INVESTIGATION OF AGED HOT-MIX ASPHALT PAVEMENT MODULI

by

JEREMIAH THOMAS

B.S., Kansas State University, 2008

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering
College of Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2011

Approved by:

Major Professor
Dr. Mustaque Hossain

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 capacity 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 structural capacity of an existing pavement.

This study examined structural characteristics of six test roadways in Kansas using three different test methods: Falling Weight Deflectometer (FWD), Portable Seismic Property Analyzer (PSPA), and Indirect Tensile (IDT) test. 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, especially stripping. Two test roadways that showed little signs of stripping had a minimal reduction or even an increase in AC moduli. Thus, the stripping issue needs to be addressed to ensure longevity of AC pavements. While the correlation between test methods studied was mostly consistent for each roadway, no universal correlation was found.

The structural coefficient of each AC layer was determined based on the resilient modulus of the layer. It was found the structural layer coefficients do not typically decrease with age at the same rate, and the rate of decrease is a function of the distresses observed.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AA1	Aggregate Asphalt Grading 1
AASHTO	American Association of State Highway and Transportation Officials
AB3	Aggregate Binder, Limestone
AC	Asphalt Concrete
ACB2R	Asphaltic Concrete Base Grading 2 Revised (50%-75% Limestone and 25%-50% Sand)
ACB3	Asphaltic Concrete Base Grading 3 (50%-100% Limestone)
ASTM	American Society for Testing and Materials
BC1	Bituminous Construction Grading 1 (15% Sand)
BITCOV	Bituminous Cover, Old Wearing Course
BM1T	Bituminous Mix with Combined Aggregates (30% Crushed Material and 15% Natural Sand)
BM2	Bituminous Mix with Mixed Aggregates (50% Crushed Material and 15% Sand)
BM2A	Bituminous Mat Grading 2 (Coarse)
BM3	Bituminous Mix (Chat)
CRECYL	Cold Recycle Pavement
C.V.	Coefficient of Variation
FWD	Falling Weight Deflectometer
HM3A	Mixed Asphalt (50%-100% Crushed Stone)
HM3B	Mixed Asphalt (Crushed Gravel)
HMA	Hot-Mix Asphalt
HMSP	Hot-Mix Asphalt Special for Project
HRECYL	Hot Recycle Pavement
IDT Test	Indirect Tensile Test
KDOT	Kansas Department of Transportation
LVDT	Linear Variable Differential Transformer
M-EPDG	Mechanical-Empirical Pavement Design Guide

Mr	Resilient Modulus
NDT	Nondestructive Test
PSPA	Portable Seismic Property Analyzer
SEAL	Asphalt and Aggregate Seal
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)
SN	Structural Number
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)
SR190B	Superpave Recycle Mix (19.0 mm Nominal Maximum Aggregate Size, Below Maximum Density)
SRECYL	Surface Recycle Pavement (Heater Scarifier)
St. Dev.	Standard Deviation
SUBMOD	Subgrade Modification

Acknowledgements

I would like to take this opportunity to express my sincere gratitude to my major professor Dr. Mustaque Hossain for his invaluable guidance, constant supervision, motivation, and encouragement throughout this research and preparation of this thesis. I would also like to thank Dr. Sunanda Dissanayake and Dr. Kyle Riding for being my committee members and providing input to this thesis.

I am very grateful 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 backcalculation.

I also appreciate Mr. Curtis Eichman and the crew at the Kansas Department of Transportation (KDOT) Materials and Research Lab for providing the FWD deflection data. Finally, I would like to thank KDOT for providing funding for this study.

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 10 years. At this time, pavements are designed to be rehabilitated with an asphalt overlay.

Currently, the flexible pavement design using the 1993 AASHTO Design Guide allows the year 10 and year 20 overlay thicknesses to be determined by each state agency. AASHTO (1993) describes a method for calculating the effective structural number, SN (SNeff) of existing flexible pavements based on condition survey data. The structural layer coefficients for the surface and the base layer are assigned according to the severity of distresses at the pavement surface. Equation 1.1 has been recommended by AASHTO (1993) to calculate SN.

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

where,

a_i = structural coefficient of layer i,

h_i = thickness of layer i (in), and

m_i = drainage coefficient, applied only to granular materials in the base and subbase 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 (Van Til et al., 1972). Typical values for structural layer coefficients for different pavement materials have been given by Witczak and Yoder (1975) and Paterson (1987). AASHTO (1993) has also recommended calculating SN using nondestructive (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. However, currently KDOT is considering a longer analysis period such as 40 years. KDOT funded this 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 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 capacity 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 0.26. For future overlays, the respective layer coefficients will be decreased by 0.08. 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 (3):

$$a_1 = 0.40 * \log\left(\frac{E}{3000\ \text{MPa}}\right) + 0.44 \qquad 0.20 < a_1 < 0.44 \qquad \text{Equation 1.2}$$

where,

E = modulus of elasticity (MPa).

Note: Equation was preserved in its original form with metric units.

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

The newly released Mechanical-Empirical Pavement Design Guide's (M-EPDG) prediction of pavement response and performance takes into account the fundamental properties of the layer materials (NCHRP, 2004). Among these, the most important property of an AC pavement is the dynamic modulus. In the overlay analysis of an AC pavement, the modulus of the existing pavement is characterized by a damaged modulus that represents the condition at the time of the overlay 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 AC mixtures. Thus, the M-EPDG recommends 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 AC mixes and the backcalculated AC pavement modulus has been established to date. Therefore, there is a need to understand how the aged AC properties affect future pavement performance.

1.3 Objectives of Study

This study analyzed 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 primary goals of this study were:

1. To determine how AC pavement layer moduli change over their lifetime;
2. To develop a correlation between moduli obtained from FWD, PSPA, and IDT tests; and
3. To determine the effect of aging on the pavement structural capacity.

1.4 Thesis Outline

This thesis is divided into five 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 test procedures 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. Finally, Chapter 5 summarizes the findings of the research work in the form of conclusions drawn from the research and suggests recommendations.

Chapter 2 - LITERATURE REVIEW

2.1 Falling Weight Deflectometer (FWD) 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 standard practice. The Falling Weight Deflectometer (FWD), the most developed NDT for AC pavements, applies heavy loads to the pavement and measures surface deflections by simulating truck traffic wheel loading (Hoffman and Thompson, 1982).

The FWD is a trailer mounted device and applies an impulse load of up to 27,000 lbs by dropping a mass from various heights onto an 11.8-inch diameter circular load plate. The resulting load pulse is largely a haversine wave with duration of 25 to 30 milliseconds (Gedafa et al., 2010). The peak vertical deflections are measured by up to seven transducers located at the center of the load plate and at several locations at varying radial distances from the center, often at 12-inch increments (Figure 2.1). The deflections measured closest to the applied load are mostly affected by the modulus of the AC layer, while the subgrade modulus affects the deflections measured further away from the load. The surface temperature of the pavement is also measured during testing by an infrared thermometer to allow for more accurate analysis of the deflection data.

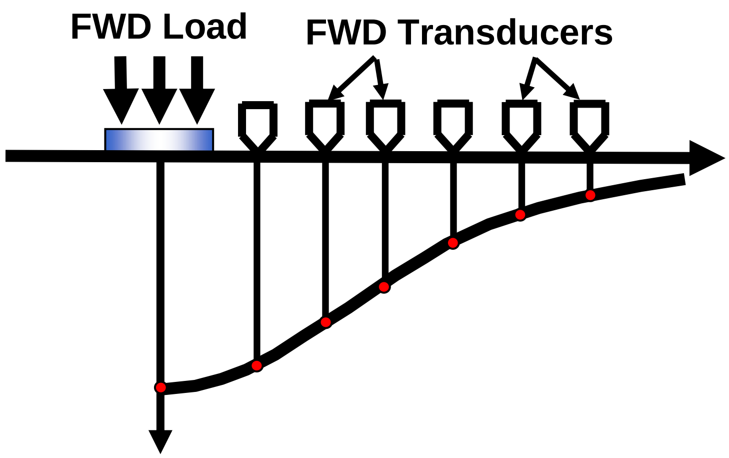

Figure 2.1 Schematic of Surface Deflection during FWD Testing

2.2 Portable Seismic Property Analyzer (PSPA) Testing

The PSPA is a handheld device that consists of a control module, source, and two receivers, as shown in Figure 2.2. The source produces high frequency waves in the pavement which are measured by the receivers. The receivers measure the surface (Rayleigh) waves because they contain about two-thirds of the seismic energy making them the easiest waves to measure (Celaya et al., 2009).

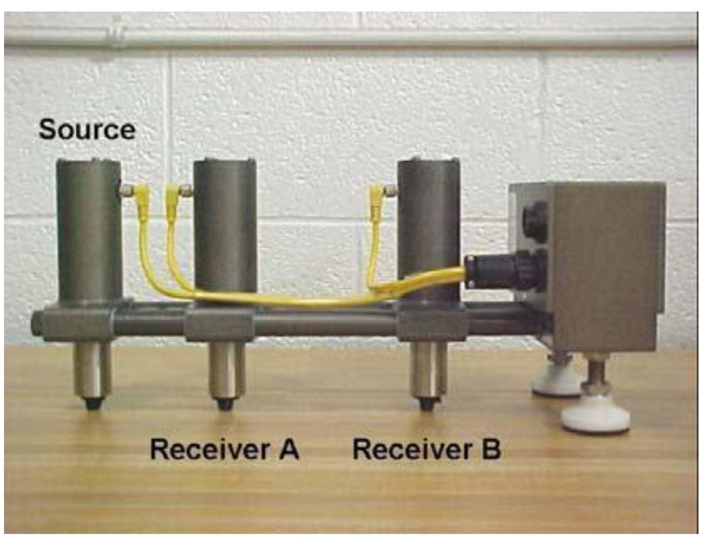

Figure 2.2 Portable Seismic Property Analyzer (Celaya et al., 2009)

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

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

where,

v = Poisson's ratio, and

ρ = the density of the material.

2.3 Modulus Backcalculation

The output from FWD testing includes temperature, load, and deflection. To obtain the moduli of the pavement layers from this data, backcalculation must be performed using an analysis program. Backcalculation is the process of calculating the pavement deflections by varying the pavement layer moduli through iterations to best match the field measured deflections (Huang, 2003). The backcalculated deflections are compared to the FWD-measured deflections. If the deflections do not match, the moduli are adjusted until a satisfactory match is obtained.

There are many backcalculation programs available including EVERCALC, MODCOMP5, MODULUS, BISDEF, CHEVDEF, ELSDEF, MICHBACK, and ELMOD. Research has shown EVERCALC produces consistent results for most pavement types (Gedafa et al., 2009). Therefore, EVERCALC was used for the analysis.

EVERCALC was developed 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).

Several features are included in EVERCALC that make it useful for backcalculating 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). These features make the program capable of analyzing most pavements, including the pavements in this project.

EVERCALC follows the process shown in Figure 2.3 to calculate the pavement modulus. First, the measured deflections, transducer spacing, load magnitude, and layer thicknesses from the FWD testing must be input into the program. Next, the program starts with seed moduli to perform an iterative analysis until the calculated moduli yield a deflection basin closest to the FWD measured deflection basin. The iterative analysis is completed when the root-mean-square (RMS) (Equation 2.2) error is minimized (WSDOT, 2005).

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

where,

d_{ci} = calculated pavement surface deflection at sensor i,

d_{mi} = measured pavement surface deflection at sensor i, and

n = number of deflection sensors used in the backcalculation process.

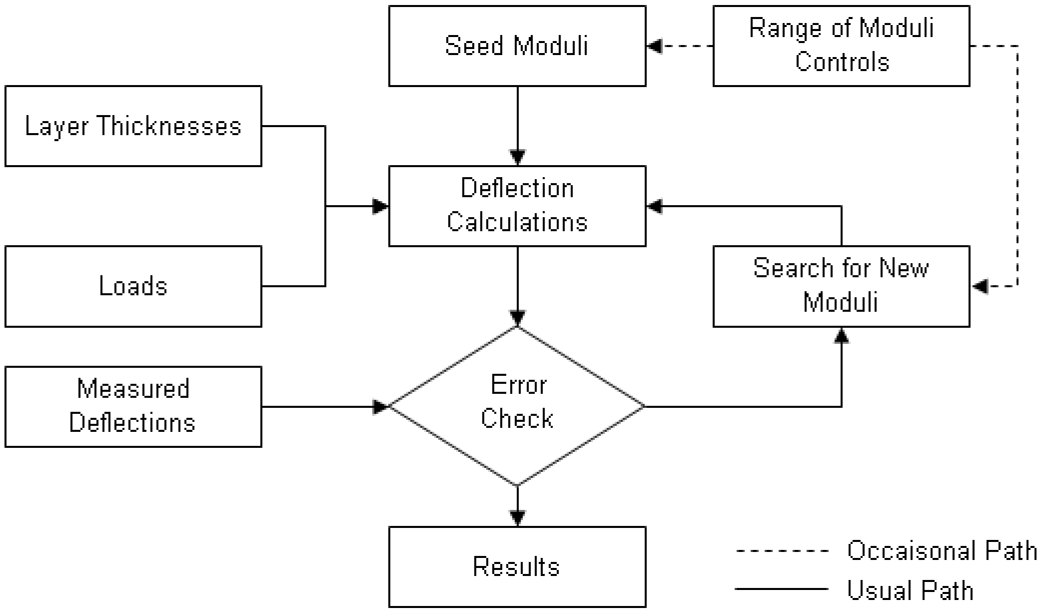

Figure 2.3 Flowchart of FWD Backcalculation Process (WSDOT, 2011)

One potential problem with backcalculation 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 moduli that will result in similar deflections. To minimize the solutions, the seed moduli and moduli range should limit the backcalculation results to only include reasonable solutions.

2.4 Temperature Correction

In order to compare data from different testing methods, the moduli from each method must be corrected to the same conditions. The most important environmental condition affecting the deflection and backcalculated 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 temperature of AC pavements at the one-third depth (Inge and Kim, 1995). The BELLS 3 equation (Equation 2.3) was developed for FWD testing where the pavement is typically shaded for less than one minute (FHWA, 2000).

$$T_d = 0.95 + 0.892T_s + \left(\log(d) - 1.25\right)\left[1.83\sin\left(2\pi\frac{A}{18}\right) - 0.448T_s + 0.621T_{avg}\right] + 0.042T_s\sin\left(2\pi\frac{B}{18}\right) \quad \text{Equation 2.3}$$

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).

