 | 2376 | 85.5 | 3.6 |
| 56-3-2 | 1 | 1737.8 | 1790.7 | 1675.0 | 1787.7 | 1754.2 | 1749 | 47.1 | 2.7 |
| | 2 | 1920.2 | 1939.6 | 1886.6 | 1881.8 | 1882.3 | 1902 | 26.4 | 1.4 |
| 56-3-3 | 1 | 2253.9 | 2123.4 | 2129.6 | 2114.7 | 2114.0 | 2147 | 60.0 | 2.8 |
| | 2 | 2205.7 | 2126.6 | 2092.7 | 2062.7 | 2108.4 | 2119 | 53.7 | 2.5 |
| 56-3-4 | 1 | 1498.4 | 1502.3 | 1461.6 | 1430.3 | 1463.8 | 1471 | 29.7 | 2.0 |
| | 2 | 1419.9 | 1354.6 | 1412.6 | 1383.9 | 1386.1 | 1391 | 26.0 | 1.9 |
| 56-4-1 | 1 | 2170.0 | 2466.4 | 2449.8 | 2405.5 | 2350.8 | 2369 | 119.7 | 5.1 |
| | 2 | 2720.6 | 2683.3 | 2505.1 | 2677.2 | 2539.4 | 2625 | 96.1 | 3.7 |
| 56-4-2 | 1 | 1522.1 | 1513.8 | 1506.9 | 1465.9 | 1466.2 | 1495 | 27.0 | 1.8 |
| | 2 | 1502.8 | 1520.8 | 1436.9 | 1443.4 | 1430.1 | 1467 | 41.9 | 2.9 |
| 56-4-3 | 1 | 1354.7 | 1305.9 | 1279.1 | 1241.8 | 1312.0 | 1299 | 41.8 | 3.2 |
| | 2 | 1493.2 | 1444.3 | 1473.2 | 1379.8 | 1357.1 | 1430 | 58.9 | 4.1 |
| 56-5-1 | 1 | 2167.1 | 2029.6 | 1991.0 | 2049.6 | 1978.1 | 2043 | 75.1 | 3.7 |
| | 2 | 2621.0 | 2564.4 | 2389.9 | 2514.4 | 2429.4 | 2504 | 94.9 | 3.8 |
| 56-5-2 | 1 | 1628.7 | 1737.6 | 1678.4 | 1547.1 | 1675.5 | 1653 | 70.9 | 4.3 |
| | 2 | 2025.0 | 2014.4 | 2122.4 | 1970.0 | 2146.7 | 2056 | 75.3 | 3.7 |
| 56-5-3 | 1 | 1930.6 | 1689.0 | 2054.7 | 1870.5 | 1856.4 | 1880 | 132.5 | 7.0 |
| | 2 | 2461.1 | 2407.2 | 2377.5 | 2209.4 | 2138.4 | 2319 | 137.9 | 5.9 |
| 56-5-4 | 1 | 1147.3 | 1151.5 | 1126.2 | 1096.5 | 1110.8 | 1126 | 23.5 | 2.1 |
| | 2 | 1263.2 | 1268.4 | 1262.2 | 1234.3 | 1241.7 | 1254 | 15.0 | 1.2 |
| 56-6-1 | 1 | 1685.3 | 1605.0 | 1692.6 | 1717.7 | 1672.9 | 1675 | 42.3 | 2.5 |
| | 2 | 1998.4 | 2031.8 | 1953.0 | 1858.5 | 1935.7 | 1955 | 66.1 | 3.4 |
| 56-6-2 | 1 | 1925.8 | 1872.9 | 1913.7 | 1883.6 | 1904.5 | 1900 | 21.7 | 1.1 |
| | 2 | 1618.6 | 1551.4 | 1609.8 | 1602.3 | 1690.0 | 1614 | 49.7 | 3.1 |
| 56-6-3 | 1 | 1869.2 | 1808.7 | 1807.5 | 1859.0 | 1807.3 | 1830 | 31.1 | 1.7 |
| | 2 | 1441.6 | 1433.3 | 1486.3 | 1469.7 | 1392.8 | 1445 | 36.0 | 2.5 |
| 56-6-4 | 1 | 1050.2 | 1061.8 | 1010.1 | 1029.8 | 1000.7 | 1031 | 25.8 | 2.5 |
| | 2 | 1075.8 | 1036.1 | 1068.3 | 1050.7 | 1023.6 | 1051 | 21.7 | 2.1 |

## TABLE A.2
## IDT Results for US-56 in Stevens County, Continued

| Specimen | Trial No | Mr 1 (Modulus by Cycle (ksi)) | Mr 2 | Mr 3 | Mr 4 | Mr 5 | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| 56-7-1 | 1 | 2035.8 | 1953.9 | 1952.0 | 1945.9 | 1880.2 | 1954 | 55.3 | 2.8 |
| | 2 | 2091.9 | 2148.2 | 2211.4 | 2221.1 | | 2168 | 60.2 | 2.8 |
| 56-7-2 | 1 | 1899.8 | 1846.0 | 1885.8 | 1866.8 | 1905.7 | 1881 | 24.6 | 1.3 |
| | 2 | 2031.8 | 2088.5 | 2078.0 | 1917.1 | 2171.8 | 2057 | 93.3 | 4.5 |
| 56-7-3 | 1 | 1540.1 | 1608.3 | 1533.1 | 1547.9 | 1526.9 | 1551 | 32.8 | 2.1 |
| | 2 | 1691.9 | 1660.3 | 1598.0 | 1574.5 | 1571.5 | 1619 | 54.1 | 3.3 |
| 56-7-4 | 1 | 1004.6 | 997.0 | 994.0 | 986.2 | 988.6 | 994 | 7.3 | 0.7 |
| | 2 | 483.5 | 483.0 | 477.5 | 476.9 | 467.7 | 478 | 6.3 | 1.3 |
| 56-8-1 | 1 | 1891.9 | 1827.8 | 1814.0 | 1736.9 | | 1818 | 63.7 | 3.5 |
| | 2 | 2155.8 | 2105.7 | 2044.7 | 2153.8 | | 2115 | 52.2 | 2.5 |
| 56-8-2 | 1 | 1994.3 | 2119.6 | 2119.6 | 2112.6 | 2117.3 | 2093 | 55.1 | 2.6 |
| | 2 | 3124.3 | 2903.0 | 2951.9 | 3044.0 | 3210.7 | 3047 | 125.1 | 4.1 |
| 56-8-3 | 1 | 1867.9 | 1792.8 | 1715.3 | 1760.1 | 1828.8 | 1793 | 59.2 | 3.3 |
| | 2 | 1662.1 | 1743.0 | 1636.4 | 1652.8 | 1809.3 | 1701 | 73.3 | 4.3 |
| 56-8-4 | 1 | 1484.4 | 1408.3 | 1445.0 | 1456.2 | 1418.4 | 1442 | 30.4 | 2.1 |
| | 2 | 1760.0 | 1723.2 | 1747.0 | 1845.3 | 1753.2 | 1766 | 46.6 | 2.6 |
| 56-9-1 | 1 | 2037.4 | 2022.2 | 2128.8 | 2041.0 | 2064.9 | 2059 | 42.0 | 2.0 |
| | 2 | 2482.5 | 2642.4 | 2610.3 | 2601.2 | | 2584 | 70.0 | 2.7 |
| 56-9-2 | 1 | 2053.0 | 1989.8 | 2010.0 | 1990.7 | 2010.3 | 2011 | 25.6 | 1.3 |
| | 2 | 2134.8 | 1999.9 | 2097.7 | 1942.5 | 2074.0 | 2050 | 77.6 | 3.8 |
| 56-9-3 | 1 | 1855.3 | 1872.7 | 1785.5 | 1878.9 | 1842.8 | 1847 | 37.2 | 2.0 |
| | 2 | 1795.6 | 1838.5 | 1805.6 | 1800.7 | 1816.1 | 1811 | 17.0 | 0.9 |
| 56-9-4 | 1 | 1025.4 | 1005.6 | 1016.6 | 1013.7 | 991.1 | 1010 | 13.0 | 1.3 |
| | 2 | 1086.4 | 1063.8 | 1073.9 | 1033.9 | 1057.2 | 1063 | 19.6 | 1.8 |
| 56-10-1 | 1 | 2411.3 | 2392.6 | 2242.7 | 2119.8 | 2147.8 | 2263 | 135.1 | 6.0 |
| | 2 | 1956.9 | 1856.6 | 1915.2 | 1963.9 | 1948.0 | 1928 | 44.1 | 2.3 |
| 56-10-2 | 1 | 1873.4 | 1900.3 | 2029.7 | 1929.3 | 1875.4 | 1922 | 64.5 | 3.4 |
| | 2 | 1965.4 | 2023.7 | 2061.2 | 1913.7 | 2006.4 | 1994 | 56.6 | 2.8 |
| 56-10-3 | 1 | 2056.0 | 2017.1 | 2053.7 | 1922.1 | 1990.3 | 2008 | 55.1 | 2.7 |
| | 2 | 1684.5 | 1755.3 | 1761.8 | 1706.8 | 1693.1 | 1720 | 35.9 | 2.1 |
| 56-10-4 | 1 | 594.7 | 569.6 | 545.3 | 537.7 | 528.2 | 555 | 26.9 | 4.9 |
| | 2 | 626.3 | 600.4 | 600.6 | 584.6 | 583.5 | 599 | 17.3 | 2.9 |

**TABLE A.3**
**IDT Results for US-59 in Neosho County**

| Specimen | Trial No | Modulus by Cycle (ksi) | | | | | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| | | Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | | | |
| 59-1-1 | 1 | 2079.1 | 2140.9 | 2135.7 | 1934.2 | 1878.1 | 2034 | 120.48 | 5.92 |
| | 2 | 2227.0 | 2311.8 | 2221.5 | 2211.5 | 2150.2 | 2224 | 57.70 | 2.59 |
| 59-1-2 | 1 | 1457.4 | 1434.9 | 1428.1 | 1466.1 | 1395.8 | 1436 | 27.58 | 1.92 |
| | 2 | 1469.0 | 1492.6 | 1470.1 | 1484.3 | 1500.6 | 1483 | 13.79 | 0.93 |
| 59-1-3 | 1 | 1107.5 | 1105.5 | 1063.8 | 1085.5 | 1104.2 | 1093 | 18.69 | 1.71 |
| | 2 | 927.1 | 925.1 | 923.7 | 890.5 | 910.7 | 915 | 15.33 | 1.68 |
| 59-2-1 | 1 | 2330.9 | 2325.2 | 2384.3 | 2445.6 | 2450.4 | 2387 | 60.05 | 2.52 |
| | 2 | 1949.1 | 1873.9 | 1995.9 | 1851.4 | 1818.8 | 1898 | 72.84 | 3.84 |
| 59-2-2 | 1 | 1249.5 | 1232.8 | 1198.9 | 1183.9 | 1197.8 | 1213 | 27.40 | 2.26 |
| | 2 | 1288.2 | 1225.4 | 1238.9 | 1252.2 | 1216.7 | 1244 | 28.03 | 2.25 |
| 59-2-3 | 1 | 643.4 | 642.6 | 648.6 | 633.7 | 631.3 | 640 | 7.21 | 1.13 |
| | 2 | 645.2 | 636.3 | 632.9 | 627.4 | 622.1 | 633 | 8.79 | 1.39 |
| 59-3-1 | 1 | 1445.7 | 1457.2 | 1452.5 | 1396.6 | 1431.9 | 1437 | 24.38 | 1.70 |
| | 2 | 1437.1 | 1419.9 | 1439.6 | 1426.9 | 1393.2 | 1423 | 18.63 | 1.31 |
| 59-3-2 | 1 | 1606.2 | 1544.9 | 1558.3 | 1524.6 | | 1559 | 34.69 | 2.23 |
| | 2 | 1271.0 | 1231.6 | 1218.6 | 1220.1 | | 1235 | 24.48 | 1.98 |
| 59-3-3 | 1 | 1205.7 | 1232.8 | 1218.8 | 1252.7 | 1211.8 | 1224 | 18.77 | 1.53 |
| | 2 | 1159.1 | 1153.9 | 1166.8 | 1155.5 | 1170.5 | 1161 | 7.23 | 0.62 |
| 59-3-4 | 1 | 611.3 | 607.0 | 591.6 | 587.9 | 572.1 | 594 | 15.73 | 2.65 |
| | 2 | 577.5 | 569.6 | 562.6 | 557.5 | 554.1 | 564 | 9.45 | 1.67 |
| 59-4-1 | 1 | 1750.0 | 1745.2 | 1679.2 | 1730.8 | 1703.3 | 1722 | 29.92 | 1.74 |
| | 2 | 1934.8 | 2008.6 | 1926.6 | 1948.3 | 1959.4 | 1956 | 32.24 | 1.65 |
| 59-4-2 | 1 | 1593.4 | 1533.2 | 1537.1 | 1514.7 | | 1545 | 33.95 | 2.20 |
| | 2 | 1388.9 | 1353.1 | 1337.3 | 1348.1 | | 1357 | 22.35 | 1.65 |
| 59-4-3 | 1 | 741.5 | 728.0 | 737.5 | 747.1 | 728.4 | 737 | 8.30 | 1.13 |
| | 2 | 754.2 | 759.6 | 731.1 | 739.5 | 728.6 | 743 | 13.80 | 1.86 |
| 59-4-4 | 1 | 841.4 | 817.8 | 800.3 | 801.5 | 792.3 | 811 | 19.52 | 2.41 |
| | 2 | 702.7 | 671.6 | 653.6 | 656.6 | 657.0 | 668 | 20.47 | 3.06 |
| 59-4-5 | 1 | 802.2 | 785.1 | 762.3 | 775.2 | 788.0 | 783 | 14.87 | 1.90 |
| | 2 | 797.2 | 800.3 | 809.9 | 784.9 | 799.0 | 798 | 8.95 | 1.12 |
| 59-4-6 | 1 | 1066.8 | 1041.7 | 1037.2 | 1061.1 | 1034.4 | 1048 | 14.71 | 1.40 |
| | 2 | 1181.3 | 1176.6 | 1173.4 | 1100.9 | 1144.5 | 1155 | 33.66 | 2.91 |
| 59-5-1 | 1 | 2362.4 | 2307.8 | 2161.6 | 2207.4 | 2345.6 | 2277 | 88.21 | 3.87 |
| | 2 | 2335.4 | 2237.8 | 2263.8 | 2254.9 | 2193.8 | 2257 | 51.39 | 2.28 |
| 59-5-2 | 1 | 1452.4 | 1414.1 | 1384.0 | 1411.1 | 1366.0 | 1406 | 32.89 | 2.34 |
| | 2 | 1329.0 | 1237.0 | 1275.5 | 1301.6 | 1260.4 | 1281 | 35.76 | 2.79 |
| 59-6-1 | 1 | 1879.9 | 1823.9 | 1929.2 | 1782.3 | 1829.5 | 1849 | 56.68 | 3.07 |
| | 2 | 1917.0 | 1932.0 | 1843.2 | 1970.1 | 1884.6 | 1909 | 48.09 | 2.52 |

