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Effect Of Asphalt Emulsion On Surface Treated Flexible Pavements Using The Bending Beam Rheometer

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EFFECT OF ASPHALT EMULSION ON SURFACE TREATED FLEXIBLE

PAVEMENTS USING THE BENDING BEAM RHEOMETER

By

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Chip and scrub seal treatments are common pavement preservation practices that use asphalt emulsions. Their performance has been studied for several years, yet many questions remain. The primary thesis objective was to study near surface behaviors of flexible pavements that are candidates for seal treatments.

This study investigated the ability of the bending beam rheometer (*BBR*) to detect pavement surface changes due to the application of asphalt emulsion. Estimated stiffness and m-value data was recorded for three asphalt concrete mixtures using mixture beams approximately 120 mm long by 12 mm wide by 7.7 mm thick sawn from the surface of asphalt specimens. One mixture was plant mixed and laboratory compacted, while the other two were field-aged mixtures. This study gauges effect of treating specimens with emulsions commonly used in Mississippi in conditioned and unconditioned states.

DEDICATION

This thesis is dedicated to my family for their continual love and support.

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Finally, the author would like to thank his family as well as his fiancé for their support throughout this study.

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LIST OF EQUATIONS

LIST OF ABBREVIATIONS

A0	Aged 0 Days
A3	Aged 3 Days
A7	Aged 7 Days
A14	Aged 14 Days
A30	Aged 30 Days
A45	Aged 45 Days
A60	Aged 60 Days
AASHTO	American Association of State Highway and Transportation Officials
A_1	First Acidaffins
A_2	Second Acidaffins
ASTM	American Society for Testing and Materials
b	Width, mm
BBR	Bending Beam Rheometer
CFS-2HP	Cationic Fast Set with High Polymer
CHFRS-2P	Cationic High Float Rapid Set with Polymer
cov	Coefficient of Variation
CRS-2	Cationic Rapid Set
CRS-2P SBR	Cationic Rapid Set with Polymer (styrene butadiene rubber)
CRS-2P SBS	Cationic Rapid Set with Polymer (styrene butadiene styrene)

DSR	Dynamic Shear Rheometer
δ	Deflection, mm
E1	Emulsion 1
E2	Emulsion 2
E3	Emulsion 3
E3a	Emulsion 3a
E4	Emulsion 4
E5	Emulsion 5
E6	Emulsion 6
E7	Emulsion 7
ERDC	Engineering Research and Development Center
F	Load, mN
FR	Frontage Road
G_{mm}	Theoretical Maximum Specific Gravity
h	Thickness, mm
H_0	Null Hypothesis
Hwy 45	Highway 45
IDT	Indirect Tensile Test
IQR	Interquartile Range
L	Length, mm
MDOT	Mississippi Department of Transportation
N	Number of Replicates
Ni	Nitrogen Compounds

NCPP	National Center for Pavement Preservation
NMAS	Nominal Maximum Aggregate Size
P	Paraffins
PASS-CR	Polymerized Asphalt Surface Sealer
P_b	Percent Binder by Total Mass of Mixture
P_{be}	Percent Effective Binder Content by Total Mass of Mixture
RAP	Reclaimed Asphalt Pavement
R_m	Mean Residue Removed After Scraping
RVE	Representative Volume Element
Se(t)	Estimated Creep Stiffness
Se(t)T	Treated Estimated Creep Stiffness
Se(t)U	Untreated Estimated Creep Stiffness
S_t	Indirect Tensile Strength
SGC	Superpave Gyratory Compactor
Sm(t)	Measured Creep Stiffness
SP	Sawing Pattern
VMA	Voids in the Mineral Aggregate

CHAPTER I

INTRODUCTION

1.1 Background

The role of pavement preservation has not always been considered to be as important to the paving industry as it is in present day. State and federal agencies are assigned the task of improving and maintaining overall system health, safety, and user cost, all on a limited budget. As demands on the United States highway system continue to grow, the need for cost-saving pavement preservation and maintenance becomes more prevalent. The concept of performing preventative maintenance on roads in 'good condition' in order to put off the need for costly rehabilitation has been stated to extend pavement life and reduce life cycle cost (Gransberg and James, 2005, Cheng, et al. 2011). This concept of preventive maintenance can show how spending one dollar on preservation eliminates or delays spending $6 to $10 on rehabilitation or reconstruction according to Galehouse et al., (2003).

In 2003, the National Center for Pavement Preservation (NCPP) was established to advance and improve pavement preservation practices through education, research and outreach (NCPP, 2011). Preservation requires advanced understanding of materials and their test methodologies related to in-service performance (Howard et al., 2009). With the potential financial advantages of pavement preservation, infrastructure stands to benefit through more efficient treatments and allocation of budgets if performance can be achieved. Targeted research can improve the effectiveness of a treatment and the understanding on when and how to treat pavements more efficiently. In return, long term preservation and management practices can extend pavement life, reducing life cycle cost and alleviating financial pressures on state agencies.

Chip and scrub seals are common flexible pavement surface treatments. A key role of a sealant is to prevent water intrusion into the base and subgrade by sealing the fine cracks in the underlying pavement (Gransberg and James 2005). The initial cost of this type of treatment is low compared to a thin asphalt overlay (Gransberg and James 2005). Seal treatments also provide an economical and efficient way to provide skid resistance and quick construction (Gransberg and James 2005). This makes chip seals an acceptable choice when the structural capacity of the existing pavement is adequate, because chip seals do not improve load capacity (Gransberg and James 2005).

In addition to treating the surface, the application of asphalt emulsion through maintenance practices like chip and scrub seals can have rejuvenating internal effects on a pavement. Asphalt binder, the cementing agent in asphalt pavement, experiences hardening as a result of oxidation (Boyer, 2000). The application of asphalt emulsions results in a percentage of new binder incorporated into the pavement which can potentially rejuvenate the surface. Rejuvenation (when successful) softens the pavement surface which can result in cost-effective pavement rehabilitation.

1.2 Objectives

The primary objective of this thesis was the investigation of the ability to detect the effects of a flexible pavement surface treatment in the laboratory. The effects measured were estimated stiffness values of asphalt pavement specimens. The surface treatments were the application of various types of asphalt emulsion. Instead of using laboratory tests such as penetration, viscosity, ductility, or Dynamic Shear Rheometer *(DSR)* results to measure changes in stiffness, the focus of this thesis is the ability to detect a softening or reduction in stiffness at the surface of asphalt pavement using the Bending Beam Rheometer *(BBR)*. *BBR* tests were performed on mixture beams sawn from the surface of emulsion-treated asphalt specimens.

Specific objectives were chosen in an attempt to further understand the new concept being studied.

- Can beam specimens be sawn from the pavement surface with repeatable dimensions?
- Can an emulsion's effect be detected statistically?
- How does variability compare to Indirect Tensile Test (*IDT*) results?
- Can laboratory aging be detected with this type of testing?
- Can the interaction effects measured be joined to predict stiffness?

1.3 Scope

This research is part of a larger study to potentially be used in performance-based specifications for the Mississippi Department of Transportation (MDOT). This thesis primarily focuses on the portion of the MDOT study using the *BBR* to investigate the effects of chip and scrub seal treatments on flexible pavements in the laboratory. The research relies mostly on experimental data.

The scope of this research embodies a fairly new approach to pavement preservation which is to test the pavement surface as a mixture and not via recovered binder. This thesis developed a specimen production and specimen testing procedure in order to evaluate mixture beams in the *BBR*. This thesis investigates the effects of aged and un-aged asphalt emulsions on both field-aged and laboratory-compacted asphalt pavements. The interaction effects, including the amount of asphalt added to the pavement as a result of the emulsion, emulsion properties, and pavement type, were statistically compared alongside estimated stiffness results. This was done to investigate relationships between the interaction effects and the test results.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The research encompassed by this thesis investigates near surface behaviors of flexible pavements that are candidates for seal treatments, in particular chip or scrub seals. The research focuses on the ability of the *BBR* to detect stiffness changes, or any rejuvenation effect on stiffness, in mixture beams sawn from the surface of emulsion-treated asphalt specimens. This chapter provides information obtained during review of literature to collect information pertaining to the subjects of rejuvenation, asphalt emulsions used in near surface treatments of flexible pavements, and the performance of creep tests using the *BBR* and *IDT*.

2.2 Surface Treatments in Pavement Preservation

Pavement preservation is a program of activities including corrective maintenance, preventive maintenance, and rehabilitation with the goal of preserving pavements, enhancing performance, extending pavement life, and meeting the general driving public's needs (FHWA, 1999). The American Association of State Highway and Transportation Officials (AASHTO) defines preventive maintenance as a planned strategy of cost effective treatments to an existing roadway system that preserves the system, retards future deterioration, and maintains or improves functionality of the system without substantially increasing structural capacity. Preventive maintenance of asphalt concrete can often extend the pavement life for several years at relatively low costs (Brown, 1988). There are several types of preventive maintenance including rejuvenators, slurry seals, crack sealing, and various surface treatments.

A chip seal is constructed of a layer of asphalt binder or emulsion topped with a layer of embedded aggregate lying one stone thick (Gransberg and James, 2005). The primary role of a chip seal is to prevent water intrusion into the base and subgrade by sealing the fine cracks in the underlying pavement (Gransberg and James, 2005). The application of the aggregate protects the asphalt layer and creates a macrotexture creating a skid-resistance surface for vehicles. The initial cost of chip sealing is low compared to a thin asphalt overlay (Gransberg and James, 2005). A scrub seal is similar to a chip seal except the asphalt binder or emulsion is scrubbed into the voids with a broom before aggregate application. An additional benefit of these treatments is the enrichment or rejuvenation of the existing pavement surface to contest the distresses caused by oxidation (Gransberg and James, 2005). While asphalt pavements can fail due to poor design and improper construction, oxidation is primarily the natural cause of deterioration.

2.3 Asphalt Rejuvenation and Emulsions

Asphalt binder, the cementing agent in asphalt pavement, experiences hardening as a result of oxidation (Boyer, 2000). Asphalt binders are comprised of two main parts, asphaltenes and maltenes. Asphaltenes are the hard, brittle portion of the asphalt that is insoluble and not affected by oxidation (Browridge, 2010). Their purpose is to serve as a bodying agent (Boyer, 2000). Maltenes, which are oily and resinous in appearance, is the name given to the rest of the asphalt material and are comprised of four divisions (Browridge, 2010). The four divisions are:

- Polar compounds or Nitrogen bases (N): components of highly reactive resins, which act as a peptizer for the asphaltenes (Boyer, 2000).
- First Acidiffins (A_1): components of resinous hydrocarbons which function as a solvent for the peptized asphaltenes (Boyer, 2000).
- Second Acidiffins (A_2): components of slightly unsaturated hydrocarbons that also serve as a solvent for the peptized asphaltenes (Boyer, 2000)
- Saturated Hydrocarbons or Paraffins (P): components of hydrocarbons, which function as a jelling agent for the asphalt components (Boyer, 2000)

In what is commonly referred to as Rostler Analysis, ASTM D-2006-70 describes the Maltenes Distribution Ratio, Eq. 2.1, which is used to properly formulate a rejuvenator.

Eq. 2.1

As the maltenes distribution ratio decreases during natural weathering and oxidation, the pavement becomes dry and brittle (Boyer, 2000). During this process asphalt rejuvenators can be applied to help restore the balance of maltenes and asphaltenes. A typical candidate is a structurally sound asphalt pavement 3 to 7 years old showing early signs of distress (Browridge, 2010). However, emulsions are also used on new pavements as a seal to decrease permeability.

Rejuvenators are placed with the intention to revitalize aged asphalt by reversing or slowing pitting, raveling, and/or shrinkage which leads to hairline cracking, and reducing air and water infiltration (Browridge, 2010). Brown (1988) describes the purpose of the rejuvenator is to penetrate into the pavement surface in order to soften the asphalt binder and to seal the pavement helping to retard other subsequent distresses. The air voids should be at least 7 to 8 percent in order to provide adequate permeability to allow sufficient penetrating of the rejuvenator (Brown, 1988). Note the aforementioned statement applies primarily to fog seals.

Many agencies have taken advantage of the economic benefits of using a rejuvenator to extend the life of aging and brittle pavements (Boyer, 2000). Additional benefits include added visibility to road markings, support of a good bond between existing pavement and a new overlay caused by the softening, and ductility of the old surface is improved (Boyer, 2000).

When designing chip seals, several different types of asphalt emulsions are available for use including anionic, cationic, rejuvenating, polymer-modified, and high float formulations (Simpson 2006). Emulsions are made with different grades of asphalt and formulated with different formulas for use in surface treatments (Stevenson and Williams 1996).

The CRS-2 emulsion is a cationic emulsified asphalt with high viscosity and a rapid setting breaking time. The CRS-2P SBR is an emulsified asphalt, made with styrene-butadiene-rubber, with a latex polymer modifier. This emulsion forms a “honeycomb” structure around asphalt particles providing strength and rejuvenating properties (Takamura, 2001). A study performed by the BASF corporation showed CRS-

2P SBR to result in less wet abrasion loss when compared to other polymer modified asphalt emulsions and great chip retention when compared to unmodified CRS-2 emulsion. CRS-2P SBS is an emulsified asphalt made with polymerizing CRS-2 with styrene-butadiene-styrene.

PASS-CR, CHFRS-2P, CFS-2HP, and Road Armor emulsions are proprietary products. PASS-CR is a polymer modified asphalt rejuvenating agent particularly formulated for scrub and chip seal use able to repair more severe deterioration (Western Emulsions 2010). This emulsion is made of liquid asphalt, a rejuvenator, and a flexible polymer and can also be applied as a 'cold-pour' crack sealant (Western Emulsions 2010). CHFRS-2P is a cationic, polymer modified, emulsified asphalt with high viscosity, high float, and a rapid setting breaking time. This emulsion is specially formulated for chip seal applications designed for early chip retention and quicker return of traffic (Western Emulsions 2010). Road Armor is made of a rapid setting, polymer modified asphalt. This emulsion is designed for chip seal surface treatments.

Due to the proprietary nature of emulsified asphalt products, performance specifications are recommended (Shoenberger 2003; Boyer, 2000). It is common to find some specifications calling for a stiffness reduction at or near the surface of the pavement and others including a certain application rate (Shoenberger, 2003; Boyer, 2000). Specifying certain application rates should be avoided due to the rejuvenator products' varying performance depending on the environment (Boyer, 2000). Penetration, viscosity, ductility, and dynamic shear rheometer (*DSR*) results are common material property alternatives used to gauge changes in stiffness or performance (Shoenberger, 2003). Coons and Wright (1968) performed a study identifying that viscosity in the top

12.7 mm increases with age while larger depths see minimal change indicating the importance of the near surface pavement. Multiple studies have been performed investigating the effectiveness of rejuvenators.

A study performed by the US Army Research and Development Center (ERDC) placed several different rejuvenators and seal coats on two airfields for one year comparing their effect on binder properties to the untreated properties (Shoenberger, 2003). The products were evaluated in the field based on skid resistance, texture, and changes in visual appearance. The products were evaluated in the laboratory based on penetration, viscosity, and *DSR* results. The study recommended the *DSR* not to be used to gauge the effectiveness of rejuvenating materials. In general, the study found each rejuvenator to reduce the viscosity of the pavement indicating acceptable performance. A future more in-depth study was suggested in order to be able to make absolute conclusions (Shoenberger, 2003).

A 1970 study sponsored by the Air Force Weapons Laboratory investigated five products applied at equal application rates. These products were subject to permeability, penetration, viscosity, and pellet abrasion tests. Ultimately, the study concluded the products acted as asphalt rejuvenators in that their viscosity was improved and the loss of aggregate was improved (Boyer, 2000).

An additional 1974 study sponsored by the Air Force Civil Engineering Center and performed by the U.S. Army Corps of Engineers Waterways Experiment Station, treated pavements at three Air Force bases in differing climate regions of the country with four proprietary rejuvenator products (Boyer, 2000). Two of the products were deemed successful rejuvenators through viscosity and penetration tests (Boyer, 2000).

The study also concluded that viscosity of the treated pavement was a better indicator of rejuvenation effects than a penetration test (Boyer, 2000).

2.4 Measuring Binder and Mixture Properties in the *BBR*

For asphalt binders, the *BBR* is used to indicate ability to resist low temperature cracking by measuring low temperature stiffness and relaxation properties. In accordance with ASTM D 6648-08, binders are tested in the *BBR* to determine the flexural creep stiffness or compliance and m-value of the material at specified temperatures. This process involves conditioning binder for one hour at the desired temperature, and thereafter a constant load is applied to the simply supported beam of asphalt binder. *Flexural creep stiffness*, *Sm(t)*, is the ratio found by dividing the maximum bending stress in the mixture beam by the maximum bending strain (AASHTO T 313-09). *Estimated creep stiffness*, *Se(t)*, is obtained by fitting a second order polynomial to the logarithm of the measured stiffness at time intervals and the logarithm of time (AASHTO T313-09). The m-value is the absolute value of the slope of the logarithm of the stiffness curve verses the logarithm of time. The results of this test procedure are given as a plot of the inverse of creep compliance, which is flexural creep stiffness verses time (Marasteanu et al. 2009). The measured stiffness is calculated at designated time intervals using the following equation:

$$Sm(t) = \frac{\quad}{\delta} \qquad \text{Eq. 2.2}$$

Where:

Sm(t) = measured creep stiffness

F = load, mN

L = length, mm

b = width, mm

h = thickness, mm

δ = deflection, mm

The *BBR* is versatile in the various ways it can be applied to measuring material properties. With the increasing use of reclaimed asphalt pavement (*RAP*) in asphalt mixes, Ma et al. (2010) investigated a method of estimating *RAP* binder low temperature properties without performing extraction and recovery methods. The authors tested fresh binder with fine *RAP* materials in the *BBR* and measured the stiffness and m-value at 60 seconds with repeatable results.

Marasteanu (2004) investigated the relationship between the stiffness and the m-value calculated in the *BBR* in the development of thermal stresses in asphalt pavements. Neat and modified binders were tested and showed thermal stress development was controlled by the binder stiffness.

The research in this thesis investigates use of the *BBR* to measure changes in flexural creep stiffness on asphalt mixture beams sawn from the surface of treated asphalt cores. Using surface mixture beams allows the *BBR* to investigate changes in stiffness due to surface treatments. The practice of performing flexural creep stiffness tests using asphalt mixture beams in the *BBR* is a relatively recent development in the pavement industry, but one that has yielded valuable data. Review of literature could not find a study using asphalt mixture beams in the *BBR* that were sawn from the surface of field-aged pavement. Several studies have, however, investigated *BBR* mixture beams (Marasteanu, 2009; Velasquez, 2009; Zofka, 2005; 2008). Also, some studies have compared *BBR* use to Indirect Tensile (*IDT*) testing in measuring creep stiffness in asphalt mixtures (Marasteanu, 2009; Velasquez, 2009; Zofka, 2008)

The *IDT* test is one method of measuring an asphalt mixture's potential for rutting or cracking by measuring the strength and quality of the asphalt mixture. In accordance to ASTM D 6931-07, a cylindrical specimen is loaded in compression along its vertical diameter plane at a specified rate and temperature to calculate the indirect tensile strength (S_t) of the specimen. Marasteanu et al. (2009) described potential advantages and disadvantages to the different methods of obtaining creep stiffness. The *BBR*'s ability to investigate surface aging, microcracking, creep stiffness from different layers in the pavement, and the effectiveness of surface treatments is advantageous.

2.4.1 Concerns with Testing Asphalt Mixture Beams in the *BBR*

Given the *BBR* was not intended for testing asphalt mixture beams, there exist concerns with the nature of the testing and corresponding results. There are concerns related to the mixture beam specimen sizes properly representing asphalt mixtures. A concern particularly related to this thesis is the surface origin of the mixture beam specimens. Review of literature did not reveal any instances of this type of testing. Similar mixture beam studies repeatedly suggested sawing from within the core to avoid the variability and aged characteristics of the surface (Marasteanu, 2009; Velasquez, 2009; Zofka, 2005; 2008). This issue represented the primary concern and question moving forward.

Another concern is that mixture beam thicknesses are smaller than the mixture nominal maximum aggregate size (NMAS), which violates the representative volume element (*RVE*) concept. This testing concept calls for minimum specimen dimensions to obtain quality and consistent test results (Zofka et al. 2008). With all testing, representative samples or specimens should sufficiently represent the properties of the test material. Specimens that do not represent these properties will produce inconsistent data (Weissman et al. 1999). However, Zofka et al. (2008) contest that this dimensional match is primarily for asphalt mixture components at higher temperatures. They concluded that at lower temperatures, the disparity in stiffness between aggregates and asphalt binder significantly reduces. Zofka et al. (2008) describe how the asphalt binder begins to behave as a brittle coelastic material as temperatures approach the area of the asphalt binder's glass transition temperature. s the materials have similar responses, the bulk properties of the asphalt mixture become much less dependent on size and aggregate distribution at these lower temperatures (Zofka et al. 2008). Velasquez (2009) supports this conclusion on *RVE* in asphalt concrete with applications to low temperature. Part of the Velasquez (2009) findings confirm the ability to measure creep stiffness in mixture beams (6.25 by 12.5 by 100 mm) using the *BBR* at low temperatures while remaining above the low limit of the binder performance grade. It was also found the volumetric fraction and size distribution of aggregates vary in a similar manner in mixture beams two and three times the size of the original dimensions. These findings helped support the decisions made in this research regarding mixture beam size and test temperature.

In a study investigating techniques for determining errors in asphalt binder rheological data, Marasteanu and Anderson (2001) concluded inspecting data graphically is the preferred method of identifying testing errors in the *BBR*. The authors describe how asphalt binder does not show sudden changes in behavior with respect to time or temperature. This means any variation or sudden change in the slope of the test data when changing test temperature or the time and frequency of loading time can be attributed to testing error. A technique used for identifying problems with dynamic shear rheometer tests, known as Black diagrams, should not be used with *BBR* data because of difficulties calculating m-values according to Marasteanu and Anderson (2001).

2.4.2 Related Studies and Applications Testing Mixture Beams in the *BBR*

Multiple studies have been performed obtaining creep stiffness during *BBR* testing of asphalt mixture beams. Although no literature was found investigating the use of surface mixture beams, similar concepts and methods can be applied to such testing.

A study performed by Zofka et al. (2005) used *BBR* mixture beam testing to develop a method to obtain low temperature properties of asphalt binders in a mixture without extraction and recovery. The study used the Hirsch model to back calculate stiffness data to compare to extracted binder stiffness values. The benefit of developing such a method is the possibility of obtaining *RAP* binder properties required in blending charts used to design mixtures that use *RAP*. Testing aged pavements could also benefit.

Zofka et al. (2005) initially removed the top 10 mm off of gyratory specimens in order to create a smooth surface. Six 12-mm round slices were then cut, producing seven rectangular beams each, 6-to 8-mm thick and trimmed to 101 mm. The authors described the thickness cut as most the difficult, obtaining varying thicknesses ranging from 6-to 9-mm. It was recommended this value be measured for use in calculations. Three mixture beams of each unique combination of binder, percentage *RAP*, and *RAP* source were conditioned for one hour and tested at -18°C and -24°C.

The limited analysis performed by Zoftka et al. (2005) study demonstrated the ability of asphalt mixture beams to measure low temperature stiffness in the asphalt mixtures tested. The coefficient of variation (cov), a measure of dispersion defined as the standard divided by the mean, for replicate measurements was in the range of 3.6% to 19% which was deemed acceptable for mixture testing at low temperatures.

IDT testing was performed on gyratory mixture specimens to determine if the *BBR* mixture stiffness values were similar to the stiffness values obtained according to AASHTO TP9 specification. The limited testes performed at both -18°C and -24°C indicted that the stiffness values obtained with the two test methods were reasonably similar. This study also shows that the Hirsch model can be used, with a minor modification, to back calculate binder stiffness from *BBR* mixtures stiffness.

A study performed by Marasteanu et al. (2009) investigated the idea of performing creep tests on asphalt mixture beams with the *BBR* due to the many apparent advantages compared to the current *IDT* specification. The authors developed a beams preparation procedure using tall gyratory pills in which beams were uniformly sawn from the center. Good results were obtained using the *BBR* with test loads of 1961 mN at PG low temperature + 22°C and 4413 mN at PG low temperature + 10°C. For PG low temperature - 2°C, the authors recommended to use predictions formed from the higher two temperatures. This study also concluded that the cooling medium and reasonable variation in voids do not significantly affect asphalt mixture creep stiffness results when tested at low temperatures.

Marasteanu et al. (2009) compared *BBR* and *IDT* results of 20 laboratory mixes of various material combinations and field cores from 4 pavements. In the laboratory mixes, *IDT* creep stiffness was 86.5% of the *BBR* values using a linear relationship. The authors attributed aging gradient to the inability to form a similar relationship with the field samples. The authors observed similar results between creep stiffness values from *IDT* and *BBR* testing.

Marasteanu et al. (2009) also investigated common concerns with testing mixture beams in the *BBR*. In a related study to Valequez (2009), statistical analyses showed mixture beams with thickness and width ranges of 5.31-to 6.57-mm and 12.02-to 12.90-mm as a *RVE* of the material for PG low limit + 22°C and PG low limit + 10°C. The authors also utilized finite element modeling comparing the influence of specimen geometry and aggregate spatial distribution in *IDT* and *BBR* testing, which was found to be within 4% of each other.

CHAPTER III

EXPERIMENTAL PROGRAM

3.1 Overview of Experimental Program

The research encompassed by this thesis is part of State Study 211, which has a goal of providing a draft performance specification for chip and scrub sealing activities to MDOT. This thesis focused on testing near surface mixture beams in the *BBR*. A total of 773 mixture beams were successfully tested in the *BBR* to investigate 72 different combinations of emulsion type, emulsion application rate, aging time, pavement type, and surface variability conditions.

Since this thesis is a portion of a larger study, certain materials and procedures evolved simultaneously alongside other studies. Parts of this research were performed in conjunction with Jordan (2010), and instances where protocols and procedures entirely coincide will be referenced to Jordan (2010). Properties of many of the materials tested that are presented in this chapter were measured by Jordan (2010) and are the same as the values provided therein.

3.2 Terminology

During testing and analysis, specimens were identified in the following manner. Each unique combination of treatments applied to a set of specimens was assigned a Mixture ID. Mixture ID's are identified with the letter 'M' immediately followed by a number (e.g. M1 refers to Mixture ID 1). This Mixture ID designation is followed by a series of labels describing the pavement type and treatment combination. To identify the unique treatment combinations of *BBR* testing, an identification system was formed according to the format in Equation 3.1. This format is also used in Appendix A where raw *BBR* test data are organized into tables according to Mixture ID. The individual components of the identification system are described as follows.

$$1\text{-}2/3\text{-}4\text{-}5 \qquad \text{Eq. 3.1}$$

1: The first position in the specimen identification format designates Mixture ID. Possible values for this label are M1 to M73, with examples shown below.