Note: Equation was preserved in its original form with metric units.

A and B are computed as follows:

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

where,

t_d = time of day (decimal hours).

The modulus is then adjusted using Equation 2.4 which was developed using deflections from intact locations (Chen et al., 2000). 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).

$$E_{T_w} = \frac{E_{T_d}}{\left(T_w^{\ 2.4462} \times T_d^{\ -2.4462}\right)} \qquad \text{Equation 2.4}$$

where,

E_{T_w} = adjusted modulus at T_w (ksi),

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

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

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

2.5 Indirect Tension (IDT) Resilient Modulus Testing

The IDT test is designed to simulate the tensile forces that develop in asphalt concrete (AC) pavements under traffic loading (Mamlouk and Zaniewski, 2005). 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 2.4).

Tests are often run with 100 preconditioning cycles before five test cycles are applied to the specimen (Romanoschi and Metcalf, 1999; Loulizi et al., 2007). The cyclic load is a haversine wave typically applied with a 0.1 sec load period and a rest period of 0.9 sec, shown in Figure 2.5 (a) (AASHTO, 2000). Both 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 ΔV_I and ΔH_I in Figure 2.5 (b and c). There is

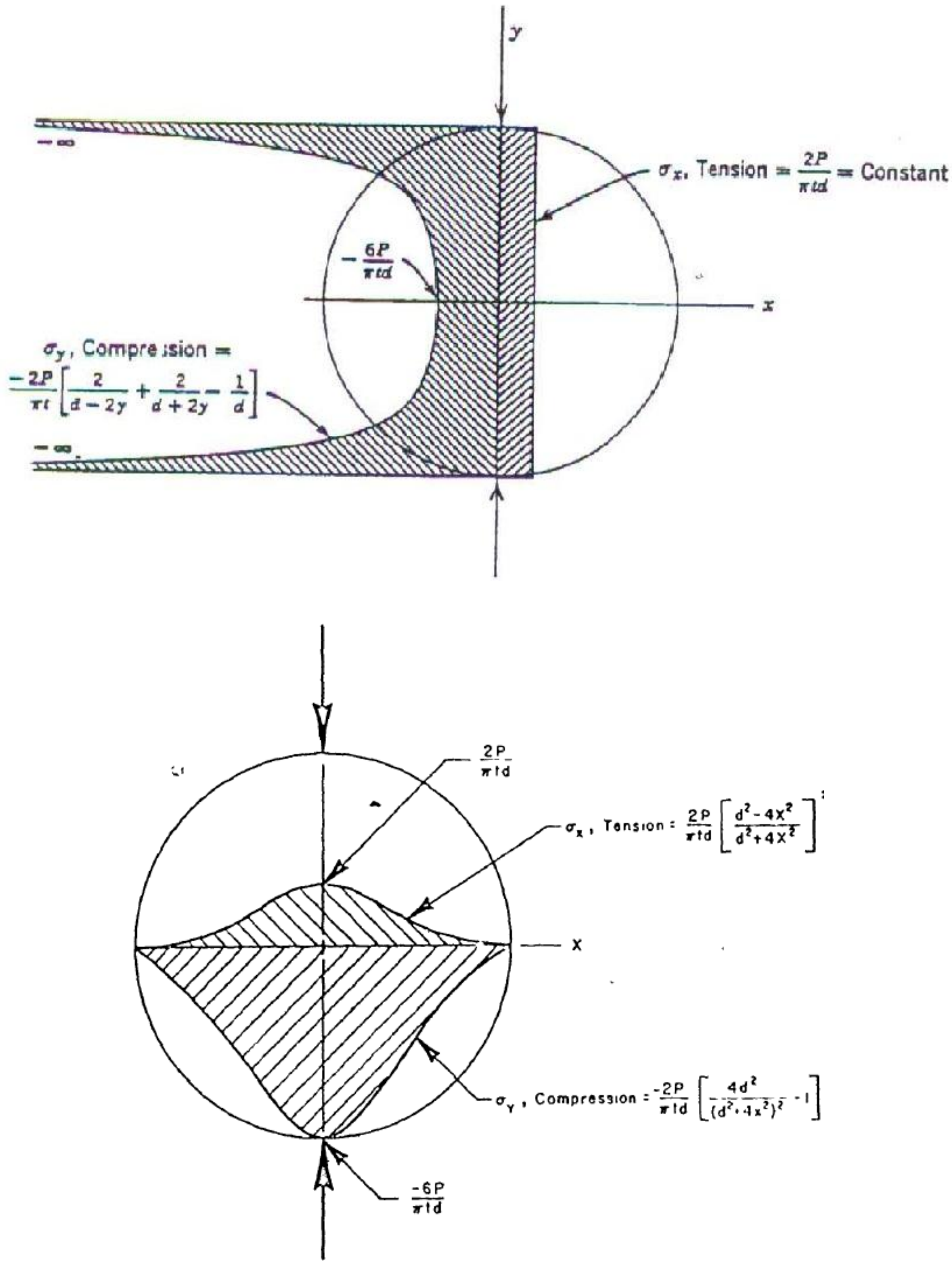

Figure 2.4 Theoretical Stress Distribution along the Vertical and Horizontal Axes during IDT Testing (Frocht, 1957)

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 ΔV_T and ΔH_T in Figure 2.5 (b and c). For resilient modulus calculations, the Poisson's ratio is often assumed to be 0.35 (Huang, 2003). After the test is run once on each specimen, the specimen is rotated 90 degrees, 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 run at multiple temperatures, typically 41°, 77°, and 104°F, to assess how the AC moduli change with temperature (Mamlouk and Zaniewski, 2005).

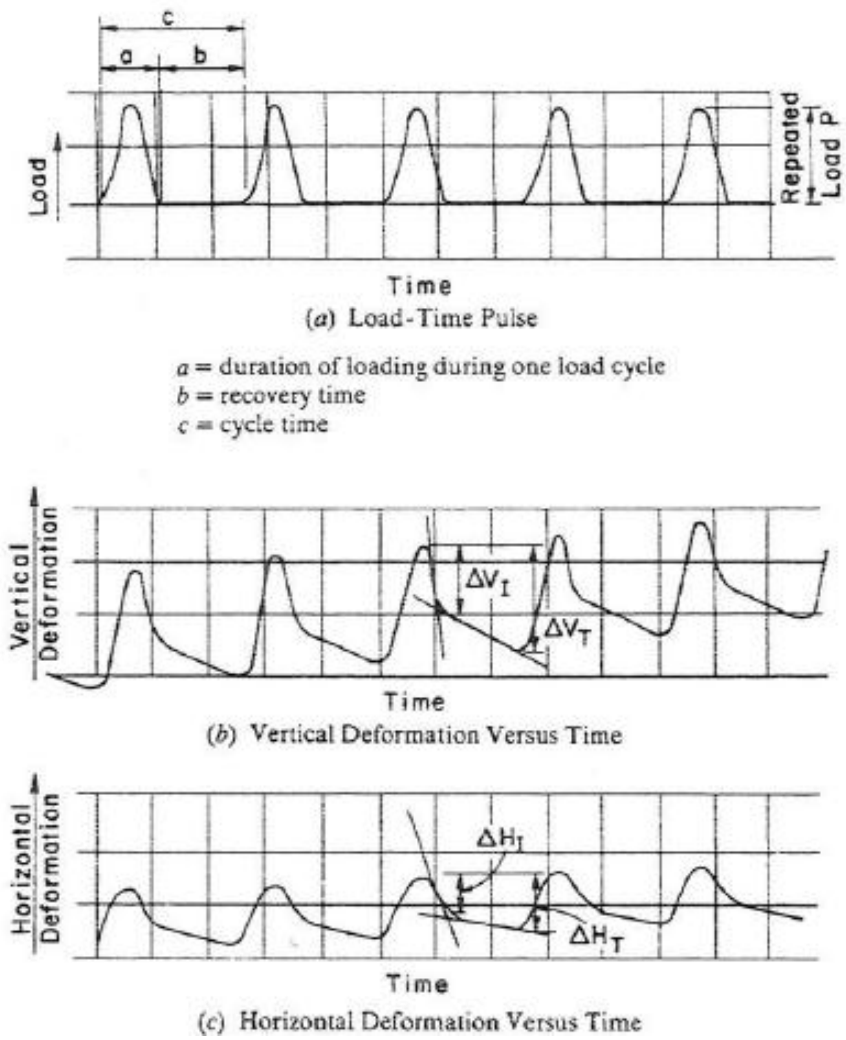

Figure 2.5 IDT Cyclic Loading and Deformations (ASTM, 1983)

2.6 Correlation between Laboratory and Backcalculated Moduli

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

There are some environmental and material factors 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 method results may also be caused by disturbance during coring and a different aggregate orientation during laboratory testing (Mikhail et al., 1999).

Research conducted by Akram et al. (1994), Harold and Killingsworth (1998), Mikhail et al. (1999), Loulizi et al. (2007), and Gedafa et al. (2010) has not been successful in finding a correlation between field and laboratory moduli, but some 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 Summary of Literature Review

FWD testing simulates traffic loading by dropping a weight onto a load plate that results in pavement surface deflections. The PSPA is a hand-held device that calculates the pavement modulus by producing and measuring high frequency surface waves. Pavement moduli are backcalculated from FWD data by performing an iterative analysis until the calculated moduli yield a deflection basin closest to the FWD-measured deflection basin. EVERCALC is a program used in the backcalculation of pavement layer moduli, and it can analyze multiple pavement layers. AC moduli are greatly affected by temperature, so the moduli from different testing methods must all be adjusted to the same temperature for a valid comparison. IDT testing simulates the tensile forces that develop in the AC under traffic loading by applying a compressive force along the vertical axis of a cylindrical axis of a specimen which causes tensile stress along the horizontal axis. Most past studies have found no good correlation between field and laboratory testing moduli, but some studies showed promising results.

Chapter 3 - TEST ROADWAYS 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 the state. 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 core samples could be obtained. Each pavement was also required to have had at least two overlays over its lifetime. Finally, a variety of roadway types (Interstates, US highways, and Kansas state highways) and locations across the state were chosen so the selected roadways would be a good representation of the pavements in Kansas. Considering 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 Table 3.1 and Figure 3.1. The construction history for each test roadway is given 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