## TABLE A.3
## IDT Results for US-59 in Neosho County, Continued

| Specimen | Trial No | Modulus by Cycle (ksi) Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| 59-7-1 | 1 | 2354.6 | 2254.1 | 2243.3 | 2369.2 | 2342.3 | 2313 | 59.30 | 2.56 |
| | 2 | 2084.8 | 2117.9 | 2164.0 | 2183.5 | 2061.0 | 2122 | 51.64 | 2.43 |
| 59-7-2 | 1 | 913.5 | 894.6 | 881.8 | 866.7 | | 889 | 19.84 | 2.23 |
| | 2 | 1068.1 | 1038.9 | 1032.7 | 1011.9 | | 1038 | 23.23 | 2.24 |
| 59-7-3 | 1 | 735.3 | 735.5 | 734.8 | 725.4 | 730.8 | 732 | 4.33 | 0.59 |
| | 2 | 760.8 | 755.1 | 749.0 | 746.9 | 724.6 | 747 | 13.80 | 1.85 |
| 59-7-4 | 1 | 570.5 | 548.5 | 546.2 | 539.7 | 531.6 | 547 | 14.54 | 2.66 |
| | 2 | 630.2 | 597.0 | 601.9 | 587.5 | 582.8 | 600 | 18.54 | 3.09 |
| 59-7-5 | 1 | 1032.4 | 984.1 | 988.3 | 974.8 | 986.0 | 993 | 22.53 | 2.27 |
| | 2 | 823.0 | 822.8 | 809.2 | 809.6 | 809.0 | 815 | 7.46 | 0.92 |
| 59-7-6 | 1 | 1614.1 | 1635.0 | 1576.9 | 1649.4 | 1606.4 | 1616 | 27.82 | 1.72 |
| | 2 | 1450.9 | 1437.9 | 1490.7 | 1437.7 | 1467.2 | 1457 | 22.43 | 1.54 |
| 59-8-1 | 1 | 2266.9 | 2245.3 | 2371.7 | 2260.8 | 2351.9 | 2299 | 58.00 | 2.52 |
| | 2 | 2122.0 | 1981.0 | 1954.1 | 1988.1 | 2004.2 | 2010 | 65.22 | 3.25 |
| 59-8-2 | 1 | 1657.5 | 1567.9 | 1543.3 | 1606.1 | 1521.5 | 1579 | 53.89 | 3.41 |
| | 2 | 1489.5 | 1433.6 | 1397.3 | 1409.4 | 1378.0 | 1422 | 43.00 | 3.02 |
| 59-8-3 | 1 | 821.6 | 804.8 | 785.6 | 768.8 | 752.8 | 787 | 27.47 | 3.49 |
| | 2 | 871.4 | 859.3 | 852.7 | 830.1 | 842.3 | 851 | 15.82 | 1.86 |
| 59-8-4 | 1 | 657.7 | 634.0 | 624.2 | 617.5 | 614.1 | 630 | 17.49 | 2.78 |
| | 2 | 534.9 | 511.2 | 495.6 | 488.4 | 494.6 | 505 | 18.72 | 3.71 |
| 59-9-1 | 1 | 1813.2 | 1705.9 | 1786.4 | 1775.2 | 1684.4 | 1753 | 55.13 | 3.15 |
| | 2 | 1613.5 | 1567.0 | 1565.2 | 1570.7 | 1600.9 | 1583 | 22.23 | 1.40 |
| 59-9-2 | 1 | 1330.6 | 1284.6 | 1254.1 | 1214.9 | 1207.0 | 1258 | 51.16 | 4.07 |
| | 2 | 1318.7 | 1275.0 | 1255.4 | 1246.4 | 1235.4 | 1266 | 32.75 | 2.59 |
| 59-9-3 | 1 | 885.8 | 890.5 | 867.6 | 867.4 | 861.8 | 875 | 12.68 | 1.45 |
| | 2 | 873.7 | 869.3 | 844.5 | 842.1 | 858.2 | 858 | 14.22 | 1.66 |
| 59-9-4 | 1 | 1003.1 | 975.2 | 987.5 | 981.5 | 958.0 | 981 | 16.54 | 1.69 |
| | 2 | 818.4 | 803.9 | 819.4 | 831.7 | 834.6 | 822 | 12.24 | 1.49 |
| 59-10-1 | 1 | 2901.0 | 2866.0 | 2475.3 | 2649.4 | 2463.8 | 2671 | 207.71 | 7.78 |
| | 2 | 2619.2 | 2459.6 | 2590.1 | 2679.1 | 2775.0 | 2625 | 116.24 | 4.43 |
| 59-10-2 | 1 | 2796.3 | 2796.2 | 2894.3 | 2828.1 | 2820.1 | 2827 | 40.21 | 1.42 |
| | 2 | 2388.3 | 2361.8 | 2313.7 | 2359.0 | 2321.4 | 2349 | 30.90 | 1.32 |
| 59-10-3 | 1 | 979.3 | 969.1 | 981.8 | 976.1 | 972.2 | 976 | 5.16 | 0.53 |
| | 2 | 966.9 | 956.1 | 945.3 | 915.1 | 925.3 | 942 | 21.39 | 2.27 |
| 59-10-4 | 1 | 536.4 | 506.0 | 494.0 | 480.4 | 481.3 | 500 | 23.09 | 4.62 |
| | 2 | 508.6 | 493.8 | 488.2 | 485.9 | 479.6 | 491 | 10.98 | 2.23 |

## TABLE A.4
## IDT Results for US-169 in Miami County

| Specimen | Trial No | Modulus by Cycle (ksi) | | | | | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| | | Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | | | |
| 169-1-1 | 1 | 4471.4 | 4393.1 | 4474.3 | 4299.6 | 4340.6 | 4396 | 77.8 | 1.8 |
| | 2 | 4568.8 | 4632.2 | 4547.9 | 4361.9 | 4468.1 | 4516 | 104.1 | 2.3 |
| 169-1-2 | 1 | 4224.5 | 4280.7 | 4179.8 | 4053.5 | 4034.3 | 4155 | 107.4 | 2.6 |
| | 2 | 3966.9 | 4128.9 | 4419.6 | 4219.6 | 4144.9 | 4176 | 164.5 | 3.9 |
| 169-1-3 | 1 | 5699.6 | 5730.6 | 5806.7 | 5350.2 | 5949.1 | 5707 | 221.6 | 3.9 |
| | 2 | 6037.1 | 5724.2 | 5738.0 | 6228.4 | 5820.7 | 5910 | 217.7 | 3.7 |
| 169-1-4 | 1 | 5748.3 | 5775.2 | 5909.3 | 5598.4 | 5411.0 | 5688 | 190.4 | 3.3 |
| | 2 | 5747.2 | 5664.0 | 6021.8 | 5394.9 | 5870.4 | 5740 | 235.2 | 4.1 |
| 169-1-5 | 1 | 6137.5 | 5990.6 | 5952.4 | 6219.5 | 6111.1 | 6082 | 109.5 | 1.8 |
| | 2 | 6688.4 | 5935.8 | 6330.1 | 5979.1 | 6043.3 | 6195 | 315.6 | 5.1 |
| 169-1-6 | 1 | 7350.4 | 8257.8 | 7674.9 | 7868.2 | 7776.9 | 7786 | 328.4 | 4.2 |
| | 2 | 8444.7 | 7468.5 | 8168.7 | 7686.3 | 7794.1 | 7912 | 390.9 | 4.9 |
| 169-2-1 | 1 | 3036.6 | 3203.8 | 3196.9 | 2830.7 | 2907.4 | 3035 | 167.9 | 5.5 |
| | 2 | 2944.8 | 3009.5 | 2866.3 | 3020.3 | 2817.4 | 2932 | 88.6 | 3.0 |
| 169-2-2 | 1 | 3768.9 | 3901.2 | 3941.4 | 3694.9 | 3861.4 | 3834 | 100.5 | 2.6 |
| | 2 | 3886.7 | 3770.4 | 3919.4 | 3759.4 | 4026.2 | 3872 | 110.9 | 2.9 |
| 169-2-3 | 1 | 4300.7 | 4144.9 | 4337.0 | 4197.6 | 4416.2 | 4279 | 108.7 | 2.5 |
| | 2 | 4177.4 | 4228.7 | 4039.6 | 4189.0 | 4084.9 | 4144 | 78.6 | 1.9 |
| 169-2-4 | 1 | 4158.7 | 3859.8 | 4157.9 | 3908.0 | 3966.6 | 4010 | 140.4 | 3.5 |
| | 2 | 3980.9 | 3952.1 | 3845.8 | 3905.1 | 3819.1 | 3901 | 68.5 | 1.8 |
| 169-2-5 | 1 | 6254.2 | 5607.2 | 6190.4 | 5323.9 | 5612.8 | 5798 | 405.5 | 7.0 |
| | 2 | 5955.3 | 5934.6 | 5587.8 | 6087.2 | 5984.6 | 5910 | 189.4 | 3.2 |
| 169-2-6 | 1 | 5748.4 | 5777.5 | 5792.6 | 5490.7 | 5715.0 | 5705 | 123.3 | 2.2 |
| | 2 | 5686.7 | 5775.4 | 5199.5 | 5593.6 | 6230.7 | 5697 | 370.6 | 6.5 |
| 169-3-1 | 1 | 4534.4 | 4524.4 | 4784.0 | 4527.9 | 4289.5 | 4532 | 174.9 | 3.9 |
| | 2 | 4580.6 | 4471.4 | 4424.1 | 4730.5 | 4439.7 | 4529 | 128.0 | 2.8 |
| 169-3-2 | 1 | 6205.0 | 6164.3 | 6185.0 | 6331.0 | 5930.5 | 6163 | 145.4 | 2.4 |
| | 2 | 6142.5 | 6163.2 | 6692.2 | 5903.1 | 6148.3 | 6210 | 290.4 | 4.7 |
| 169-3-3 | 1 | 6890.6 | 6762.8 | 6641.6 | 7566.0 | 6971.9 | 6967 | 357.9 | 5.1 |
| | 2 | 6391.3 | 7255.3 | 6863.0 | 6725.9 | 6595.9 | 6766 | 323.9 | 4.8 |
| 169-3-4 | 1 | 6577.9 | 6088.7 | 6791.9 | 6452.5 | 5962.8 | 6375 | 343.8 | 5.4 |
| | 2 | 6117.5 | 6685.6 | 6172.6 | 6005.1 | 6597.2 | 6316 | 305.1 | 4.8 |
| 169-3-5 | 1 | 6415.8 | 6114.6 | 6195.4 | 5804.9 | 6355.0 | 6177 | 240.5 | 3.9 |
| | 2 | 5955.5 | 5764.1 | 6194.2 | 6220.7 | 5754.4 | 5978 | 224.7 | 3.8 |
| 169-4-1 | 1 | 3060.8 | 2970.3 | 3133.7 | 2851.3 | 2854.5 | 2974 | 124.9 | 4.2 |
| | 2 | 3073.1 | 3000.0 | 2872.6 | 2962.1 | 3042.7 | 2990 | 78.0 | 2.6 |
| 169-4-2 | 1 | 4015.4 | 3925.8 | 3657.3 | 3828.6 | 4041.8 | 3894 | 156.4 | 4.0 |
| | 2 | 4206.2 | 3973.4 | 4070.6 | 4169.5 | 3905.6 | 4065 | 127.2 | 3.1 |
| 169-4-3 | 1 | 8198.1 | 7020.2 | 8281.3 | 6897.1 | 7243.1 | 7528 | 662.1 | 8.8 |
| | 2 | 7486.8 | 7531.8 | 8167.8 | 7143.0 | 6831.9 | 7432 | 499.5 | 6.7 |
| 169-4-4 | 1 | 6597.4 | 6500.3 | 6602.6 | 6772.4 | 6355.3 | 6566 | 153.0 | 2.3 |
| | 2 | 6467.4 | 6168.7 | 7148.8 | 6022.9 | 6355.3 | 6433 | 435.2 | 6.8 |
| 169-4-5 | 1 | 6073.0 | 6040.6 | 6235.1 | 6254.8 | 6254.8 | 6172 | 105.8 | 1.7 |
| | 2 | 5839.4 | 6038.3 | 5679.7 | 6448.7 | 5861.3 | 5973 | 294.5 | 4.9 |