M1:	Mixture ID 1
M73:	Mixture ID 73

2: The second position in the specimen identification system designates pavement type. Possible values for this label are:

H45:	Hwy 45 Asphalt Pavement
FR:	Frontage Road Asphalt Pavement
Plant Mix:	Laboratory-Compacted Plant Mix Asphalt Pavement

3: The third position in the specimen identification system designates emulsion type. Possible values for this label are in Table 3.1, with examples shown below.

E0:	No emulsion, or a control test
E1:	Emulsion 1 from Table 3.1
E2:	Emulsion 2 from Table 3.1

4: The fourth position in the specimen identification system designates emulsion application rate. Possible values for this label are:

R0.00: No emulsion applied, or 0.0 L/m^2 (0.0 gal/yd^2)

R0.91: Emulsion applied at 0.91 L/m^2 (0.2 gal/yd^2)

R1.36: Emulsion applied at 1.36 L/m^2 (0.3 gal/yd^2)

R1.81: Emulsion applied at 1.81 L/m^2 (0.4 gal/yd^2)

5: The fifth position in the specimen identification system designates the number of days the specimen was conditioned (or aged) in an oven at 60°C before sawing into beams and testing. Examples for this label are:

A0: 0 Day Aging Period

A7: 7 Day Aging Period

A30: 30 Day Aging Period

To identify the treatment combinations of indirect tensile (*IDT*) testing, a similar version of Equation 3.1 is used in this experimental program. The first and second positions remain the same as *BBR* testing. The third position designates the type of testing represented by using the letters '*IDT*' for indirect tensile test. The fourth and final position designates the diameter of specimen being tested, either 100 mm or 150 mm.

3.3 Materials Tested

Seven distinct emulsions, two field-aged asphalt pavements, and one un-aged asphalt plant mix were used in this study. Three companies supplied the emulsions: Blacklidge Emulsions, Inc.; Ergon Asphalt and Emulsions, Inc.; and Road Science LLC (formerly SEM Materials). These companies and materials essentially represented Mississippi's emulsion suppliers and range of material properties at the time of this research.

3.3.1 Asphalt Emulsions

The emulsions tested were: CRS-2, CRS-2P (SBR), CRS-2P (SBS), PASS-CR, CHFRS-2P, Road Armor, and CFS-2HP. Table 3.1 contains the emulsion labeling system and fundamental properties. PASS-CR (emulsion 3) was the only field sample which was from Highway 17 in Carroll County, Mississippi in 2007. PASS-CR (emulsion 3*a*) was obtained in 2010 for additional testing.

Paragon Technical Services, Inc. (PTSi), Road Science LLC, and Blacklidge Emulsions, Inc. performed property testing on all emulsions used for this project. AASHTO M-208, the standard specification test method for cationic emulsified asphalt, was performed on all products. The particle charge test was omitted while emulsion pH and particle size analysis were added. Distillation tests were conducted by the standard method (260 °C) for the CRS-2 emulsion. Distillation tests for the other six polymer modified emulsion types were conducted by the modified method (177 °C). The modified approach was conducted at the same bottom thermometer distillation temperature for modified emulsions. Emulsion storage, handling, quality assurance, and re-heating procedures followed Jordan (2010).

Table 3.1 Properties of Emulsions Tested

ID	Type	Tested	Supplier	Source	pH	ER	Size (µm)	Sieve (%)	Dem (%)	Oil (%)	Res (%)	24 hr (%)	25 C Duct (cm)	4C Pen (dmm)	25C Pen (dmm)	25 C SFS Visc (s)	50 C SFS Visc (s)
1	CRS-2	Oct 08	Ergon	1	3.68	---	4.01	0.01	94	0.13	69.9	0.10	117	---	130	---	452
2	CRS-2P-SBR	Oct 08	Ergon	1	3.91	---	7.29	0.04	80	0.13	68.1	0.14	50	---	104	---	73
3	PASS-CR	Nov 07	Ergon	6	2.66	---	5.29	0.01	61	0.63	67.6	1.05	58	---	250	---	94
3a	PASS-CR	Jun 10	Ergon	1	---	65	---	0.00	56	---	65.6	0.01	---	89	---	972	---
4	CHFRS-2P	Nov 08	Ergon	1	2.62	---	7.12	0.02	81	0.25	69.8	2.50	150	---	129	---	59
5	CRS-2P-SBS	May 09	Road Sci	2	1.78	---	2.58	0.00	59	0.10	68.5	-0.20	145	---	122	---	124
6	Road Armor	May 09	Road Sci	3	2.26	65	5.48	0.05	101	0.50	70.7	0.02	114	---	84	---	145
7	CFS-2HP	May 09	Blacklidge	4	3.00	---	4.51	0.01	67	0.50	72.3	0.04	80	---	68	---	36

Source ID:
1: Plant-Pleasanton, TX
2: Laboratory-Tulsa, OK
3: Plant-Garden City, GA
4: Laboratory-Gulfport, MS
6: Field-Hwy 17, MS (Howard 2009)

Legend:
ER =Elastic Recovery at 10 C
Size = Particle Size
Dem = Demulsibility
Oil = Oil Percent by Volume
Res = Residue
24 hr = 24 hr storage
Duct = Ductility
Pen = Penetration
Visc = Viscosity

3.3.2 Aged Asphalt Concrete

Two field-aged asphalt concrete pavements were used in this project; 1) frontage road adjacent to Highway 25 in Starkville, MS (FR); 2) abandoned portion of Highway 45 in Crawford, MS (Hwy 45). Aside from availability, these pavements were chosen because they had different permeabilities and were both formerly in service. The procedure for choosing sections of the pavement for sampling, obtaining asphalt concrete slabs, coring the slabs, and testing the permeability of each pavement is described in Jordan (2010). Averaged key properties of the aged asphalt concrete used in this thesis can be found in Table 3.2.

Table 3.2 Key Properties of Aged Asphalt Concrete (Jordan 2010)

Pavement	**Asphalt Content**	**Permeability at 20 C**	**Viscosity at 135 °C**	**Viscosity at 165 °C**	**Density**
	(%)	**(cm/sec)**	**(cP)**	**(cP)**	**(kg/m^3)**
Hwy 45	4.9	$470*10^{-9}$	9302	1204	2146
FR	5.4	$657*10^{-6}$	10902	1419	2098

Note: Viscosity is of top 6.3 mm of pavement

3.3.3 Un-aged Asphalt Concrete

One source of plant mixed asphalt was used in this project. It was obtained from APAC-Mississippi, Inc. in Lowndes County on September 2, 2010. The material was sampled at the plant (plant mix temperature of 160 C), brought to the laboratory, allowed to cool, and reheated prior to compacting asphalt specimens in a superpave gyratory compactor (*SGC*) to 7 ± 1% air voids measured by AASHTO T331 (Corelok). The binder was PG67-22, P_b was 6% (5.2% virgin), G_{mm} was 2.358, *VMA* was 15.5%, and the dust to P_{be} ratio was 1.13. Aggregate properties are provided in Figure 3.1.

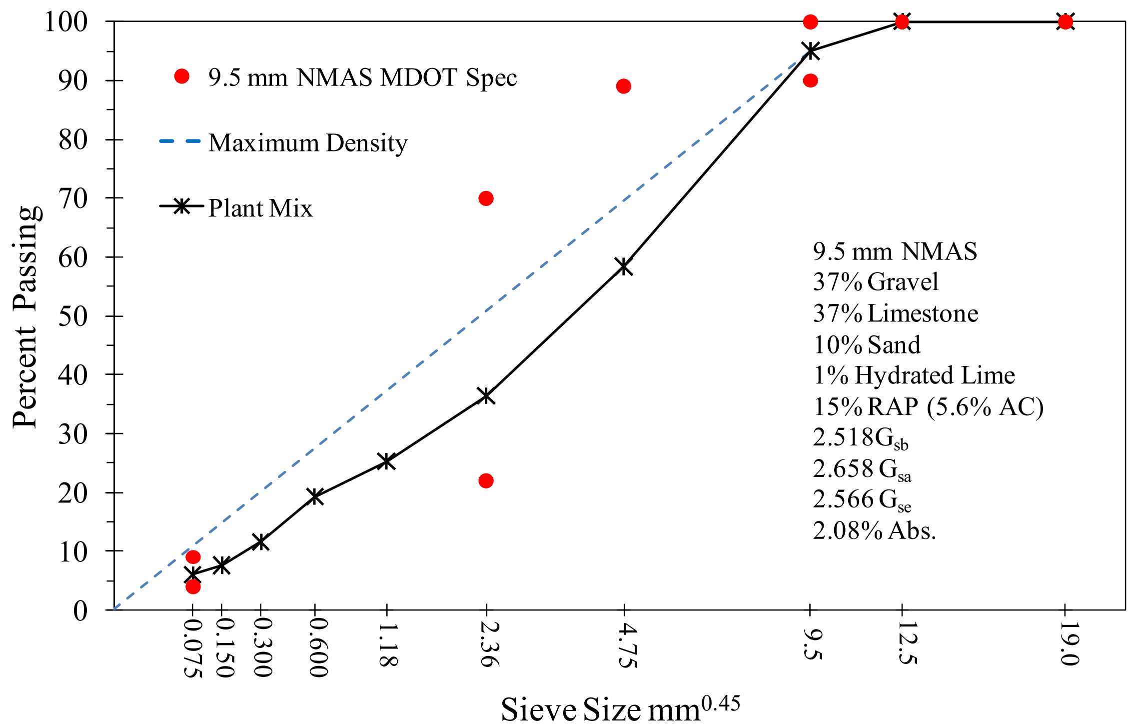


Figure 3.1 Aggregate Properties of Un-aged Plant Mix

3.4 Indirect Tensile Strength Testing

IDT strength and time to failure were tested on 100-mm and 150-mm diameter asphalt specimens (cores and SGC compacted material) using an Interlaken universal testing machine. The thickness was recorded for all specimens, and loading versus time data were recorded at a frequency of 30 Hz to measure indirect tensile strength (S_t) at failure and load deflection characteristics. Cores with noticeable surface cracks and uneven edges were not used in testing as they were not used in *BBR* testing. Before testing began, the specimens achieved thermal equilibrium of -12°C by being placed inside the Interlaken environmental chamber shown in Figure 3.2*a* for 12 hours. This temperature was chosen since *BBR* specimens were tested at this temperature. While testing 100 mm specimens, the temperature chamber could not maintain the desired temperatures for any extended period of time. Therefore, the specimens were conditioned in a freezer at -12°C, while being monitored by a thermometer, and placed in the Interlaken environmental chamber at -12°C and tested. The specimens were tested inside the environmental chamber as shown in Figure 3.2*b*.

(a) Conditioning Cores

(b) Indirect Tensile Strength Testing

Figure 3.2 Indirect Tensile Strength Test Procedure

3.5 Preparation of Near Surface Treated Mixture Beams

Preparation of test specimens was a key component to the work performed in this study. Testing of precisely sawn specimens directly from the surface of in-situ pavements poses many challenges and has been attempted by, at most, few researchers. The remainder of this section details the procedures used to successfully saw test specimens directly from the surface of field-aged pavements.

3.5.1 Application of Emulsion to Cores

The procedure used to apply emulsion to the core samples was detailed in Jordan (2010). Essentially, plastic spoons were used to apply the desired emulsion application rate to a 150 mm diameter core: 0.00, 0.91, 1.36, and 1.81 L/m^2 (0.00, 0.20. 0.30, and 0.40 gal/yd^2). The bottom of the asphalt cores had a relatively level surface to inhibit emulsion runoff. Figure 3.3*a* shows the application of emulsion to an asphalt core using a plastic spoon and Figure 3.3*b* shows the finished product just after treatment. The emulsion application process can be performed quickly and repeatedly as long as the emulsion being applied is kept consistent.

(a) *Emulsion Application to Core*

(b) *Finished Core after Treatment*

Figure 3.3   Emulsion Application to Asphalt Cores

The cores were left undisturbed for four days after emulsion application. Thereafter, the cores were stored at room temperature until a constant mass was obtained that was verified by monitoring mass loss with time. The treated asphalt cores then sat four more days to allow complete volatile loss to occur at room temperature. Oven aging of cores was performed prior to scraping but after constant mass was obtained and four days had elapsed. Thereafter, the cores (aged or un-aged) were ready for scraping.

Scraping removed the surplus emulsion from the surface of the pavement that would be holding the covered aggregates in place. It was found to be preferable for this type of testing for all cores to be scraped before sawing. Un-scraped cores can be sawn into mixture beams; however the presence of surplus emulsion creates difficulties with precise cutting and storage. Any scraping performed after sawing would also likely permanently damage the specimens. Therefore, all treated cores were scraped in the same manner, before sawing, which resulted in comparable sawing and testing conditions for the mixture beams that once had different application rates. The effects of varying emulsion thicknesses could have also had adverse effects during *BBR* testing.

The scraping procedure began by heating a treated specimen at 60° C for approximately one hour. The weight of the heated cores were recorded before having their emulsion scraped off using a putty knife as shown in Figure 3.4*a*. P 60 grade sandpaper was then used to remove any excess emulsion as shown in Figure 3.4*b*. Cores were considered fully scraped when at least ten aggregates were visible after sanding. The amount of emulsion scraped from a core was then recorded. Upon completion of this procedure, finished scraped cores similar to Figure 3.4*c* were stored in the laboratory (Figure 3.4*d*) to await further test preparation.

(a) Scraping Treated Core

(b) Sanding of Core

(c) Finished Scraped Core

(d) Core Storage

Figure 3.4 Scraping Procedure of Emulsion Applied Cores

3.5.2 Sawing of Mixture Beams

This section describes the procedure used to cut mixture beams from the surface of asphalt cores for subsequent testing in the *BBR*. The approximate size of the mixture beams is 120 mm long by 12 mm wide by 7-to 8-mm thick. The laboratory saw used in this study was a Buehler Delta® Abrasimet® Abrasive Cutter. The blades were Troxell Premium Diamond Blades.

This study developed a procedure to produce consistent, appropriately sized mixture beams for testing. The asphalt cores used in this procedure were 150-mm diameter and approximately 38-mm thick as it was found to be the most suitable size for the saw. Cores should have relatively smooth bases as jagged or uneven bases can affect consistency of specimen production. After making any cut, the saw was checked for any small pieces of aggregate or debris that could have hindered precise cuts or alignment within the clamps. Also, ice was typically placed in the water bath of the saw to cool the blade, and thus the binder in the core to minimize smearing or other undesirable behaviors.

This study used two sawing patterns, A and B, which can be seen in Figure 3.5 and Figure 3.6. One asphalt core can produce up to six suitable *BBR* mixture beam specimens. However, it was discovered that, at times, the asphalt cores were unable to produce the sixth adequately sized mixture beam. This was found to be a result of sawing precision for initial cuts (Cut 3 primarily) and not core integrity. A decision was made during the study to limit the amount of beams cut from a single asphalt core to five in order to be more consistent in specimen production.

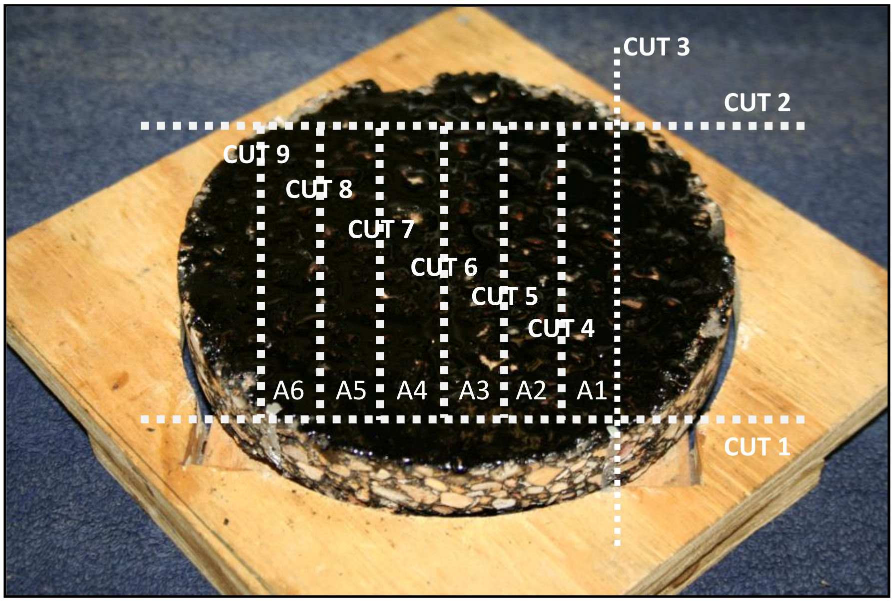


Figure 3.5 Sawing Pattern (SP) A

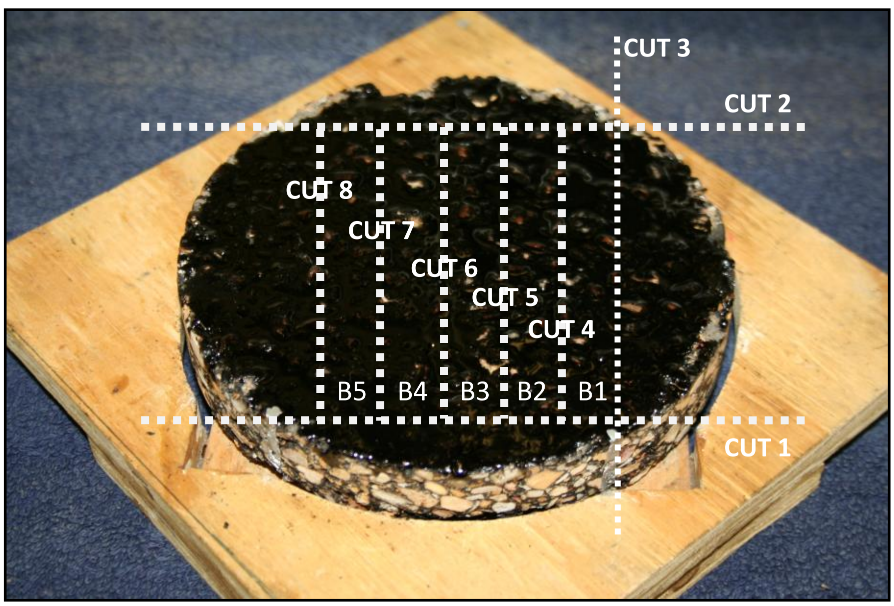
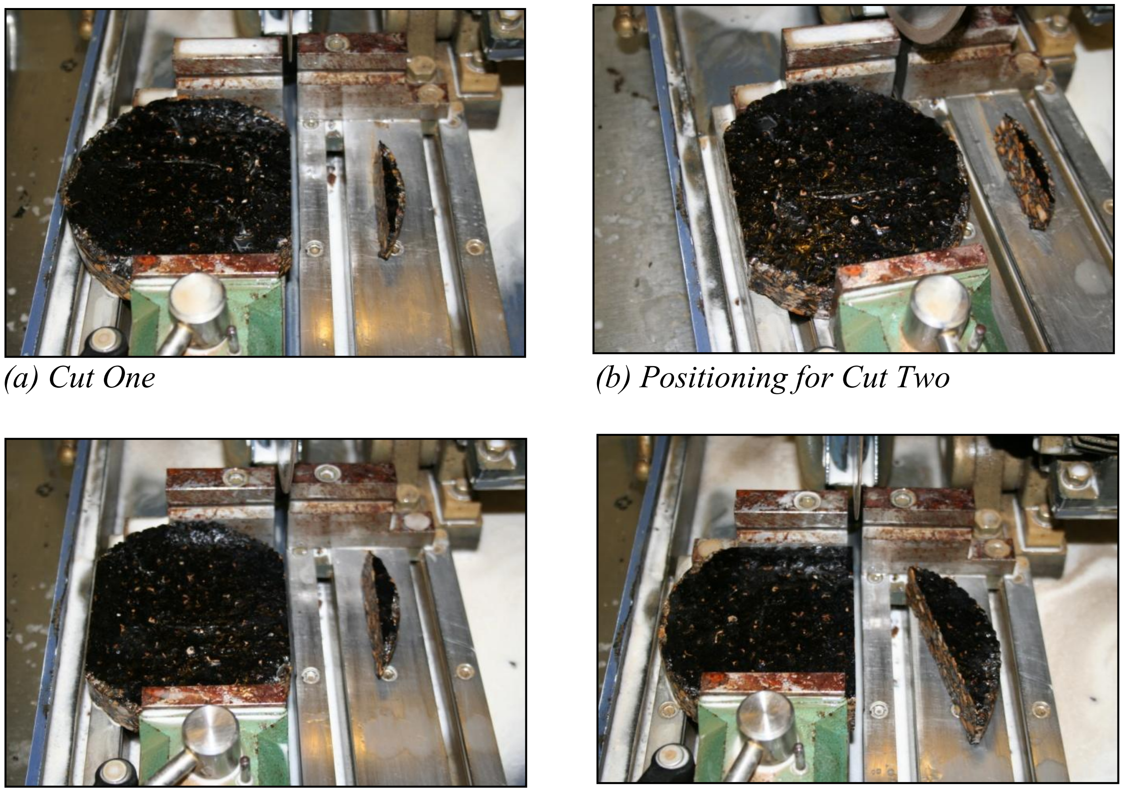


Figure 3.6 Sawing Pattern (SP) B

Both sawing patterns began with the core being placed into a wooden mold to be marked for Cut 1. The curved shape of the core limits the area where the required beam length can be produced. Thus, the mold helped evenly remove the part of the core which would not be needed. Figures 3.5 and 3.6 show an overview of the progression of cuts used to produce the near surface mixture beams in this study.

Once the asphalt core had been marked, the marked edge was removed by Cut 1 as shown in Figure 3.7*a*. After one edge was removed, the sample was rotated 180° in the saw, aligning the edge of Cut 1 with the left side of the saw base as shown in Figure 3.7*b*. The left edge of the saw base conveniently produces a 119 mm length beam, which is satisfactory and also ensures a parallel edge to Cut 1. Once aligned, Cut 2 was made (Figure 3.7*c*). The core was then rotated 90°, which allowed the parallel sides produced from Cut 1 and 2 to firmly secure the core in the saw clamps (Figure 3.7*d*). Cut 3 removed the remaining curved edge core as shown in Figure 3.7*d*. With the remaining block, the 12-mm-wide sections were cut.



(a) Cut One *(b) Positioning for Cut Two*

(c) Cut Two *(d) Cut Three*

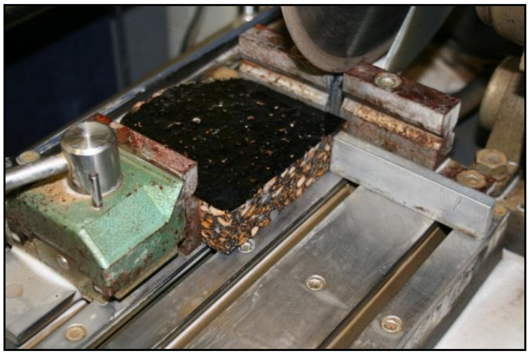
Figure 3.7 Initial Asphalt Core Preparations for Sawing

An aluminum plate was used to assist with cutting the 12-mm-wide mixture beams. The plate was 107-mm-long and was placed flush with the right edge of the saw base as shown in Figure 3.8*a*. With the core 107 mm from the right saw base, a 12-mm-wide section was produced as the saw blade lies 119 mm from each outer edge of the saw base. The plate was measured at various places along the core to ensure an even cut. The distance was checked along the entire side of the core to produce a quality cut. It was important when making these cuts to ensure the adjustable clamp was straight, the core did not move when levers were tightened, and the plate was flush with the saw base before making Cut 4 (Figure 3.8*b*).

In sawing pattern (SP) A, the method was repeated for Cut 5 through Cut 9 producing five or six 12 mm parallel sections depending on initial alignment previously discussed. The result is shown in Figure 3.8*c*. In SP B, each 12 mm parallel section was labeled depicting its location in the asphalt core. This detailed labeling system helped to determine any potential performance trends of *BBR* mixture beams relative to their initial location in the core. The final cut in SP B was Cut 8, as shown in Figure 3.5.

In order to make the final cut, one of the 12-mm pieces was laid on its side and placed between the clamps *emulsion side* or *surface* facing toward the saw as shown in Figure 3.8*d*. A different aluminum plate measuring 112-mm was placed flush with the right edge of the base similarly to previous steps. This plate placed against the core and flush with the saw base would produce a 7-mm nominal cut as shown in Figure 3.8*e*. The same procedure and technique were repeated for each of the 12 mm sections.

Several beams broke during the 7-mm nominal cut. The saw also had a tendency to leave a slight excess on one end when making a cut. The excess was ground down using the saw as seen in Figure 3.8*f*. It was important to support the beam as shown to ensure the grinding did not break the beam. This was performed by starting the saw, quickly stopping it, and raising the lid. The saw would continue to spin with enough speed to safely grind the beam down evenly.



(a) Plate Measuring 12mm Cut

(b) Cut 4

(c) Cuts 5 through 8

(d) Plate Measuring 7mm Target Cut

(e) Final Cut Producing BBR Mixture Beam

(f) Beam Grinding

Figure 3.8 *BBR* Mixture Beam Cutting Procedure – SP B Shown

3.5.3 Labeling and Storage of Mixture Beams

The process of labeling and storing mixture beams began upon completion of the procedure in Section 3.5.2. Once specimens were sawn, they were immediately labeled to identify various treatment combinations and location within the core (SP B only) as shown in Figures 3.9*a* and 3.9*b*. Individual specimens were identified using a similar version of the identification system found in Section 3.2. Abbreviated labels designated each component of Equation 3.1 with the exception of component 1, Mixture ID. Mixture ID does not differentiate replicate specimens within the unique treatment combinations; it merely groups the replicates together to report a representative value. In place of Mixture ID, individual specimens were being labeled by both core and replicate number (SP A) or core number and replicate location (SP B).

Upon being labeled, the mixture beams were individually measured with a caliper at five, equally spaced locations along the beam. Both thickness and width were recorded and averaged to form a representative value for that beam to be input into the *BBR* software. The thickness measurements are the only input into the software prior to testing. This process can be seen in Figure 3.9*c*. At this point, beams were also inspected for damage and to ensure dimensional requirements were met.