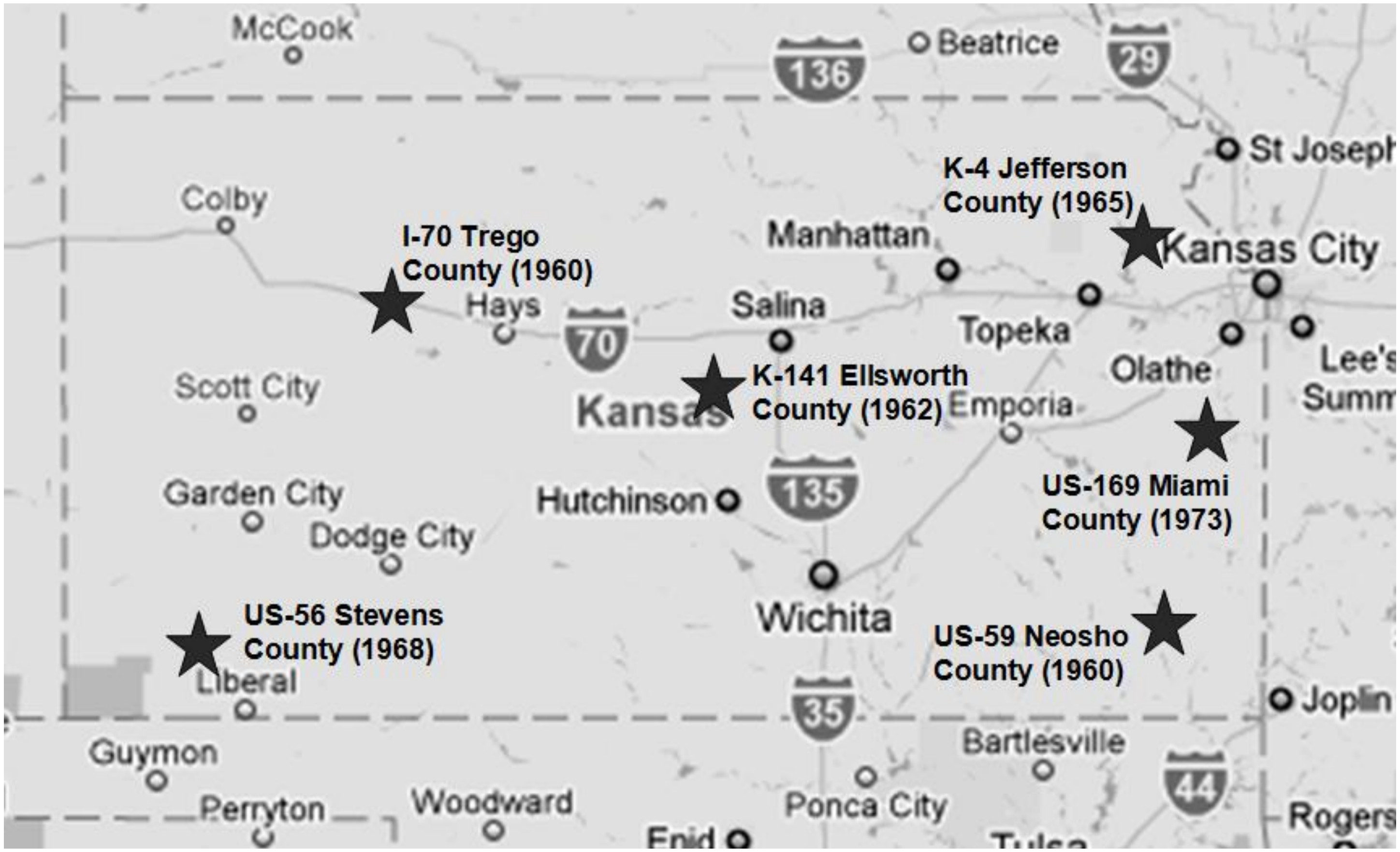

Figure 3.1 Project Locations in Kansas

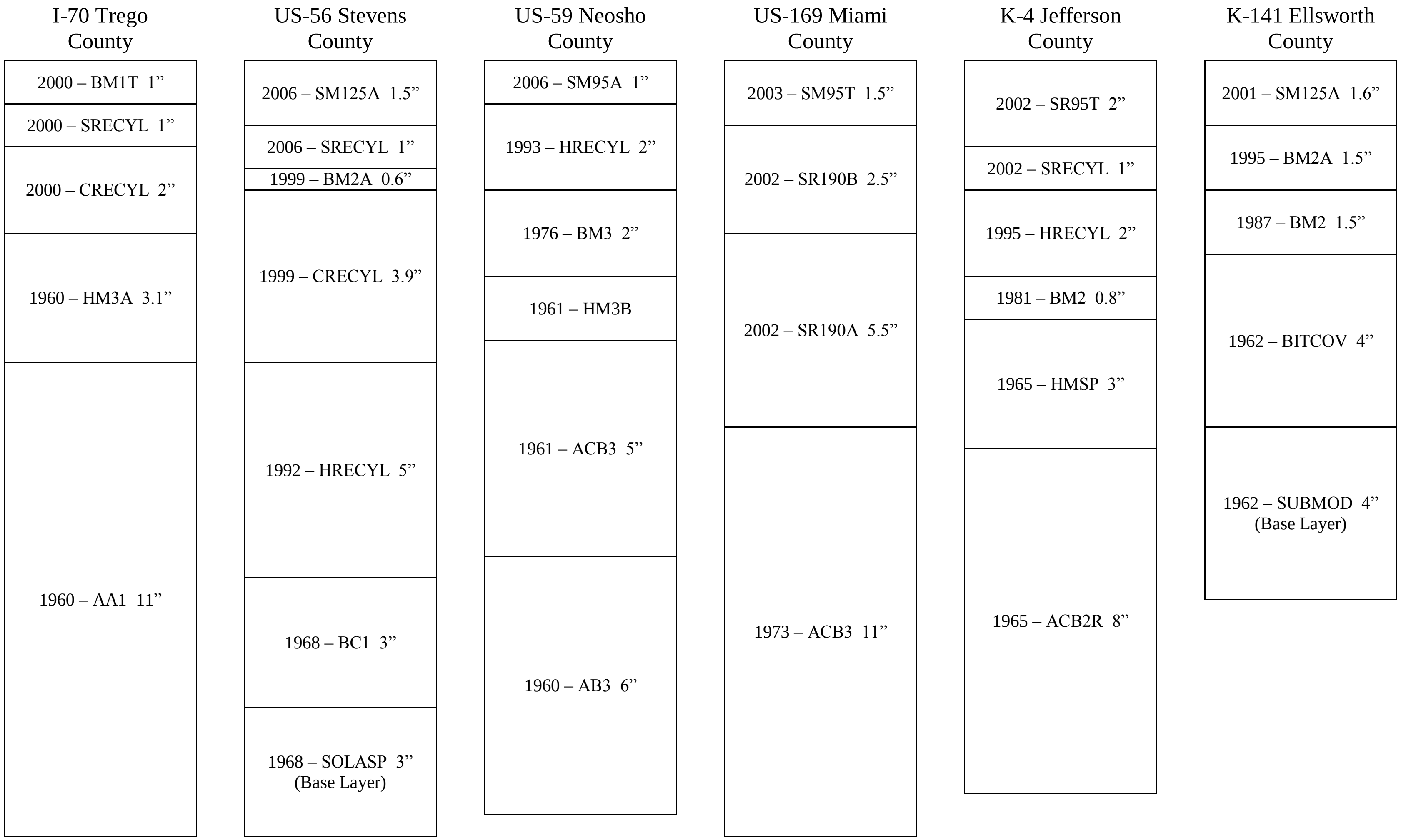

Figure 3.2 Pavement History for each Test Roadway

Note: Refer to the List of Abbreviations for more detailed layer descriptions

3.2 Data Collection

3.2.1 Falling Weight Deflectometer (FWD)

A Dynatest 8000, shown in Figure 3.3, was used to obtain FWD deflection data for each of the test roadways. FWD data was collected along the outer wheel path and was taken at 50-ft intervals. At each test station, six FWD drops were used 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 radial distances of 8, 12, 18, 24, 36, and 60 inches.

Figure 3.3 Dynatest 8000 FWD Tester

3.2.2 Portable Seismic Property Analyzer (PSPA)

PSPA tests were typically conducted at 600-ft intervals starting 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 ensure 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, cores were obtained. Cores were typically taken at 600-ft intervals using a diamond tipped circular coring bit (Figure 3.4). The portable drill was not powerful enough for the deep pavements and large six inch diameter cores; therefore a trailer mounted drill was used for the remaining projects.

The six-inch diameter 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). For thicker layers such as ACB3 and AB3 on US-59, multiple specimens were cut. When possible, the cut was made at the interface of the layers. Table 3.2 shows the number of test specimens obtained from each AC layer out of the maximum number of specimens possible based on the number of cores obtained and the thickness of the layer.

Some layers, such as BM2 and BITCOV on K-141, were too stripped for attaching the LVDTs on all IDT test specimens. Twelve cores were obtained from I-70 because cores one and two were re-cored with the trailer mounted coring drill. No specimens of the bottommost layer of I-70, AA1, were tested because it was too degraded to obtain a quality specimen.

(a) Portable Drill

(b) Trailer Mounted Drill

Figure 3.4 Pavement Coring Drills

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	9/12	SM125A, SRECYL	2006	10/10	SM95A, HRECYL	1993	10/10
CRECYL	2000	12/12	BM2A, CRECYL	1999	10/10	BM3, HM3B	1976	9/10
HM3A	1960	11/12	HRECYL	1992	10/10	ACB3	1961	10/12
AA1	1960	0/12	BC1	1968	9/10	AB3	1960	8/12

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	10/10	SR95T, SRECYL	2002	7/10	SM125A, BM2A	2001	10/10
SR-190A	2002	10/10	HRECYL, BM2	1995	8/10	BM2	1987	6/10
ACB3	1973	37	HMSP	1965	10/10	BITCOV	1962	5/10
			ACB2R	1965	9/10			

Note: Refer to the List of Abbreviations for more detailed layer descriptions

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 calls for epoxying a horizontal and a vertical linear variable differential transformer (LVDT) to each face of the specimen with a gage length of 75 mm (3 in) to measure deformations in each direction due to a compressive load applied along the vertical axis. The deformations from the two horizontal LVDTs were averaged to calculate the mean modulus, standard deviation, and coefficient of variation.

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. Only five preconditioning cycles and five test cycles were applied to the specimens to find the resilient modulus because fatigue testing was to be performed on the specimens later. Figure 2.5 shows the typical loading cycle and resulting deformations. The peak load applied was 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 haversine load pulse correctly. The effect of changing the length of the rest period is unknown, but it is likely insignificant (Huang, 2003). The typical total deformation recovery was two to five micrometers (0.079 to 0.197 mils) with a maximum of 15 micrometers (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 0.6 micrometers (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.

Resilient Modulus calculations can be based off either the initial or total deformation recovery. For this research, the total deformation recovery was used. Tests were performed at only one temperature (68°F) since the results were compared to other testing methods and temperature sensitivity was not being considered in this study. After testing the specimens along one axis, they were turned 90 degrees and tested again along the other axis to receive a more representative average modulus (ASTM, 1983).

Chapter 4 - DATA ANALYSIS

4.1 Modulus Backcalculation

Each test roadway was divided into ten sections approximately 600-ft in length. In each section, eleven Falling Weight Deflectometer (FWD) tests were conducted at 50-ft intervals. The locations of the pavement cores, approximately the middle of each test section, and the backcalculation results are shown in Appendix A.

Backcalculation of layer moduli was performed with EVERCALC. Results were calculated for three 9,000 lb FWD drops at each station. Most of the roadways were analyzed as a two layer system: asphalt pavement and subgrade. Some of the stations required the addition of a stiff layer at varying depths to minimize the backcalculated deflection error. A stiff layer is a layer at which there is zero deflection often caused by bedrock or a water table.

The moduli of each individual AC layer were not calculated because the difference in moduli between AC layers is not large enough to differentiate (Gedafa et al., 2010). Also, the backcalculation process becomes much more difficult when more layers are considered. There is an increased risk of not calculating reasonable results since there is no unique solution for a given set of surface deflections. Therefore, all AC layers were combined into one pavement layer for analysis.

4.2 Portable Seismic Property Analyzer (PSPA) Analysis

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 Appendix B.

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 resulting in a large deviation at many of the core locations.

Results for US-169 PSPA moduli ranged from 1,650 to 10,900 ksi. I-70 also had very high PSPA readings for cores one and two of about 1,600 ksi compared to approximately 450 ksi from the other cores. These variations were likely caused by a difference in the moisture content of the pavement. For cores one and two of I-70, the PSPA tests were run after the pavement cores were taken. This order of testing is incorrect because the coring drill uses water to decrease the friction between the coring bit and the AC pavement which will affect the PSPA moduli. Therefore, the PSPA test was conducted before cores were obtained for cores three through ten for I-70.

4.3 Temperature Correction

As mentioned earlier, the FWD and PSPA calculated moduli need to be corrected for temperature for comparison with IDT moduli. To determine the corrected AC modulus for FWD and PSPA testing, a two-step procedure was followed. The BELLS3 equation (Equation 2.3) was used to find the mid-depth temperature of the pavement at the time of testing. Next, the FWD and PSPA moduli were corrected to 68°F, the same temperature as the IDT testing temperature, with Equation 2.4. The temperature-corrected moduli are shown in Appendices A and B.

4.4 Indirect Tension (IDT) Test Result Analysis

As mentioned earlier, 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 disintegrated to obtain a quality specimen.

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, typical for AC.

$$Mr_T = \frac{P(\nu + 0.27)}{t \Delta H_T} \qquad \text{Equation 4.1}$$

where,

Mr_T = total resilient modulus of elasticity (ksi),

P = cyclic load (kips),

ν = Poisson's ratio,

t = thickness of specimen (in), and

ΔH_T = total recoverable horizontal deformation (in).

After the moduli were calculated for each AC layer, the results were reduced to one equivalent modulus for the core ($Mr_{equivalent}$) using Equation 4.2 so the IDT results could be compared to the FWD and PSPA results.

$$Mr_{equivalent} = \frac{\sum (M_r \times d)}{\sum d} \qquad \text{Equation 4.2}$$

where,

M_r = resilient modulus of specimen (ksi), and

d = thickness of specimen (in).

The IDT moduli were compared to the year of construction for each AC layer in Tables 4.1 through 4.6 and Figures 4.4 through 4.9. The figures show the modulus of most AC layers typically decreases linearly with age assuming every AC layer for each test roadway was constructed with the same modulus. This is expected because the AC deteriorates due to 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-size aggregates, but AC with small-size aggregates showed the greatest amount of stripping. An example of a specimen with moderate stripping is shown in Figure 4.1.

Figure 4.1 Typical IDT specimen for K-141 showing moderate stripping

I-70 and K-4 (Tables 4.1 and 4.5 and Figures 4.4 and 4.8) show a lower reduction in modulus with age. The bottom layer on I-70, AA1 built in 1960, was not tested in IDT because it was too disintegrated to obtain a quality specimen. If that layer had been considered, it would likely increase the slope of the line to be a closer match to the other test roadways. The specimens for K-4 showed a lower reduction in modulus with age because they showed little or no signs of stripping (Figure 4.2).

Figure 4.2 Typical Core from K-4

One test roadway, US-169 in Miami County, did not follow the typical aging pattern. US-169 showed an increase in resilient modulus with age, as shown in Table 4.4 and Figure 4.6, because the specimens showed no deterioration. Figure 4.3 shows the picture of a typical core from US-169. The increase in modulus with age could be explained by two possibilities: the AC layers being compacted by traffic loading and the older AC layers having a higher modulus at construction. The compaction from traffic loading happened in all six of the test roadways, but it may only be noticeable on US-169 because the specimens were not deteriorated. As mentioned earlier, the M-EPDG predicts the moduli of aged AC specimens are likely to be higher than new AC mixtures which is supported by the results from this undeteriorated roadway.

Figure 4.3 Typical Core from US-169

Table 4.1 IDT Year Analysis for I-70 in Trego County

Layer	Year	Mr avg (ksi)	St. Dev.	Variance	High Mr (ksi)	Low Mr (ksi)
BM1T, SRECYL	2000	3,002	812	27.1	4,648	2,115
CRECYL	2000	2,722	338	12.4	3,196	2,049
HM3A	1960	2,037	520	25.5	2,872	1,312

Note: Refer to the List of Abbreviations for more detailed layer descriptions

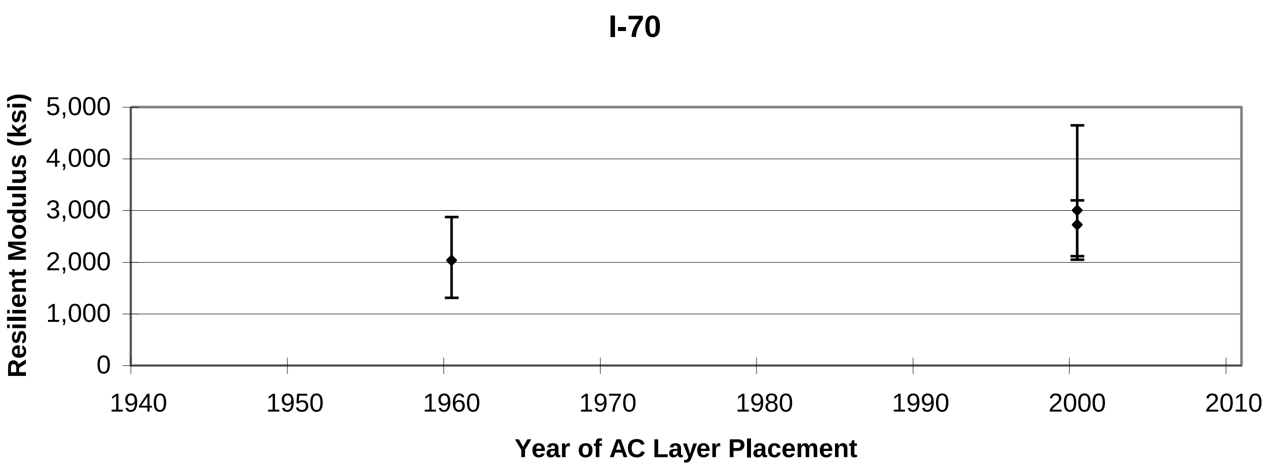

Figure 4.4 IDT Year Analysis for I-70

Table 4.2 IDT Year Analysis for US-56 in Stevens

Layer	Year	Mr avg (ksi)	St. Dev.	Variance	High Mr (ksi)	Low Mr (ksi)
SM125A, SRECYL	2006	2,193	232	10.6	2,516	1,815
BM2A, CRECYL	1999	2,081	418	20.1	2,731	1,481
HRECYL	1992	1,861	287	15.4	2,283	1,364
BC1	1968	1,109	338	30.5	1,604	577