## TABLE A.4
## IDT Results for US-169 in Miami County, Continued

| Specimen | Trial No | Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| | | Modulus by Cycle (ksi) | | | | | | | |
| 169-5-1 | 1 | 3962.1 | 4013.5 | 3899.3 | 3731.7 | 3837.8 | 3889 | 109.9 | 2.8 |
| | 2 | 3852.8 | 3959.6 | 3868.4 | 3782.6 | 4053.3 | 3903 | 104.9 | 2.7 |
| 169-5-2 | 1 | 3189.8 | 3133.4 | 2994.8 | 3000.4 | 3067.8 | 3077 | 84.6 | 2.7 |
| | 2 | 3298.1 | 3195.1 | 3217.3 | 2916.3 | 3068.4 | 3139 | 149.3 | 4.8 |
| 169-5-3 | 1 | 7007.1 | 7200.9 | 6980.2 | 7075.2 | 7164.5 | 7086 | 96.0 | 1.4 |
| | 2 | 7614.1 | 6805.3 | 7299.2 | 6902.7 | 7234.4 | 7171 | 325.0 | 4.5 |
| 169-5-4 | 1 | 5955.8 | 6036.1 | 5716.2 | 5741.7 | 5592.7 | 5808 | 182.4 | 3.1 |
| | 2 | 6058.9 | 5802.7 | 5667.3 | 5633.8 | 6256.4 | 5884 | 267.2 | 4.5 |
| 169-5-5 | 3 | 5815.5 | 5624.9 | 5488.9 | 5650.1 | 5865.5 | 5689 | 152.3 | 2.7 |
| | 4 | 5963.6 | 5414.4 | 5740.8 | 5503.1 | 5060.4 | 5536 | 341.6 | 6.2 |
| 169-5-6 | 5 | 6038.6 | 6118.8 | 6614.1 | 5795.4 | 6064.2 | 6126 | 299.6 | 4.9 |
| | 6 | 6077.7 | 6397.6 | 5871.5 | 6379.8 | 5903.3 | 6126 | 252.4 | 4.1 |
| 169-6-1 | 1 | 3072.6 | 2944.2 | 3101.5 | 3025.6 | 3116.5 | 3052 | 69.6 | 2.3 |
| | 2 | 3099.3 | 3206.1 | 3164.5 | 3072.7 | 2999.5 | 3108 | 80.5 | 2.6 |
| 169-6-2 | 1 | 3129.4 | 3222.7 | 4989.2 | 3034.5 | | 3594 | 933.3 | 26.0 |
| | 2 | 3262.7 | 3071.6 | 3008.0 | 3101.9 | 3068.4 | 3103 | 95.8 | 3.1 |
| 169-6-3 | 1 | 1920.9 | 1798.4 | 1735.1 | 1598.3 | | 1763 | 134.3 | 7.6 |
| | 2 | 1830.9 | 1697.9 | 1683.9 | 1875.2 | | 1772 | 95.5 | 5.4 |
| 169-6-4 | 1 | 2188.4 | 2008.0 | 1949.4 | 1988.9 | 2078.1 | 2043 | 93.9 | 4.6 |
| | 2 | 2188.3 | 2218.6 | 2251.3 | 2273.0 | | 2233 | 37.2 | 1.7 |
| 169-6-5 | 1 | 5609.4 | 5272.4 | 5374.7 | 5150.1 | | 5352 | 194.8 | 3.6 |
| | 2 | 5289.8 | 5160.9 | 5456.0 | 4870.2 | 4929.6 | 5141 | 244.9 | 4.8 |
| 169-6-6 | 1 | 4931.8 | 5139.5 | 5052.0 | 5188.7 | 4840.9 | 5031 | 144.1 | 2.9 |
| | 2 | 5279.3 | 5267.0 | 5062.0 | 5127.8 | 5037.5 | 5155 | 113.1 | 2.2 |
| 169-7-1 | 1 | 1203.4 | 1175.9 | 1154.3 | 1147.3 | 1136.4 | 1163 | 26.6 | 2.3 |
| | 2 | 1249.5 | 1221.7 | 1187.6 | 1197.7 | 1176.6 | 1207 | 29.2 | 2.4 |
| 169-7-2 | 1 | 1104.7 | 1081.9 | 1092.3 | 1102.0 | | 1095 | 10.4 | 0.9 |
| | 2 | 1009.2 | 1033.2 | 959.5 | 956.6 | | 990 | 37.8 | 3.8 |
| 169-7-3 | 1 | 2134.6 | 2014.1 | 1998.0 | 2052.5 | 2157.6 | 2071 | 71.5 | 3.5 |
| | 2 | 1747.2 | 1768.5 | 1769.6 | 1769.1 | 1780.6 | 1767 | 12.1 | 0.7 |
| 169-7-5 | 1 | 2016.7 | 2064.7 | 2041.6 | 2031.8 | 1886.0 | 2008 | 70.5 | 3.5 |
| | 2 | 1781.2 | 1791.2 | 1733.2 | 1826.7 | 1782.3 | 1783 | 33.4 | 1.9 |
| 169-7-6 | 1 | 2133.0 | 2193.4 | 2155.7 | 2186.8 | 2173.5 | 2168 | 24.5 | 1.1 |
| | 2 | 2111.2 | 2062.6 | 2007.8 | 1990.6 | | 2043 | 54.9 | 2.7 |
| 169-8-1 | 1 | 2185.7 | 2120.1 | 2112.8 | 2128.9 | 2129.7 | 2135 | 28.9 | 1.4 |
| | 2 | 1550.5 | 1555.1 | 1535.2 | 1503.9 | 1493.0 | 1528 | 27.8 | 1.8 |
| 169-8-2 | 1 | 1581.5 | 1525.2 | 1603.3 | 1549.6 | 1608.9 | 1574 | 35.7 | 2.3 |
| | 2 | 1557.7 | 1559.8 | 1565.9 | 1552.7 | 1492.0 | 1546 | 30.4 | 2.0 |
| 169-8-3 | 1 | 2117.7 | 2002.8 | 1957.4 | 1898.8 | 1870.7 | 1969 | 97.4 | 4.9 |
| | 2 | 2149.2 | 2100.1 | 2021.1 | 1941.6 | 1933.2 | 2029 | 95.4 | 4.7 |
| 169-8-4 | 1 | 2716.6 | 2702.8 | 2734.2 | 2703.0 | 2755.3 | 2722 | 22.4 | 0.8 |
| | 2 | 4895.7 | 4863.9 | 5027.7 | | | 4929 | 86.9 | 1.8 |
| 169-8-5 | 1 | 2617.2 | 2533.2 | 2521.5 | 2695.6 | | 2592 | 81.2 | 3.1 |
| | 2 | 2173.7 | 2201.9 | 2153.6 | 2163.4 | | 2173 | 20.8 | 1.0 |
| 169-8-6 | 1 | 2479.4 | 2485.9 | 2505.4 | 2494.3 | 2529.8 | 2499 | 19.8 | 0.8 |
| | 2 | 2702.3 | 2664.4 | 2533.2 | 2620.6 | 2558.5 | 2616 | 70.6 | 2.7 |

## TABLE A.4
## IDT Results for US-169 in Miami County, Continued

| | | Modulus by Cycle (ksi) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Specimen | Trial No | Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | Mr ave (ksi) | Std. Dev. | C.V. |
| 169-9-1 | 1 | 2179.8 | 2079.5 | 1997.8 | 1993.3 | 2048.6 | 2060 | 76.1 | 3.7 |
| | 2 | 1487.2 | 1502.0 | 1416.7 | 1421.5 | 1472.6 | 1460 | 38.8 | 2.7 |
| 169-9-2 | 1 | 1558.3 | 1622.7 | 1474.7 | 1401.3 | 1405.7 | 1493 | 96.8 | 6.5 |
| | 2 | 2160.9 | 1830.8 | 1849.2 | 1862.9 | 1889.7 | 1919 | 137.1 | 7.1 |
| 169-9-3 | 1 | 2347.2 | 2210.5 | 2157.6 | 2298.7 | | 2253 | 85.4 | 3.8 |
| | 2 | 2679.7 | 2570.4 | 2466.2 | 2667.1 | | 2596 | 99.3 | 3.8 |
| 169-9-4 | 1 | 2275.4 | 2376.8 | 2292.4 | 2369.8 | 2281.0 | 2319 | 49.9 | 2.2 |
| | 2 | 1955.0 | 1962.8 | 2070.4 | 2090.1 | 2045.9 | 2025 | 62.3 | 3.1 |
| 169-9-5 | 1 | 1722.2 | 1650.4 | 1747.0 | 1706.8 | 1766.1 | 1719 | 44.3 | 2.6 |
| | 2 | 1998.2 | 1898.4 | 1929.8 | 1903.6 | 1943.4 | 1935 | 40.1 | 2.1 |
| 169-9-6 | 1 | 1778.0 | 1741.0 | 1829.9 | 1751.8 | 1841.2 | 1788 | 45.3 | 2.5 |
| | 2 | 1901.3 | 1827.6 | 1733.4 | 1804.4 | 1781.9 | 1810 | 61.9 | 3.4 |
| 169-10-1 | 1 | 1146.2 | 1149.2 | 1143.9 | 1112.5 | 1093.2 | 1129 | 24.9 | 2.2 |
| | 2 | 1137.9 | 1166.7 | 1139.4 | 1105.4 | 1140.3 | 1138 | 21.8 | 1.9 |
| 169-10-2 | 1 | 1178.7 | 1220.2 | 1156.7 | 1190.7 | 1211.6 | 1192 | 25.5 | 2.1 |
| | 2 | 1634.0 | 1566.9 | 1561.7 | 1576.1 | 1590.3 | 1586 | 29.1 | 1.8 |
| 169-10-3 | 1 | 3218.8 | 3146.3 | 3157.0 | 2917.3 | 3010.9 | 3090 | 122.8 | 4.0 |
| | 2 | 2510.4 | 2333.7 | 2422.7 | 2420.3 | 2528.5 | 2443 | 78.6 | 3.2 |
| 169-10-4 | 1 | 2877.1 | 2748.5 | 2876.5 | 2774.2 | 2661.7 | 2788 | 91.5 | 3.3 |
| | 2 | 3206.9 | 2950.9 | 3063.2 | 2948.2 | 3014.5 | 3037 | 106.5 | 3.5 |
| 169-10-5 | 1 | 3437.1 | 3728.3 | 3371.6 | 3115.9 | 3227.1 | 3376 | 233.3 | 6.9 |
| | 2 | 3130.1 | 2941.8 | 2834.0 | 2815.9 | 2810.1 | 2906 | 136.0 | 4.7 |
| 169-10-6 | 1 | 3767.7 | 3656.4 | 3660.7 | 3574.3 | 3544.8 | 3641 | 87.1 | 2.4 |
| | 2 | 3428.2 | 3366.2 | 3277.0 | 3286.9 | 3449.6 | 3362 | 79.0 | 2.3 |

## TABLE A.5
## IDT Results for K-4 in Jefferson County

| Specimen | Trial No | Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| | | Modulus by Cycle (ksi) | | | | | | | |
| 4-1-1 | 1 | 3897.1 | 3840.6 | 3705.9 | 3757.0 | 3656.5 | 3771 | 97.9 | 2.6 |
| | 2 | 3713.8 | 3838.4 | 3553.6 | 3578.2 | 3843.9 | 3706 | 138.0 | 3.7 |
| 4-1-3 | 1 | 3140.3 | 3385.0 | 3536.9 | 3464.3 | 3548.9 | 3415 | 167.0 | 4.9 |
| | 2 | 3553.9 | 3430.7 | 3434.8 | 3274.4 | 3314.3 | 3402 | 110.6 | 3.3 |
| 4-2-1 | 1 | 2598.1 | 2622.3 | 2543.1 | 2607.9 | 2634.2 | 2601 | 35.2 | 1.4 |
| | 2 | 2896.4 | 2831.0 | 2775.2 | 2780.3 | 2710.5 | 2799 | 69.4 | 2.5 |
| 4-2-2 | 1 | 2833.4 | 2790.1 | 2641.0 | 2767.1 | 2858.2 | 2778 | 84.4 | 3.0 |
| | 2 | 2950.9 | 3162.7 | 3064.2 | 2861.1 | 3034.4 | 3015 | 114.5 | 3.8 |
| 4-2-3 | 1 | 2897.3 | 3031.0 | 3053.0 | 2980.9 | 2948.0 | 2982 | 62.8 | 2.1 |
| | 2 | 3249.5 | 3204.3 | 3204.1 | 3025.3 | 3104.9 | 3158 | 90.9 | 2.9 |
| 4-2-4 | 1 | 2129.9 | 2048.3 | 2076.1 | 2036.2 | 2047.5 | 2068 | 37.8 | 1.8 |
| | 2 | 1832.9 | 1813.6 | 1871.9 | 1713.4 | 1803.4 | 1807 | 58.5 | 3.2 |
| 4-3-2 | 1 | 2803.5 | 2736.8 | 2716.8 | 2945.0 | 2775.9 | 2796 | 90.0 | 3.2 |
| | 2 | 2579.9 | 2643.3 | 2665.2 | 2673.1 | 2612.9 | 2635 | 38.6 | 1.5 |
| 4-3-3 | 1 | 2227.8 | 2136.8 | 2147.9 | 2227.3 | 2207.8 | 2190 | 44.0 | 2.0 |
| | 2 | 2309.8 | 2297.4 | 2312.4 | 2285.3 | 2272.2 | 2295 | 16.9 | 0.7 |
| 4-3-4 | 1 | 2981.1 | 2906.8 | 2845.5 | 2831.4 | 2862.6 | 2885 | 60.5 | 2.1 |
| | 2 | 1934.3 | 1960.5 | 1870.0 | 1857.1 | 1939.0 | 1912 | 45.7 | 2.4 |
| 4-4-1 | 1 | 2350.6 | 2313.1 | 2333.1 | 2337.2 | 2287.6 | 2324 | 24.5 | 1.1 |
| | 2 | 2198.3 | 2201.9 | 2188.4 | 2199.2 | 2156.9 | 2189 | 18.6 | 0.8 |
| 4-4-2 | 1 | 2239.7 | 2161.3 | 2247.7 | 2088.2 | 2081.4 | 2164 | 79.6 | 3.7 |
| | 2 | 1825.3 | 1852.2 | 1778.3 | 1785.1 | 1803.8 | 1809 | 30.3 | 1.7 |
| 4-4-3 | 1 | 2489.3 | 2565.5 | 2459.4 | 2418.2 | 2584.3 | 2503 | 70.4 | 2.8 |
| | 2 | 2185.0 | 2149.0 | 2026.9 | 2061.7 | 2006.7 | 2086 | 77.7 | 3.7 |
| 4-4-4 | 1 | 2414.1 | 2398.6 | 2245.4 | 2367.2 | 2317.7 | 2349 | 68.5 | 2.9 |
| | 2 | 3067.8 | 3037.7 | 3037.4 | 3057.1 | 3092.9 | 3059 | 23.2 | 0.8 |
| 4-5-1 | 1 | 3069.7 | 3049.8 | 2998.1 | 3112.2 | 3023.2 | 3051 | 43.8 | 1.4 |
| | 2 | 2614.7 | 2566.0 | 2641.4 | 2865.6 | 2711.4 | 2680 | 116.4 | 4.3 |
| 4-5-2 | 1 | 3310.1 | 3409.6 | 3225.3 | 3253.3 | 3387.1 | 3317 | 80.6 | 2.4 |
| | 2 | 2809.5 | 2746.8 | 2975.8 | 2829.2 | 2852.8 | 2843 | 84.1 | 3.0 |
| 4-5-3 | 1 | 2550.1 | 2361.2 | 2619.0 | 2357.6 | 2403.6 | 2458 | 119.2 | 4.8 |
| | 2 | 2579.7 | 2509.7 | 2359.0 | 2330.6 | 2564.4 | 2469 | 116.5 | 4.7 |
| 4-5-4 | 1 | 2358.4 | 2142.8 | 2350.6 | 2149.5 | 2307.1 | 2262 | 107.3 | 4.7 |
| | 2 | 2692.0 | 2537.2 | 2570.7 | 2565.6 | 2573.5 | 2588 | 60.0 | 2.3 |
| 4-6-2 | 1 | 1887.6 | 1871.7 | 1931.8 | 1954.8 | 1855.5 | 1900 | 41.7 | 2.2 |
| | 2 | 2583.4 | 2651.6 | 2536.1 | 2617.1 | 2473.2 | 2572 | 69.9 | 2.7 |
| 4-6-3 | 1 | 2526.0 | 2535.2 | 2459.0 | 2445.1 | 2413.6 | 2476 | 52.8 | 2.1 |
| | 2 | 2151.7 | 2122.2 | 2062.3 | 2095.6 | 2134.5 | 2113 | 35.1 | 1.7 |
| 4-6-4 | 1 | 2454.3 | 2408.7 | 2452.1 | 2546.7 | 2497.0 | 2472 | 52.2 | 2.1 |
| | 2 | 1970.7 | 2105.3 | 2143.7 | 1977.1 | 2038.1 | 2047 | 76.7 | 3.7 |
| 4-7-2 | 1 | 2233.3 | 2383.3 | 2366.1 | 2274.6 | 2245.5 | 2301 | 69.6 | 3.0 |
| | 2 | 2341.8 | 2403.1 | 2380.4 | 2340.9 | 2193.8 | 2332 | 81.7 | 3.5 |
| 4-7-3 | 1 | 3325.9 | 3145.7 | 3279.7 | 3254.9 | 3444.0 | 3290 | 108.6 | 3.3 |
| | 2 | 2195.8 | 2189.2 | 2124.2 | 2117.4 | 2201.6 | 2166 | 41.3 | 1.9 |
| 4-7-4 | 1 | 2937.2 | 2846.1 | 2680.7 | 2542.0 | 2501.4 | 2701 | 188.7 | 7.0 |
| | 2 | 2273.1 | 2247.5 | 2225.3 | 2201.3 | 2298.6 | 2249 | 38.3 | 1.7 |