After the mixture beams had been sawn, labeled, and measured, they were stored in plastic tackle boxes as shown in Figure 3.9*d* and allowed to reach constant mass prior to testing. This was found to be a successful method of storage for several reasons. First, the mixture beams are delicate. Preliminary methods discovered the emulsified mixture beams should not be stacked in order to prevent potential damage and stresses applied by separating beams sticking to the container or to each other. Tackle boxes provided a transparent container with small compartments which minimized potential damage during storage.

(a) Labeling and Storage

(b) Mixture Beam Labeling

(c) Mixture Beam Measuring

(d) Mixture Beam Storage

Figure 3.9 Labeling and Storage of Mixture Beams

3.6 Bending Beam Rheometer (*BBR*) Testing

A CANNON Thermoelectric *BBR* (Figure 3.10*a*) was used to perform flexural creep testing in order to investigate the mechanical properties of the different asphalt mixture and emulsion rate combinations that were cut into mixture beams according to the procedure in Section 3.5. Due to the varying surface characteristics of the pavements tested, the thickness and width of the mixture beams were the average of five, evenly distributed measurements along the beam. This was performed in order to achieve more precise input values for the *BBR* software. During this process, mixture beams were also examined for visible deformations that may have had adverse effects on the testing data, such as surface cracks or missing aggregate. Mixture beams found to have extreme deformations were discarded and recorded as beams broken during sawing. Figures 3.10*c* and 3.10*d* show examples of acceptable and unacceptable mixture beams.

All of the acceptable mixture beam specimens were immersed in the *BBR* cooling bath in methanol for 60 ± 5 minutes as shown in Figure 3.10*e*. This ensured the specimens reached thermal equilibrium at -12°C before being tested. The test parameters for the mixture beams consisted of a 4.9 N constant load applied to the midpoint of the beam for a 1,000 second test duration. The *BBR* measures the midpoint deflection of the mixture beam verses time every 0.5 seconds. Representative values of creep stiffness in this study for mixture beams tested in the *BBR* were recorded at 60 seconds. Detailed testing procedure can be found in AASHTO T 313-09. Figure 3.410*b* shows a beam being tested. Figure 3.9*f* is an example of a beam breaking during a test. The desired outcome of the test was a consistent, uninterrupted collection of flexural stiffness data whereas a mixture beam breaking during the test was deem a failed test.

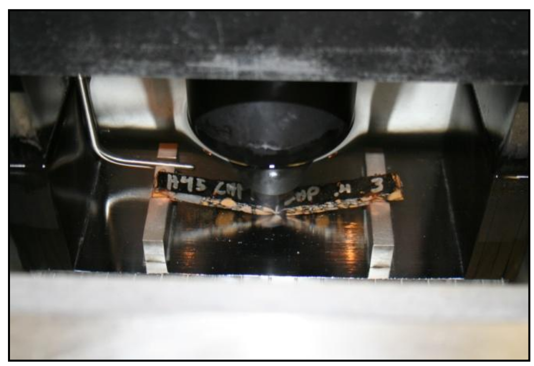
(a) Bending Beam Rheometer

(b) Mixture Beam Testing

(c) Example of an Acceptable Beam

(d) Example of an Unacceptable Beam

(e) Beams Conditioning in Methanol Bath



(f) Beam Broken During Testing

Figure 3.10 *BBR* Test Procedure

3.7 Specimens Tested

Due to the nature of this testing and the materials used in this study, the ability to produce mixture beams varied. Sawing and testing resulted in broken mixture beams in some instances due to the thin dimensions required for use in the *BBR*. The majority of the material tested was cut from the surface of aged asphalt concrete pavement which added to the rate of failure in this study. Figure 3.11 shows the procedure in which data collection was performed to account for the variability of specimen production and testing. A minimum number of replicates (*N*) was tested and every core sawn was completely tested; *N* of five, ten, and thirty was used in various parts of the study. Varying numbers of cores and mixture beams resulted but this approach was felt to be more consistent than other options. Depending on the SP, up to four or five extra replicate data points could be produced if the target value of data points fell one short and required an additional core to be cut and tested.

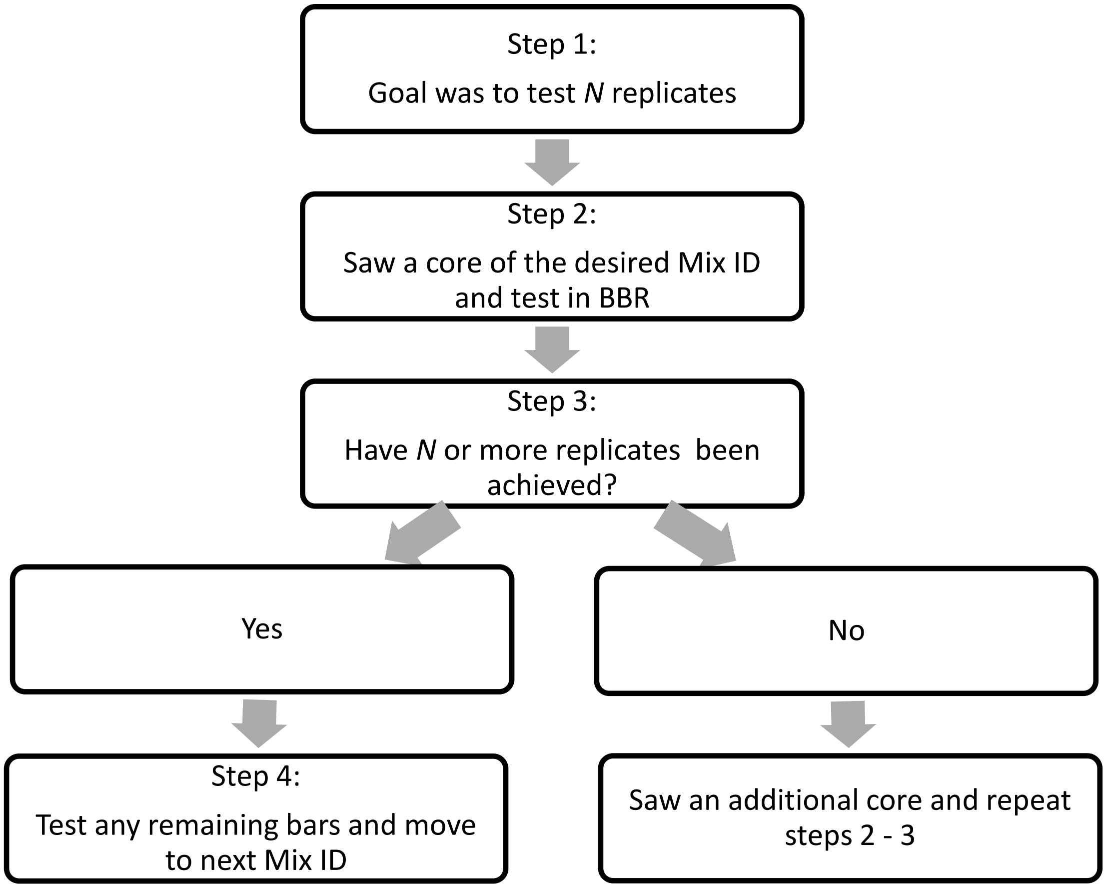


Figure 3.11 Specimen Production Flow Chart

3.7.1 *BBR* Properties of Field-Aged Asphalt Without Emulsion

Testing of control specimens was performed to investigate variability of the materials and to establish a baseline of properties for comparison to emulsion treated specimens. In general, more testing was performed on control specimens than emulsion treated specimens. The target replication (*N*) for control testing was 30 beams according to the protocol described in Figure 3.11. Table 3.3 summarizes control testing performed on FR and Hwy 45 alongside Mix ID's.

Table 3.3 *BBR* Control Test Matrix

Mix ID	Pavement	Emulsion	Cores Used	SP	*BBR* Specimens			
					Total	Broke-Saw	Broke-*BBR*	Tested
1	Hwy 45	NE	17	A	98	31	37	30
2	FR	NE	16	A	91	27	30	34
3	Hwy 45	NE	16	B	80	27	19	34
4	FR	NE	18	B	90	36	23	31

Note: ***N*=30**

Table 3.4 summarizes the detailed labeling information from SP B corresponding to Table 3.3. The performance characteristics of the sawing pattern with regard to the origin of the mixture beam within the asphalt core are shown. This data indicate the sawing patterns used and the location within the asphalt core; do not appear to have a relationship with respect to the specimens.

Table 3.4 Detailed Labeling Results of Sawing Pattern (SP) B

		BBR Specimens			
Pavement	Location	Total	Broke-Saw	Broke-*BBR*	Tested
Hwy 45	B1	16	8	1	7
	B2	16	8	3	5
	B3	16	5	6	5
	B4	16	4	4	8
	B5	16	2	5	9
	Total	*80*	*27*	*19*	*34*
FR	B1	18	10	3	5
	B2	18	7	2	9
	B3	18	5	9	4
	B4	18	10	4	4
	B5	18	4	5	9
	Total	*90*	*36*	*23*	*31*

3.7.2 Indirect Tensile Strength Testing

Indirect tensile strength testing was performed on thirty 150-mm specimens from both Hwy 45 and FR pavements. The same test was performed on thirty 100-mm specimens from the same pavements in order to ensure consistency in the original data. The results are summarized in Table 3.5.

Table 3.5 Indirect Tensile Strength Testing

Pavement	Emulsion	Core Size (mm)	*IDT* Data Points
Hwy 45	NE	150	30
FR	NE	150	30
Hwy 45	NE	100	30
FR	NE	100	30

3.7.3 Effect of Un-aged Emulsion on Field-Aged Asphalt

Testing of un-aged emulsion treated specimens was performed to investigate any effect the various emulsions or application rates had on performance in the *BBR*. Both Hwy 45 and FR pavements, along with each of the seven emulsions at each application rate, were studied. A minimum of five replicates (N=5) were tested for all 42 treatment combinations, each represented with a Mix ID as shown in Table 3.6. Sawing pattern A was used to prepare the mixture beams.

Table 3.6 *BBR* Un-aged Test Matrix

Mix ID	Pavement	Emulsion	Application Rate (L/m^2)	Cores Used	*BBR* Specimens Total	Broke-Saw	Broke-*BBR*	Tested
5	FR	6	0.91	2	10	2	3	5
6	FR	6	1.36	2	12	0	2	10
7	FR	6	1.81	3	18	2	10	6
8	Hwy 45	6	0.91	2	10	0	3	7
9	Hwy 45	6	1.36	5	30	9	14	8
10	Hwy 45	6	1.81	3	18	1	8	9
11	FR	3	0.91	2	11	2	3	6
12	FR	3	1.36	2	12	0	5	7
13	FR	3	1.81	2	11	6	0	5
14	Hwy 45	3	0.91	2	12	2	2	8
15	Hwy 45	3	1.36	2	11	1	3	7
16	Hwy 45	3	1.81	2	11	1	5	5
17	FR	1	0.91	2	11	0	3	8
18	FR	1	1.36	2	12	2	5	5
19	FR	1	1.81	2	12	0	4	8
20	Hwy 45	1	0.91	2	11	3	3	5
21	Hwy 45	1	1.36	2	12	3	2	7
22	Hwy 45	1	1.81	3	18	5	5	8
23	FR	2	0.91	3	11	3	2	6
24	FR	2	1.36	5	28	10	10	8
25	FR	2	1.81	2	12	0	0	12
26	Hwy 45	2	0.91	2	11	2	2	7
27	Hwy 45	2	1.36	3	16	3	6	7
28	Hwy 45	2	1.81	2	11	1	2	8
29	FR	5	0.91	2	14	3	3	8
30	FR	5	1.36	2	12	0	3	9
31	FR	5	1.81	2	11	5	1	5
32	Hwy 45	5	0.91	2	12	2	2	8
33	Hwy 45	5	1.36	2	12	0	3	9
34	Hwy 45	5	1.81	2	12	1	2	9
35	FR	7	0.91	3	16	0	9	7
36	FR	7	1.36	2	12	1	1	10
37	FR	7	1.81	2	12	1	5	6
38	Hwy 45	7	0.91	6	32	13	14	5
39	Hwy 45	7	1.36	3	17	1	10	6
40	Hwy 45	7	1.81	2	11	0	4	7
41	FR	4	0.91	2	11	0	3	8
42	FR	4	1.36	2	12	0	3	9
43	FR	4	1.81	2	12	2	5	7
44	Hwy 45	4	0.91	2	12	1	6	5
45	Hwy 45	4	1.36	2	11	3	3	5
46	Hwy 45	4	1.81	2	12	1	2	9

Note: *N*=5

3.7.4 Effect of Aged Emulsion on Field-Aged Asphalt

Tables 3.7 through 3.9 show the aged emulsion testing performed on aged asphalt pavements. The Hwy 45 pavement in Table 3.7 was tested at various aging increments with 1.81 L/m^2 of Emulsion 3. Table 3.8 shows a block of testing using Emulsion 3a that consolidated the aging times found in Table 3.7, with an emphasis on the initial 7 days of aging. Table 3.9 shows testing focusing on three emulsions and three application rates aged for 7 days. This block of testing further investigated the affect of aging on the stiffness results found in the *BBR*. SP A was used in Table 3.7, and SP B was used in Tables 3.8 and 3.9.

Table 3.7 Aged Test Results of Hwy 45 and Emulsion 3

Mix ID	Pavement	Emulsion	Application Rate (L/m^2)	Days Aged	Cores Used	***BBR* Specimens** Total	Broke-Saw	Broke-*BBR*	Tested
16	Hwy 45	3	1.81	0	2	11	1	5	5
47	Hwy 45	3	1.81	3	2	12	0	1	11
48	Hwy 45	3	1.81	7	2	12	0	1	11
49	Hwy 45	3	1.81	14	2	12	0	3	9
50	Hwy 45	3	1.81	30	2	10	0	1	9
51	Hwy 45	3	1.81	45	2	11	2	2	7
52	Hwy 45	3	1.81	60	2	10	0	2	8

Note: *N*=5

Table 3.8 Aged Test Results of Hwy 45 and Emulsion 3a

Mix ID	Pavement	Emulsion	Application Rate (L/m^2)	Days Aged	Cores Used	***BBR* Specimens** Total	*N*	Broke-Saw	Broke-*BBR*	Tested
53	Hwy 45	3a	1.81	0	10	50	30	18	5	25
54	Hwy 45	3a	1.81	7	10	50	30	12	10	28
55	Hwy 45	3a	1.81	30	5	20	10	5	3	12
56	Hwy 45	3a	1.81	60	5	20	10	1	7	12

Note: Insufficient emulsion was sampled to achieve target *N* values though a consistent number of cores were sawn and tested in all cases.

Table 3.9 Aged Test Results of FR

Mix ID	Pavement	Emulsion	Application Rate (L/m^2)	Days Aged	Cores Used	*BBR* Specimens			
						Total	Broke-Saw	Broke-*BBR*	Tested
57	FR	3	0.91	7	2	10	0	1	9
58	FR	3	1.36	7	2	10	2	0	8
59	FR	3	1.81	7	2	10	2	1	7
60	FR	1	0.91	7	2	10	2	0	8
61	FR	1	1.36	7	2	10	1	1	8
62	FR	1	1.81	7	2	10	1	1	8
63	FR	2	0.91	7	2	10	0	3	7
64	FR	2	1.81	7	2	10	5	0	5

Note: *N*=5

3.7.5 Effect of Emulsion on Laboratory-Compacted Asphalt

Gyratory compacted specimens were created from the plant mix described in Section 3.3.3. The gyratory specimens (7 ± 1% air voids measured via T 331) were tested to coincide with Hwy 45 cores with no emulsion (Table 3.3) as well as PASS-CR emulsion applied at 1.81 L/m^2 at four aging periods (Table 3.8). The test matrix is described in Table 3.10 and was designed to investigate the potential effect of emulsion in *BBR* testing on an asphalt core created in a controlled environment with known properties at various aging times. The data from the Hwy 45 cores provided a comparison to the laboratory-compacted data in order to investigate behavior of the aged pavement.

Table 3.10 Testing of Gyratory Compacted Asphalt Cores

Mix ID	Pavement	Emulsion	Application Rate (L/m^2)	Days Aged	Cores Used	*BBR* Specimens				
						Total	*N*	Broke-Saw	Broke-*BBR*	Tested
65	Plant Mix	NE	0.00	0	6	30	30	0	0	30
66	Plant Mix	NE	0.00	7	6	30	30	3	1	26
67	Plant Mix	NE	0.00	30	2	10	10	0	0	10
68	Plant Mix	NE	0.00	60	2	10	10	0	1	9
69	Plant Mix	3a	1.81	0	6	30	30	0	0	30
70	Plant Mix	3a	1.81	7	6	30	30	1	0	29
71	Plant Mix	3a	1.81	30	2	10	10	2	0	8
72	Plant Mix	3a	1.81	60	2	10	10	3	1	6

Note: Insufficient emulsion was sampled to achieve target *N* values though a consistent number of cores were sawn and tested in all cases.

CHAPTER IV

DATA ANALYSIS

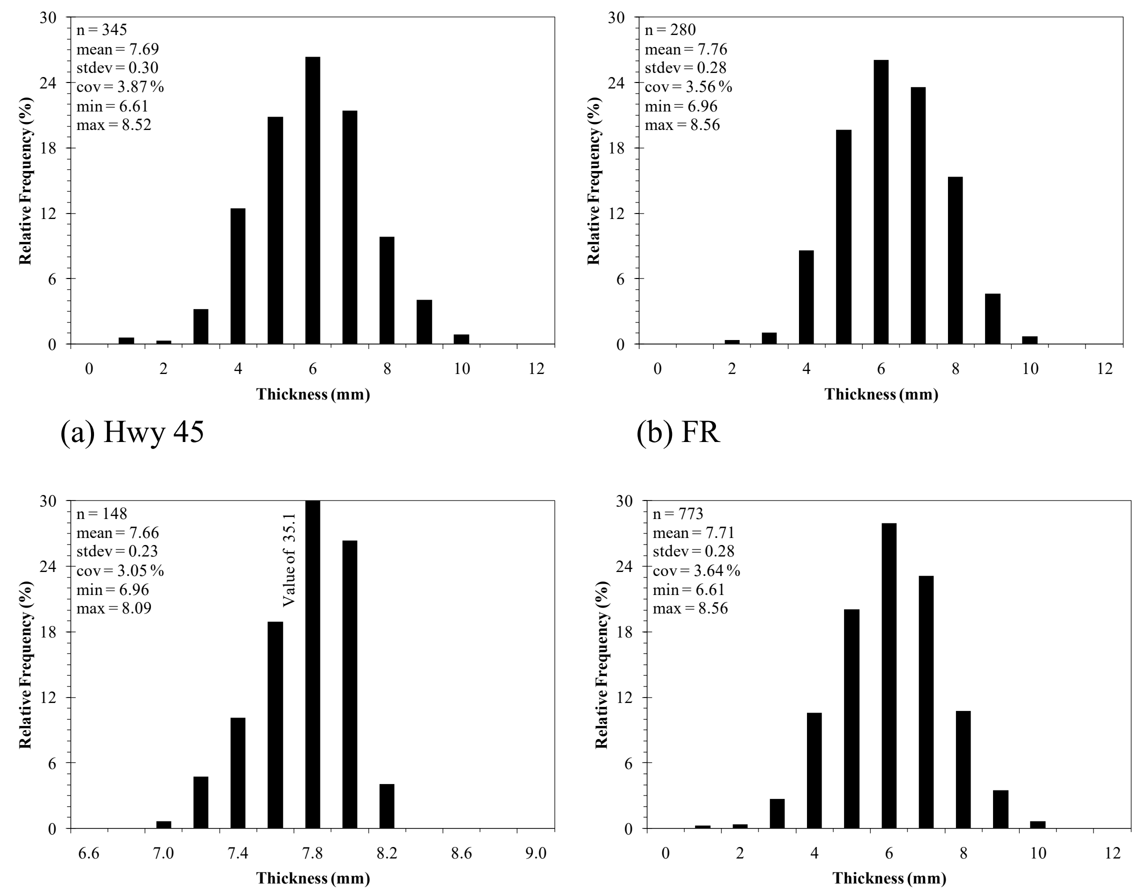
4.1 Introduction

The purpose of this thesis was to investigate the ability of the *BBR* to detect asphalt emulsion applied to a pavement surface for chip or scrub seals. This chapter analyzes data from the test matrices and procedures presented in Chapter 3. During analysis, the estimated stiffness value *Se(t)* measured at 60 seconds during *BBR* testing was used as the representative value for all *BBR* testing. Raw data used in this analysis can be found in Appendix A (*BBR* Data) and Appendix B (*IDT* Data).

4.2 Analysis of Measured *BBR* Specimens Thicknesses

The ability to produce consistent specimen dimensions was initially a concern in this study given the slight variation of the surface origin. This concern was also expressed by Maasteanu, et al. (2009). The influence of thickness in calculating flexural creep stiffness is large since thickness raised to the third power as shown in Equation 2.2. The studies found during review of literature all used mixture beams sawn from the center of an asphalt core, thus allowing better precision and allowing sawing each side of the mixture beam. This study developed a method to produce mixture beams with acceptable dimensions while also accounting for slight variations in the pavement surface. The findings by Velasquez (2009) helped support the decisions made in this research regarding mixture beam size and test temperature.

The thickness values for the 773 mixture beams successfully produced in this study are shown along with basic statistics in Figure 4.1. Measured thicknesses ranged from 6.71 to 8.56 mm with a 3.60% cov for all beams. The distribution of thickness values indicates a normal distribution and the ability to saw *BBR* specimens from the pavement surface. The cov was lower for the plant mix but mean thickness of all three materials was 7.7-mm making statistical comparisons unnecessary.



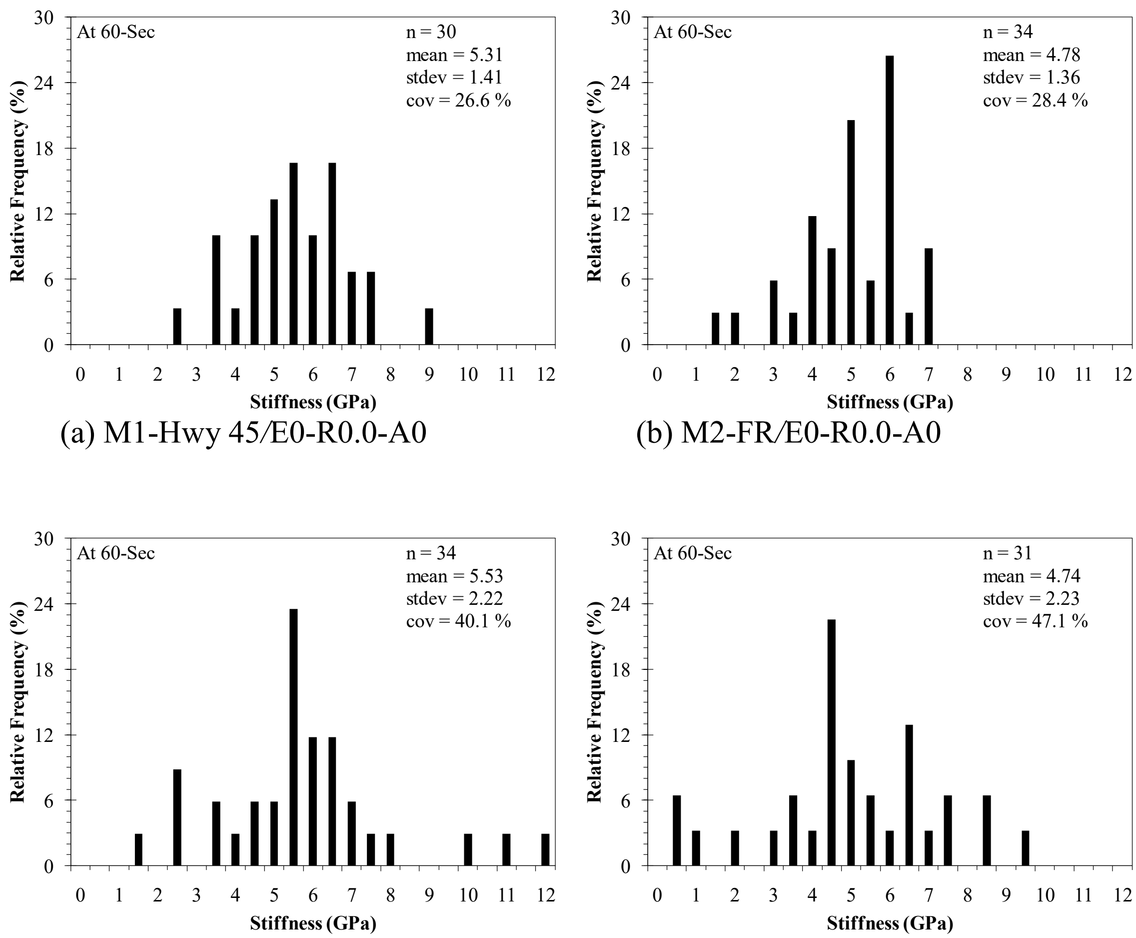
(a) Hwy 45 (b) FR

(c) Plant Mix (d) All

Figure 4.1 Sample Asphalt Mixture Beam Thicknesses

4.3 Analysis of *BBR* Properties of Asphalt Specimens Without Emulsion

Analysis of *BBR* properties of asphalt pavement without emulsion established a baseline of properties for comparison to emulsion treated field-aged specimens. The relative frequencies of each field-aged mixture in Tables 3.3 and 3.4 were plotted in Figure 4.2. As anticipated, the sawing pattern did not affect results with either pavement. Mixtures sawn from FR cores exhibited similar means of 4.78 and 4.74 GPa, while Hwy 45 cores also produced values that were fairly similar at 5.31 and 5.53 GPa, especially considering a few readings were noticeably above the rest of the data.