Note: Refer to the List of Abbreviations for more detailed layer descriptions

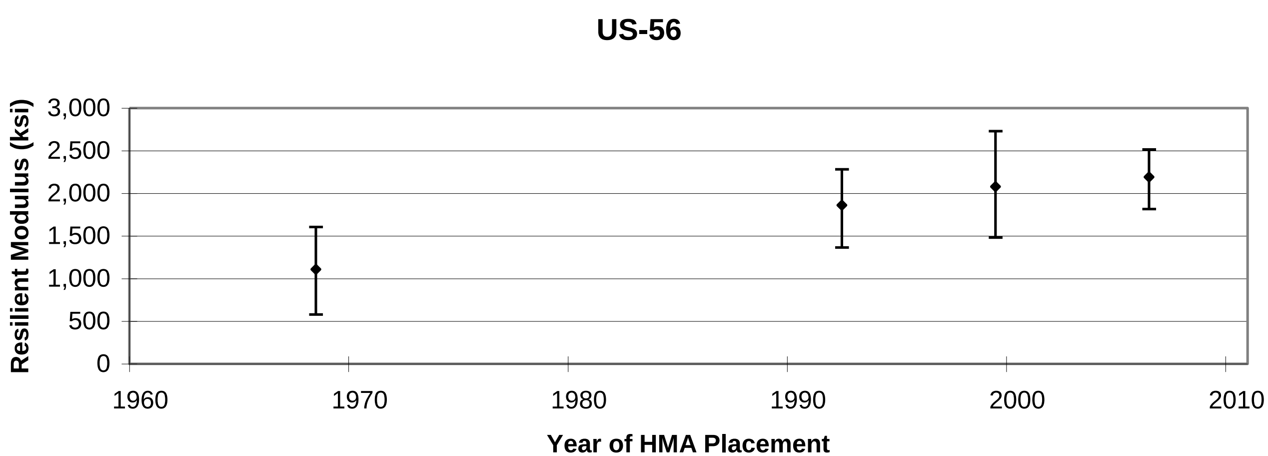

Figure 4.5 IDT Year Analysis for US-56

Table 4.3 IDT Year Analysis for US-59 in Stevens County

Layer	Year	Mr avg (ksi)	St. Dev.	Variance	High Mr (ksi)	Low Mr (ksi)
SM95A, HRECYL	1993	2,037	343	16.8	2,648	1,430
BM3, HM3B	1976	1,466	451	30.8	2,588	964
ACB3	1961	827	185	22.4	1,193	574
AB3	1960	859	343	39.9	1,537	495

Note: Refer to the List of Abbreviations for more detailed layer descriptions

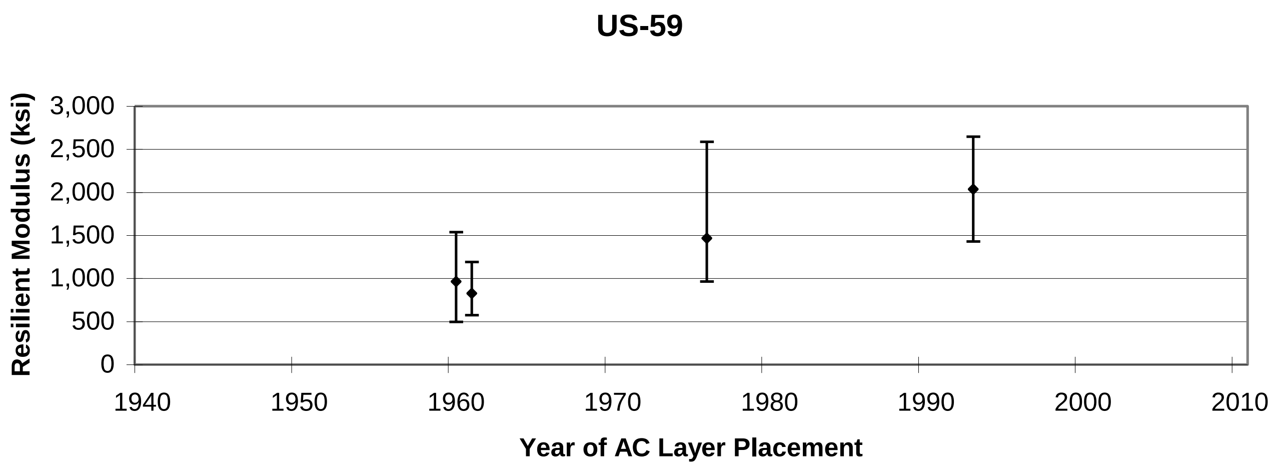

Figure 4.6 IDT Year Analysis for US-59

Table 4.4 IDT Year Analysis for US-169 in Miami County

Layer	Year	Mr avg (ksi)	St. Dev.	Variance	High Mr (ksi)	Low Mr (ksi)
SM95T, SR190B	2002	2,784	1269	45.6	4,531	1,133
SR190A	2002	3,034	1616	53.3	6,187	1,042
ACB3	1973	4,345	1972	45.4	7,849	1,768

Note: Refer to the List of Abbreviations for more detailed layer descriptions

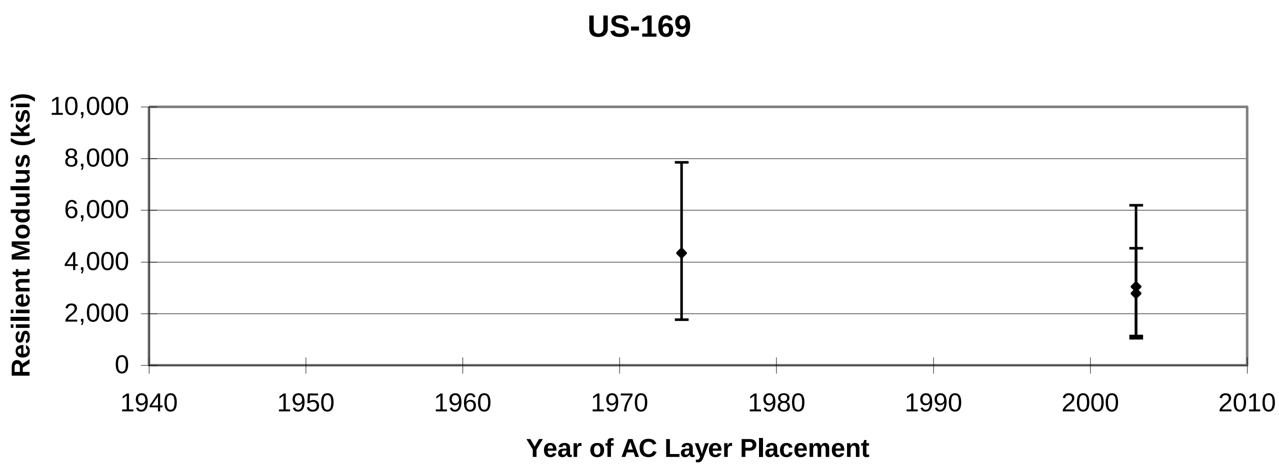

Figure 4.7 IDT Year Analysis for US-169

Table 4.5 IDT Year Analysis for K-4 in Jefferson County

Layer	Year	Mr avg (ksi)	St. Dev.	Variance	High Mr (ksi)	Low Mr (ksi)
SR95T, SRECYL	2002	2,800	490	17.5	3,739	2,257
HRECYL, BM2	1995	2,380	553	23.2	3,080	1,340
HMSP	1965	2,495	442	17.7	3,408	1,985
ACB2R	1965	2,200	422	19.2	2,704	1,241

Note: Refer to the List of Abbreviations for more detailed layer descriptions

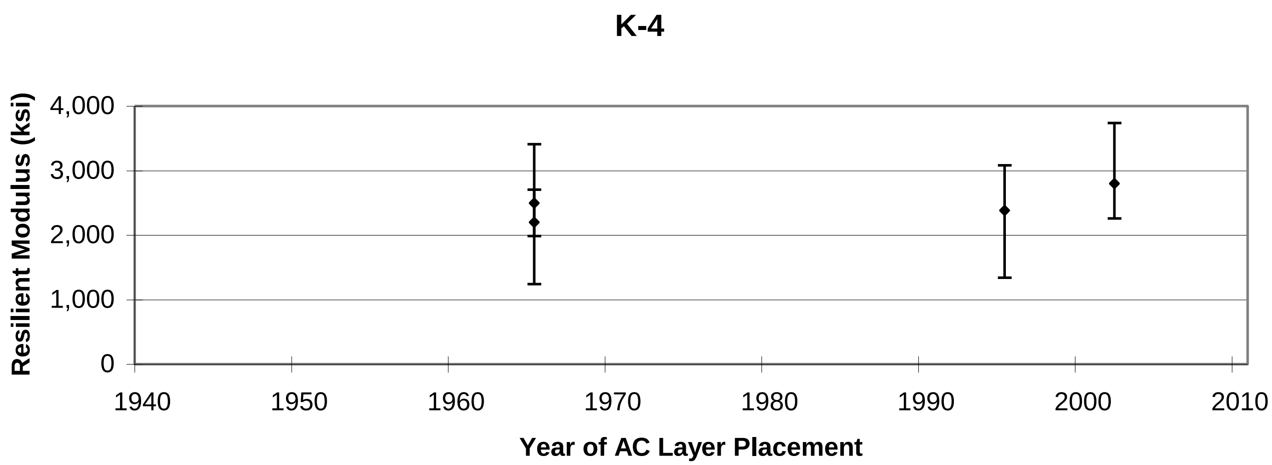

Figure 4.8 IDT Year Analysis for K-4

Table 4.6 IDT Year Analysis for K-141 in Ellsworth County

Layer	Year	Mr avg (ksi)	St. Dev.	Variance	High Mr (ksi)	Low Mr (ksi)
SM125A, BM2A	2001	2,826	337	11.9	3,410	2,381
BM2	1987	1,924	492	25.6	2,579	1,297
BITCOV	1962	1,127	591	52.4	2,016	653

Note: Refer to the List of Abbreviations for more detailed layer descriptions

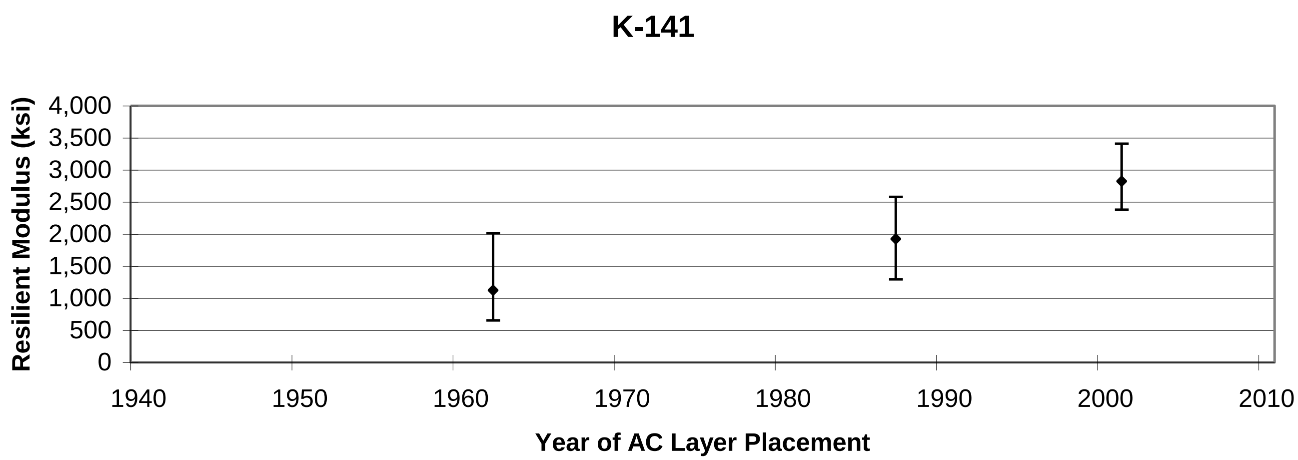

Figure 4.9 IDT Year Analysis for K-141

4.5 Comparison of Results

4.5.1 Test Method Comparison

The moduli from the testing methods (FWD, PSPA, and IDT) were compared to find if there is any correlation between different methods. Only FWD results at the stations that were also cored were compared with the PSPA and IDT results.

While there is a reasonable correlation between the outputs from the test methods at most test sites, no consistent correlation was found for all sites, as shown by the average ratios listed in Table 4.7. This may have been caused by different factors such as in-situ moisture content and specimen size.

Results for PSPA testing on US-169 have been removed from Table 4.7 because they were inconsistent, likely due to varying moisture content. PSPA results for cores one and two on I-70 were also removed from the ratio analysis because the tests were performed incorrectly.

Quality test specimens could not be obtained from any of the cores for layer AA1, the oldest layer for I-70. Had this layer been tested, the IDT moduli for this roadway would have likely been smaller. This would impact the correlation between the test methods for I-70 because FWD and PSPA test methods calculate pavement moduli for the full pavement depth.

The moduli obtained from FWD testing were consistently lower than the other test results. IDT modulus results ranged from about one to 51 times greater than the moduli from the FWD tests with the lowest and highest ratios for US-56 and K-4, respectively. Excluding PSPA results from US-169, PSPA modulus values ranged from being nearly equal to the FWD results on I-70 to approximately two times larger than the IDT results on US-56.