## TABLE A.5
## IDT Results for K-4 in Jefferson County, Continued

| Specimen | Trial No | Modulus by Cycle (ksi) | | | | | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| | | Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | | | |
| 4-8-1 | 1 | 3286.0 | 3599.7 | 3670.8 | 3543.4 | 3465.6 | 3513 | 147.6 | 4.2 |
| | 2 | 2647.1 | 2434.6 | 2446.0 | 2764.3 | 2589.5 | 2576 | 139.2 | 5.4 |
| 4-8-3 | 1 | 2292.7 | 2301.4 | 2373.5 | 2257.8 | 2299.4 | 2305 | 42.2 | 1.8 |
| | 2 | 2179.2 | 2197.4 | 2188.5 | 2226.3 | 2243.2 | 2207 | 26.9 | 1.2 |
| 4-8-4 | 1 | 2233.8 | 2108.5 | 2236.1 | 2129.1 | 2157.8 | 2173 | 59.1 | 2.7 |
| | 2 | 2408.2 | 2329.7 | 2238.9 | 2263.1 | 2441.6 | 2336 | 88.2 | 3.8 |
| 4-9-1 | 3 | 2552.1 | 2460.0 | 2478.4 | 2409.5 | 2358.4 | 2452 | 73.1 | 3.0 |
| | 4 | 2436.2 | 2416.0 | 2372.2 | 2375.3 | 2364.1 | 2393 | 31.5 | 1.3 |
| 4-9-2 | 5 | 2582.8 | 2778.1 | 2649.6 | 2744.4 | 2595.4 | 2670 | 87.8 | 3.3 |
| | 6 | 2246.3 | 2272.1 | 2280.4 | 2374.5 | 2192.2 | 2273 | 66.3 | 2.9 |
| 4-9-3 | 1 | 2289.1 | 2094.6 | 2172.9 | 2144.9 | 2133.9 | 2167 | 73.8 | 3.4 |
| | 2 | 1916.6 | 1810.7 | 1777.5 | 1716.6 | 1792.5 | 1803 | 72.8 | 4.0 |
| 4-9-4 | 1 | 1978.9 | 1915.4 | 2030.9 | 1983.2 | 2047.5 | 1991 | 51.7 | 2.6 |
| | 2 | 2293.4 | 2220.1 | 2180.0 | 2233.8 | 2177.5 | 2221 | 47.4 | 2.1 |
| 4-10-1 | 1 | 2612.1 | 2362.5 | 2617.6 | 2618.5 | 2446.2 | 2531 | 119.7 | 4.7 |
| | 2 | 2724.3 | 2564.5 | 2571.5 | 2505.6 | 2730.6 | 2619 | 102.0 | 3.9 |
| 4-10-2 | 1 | 1209.0 | 1161.8 | 1172.6 | 1185.2 | 1164.4 | 1179 | 19.3 | 1.6 |
| | 2 | 1549.0 | 1468.4 | 1483.7 | 1520.4 | 1482.2 | 1501 | 33.1 | 2.2 |
| 4-10-3 | 1 | 1806.1 | 1729.1 | 1731.4 | 1733.4 | 1719.6 | 1744 | 35.2 | 2.0 |
| | 2 | 2803.7 | 2654.9 | 2767.3 | 2539.6 | 2625.3 | 2678 | 107.5 | 4.0 |
| 4-10-4 | 1 | 1156.1 | 1139.3 | 1116.9 | 1103.4 | 1042.3 | 1112 | 43.7 | 3.9 |
| | 2 | 1396.2 | 1379.9 | 1385.3 | 1348.2 | 1342.4 | 1370 | 23.8 | 1.7 |

## TABLE A.6
## IDT Results for K-141 in Ellsworth County

| Specimen | Trial No | Modulus by Cycle (ksi) Mr 1 | Mr 2 | Mr 3 | Mr 4 | Mr 5 | Mr ave (ksi) | Std. Dev. | C.V. |
|---|---|---|---|---|---|---|---|---|---|
| 141 1-1 | 1 | 2880.7 | 2925.3 | 2870.9 | 2972.0 | 2941.6 | 2918 | 42.2 | 1.4 |
| | 2 | 3216.5 | 2956.6 | 3199.0 | 3154.5 | 3098.6 | 3125 | 104.6 | 3.3 |
| 141 1-2 | 1 | 1947.3 | 1921.2 | 1921.9 | 1974.9 | 1893.0 | 1932 | 30.9 | 1.6 |
| | 2 | 2782.9 | 2749.5 | 2626.0 | 2698.1 | 2847.1 | 2741 | 83.9 | 3.1 |
| 141 2-1 | 1 | 3411.3 | 3267.2 | 3249.9 | 3184.8 | 3284.0 | 3279 | 82.8 | 2.5 |
| | 2 | 3507.1 | 3409.1 | 3633.4 | 3717.7 | 3436.8 | 3541 | 131.5 | 3.7 |
| 141 2-3 | 1 | 1511.4 | 1410.6 | 1382.3 | 1400.8 | 1433.3 | 1428 | 50.3 | 3.5 |
| | 2 | 1487.3 | 1443.0 | 1425.6 | 1445.3 | 1447.1 | 1450 | 22.7 | 1.6 |
| 141 2-4 | 1 | 681.3 | 643.5 | 620.1 | 593.8 | 570.6 | 622 | 43.1 | 6.9 |
| | 2 | 794.4 | 756.0 | 712.5 | 681.7 | 666.5 | 722 | 52.9 | 7.3 |
| 141 3-1 | 1 | 3055.1 | 3024.8 | 2959.7 | 2871.7 | 2818.9 | 2946 | 100.0 | 3.4 |
| | 2 | 2828.6 | 2820.5 | 2712.8 | 2727.8 | 2697.3 | 2757 | 62.3 | 2.3 |
| 141 4-1 | 1 | 2547.5 | 2460.7 | 2558.0 | 2491.9 | 2532.2 | 2518 | 40.7 | 1.6 |
| | 2 | 2577.4 | 2630.2 | 2713.5 | 2694.7 | 2683.6 | 2660 | 55.5 | 2.1 |
| 141 5-1 | 1 | 3093.2 | 2935.2 | 3002.5 | 2904.3 | 2883.1 | 2964 | 85.3 | 2.9 |
| | 2 | 3068.3 | 2860.3 | 2889.9 | 2914.2 | 2891.9 | 2925 | 82.4 | 2.8 |
| 141 5-2 | 1 | 1288.7 | 1263.7 | 1329.9 | 1265.9 | 1279.1 | 1285 | 26.9 | 2.1 |
| | 2 | 1341.0 | 1277.4 | 1310.4 | 1307.7 | 1304.7 | 1308 | 22.6 | 1.7 |
| 141 6-1 | 1 | 2290.0 | 2302.7 | 2231.5 | 2278.0 | 2236.8 | 2268 | 32.0 | 1.4 |
| | 2 | 2698.0 | 2630.2 | 2582.4 | 2400.5 | 2577.4 | 2578 | 110.3 | 4.3 |
| 141 6-2 | 1 | 1784.6 | 1842.0 | 1697.1 | 1709.2 | 1756.7 | 1758 | 58.9 | 3.3 |
| | 2 | 2001.5 | 1970.6 | 1884.6 | 1932.8 | 1958.9 | 1950 | 44.0 | 2.3 |
| 141 6-3 | 1 | 810.4 | 823.9 | 799.0 | 803.7 | 794.3 | 806 | 11.5 | 1.4 |
| | 2 | 908.3 | 897.1 | 919.9 | 901.7 | 882.0 | 902 | 14.0 | 1.5 |
| 141 7-1 | 1 | 2341.0 | 2328.8 | 2300.1 | 2423.4 | 2251.7 | 2329 | 63.0 | 2.7 |
| | 2 | 2465.5 | 2396.8 | 2493.9 | 2313.2 | 2495.7 | 2433 | 78.0 | 3.2 |
| 141 7-2 | 1 | 2014.4 | 2021.0 | 1974.9 | 2048.0 | 1965.2 | 2005 | 34.2 | 1.7 |
| | 2 | 2032.8 | 2008.5 | 2040.3 | 1965.5 | 2031.3 | 2016 | 30.4 | 1.5 |
| 141 8-1 | 1 | 2713.5 | 2758.1 | 2675.6 | 2769.2 | 2658.8 | 2715 | 48.8 | 1.8 |
| | 2 | 2874.6 | 2825.4 | 3069.4 | 2925.5 | 3026.7 | 2944 | 102.2 | 3.5 |
| 141 8-3 | 1 | 575.4 | 562.1 | 562.1 | 554.9 | | 564 | 8.6 | 1.5 |
| | 2 | 796.7 | 761.4 | 739.2 | 721.0 | 689.5 | 742 | 40.5 | 5.5 |
| 141 9-1 | 1 | 3404.9 | 3535.0 | 3265.0 | 3221.2 | 3170.4 | 3319 | 148.8 | 4.5 |
| | 2 | 3130.4 | 3123.0 | 3088.9 | 3148.4 | 3100.2 | 3118 | 23.8 | 0.8 |
| 141 9-2 | 1 | 2867.9 | 2810.7 | 2920.6 | 2771.4 | 2721.9 | 2819 | 78.2 | 2.8 |
| | 2 | 2382.9 | 2293.0 | 2393.3 | 2298.2 | 2325.9 | 2339 | 47.0 | 2.0 |
| 141 10-1 | 1 | 2150.9 | 1972.0 | 2691.0 | 2431.0 | 2305.9 | 2310 | 273.6 | 11.8 |
| | 2 | 2969.8 | 2711.6 | 2892.7 | 2957.8 | 2818.6 | 2870 | 107.1 | 3.7 |
| 141 10-2 | 1 | 1378.5 | 1362.0 | 1357.3 | 1339.3 | 1310.4 | 1349 | 25.9 | 1.9 |
| | 2 | 1669.2 | 1545.3 | 1552.3 | 1587.4 | 1586.4 | 1588 | 49.2 | 3.1 |
| 141 10-3 | 1 | 2147.0 | 2265.6 | 2166.8 | 2096.1 | 2168.0 | 2169 | 61.5 | 2.8 |
| | 2 | 1809.0 | 1852.6 | 1891.4 | 1886.0 | 1881.7 | 1864 | 34.3 | 1.8 |

# Appendix B: IDT Analyzed Layer Results

**TABLE B.1**
**IDT Results for I-70 in Trego County**

| Specimen | Layer Info | Year | Mr avg (ksi) | Mr for Core |
|---|---|---|---|---|
| 70-1-1-1 | BM1T, SRECYL | 2000 | 2,115 | 2241 |
| 70-1-2-1 | CRECYL | 2000 | 2,321 | |
| 70-1-1-2 | BM1T, SRECYL | 2000 | 2,469 | 2428 |
| 70-1-2-2 | CRECYL | 2000 | 2,765 | |
| 70-1-3-2 | HM3A | 1960 | 2,071 | |
| 70-2-1-1 | BM1T, SRECYL | 2000 | 2,574 | 2430 |
| 70-2-2-1 | CRECYL | 2000 | 3,196 | |
| 70-2-3-1 | HM3A | 1960 | 1,475 | |
| 70-2-1-2 | BM1T, SRECYL | 2000 | 2,816 | 2244 |
| 70-2-2-2 | CRECYL | 2000 | 2,456 | |
| 70-2-3-2 | HM3A | 1960 | 1,312 | |
| 70-3-1 | BM1T, SRECYL | 2000 | 3,180 | 2981 |
| 70-3-2 | CRECYL | 2000 | 2,903 | |
| 70-3-3 | HM3A | 1960 | 2,872 | |
| 70-4-1 | BM1T, SRECYL | 2000 | 2,972 | 2698 |
| 70-4-2 | CRECYL | 2000 | 2,980 | |
| 70-4-3 | HM3A | 1960 | 2,193 | |
| 70-5-1 | BM1T, SRECYL | 2000 | 3,900 | 2850 |
| 70-5-2 | CRECYL | 2000 | 3,017 | |
| 70-5-3 | HM3A | 1960 | 1,725 | |
| 70-6-2 | CRECYL | 2000 | 2,554 | 2005 |
| 70-6-3 | HM3A | 1960 | 1,467 | |
| 70-7-1 | BM1T, SRECYL | 2000 | 4,648 | 3451 |
| 70-7-2 | CRECYL | 2000 | 2,994 | |
| 70-7-3 | HM3A | 1960 | 2,761 | |
| 70-8-1 | BM1T, SRECYL | 2000 | 2,340 | 2439 |
| 70-8-2 | CRECYL | 2000 | 2,545 | |
| 70-8-3 | HM3A | 1960 | 2,430 | |
| 70-9-2 | CRECYL | 2000 | 2,049 | 2109 |
| 70-9-3 | HM3A | 1960 | 2,180 | |
| 70-10-2 | CRECYL | 2000 | 2,888 | 2422 |
| 70-10-3 | HM3A | 1960 | 1,926 | |