(a) M1-Hwy 45/E0-R0.0-A0

(b) M2-FR/E0-R0.0-A0

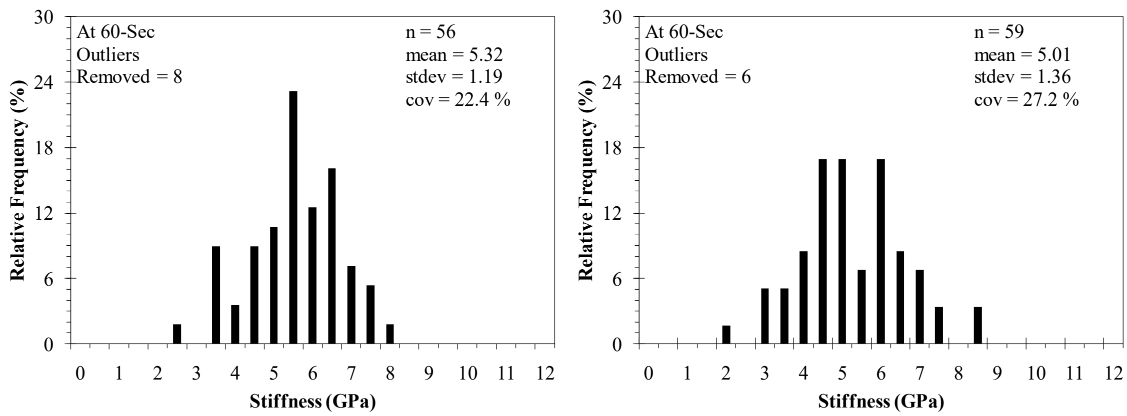
(c) M3-Hwy 45/E0-R0.0-A0

(d) M4-FR/E0-R0.0-A0

Figure 4.2 *BBR* Field-Aged Asphalt Control Relative Frequency Data

The mean value of these mixtures is a good representation of the central value of a group of data, but as with any data set, it is vulnerable to distortion due to extreme values, or outliers. Further analysis of the data presented in Figure 4.2 revealed the presence of statistical outliers. Outliers were identified using a method measuring the data's distance from the interquartile range (*IQR*). The *IQR* is the difference between the upper and lower quartiles, or the 75^{th} and 25^{th} percentiles. Even though the *IQR* can be sensitive to data sets about the midpoint, it is very useful when comparing the variabilities of several data sets (Ott and Longnecker 2010). This method designates both mild outliers and extreme outliers, with extreme outliers defined as being more than ±1.5 and ±3 times the *IQR* respectively.

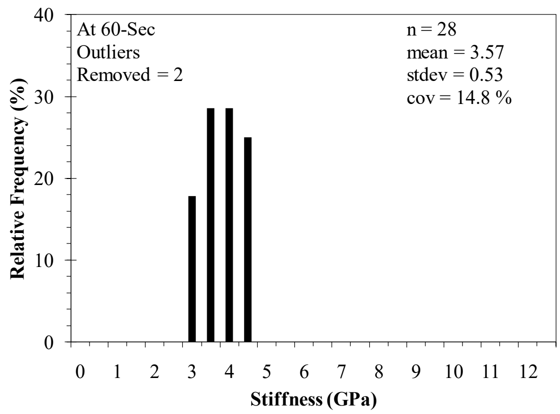
The similarity of results shown in Figure 4.2 suggest field-aged asphalt without emulsions with different sawing patterns can be combined creating a larger data set to establish a baseline for control data. Figure 4.3 shows the combined data set of both pavement materials after mild and extreme outliers had been removed. Three tests for normality were performed on the two combined data sets, Anderson-Darling, Ryan-Joiner which is similar to Shapiro-Wilk (Ryan and Joiner, 1976), and Kolmogorov-Smirnov. These tests represent three common measures of normality. Kolmogorov-Smirnov samples are standardized and compared with a standard normal distribution. The Anderson-Darling test, commonly regarded as the most powerful test, gives more weight to the tails than Kolmogorov-Smirnov by calculating critical values. Ryan-Joiner tests compute a correlation coefficient equivalent to the Shapiro-Wilk test W approximation (Ryan and Joiner, 1976). Figure 4.2(a) yielded p-values of 0.582 for Anderson-Darling, >0.100 for Ryan-Joiner, and >0.150 for Kolmogorov-Smirnov. Figure 4.1(b) yielded p-values of 0.841 for Anderson-Darling, >0.100 for Ryan-Joiner, and >0.150 for Kolmogorov-Smirnov. By obtaining p-values >0.05, the results demonstrate each data set shows no significant departure from normality. The remainder of the analysis uses the Figure 4.3 data sets as the control when field-aged asphalt is used.



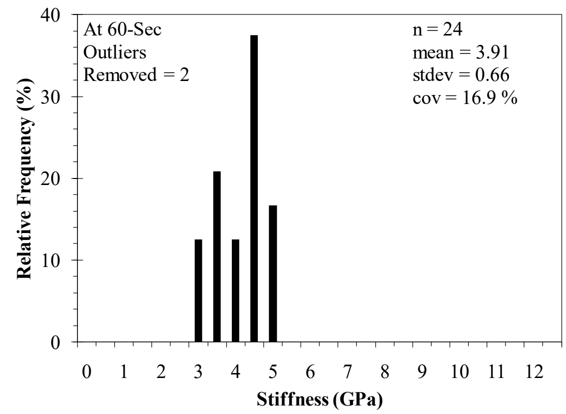
(a) M1 & M3-Hwy 45/E0-R0.0-A0 (b) M2 & M4-FR/E0-R0.0-A0

Figure 4.3 Combined *BBR* Field-Aged Asphalt Control Data

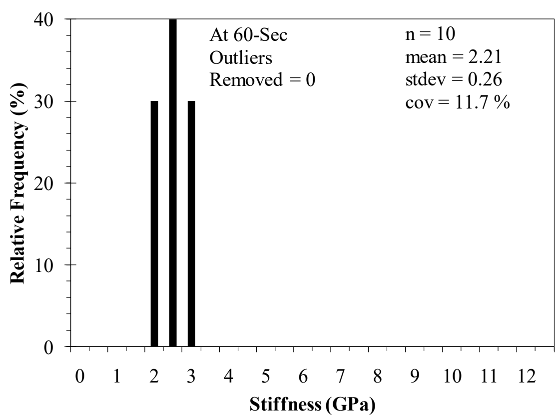
Figure 4.4 plots all Plant Mix *BBR* results with no emulsion with outliers removed. The same outlier removal was taken as with Hwy 45 and FR pavements. This dataset includes aging times of 0, 7, 30, and 60 days in an oven at 60°C. The mean stiffness is lowest in the 30 day aged data at 2.21 GPa and highest in the 60 day aged data at 4.59 GPa. Neither the 30 nor 60 day data has much replication which may contribute to the result. There is increased stiffness from 0 to 7 days aging of 3.57 to 3.91 GPa; both data sets have considerable replication. Uniform materials and construction yield Plant Mix cov values lower than the Hwy 45 and FR pavements, (Figure 4.3) an expected result. Anderson-Darling, Ryan-Joiner, and Kolmogorov-Smirnov tests for normality were performed on each Mix ID in Figure 4.4. Each Mix ID obtained p-values >0.05 in each test, demonstrating no significant departure from normality.



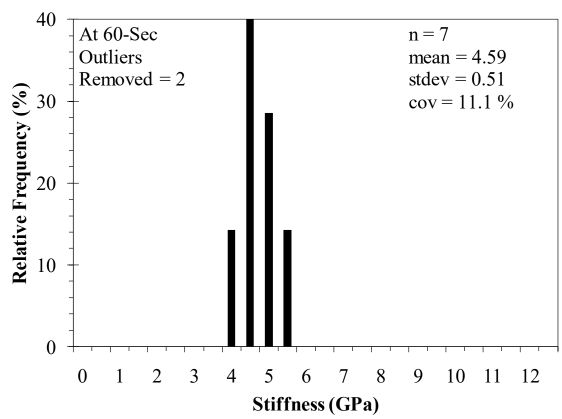
(a) M65-Plant Mix/E0-R0.0-A0



(b) M66-Plant Mix/E0-R0.0-A7



(c) M67-Plant Mix/E0-R0.0-A30



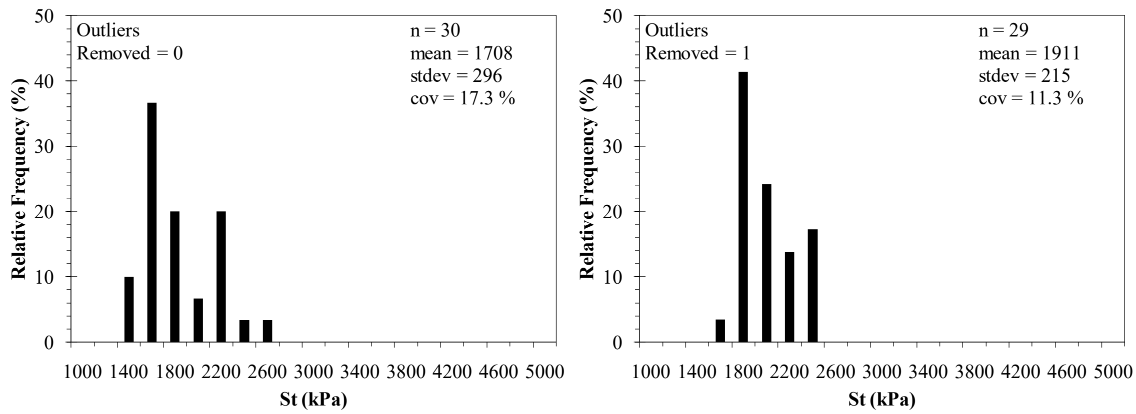
(d) M68-Plant Mix/E0-R0.0-A60

Figure 4.4 *BBR* Plant Mixed Asphalt Control Relative Frequency Data

4.4 Tensile Strength Properties of Asphalt Specimens Without Emulsion

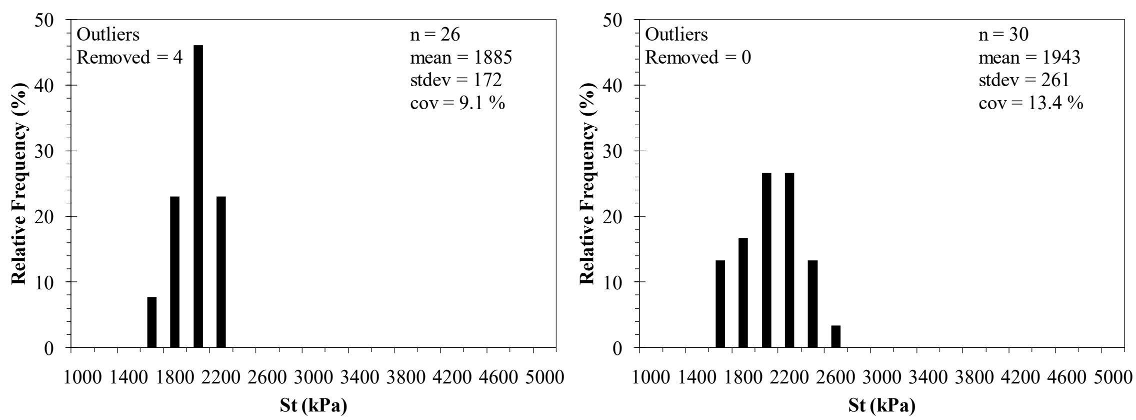
Figures 4.5 through 4.7 plot all *IDT* results for Hwy 45, FR, and Plant Mix pavements, respectively. This dataset includes specimen dimensions of 100 and 150 mm with a sample size of 30 replicates for each condition considered. The same outlier removal method was used as with the *BBR* data in previous sections. Anderson-Darling, Ryan-Joiner, and Kolmogorov-Smirnov tests for normality were performed on each Mix ID in Figures 4.5, 4.6, and 4.7. Only the Hwy 45 100 mm data set was found to have a significant departure from normality. The cov data ranged from 9.1 to 19.1% with an average of 13.4%. There were no noticeable trends of cov values between specimen size or between pavements.

Initially, thirty Hwy 45 150 mm specimens were tested and yielded values of 1498 kPa for mean St with a 20.2% cov. The cov values were unusually higher than other tests, resulting in this data set being re-tested yielding a mean *St* of 1708 kPa with a 17.3% cov that is shown in Figure 4.5a. The new data set yielded a higher *St* and a lower cov. The relative frequency histogram also shows results closer to expected values.



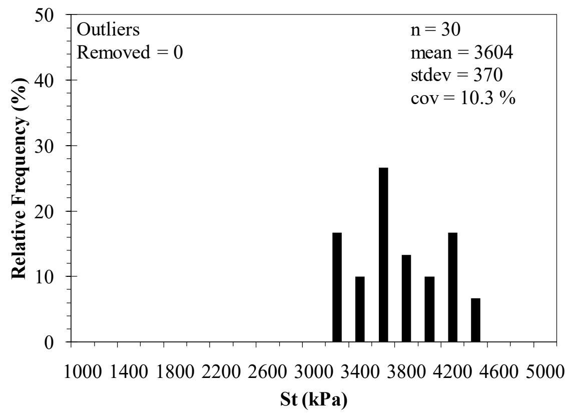
(a) Hwy 45 – 150-mm (b) Hwy 45 – 100-mm

Figure 4.5 *IDT* Testing of Hwy 45 Field-Aged Pavement

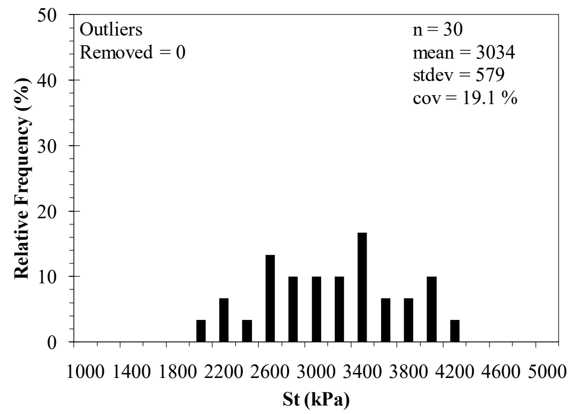


(a) FR – 150-mm (b) FR – 100-mm

Figure 4.6 *IDT* Testing of FR Field-Aged Pavement



(a) Plant Mix – 150-mm



(b) Plant Mix – 100-mm

Figure 4.7 *IDT* Testing of Plant Mix Pavement

4.5 Comparison of *BBR* and *IDT* Properties Without Emulsion

Using data from Sections 4.3 and 4.4, comparisons of *BBR* and *IDT* properties were made; all testing was performed at -12°C. One property of interest was data variability. Using the cov, results indicate *BBR* testing is in general, more variable than *IDT* testing, though not so much so that meaningful results cannot be obtained. The cov data from sections 4.2 and 4.3 are summarized in Table 4.1.

Table 4.1 Comparison of *BBR* and *IDT* cov Properties Without Emulsion

Pavement	Testing Method	cov (%)
Hwy 45	*IDT* – 150 mm	17.3
	IDT – 100 mm	11.3
	BBR	22.4
FR	*IDT* – 150 mm	9.1
	IDT – 100 mm	13.4
	BBR	27.2
Plant Mix	*IDT* – 150 mm	10.3
	IDT – 100 mm	19.1
	BBR	14.8

In the Hwy 45 and FR pavements, the *BBR* yielded a variation roughly twice that of *IDT* testing. In the Plant Mix, less variation was expected due to the uniform pavement. The *BBR* cov falling within the two *IDT* data sets, though, was not expected but is a positive result and supports use of *BBR* testing of mixture beams. It is possible that some of the 100 mm readings for the Plant Mix are too low, which would increase the mean value and decrease the cov.

4.6 Investigation of Un-aged Emulsion on Field-Aged Asphalt

4.6.1 Statistical Investigation of Emulsion Application Rates

The study of un-aged emulsion on field-aged asphalt began by organizing similar *BBR* mean stiffness data with different application rates from lowest to highest (Table 4.2). Comparing application rates of each emulsion did not align with general behavioral assumptions. If emulsion reduces stiffness, then 1.81 L/m^2 should reduce stiffness the most provided the pavement does not take on all possible emulsion at a lower application rate (0.91 or 1.36 L/m^2). Out of total of seven cases, in the Hwy 45 pavement, 1.81 L/m^2 had the lowest stiffness in 4 cases. The 0.91 L/m^2 application rate also reduced stiffness the least occurred in 4 cases but not always the same cases as the 1.81 L/m^2 reducing stiffness the most. Similarly, 1.36 L/m^2 is in the middle in 4 cases, but not necessarily the same instances as the 1.81 L/m^2. The FR pavement exhibits similar results with the 1.81 L/m^2 application rate reducing stiffness the most in 2 of the 7 cases. The 0.91 L/m^2 application rate reducing stiffness the least occurred in 4 cases, and the 1.36 L/m^2 is in the middle in 2 cases. Results seem to indicate inability to correlate stiffness reduction to application rate meaning the pavements may not be sensitive to application rate within the range of values used. The observation prompted a statistical investigation into the effect of varying application rates within each emulsion on each pavement.

Table 4.2 Un-aged Emulsion Application Rate Comparisons

Pavement	Emulsion	Mean Stiffness (GPa)	Application Rate (L/m^2)	Groups	p Value
Hwy 45		4.20	1.81	A	
	1	4.99	1.36	A	0.4233
		5.58	0.91	A	
		3.66	1.81	A	
	2	3.71	0.91	A	0.2126
		4.95	1.36	A	
		3.00	1.81	A	
	3	4.00	1.36	A	0.4926
		4.50	0.91	A	
		4.78	0.91	A	
	4	5.57	1.36	A	0.8788
		5.87	1.81	A	
		3.25	1.36	A	
	5	4.08	0.91	AB	0.3743
		5.34	1.81	B	
		2.67	1.36	A	
	6	3.29	1.81	AB	0.1578
		4.22	0.91	B	
		4.52	1.81	A	
	7	4.87	1.36	A	0.3431
		5.16	0.91	A	
FR		4.60	1.36	A	
	1	4.77	1.81	A	0.0544
		5.46	0.91	A	
		4.54	0.91	A	
	2	4.66	1.36	A	0.0511
		5.29	1.81	A	
		3.34	1.81	A	
	3	4.30	0.91	AB	0.2201
		4.74	1.36	B	
		4.05	1.36	A	
	4	4.71	1.81	B	0.2076
		6.75	0.91	B	
		3.46	1.36	A	
	5	3.63	1.81	A	0.3891
		3.74	0.91	A	
		3.46	1.81	A	
	6	4.52	1.36	AB	0.6010
		5.00	0.91	B	
		4.29	0.91	A	
	7	4.85	1.81	A	0.4437
		5.45	1.36	A	

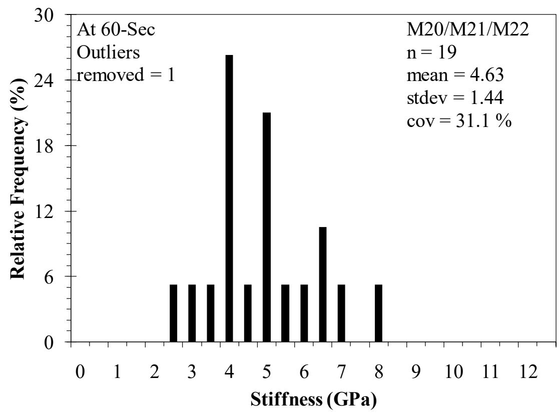
The majority of the statistical analysis was performed in SAS statistical software using a general linear model which uses the method of least squares to fit general linear models. Data within each of the 14 pavement-emulsion combinations (42 mixes shown in Table 3.8) were grouped by application rate. This grouping compared the statistical difference in stiffness between the three application rates within one treatment combination. Stiffness values at 60 seconds of *BBR* testing were used as the quantitative dependent variable. The MEANS statement was used to compute the arithmetic means and standard deviations of mean stiffness values. You can specify only classification effects in the MEANS statement. The classification effect chosen was application rate. The LINES statement presents the results of the LSD, least significant difference, option. This option performs pairwise *t* tests, equivalent to Fisher's least significant difference test in the case of equal cell sizes, for all main-effect means in the MEANS statement. In this investigation, samples were typically of unequal sizes in which the harmonic mean of the cell sizes is used to compute the critical ranges. This approach is reasonable if the cell sizes are not too different.

Application rates are shown with different letter groupings that represent significantly different values with respect to mean stiffness. Sometimes, an application rate is assigned two letter groupings, i.e. A and B. In this case, the value is not significantly different than any value also designated with an A or B.

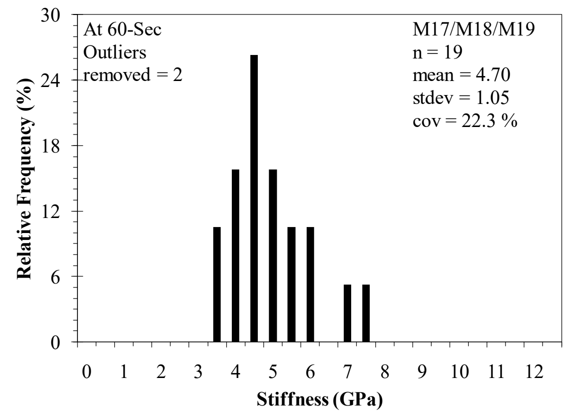
The three application rates were compared as a whole with a statistical p-value threshold of 0.05. Values below this threshold would reject the null hypothesis (H_o: $\mu_{1.81} = \mu_{1.36} = \mu_{0.91}$) claiming all application rates were significantly different. Values above the threshold do not reject the null hypothesis and claim the difference between all three application rates is not significant. Results are found in Table 4.2. The three emulsion application rates for each of the 14 combinations of emulsion and pavement were found to not be statistically significant according to their respective p-values. Each of the 14 p-values failed to reject the null hypothesis. This indicates that the application rates within each combination are not statistically significant. FR with emulsion 1 and emulsion 2 were close to rejecting the null hypothesis but did not fall below the threshold.

Statistically, the p-value determined the application rates were not a significant treatment in the data shown in Table 4.2 by accepting the null hypothesis. Groups are shown to illustrate, within each of the 14 combinations, the absence of significant difference between the three application rates in most instances. If the p-value were to reject the null hypothesis, the groups would be used to investigate the treatments that are significantly different.

Engineering judgment using the data presented thus far indicates a reasonable possibility that the application rate has some effect on stiffness change but that it is a second order effect relative to parameters such as pavement type, emulsion type, and/or stiffness variability of the cores. Based on the statistical analysis results in Table 4.2, the three application rates were combined for further analysis. This decision is reasonable since no statistical effects were detected and because all groups were initially treated the same, i.e. three application rates with N=5 as a replication target. Figures 4.8 through 4.14 show the combined data for each emulsion on Hwy 45 and FR pavements. The designation (M) refers to the Mix ID's of Table 3.8. Figures 4.8 through 4. 4 also include the number of outliers removed from the data set, Mix IDs, and adjusted basic statistical descriptions, which were performed the same as in Section 4.2.