Table 4.7 Average Ratios of Testing Method Moduli

Route	FWD / PSPA	FWD / IDT	PSPA / FWD	PSPA / IDT	IDT / FWD	IDT / PSPA
I-70	0.7	0.1	1.3	0.2	9.1	6.2
US-56	0.3	0.6	3.5	1.9	1.8	0.5
US-59	0.5	0.3	2.5	0.6	4.9	1.9
US-169	N/A	0.4	N/A	N/A	3.3	N/A
K-4	N/A	0.1	N/A	N/A	20.4	N/A
K-141	0.1	0.2	9.9	1.4	7.4	0.8

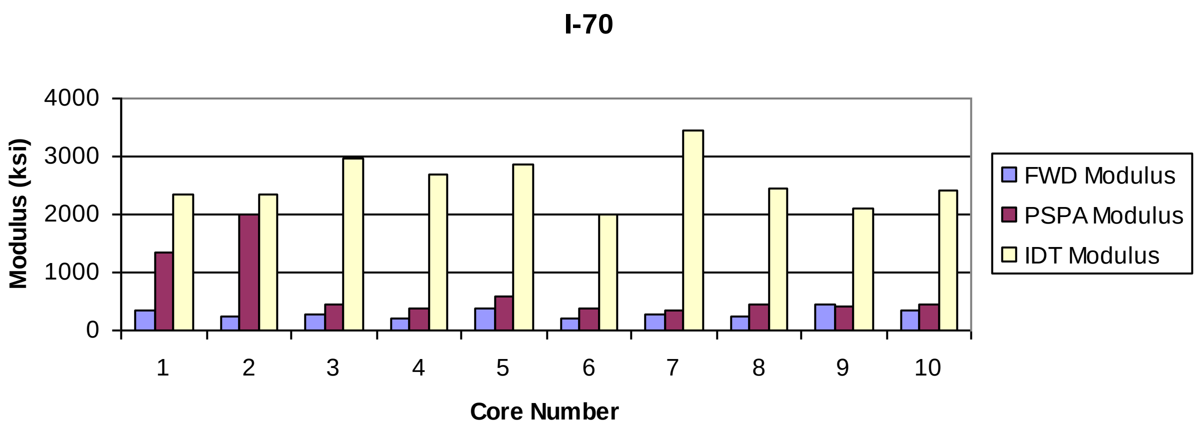

Figure 4.10 Modulus Comparison for I-70 in Trego County

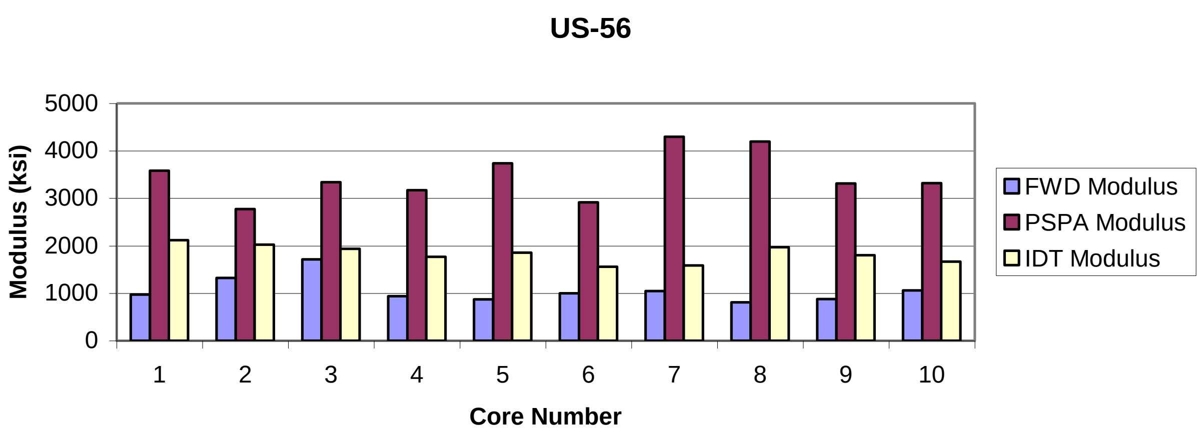

Figure 4.11 Modulus Comparison for US-56 in Stevens County

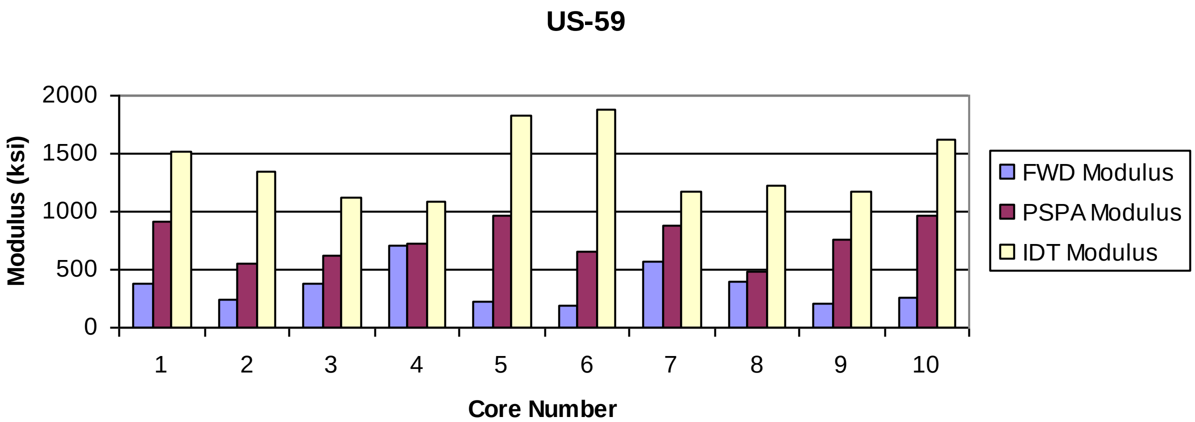

Figure 4.12 Modulus Comparison for US-59 in Neosho County

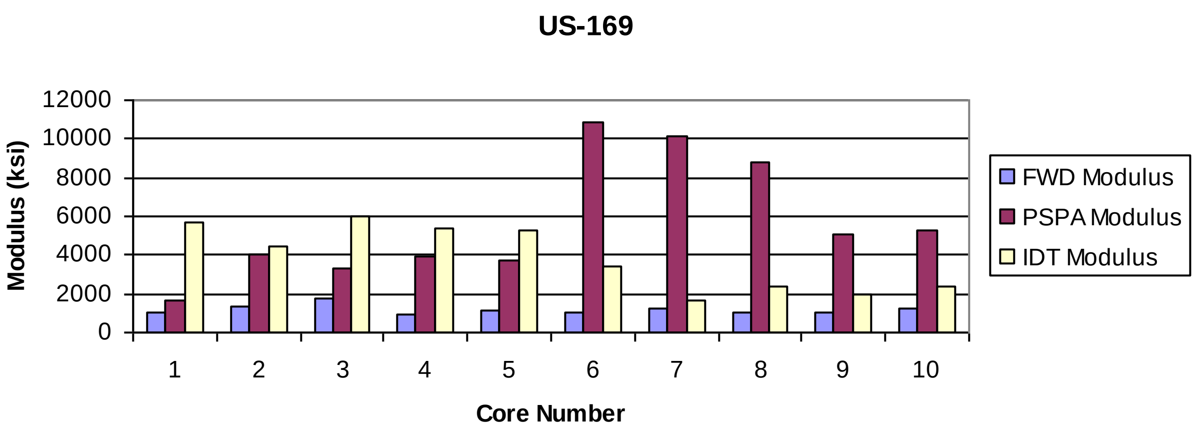

Figure 4.13 Modulus Comparison for US-169 in Miami County

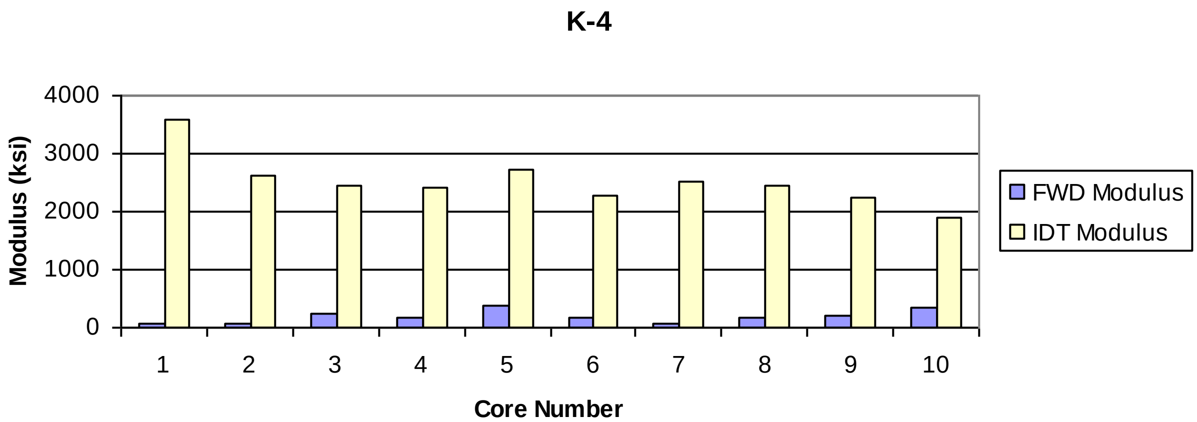

Figure 4.14 Modulus Comparison for K-4 in Jefferson County

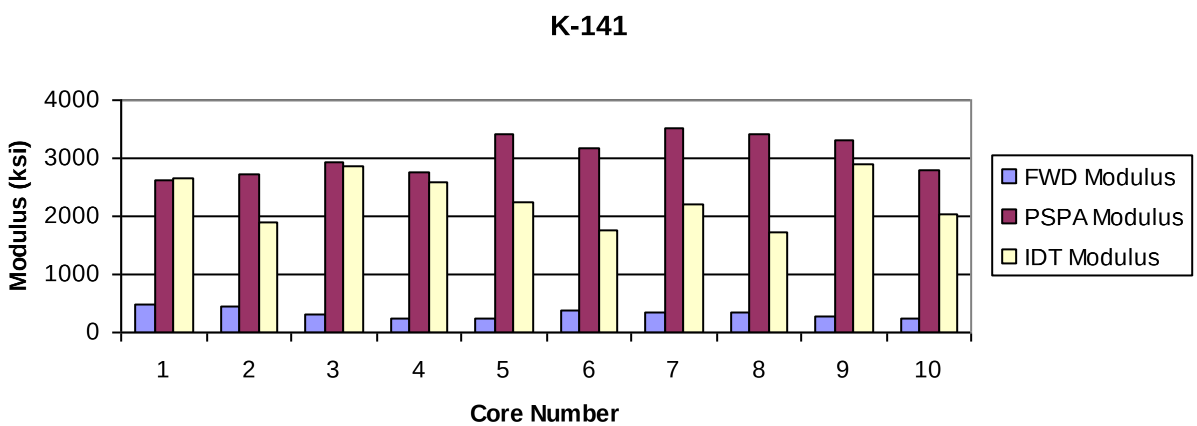

Figure 4.15 Modulus Comparison for K-141 in Ellsworth County

4.5.2 Depth Comparison

Test results were also analyzed by pavement depth to determine if depth influenced the moduli. Pavement depth was determined from the cores. 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, especially the bottommost layer.

Excluding the PSPA moduli for US-169, most data was consistent and independent of pavement depth. However, there were a couple exceptions to this pattern. IDT moduli for US-59 and K-4, shown in Figures 4.18 and 4.20, decreased linearly with depth, and the FWD moduli for US-59 increased with depth. These results possibly suggest the moduli for FWD, PSPA, and IDT tests converge for deeper pavements. It should be noted that US-59 is one of the deepest pavements tested in this study, but I-70 and US-169, the other pavements with depths over 20-inches, do not follow the same pattern.

The IDT moduli results for US-59 were skewed because cores five and six, the cores with the highest IDT moduli, did not include the older pavement layers because quality specimens could not be obtained. Also, cores four and seven had lower IDT moduli because layers ACB3 and AB3, the oldest layers in the cores, had two specimens each while the other cores tested a maximum of one specimen for each layer.