## TABLE B.2
## IDT Results for US-56 in Stevens County

| Specimen | Layer Info | Year | Mr avg (ksi) | Mr for Core |
|---|---|---|---|---|
| 56-1-1 | SM125A, SRECYL, | 2006 | 2,046 | 2121 |
| 56-1-2 | BM2A | 1999 | 2,731 | |
| 56-1-3 | CRECYL | 1999 | 2,283 | |
| 56-1-4 | HRECYL | 1992 | 1,424 | |
| 56-2-1 | SM125A, SRECYL, | 2006 | 2,516 | 2025 |
| 56-2-2 | BM2A | 1999 | 2,630 | |
| 56-2-3 | CRECYL | 1999 | 2,069 | |
| 56-2-4 | HRECYL | 1992 | 942 | |
| 56-3-1 | SM125A, SRECYL, | 2006 | 2,336 | 1934 |
| 56-3-2 | BM2A | 1999 | 1,826 | |
| 56-3-3 | CRECYL | 1999 | 2,133 | |
| 56-3-4 | HRECYL | 1992 | 1,431 | |
| 56-4-1 | SM125A, SRECYL, | 2006 | 2,497 | 1771 |
| 56-4-2 | BM2A | 1999 | 1,481 | |
| 56-4-3 | CRECYL | 1999 | 1,364 | |
| 56-5-1 | SM125A, SRECYL, | 2006 | 2,273 | 1853 |
| 56-5-2 | BM2A | 1999 | 1,855 | |
| 56-5-3 | CRECYL | 1999 | 2,099 | |
| 56-5-4 | HRECYL | 1992 | 1,190 | |
| 56-6-1 | SM125A, SRECYL, | 2006 | 1,815 | 1558 |
| 56-6-2 | BM2A | 1999 | 1,757 | |
| 56-6-3 | CRECYL | 1999 | 1,638 | |
| 56-6-4 | HRECYL | 1992 | 1,041 | |
| 56-7-1 | SM125A, SRECYL, | 2006 | 2,061 | 1585 |
| 56-7-2 | BM2A | 1999 | 1,969 | |
| 56-7-3 | CRECYL | 1999 | 1,585 | |
| 56-7-4 | HRECYL | 1992 | 736 | |
| 56-8-1 | SM125A, SRECYL, | 2006 | 1,966 | 1968 |
| 56-8-2 | BM2A | 1999 | 2,570 | |
| 56-8-3 | CRECYL | 1999 | 1,747 | |
| 56-8-4 | HRECYL | 1992 | 1,604 | |
| 56-9-1 | SM125A, SRECYL, | 2006 | 2,321 | 1804 |
| 56-9-2 | BM2A | 1999 | 2,030 | |
| 56-9-3 | CRECYL | 1999 | 1,829 | |
| 56-9-4 | HRECYL | 1992 | 1,037 | |
| 56-10-1 | SM125A, SRECYL, | 2006 | 2,095 | 1670 |
| 56-10-2 | BM2A | 1999 | 1,958 | |
| 56-10-3 | CRECYL | 1999 | 1,864 | |
| 56-10-4 | HRECYL | 1992 | 577 | |

## TABLE B.3
## IDT Results for US-59 in Neosho County

| Specimen | Layer Info | Year | Mr avg (ksi) | Mr for Core |
|---|---|---|---|---|
| 59-1-1 | SM95A, HRECYLCL, | 1993 | 2,129 | 1521 |
| 59-1-2 | BM3, HM3B, | 1976 | 1,460 | |
| 59-1-3 | ACB3 | 1961 | 1,004 | |
| 59-2-1 | SM95A, HRECYLCL, | 1993 | 2,143 | 1346 |
| 59-2-2 | BM3, HM3B, | 1976 | 1,228 | |
| 59-2-3 | ACB3 | 1961 | 636 | |
| 59-3-1 | SM95A, HRECYLCL, | 1993 | 1,430 | 1113 |
| 59-3-2 | BM3, HM3B, | 1976 | 1,397 | |
| 59-3-3 | ACB3 | 1961 | 1,193 | |
| 59-3-4 | AB3 | 1960 | 579 | |
| 59-4-1 | SM95A, HRECYLCL, | 1993 | 1,839 | 1081 |
| 59-4-2 | BM3, HM3B, | 1976 | 1,451 | |
| 59-4-3 | ACB3 | 1961 | 740 | |
| 59-4-4 | ACB3 | 1961 | 739 | |
| 59-4-5 | AB3 | 1960 | 790 | |
| 59-4-6 | AB3 | 1960 | 1,102 | |
| 59-5-1 | SM95A, HRECYLCL, | 1993 | 2,267 | 1835 |
| 59-5-2 | BM3, HM3B, | 1976 | 1,343 | |
| 59-6-1 | SM95A, HRECYLCL, | 1993 | 1,879 | 1879 |
| 59-7-1 | SM95A, HRECYLCL, | 1993 | 2,217 | 1168 |
| 59-7-2 | BM3, HM3B, | 1976 | 964 | |
| 59-7-3 | ACB3 | 1961 | 740 | |
| 59-7-4 | ACB3 | 1961 | 574 | |
| 59-7-5 | AB3 | 1960 | 904 | |
| 59-7-6 | AB3 | 1960 | 1,537 | |
| 59-8-1 | SM95A, HRECYLCL, | 1993 | 2,155 | 1228 |
| 59-8-2 | BM3, HM3B, | 1976 | 1,500 | |
| 59-8-3 | ACB3 | 1961 | 819 | |
| 59-8-4 | AB3 | 1960 | 567 | |
| 59-9-1 | SM95A, HRECYLCL, | 1993 | 1,668 | 1167 |
| 59-9-2 | BM3, HM3B, | 1976 | 1,262 | |
| 59-9-3 | ACB3 | 1961 | 866 | |
| 59-9-4 | AB3 | 1960 | 901 | |
| 59-10-1 | SM95A, HRECYLCL, | 1993 | 2,648 | 1626 |
| 59-10-2 | BM3, HM3B, | 1976 | 2,588 | |
| 59-10-3 | ACB3 | 1961 | 959 | |
| 59-10-4 | AB3 | 1960 | 495 | |

## TABLE B.4
## IDT Results for US-169 in Miami County

| Specimen | Layer Info | Year | Mr avg (ksi) | Mr for Core |
|---|---|---|---|---|
| 169-1-1 | SM-9.5T, SR-19B | 2002 | 4456 | 5678 |
| 169-1-2 | SR-19A | 2002 | 4165 | |
| 169-1-3 | ACB3 | 1973 | 5808 | |
| 169-1-4 | ACB-3 | 1973 | 5714 | |
| 169-1-5 | ACB-3 | 1973 | 6139 | |
| 169-1-6 | ACB-3 | 1973 | 7849 | |
| 169-2-1 | SM-9.5T, SR-19B | 2002 | 2983 | 4421 |
| 169-2-2 | SR-19A | 2002 | 3853 | |
| 169-2-3 | ACB3 | 1973 | 4212 | |
| 169-2-4 | ACB3 | 1973 | 3955 | |
| 169-2-5 | ACB3 | 1973 | 5854 | |
| 169-2-6 | ACB3 | 1973 | 5701 | |
| 169-3-1 | SM-9.5T, SR-19B | 2002 | 4531 | 6007 |
| 169-3-2 | SR-19A | 2002 | 6187 | |
| 169-3-3 | ACB3 | 1973 | 6866 | |
| 169-3-4 | ACB-3 | 1973 | 6345 | |
| 169-3-5 | ACB-3 | 1973 | 6077 | |
| 169-4-1 | SM-9.5T, SR-19B | 2002 | 2982 | 5391 |
| 169-4-2 | SR-19A | 2002 | 3979 | |
| 169-4-3 | ACB3 | 1973 | 7480 | |
| 169-4-4 | ACB3 | 1973 | 6499 | |
| 169-4-5 | ACB3 | 1973 | 6073 | |
| 169-5-1 | SM-9.5T, SR-19B | 2002 | 3896 | 5251 |
| 169-5-2 | SR-19A | 2002 | 3108 | |
| 169-5-3 | ACB3 | 1973 | 7128 | |
| 169-5-4 | ACB-3 | 1973 | 5846 | |
| 169-5-5 | ACB-3 | 1973 | 5613 | |
| 169-5-6 | ACB-3 | 1973 | 6126 | |
| 169-6-1 | SM-9.5T, SR-19B | 2002 | 3080 | 3385 |
| 169-6-2 | SR-19A | 2002 | 3348 | |
| 169-6-3 | ACB3 | 1973 | 1768 | |
| 169-6-4 | ACB3 | 1973 | 2138 | |
| 169-6-5 | ACB3 | 1973 | 5246 | |
| 169-6-6 | ACB3 | 1973 | 5093 | |
| 169-7-1 | SM-9.5T, SR-19B | 2002 | 1185 | 1619 |
| 169-7-2 | SR-19A | 2002 | 1042 | |
| 169-7-3 | ACB3 | 1973 | 1919 | |
| 169-7-5 | ACB-3 | 1973 | 1896 | |
| 169-7-6 | ACB-3 | 1973 | 2106 | |
| 169-8-1 | SM-9.5T, SR-19B | 2002 | 1832 | 2354 |
| 169-8-2 | SR-19A | 2002 | 1560 | |
| 169-8-3 | ACB3 | 1973 | 1999 | |
| 169-8-4 | ACB3 | 1973 | 3826 | |
| 169-8-5 | ACB3 | 1973 | 2382 | |
| 169-8-6 | ACB3 | 1973 | 2557 | |
| 169-9-1 | SM-9.5T, SR-19B | 2002 | 1760 | 1934 |
| 169-9-2 | SR-19A | 2002 | 1706 | |
| 169-9-3 | ACB3 | 1973 | 2425 | |
| 169-9-4 | ACB-3 | 1973 | 2172 | |
| 169-9-5 | ACB-3 | 1973 | 1827 | |
| 169-9-6 | ACB-3 | 1973 | 1799 | |
| 169-10-1 | SM-9.5T, SR-19B | 2002 | 1133 | 2409 |
| 169-10-2 | SR-19A | 2002 | 1389 | |
| 169-10-3 | ACB3 | 1973 | 2767 | |
| 169-10-4 | ACB3 | 1973 | 2912 | |
| 169-10-5 | ACB3 | 1973 | 3141 | |
| 169-10-6 | ACB3 | 1973 | 3501 | |

## TABLE B.5
## IDT Results for K-4 in Jefferson County

| Specimen | Layer Info | Year | Mr avg (ksi) | Mr for Core |
|---|---|---|---|---|
| K-4 1-1 | SR95T, SRECYCL | 2002 | 3,739 | 3570 |
| K-4 1-3 | HMSP | 1965 | 3,408 | |
| K-4 2-1 | SR95T, SRECYCL | 2002 | 2,700 | 2633 |
| K-4 2-2 | HRECYCL, BM2 | 1995 | 2,896 | |
| K-4 2-3 | HMSP | 1965 | 3,070 | |
| K-4 2-4 | ACB2R | 1965 | 1,937 | |
| K-4 3-2 | HRECYCL, BM2 | 1995 | 2,715 | 2454 |
| K-4 3-3 | HMSP | 1965 | 2,242 | |
| K-4 3-4 | ACB2R | 1965 | 2,399 | |
| K-4 4-1 | SR95T, SRECYCL | 2002 | 2,257 | 2417 |
| K-4 4-2 | HRECYCL, BM2 | 1995 | 1,986 | |
| K-4 4-3 | HMSP | 1965 | 2,295 | |
| K-4 4-4 | ACB2R | 1965 | 2,704 | |
| K-4 5-1 | SR95T, SRECYCL | 2002 | 2,865 | 2726 |
| K-4 5-2 | HRECYCL, BM2 | 1995 | 3,080 | |
| K-4 5-3 | HMSP | 1965 | 2,464 | |
| K-4 5-4 | ACB2R | 1965 | 2,425 | |
| K-4 6-2 | HRECYCL, BM2 | 1995 | 2,236 | 2263 |
| K-4 6-3 | HMSP | 1965 | 2,295 | |
| K-4 6-4 | ACB2R | 1965 | 2,259 | |
| K-4 7-2 | HRECYCL, BM2 | 1995 | 2,316 | 2521 |
| K-4 7-3 | HMSP | 1965 | 2,728 | |
| K-4 7-4 | ACB2R | 1965 | 2,475 | |
| K-4 8-1 | SR95T, SRECYCL | 2002 | 3,045 | 2458 |
| K-4 8-3 | HMSP | 1965 | 2,256 | |
| K-4 8-4 | ACB2R | 1965 | 2,255 | |
| K-4 9-1 | SR95T, SRECYCL | 2002 | 2,422 | 2228 |
| K-4 9-2 | HRECYCL, BM2 | 1995 | 2,472 | |
| K-4 9-3 | HMSP | 1965 | 1,985 | |
| K-4 9-4 | ACB2R | 1965 | 2,106 | |
| K-4 10-1 | SR95T, SRECYCL | 2002 | 2,575 | 1895 |
| K-4 10-2 | HRECYCL, BM2 | 1995 | 1,340 | |
| K-4 10-3 | HMSP | 1965 | 2,211 | |
| K-4 10-4 | ACB2R | 1965 | 1,241 | |

## TABLE B.6
## IDT Results for K-141 in Ellsworth County

| Specimen | Layer Info | Year | Mr avg (ksi) | Mr for Core |
|---|---|---|---|---|
| 141-1-1 | SM125A, BM2A | 1995 | 3,022 | 2665 |
| 141-1-2 | BM2 | 1987 | 2,336 | |
| 141-2-1 | SM125A, BM2A | 1995 | 3,410 | 1887 |
| 141-2-3 | BITCOV | 1962 | 1,439 | |
| 141-2-4 | BITCOV | 1962 | 672 | |
| 141-3-1 | SM125A, BM2A | 1995 | 2,852 | 2852 |
| 141-4-1 | SM125A, BM2A | 1995 | 2,589 | 2589 |
| 141-5-1 | SM125A, BM2A | 1995 | 2,944 | 2250 |
| 141-5-2 | BM2 | 1987 | 1,297 | |
| 141-6-1 | SM125A, BM2A | 1995 | 2,423 | 1764 |
| 141-6-2 | BM2 | 1987 | 1,854 | |
| 141-6-3 | BITCOV | 1962 | 854 | |
| 141-7-1 | SM125A, BM2A | 1995 | 2,381 | 2197 |
| 141-7-2 | BM2 | 1987 | 2,010 | |
| 141-8-1 | SM125A, BM2A | 1995 | 2,830 | 1711 |
| 141-8-3 | BITCOV | 1962 | 653 | |
| 141-9-1 | SM125A, BM2A | 1995 | 3,219 | 2894 |
| 141-9-2 | BM2 | 1987 | 2,579 | |
| 141-10-1 | SM125A, BM2A | 1995 | 2,590 | 2021 |
| 141-10-2 | BM2 | 1987 | 1,469 | |
| 141-10-3 | BITCOV | 1962 | 2,016 | |