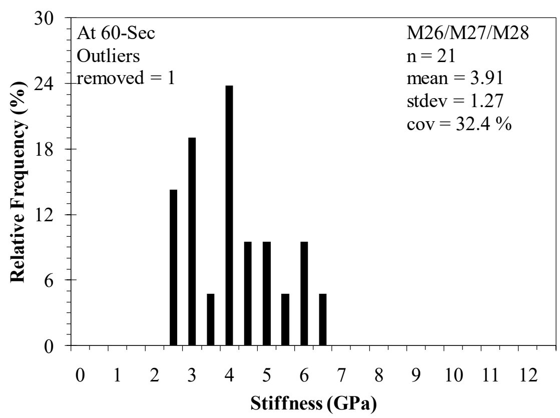


(a) Hwy 45

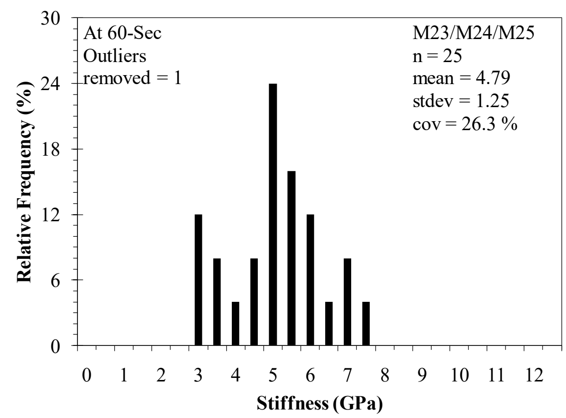


(b) FR

Figure 4.8 Un-aged Emulsion 1 Results on Field-Aged Pavement

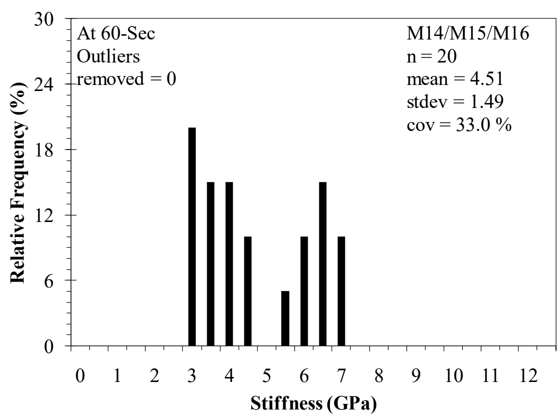


(a) Hwy 45

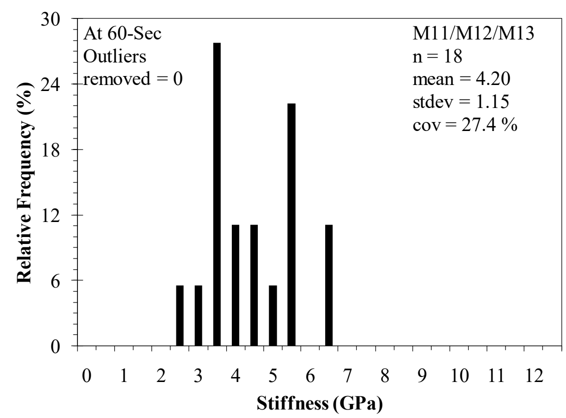


(b) FR

Figure 4.9 Un-aged Emulsion 2 Results on Field-Aged Pavement

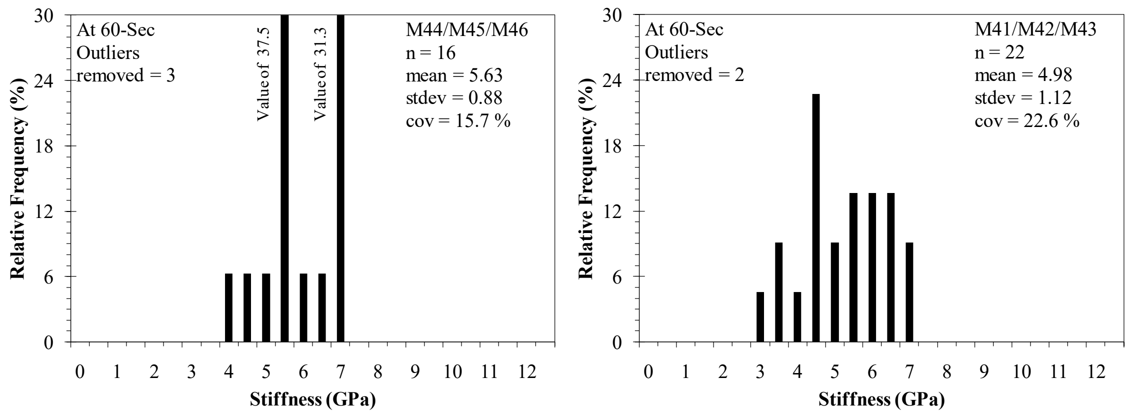


(a) Hwy 45



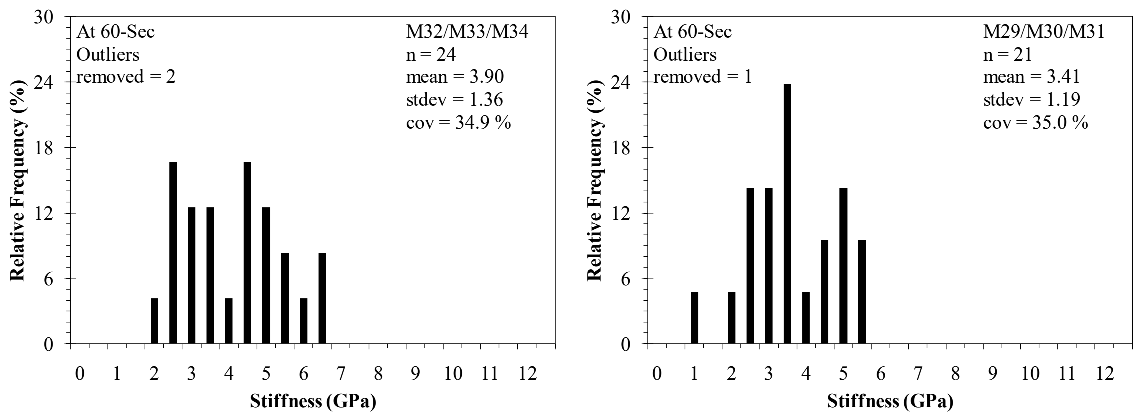
(b) FR

Figure 4.10 Un-aged Emulsion 3 Results on Field-Aged Pavement



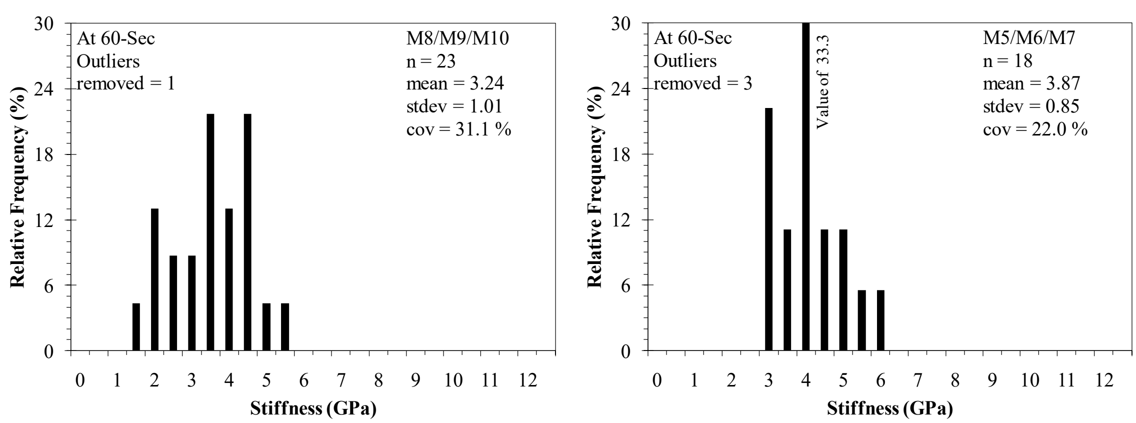
(a) Hwy 45 (b) FR

Figure 4.11 Un-aged Emulsion 4 Results on Field-Aged Pavement



(a) Hwy 45 (b) FR

Figure 4.12 Un-aged Emulsion 5 Results on Field-Aged Pavement



(a) Hwy 45 (b) FR

Figure 4.13 Un-aged Emulsion 6 Results on Field-Aged Pavement

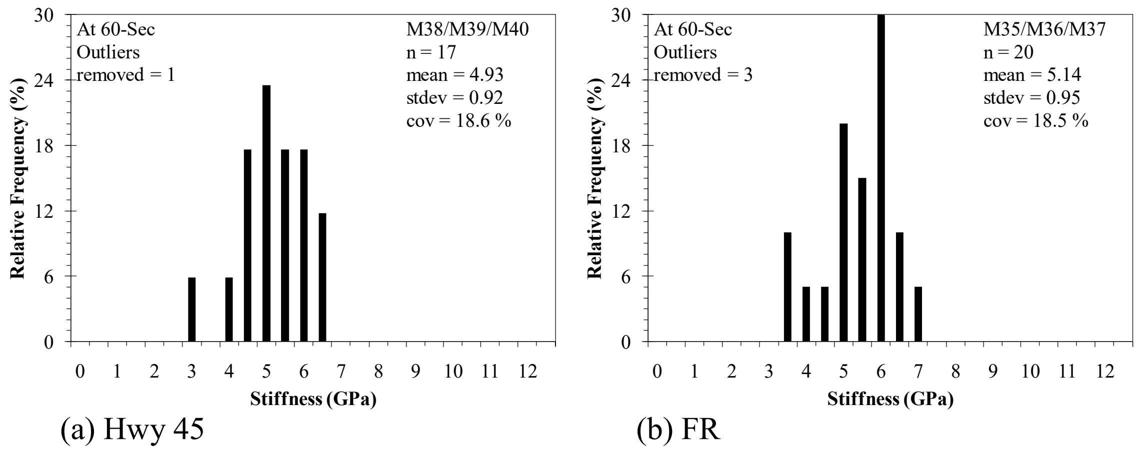


Figure 4.14 Un-aged Emulsion 7 Results on Field-Aged Pavement

After combining application rates, 14 data sets encompassed all un-aged emulsion on field-aged pavement data. Anderson-Darling normality tests were performed on each combination revealing only Hwy 45 Emulsion 4 did not have a distribution considered normal. These data sets were investigated in a statistical manner similar to Table 4.2 with a p-value threshold of 0.05. Table 4.3 shows two statistical tests investigating the mean difference for each emulsion including the control. In the case of both pavements, the null hypothesis (H_o: $\mu_{E0} = \mu_{E1} = \mu_{E2} = \mu_{E3} = \mu_{E4} = \mu_{E5} = \mu_{E6} = \mu_{E7}$) was rejected since p-values were <0.0001. Table 4.3 organizes the results by mean stiffness along with letter groupings using the same approach shown in Table 4.2. The letter groupings illustrate the presence of significantly different relationships between certain emulsion types.

In both pavements, emulsions 4 and 7 yielded the highest mean stiffness values resulting in one emulsion measuring higher than the control data. In the Hwy 45 pavement, the control is statistically different than emulsions 2, 5, and 6. In the FR pavement, the control is statistically different than emulsions 1, 2, 3, 5, and 6. The two cases where mean stiffness is higher than the control data, also exhibit the two lowest cov values of the 14 combinations. Their measured cov values are noticeably lower than typical values for the material. This may suggest more uniform properties and a low presence of cracking relative to other cores used in the study. A low level of cracking in a tested core would imply higher mean stiffness values.

Table 4.3 Combined Un-aged Emulsion Application Rate Comparisons

Pavement	Emulsion	Mean Stiffness (GPa)	Grouping	Standard Deviation	cov
Hwy 45	6	3.24	A	1.01	31.1
	5	3.90	AB	1.36	34.9
	2	3.91	AB	1.27	32.4
	3	4.51	BC	1.49	33.0
	1	4.63	BCD	1.44	31.1
	7	4.93	CDE	0.92	18.6
	Control	5.32	DE	1.19	22.4
	4	5.63	E	0.88	15.7
FR	5	3.41	A	1.19	35.0
	6	3.87	AB	0.85	22.0
	3	4.20	BC	1.15	27.4
	1	4.70	CD	1.05	22.2
	2	4.79	CD	1.25	26.1
	4	4.98	D	1.12	22.6
	Control	5.01	D	1.36	27.2
	7	5.14	D	0.95	18.5

In Table 4.3, results were compared to the emulsion properties tested in Table 3.1 using the measured characteristics of the different emulsions for prediction purposes. The 25 C penetration test values indicate the hardness of the emulsion. The lower the penetration number, the harder the material and presumably, the higher the stiffness. The data in Table 4.3 does not follow this trend. Emulsions with statistically similar mean stiffness in Table 4.3, are not found in similar groupings according to 25 C penetration test data or SFS 50 C viscosity data.

4.6.2 Regression Analysis of Interaction Effects

A regression analysis was performed using emulsion properties found in Table 3.1 alongside other known pavement properties, treatments, and similar independent variables in this study to quantify any potential interaction effects combining to affect mean stiffness change. Minitab® statistical software was used to perform the regression analysis. Interaction terms in this analysis include 25 C penetration test data, SFS 50 C viscosity data, water permeability of the pavements, a categorical variable of pavement type, and the amount of emulsion penetrated. The amount of emulsion penetrated was calculated using the residue value of each emulsion in Table 3.1. The residue value describes the percentage of water in the emulsion. By knowing the amount of emulsion applied to each specimen and the mean residue removed during the scraping procedure (R_m), the amount of asphalt that penetrated into the pavement can be estimated. This calculation is shown in Equation 4.1.

$$\left(\text{Emulsion Applied} \times \text{Residue Value as decimal} \right) - R_m = \text{Asphalt Added} \qquad \text{Eq. 4.1}$$

Table 4.4 shows each combination of un-aged emulsion and field-aged pavement with their subsequent amount of penetrated emulsion. Some Mix IDs lacked scraping data due to laboratory measurement error. In these cases, R_m data collected by Jordan (2010) was used to supplement Table 4.4. The standard deviation of R_m was only available for Mix IDs with sufficient data. As discussed in Chapter 3, parts of these two studies were performed in conjunction. The same scraping procedure was performed on similarly treated asphalt samples.

Table 4.4 Amount of Emulsion Penetrating Aged Pavement

Mix ID	**Pavement**	**Emulsion**	**App Rate (L/m^2)**	**Residue (%)**	**Emulsion Applied (g)**	***Rm* (g)**	**Std Dev**	**Asphalt Added (g)**	$\frac{Se(t)U}{Se(t)T}$
5	FR	6	0.91		17.5	4.2	-	8.2	1.00
6	FR	6	1.36	70.7	25.5	10.2	0.42	7.8	1.11
7	FR	6	1.81		33.4	14.5	0.95	9.1	1.45
8	Hwy 45	6	0.91		17.5	4.0	2.19	8.4	1.26
9	Hwy 45	6	1.36	70.7	25.5	8.6	1.12	9.4	1.99
10	Hwy 45	6	1.81		33.4	15.2	1.21	8.4	1.62
11	FR	3	0.91		17.5	5.6	1.06	6.3	1.17
12	FR	3	1.36	67.6	25.5	9.8	3.46	7.5	1.06
13	FR	3	1.81		33.4	12.9	-	9.7	1.50
14	Hwy 45	3	0.91		17.5	5.8	1.48	6.1	1.18
15	Hwy 45	3	1.36	67.6	25.5	8.8	-	8.4	1.33
16	Hwy 45	3	1.81		33.4	8.4	2.62	14.2	1.77
17	FR	1	0.91		17.5	5.9	0.78	6.4	0.92
18	FR	1	1.36	69.9	25.5	9.9	0.99	7.9	1.09
19	FR	1	1.81		33.4	15.2	0.00	8.1	1.05
20	Hwy 45	1	0.91		17.5	4.5	1.13	7.7	0.95
21	Hwy 45	1	1.36	69.9	25.5	8.7	0.78	9.2	1.07
22	Hwy 45	1	1.81		33.4	15.0	1.06	8.3	1.27
23	FR	2	0.91		17.5	4.1	0.40	7.8	1.10
24	FR	2	1.36	68.1	25.5	6.7	2.31	10.7	1.08
25	FR	2	1.81		33.4	11.4	-	11.3	0.95
26	Hwy 45	2	0.91		17.5	2.4	0.00	9.5	1.43
27	Hwy 45	2	1.36	68.1	25.5	7.8	0.42	9.5	1.07
28	Hwy 45	2	1.81		33.4	12.9	0.07	9.9	1.45
29	FR	5	0.91		17.5	2.9	1.00	9.1	1.34
30	FR	5	1.36	68.5	25.5	10.2	0.49	7.3	1.45
31	FR	5	1.81		33.4	14.0	0.93	8.9	1.38
32	Hwy 45	5	0.91		17.5	3.7	1.28	8.3	1.30
33	Hwy 45	5	1.36	68.5	25.5	8.5	2.24	9.0	1.64
34	Hwy 45	5	1.81		33.4	14.3	0.85	8.6	1.00
35	FR	7	0.91		17.5	3.6	2.20	9.1	1.17
36	FR	7	1.36	72.3	25.5	7.9	2.33	10.6	0.92
37	FR	7	1.81		33.4	11.0	1.98	13.1	1.03
38	Hwy 45	7	0.91		17.5	3.8	0.70	8.9	1.03
39	Hwy 45	7	1.36	72.3	25.5	8.5	-	9.9	1.09
40	Hwy 45	7	1.81		33.4	10.4	-	13.7	1.18
41	FR	4	0.91		17.5	4.5	-	7.7	0.74
42	FR	4	1.36	69.8	25.5	7.2	-	10.6	1.24
43	FR	4	1.81		33.4	15.5	0.95	7.9	1.06
44	Hwy 45	4	0.91		17.5	4.2	-	8.0	1.11
45	Hwy 45	4	1.36	69.8	25.5	10.6	0.35	7.2	0.96
46	Hwy 45	4	1.81		33.4	9.6	-	13.7	0.91

Upon collecting interaction affects, the regression models were performed investigating effects on mean stiffness. The dependent variable used in the regression models was the ratio of untreated (*U*) to treated (*T*) estimated creep stiffness (*Se(t)*) values found by Equation 4.2. The ratio of *Se(t)* values are shown in Table 4.4. The dependent variable was investigated by regression analysis in various combinations of the interaction affects.

$$\frac{Se(t)U}{Se(t)T} = f\,(\text{Pavement and Emulsion Properties}) \qquad \text{Eq. 4.2}$$

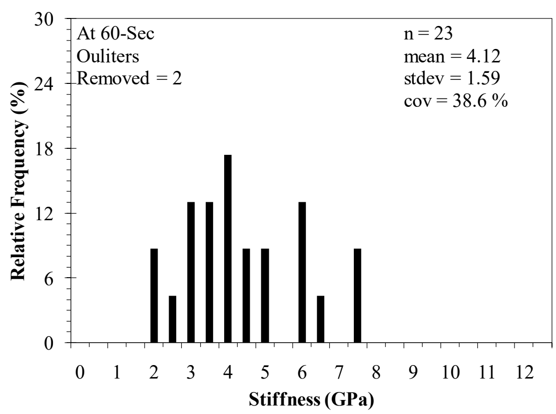
Table 4.5 shows the different regression analysis performed and their subsequent R^2 values. R^2 is a value between 0 and calculated to describe the regression's ability to predict a result. Specifically, a maximum R^2 value of 11.5%, as shown in the table, signifies that 11.5% of the variation between the dependent and independent variables can be explained by the regression. As shown in Table 4.5, the multiple regression analysis was not able to predict the resulting stiffness values in this study.

Table 4.5 Regression Analyses Performed

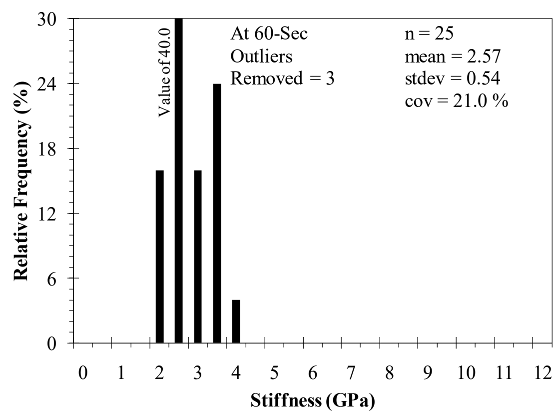
Regression	**R^2 Value**
Stiffness vs. 25 C Penetration Test	2.2%
Stiffness vs. 50 C SFS	0.8%
Stiffness vs. Asphalt Added	2.0%
Stiffness vs. Water Permeability	7.1%
Stiffness vs. Asphalt Added & Pavement	8.2%
Stiffness vs. ALL	11.5%

4.7 Effect of Aged Emulsion on Field-Aged Asphalt

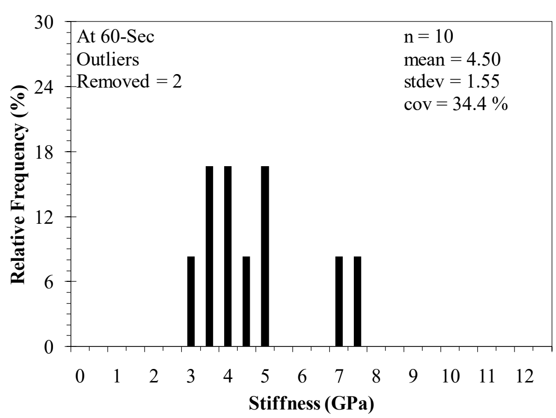
Figure 4.15 plots aged emulsion 3a Hwy 45 *BBR* results. The same outlier removal was taken as with previous tests. This dataset includes aging times of 0, 7, 30, and 60 days in an oven at 60°C. The mean stiffness is lowest in the 7 day aged data at 2.95 GPa and highest in the 60 day aged data at 5.10 GPa. There is decreased stiffness from 0 to 7 days aging of 4.12 to 2.95 GPa. There is reason to suspect the 7 day aged data considering trends observed for 0, 30, and 60 days and the mean value of Hwy 45, untreated, of 5.32 (Figure 4.3*a*). All data but the 7 day aged specimens are converging toward the untreated stiffness. The data yields a wide range of cov values. Anderson-Darling, Ryan-Joiner, and Kolmogorov-Smirnov tests for normality were performed on each Mix ID in Figure 4.15. Each Mix ID obtained p-values >0.05 in each test, demonstrating no significant departure from normality.



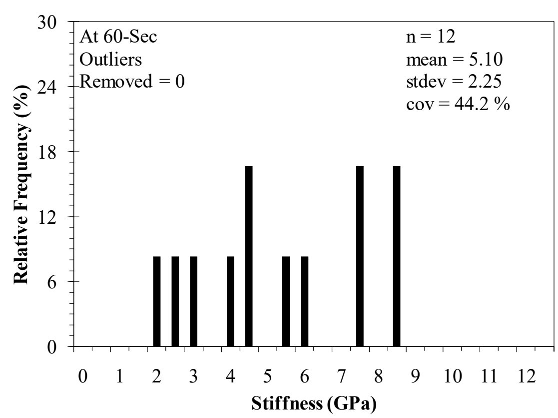
(a) M53-Hwy 45/E3a-R1.81-A0



(b) M54-Hwy 45/E3a-R1.81-A7



(c) M55-Hwy 45/E3a-R1.81-A30



(d) M56-Hwy 45/E3a-R1.81-A60

Figure 4.15 Aged Emulsion 3a Results of Field-Aged Pavement

Figures 4.16 and 4.17 plot aged emulsion 3 Hwy 45 *BBR* results. The same outlier removal was taken as with previous tests. This dataset includes aging times of 0, 3, 7, 14, 30, 45, and 60 days in an oven at 60°C. The mean stiffness is lowest in the 3 day aged data at 4.26 GPa and highest in the 60 day aged data at 5.98 GPa. Stiffness does not consistently increase or decrease. Anderson-Darling, Ryan-Joiner, and Kolmogorov-Smirnov tests for normality were performed on each Mix ID in Figures 4.16 and 4.17. Each Mix ID obtained p-values >0.05 in each test, demonstrating no significant departure from normality.

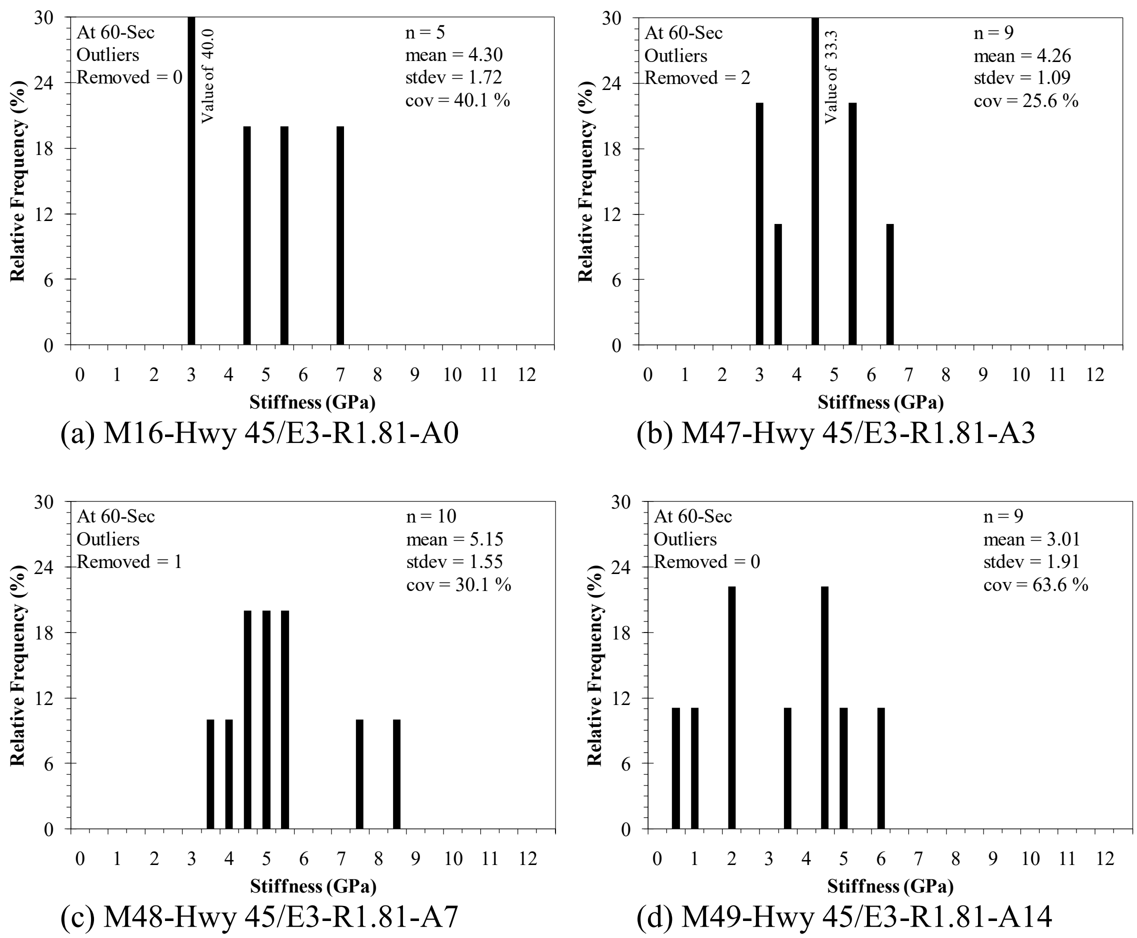
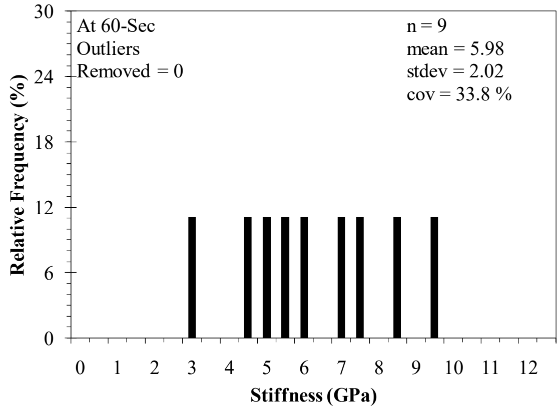
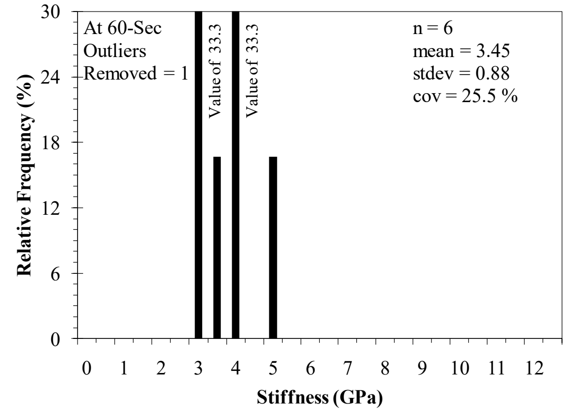


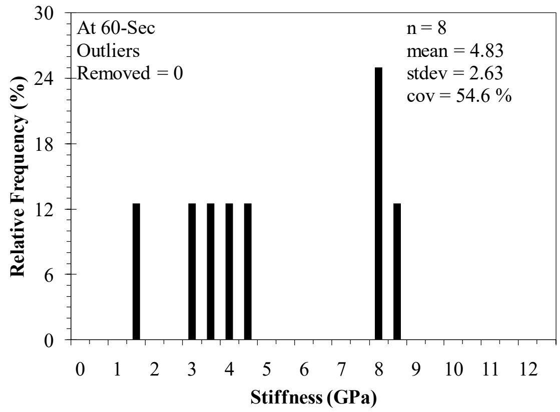
Figure 4.16 Aged Emulsion 3 Results of Hwy 45 Field-Aged Pavement up to 14 Days



(e) M50-Hwy 45/E3-R1.81-A30



(f) M51-Hwy 45/E3-R1.81-A45



(g) M52-Hwy 45/E3-R1.81-A60

Figure 4.17 Aged Emulsion 3 Results of Hwy 45 Field-Aged Pavement 30 to 60 Days

Two sample t-test functions were performed on various data in Figures 4.15, 4.16, and 4.17 comparing combinations of emulsions 3 and 3a with various aging durations. These statistical comparisons (H_o: $\mu_1 = \mu_2$; H_a: $\mu_1 \neq \mu_2$) were tested at a level of significance of 0.05. Table 4.6 shows the results of each comparison. result of 'Sig' defines a comparison which shows evidence to reject the null hypothesis that the mean stiffness values tested are the same. result of ' ot Sig' fails to reject the null hypothesis.

In the data shown in Figure 4.15, only the 7 day aging time was found to be significantly different than zero aging. The reduction of stiffness values found in the combined average of the data in Figure 4.15 was found to be significantly lower than the Hwy 45 control data in Figure 4.3a.