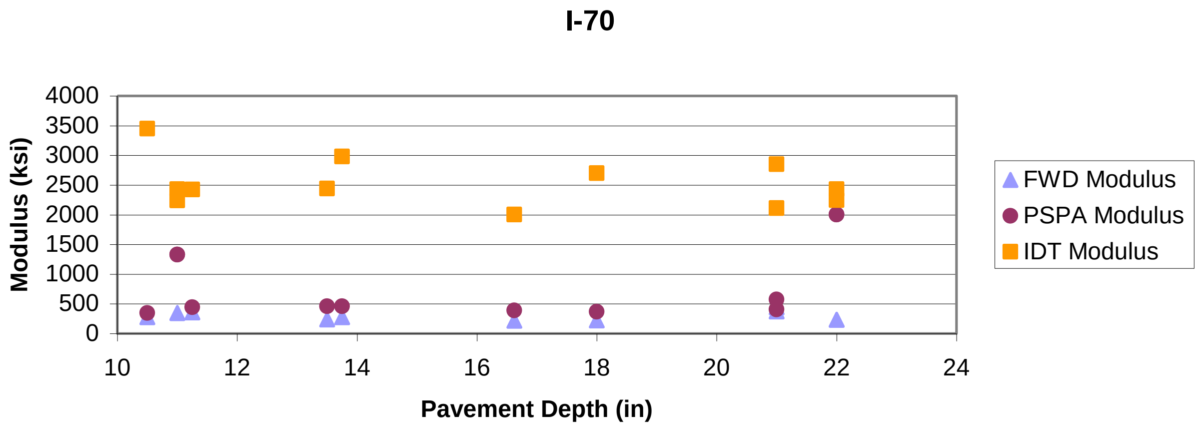

Figure 4.16 Modulus Comparison by Depth for I-70 in Trego County

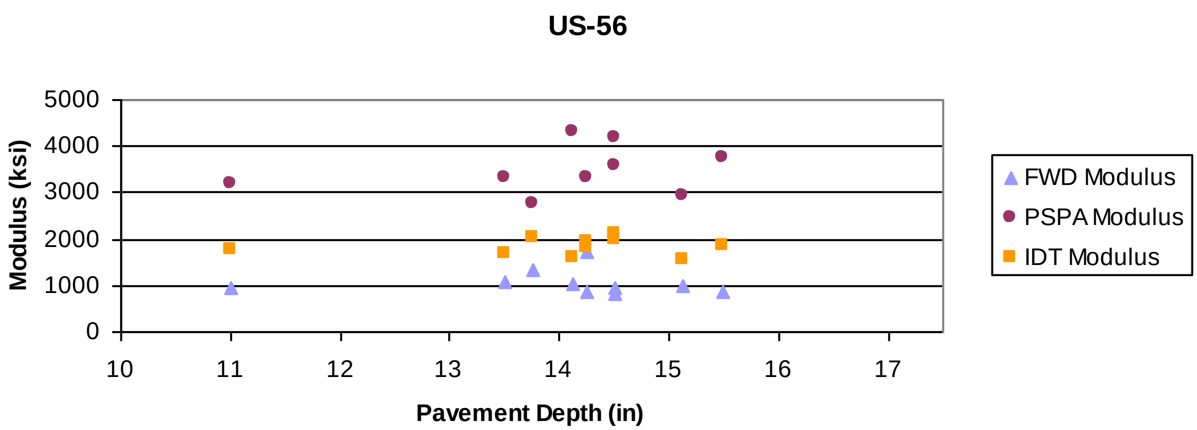

Figure 4.17 Modulus Comparison by Depth for US-56 in Stevens County

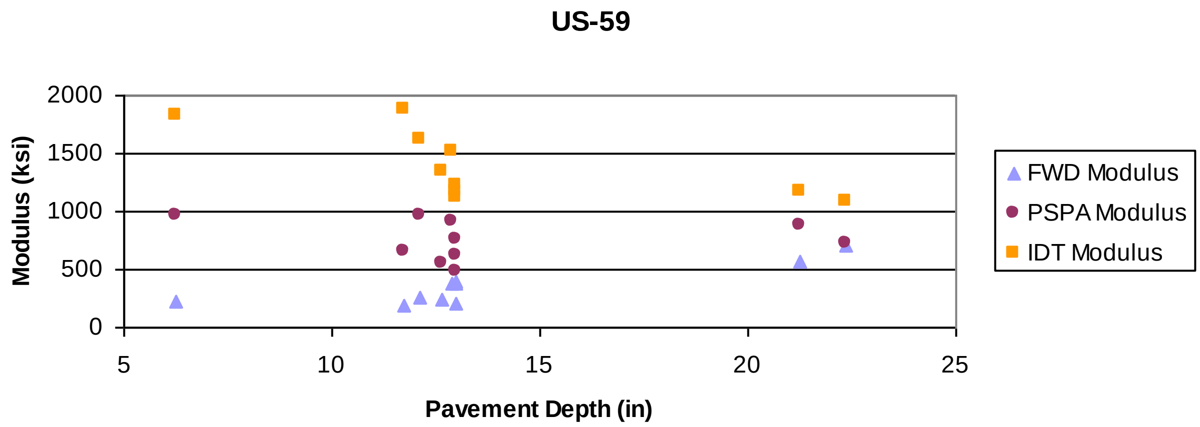

Figure 4.18 Modulus Comparison by Depth for US-59 in Neosho County

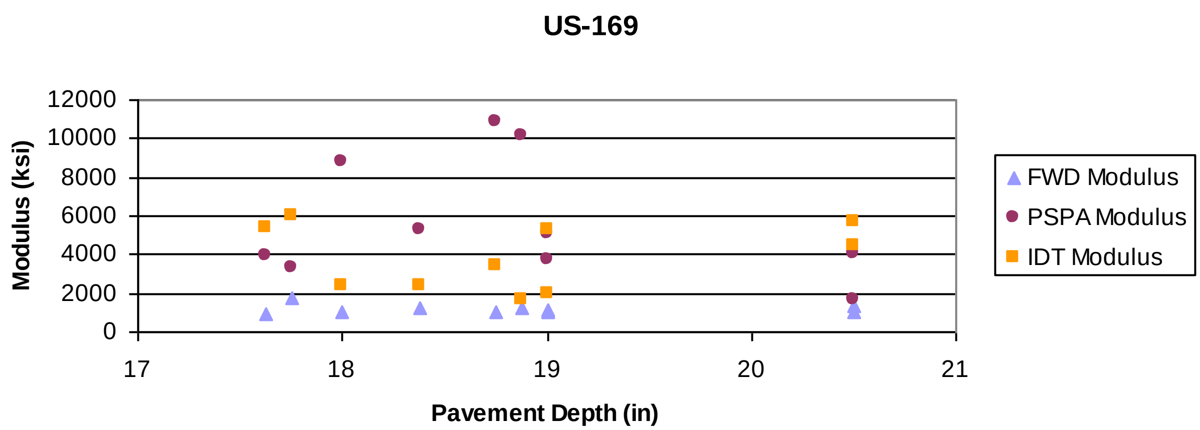

Figure 4.19 Modulus Comparison by Depth for US-169 in Miami County

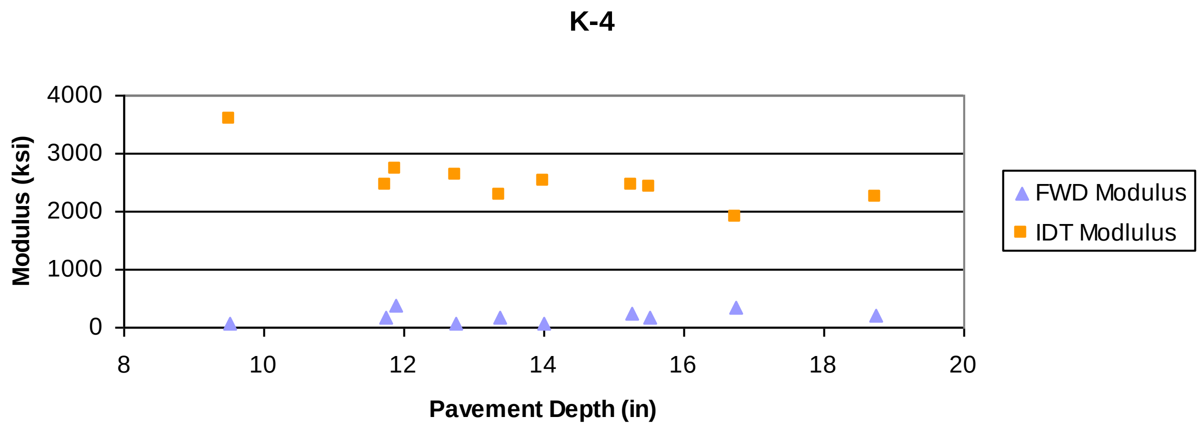

Figure 4.20 Modulus Comparison by Depth for K-4 in Jefferson County

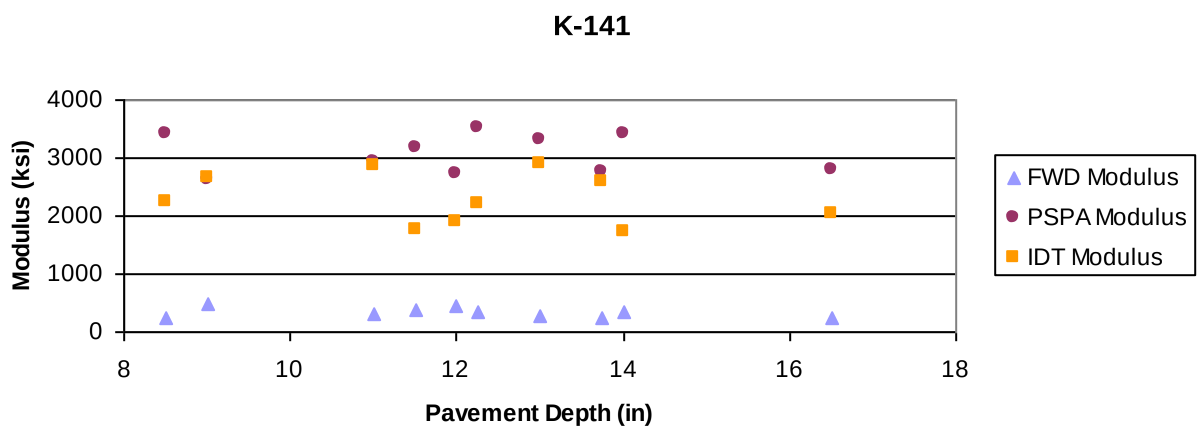

Figure 4.21 Modulus Comparison by Depth for K-141 in Ellsworth County

4.5.3 Structural Layer Coefficients

As mentioned earlier, the thickness of an asphalt overlay is related to the structural capacity of the existing pavement. For new pavement design, KDOT uses 0.42 as the structural coefficient for the top one-third of the pavement thickness, and the remaining thickness has a layer coefficient of 0.34. The layer coefficient for each AC layer is assumed to decrease by 0.08 when an overlay is designed. For the first overlay on a pavement, the overlay would have a layer coefficient of 0.42, the top one-third of the existing pavement will be 0.34, and the remaining thickness will is 0.26.

The correlation between layer coefficient and layer resilient modulus is approximately linear for AC with a resilient modulus greater than 200 ksi, as shown in Figure 4.22. Based on this, the layer coefficient for each layer of the test roadways was calculated. The surface layer of each test roadway 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 4.21. 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 4.23.

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

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.

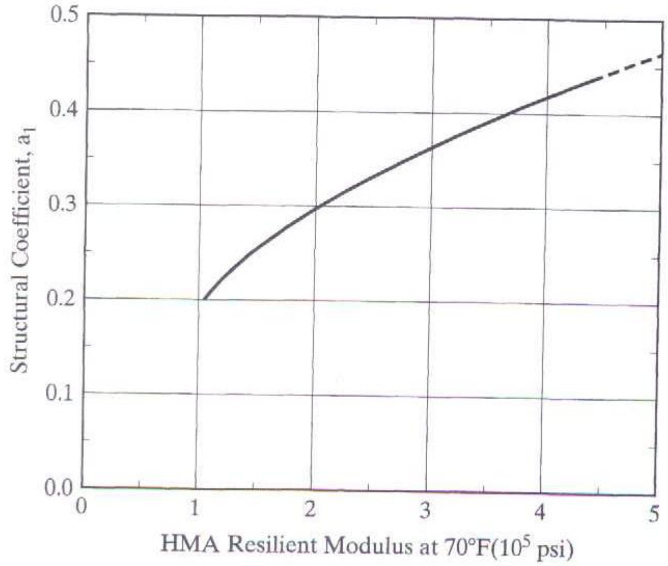

Figure 4.22 Chart for Estimating Layer Coefficient based on Resilient Modulus (Van Til, 1972)

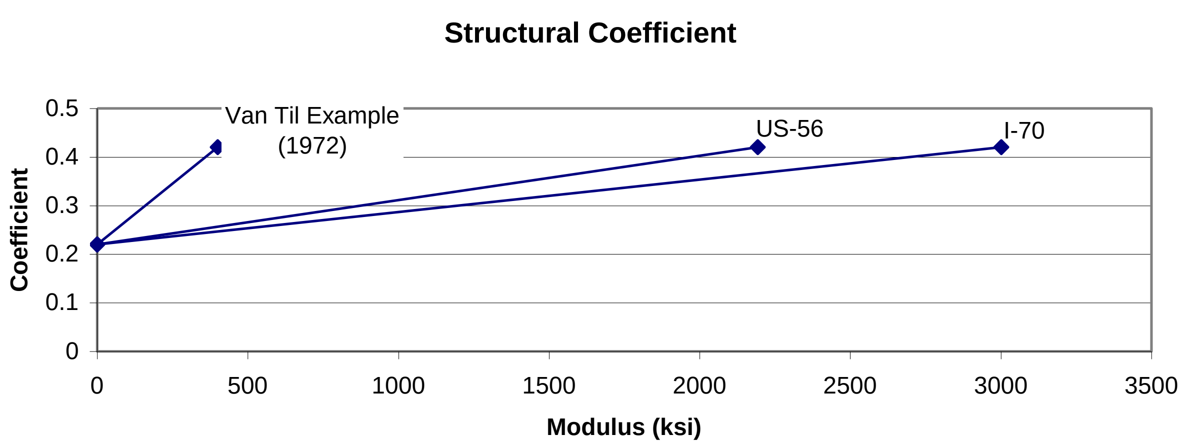

Figure 4.23 Examples for Determining Structural Coefficient for Each Layer

The percent of modulus in Table 4.8 was calculated by the percentage of the modulus retained by the AC layer assuming the modulus of the surface layer was the design modulus of each layer for that test roadway.

As shown in Table 4.8, the structural coefficient of the layers does not decrease at the rate assumed by KDOT. The actual rate of decline is lower. The fastest rate of decline of structural coefficient was 0.04 per ten years for ACB3 and AB3 on US-59, HRECYL/BM2 on K-4, and BM2 on K-141 which is lower than the 0.08 unit reduction 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 subbase 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 approximately 0.08 units for ten years, exactly as assumed by KDOT. Thus stripped pavements appear to deteriorate at a rate much faster than other non-stripped layers.

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.

Table 4.8 Structural Layer Coefficient for each AC Layer

	Layer	Year	Design Thickness (in)	Mr avg (ksi)	Modulus Range	Percent of Modulus	Structural Coefficient	Change in Structural Coefficient per Ten Years
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	0.016
	AA1	1960	11	N.A.*	N.A.*	N.A.*	0.11	0.078
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	0.015
	HRECYL	1992	3.9	1,861	1,364 - 2,283	85	0.39	0.022
	BC1	1968	5	1,109	577 - 1,604	51	0.32	0.026
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	0.033
	ACB3	1961	5	827	574 - 1,193	41	0.30	0.037
	AB3	1960	6	859	495 - 1,537	42	0.30	0.035
US-169 Miami County	SM95T, SR190B	2002	4	2,784	1,133 - 4,531	100	0.42	
	SR-190A	2002	5.5	3,034	1,042 - 6,187	109	0.44	increase
	ACB3	1973	11	4,345	1,768 - 7,849	156	0.53	increase
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	0.043
	HMSP	1965	3	2,495	1,985 - 3,408	89	0.40	0.006
	ACB2R	1965	8	2,200	1,241 - 2,704	79	0.38	0.012
K-141 Ellsworth County	SM125A, BM2A	2001	3.1	2,826	2,381 - 3,410	100	0.42	
	BM2	1987	1.5	1,924	1,297 - 2,579	68	0.36	0.046
	BITCOV	1962	4	1,127	653 - 2,016	40	0.30	0.036

Chapter 5 - CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. Poor correlation was found between the moduli results from FWD, PSPA, and IDT tests. Even though most test roadways showed a fairly consistent correlation between the test results, there was no consistency between roadways.

2. Pavements with deterioration showed the biggest change in modulus with age. The most prominent form of deterioration observed was stripping. Mixtures with small-size aggregates showed more stripping.

3. Pavements that showed little or no signs of stripping, such as US-169 and K-4, had a lower reduction in modulus with age. US-169 even showed an increase in modulus possibly caused by compaction from traffic loading. Thus absence of deterioration in AC pavements ensures longevity.