# Appendix C: Back-Calculation Results

**TABLE C.1**
**Back-Calculation Results for I-70 in Trego County**

| | Section 1 | | | | | Section 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 0 | 135.0 | 0.47 | 0.35 | 181.3 | | 283.3 | 4.04 | 1.42 | 364.2 | |
| 50 | 154.7 | 0.20 | 0.13 | 208.8 | | 263.3 | 2.30 | 0.87 | 343.4 | |
| 100 | 246.8 | 0.80 | 0.32 | 335.3 | | 352.2 | 9.17 | 2.61 | 462.5 | |
| 150 | 223.2 | 2.58 | 1.15 | 302.9 | | 386.3 | 1.91 | 0.49 | 505.2 | |
| 200 | 237.0 | 6.17 | 2.60 | 324.6 | | 281.8 | 1.87 | 0.66 | 376.4 | |
| 250 | 252.0 | 8.42 | 3.34 | 346.2 | X | 175.4 | 4.61 | 2.63 | 234.3 | X |
| 300 | 241.2 | 3.87 | 1.60 | 333.9 | | 251.9 | 1.38 | 0.55 | 335.1 | |
| 350 | 203.4 | 2.40 | 1.18 | 283.2 | | 152.0 | 0.34 | 0.22 | 202.4 | |
| 400 | 149.6 | 0.90 | 0.60 | 208.2 | | 208.5 | 2.09 | 1.00 | 278.9 | |
| 450 | 122.0 | 0.30 | 0.25 | 170.2 | | 325.2 | 1.20 | 0.37 | 438.0 | |
| 500 | 188.6 | 1.12 | 0.59 | 264.9 | | 277.2 | 7.03 | 2.54 | 374.5 | |

| | Section 3 | | | | | Section 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 125.0 | 0.43 | 0.34 | 181.0 | | 189.5 | 1.40 | 0.74 | 274.0 | |
| 100 | 123.4 | 1.26 | 1.02 | 179.5 | | 88.8 | 0.31 | 0.35 | 128.0 | |
| 150 | 99.4 | 0.89 | 0.89 | 144.1 | | 127.8 | 1.88 | 1.47 | 183.7 | |
| 200 | 140.8 | 2.58 | 1.84 | 204.1 | | 127.2 | 1.14 | 0.90 | 184.2 | |
| 250 | 189.0 | 3.07 | 1.62 | 277.1 | X | 154.7 | 1.65 | 1.07 | 223.4 | X |
| 300 | 154.5 | 1.22 | 0.79 | 225.2 | | 131.6 | 0.12 | 0.09 | 190.2 | |
| 350 | 88.4 | 1.31 | 1.48 | 128.9 | | 153.9 | 10.18 | 6.61 | 223.0 | |
| 400 | 101.5 | 0.96 | 0.95 | 149.9 | | 129.3 | 0.45 | 0.35 | 189.0 | |
| 450 | 129.5 | 0.77 | 0.60 | 189.3 | | 159.1 | 0.91 | 0.57 | 234.0 | |
| 500 | 143.4 | 1.13 | 0.79 | 210.9 | | 89.2 | 0.73 | 0.82 | 132.9 | |

| | Section 5 | | | | | Section 6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 227.5 | 1.17 | 0.51 | 348.0 | | 223.5 | 18.35 | 8.21 | 359.8 | |
| 100 | 196.1 | 1.63 | 0.83 | 301.0 | | 209.3 | 1.34 | 0.64 | 339.1 | |
| 150 | 169.3 | 1.87 | 1.11 | 262.5 | | 161.9 | 2.29 | 1.41 | 265.5 | |
| 200 | 170.6 | 1.01 | 0.59 | 265.9 | | 188.7 | 1.29 | 0.68 | 312.1 | |
| 250 | 238.4 | 2.78 | 1.16 | 372.4 | X | 129.5 | 1.00 | 0.77 | 215.1 | X |
| 300 | 214.1 | 2.13 | 0.99 | 338.2 | | 163.2 | 3.26 | 2.00 | 271.3 | |
| 350 | 161.2 | 0.81 | 0.50 | 254.3 | | 186.4 | 0.89 | 0.48 | 314.2 | |
| 400 | 192.5 | 1.27 | 0.66 | 306.4 | | 213.0 | 1.31 | 0.61 | 360.8 | |
| 450 | 192.7 | 1.24 | 0.64 | 309.0 | | 212.8 | 1.45 | 0.68 | 363.1 | |
| 500 | 111.9 | 2.64 | 2.36 | 181.2 | | 128.2 | 1.39 | 1.09 | 219.2 | |

## TABLE C.1
## Back-Calculation Results for I-70 in Trego County, Continued

| | Section 7 | | | | | Section 8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 354.1 | 41.18 | 11.63 | 600.7 | | 193.8 | 0.93 | 0.48 | 344.6 | |
| 100 | 325.2 | 2.22 | 0.68 | 551.0 | | 66.2 | 0.65 | 0.97 | 120.5 | |
| 150 | 294.8 | 5.70 | 1.93 | 504.7 | | 93.2 | 0.42 | 0.45 | 170.7 | |
| 200 | 206.2 | 1.45 | 0.70 | 356.2 | | 181.5 | 1.15 | 0.63 | 335.5 | |
| 250 | 160.5 | 0.86 | 0.53 | 275.2 | X | 127.3 | 1.32 | 1.04 | 236.9 | X |
| 300 | 126.8 | 4.71 | 3.71 | 220.0 | | 144.3 | 4.99 | 3.46 | 268.7 | |
| 350 | 291.1 | 1.03 | 0.35 | 513.5 | | 91.1 | 0.16 | 0.18 | 172.1 | |
| 400 | 253.3 | 3.10 | 1.22 | 447.4 | | 80.8 | 0.41 | 0.50 | 153.3 | |
| 450 | 142.6 | 0.61 | 0.43 | 251.9 | | 130.3 | 0.57 | 0.43 | 248.1 | |
| 500 | 82.2 | 0.39 | 0.47 | 145.4 | | 113.4 | 0.53 | 0.47 | 217.3 | |

| | Section 9 | | | | | Section 10 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 178.0 | 2.55 | 1.43 | 346.7 | | 189.8 | 2.43 | 1.28 | 405.2 | |
| 100 | 245.1 | 4.76 | 1.94 | 477.5 | | 97.6 | 1.12 | 1.15 | 210.9 | |
| 150 | 367.5 | 0.00 | 0.00 | 719.3 | | 126.4 | 1.60 | 1.26 | 274.4 | |
| 200 | 181.8 | 3.45 | 1.90 | 360.9 | | 111.3 | 1.72 | 1.54 | 243.5 | |
| 250 | 224.0 | 3.70 | 1.65 | 442.5 | X | 165.2 | 1.61 | 0.98 | 356.0 | X |
| 300 | 320.8 | 1.26 | 0.39 | 638.4 | | 157.3 | 2.12 | 1.35 | 340.0 | |
| 350 | 385.2 | 3.22 | 0.84 | 773.3 | | 144.4 | 1.83 | 1.27 | 310.5 | |
| 400 | 224.3 | 4.73 | 2.11 | 450.0 | | 296.6 | 6.38 | 2.15 | 647.7 | |
| 450 | 204.7 | 5.86 | 2.86 | 418.1 | | 189.6 | 2.03 | 1.07 | 416.4 | |
| 500 | 344.4 | 10.34 | 3.00 | 707.5 | | 206.1 | 2.58 | 1.25 | 456.5 | |

## TABLE C.2
## Back-Calculation Results for US-56 in Stevens County

| | Section 1 | | | | | Section 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 237.1 | 1.38 | 0.58 | 989.2 | | 340.5 | 3.80 | 1.12 | 949.7 | |
| 100 | 153.5 | 1.88 | 1.23 | 1100.9 | | 87.5 | 1.12 | 1.29 | 1258.0 | |
| 150 | 415.5 | 0.96 | 0.23 | 1130.9 | | 380.0 | 5.97 | 1.57 | 1082.7 | |
| 200 | 80.2 | 0.92 | 1.14 | 1060.7 | | 411.4 | 5.69 | 1.38 | 1148.3 | |
| 250 | 406.4 | 17.81 | 4.38 | 969.4 | X | 389.3 | 0.06 | 0.01 | 1320.4 | X |
| 300 | 362.4 | 6.80 | 1.88 | 1120.5 | | 510.9 | 5.16 | 1.01 | 1046.6 | |
| 350 | 156.3 | 0.26 | 0.17 | 1172.6 | | 141.5 | 1.34 | 0.95 | 900.9 | |
| 400 | 340.8 | 2.23 | 0.65 | 868.5 | | 436.7 | 4.81 | 1.10 | 1128.2 | |
| 450 | 350.1 | 4.04 | 1.15 | 758.8 | | 404.5 | 14.48 | 3.58 | 1143.4 | |
| 500 | 191.6 | 0.67 | 0.35 | 1037.8 | | 440.5 | 3.67 | 0.83 | 1226.6 | |

| | Section 3 | | | | | Section 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 462.6 | 8.74 | 1.89 | 1592.5 | | 306.0 | 1.05 | 0.34 | 723.4 | |
| 100 | 170.4 | 1.00 | 0.59 | 1367.6 | | 183.2 | 2.57 | 1.40 | 1101.1 | |
| 150 | 311.7 | 1.38 | 0.44 | 1129.9 | | 379.9 | 5.46 | 1.44 | 969.3 | |
| 200 | 375.8 | 6.85 | 1.82 | 1619.8 | | 109.3 | 1.19 | 1.09 | 1089.0 | |
| 250 | 352.6 | 8.52 | 2.42 | 1712.4 | X | 93.1 | 0.61 | 0.65 | 937.9 | X |
| 300 | 114.6 | 0.78 | 0.68 | 1274.9 | | 365.5 | 4.55 | 1.25 | 785.5 | |
| 350 | 358.2 | 10.08 | 2.81 | 1240.5 | | 484.0 | 4.45 | 0.92 | 914.6 | |
| 400 | 319.1 | 7.01 | 2.20 | 582.0 | | 169.8 | 1.33 | 0.78 | 755.0 | |
| 450 | 413.7 | 7.54 | 1.82 | 549.2 | | 91.9 | 0.89 | 0.97 | 1381.0 | |
| 500 | 411.6 | 1.93 | 0.47 | 490.2 | | 496.6 | 4.31 | 0.87 | 1219.7 | |

| | Section 5 | | | | | Section 6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 230.9 | 7.86 | 3.40 | 856.8 | | 325.1 | 1.42 | 0.44 | 805.7 | |
| 100 | 293.3 | 6.90 | 2.35 | 1144.2 | | 296.8 | 3.84 | 1.29 | 515.5 | |
| 150 | 342.4 | 1.23 | 0.36 | 821.9 | | 235.2 | 5.48 | 2.33 | 639.1 | |
| 200 | 66.1 | 0.71 | 1.07 | 939.7 | | 337.2 | 1.19 | 0.35 | 946.9 | |
| 250 | 403.8 | 2.03 | 0.50 | 867.3 | X | 231.6 | 2.61 | 1.13 | 997.1 | X |
| 300 | 79.3 | 0.49 | 0.62 | 713.8 | | 135.9 | 2.29 | 1.68 | 654.4 | |
| 350 | 351.1 | 6.26 | 1.78 | 692.1 | | 267.6 | 25.49 | 9.53 | 666.5 | |
| 400 | 318.0 | 1.84 | 0.58 | 706.3 | | 289.0 | 4.54 | 1.57 | 928.5 | |
| 450 | 352.8 | 4.19 | 1.19 | 641.0 | | 357.1 | 3.98 | 1.11 | 714.0 | |
| 500 | 301.2 | 2.27 | 0.76 | 659.6 | | 237.5 | 10.49 | 4.42 | 726.7 | |

## TABLE C.2
## Back-Calculation Results for US-56 in Stevens County, Continued

| | Section 7 | | | | | Section 8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 91.0 | 1.21 | 1.33 | 1013.7 | | 333.5 | 6.64 | 1.99 | 645.6 | |
| 100 | 312.2 | 8.35 | 2.67 | 1254.3 | | 363.9 | 6.54 | 1.80 | 708.6 | |
| 150 | 310.2 | 2.96 | 0.95 | 1175.6 | | 187.2 | 6.07 | 3.24 | 896.6 | |
| 200 | 304.4 | 4.75 | 1.56 | 662.6 | | 232.2 | 0.78 | 0.34 | 623.4 | |
| 250 | 146.3 | 1.31 | 0.89 | 1046.9 | X | 334.0 | 6.87 | 2.06 | 806.5 | X |
| 300 | 378.9 | 1.64 | 0.43 | 1151.6 | | 287.5 | 2.96 | 1.03 | 1011.7 | |
| 350 | 59.3 | 1.01 | 1.71 | 1001.3 | | 315.4 | 14.60 | 4.63 | 1002.0 | |
| 400 | 287.7 | 2.45 | 0.85 | 776.2 | | 273.4 | 1.37 | 0.50 | 1218.8 | |
| 450 | 360.2 | 4.31 | 1.20 | 840.4 | | 137.5 | 6.08 | 4.42 | 1038.8 | |
| 500 | 326.3 | 4.91 | 1.51 | 939.1 | | 220.0 | 3.47 | 1.58 | 968.2 | |

| | Section 9 | | | | | Section 10 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 264.9 | 2.84 | 1.07 | 897.2 | | 323.8 | 6.70 | 2.07 | 1281.5 | |
| 100 | 320.6 | 1.21 | 0.38 | 776.0 | | 307.1 | 2.97 | 0.97 | 1295.6 | |
| 150 | 83.1 | 1.66 | 2.00 | 750.2 | | 308.8 | 2.11 | 0.68 | 965.7 | |
| 200 | 223.2 | 2.60 | 1.16 | 707.3 | | 340.7 | 3.22 | 0.94 | 1160.2 | |
| 250 | 290.0 | 0.59 | 0.20 | 878.2 | X | 236.7 | 2.84 | 1.20 | 1056.3 | X |
| 300 | 339.0 | 6.92 | 2.04 | 776.6 | | 401.1 | 4.68 | 1.17 | 1272.0 | |
| 350 | 295.5 | 8.71 | 2.95 | 589.1 | | 337.9 | 3.01 | 0.89 | 980.8 | |
| 400 | 359.2 | 4.96 | 1.38 | 628.9 | | 399.4 | 13.40 | 3.35 | 1170.7 | |
| 450 | 306.4 | 2.58 | 0.84 | 1018.9 | | 264.5 | 10.06 | 3.80 | 1470.9 | |
| 500 | 287.5 | 2.01 | 0.70 | 948.6 | | 243.4 | 2.77 | 1.14 | 1343.6 | |