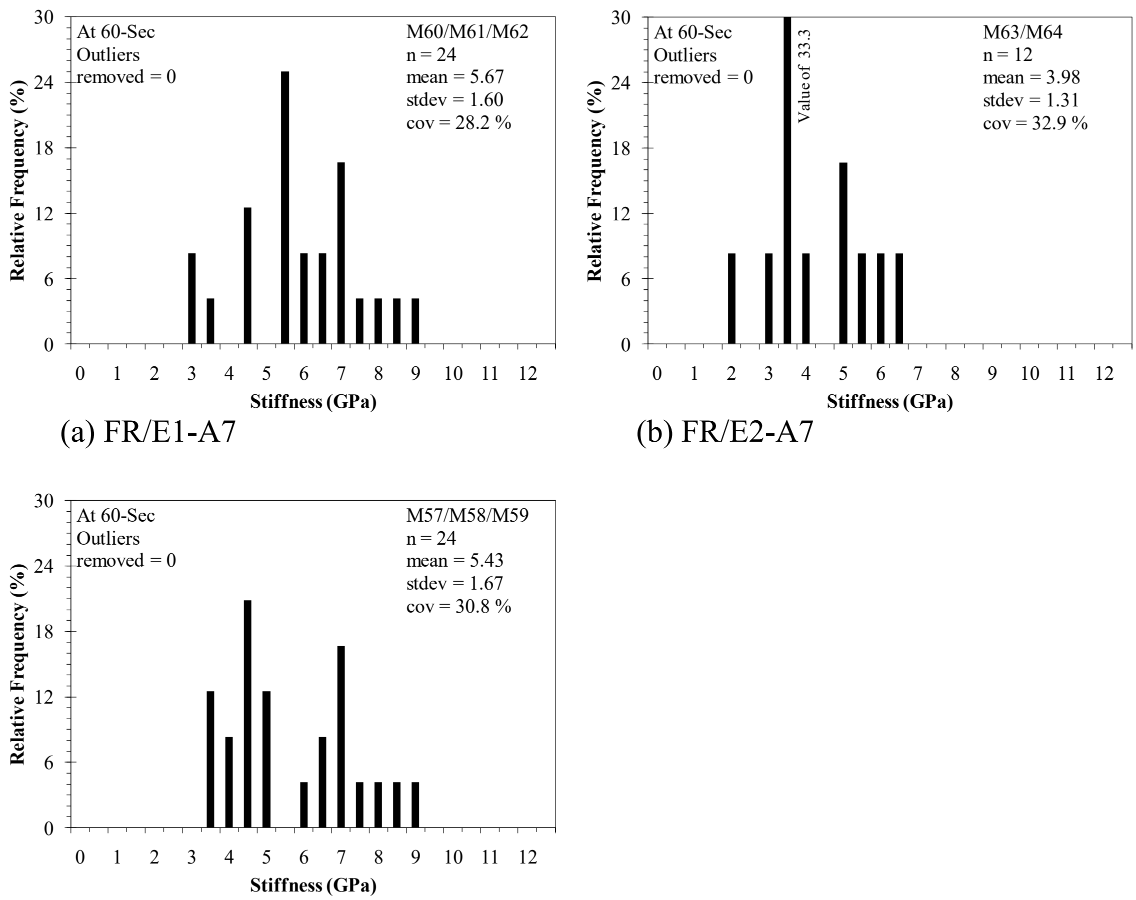
Using similar increasing aging durations found in Figures 4.16 and 17; mean stiffness values from Emulsions 3a and 3 were compared. In these comparisons, only the 7 day aging time was found to be significantly different between emulsions. These results suggest Emulsions 3a and 3 behave similarly within this aging study. This result is encouraging as they were two samples of the same emulsion.

Table 4.6 Hwy 45 Aging Comparisons with Emulsion 3 and 3a

Mix ID	**Comparison**	**Mean Stiffness (GPa)**	**Result**
M53 M54	E3a-A0 E3a-A7	4.12 2.57	Sig
M53 M55	E3a-A0 E3a-A30	4.12 4.50	Not Sig
M53 M56	E3a-A0 E3a-A60	4.12 5.10	Not Sig
M53/M54/M55/M56 M2/M4	E3a-A0-7-30-60 E0-A0	3.79 5.32	Sig
M53 M14/M15/M16	E3a-A0 E3-A0	4.12 4.51	Not Sig
M54 M48	E3a-A7 E3-A7	2.57 5.15	Sig
M55 M50	E3a-A30 E3-A30	4.50 5.98	Not Sig
M56 M52	E3a-A60 E3-A60	5.10 4.83	Not Sig

Figure 4.18 plots 7 day aged FR *BBR* results. The same outlier removal was taken as with previous tests. This dataset includes emulsions 1, 2, and 3. The mean stiffness is

lowest in emulsion 2 data at 3.98 GPa and highest in emulsion 1 data at 5.67 GPa. The data yields a similar range of cov values. Anderson-Darling, Ryan-Joiner, and Kolmogorov-Smirnov tests for normality were performed on each Mix ID in Figure 4.18. Each Mix ID obtained p-values >0.05 in each test, demonstrating no significant departure from normality.



(a) FR/E1-A7

(b) FR/E2-A7

(c) FR/E3-A7

Figure 4.18 Aged Results of FR Field-Aged Pavement

Statistical comparisons were performed on the data in Figure 4.18 investigating the results of seven day aging on three emulsions applied to FR field-aged pavement. Each dataset was compared to corresponding data in Figures 4.8, 4.9, and 4.10. The comparison showed emulsion 2 was not significantly different after 7 day aging. Emulsion two was the only dataset of the three to decrease in stiffness with aging, which would require more testing to explain. The stiffness values of emulsion 1 and emulsion 3 increased after seven day aging and resulted in significantly different data. Table 4.7 shows the results of the comparison.

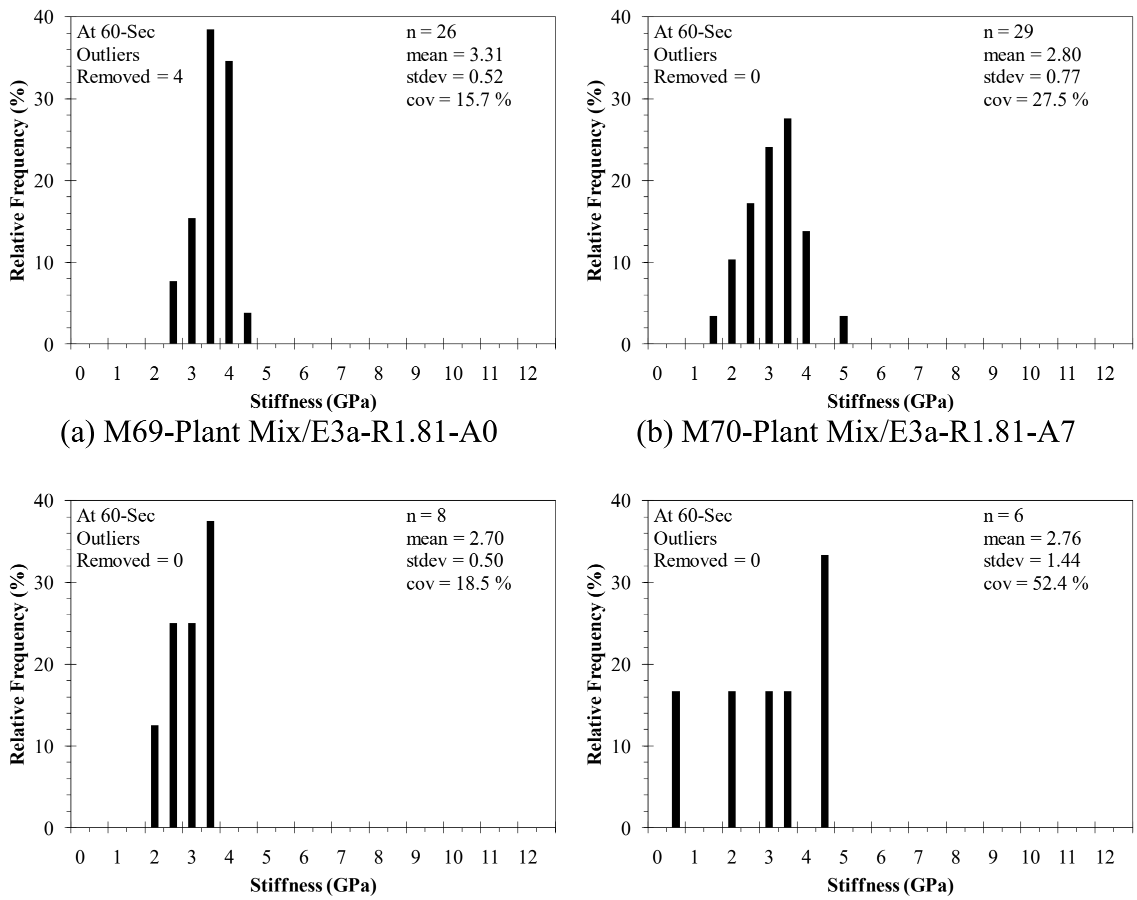
Table 4.7 FR Aging Comparisons with Emulsions 1, 2, and 3

Comparison	**Mean Stiffness (GPa)**	**Result**
E1-A0	4.70	Sig
E1-A7	5.67	
E2-A0	4.79	Not Sig
E2-A7	3.98	
E3-A0	4.20	Sig
E3-A7	5.43	

4.8 Effect of Emulsion on Laboratory-Compacted Asphalt

Figure 4.18 plots all Plant Mix *BBR* results with emulsion. The same outlier removal was taken as with previous tests. This dataset includes aging times of 0, 7, 30, and 60 days in an oven at 60°C. The mean stiffness is lowest in the 30 day aged data at 2.70 GPa and highest in the 0 day aged data at 3.31 GPa. There is decreased stiffness from 0 to 7 days aging of 3.31 to 2.80 GPa. The data yields a wide range of cov values. Mix IDs with higher replication, M69 and M70, exhibit values both lower and similar to field pavements. Anderson-Darling, Ryan-Joiner, and Kolmogorov-Smirnov tests for normality were performed on each Mix ID in Figure 4.18. Each Mix ID obtained p-values >0.05 in each test, demonstrating no significant departure from normality.

Comparing the results in Figure 4.19 to laboratory-compacted asphalt without emulsion in Figure 4.4 yields a couple of important observations. Similar replicate numbers and subsequent aging times were used in each data set. The *BBR* specimens without emulsion exhibit higher mean values in 3 of 4 aging times along with lower cov values in 4 of 4 aging times. Both data sets were found to be normal.



(a) M69-Plant Mix/E3a-R1.81-A0 (b) M70-Plant Mix/E3a-R1.81-A7

(c) M71-Plant Mix/E3a-R1.81-A30 (d) M72-Plant Mix/E3a-R1.81-A60

Figure 4.19 Aged Laboratory-Compacted Asphalt with Emulsion 3a

A statistical investigation was performed on the data in Figure 4.19 involving varying caparisons of Plant Mix pavement. First, each aging time was compared to Figure 4.19*a*, zero aged data. Only the 60 day aging time was found not to be significantly different than zero aging. The 7 day aged data is significantly different just as in Table 4.6 and 4.7.

Statistical comparisons were also made between emulsion treated and control Plant Mix pavement at similar aging times. Of the four aging times tested, the 7 and 60 day aging times were found to be significantly different after the application of emulsion 3a reduced stiffness. The reduction of stiffness at 0 day aging, and the increase in stiffness at 30 day aging were not found to be significantly different. The reduction of stiffness values found between the combined averages of the data in Figure 4.19 and Figure 4.4, Plant Mix control data, was found to be significantly different. The combined average of the data in Figure 4.9 was also found to be significantly different from the un-aged control Plant Mix data.

Table 4.8 Plant Mix Aging Comparisons with Emulsion 3a

Comparison	Mean Stiffness (GPa)	Result
E3a-A0 E3a-A7	3.31 2.80	Sig
E3a-A0 E3a-A30	3.31 2.70	Sig
E3a-A0 E3a-A60	3.31 2.76	Not Sig
E3a-A0 E0-A0	3.31 3.57	Not Sig
E3a-A7 E0-A7	2.80 3.91	Sig
E3a-A30 E0a-A30	2.70 2.21	Sig
E3a-A60 E0-A60	2.76 4.59	Sig
E3a-A0-7-30-60 E0-A0-7-30-60	2.97 3.59	Sig
E3a-A0-7-30-60 E0-A0	2.97 3.57	Sig

4.9 Summary of Findings

The tests performed in this study provided supporting evidence to the ability to of the *BBR* to detect asphalt emulsion applied to a pavement surface. From the beginning, this study set to investigate unproven concepts and procedures. One such concept was the ability to produce mixture beams for the *BBR* originating from field-aged asphalt concrete pavement surfaces. This study successfully demonstrated that ability to produce the aforementioned mixture beams and identified related challenges. The results also showed the original asphalt emulsion application rates (0.91, 1.36, and 1.81 L/m^2) were not statistically different in the scope of this study. Using the data recorded, this study analyzed the effect of emulsion on three asphalt concrete mixtures. This study also investigated the comparative effect of the different pavements as well as the use of several aging times.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This thesis investigated the ability to detect the effects of a flexible pavement surface treatment in the laboratory using mixture beams in the *BBR*. This study began with the intention of correlating fundamental properties in order to develop an equation to predict measured stiffness. The *BBR* was able to measure effects of adding emulsion to both field-aged and laboratory-compacted specimens sawn from the surface of a pavement. The information in this study, along with the test methods developed, can be used as a starting point for further development resulting in performance specifications for gauging effects of asphalt emulsion application.

This research found the dimensions of mixture beams sawn from the surface of the pavement to be repeatable. Sawing mixture beams from the surface required the development of methods for specimen production, handling, and testing. Thickness measurements, the smallest cut, had a cov of less than 4.0%. However, mixture beams initially attempted to be sawn broke during the fabrication process. This information is useful for future researchers assessing material or specimen needs. As this study progressed, investigating unproven test methods required adaptations to test matrices in order to produce suitable and well-rounded comparisons.

Overall, the *BBR* proved capable of gauging the effect of various emulsions and different pavement types. The cov results indicate *BBR* testing is in general, more variable than *IDT* testing, though not so much so that meaningful results cannot be obtained. In the Hwy 45 and FR pavements, the *BBR* yielded a variation roughly twice that of *IDT* testing. The Plant Mix specimens showed less variation, as expected, due to the uniform pavement. The addition of emulsion decreased the stiffness for both lab and field mixtures. This data was viewed as a positive result in support of the use of *BBR* testing of mixture beams.

In general, this study spent time developing a testing procedure which proved capable of producing valuable data. Initial tests into multiple areas of interest such as various pavement behaviors at the surface, aging, and asphalt absorption were encouraging, but require further testing in order to determine their applicability. This thesis could serve as a basis toward developing performance based specifications for flexible pavement surface treatments like chip and scrub seals, which is greatly needed in the current pavement community.

5.2 Recommendations

The current study embodies a new approach to pavement preservation by testing the pavement surface as a mixture rather than through binder recovery. As test methods continue to be developed, more refined research into specific aspects of this study is recommended. Further research efforts should focus on incorporating more mixtures with similar gradations, aggregate types, and asphalt cement types in order to reduce the number of variables. Further studies investigating a method of aging should also be performed to better understand its effect on the data. This could include a combination of more frequent aging times, long term aging studies, or the use of un-aged pavement. These suggestions could further investigate the effects of laboratory aging and build a stronger correlation between laboratory and field data in the future.

Specific recommendations are as follows.

- Test emulsion 3 at multiple aging times with more replication.
- Test more pavement-emulsion combinations after 7 days of 60°C oven aging.
- Investigate m-value data from field-aged pavement treated with emulsion.

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APPENDIX A

BENDING BEAM RHEOMETER TEST DATA

Table A.1 *BBR* Mixture Data for M1-Hwy 45/E0-R0.0-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.64	5.44	5.17	4.88	4.55	4.21	3.86	3.51	0.052	0.052	0.062	0.078	0.092	0.105	0.119	0.133
-		2	7.27	6.95	6.58	6.19	5.79	5.39	4.98	4.57	0.067	0.075	0.083	0.092	0.101	0.109	0.118	0.127
-		3	7.76	7.44	7.05	6.64	6.20	5.74	5.28	4.82	0.061	0.071	0.082	0.093	0.104	0.115	0.126	0.137
-		4	5.12	4.93	4.69	4.41	4.12	3.80	3.48	3.15	0.054	0.067	0.080	0.094	0.108	0.122	0.135	0.149
-		5	6.23	5.96	5.61	5.23	4.81	4.38	3.95	3.51	0.064	0.078	0.095	0.111	0.127	0.143	0.160	0.176
-		6	8.82	8.40	7.89	7.33	6.75	6.15	5.55	4.96	0.071	0.084	0.098	0.113	0.127	0.141	0.156	0.170
-		7	4.75	4.55	4.31	4.05	3.78	3.50	3.22	2.94	0.064	0.073	0.084	0.094	0.105	0.115	0.126	0.136
-		8	4.17	3.92	3.59	3.23	2.85	2.47	2.10	1.75	0.086	0.111	0.139	0.166	0.194	0.222	0.250	0.277
-		9	7.82	7.51	7.13	6.71	6.27	5.80	5.33	4.86	0.059	0.069	0.081	0.093	0.105	0.117	0.129	0.141
-		10	6.99	6.74	6.44	6.11	5.76	5.39	5.02	4.64	0.053	0.062	0.071	0.081	0.090	0.099	0.109	0.118
-		11	6.05	5.80	5.50	5.16	4.80	4.43	4.05	3.67	0.061	0.072	0.085	0.098	0.110	0.123	0.135	0.148
-		12	2.58	2.53	2.45	2.37	2.27	2.17	2.06	1.94	0.032	0.039	0.047	0.055	0.063	0.071	0.079	0.087
-		13	3.95	3.76	3.53	3.29	3.05	2.80	2.56	2.32	0.075	0.085	0.095	0.105	0.116	0.126	0.137	0.147
-		14	3.64	3.53	3.39	3.24	3.07	2.90	2.72	2.53	0.045	0.053	0.062	0.071	0.080	0.089	0.098	0.107
-		15	4.69	4.56	4.39	4.20	4.01	3.80	3.58	3.36	0.043	0.050	0.058	0.066	0.073	0.081	0.089	0.097

Table A.1 Continued

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa) 8	15	30	60	120	240	480	960	Test Time (sec) and Mixture m-value 8	15	30	60	120	240	480	960
-	A	16	6.25	5.95	5.59	5.23	4.86	4.48	4.11	3.74	0.074	0.083	0.092	0.102	0.111	0.121	0.130	0.140
-		17	8.99	8.55	8.03	7.49	6.94	6.39	5.84	5.31	0.077	0.085	0.095	0.105	0.115	0.124	0.134	0.144
-		18	6.96	6.72	6.39	6.00	5.57	5.10	4.61	4.12	0.047	0.063	0.081	0.100	0.118	0.136	0.154	0.173
-		19	9.82	9.44	9.08	8.77	8.51	8.29	8.11	7.98	0.066	0.060	0.053	0.047	0.040	0.034	0.028	0.021
-		20	5.39	5.24	5.06	4.86	4.65	4.42	4.19	3.95	0.042	0.048	0.054	0.061	0.068	0.075	0.081	0.088
-		21	6.07	5.80	5.48	5.15	4.80	4.44	4.08	3.73	0.067	0.076	0.086	0.096	0.106	0.116	0.126	0.136
-		22	7.20	6.90	6.54	6.16	5.75	5.34	4.92	4.50	0.063	0.072	0.082	0.093	0.103	0.113	0.124	0.134
-		23	5.42	5.18	4.91	4.64	4.36	4.09	3.82	3.56	0.070	0.075	0.080	0.085	0.090	0.096	0.101	0.106
-		24	6.63	6.31	5.93	5.54	5.15	4.76	4.37	4.00	0.077	0.085	0.093	0.101	0.110	0.118	0.126	0.135
-		25	5.67	5.39	5.04	4.66	4.27	3.86	3.46	3.07	0.075	0.089	0.104	0.120	0.136	0.151	0.167	0.183
-		26	4.33	4.25	4.13	3.97	3.79	3.59	3.36	3.12	0.024	0.035	0.048	0.061	0.074	0.087	0.100	0.113
-		27	7.34	7.06	6.71	6.32	5.90	5.46	5.00	4.55	0.057	0.068	0.081	0.093	0.106	0.118	0.131	0.143
-		28	7.15	6.76	6.30	5.82	5.32	4.82	4.32	3.84	0.082	0.095	0.109	0.122	0.136	0.150	0.163	0.177
-		29	7.43	7.09	6.69	6.30	5.91	5.51	5.13	4.75	0.074	0.079	0.085	0.090	0.096	0.102	0.108	0.113
-		30	6.34	6.07	5.75	5.39	5.01	4.61	4.21	3.81	0.062	0.073	0.086	0.099	0.112	0.125	0.138	0.151
		Avg	**6.22**	**5.96**	**5.65**	**5.31**	**4.96**	**4.60**	**4.24**	**3.89**	**0.061**	**0.071**	**0.082**	**0.093**	**0.104**	**0.115**	**0.126**	**0.137**
		StdDev	**1.66**	**1.58**	**1.49**	**1.41**	**1.34**	**1.27**	**1.22**	**1.18**	**0.015**	**0.016**	**0.019**	**0.023**	**0.028**	**0.032**	**0.037**	**0.042**

Table A.2 *BBR* Mixture Data for M2-FR/E0-R0.0-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.78	5.59	5.32	5.00	4.65	4.27	3.87	3.47	0.046	0.062	0.080	0.097	0.115	0.132	0.150	0.168
-		2	4.92	4.74	4.49	4.20	3.87	3.52	3.16	2.79	0.050	0.068	0.087	0.107	0.127	0.147	0.166	0.186
-		3	6.88	6.55	6.19	5.82	5.46	5.11	4.76	4.42	0.076	0.080	0.085	0.090	0.094	0.099	0.104	0.109
-		4	6.72	6.41	6.04	5.63	5.20	4.76	4.32	3.88	0.068	0.080	0.094	0.107	0.121	0.134	0.148	0.162
-		5	6.41	6.14	5.86	5.60	5.36	5.13	4.91	4.71	0.068	0.067	0.066	0.065	0.064	0.063	0.062	0.061
-		6	4.34	4.19	4.01	3.80	3.59	3.36	3.13	2.89	0.051	0.060	0.070	0.080	0.089	0.099	0.109	0.119
-		7	4.10	3.94	3.75	3.54	3.31	3.08	2.84	2.60	0.058	0.067	0.078	0.089	0.100	0.111	0.122	0.132
-		8	3.13	3.05	2.96	2.87	2.76	2.65	2.54	2.42	0.035	0.040	0.045	0.050	0.056	0.061	0.066	0.071
-		9	3.85	3.72	3.57	3.40	3.23	3.05	2.86	2.67	0.050	0.057	0.065	0.072	0.080	0.088	0.095	0.103
-		10	2.15	2.09	2.00	1.90	1.79	1.68	1.56	1.44	0.046	0.056	0.067	0.078	0.090	0.101	0.112	0.123
-		11	3.94	3.84	3.71	3.57	3.41	3.25	3.07	2.89	0.038	0.045	0.053	0.060	0.068	0.076	0.083	0.091
-		12	4.75	4.53	4.32	4.12	3.94	3.77	3.63	3.49	0.076	0.073	0.070	0.066	0.063	0.059	0.056	0.053
-		13	5.52	5.34	5.12	4.88	4.64	4.38	4.12	3.86	0.052	0.058	0.064	0.071	0.078	0.084	0.091	0.098
-		14	6.54	6.37	6.11	5.79	5.41	4.99	4.54	4.08	0.033	0.050	0.069	0.088	0.107	0.126	0.145	0.163
-		15	4.73	4.60	4.43	4.23	4.01	3.76	3.49	3.22	0.036	0.048	0.061	0.073	0.086	0.099	0.112	0.124

Table A.2 Continued

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
			8	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	16	3.86	3.77	3.65	3.53	3.40	3.25	3.11	2.95	0.035	0.041	0.047	0.053	0.059	0.065	0.071	0.077
-		17	5.65	5.49	5.26	5.00	4.70	4.38	4.04	3.69	0.041	0.053	0.067	0.081	0.095	0.109	0.123	0.137
-		18	6.67	6.44	6.16	5.86	5.54	5.20	4.86	4.51	0.052	0.060	0.069	0.077	0.086	0.094	0.103	0.111
-		19	1.07	1.06	1.05	1.04	1.02	1.01	0.99	0.97	0.013	0.015	0.018	0.020	0.022	0.025	0.027	0.029
-		20	5.69	5.44	5.16	4.88	4.60	4.32	4.05	3.77	0.068	0.073	0.078	0.083	0.088	0.093	0.098	0.103
-		21	6.84	6.60	6.28	5.91	5.51	5.08	4.63	4.18	0.050	0.064	0.079	0.095	0.110	0.125	0.140	0.156
-		22	6.23	5.98	5.68	5.37	5.05	4.72	4.40	4.07	0.062	0.069	0.077	0.085	0.093	0.100	0.108	0.116
-		23	6.42	6.10	5.74	5.37	5.01	4.65	4.30	3.96	0.079	0.085	0.091	0.097	0.104	0.110	0.117	0.123
-		24	8.17	7.81	7.35	6.84	6.30	5.74	5.17	4.61	0.065	0.080	0.095	0.111	0.127	0.142	0.158	0.173
-		25	5.71	5.48	5.21	4.93	4.63	4.33	4.03	3.72	0.061	0.068	0.077	0.085	0.093	0.101	0.110	0.118
-		26	6.53	6.24	5.92	5.59	5.26	4.93	4.60	4.28	0.069	0.074	0.080	0.085	0.091	0.097	0.102	0.108
-		27	3.49	3.35	3.17	2.98	2.77	2.55	2.33	2.11	0.060	0.072	0.085	0.098	0.110	0.123	0.136	0.149
-		28	6.98	6.75	6.46	6.13	5.77	5.38	4.98	4.56	0.047	0.058	0.070	0.082	0.094	0.106	0.118	0.131
-		29	6.03	5.72	5.35	4.95	4.54	4.12	3.70	3.29	0.077	0.090	0.104	0.119	0.133	0.147	0.162	0.176
-		30	8.27	7.85	7.35	6.83	6.29	5.74	5.20	4.66	0.077	0.088	0.100	0.113	0.125	0.138	0.150	0.162
-		31	7.90	7.56	7.14	6.70	6.22	5.74	5.25	4.76	0.065	0.076	0.087	0.099	0.111	0.123	0.135	0.147
-		32	6.84	6.53	6.14	5.70	5.23	4.75	4.25	3.77	0.065	0.081	0.098	0.115	0.132	0.150	0.167	0.184
-		33	5.79	5.53	5.20	4.84	4.45	4.04	3.63	3.23	0.066	0.080	0.097	0.113	0.129	0.146	0.162	0.178
-		34	6.76	6.42	6.02	5.59	5.15	4.70	4.25	3.81	0.075	0.087	0.100	0.113	0.126	0.139	0.152	0.165
		Avg	**5.55**	**5.33**	**5.06**	**4.78**	**4.47**	**4.16**	**3.84**	**3.52**	**0.056**	**0.065**	**0.076**	**0.086**	**0.096**	**0.106**	**0.116**	**0.127**
		StdDev	**1.66**	**1.57**	**1.47**	**1.36**	**1.24**	**1.13**	**1.02**	**0.92**	**0.016**	**0.016**	**0.018**	**0.022**	**0.026**	**0.030**	**0.035**	**0.040**