4. Overall pavement modulus is independent of the depth of pavement. The moduli showed little variation with a change in depth along the roadway.

5. The rate of deterioration of AC layers should be a function of the condition of that layer. A lower rate of deterioration of structural layer coefficient such as 0.04 per 10 years can be taken for a structurally sound layer whereas for highly deteriorated layers such as that in I-70, a rate of about 0.08 units per ten years is more appropriate. However, if the layer is the lowermost one in the pavement cross section, the structural layer coefficient of that layer can be taken as that of a granular subbase or 0.11. The layer condition can be assessed by representative coring

after Falling Weight Deflectometer testing or using newer technology like the Ground Penetrating Radar (GPR) is highly recommended. The PSPA testing can also be valuable.

5.2 Recommendations

1. Fatigue testing shall be performed on the test specimens to determine the remaining service life of each AC layer.

2. Further study is recommended to determine if there is a consistent correlation between FWD, PSPA, and IDT testing methods that would be applicable to multiple AC pavements.

References

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

AASHTO. Standard Test Method for Determining the Resilient Modulus of Bituminous Mixtures by Indirect Tension. American Association of State Highway and Transportation Officials, Washington, D.C., 2000.

Akram, T., T. Scullion, and R.E. Smith. Comparing Laboratory and Backcalculated Layer Moduli on Instrumental Pavement Sections. *Special Technical Publication 1198*, ASTM, Philadelphia, PA, 1994.

ASTM. Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures. *Annual Book of ASTM Standards,* American Society for Testing and Materials, Philadelphia, PA, 1983, pp. 671-675

Celaya, M., S. Nazarian, M. Zea, and V. Tandon. 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, August 2006.

Chen, D.H., J. Bilyeu, H.H. Lin, and M. Murphy. Temperature Correction on Falling Weight Deflectometer Measurements. *Transportation Research Record 1716*, TRB, National Research Council, Washington, D.C., 2000, pp.30-39.

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

Frocht, M. M. Photoelasticity, Vol. 2, John Vliley and Sons, New York, 1957.

Gedafa, D., M. Hossain, and S.A. Romanoschi. 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, January 2009.

Gedafa, D., M. Hossain, S.A. Romanoschi, and A.J. Gisi. Comparison of Moduli of Kansas Superpave Asphalt Mixes. *Transportation Research Record 2154*, TRB, National Research Council, Washington, D.C., 2010, pp. 114-123.

Harold, L.V., and B. Killingsworth. Comparison of Laboratory and In Situ Determined Elastic Layer Moduli. *Transportation Research Board Annual Meeting 1998,* TRB, National Research Council, Washington, D.C., 1998.

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

Huang, Y.H. Pavement Analysis and Design, 2nd Edition, Prentice Hall, Englewood Cliffs, NJ, 2003.

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

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

Mamlouk, M.S., and J.P. Zaniewski. Materials for Civil and Construction Engineers, 2nd Edition. Prentice Hall, Englewood Cliffs, NJ, 2005.

Mikhail, M.Y., S.B. Seeds, S.H. Alavi, and W.C. Ott. Evaluation of Laboratory and Backcalculated Resilient Moduli from the WesTrack Experiment. *Transportation Research Record 1687*, TRB, National Research Council, Washington, D.C., 1999, pp. 55-65.

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

Oh, J.H., E.G. Fernando, S.I. Lee, and C. Holzschuher. Correlation of Asphalt Concrete Layer Moduli Determined from Laboratory and Nondestructive Field Tests. *Transportation Research Board Annual Meeting 2011 Paper #11-3673*, TRB, National Research Council, Washington, D.C., 2011.

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

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

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

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

Ullidtz, P. Pavement Analysis. Elsevier, New York, 1987, pp. 221-223.

Van Cauwelaert, F.J., D.R. Alexander, T.D. White, and W.R. Barker. 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, 1989, pp. 171-188.

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

Washington State Department of Transportation (WSDOT). EVERSERIES USER'S GUIDE Pavement Analysis Computer Software and Case Studies. 2005.

Washington State Department of Transportation (WSDOT). *PTC Training Guides*. Web. 12 May 2011. <http://training.ce.washington.edu/wsdot/Modules/06_structural_design/backcalculation.htm>.

Yoder, E. J., and M.W. Witczak. Principles of Pavement Design. New York: John Wiley and Sons, 1975.

Appendix A – FWD Backcalculation Results

Table A.1 Backcalculation 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
0	118.4	1.64	1.38	170.5		147.7	2.37	1.60	211.0	
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
0	173.4	3.28	1.89	259.1		209.9	1.41	0.67	334.6	
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 A.1 Backcalculation 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
0	187.8	4.89	2.60	314.4		166.6	3.65	2.19	294.2	
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
0	204.7	1.11	0.54	395.0		260.7	2.35	0.90	551.1	
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 A.2 Backcalculation 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
0	149.5	1.70	1.14	205.9		317.0	2.18	0.69	453.7	
50	237.1	1.38	0.58	328.4		340.5	3.80	1.12	493.6	
100	153.5	1.88	1.23	211.7		87.5	1.12	1.29	127.2	
150	415.5	0.96	0.23	574.6		380.0	5.97	1.57	561.7	
200	80.2	0.92	1.14	110.9		411.4	5.69	1.38	601.5	
250	406.4	17.81	4.38	570.7	X	389.3	0.06	0.01	575.5	X
300	362.4	6.80	1.88	1120.5		510.9	5.16	1.01	758.4	
350	156.3	0.26	0.17	1172.6		141.5	1.34	0.95	212.5	
400	340.8	2.23	0.65	868.5		436.7	4.81	1.10	651.1	
450	350.1	4.04	1.15	758.8		404.5	14.48	3.58	606.5	
500	191.6	0.67	0.35	1037.8		440.5	3.67	0.83	668.7	

	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	268.5	0.90	0.34	413.5		510.1	8.85	1.74	873.6	
50	462.6	8.74	1.89	716.4		306.0	1.05	0.34	523.3	
100	170.4	1.00	0.59	268.9		183.2	2.57	1.40	317.0	
150	311.7	1.38	0.44	491.3		379.9	5.46	1.44	665.1	
200	375.8	6.85	1.82	600.4		109.3	1.19	1.09	191.9	
250	352.6	8.52	2.42	566.4	X	93.1	0.61	0.65	163.8	X
300	114.6	0.78	0.68	184.8		365.5	4.55	1.25	644.8	
350	358.2	10.08	2.81	587.2		484.0	4.45	0.92	863.8	
400	319.1	7.01	2.20	529.4		169.8	1.33	0.78	303.6	
450	413.7	7.54	1.82	688.2		91.9	0.89	0.97	166.4	
500	411.6	1.93	0.47	684.8		496.6	4.31	0.87	903.3	

	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	315.7	2.53	0.80	557.4		283.1	3.38	1.19	553.5	
50	230.9	7.86	3.40	416.0		325.1	1.42	0.44	636.5	
100	293.3	6.90	2.35	538.4		296.8	3.84	1.29	583.4	
150	342.4	1.23	0.36	627.8		235.2	5.48	2.33	468.6	
200	66.1	0.71	1.07	122.3		337.2	1.19	0.35	672.1	
250	403.8	2.03	0.50	753.7	X	231.6	2.61	1.13	469.0	X
300	79.3	0.49	0.62	147.8		135.9	2.29	1.68	276.8	
350	351.1	6.26	1.78	667.1		267.6	25.49	9.53	549.0	
400	318.0	1.84	0.58	599.0		289.0	4.54	1.57	592.3	
450	352.8	4.19	1.19	675.5		357.1	3.98	1.11	733.0	
500	301.2	2.27	0.76	578.2		237.5	10.49	4.42	488.4	

Table A.2 Backcalculation 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
0	255.7	5.79	2.26	544.0		304.2	4.19	1.38	652.1	
50	91.0	1.21	1.33	193.3		333.5	6.64	1.99	720.7	
100	312.2	8.35	2.67	667.3		363.9	6.54	1.80	786.5	
150	310.2	2.96	0.95	661.4		187.2	6.07	3.24	415.8	
200	304.4	4.75	1.56	648.6		232.2	0.78	0.34	515.3	
250	146.3	1.31	0.89	313.5	X	334.0	6.87	2.06	752.5	X
300	378.9	1.64	0.43	808.0		287.5	2.96	1.03	624.7	
350	59.3	1.01	1.71	127.2		315.4	14.60	4.63	684.9	
400	287.7	2.45	0.85	616.2		273.4	1.37	0.50	607.1	
450	360.2	4.31	1.20	774.0		137.5	6.08	4.42	307.0	
500	326.3	4.91	1.51	704.8		220.0	3.47	1.58	494.3	

	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	162.6	1.12	0.69	359.1		349.2	0.99	0.28	826.9	
50	264.9	2.84	1.07	599.0		323.8	6.70	2.07	770.6	
100	320.6	1.21	0.38	727.0		307.1	2.97	0.97	725.4	
150	83.1	1.66	2.00	186.7		308.8	2.11	0.68	736.7	
200	223.2	2.60	1.16	511.7		340.7	3.22	0.94	824.3	
250	290.0	0.59	0.20	670.2	X	236.7	2.84	1.20	554.1	X
300	339.0	6.92	2.04	784.0		401.1	4.68	1.17	968.3	
350	295.5	8.71	2.95	667.0		337.9	3.01	0.89	816.8	
400	359.2	4.96	1.38	826.1		399.4	13.40	3.35	966.8	
450	306.4	2.58	0.84	713.0		264.5	10.06	3.80	650.8	
500	287.5	2.01	0.70	675.8		243.4	2.77	1.14	599.8	

Table A.3 Backcalculation 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
0	524.9	4.82	0.92	737.3		443.4	8.31	1.88	319.1	
50	545.7	3.97	0.73	762.2		375.2	4.68	1.25	287.1	
100	190.6	0.93	0.49	262.7		481.4	7.66	1.59	367.7	
150	283.1	5.54	1.96	391.5		786.4	9.28	1.18	597.4	
200	273.2	0.83	0.30	377.9		449.4	3.16	0.70	342.1	
250	280.6	3.37	1.20	386.0	X	310.9	2.25	0.72	239.0	X
300	281.6	3.32	1.18	385.1		604.1	0.60	0.10	468.2	
350	203.2	0.87	0.43	277.2		393.0	4.50	1.14	304.7	
400	281.5	5.57	1.98	381.8		553.1	7.02	1.27	427.2	
450	359.5	4.59	1.28	486.1		403.2	6.03	1.50	315.2	
500	241.7	3.97	1.64	326.9		403.3	3.84	0.95	314.1	

	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	406.7	2.82	0.69	314.0		399.1	7.26	1.82	299.9	
50	239.5	1.10	0.46	187.0		245.4	1.40	0.57	186.7	
100	444.6	3.60	0.81	348.7		484.1	5.28	1.09	363.4	
150	339.3	1.10	0.32	267.2		438.5	10.19	2.32	329.8	
200	305.2	4.14	1.36	240.4		253.8	3.84	1.51	190.7	
250	470.7	12.20	2.59	371.7	X	942.8	19.69	2.09	705.4	X
300	279.8	1.35	0.48	217.2		213.8	3.29	1.54	161.0	
350	589.5	2.40	0.41	455.1		342.0	0.35	0.10	256.1	
400	369.8	3.35	0.91	285.6		306.2	5.23	1.71	230.1	
450	348.0	8.95	2.57	269.9		951.0	24.61	2.59	714.7	
500	417.9	12.29	2.94	323.6		380.4	7.75	2.04	287.4	

	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	457.7	12.50	2.73	361.7		371.2	9.01	2.43	281.9	
50	233.7	1.75	0.75	181.6		261.6	2.56	0.98	199.2	
100	293.6	4.56	1.55	230.5		249.0	2.07	0.83	188.9	
150	234.4	3.45	1.47	189.1		153.8	1.63	1.06	116.8	
200	216.8	7.57	3.49	178.5		148.8	0.87	0.59	113.9	
250	269.0	5.97	2.22	222.0	X	255.4	3.42	1.34	195.0	X
300	193.5	2.37	1.22	162.9		276.1	0.76	0.27	211.3	
350	238.2	1.85	0.78	196.3		129.4	1.93	1.49	99.6	
400	291.5	4.91	1.68	236.8		364.2	1.24	0.34	280.7	
450	193.2	1.46	0.75	154.0		228.5	2.86	1.25	176.3	
500	138.2	1.92	1.39	109.1		189.3	1.55	0.82	145.8	

Table A.3 Backcalculation 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
0	545.0	0.00	0.00	410.5		306.5	2.19	0.72	242.1	
50	221.0	3.16	1.43	166.7		230.5	1.59	0.69	181.5	
100	214.5	3.02	1.41	162.1		248.7	18.38	7.39	197.1	
150	370.0	4.93	1.33	279.0		257.9	3.80	1.47	206.1	
200	349.0	12.90	3.70	263.3		317.0	6.73	2.12	254.1	
250	753.0	2.28	0.30	576.6	X	492.3	5.83	1.18	397.2	X
300	1434.0	25.74	1.79	1101.1		368.9	4.57	1.24	300.3	
350	499.1	14.51	2.91	385.9		421.3	7.04	1.67	340.6	
400	335.0	0.60	0.18	259.7		365.0	8.96	2.46	289.5	
450	485.9	15.31	3.15	376.3		348.1	6.71	1.93	274.8	
500	460.6	3.65	0.79	354.7		336.8	4.33	1.29	267.0	

	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	259.5	2.25	0.87	204.0		245.9	3.48	1.41	195.9	
50	181.0	1.41	0.78	142.1		352.5	3.81	1.08	281.6	
100	165.4	2.30	1.39	131.3		328.8	16.12	4.90	263.6	
150	233.8	4.44	1.90	185.7		336.8	3.40	1.01	269.6	
200	360.2	1.44	0.40	286.3		365.4	5.01	1.37	289.7	
250	188.8	3.12	1.65	150.3		326.0	3.83	1.17	263.1	X
300	265.7	8.44	3.18	214.1	X	292.5	2.40	0.82	235.2	
350	228.0	3.63	1.59	183.5		356.6	1.75	0.49	284.1	
400	208.2	3.58	1.72	165.1		566.5	24.65	4.35	450.9	
450	229.3	1.04	0.46	182.7		328.3	0.40	0.12	263.1	
500	183.5	2.06	1.13	145.7		432.1	11.00	2.55	346.6	