## TABLE C.3
## Back-Calculation Results for US-59 in Neosho County

| | Section 1 | | | | | Section 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 545.7 | 3.97 | 0.73 | 762.17 | | 375.2 | 4.68 | 1.25 | 287.10 | |
| 100 | 190.6 | 0.93 | 0.49 | 262.70 | | 481.4 | 7.66 | 1.59 | 367.68 | |
| 150 | 283.1 | 5.54 | 1.96 | 391.50 | | 786.4 | 9.28 | 1.18 | 597.38 | |
| 200 | 273.2 | 0.83 | 0.30 | 377.95 | | 449.4 | 3.16 | 0.70 | 342.11 | |
| 250 | 280.6 | 3.37 | 1.20 | 385.97 | X | 310.9 | 2.25 | 0.72 | 239.05 | X |
| 300 | 281.6 | 3.32 | 1.18 | 385.08 | | 604.1 | 0.60 | 0.10 | 468.24 | |
| 350 | 203.2 | 0.87 | 0.43 | 277.21 | | 393.0 | 4.50 | 1.14 | 304.65 | |
| 400 | 281.5 | 5.57 | 1.98 | 381.75 | | 553.1 | 7.02 | 1.27 | 427.21 | |
| 450 | 359.5 | 4.59 | 1.28 | 486.10 | | 403.2 | 6.03 | 1.50 | 315.16 | |
| 500 | 241.7 | 3.97 | 1.64 | 326.86 | | 403.3 | 3.84 | 0.95 | 314.11 | |

| | Section 3 | | | | | Section 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 239.5 | 1.10 | 0.46 | 187.05 | | 245.4 | 1.40 | 0.57 | 186.68 | |
| 100 | 444.6 | 3.60 | 0.81 | 348.67 | | 484.1 | 5.28 | 1.09 | 363.44 | |
| 150 | 339.3 | 1.10 | 0.32 | 267.24 | | 438.5 | 10.19 | 2.32 | 329.79 | |
| 200 | 305.2 | 4.14 | 1.36 | 240.38 | | 253.8 | 3.84 | 1.51 | 190.65 | |
| 250 | 470.7 | 12.20 | 2.59 | 371.66 | X | 942.8 | 19.69 | 2.09 | 705.36 | X |
| 300 | 279.8 | 1.35 | 0.48 | 217.16 | | 213.8 | 3.29 | 1.54 | 160.99 | |
| 350 | 589.5 | 2.40 | 0.41 | 455.12 | | 342.0 | 0.35 | 0.10 | 256.07 | |
| 400 | 369.8 | 3.35 | 0.91 | 285.60 | | 306.2 | 5.23 | 1.71 | 230.08 | |
| 450 | 348.0 | 8.95 | 2.57 | 269.92 | | 951.0 | 24.61 | 2.59 | 714.71 | |
| 500 | 417.9 | 12.29 | 2.94 | 323.57 | | 380.4 | 7.75 | 2.04 | 287.40 | |

| | Section 5 | | | | | Section 6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 233.7 | 1.75 | 0.75 | 181.61 | | 261.6 | 2.56 | 0.98 | 199.25 | |
| 100 | 293.6 | 4.56 | 1.55 | 230.47 | | 249.0 | 2.07 | 0.83 | 188.93 | |
| 150 | 234.4 | 3.45 | 1.47 | 189.09 | | 153.8 | 1.63 | 1.06 | 116.82 | |
| 200 | 216.8 | 7.57 | 3.49 | 178.48 | | 148.8 | 0.87 | 0.59 | 113.93 | |
| 250 | 269.0 | 5.97 | 2.22 | 222.00 | X | 255.4 | 3.42 | 1.34 | 194.97 | X |
| 300 | 193.5 | 2.37 | 1.22 | 162.90 | | 276.1 | 0.76 | 0.27 | 211.31 | |
| 350 | 238.2 | 1.85 | 0.78 | 196.32 | | 129.4 | 1.93 | 1.49 | 99.64 | |
| 400 | 291.5 | 4.91 | 1.68 | 236.82 | | 364.2 | 1.24 | 0.34 | 280.74 | |
| 450 | 193.2 | 1.46 | 0.75 | 153.97 | | 228.5 | 2.86 | 1.25 | 176.25 | |
| 500 | 138.2 | 1.92 | 1.39 | 109.15 | | 189.3 | 1.55 | 0.82 | 145.80 | |

## TABLE C.3
## Back-Calculation Results for US-59 in Neosho County, Continued

| | Section 7 | | | | | Section 8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 221.0 | 3.16 | 1.43 | 166.66 | | 230.5 | 1.59 | 0.69 | 181.54 | |
| 100 | 214.5 | 3.02 | 1.41 | 162.10 | | 248.7 | 18.38 | 7.39 | 197.13 | |
| 150 | 370.0 | 4.93 | 1.33 | 278.98 | | 257.9 | 3.80 | 1.47 | 206.14 | |
| 200 | 349.0 | 12.90 | 3.70 | 263.31 | | 317.0 | 6.73 | 2.12 | 254.13 | |
| 250 | 753.0 | 2.28 | 0.30 | 576.59 | X | 492.3 | 5.83 | 1.18 | 397.22 | X |
| 300 | 1434.0 | 25.74 | 1.79 | 1101.09 | | 368.9 | 4.57 | 1.24 | 300.31 | |
| 350 | 499.1 | 14.51 | 2.91 | 385.89 | | 421.3 | 7.04 | 1.67 | 340.56 | |
| 400 | 335.0 | 0.60 | 0.18 | 259.75 | | 365.0 | 8.96 | 2.46 | 289.51 | |
| 450 | 485.9 | 15.31 | 3.15 | 376.31 | | 348.1 | 6.71 | 1.93 | 274.81 | |
| 500 | 460.6 | 3.65 | 0.79 | 354.65 | | 336.8 | 4.33 | 1.29 | 267.04 | |

| | Section 9 | | | | | Section 10 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 181.0 | 1.41 | 0.78 | 142.10 | | 352.5 | 3.81 | 1.08 | 281.58 | |
| 100 | 165.4 | 2.30 | 1.39 | 131.30 | | 328.8 | 16.12 | 4.90 | 263.55 | |
| 150 | 233.8 | 4.44 | 1.90 | 185.74 | | 336.8 | 3.40 | 1.01 | 269.57 | |
| 200 | 360.2 | 1.44 | 0.40 | 286.26 | | 365.4 | 5.01 | 1.37 | 289.70 | |
| 250 | 188.8 | 3.12 | 1.65 | 150.27 | | 326.0 | 3.83 | 1.17 | 263.06 | X |
| 300 | 265.7 | 8.44 | 3.18 | 214.08 | X | 292.5 | 2.40 | 0.82 | 235.21 | |
| 350 | 228.0 | 3.63 | 1.59 | 183.46 | | 356.6 | 1.75 | 0.49 | 284.08 | |
| 400 | 208.2 | 3.58 | 1.72 | 165.12 | | 566.5 | 24.65 | 4.35 | 450.91 | |
| 450 | 229.3 | 1.04 | 0.46 | 182.69 | | 328.3 | 0.40 | 0.12 | 263.11 | |
| 500 | 183.5 | 2.06 | 1.13 | 145.70 | | 432.1 | 11.00 | 2.55 | 346.56 | |

## TABLE C.4
## Back-Calculation Results for US-169 in Miami County

| | Section 1 | | | | | Section 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 714.3 | 56.01 | 7.84 | 1043.75 | | 655.1 | 18.86 | 2.88 | 979.97 | |
| 100 | 798.3 | 31.48 | 3.94 | 1166.66 | | 865.4 | 19.36 | 2.24 | 1318.41 | |
| 150 | 817.8 | 18.07 | 2.21 | 1187.15 | | 732.4 | 5.49 | 0.75 | 1108.45 | |
| 200 | 767.0 | 57.90 | 7.55 | 1134.05 | | 785.5 | 13.02 | 1.66 | 1189.18 | |
| 250 | 690.4 | 13.82 | 2.00 | 1027.42 | X | 893.2 | 13.82 | 1.55 | 1356.37 | X |
| 300 | 803.5 | 56.66 | 7.05 | 1193.16 | | 705.0 | 47.62 | 6.76 | 1050.76 | |
| 350 | 837.4 | 74.27 | 8.87 | 1242.69 | | 600.2 | 17.96 | 2.99 | 910.06 | |
| 400 | 620.2 | 18.92 | 3.05 | 906.30 | | 756.8 | 35.02 | 4.63 | 1162.16 | |
| 450 | 535.9 | 3.55 | 0.66 | 798.80 | | 762.7 | 11.70 | 1.53 | 1181.46 | |
| 500 | 726.0 | 22.35 | 3.08 | 1087.14 | | 808.1 | 14.27 | 1.77 | 1265.00 | |

| | Section 3 | | | | | Section 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 1028.2 | 24.92 | 2.42 | 1765.40 | | 422.9 | 8.20 | 1.94 | 733.41 | |
| 100 | 866.4 | 20.84 | 2.41 | 1437.87 | | 636.3 | 16.56 | 2.60 | 1088.84 | |
| 150 | 716.8 | 3.84 | 0.54 | 1167.74 | | 553.6 | 14.15 | 2.56 | 980.67 | |
| 200 | 1013.8 | 20.37 | 2.01 | 1675.81 | | 620.2 | 11.72 | 1.89 | 1096.34 | |
| 250 | 1065.9 | 9.43 | 0.88 | 1790.04 | X | 533.2 | 18.97 | 3.56 | 933.12 | X |
| 300 | 790.4 | 11.67 | 1.48 | 1334.43 | | 445.3 | 1.99 | 0.45 | 798.51 | |
| 350 | 756.8 | 14.45 | 1.91 | 1286.71 | | 512.4 | 2.50 | 0.49 | 901.89 | |
| 400 | 350.8 | 8.71 | 2.48 | 597.00 | | 422.4 | 8.49 | 2.01 | 752.09 | |
| 450 | 330.2 | 1.05 | 0.32 | 569.80 | | 762.6 | 4.99 | 0.65 | 1376.18 | |
| 500 | 294.7 | 3.33 | 1.13 | 504.57 | | 670.5 | 7.37 | 1.10 | 1198.85 | |

| | Section 5 | | | | | Section 6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 475.7 | 4.52 | 0.95 | 1113.19 | | 411.5 | 6.35 | 1.54 | 876.31 | |
| 100 | 623.4 | 7.61 | 1.22 | 1479.42 | | 262.3 | 2.34 | 0.89 | 547.94 | |
| 150 | 448.3 | 3.00 | 0.67 | 1081.54 | | 320.7 | 3.50 | 1.09 | 678.56 | |
| 200 | 507.9 | 2.98 | 0.59 | 1208.70 | | 475.1 | 7.54 | 1.59 | 1004.32 | |
| 250 | 464.6 | 4.25 | 0.91 | 1121.31 | X | 492.3 | 5.92 | 1.20 | 1037.99 | X |
| 300 | 382.8 | 3.93 | 1.03 | 920.36 | | 321.4 | 11.07 | 3.45 | 759.01 | |
| 350 | 364.3 | 12.67 | 3.48 | 881.39 | | 324.9 | 1.87 | 0.58 | 753.07 | |
| 400 | 374.9 | 14.11 | 3.76 | 915.98 | | 453.0 | 4.74 | 1.05 | 1065.44 | |
| 450 | 334.8 | 20.10 | 6.00 | 805.77 | | 347.8 | 5.77 | 1.66 | 813.25 | |
| 500 | 343.6 | 2.66 | 0.77 | 825.79 | | 353.4 | 15.78 | 4.47 | 841.26 | |

## TABLE C.4
## Back-Calculation Results for US-169 in Miami County, Continued

| | Section 7 | | | | | Section 8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 477.3 | 4.05 | 0.85 | 1180.31 | | 298.8 | 4.18 | 1.40 | 792.25 | |
| 100 | 586.9 | 3.91 | 0.67 | 1482.08 | | 327.9 | 8.16 | 2.49 | 872.22 | |
| 150 | 551.3 | 2.06 | 0.37 | 1380.94 | | 403.7 | 7.78 | 1.93 | 1078.40 | |
| 200 | 310.9 | 1.47 | 0.47 | 794.56 | | 280.9 | 16.78 | 5.97 | 768.23 | |
| 250 | 488.6 | 4.94 | 1.01 | 1230.37 | X | 358.0 | 11.72 | 3.27 | 995.16 | X |
| 300 | 540.0 | 17.62 | 3.26 | 1358.08 | | 465.6 | 14.76 | 3.17 | 1285.43 | |
| 350 | 466.4 | 15.29 | 3.28 | 1160.80 | | 461.4 | 10.29 | 2.23 | 1266.45 | |
| 400 | 362.3 | 1.15 | 0.32 | 928.26 | | 548.9 | 1.57 | 0.29 | 1519.82 | |
| 450 | 391.2 | 9.83 | 2.51 | 985.22 | | 465.3 | 33.15 | 7.12 | 1289.62 | |
| 500 | 434.8 | 55.06 | 12.66 | 1116.04 | | 430.9 | 2.93 | 0.68 | 1206.21 | |

| | Section 9 | | | | | Section 10 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 50 | 396.7 | 7.02 | 1.77 | 1086.79 | | 538.4 | 2.42 | 0.45 | 1497.26 | |
| 100 | 342.2 | 5.19 | 1.52 | 918.87 | | 548.4 | 16.15 | 2.94 | 1487.89 | |
| 150 | 333.8 | 6.58 | 1.97 | 897.21 | | 404.7 | 7.68 | 1.90 | 1125.28 | |
| 200 | 308.5 | 2.28 | 0.74 | 836.56 | | 479.5 | 3.57 | 0.75 | 1338.87 | |
| 250 | 380.1 | 1.17 | 0.31 | 1040.57 | X | 451.2 | 2.99 | 0.66 | 1252.53 | X |
| 300 | 335.8 | 11.32 | 3.37 | 933.58 | | 526.9 | 3.24 | 0.61 | 1449.33 | |
| 350 | 260.9 | 2.57 | 0.98 | 721.35 | | 405.8 | 1.28 | 0.31 | 1111.16 | |
| 400 | 273.4 | 3.38 | 1.24 | 747.43 | | 483.7 | 10.39 | 2.15 | 1352.45 | |
| 450 | 437.8 | 0.50 | 0.11 | 1219.38 | | 597.8 | 4.96 | 0.83 | 1612.56 | |
| 500 | 403.5 | 6.94 | 1.72 | 1098.03 | | 545.2 | 3.08 | 0.57 | 1503.83 | |