Table A.3 *BBR* Mixture Data for M3-Hwy 45/E0-R0.0-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B2	1	6.33	6.17	6.00	5.84	5.69	5.55	5.41	5.28	0.041	0.040	0.039	0.038	0.037	0.036	0.035	0.034
1	B3	2	7.48	7.20	6.87	6.53	6.18	5.83	5.48	5.13	0.059	0.064	0.070	0.076	0.082	0.087	0.093	0.099
1	B4	3	8.92	8.60	8.26	7.92	7.59	7.27	6.95	6.64	0.057	0.058	0.060	0.061	0.062	0.064	0.065	0.066
1	B5	4	2.43	2.41	2.37	2.33	2.27	2.22	2.15	2.08	0.013	0.018	0.024	0.030	0.035	0.041	0.047	0.053
2	B4	5	3.59	3.48	3.35	3.23	3.12	3.00	2.89	2.78	0.051	0.051	0.052	0.053	0.054	0.055	0.055	0.056
2	B1	6	7.66	7.29	6.89	6.49	6.10	5.72	5.36	5.00	0.078	0.081	0.084	0.087	0.091	0.094	0.097	0.101
3	B1	7	1.55	1.45	1.36	1.26	1.17	1.08	1.00	0.92	0.095	0.099	0.102	0.106	0.110	0.114	0.117	0.121
3	B4	8	4.12	3.94	3.72	3.49	3.25	3.00	2.75	2.50	0.067	0.076	0.087	0.098	0.109	0.120	0.131	0.141
3	B5	9	6.39	6.19	5.94	5.68	5.40	5.10	4.81	4.50	0.049	0.055	0.062	0.069	0.076	0.084	0.091	0.098
4	B1	10	6.21	5.97	5.68	5.37	5.03	4.69	4.33	3.97	0.057	0.066	0.077	0.087	0.098	0.109	0.119	0.130
4	B5	11	5.63	5.44	5.17	4.85	4.50	4.13	3.73	3.34	0.048	0.064	0.082	0.099	0.117	0.135	0.153	0.170
5	B3	12	5.74	5.56	5.31	5.03	4.72	4.38	4.03	3.67	0.045	0.057	0.072	0.086	0.100	0.114	0.128	0.142
6	B2	13	2.66	2.58	2.48	2.35	2.21	2.05	1.88	1.71	0.039	0.053	0.068	0.084	0.099	0.114	0.129	0.145
7	B4	14	6.63	6.36	6.04	5.70	5.36	5.02	4.67	4.32	0.064	0.071	0.078	0.086	0.093	0.100	0.107	0.115
7	B5	15	4.63	4.49	4.30	4.10	3.88	3.64	3.39	3.13	0.044	0.054	0.065	0.076	0.086	0.097	0.108	0.119

Table A.3 Continued

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa) 8	15	30	60	120	240	480	960	Test Time (sec) and Mixture m-value 8	15	30	60	120	240	480	960
8	B1	16	7.30	7.09	6.84	6.59	6.32	6.06	5.78	5.51	0.046	0.049	0.053	0.057	0.060	0.064	0.068	0.072
8	B3	17	6.02	5.84	5.55	5.20	4.78	4.33	3.85	3.37	0.037	0.059	0.084	0.108	0.132	0.157	0.181	0.205
8	B4	18	3.07	2.90	2.71	2.50	2.28	2.07	1.85	1.65	0.081	0.094	0.108	0.122	0.136	0.151	0.165	0.179
8	B5	19	4.98	4.81	4.58	4.32	4.03	3.71	3.39	3.06	0.048	0.062	0.078	0.093	0.108	0.124	0.139	0.154
9	B2	20	6.03	5.80	5.49	5.13	4.73	4.30	3.85	3.41	0.051	0.069	0.089	0.108	0.128	0.148	0.167	0.187
9	B3	21	8.51	8.11	7.66	7.20	6.75	6.31	5.87	5.44	0.075	0.080	0.085	0.090	0.096	0.101	0.107	0.112
9	B5	22	6.12	5.91	5.64	5.33	4.98	4.61	4.22	3.83	0.048	0.061	0.075	0.090	0.104	0.119	0.133	0.147
9	B4	23	4.53	4.36	4.17	3.97	3.77	3.57	3.36	3.16	0.057	0.062	0.067	0.072	0.078	0.083	0.088	0.094
10	B1	24	6.15	5.84	5.42	4.93	4.39	3.84	3.28	2.75	0.067	0.094	0.123	0.152	0.181	0.210	0.239	0.268
10	B4	25	7.74	7.36	6.88	6.35	5.79	5.22	4.64	4.08	0.072	0.088	0.106	0.124	0.142	0.160	0.177	0.195
10	B2	26	7.60	7.28	6.85	6.37	5.85	5.30	4.74	4.18	0.060	0.077	0.096	0.115	0.133	0.152	0.171	0.189
10	B5	27	6.97	6.68	6.30	5.89	5.44	4.98	4.51	4.05	0.063	0.076	0.091	0.106	0.120	0.135	0.150	0.165
11	B1	28	10.50	10.11	9.79	9.56	9.44	9.40	9.46	9.60	0.066	0.054	0.040	0.026	0.012	-0.001	-0.015	-0.029
11	B3	29	11.82	11.56	11.17	10.68	10.12	9.49	8.81	8.10	0.030	0.043	0.057	0.071	0.086	0.100	0.114	0.129
11	B4	30	6.00	5.77	5.49	5.20	4.90	4.58	4.27	3.95	0.059	0.066	0.074	0.083	0.091	0.099	0.107	0.115
11	B5	31	7.32	7.06	6.76	6.47	6.17	5.86	5.56	5.26	0.056	0.059	0.063	0.067	0.071	0.074	0.078	0.082
12	B1	32	14.51	13.74	12.84	11.90	10.95	9.99	9.04	8.12	0.082	0.092	0.104	0.115	0.126	0.138	0.149	0.161
12	B5	33	5.92	5.77	5.57	5.33	5.07	4.78	4.48	4.16	0.036	0.046	0.057	0.068	0.079	0.090	0.101	0.112
13	B2	34	6.26	6.02	5.60	5.04	4.40	3.72	3.04	2.41	0.040	0.082	0.128	0.174	0.220	0.267	0.313	0.359
		Avg	**6.39**	**6.15**	**5.85**	**5.53**	**5.20**	**4.85**	**4.50**	**4.15**	**0.055**	**0.065**	**0.076**	**0.088**	**0.099**	**0.110**	**0.121**	**0.132**
		StdDev	**2.57**	**2.46**	**2.34**	**2.22**	**2.11**	**2.01**	**1.94**	**1.88**	**0.017**	**0.018**	**0.023**	**0.031**	**0.040**	**0.050**	**0.059**	**0.069**

Table A.4 *BBR* Mixture Data for M4-FR/E0-R0.0-A0

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
			8	15	30	60	120	240	480	960	8	15	30	60	120	240	480	960
1	B1	1	4.95	4.72	4.43	4.11	3.76	3.40	3.04	2.68	0.066	0.082	0.100	0.118	0.136	0.154	0.172	0.190
1	B2	2	4.66	4.51	4.31	4.10	3.87	3.63	3.38	3.12	0.050	0.059	0.068	0.078	0.088	0.098	0.108	0.117
1	B5	3	3.17	3.04	2.88	2.70	2.51	2.32	2.12	1.93	0.062	0.073	0.085	0.097	0.110	0.122	0.134	0.147
2	B1	4	8.23	7.88	7.47	7.03	6.58	6.11	5.64	5.17	0.064	0.073	0.082	0.092	0.101	0.111	0.120	0.130
2	B2	5	9.79	9.32	8.76	8.17	7.55	6.93	6.30	5.68	0.072	0.083	0.095	0.107	0.119	0.131	0.143	0.155
2	B4	6	11.16	10.65	9.98	9.22	8.41	7.56	6.70	5.87	0.066	0.084	0.104	0.123	0.143	0.163	0.183	0.203
2	B5	7	9.02	8.59	8.05	7.46	6.85	6.22	5.59	4.98	0.072	0.086	0.101	0.116	0.131	0.146	0.161	0.177
3	B1	8	7.72	7.33	6.86	6.37	5.87	5.36	4.85	4.35	0.077	0.088	0.101	0.113	0.125	0.138	0.150	0.163
3	B4	9	6.98	6.64	6.24	5.84	5.42	5.01	4.59	4.19	0.076	0.084	0.093	0.102	0.111	0.120	0.129	0.138
4	B1	10	5.70	5.47	5.18	4.88	4.56	4.24	3.91	3.58	0.063	0.072	0.082	0.092	0.102	0.111	0.121	0.131
4	B2	11	5.45	5.23	4.96	4.67	4.37	4.07	3.76	3.45	0.062	0.071	0.081	0.091	0.100	0.110	0.120	0.129
4	B3	12	6.33	5.98	5.56	5.13	4.68	4.23	3.79	3.36	0.085	0.097	0.111	0.125	0.138	0.152	0.165	0.179
5	B1	13	6.06	5.84	5.57	5.29	4.99	4.68	4.36	4.04	0.055	0.063	0.071	0.080	0.088	0.097	0.106	0.114
6	B2	14	5.07	4.78	4.42	4.03	3.64	3.24	2.85	2.48	0.088	0.104	0.122	0.140	0.158	0.176	0.194	0.212
6	B5	15	5.43	4.19	3.43	3.06	2.98	3.18	3.70	4.70	0.469	0.354	0.227	0.100	-0.027	-0.154	-0.281	-0.409

Table A.4 Continued

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
7	B2	16	4.92	4.76	4.55	4.32	4.07	3.81	3.53	3.25	0.048	0.058	0.069	0.081	0.092	0.103	0.115	0.126
7	B4	17	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.13	0.084	0.085	0.087	0.088	0.089	0.091	0.092	0.093
8	B2	18	3.84	3.67	3.47	3.26	3.04	2.81	2.58	2.35	0.066	0.076	0.086	0.096	0.107	0.117	0.128	0.138
8	B5	19	1.93	1.91	1.88	1.85	1.81	1.77	1.73	1.69	0.019	0.022	0.024	0.027	0.030	0.033	0.036	0.039
9	B2	20	0.27	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.003	0.004	0.005	0.006	0.008	0.009	0.010	0.011
10	B2	21	4.18	4.02	3.80	3.53	3.24	2.93	2.60	2.28	0.053	0.072	0.093	0.115	0.136	0.158	0.179	0.201
10	B5	22	4.57	4.41	4.23	4.02	3.79	3.55	3.31	3.06	0.049	0.058	0.068	0.078	0.088	0.099	0.109	0.119
11	B2	23	8.07	7.69	7.22	6.72	6.18	5.63	5.08	4.54	0.070	0.083	0.098	0.112	0.127	0.141	0.156	0.170
11	B5	24	4.45	4.33	4.18	4.03	3.86	3.69	3.51	3.33	0.043	0.047	0.052	0.058	0.063	0.068	0.073	0.078
12	B3	25	7.25	6.98	6.61	6.17	5.69	5.17	4.64	4.11	0.051	0.069	0.088	0.108	0.127	0.147	0.166	0.186
12	B4	26	5.60	5.40	5.17	4.92	4.67	4.40	4.14	3.87	0.055	0.061	0.067	0.074	0.080	0.086	0.093	0.099
13	B3	27	0.93	0.92	0.91	0.90	0.90	0.88	0.87	0.86	0.008	0.010	0.012	0.014	0.017	0.019	0.021	0.024
13	B5	28	4.51	4.41	4.29	4.16	4.01	3.87	3.71	3.55	0.035	0.039	0.043	0.048	0.052	0.056	0.061	0.065
14	B3	29	8.90	8.61	8.33	8.11	7.94	7.81	7.71	7.66	0.056	0.050	0.042	0.035	0.028	0.021	0.013	0.006
15	B5	30	6.99	6.70	6.37	6.02	5.66	5.29	4.92	4.55	0.062	0.070	0.078	0.085	0.093	0.101	0.109	0.117
15	B5	31	7.56	7.23	6.85	6.46	6.06	5.65	5.25	4.85	0.068	0.074	0.082	0.089	0.096	0.104	0.111	0.118
		Avg	**5.60**	**5.34**	**5.04**	**4.74**	**4.43**	**4.12**	**3.82**	**3.55**	**0.071**	**0.076**	**0.081**	**0.087**	**0.092**	**0.098**	**0.103**	**0.109**
		StdDev	**2.65**	**2.53**	**2.39**	**2.23**	**2.06**	**1.90**	**1.74**	**1.63**	**0.077**	**0.057**	**0.039**	**0.033**	**0.044**	**0.064**	**0.087**	**0.111**

Table A.5 *BBR* Mixture Data for M5-FR/E6-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	6.24	5.69	5.13	4.61	4.13	3.69	3.29	2.92	0.144	0.148	0.152	0.156	0.160	0.165	0.169	0.173
-		2	9.58	5.53	5.03	7.24	6.49	5.77	5.10	4.48	0.124	0.133	0.143	0.153	0.163	0.173	0.183	0.193
-		3	6.31	4.81	4.33	3.84	3.38	2.95	2.56	2.20	0.144	0.155	0.166	0.178	0.189	0.200	0.212	0.223
-		4	4.34	4.04	3.70	3.36	3.03	2.70	2.39	2.10	0.109	0.121	0.133	0.145	0.157	0.170	0.182	0.194
-		5	7.76	7.18	6.55	5.93	5.33	4.75	4.20	3.66	0.117	0.127	0.138	0.150	1.161	0.172	0.183	0.195
		Avg	**6.85**	**5.45**	**4.95**	**5.00**	**4.47**	**3.97**	**3.51**	**3.07**	**0.128**	**0.137**	**0.146**	**0.156**	**0.366**	**0.176**	**0.186**	**0.196**
		StdDev	**1.95**	**1.17**	**1.07**	**1.59**	**1.43**	**1.28**	**1.14**	**1.01**	**0.016**	**0.014**	**0.013**	**0.013**	**0.445**	**0.014**	**0.016**	**0.018**

Table A.6 *BBR* Mixture Data for M6-FR/E6-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	4.96	4.67	4.33	3.99	3.64	3.30	2.96	2.63	0.090	0.101	0.113	0.126	0.138	0.150	0.162	0.174
-		2	5.65	5.01	4.39	3.86	3.40	3.00	2.66	2.36	0.193	0.190	0.187	0.184	0.181	0.178	0.178	0.172
-		3	4.10	3.63	3.16	2.72	2.33	1.98	1.67	1.40	0.189	0.198	0.209	0.219	0.230	0.240	0.250	0.261
-		4	4.41	3.99	3.55	3.13	2.73	2.37	2.04	1.75	0.155	0.165	0.176	0.187	0.199	0.210	0.221	0.232
-		5	4.85	4.30	3.74	3.73	2.76	2.35	1.99	1.66	0.187	0.196	0.207	0.218	0.228	0.239	0.249	0.260
-		6	6.29	5.73	5.18	4.67	4.21	3.80	3.43	3.09	0.147	0.147	0.148	0.148	0.149	0.149	0.150	0.150
-		7	5.71	5.12	4.52	3.97	3.47	3.02	2.61	2.25	0.170	0.176	0.183	0.191	0.198	0.205	0.212	0.220
-		8	6.46	5.99	5.50	5.03	4.59	4.17	3.78	3.42	0.117	0.121	0.126	0.130	0.135	0.139	0.144	0.148
-		9	9.47	8.95	8.34	7.72	7.10	6.48	5.87	5.28	0.086	0.095	0.106	0.116	0.127	0.137	0.148	0.158
-		10	7.39	7.07	6.71	6.34	5.97	5.59	5.21	4.83	0.067	0.072	0.079	0.085	0.091	0.098	0.104	0.111
		Avg	**5.93**	**5.45**	**4.94**	**4.52**	**4.02**	**3.61**	**3.22**	**2.87**	**0.140**	**0.146**	**0.153**	**0.160**	**0.168**	**0.175**	**0.182**	**0.189**
		StdDev	**1.60**	**1.60**	**1.58**	**1.51**	**1.51**	**1.46**	**1.39**	**1.32**	**0.047**	**0.046**	**0.046**	**0.046**	**0.046**	**0.048**	**0.049**	**0.051**

Table A.7 *BBR* Mixture Data for M7-FR/E6-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	4.22	3.81	3.39	3.00	2.65	2.32	2.03	1.75	0.159	0.165	0.172	0.179	0.186	0.192	0.189	0.206
-		2	3.77	3.44	3.08	2.74	2.42	2.12	1.84	1.59	0.142	0.152	0.163	0.174	0.186	0.197	0.208	0.219
-		3	3.91	3.55	3.19	2.85	2.54	2.25	1.99	1.75	0.150	0.154	0.160	0.165	0.170	0.175	0.180	0.186
-		4	5.63	5.21	4.75	4.29	3.85	3.42	3.02	2.64	0.117	0.128	0.140	0.151	0.163	0.175	0.187	0.199
-		5	6.03	5.37	4.73	4.17	3.69	3.26	2.89	2.59	0.185	0.184	0.182	0.180	0.178	0.176	0.174	0.172
-		6	5.16	4.69	4.19	3.72	3.28	2.87	2.49	2.14	0.146	0.156	0.167	0.178	0.188	0.199	0.210	0.221
		Avg	**4.79**	**4.35**	**3.89**	**3.46**	**3.07**	**2.71**	**2.38**	**2.08**	**0.150**	**0.157**	**0.164**	**0.171**	**0.179**	**0.186**	**0.191**	**0.201**
		StdDev	**0.95**	**0.86**	**0.77**	**0.69**	**0.62**	**0.56**	**0.50**	**0.46**	**0.022**	**0.018**	**0.014**	**0.011**	**0.010**	**0.012**	**0.015**	**0.019**

Table A.8 *BBR* Mixture Data for M8-Hwy 45/E6-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	4.52	4.03	3.51	3.01	2.55	2.12	1.74	1.41	0.170	0.190	0.211	0.232	0.253	0.274	0.295	0.316
-		2	5.57	5.08	4.57	4.11	3.67	3.27	2.91	2.57	0.145	0.149	0.154	0.159	0.164	0.168	0.173	0.178
-		3	5.49	5.03	4.56	4.11	3.68	3.29	2.92	2.58	0.133	0.140	0.147	0.154	0.161	0.168	0.175	0.182
-		4	5.87	5.42	4.93	4.44	3.96	3.51	3.08	2.68	0.120	0.132	0.144	0.157	0.170	0.183	0.195	0.208
-		5	5.58	5.15	4.67	4.20	3.75	3.32	2.91	2.53	0.122	0.133	0.146	0.158	0.171	0.183	0.195	0.208
-		6	7.60	7.06	6.52	6.02	5.57	5.15	4.78	4.43	0.118	0.117	0.115	0.114	0.112	0.110	0.109	0.107
-		7	5.00	4.56	4.09	3.65	3.24	2.86	2.51	2.19	0.145	0.153	0.160	0.168	0.176	0.184	0.192	0.200
		Avg	**5.66**	**5.19**	**4.69**	**4.22**	**3.77**	**3.36**	**2.98**	**2.63**	**0.136**	**0.145**	**0.154**	**0.163**	**0.172**	**0.181**	**0.191**	**0.200**
		StdDev	**0.96**	**0.94**	**0.93**	**0.92**	**0.92**	**0.92**	**0.91**	**0.91**	**0.019**	**0.023**	**0.029**	**0.035**	**0.042**	**0.048**	**0.055**	**0.062**

Table A.9 *BBR* Mixture Data for M9- Hwy 45/E6-R1.36-A0

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
			8	15	30	60	120	240	480	960	8	15	30	60	120	240	480	960
-	A	1	2.31	2.20	2.09	1.98	1.88	1.78	1.69	1.60	0.075	0.075	0.076	0.077	0.078	0.078	0.079	0.080
-		2	3.54	3.11	2.69	2.31	1.97	1.68	1.42	1.19	0.201	0.208	0.215	0.223	0.230	0.238	0.246	0.253
-		3	4.55	4.17	3.74	3.31	2.88	2.48	2.11	1.77	0.131	0.148	0.168	0.187	0.206	0.226	0.245	0.265
-		4	1.60	1.51	1.41	1.31	1.22	1.13	1.04	0.96	0.091	0.095	0.100	0.105	0.109	0.114	0.118	0.123
-		5	4.14	3.76	3.38	3.03	2.71	2.42	2.15	1.91	0.151	0.154	0.157	0.160	0.162	0.165	0.168	0.171
-		6	6.52	6.06	5.55	5.05	4.56	4.08	3.63	3.21	0.111	0.121	0.132	0.142	0.153	0.164	0.174	0.185
-		7	3.43	3.09	2.72	2.36	2.03	1.73	1.46	1.21	0.162	0.176	0.192	0.208	0.224	0.240	0.256	0.272
-		8	2.31	2.20	2.09	1.98	1.88	1.78	1.69	1.60	0.075	0.075	0.076	0.077	0.078	0.078	0.079	0.080
		Avg	**3.55**	**3.26**	**2.96**	**2.67**	**2.39**	**2.14**	**1.90**	**1.68**	**0.125**	**0.132**	**0.140**	**0.147**	**0.155**	**0.163**	**0.171**	**0.179**
		StdDev	**1.56**	**1.43**	**1.28**	**1.15**	**1.02**	**0.90**	**0.79**	**0.70**	**0.045**	**0.048**	**0.052**	**0.057**	**0.062**	**0.068**	**0.074**	**0.080**

Table A.10 *BBR* Mixture Data for M10-Hwy 45/E6-R1.81-A0

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
			8	15	30	60	120	240	480	960	8	15	30	60	120	240	480	960
-	A	1	4.85	4.34	3.81	3.33	2.88	2.48	2.12	1.80	0.174	0.182	0.192	0.202	0.211	0.221	0.230	0.240
-		2	4.09	3.54	3.02	2.58	2.20	1.88	1.60	1.37	0.230	0.230	0.229	0.229	0.229	0.228	0.228	0.228
-		3	1.90	1.81	1.71	1.61	1.52	1.44	1.36	1.28	0.080	0.081	0.082	0.082	0.083	0.084	0.084	0.085
-		4	5.60	5.14	4.64	4.16	3.70	3.26	2.85	2.47	0.130	0.141	0.153	0.164	0.176	0.188	0.200	0.211
-		5	4.93	4.50	4.05	3.62	3.22	2.85	2.50	2.19	0.142	0.149	0.157	0.165	0.174	0.182	0.190	0.198
-		6	4.37	3.92	3.46	3.05	2.68	2.35	2.05	1.79	0.172	0.176	0.180	0.184	0.189	0.193	0.197	0.201
-		7	4.19	3.80	3.39	3.00	2.63	2.29	1.97	1.69	0.149	0.159	0.171	0.183	0.195	0.207	0.219	0.231
-		8	6.07	5.60	5.12	4.68	4.28	3.91	3.57	3.27	0.129	0.129	0.129	0.129	0.130	0.130	0.130	0.130
-		9	5.00	4.55	4.07	3.62	3.20	2.82	2.46	2.14	0.147	0.155	0.164	0.173	0.181	0.190	0.199	0.207
		Avg	**4.56**	**4.13**	**3.70**	**3.29**	**2.92**	**2.59**	**2.28**	**2.00**	**0.150**	**0.156**	**0.162**	**0.168**	**0.174**	**0.180**	**0.186**	**0.192**
		StdDev	**1.19**	**1.09**	**0.98**	**0.89**	**0.81**	**0.73**	**0.67**	**0.61**	**0.041**	**0.041**	**0.041**	**0.042**	**0.044**	**0.046**	**0.049**	**0.051**

Table A.11 *BBR* Mixture Data for M11- FR/E3-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.75	5.10	4.46	3.90	3.41	2.97	2.59	2.25	0.191	0.192	0.193	0.195	0.196	0.198	0.199	0.201
-		2	8.21	7.55	6.85	6.18	5.54	4.94	4.39	3.87	0.129	0.137	0.145	0.153	0.161	0.169	0.177	0.185
-		3	4.10	3.90	3.69	3.49	3.29	3.11	2.92	2.75	0.077	0.079	0.081	0.082	0.084	0.086	0.088	0.090
-		4	4.08	3.78	3.45	3.14	2.84	2.55	2.29	2.04	0.120	0.127	0.134	0.141	0.148	0.155	0.162	0.169
-		5	4.43	4.23	3.98	3.71	3.42	3.13	2.83	2.54	0.069	0.081	0.095	0.109	0.122	0.136	0.150	0.164
-		6	6.03	5.81	5.58	5.37	5.18	5.01	4.85	4.71	0.062	0.059	0.056	0.053	0.050	0.048	0.045	0.042
		Avg	**5.43**	**5.06**	**4.67**	**4.30**	**3.95**	**3.62**	**3.31**	**3.03**	**0.108**	**0.113**	**0.117**	**0.122**	**0.127**	**0.132**	**0.137**	**0.142**
		StdDev	**1.60**	**1.44**	**1.31**	**1.20**	**1.12**	**1.07**	**1.05**	**1.04**	**0.049**	**0.049**	**0.050**	**0.051**	**0.053**	**0.056**	**0.058**	**0.062**