Table A.4 Backcalculation 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
0	698.3	2.74	0.39	1021.0		678.5	4.71	0.69	1016.8	
50	714.3	56.01	7.84	1043.7		655.1	18.86	2.88	980.0	
100	798.3	31.48	3.94	1166.7		865.4	19.36	2.24	1318.4	
150	817.8	18.07	2.21	1187.1		732.4	5.49	0.75	1108.5	
200	767.0	57.90	7.55	1134.1		785.5	13.02	1.66	1189.2	
250	690.4	13.82	2.00	1027.4	X	893.2	13.82	1.55	1356.4	X
300	803.5	56.66	7.05	1193.2		705.0	47.62	6.76	1050.8	
350	837.4	74.27	8.87	1242.7		600.2	17.96	2.99	910.1	
400	620.2	18.92	3.05	906.3		756.8	35.02	4.63	1162.2	
450	535.9	3.55	0.66	798.8		762.7	11.70	1.53	1181.5	
500	726.0	22.35	3.08	1087.1		808.1	14.27	1.77	1265.0	

	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	910.9	13.74	1.51	1485.7		306.0	4.38	1.43	521.0	
50	1028.2	24.92	2.42	1765.4		422.9	8.20	1.94	733.4	
100	866.4	20.84	2.41	1437.9		636.3	16.56	2.60	1088.8	
150	716.8	3.84	0.54	1167.7		553.6	14.15	2.56	980.7	
200	1013.8	20.37	2.01	1675.8		620.2	11.72	1.89	1096.3	
250	1065.9	9.43	0.88	1790.0	X	533.2	18.97	3.56	933.1	X
300	790.4	11.67	1.48	1334.4		445.3	1.99	0.45	798.5	
350	756.8	14.45	1.91	1286.7		512.4	2.50	0.49	901.9	
400	350.8	8.71	2.48	597.0		422.4	8.49	2.01	752.1	
450	330.2	1.05	0.32	569.8		762.6	4.99	0.65	1376.2	
500	294.7	3.33	1.13	504.6		670.5	7.37	1.10	1198.9	

	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
0	409.0	3.81	0.93	959.4		386.4	7.16	1.85	813.3	
50	475.7	4.52	0.95	1113.2		411.5	6.35	1.54	876.3	
100	623.4	7.61	1.22	1479.4		262.3	2.34	0.89	547.9	
150	448.3	3.00	0.67	1081.5		320.7	3.50	1.09	678.6	
200	507.9	2.98	0.59	1208.7		475.1	7.54	1.59	1004.3	
250	464.6	4.25	0.91	1121.3	X	492.3	5.92	1.20	1038.0	X
300	382.8	3.93	1.03	920.4		321.4	11.07	3.45	759.0	
350	364.3	12.67	3.48	881.4		324.9	1.87	0.58	753.1	
400	374.9	14.11	3.76	916.0		453.0	4.74	1.05	1065.4	
450	334.8	20.10	6.00	805.8		347.8	5.77	1.66	813.3	
500	343.6	2.66	0.77	825.8		353.4	15.78	4.47	841.3	

Table A.4 Backcalculation 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
0	508.6	19.58	3.85	1229.9		330.1	6.44	1.95	856.1	
50	477.3	4.05	0.85	1180.3		298.8	4.18	1.40	792.3	
100	586.9	3.91	0.67	1482.1		327.9	8.16	2.49	872.2	
150	551.3	2.06	0.37	1380.9		403.7	7.78	1.93	1078.4	
200	310.9	1.47	0.47	794.6		280.9	16.78	5.97	768.2	
250	488.6	4.94	1.01	1230.4	X	358.0	11.72	3.27	995.2	X
300	540.0	17.62	3.26	1358.1		465.6	14.76	3.17	1285.4	
350	466.4	15.29	3.28	1160.8		461.4	10.29	2.23	1266.5	
400	362.3	1.15	0.32	928.3		548.9	1.57	0.29	1519.8	
450	391.2	9.83	2.51	985.2		465.3	33.15	7.12	1289.6	
500	434.8	55.06	12.66	1116.0		430.9	2.93	0.68	1206.2	

	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
0	419.6	4.03	0.96	1149.5		533.2	5.62	1.05	1431.1	
50	396.7	7.02	1.77	1086.8		538.4	2.42	0.45	1497.3	
100	342.2	5.19	1.52	918.9		548.4	16.15	2.94	1487.9	
150	333.8	6.58	1.97	897.2		404.7	7.68	1.90	1125.3	
200	308.5	2.28	0.74	836.6		479.5	3.57	0.75	1338.9	
250	380.1	1.17	0.31	1040.6	X	451.2	2.99	0.66	1252.5	X
300	335.8	11.32	3.37	933.6		526.9	3.24	0.61	1449.3	
350	260.9	2.57	0.98	721.4		405.8	1.28	0.31	1111.2	
400	273.4	3.38	1.24	747.4		483.7	10.39	2.15	1352.4	
450	437.8	0.50	0.11	1219.4		597.8	4.96	0.83	1612.6	
500	403.5	6.94	1.72	1098.0		545.2	3.08	0.57	1503.8	

Table A.5 Backcalculation Results for K-4 in Jefferson 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	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	

	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	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	

	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	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 A.5 Backcalculation 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 A.6 Backcalculation 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 A.6 Backcalculation 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	

Appendix B – PSPA Results

Table B.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 B.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 B.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 B.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 B.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

Appendix C – IDT Results

Table C.1 IDT Results for I-70 in Trego 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)							
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 C.1 IDT Results for I-70 in Trego 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.
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 C.2 IDT Results for US-56 in Stevens County

		Modulus by Cycle (ksi)							
Specimen	Trial No	Mr 1	Mr 2	Mr 3	Mr 4	Mr 5	Mr ave (ksi)	Std. Dev.	C.V.
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 C.2 IDT Results for US-56 in Stevens 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.
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 C.3 IDT Results for US-59 in Neosho 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.
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 C.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 C.4 IDT Results for US-169 in Miami 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.
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 C.4 IDT Results for US-169 in Miami 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			
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 C.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 C.5 IDT Results for K-4 in Jefferson 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.
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 C.5 IDT Results for K-4 in Jefferson County

		Modulus by Cycle (ksi)							
Specimen	Trial No	Mr 1	Mr 2	Mr 3	Mr 4	Mr 5	Mr ave (ksi)	Std. Dev.	C.V.
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 C.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 D – IDT Analyzed Layer Results

Table D.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	

Note: Refer to the List of Abbreviations for more detailed layer descriptions

Table D.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, CRECYL	1999	2,731	
56-1-3	HRECYL	1992	2,283	
56-1-4	BC1	1968	1,424	
56-2-1	SM125A, SRECYL,	2006	2,516	2025
56-2-2	BM2A, CRECYL	1999	2,630	
56-2-3	HRECYL	1992	2,069	
56-2-4	BC1	1968	942	
56-3-1	SM125A, SRECYL,	2006	2,336	1934
56-3-2	BM2A, CRECYL	1999	1,826	
56-3-3	HRECYL	1992	2,133	
56-3-4	BC1	1968	1,431	
56-4-1	SM125A, SRECYL,	2006	2,497	1771
56-4-2	BM2A, CRECYL	1999	1,481	
56-4-3	HRECYL	1992	1,364	
56-5-1	SM125A, SRECYL,	2006	2,273	1853
56-5-2	BM2A, CRECYL	1999	1,855	
56-5-3	HRECYL	1992	2,099	
56-5-4	CB1	1968	1,190	
56-6-1	SM125A, SRECYL,	2006	1,815	1558
56-6-2	BM2A, CRECYL	1999	1,757	
56-6-3	HRECYL	1992	1,638	
56-6-4	BC1	1968	1,041	
56-7-1	SM125A, SRECYL,	2006	2,061	1585
56-7-2	BM2A, CRECYL	1999	1,969	
56-7-3	HRECYL	1992	1,585	
56-7-4	BC1	1968	736	
56-8-1	SM125A, SRECYL,	2006	1,966	1968
56-8-2	BM2A, CRECYL	1999	2,570	
56-8-3	HRECYL	1992	1,747	
56-8-4	BC1	1968	1,604	
56-9-1	SM125A, SRECYL,	2006	2,321	1804
56-9-2	BM2A, CRECYL	1999	2,030	
56-9-3	HRECYL	1992	1,829	
56-9-4	BC1	1968	1,037	
56-10-1	SM125A, SRECYL,	2006	2,095	1670
56-10-2	BM2A, CRECYL	1999	1,958	
56-10-3	HRECYL	1992	1,864	
56-10-4	BC1	1968	577	

Note: Refer to the List of Abbreviations for more detailed layer descriptions

Table D.3 IDT Results for US-59 in Neosho County

Specimen	Layer Info	Year	Mr avg (ksi)	Mr for Core
59-1-1	SM95A, HRECYL,	1993	2,129	1521
59-1-2	BM3, HM3B,	1976	1,460	
59-1-3	ACB3	1961	1,004	
59-2-1	SM95A, HRECYL,	1993	2,143	1346
59-2-2	BM3, HM3B,	1976	1,228	
59-2-3	ACB3	1961	636	
59-3-1	SM95A, HRECYL,	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, HRECYL,	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, HRECYL,	1993	2,267	1835
59-5-2	BM3, HM3B,	1976	1,343	
59-6-1	SM95A, HRECYL,	1993	1,879	1879
59-7-1	SM95A, HRECYL,	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, HRECYL,	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, HRECYL,	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, HRECYL,	1993	2,648	1626
59-10-2	BM3, HM3B,	1976	2,588	
59-10-3	ACB3	1961	959	
59-10-4	AB3	1960	495	

Note: Refer to the List of Abbreviations for more detailed layer descriptions

Table D.4 IDT Results for US-169 in Miami County.

Specimen	Layer Info	Year	Mr avg (ksi)	Mr for Core
169-1-1	SM95T, SR190B	2002	4456	5678
169-1-2	SR190A	2002	4165	
169-1-3	ACB3	1973	5808	
169-1-4	ACB3	1973	5714	
169-1-5	ACB3	1973	6139	
169-1-6	ACB3	1973	7849	
169-2-1	SM95T, SR190B	2002	2983	4421
169-2-2	SR190A	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	SM95T, SR190B	2002	4531	6007
169-3-2	SR190A	2002	6187	
169-3-3	ACB3	1973	6866	
169-3-4	ACB3	1973	6345	
169-3-5	ACB3	1973	6077	
169-4-1	SM95T, SR190B	2002	2982	5391
169-4-2	SR190A	2002	3979	
169-4-3	ACB3	1973	7480	
169-4-4	ACB3	1973	6499	
169-4-5	ACB3	1973	6073	
169-5-1	SM95T, SR190B	2002	3896	5251
169-5-2	SR190A	2002	3108	
169-5-3	ACB3	1973	7128	
169-5-4	ACB3	1973	5846	
169-5-5	ACB3	1973	5613	
169-5-6	ACB3	1973	6126	
169-6-1	SM95T, SR190B	2002	3080	3385
169-6-2	SR190A	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	SM95T, SR190B	2002	1185	1619
169-7-2	SR190A	2002	1042	
169-7-3	ACB3	1973	1919	
169-7-5	ACB3	1973	1896	
169-7-6	ACB3	1973	2106	
169-8-1	SM95T, SR190B	2002	1832	2354
169-8-2	SR190A	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	SM95T, SR190B	2002	1760	1934
169-9-2	SR190A	2002	1706	
169-9-3	ACB3	1973	2425	
169-9-4	ACB3	1973	2172	
169-9-5	ACB3	1973	1827	
169-9-6	ACB3	1973	1799	
169-10-1	SM95T, SR190B	2002	1133	2409
169-10-2	SR190A	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	

Note: Refer to the List of Abbreviations for more detailed layer descriptions

Table D.5 IDT Results for K-4 in Jefferson County

Specimen	Layer Info	Year	Mr avg (ksi)	Mr for Core
K-4 1-1	SR95T, SRECYL	2002	3,739	3570
K-4 1-3	HMSP	1965	3,408	
K-4 2-1	SR95T, SRECYL	2002	2,700	2633
K-4 2-2	HRECYL, BM2	1995	2,896	
K-4 2-3	HMSP	1965	3,070	
K-4 2-4	ACB2R	1965	1,937	
K-4 3-2	HRECYL, 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, SRECYL	2002	2,257	2417
K-4 4-2	HRECYL, 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, SRECYL	2002	2,865	2726
K-4 5-2	HRECYL, BM2	1995	3,080	
K-4 5-3	HMSP	1965	2,464	
K-4 5-4	ACB2R	1965	2,425	
K-4 6-2	HRECYL, 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	HRECYL, 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, SRECYL	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, SRECYL	2002	2,422	2228
K-4 9-2	HRECYL, 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, SRECYL	2002	2,575	1895
K-4 10-2	HRECYL, BM2	1995	1,340	
K-4 10-3	HMSP	1965	2,211	
K-4 10-4	ACB2R	1965	1,241	

Note: Refer to the List of Abbreviations for more detailed layer descriptions

Table D.6 IDT Results for K-141 in Ellsworth County

Specimen	Layer Info	Year	Mr avg (ksi)	Mr for Core
141-1-1	SM125A, BM2A	2001	3,022	2665
141-1-2	BM2	1987	2,336	
141-2-1	SM125A, BM2A	2001	3,410	1887
141-2-3	BITCOV	1962	1,439	
141-2-4	BITCOV	1962	672	
141-3-1	SM125A, BM2A	2001	2,852	2852
141-4-1	SM125A, BM2A	2001	2,589	2589
141-5-1	SM125A, BM2A	2001	2,944	2250
141-5-2	BM2	1987	1,297	
141-6-1	SM125A, BM2A	2001	2,423	1764
141-6-2	BM2	1987	1,854	
141-6-3	BITCOV	1962	854	
141-7-1	SM125A, BM2A	2001	2,381	2197
141-7-2	BM2	1987	2,010	
141-8-1	SM125A, BM2A	2001	2,830	1711
141-8-3	BITCOV	1962	653	
141-9-1	SM125A, BM2A	2001	3,219	2894
141-9-2	BM2	1987	2,579	
141-10-1	SM125A, BM2A	2001	2,590	2021
141-10-2	BM2	1987	1,469	
141-10-3	BITCOV	1962	2,016	

Note: Refer to the List of Abbreviations for more detailed layer descriptions