## TABLE C.5
## Back-Calculation Results for K-4 in Jefferson County

| Station | Section 1 Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Section 2 Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 86.6 | 0.75 | 0.86 | 74.0 | | 150.8 | 2.37 | 1.57 | 148.0 | |
| 50 | 85.5 | 1.27 | 1.49 | 74.5 | | 166.5 | 2.46 | 1.48 | 163.5 | |
| 100 | 58.1 | 1.15 | 1.98 | 50.6 | | 88.7 | 0.89 | 1.01 | 85.7 | |
| 150 | 96.0 | 1.75 | 1.82 | 85.3 | | 67.3 | 1.89 | 2.81 | 66.1 | |
| 200 | 160.9 | 2.20 | 1.37 | 140.2 | | 78.2 | 1.98 | 2.54 | 76.8 | |
| 250 | 80.8 | 2.65 | 3.28 | 70.4 | X | 80.7 | 0.42 | 0.53 | 79.2 | X |
| 300 | 198.3 | 7.08 | 3.57 | 176.2 | | 56.7 | 1.31 | 2.30 | 56.6 | |
| 350 | 73.2 | 3.62 | 4.95 | 63.8 | | 47.5 | 0.82 | 1.74 | 47.5 | |
| 400 | 71.8 | 8.25 | 11.50 | 63.8 | | 60.2 | 1.48 | 2.45 | 60.2 | |
| 450 | 87.1 | 0.44 | 0.51 | 77.4 | | 43.3 | 0.35 | 0.80 | 43.3 | |
| 500 | 71.5 | 1.92 | 2.69 | 63.5 | | 54.0 | 1.24 | 2.29 | 54.0 | |

| Station | Section 3 Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Section 4 Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 237.8 | 5.57 | 2.34 | 259.9 | | 75.7 | 0.39 | 0.52 | 85.8 | |
| 50 | 130.5 | 0.38 | 0.29 | 140.6 | | 124.5 | 1.25 | 1.00 | 145.1 | |
| 100 | 105.5 | 1.24 | 1.17 | 115.3 | | 128.9 | 1.19 | 0.92 | 141.7 | |
| 150 | 128.5 | 0.20 | 0.15 | 142.6 | | 176.1 | 2.87 | 1.63 | 196.4 | |
| 200 | 126.2 | 1.04 | 0.83 | 140.0 | | 421.6 | 4.36 | 1.03 | N/A | |
| 250 | 207.9 | 0.95 | 0.45 | 227.3 | X | 150.9 | 1.52 | 1.01 | 166.0 | X |
| 300 | 94.1 | 0.75 | 0.80 | 102.9 | | 153.5 | 1.85 | 1.20 | 168.8 | |
| 350 | 120.4 | 0.80 | 0.67 | 131.6 | | 208.4 | 1.64 | 0.79 | 229.2 | |
| 400 | 174.9 | 2.73 | 1.56 | 191.3 | | 230.9 | 2.42 | 1.05 | 254.0 | |
| 450 | 99.9 | 1.55 | 1.55 | 111.0 | | 109.8 | 2.13 | 1.94 | 122.6 | |
| 500 | 138.0 | 3.64 | 2.64 | 155.5 | | 87.4 | 1.70 | 1.95 | 99.0 | |

| Station | Section 5 Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Section 6 Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 96.8 | 0.57 | 0.58 | 114.3 | | 76.6 | 0.65 | 0.84 | 109.2 | |
| 50 | 135.4 | 2.20 | 1.63 | 165.1 | | 77.9 | 1.06 | 1.36 | 111.2 | |
| 100 | 103.6 | 0.55 | 0.53 | 130.4 | | 103.0 | 0.46 | 0.45 | 144.8 | |
| 150 | 121.6 | 2.00 | 1.64 | 155.6 | | 107.9 | 0.79 | 0.73 | 158.5 | |
| 200 | 235.4 | 3.35 | 1.42 | 330.6 | | 64.7 | 0.49 | 0.76 | 93.7 | |
| 250 | 250.6 | 2.01 | 0.80 | 379.6 | X | 108.3 | 1.81 | 1.67 | 159.3 | X |
| 300 | 216.5 | 1.37 | 0.63 | 323.3 | | 53.7 | 1.38 | 2.57 | 80.1 | |
| 350 | 265.9 | 2.93 | 1.10 | 373.8 | | 67.1 | 0.97 | 1.44 | 101.7 | |
| 400 | 181.7 | 4.08 | 2.25 | 255.6 | | 130.3 | 2.15 | 1.65 | 194.7 | |
| 450 | 162.8 | 0.08 | 0.05 | 225.5 | | 65.9 | 0.60 | 0.91 | 99.9 | |
| 500 | 127.0 | 0.63 | 0.49 | 176.0 | | 44.6 | 0.37 | 0.84 | 66.8 | |

## TABLE C.5
## Back-Calculation Results for K-4 in Jefferson County, Continued

| | Section 7 | | | | | Section 8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 0 | 191.7 | 1.44 | 0.75 | 288.8 | | 84.0 | 0.78 | 0.93 | 125.7 | |
| 50 | 48.2 | 0.76 | 1.58 | 71.6 | | 81.2 | 1.07 | 1.31 | 121.6 | |
| 100 | 86.1 | 1.96 | 2.28 | 128.0 | | 90.2 | 0.78 | 0.86 | 133.2 | |
| 150 | 107.5 | 2.46 | 2.29 | 157.7 | | 114.7 | 1.60 | 1.40 | 169.4 | |
| 200 | 39.7 | 0.60 | 1.52 | 59.9 | | 159.3 | 1.34 | 0.84 | 246.4 | |
| 250 | 39.1 | 0.88 | 2.24 | 60.0 | X | 106.0 | 0.92 | 0.87 | 169.1 | X |
| 300 | 55.4 | 1.15 | 2.07 | 82.6 | | 139.9 | 2.52 | 1.80 | 220.0 | |
| 350 | 64.1 | 0.71 | 1.11 | 89.1 | | 111.8 | 0.31 | 0.28 | 178.7 | |
| 400 | 79.2 | 1.08 | 1.37 | 101.0 | | 223.5 | 1.70 | 0.76 | 357.3 | |
| 450 | 71.8 | 0.48 | 0.66 | 107.2 | | 146.6 | 2.50 | 1.71 | 238.2 | |
| 500 | 83.4 | 0.48 | 0.57 | 126.5 | | 157.8 | 0.79 | 0.50 | 256.6 | |

| | Section 9 | | | | | Section 10 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 0 | 132.8 | 1.06 | 0.80 | 208.4 | | 250.2 | 1.39 | 0.56 | 468.2 | |
| 50 | 147.4 | 1.62 | 1.10 | 240.0 | | 164.6 | 6.01 | 3.65 | 308.5 | |
| 100 | 106.1 | 0.86 | 0.81 | 177.0 | | 155.5 | 3.11 | 2.00 | 288.0 | |
| 150 | 149.9 | 1.73 | 1.15 | 241.5 | | 133.9 | 2.73 | 2.04 | 245.2 | |
| 200 | 117.3 | 1.66 | 1.42 | 193.7 | | 127.4 | 1.98 | 1.55 | 242.9 | |
| 250 | 118.0 | 1.45 | 1.23 | 202.2 | X | 187.3 | 1.83 | 0.98 | 361.2 | X |
| 300 | 131.8 | 0.42 | 0.32 | 234.2 | | 133.9 | 0.82 | 0.61 | 258.5 | |
| 350 | 93.0 | 1.18 | 1.27 | 169.3 | | 139.4 | 0.39 | 0.28 | 272.7 | |
| 400 | 118.9 | 2.00 | 1.68 | 221.7 | | 115.9 | 2.03 | 1.75 | 227.0 | |
| 450 | 133.1 | 2.55 | 1.91 | 248.6 | | 101.3 | 2.86 | 2.83 | 196.3 | |
| 500 | 171.1 | 1.99 | 1.16 | 331.0 | | 130.1 | 2.51 | 1.93 | 248.9 | |

## TABLE C.6
## Back-Calculation Results for K-141 in Ellsworth County

| | Section 1 | | | | | Section 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 0 | 80.8 | 0.66 | 0.82 | 208.9 | | 150.8 | 2.60 | 1.72 | 345.8 | |
| 50 | 184.1 | 5.52 | 3.00 | 482.0 | | 172.6 | 6.45 | 3.74 | 413.0 | |
| 100 | 97.1 | 1.42 | 1.46 | 280.3 | | 175.4 | 0.31 | 0.18 | 437.0 | |
| 150 | 258.0 | 24.09 | 9.34 | 665.7 | | 236.5 | 7.88 | 3.33 | 570.6 | |
| 200 | 118.3 | 1.83 | 1.54 | 307.1 | | 237.6 | 3.55 | 1.49 | 580.0 | |
| 250 | 186.5 | 1.76 | 0.95 | 474.7 | X | 188.0 | 0.60 | 0.32 | 460.3 | X |
| 300 | 249.8 | 4.26 | 1.71 | 653.4 | | 246.8 | 9.85 | 3.99 | 596.7 | |
| 350 | 203.0 | 1.75 | 0.86 | 515.2 | | 250.2 | 2.45 | 0.98 | 613.5 | |
| 400 | 205.1 | 7.64 | 3.72 | 515.3 | | 173.5 | 9.58 | 5.52 | 436.1 | |
| 450 | 188.3 | 2.85 | 1.52 | 474.6 | | 67.2 | 0.72 | 1.07 | 167.5 | |
| 500 | 204.4 | 2.62 | 1.28 | 510.2 | | 183.2 | 5.53 | 3.02 | 462.0 | |

| | Section 3 | | | | | Section 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 0 | 129.8 | 0.53 | 0.41 | 333.7 | | 81.8 | 0.59 | 0.72 | 210.8 | |
| 50 | 195.8 | 2.84 | 1.45 | 510.6 | | 37.3 | 0.40 | 1.06 | 98.0 | |
| 100 | 61.5 | 1.33 | 2.16 | 163.4 | | 106.7 | 1.82 | 1.70 | 286.4 | |
| 150 | 138.2 | 2.86 | 2.07 | 366.0 | | 46.1 | 0.50 | 1.09 | 123.0 | |
| 200 | 198.6 | 6.07 | 3.06 | 526.9 | | | | | | |
| 250 | 115.7 | 1.03 | 0.89 | 317.0 | X | 89.2 | 2.42 | 2.72 | 245.1 | X |
| 300 | 127.6 | 1.85 | 1.45 | 344.1 | | 114.3 | 1.97 | 1.73 | 316.1 | |
| 350 | 52.4 | 1.10 | 2.09 | 141.8 | | 95.0 | 1.78 | 1.87 | 263.9 | |
| 400 | 237.9 | 1.86 | 0.78 | 647.8 | | 95.9 | 0.60 | 0.63 | 263.7 | |
| 450 | 136.7 | 6.20 | 4.53 | 373.2 | | 472.1 | 3.10 | 0.66 | 1320.6 | |
| 500 | 80.3 | 1.56 | 1.95 | 221.3 | | 139.6 | 2.37 | 1.70 | 390.2 | |

| | Section 5 | | | | | Section 6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 0 | 240.1 | 12.45 | 5.18 | 708.8 | | 175.2 | 15.00 | 8.56 | 535.7 | |
| 50 | 353.4 | 17.05 | 4.82 | 1118.3 | | 96.2 | 2.43 | 2.52 | 299.6 | |
| 100 | 251.7 | 2.17 | 0.86 | 797.7 | | 330.2 | 13.21 | 4.00 | 1005.9 | |
| 150 | 260.1 | 1.53 | 0.59 | 825.0 | | 158.9 | 1.14 | 0.71 | 483.7 | |
| 200 | 260.3 | 10.82 | 4.16 | 825.6 | | 42.4 | 0.97 | 2.28 | 125.4 | |
| 250 | 72.5 | 0.93 | 1.29 | 233.6 | X | 128.4 | 1.55 | 1.21 | 391.7 | X |
| 300 | 156.1 | 2.96 | 1.90 | 499.6 | | 72.3 | 0.89 | 1.22 | 226.1 | |
| 350 | 191.3 | 2.52 | 1.32 | 612.5 | | 32.1 | 0.52 | 1.63 | 97.7 | |
| 400 | 256.7 | 5.93 | 2.31 | 845.2 | | 48.0 | 0.93 | 1.93 | 150.6 | |
| 450 | 345.7 | 10.47 | 3.03 | 1122.7 | | 69.6 | 2.55 | 3.67 | 220.0 | |
| 500 | 184.4 | 8.04 | 4.36 | 607.8 | | 228.4 | 3.92 | 1.71 | 710.2 | |

**TABLE C.6**
**Back-Calculation Results for K-141 in Ellsworth County, Continued**

| | Section 7 | | | | | Section 8 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 0 | 106.7 | 4.67 | 4.38 | 334.5 | | 37.7 | 1.31 | 3.46 | 119.3 | |
| 50 | 26.8 | 0.62 | 2.32 | 83.6 | | 92.0 | 5.50 | 5.98 | 293.1 | |
| 100 | 64.8 | 1.02 | 1.58 | 204.9 | | 139.1 | 11.68 | 8.40 | 438.0 | |
| 150 | 42.1 | 1.09 | 2.59 | 132.9 | | 105.4 | 1.48 | 1.40 | 339.4 | |
| 200 | 118.4 | 11.61 | 9.80 | 374.8 | | 69.3 | 0.55 | 0.79 | 222.9 | |
| 250 | 109.9 | 1.32 | 1.20 | 344.7 | X | 112.2 | 1.39 | 1.23 | 361.5 | X |
| 300 | 232.0 | 9.37 | 4.04 | 740.0 | | 21.4 | 0.60 | 2.81 | 69.1 | |
| 350 | 102.4 | 3.88 | 3.79 | 322.1 | | 79.8 | 0.57 | 0.71 | 258.2 | |
| 400 | 115.4 | 2.04 | 1.76 | 371.5 | | 190.2 | 9.75 | 5.13 | 619.5 | |
| 450 | 117.0 | 2.30 | 1.96 | 381.5 | | 154.4 | 5.33 | 3.45 | 506.1 | |
| 500 | 147.0 | 2.14 | 1.46 | 479.7 | | 62.9 | 0.70 | 1.11 | 208.3 | |

| | Section 9 | | | | | Section 10 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | Mean | St. Dev. | C.V. | Temp Corr. Modulus | Location of Core | Mean | St. Dev. | C.V. | Temp Corr Modulus | Location of Core |
| 0 | 213.2 | 1.01 | 0.48 | 712.9 | | 75.3 | 0.86 | 1.14 | 246.8 | |
| 50 | 171.1 | 4.16 | 2.43 | 578.0 | | 112.7 | 1.03 | 0.91 | 363.9 | |
| 100 | 110.3 | 0.64 | 0.58 | 376.9 | | 76.2 | 0.63 | 0.83 | 245.7 | |
| 150 | 85.6 | 2.28 | 2.67 | 296.3 | | 61.2 | 0.71 | 1.16 | 200.6 | |
| 200 | 142.7 | 5.19 | 3.64 | 489.4 | | 101.5 | 0.58 | 0.57 | 335.8 | |
| 250 | 76.2 | 1.60 | 2.10 | 261.1 | X | 72.0 | 0.82 | 1.13 | 239.9 | X |
| 300 | 108.6 | 2.50 | 2.30 | 374.8 | | 64.1 | 1.40 | 2.19 | 209.4 | |
| 350 | 76.8 | 1.85 | 2.41 | 260.1 | | 91.1 | 1.36 | 1.49 | 297.2 | |
| 400 | 26.3 | 2.21 | 8.41 | 91.3 | | 132.0 | 0.60 | 0.45 | 423.3 | |
| 450 | 83.9 | 1.15 | 1.37 | 290.9 | | 80.9 | 1.59 | 1.96 | 269.2 | |
| 500 | 77.6 | 1.25 | 1.62 | 267.7 | | 108.8 | 4.59 | 4.21 | 358.8 | |

# K-TRAN

## KANSAS TRANSPORTATION RESEARCH AND NEW-DEVELOPMENT PROGRAM



AD ASTRA PER ASPERA

Kansas

Department of Transportation