Table A.12 *BBR* Mixture Data for M12-FR/E3-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	4.59	4.14	3.69	3.28	2.91	2.57	2.26	1.99	0.160	0.164	0.168	0.172	0.177	0.181	0.185	0.190
-		2	6.17	5.85	5.46	5.04	4.60	4.16	3.72	3.29	0.078	0.092	0.107	0.123	0.138	0.154	0.169	0.184
-		3	7.25	6.45	5.65	4.93	4.29	3.72	3.21	2.77	0.184	0.189	0.194	0.199	0.204	0.209	0.214	0.219
-		4	6.49	5.74	5.00	4.34	3.76	3.24	2.79	2.39	0.193	0.197	0.202	0.206	0.211	0.215	0.220	0.225
-		5	7.03	6.44	5.82	5.24	4.69	4.18	3.71	3.28	0.136	0.142	0.149	0.156	0.162	0.169	0.176	0.183
-		6	7.30	6.98	6.60	6.19	5.76	5.32	4.88	4.45	0.067	0.077	0.087	0.098	0.108	0.119	0.129	0.140
-		7	5.26	4.93	4.55	4.15	3.75	3.36	2.98	2.62	0.097	0.110	0.124	0.138	0.152	0.166	0.181	0.195
		Avg	**6.30**	**5.79**	**5.25**	**4.74**	**4.25**	**3.79**	**3.37**	**2.97**	**0.131**	**0.139**	**0.147**	**0.156**	**0.165**	**0.173**	**0.182**	**0.191**
		StdDev	**1.04**	**0.98**	**0.94**	**0.92**	**0.90**	**0.88**	**0.84**	**0.80**	**0.051**	**0.047**	**0.044**	**0.040**	**0.036**	**0.033**	**0.030**	**0.028**

Table A.13 *BBR* Mixture Data for M13- FR/E3-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	3.85	3.45	3.03	2.65	2.29	1.96	1.67	1.41	0.168	0.179	0.191	0.204	0.216	0.228	0.240	0.253
-		2	3.47	3.15	2.82	2.50	2.20	1.93	1.68	1.45	0.148	0.157	0.167	0.177	0.188	0.198	0.208	0.218
-		3	6.89	6.36	5.76	5.17	4.59	4.04	3.52	3.04	0.123	0.135	0.149	0.164	0.178	0.192	0.206	0.220
-		4	4.32	3.98	3.59	3.22	2.85	2.50	2.17	1.87	0.126	0.139	0.153	0.167	0.181	0.195	0.209	0.224
-		5	4.25	3.92	3.55	3.18	2.82	2.47	2.15	1.85	0.123	0.137	0.151	0.166	0.181	0.196	0.210	0.225
		Avg	**4.56**	**4.17**	**3.75**	**3.34**	**2.95**	**2.58**	**2.24**	**1.92**	**0.138**	**0.149**	**0.162**	**0.176**	**0.189**	**0.202**	**0.215**	**0.228**
		StdDev	**1.35**	**1.27**	**1.17**	**1.07**	**0.96**	**0.86**	**0.76**	**0.66**	**0.020**	**0.019**	**0.018**	**0.017**	**0.016**	**0.015**	**0.014**	**0.014**

Table A.14 *BBR* Mixture Data for M14-Hwy 45/E3-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.63	5.05	4.44	3.86	3.32	2.83	2.39	1.99	0.166	0.179	0.194	0.209	0.224	0.239	0.253	0.268
-		2	7.78	7.27	6.75	6.27	5.82	5.42	5.04	4.69	0.109	0.108	0.107	0.106	0.105	0.104	0.104	0.103
-		3	7.79	7.09	6.35	5.64	4.98	4.36	3.80	3.28	0.146	0.155	0.165	0.175	0.185	0.195	0.205	0.215
-		4	5.21	4.64	4.07	3.57	3.12	2.73	2.38	2.07	0.184	0.186	0.189	0.191	0.194	0.196	0.199	0.201
-		5	7.93	7.34	6.81	6.40	6.08	5.84	5.68	5.59	0.131	0.116	0.099	0.082	0.065	0.049	0.032	0.015
-		6	5.02	4.44	3.88	3.38	2.96	2.58	2.26	1.98	0.197	0.197	0.196	0.195	0.195	0.194	0.194	0.193
-		7	8.32	7.51	6.68	5.93	5.24	4.62	4.06	3.56	0.162	0.166	0.170	0.175	0.180	0.184	0.189	0.193
-		8	5.63	5.05	4.44	3.86	3.32	2.83	2.39	1.99	0.166	0.179	0.194	0.209	0.224	0.239	0.253	0.268
		Avg	**5.31**	**4.91**	**4.56**	**4.17**	**3.75**	**3.34**	**2.95**	**2.58**	**6.664**	**6.049**	**5.428**	**4.864**	**4.355**	**3.901**	**3.500**	**3.144**
		StdDev	**1.76**	**1.56**	**1.35**	**1.27**	**1.17**	**1.07**	**0.96**	**0.86**	**1.405**	**1.360**	**1.324**	**1.308**	**1.304**	**1.320**	**1.351**	**1.401**

Table A.15 *BBR* Mixture Data for M15-Hwy 45/E3-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								**Test Time (sec) and Mixture m-value**							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.64	5.16	4.64	4.15	3.67	3.23	2.82	2.44	0.137	0.147	0.158	0.169	0.180	0.191	0.202	0.213
-		2	3.36	3.29	3.23	3.17	3.13	3.09	3.06	3.04	0.033	0.030	0.026	0.023	0.019	0.016	0.013	0.009
-		3	4.83	4.18	3.54	2.98	2.50	2.09	1.73	1.43	0.228	0.235	0.242	0.250	0.257	0.265	0.272	0.279
-		4	7.74	7.35	6.92	6.48	6.03	5.59	5.16	4.74	0.078	0.085	0.092	0.099	0.106	0.113	0.120	0.127
-		5	5.03	4.48	3.92	3.40	2.94	2.52	2.14	1.81	0.179	0.188	0.198	0.208	0.217	0.227	0.237	0.247
-		6	7.76	7.43	7.08	6.74	6.41	6.09	5.78	5.48	0.068	0.070	0.071	0.072	0.073	0.075	0.076	0.077
-		7	4.30	3.82	3.32	2.86	2.43	2.05	1.72	1.42	0.183	0.196	0.210	0.224	0.238	0.252	0.266	0.280
		Avg	**5.52**	**5.10**	**4.66**	**4.25**	**3.87**	**3.52**	**3.20**	**2.91**	**0.129**	**0.136**	**0.142**	**0.149**	**0.156**	**0.163**	**0.169**	**0.176**
		StdDev	**1.67**	**1.67**	**1.66**	**1.66**	**1.66**	**1.65**	**1.64**	**1.62**	**0.072**	**0.076**	**0.081**	**0.086**	**0.091**	**0.096**	**0.101**	**0.106**

Table A.16 *BBR* Mixture Data for M16-Hwy 45/E3-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								**Test Time (sec) and Mixture m-value**							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	8.80	8.06	7.32	6.63	6.01	5.45	4.94	4.47	0.140	0.140	0.141	0.141	0.142	0.142	0.143	0.143
-		2	4.32	3.79	3.28	2.83	2.45	2.11	1.82	1.56	0.207	0.208	0.210	0.211	0.213	0.215	0.216	0.218
-		3	3.88	3.41	2.96	2.58	2.26	1.98	1.73	1.53	0.207	0.204	0.200	0.197	0.193	0.190	0.187	0.183
-		4	5.72	5.15	4.56	4.03	3.55	3.12	2.72	2.37	0.166	0.170	0.176	0.181	0.186	0.191	0.197	0.202
-		5	7.93	7.03	6.16	5.41	4.77	4.21	3.72	3.30	0.195	0.192	0.188	0.185	0.182	0.178	0.175	0.171
		Avg	**6.13**	**5.49**	**4.86**	**4.30**	**3.81**	**3.37**	**2.99**	**2.65**	**0.183**	**0.183**	**0.183**	**0.183**	**0.183**	**0.183**	**0.184**	**0.183**
		StdDev	**2.17**	**2.02**	**1.87**	**1.72**	**1.59**	**1.47**	**1.36**	**1.25**	**0.029**	**0.028**	**0.027**	**0.026**	**0.026**	**0.027**	**0.027**	**0.029**

Table A.17 *BBR* Mixture Data for M17-FR/E1-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.86	5.38	4.85	4.35	3.86	3.40	2.97	2.58	0.131	0.142	0.153	0.165	0.177	0.188	0.200	0.212
-		2	6.81	6.47	6.10	5.73	5.37	5.02	4.68	4.35	0.080	0.083	0.087	0.091	0.095	0.099	0.103	0.107
-		3	5.84	5.40	4.91	4.44	3.98	3.54	3.12	2.73	0.120	0.130	0.141	0.153	0.164	0.175	0.186	0.197
-		4	9.02	8.62	8.14	7.61	7.07	6.51	5.94	5.38	0.067	0.078	0.090	0.101	0.113	0.125	0.137	0.149
-		5	4.69	4.41	4.02	3.56	3.08	2.58	2.11	1.68	0.080	0.115	0.154	0.193	0.232	0.271	0.310	0.349
-		6	6.68	6.24	5.75	5.24	4.75	4.26	3.79	3.35	0.102	0.113	0.125	0.138	0.150	0.162	0.174	0.187
-		7	9.22	8.72	8.24	7.83	7.49	7.20	6.96	6.77	0.093	0.086	0.077	0.069	0.061	0.052	0.044	0.036
-		8	6.19	5.74	5.30	4.89	4.52	4.18	3.87	3.58	0.118	0.117	0.116	0.115	0.114	0.112	0.111	0.110
		Avg	**6.79**	**6.37**	**5.91**	**5.46**	**5.02**	**4.59**	**4.18**	**3.80**	**0.099**	**0.108**	**0.118**	**0.128**	**0.138**	**0.148**	**0.158**	**0.168**
		StdDev	**1.58**	**1.55**	**1.54**	**1.54**	**1.56**	**1.58**	**1.61**	**1.65**	**0.023**	**0.023**	**0.031**	**0.042**	**0.054**	**0.067**	**0.080**	**0.093**

Table A. 18 *BBR* Mixture Data for M18-FR/E1-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.53	5.15	4.61	3.99	3.35	2.71	2.13	1.61	0.091	0.135	0.183	0.231	0.279	0.327	0.375	0.423
-		2	6.85	6.45	5.99	5.51	5.02	4.54	4.07	3.61	0.090	0.101	0.114	0.127	0.139	0.152	0.165	0.177
-		3	6.06	5.52	4.96	4.42	3.92	3.46	3.03	2.64	0.143	0.151	0.160	0.169	0.178	0.187	0.195	0.204
-		4	5.89	5.63	5.34	5.05	4.77	4.49	4.22	3.96	0.071	0.074	0.078	0.081	0.085	0.088	0.092	0.095
-		5	5.36	4.94	4.48	4.03	3.61	3.20	2.82	2.47	0.127	0.136	0.146	0.156	0.167	0.177	0.187	0.197
		Avg	**5.94**	**5.54**	**5.08**	**4.60**	**4.13**	**3.68**	**3.25**	**2.86**	**0.104**	**0.119**	**0.136**	**0.153**	**0.170**	**0.186**	**0.203**	**0.219**
		StdDev	**0.58**	**0.58**	**0.61**	**0.66**	**0.73**	**0.81**	**0.88**	**0.94**	**0.030**	**0.031**	**0.041**	**0.055**	**0.071**	**0.088**	**0.104**	**0.122**

Table A.19 *BBR* Mixture Data for M19-FR/E1-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.50	5.21	4.86	4.49	4.10	3.71	3.32	2.94	0.078	0.092	0.107	0.122	0.138	0.153	0.168	0.183
-		2	4.78	4.32	3.85	3.40	2.99	2.62	2.28	1.97	0.157	0.164	0.172	0.181	0.189	0.197	0.205	0.214
-		3	4.60	4.19	3.73	3.30	2.88	2.49	2.13	1.80	0.142	0.157	0.172	0.188	0.203	0.219	0.234	0.250
-		4	6.15	5.65	5.10	4.57	4.06	3.58	3.13	2.71	0.130	0.141	0.153	0.165	0.177	0.189	0.201	0.213
-		5	6.09	5.56	5.02	4.52	4.07	3.65	3.27	2.93	0.143	0.146	0.149	0.151	0.154	0.157	0.160	0.162
-		6	9.70	8.86	7.97	7.12	6.32	5.58	4.88	4.25	0.140	0.148	0.158	0.167	0.177	0.186	0.196	0.205
-		7	9.06	8.35	7.60	6.87	6.18	5.53	4.92	4.35	0.126	0.133	0.141	0.149	0.157	0.165	0.173	0.181
-		8	4.21	4.10	3.99	3.88	3.77	3.66	3.55	3.44	0.040	0.041	0.041	0.042	0.042	0.043	0.043	0.044
		Avg	**6.26**	**5.78**	**5.27**	**4.77**	**4.30**	**3.85**	**3.44**	**3.05**	**0.120**	**0.128**	**0.137**	**0.146**	**0.155**	**0.164**	**0.173**	**0.182**
		StdDev	**2.05**	**1.85**	**1.65**	**1.46**	**1.30**	**1.16**	**1.03**	**0.94**	**0.040**	**0.041**	**0.044**	**0.047**	**0.050**	**0.053**	**0.058**	**0.062**

Table A.20 *BBR* Mixture Data for M20-Hwy 45/E1-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	9.97	9.51	9.01	8.51	8.02	7.54	7.07	6.61	0.073	0.077	0.080	0.084	0.087	0.091	0.095	0.098
-		2	4.55	4.36	4.14	3.89	3.64	3.38	3.12	2.85	0.062	0.071	0.082	0.092	0.102	0.112	0.123	0.133
-		3	8.53	7.83	7.08	6.37	5.69	5.06	4.47	3.93	0.133	0.141	0.149	0.157	0.166	0.174	0.183	0.191
-		4	5.25	4.73	4.20	3.71	3.26	2.86	2.50	2.17	0.164	0.169	0.175	0.181	0.187	0.193	0.199	0.205
-		5	7.56	6.86	6.12	5.43	4.78	4.18	3.63	3.14	0.150	0.159	0.168	0.178	0.188	0.198	0.208	0.218
		Avg	**7.17**	**6.66**	**6.11**	**5.58**	**5.08**	**4.60**	**4.16**	**3.74**	**0.116**	**0.123**	**0.131**	**0.138**	**0.146**	**0.154**	**0.162**	**0.169**
		StdDev	**2.26**	**2.15**	**2.05**	**1.97**	**1.90**	**1.84**	**1.78**	**1.72**	**0.046**	**0.046**	**0.046**	**0.047**	**0.048**	**0.049**	**0.050**	**0.051**

Table A.21 *BBR* Mixture Data for M21-Hwy 45/E1-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	6.96	6.59	6.15	5.70	5.23	4.76	4.30	3.85	0.082	0.093	0.105	0.117	0.130	0.142	0.154	0.166
-		2	4.19	3.80	3.40	3.03	2.68	2.37	2.08	1.82	0.152	0.158	0.164	0.171	0.177	0.184	0.190	0.197
-		3	4.09	3.66	3.21	2.80	2.41	2.06	1.75	1.47	0.171	0.182	0.195	0.207	0.220	0.232	0.244	0.257
-		4	7.89	7.57	7.16	6.71	6.21	5.70	5.17	4.64	0.059	0.073	0.088	0.103	0.118	0.133	0.148	0.163
-		5	6.68	5.95	5.20	4.51	3.88	3.32	2.81	2.36	0.178	0.188	0.200	0.211	0.222	0.233	0.245	0.256
-		6	10.24	9.42	8.53	7.66	6.83	6.04	5.30	4.62	0.127	0.138	0.149	0.160	0.171	0.183	0.194	0.205
-		7	6.39	5.78	5.14	4.53	3.97	3.44	2.97	2.54	0.154	0.165	0.176	0.187	0.198	0.209	0.220	0.231
		Avg	**6.63**	**6.11**	**5.54**	**4.99**	**4.46**	**3.96**	**3.48**	**3.04**	**0.132**	**0.142**	**0.154**	**0.165**	**0.177**	**0.188**	**0.199**	**0.211**
		StdDev	**2.13**	**2.03**	**1.92**	**1.81**	**1.69**	**1.57**	**1.44**	**1.32**	**0.045**	**0.044**	**0.043**	**0.042**	**0.041**	**0.040**	**0.039**	**0.039**

Table A.22 *BBR* Mixture Data for M22-Hwy 45/E1-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.69	5.50	5.24	4.95	4.62	4.28	3.92	3.55	0.049	0.062	0.076	0.091	0.105	0.120	0.134	0.149
-		2	5.43	5.12	4.80	4.51	4.23	3.97	3.73	3.51	0.093	0.093	0.092	0.092	0.091	0.091	0.090	0.089
-		3	5.93	5.37	4.77	4.19	3.64	3.13	2.67	2.25	0.151	0.165	0.180	0.194	0.209	0.224	0.239	0.254
-		4	8.42	7.77	7.06	6.37	5.70	5.05	4.45	3.88	0.122	0.132	0.144	0.155	0.167	0.178	0.190	0.201
-		5	5.23	4.74	4.24	3.78	3.36	2.97	2.62	2.30	0.154	0.158	0.163	0.169	0.174	0.179	0.184	0.189
-		6	4.43	4.22	3.97	3.71	3.44	3.17	2.90	2.64	0.074	0.083	0.093	0.103	0.113	0.123	0.133	0.143
-		7	5.63	5.05	4.47	3.93	3.44	2.99	2.58	2.22	0.167	0.174	0.182	0.190	0.197	0.205	0.213	0.221
-		8	2.54	2.41	2.27	2.12	1.96	1.81	1.66	1.51	0.076	0.085	0.094	0.104	0.113	0.123	0.133	0.142
		Avg	**5.41**	**5.02**	**4.60**	**4.20**	**3.80**	**3.42**	**3.07**	**2.73**	**0.111**	**0.119**	**0.128**	**0.137**	**0.146**	**0.155**	**0.165**	**0.174**
		StdDev	**1.63**	**1.49**	**1.34**	**1.21**	**1.09**	**0.99**	**0.90**	**0.83**	**0.044**	**0.043**	**0.044**	**0.044**	**0.046**	**0.047**	**0.050**	**0.053**

Table A.23 *BBR* Mixture Data for M23-FR/E2-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	6.49	6.14	5.75	5.35	4.96	4.57	4.20	3.83	0.086	0.092	0.099	0.106	0.113	0.120	0.127	0.135
-		2	3.55	3.27	2.97	2.67	2.37	2.09	1.83	1.58	0.121	0.134	0.148	0.162	0.175	0.189	0.203	0.217
-		3	6.53	6.22	5.83	5.41	4.97	4.52	4.07	3.63	0.072	0.085	0.100	0.115	0.129	0.144	0.159	0.174
-		4	6.68	6.31	5.90	5.49	5.08	4.67	4.27	3.88	0.085	0.092	0.101	0.109	0.117	0.125	0.134	0.142
-		5	3.14	2.95	2.76	2.58	2.42	2.27	2.13	2.00	0.100	0.099	0.097	0.095	0.094	0.092	0.090	0.089
-		6	7.09	6.67	6.20	5.74	5.30	4.87	4.46	4.07	0.096	0.101	0.107	0.113	0.119	0.124	0.130	0.136
		Avg	**5.58**	**5.26**	**4.90**	**4.54**	**4.18**	**3.83**	**3.49**	**3.17**	**0.093**	**0.101**	**0.109**	**0.117**	**0.125**	**0.132**	**0.141**	**0.149**
		StdDev	**1.75**	**1.68**	**1.59**	**1.49**	**1.39**	**1.29**	**1.18**	**1.08**	**0.017**	**0.017**	**0.020**	**0.023**	**0.027**	**0.032**	**0.038**	**0.043**

Table A.24 *BBR* Mixture Data for M24-FR/E2-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	6.06	5.75	5.38	5.00	4.61	4.22	3.84	3.46	0.080	0.090	0.100	0.111	0.122	0.133	0.143	0.154
-		2	5.74	5.36	4.94	4.53	4.13	3.73	3.36	3.00	0.104	0.112	0.121	0.130	0.140	0.149	0.158	0.167
-		3	5.21	4.76	4.26	3.77	3.30	2.85	2.44	2.07	0.138	0.152	0.168	0.184	0.200	0.216	0.232	0.248
-		4	9.41	9.05	8.66	8.28	7.93	7.58	7.25	6.93	0.063	0.063	0.063	0.064	0.064	0.064	0.065	0.065
-		5	3.93	3.68	3.43	3.22	3.03	2.86	2.72	2.59	0.108	0.103	0.097	0.091	0.085	0.079	0.073	0.067
-		6	7.38	6.87	6.30	5.76	5.23	4.73	4.25	3.81	0.113	0.119	0.127	0.134	0.142	0.149	0.157	0.164
-		7	3.55	3.28	2.98	2.69	2.40	2.12	1.86	1.62	0.119	0.131	0.144	0.157	0.170	0.183	0.196	0.209
-		8	4.79	4.55	4.29	4.03	3.79	3.55	3.32	3.10	0.081	0.084	0.087	0.090	0.092	0.095	0.098	0.101
		Avg	**5.76**	**5.41**	**5.03**	**4.66**	**4.30**	**3.96**	**3.63**	**3.32**	**0.101**	**0.107**	**0.113**	**0.120**	**0.127**	**0.134**	**0.140**	**0.147**
		StdDev	**1.91**	**1.86**	**1.81**	**1.76**	**1.72**	**1.68**	**1.65**	**1.62**	**0.024**	**0.028**	**0.033**	**0.039**	**0.046**	**0.052**	**0.059**	**0.065**

Table A.25 *BBR* Mixture Data for M25-FR/E2-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	6.28	5.80	5.29	4.81	4.35	3.91	3.51	3.13	0.123	0.129	0.135	0.142	0.149	0.155	0.162	0.169
-		2	5.97	5.52	5.03	4.54	4.07	3.62	3.20	2.81	0.120	0.130	0.141	0.152	0.163	0.173	0.184	0.195
-		3	7.77	7.41	6.98	6.54	6.07	5.60	5.13	4.67	0.071	0.080	0.090	0.101	0.111	0.121	0.132	0.142
-		4	8.45	7.70	6.92	6.20	5.52	4.90	4.33	3.81	0.145	0.151	0.157	0.163	0.169	0.175	0.181	0.187
-		5	7.50	6.89	6.27	5.69	5.16	4.66	4.21	3.79	0.132	0.135	0.138	0.141	0.144	0.147	0.150	0.153
-		6	8.67	8.17	7.60	7.04	6.49	5.94	5.41	4.90	0.092	0.099	0.107	0.115	0.123	0.131	0.139	0.147
-		7	6.57	5.89	5.17	4.49	3.86	3.29	2.77	2.32	0.168	0.181	0.196	0.210	0.224	0.239	0.253	0.268
-		8	6.55	6.05	5.53	5.05	4.61	4.20	3.83	3.49	0.128	0.129	0.130	0.131	0.132	0.133	0.135	0.136
-		9	4.01	3.78	3.53	3.27	3.01	2.75	2.50	2.26	0.088	0.096	0.105	0.115	0.124	0.133	0.142	0.151
-		10	6.28	5.80	5.29	4.81	4.35	3.91	3.51	3.13	0.123	0.129	0.135	0.142	0.149	0.155	0.162	0.169
-		11	5.97	5.52	5.03	4.54	4.07	3.62	3.20	2.81	0.120	0.130	0.141	0.152	0.163	0.173	0.184	0.195
-		12	7.77	7.41	6.98	6.54	6.07	5.60	5.13	4.67	0.071	0.080	0.090	0.101	0.111	0.121	0.132	0.142
		Avg	**6.82**	**6.33**	**5.80**	**5.29**	**4.80**	**4.33**	**3.89**	**3.48**	**0.115**	**0.122**	**0.130**	**0.139**	**0.147**	**0.155**	**0.163**	**0.171**
		StdDev	**1.29**	**1.23**	**1.16**	**1.11**	**1.06**	**1.01**	**0.96**	**0.91**	**0.029**	**0.029**	**0.030**	**0.030**	**0.031**	**0.033**	**0.035**	**0.037**

Table A.26 *BBR* Mixture Data for M26-Hwy 45/E2-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	3.42	3.10	2.79	2.50	2.25	2.01	1.80	1.61	0.153	0.154	0.155	0.156	0.158	0.159	0.160	0.161
-		2	3.54	3.24	2.91	2.61	2.32	2.05	1.80	1.56	0.138	0.146	0.156	0.165	0.175	0.184	0.194	0.203
-		3	4.87	4.48	4.08	3.70	3.34	3.01	2.71	2.43	0.131	0.135	0.139	0.143	0.147	0.152	0.156	0.160
-		4	3.09	2.87	2.62	2.37	2.13	1.90	1.68	1.48	0.116	0.126	0.137	0.148	0.159	0.170	0.181	0.192
-		5	6.29	5.82	5.34	4.88	4.45	4.04	3.66	3.30	0.119	0.123	0.128	0.132	0.136	0.141	0.145	0.150
-		6	7.46	6.76	6.05	5.41	4.83	4.30	3.82	3.39	0.156	0.158	0.161	0.163	0.166	0.168	0.171	0.173
-		7	5.94	5.47	4.97	4.50	4.05	3.63	3.23	2.87	0.128	0.134	0.141	0.148	0.155	0.162	0.169	0.176
		Avg	**4.94**	**4.53**	**4.11**	**3.71**	**3.34**	**2.99**	**2.67**	**2.38**	**0.134**	**0.139**	**0.145**	**0.151**	**0.157**	**0.162**	**0.168**	**0.174**
		StdDev	**1.68**	**1.53**	**1.38**	**1.25**	**1.13**	**1.02**	**0.92**	**0.84**	**0.016**	**0.014**	**0.012**	**0.012**	**0.013**	**0.014**	**0.016**	**0.019**

Table A.27 *BBR* Mixture Data for M27-Hwy 45/E2-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	8.09	7.64	7.09	6.49	5.88	5.26	4.64	4.05	0.084	0.100	0.117	0.135	0.152	0.170	0.188	0.205
-		2	4.98	4.46	3.95	3.51	3.12	2.78	2.48	2.21	0.177	0.175	0.173	0.171	0.169	0.167	0.165	0.163
-		3	2.69	2.50	2.30	2.11	1.94	1.77	1.61	1.47	0.116	0.118	0.122	0.125	0.128	0.131	0.134	0.137
-		4	6.77	6.53	6.24	5.93	5.60	5.27	4.93	4.58	0.055	0.062	0.070	0.077	0.085	0.093	0.100	0.108
-		5	5.83	5.53	5.18	4.82	4.45	4.07	3.69	3.33	0.078	0.088	0.099	0.111	0.122	0.134	0.145	0.157
-		6	5.65	5.07	4.49	3.96	3.49	3.06	2.68	2.34	0.170	0.174	0.178	0.182	0.186	0.190	0.194	0.198
-		7	10.56	9.68	8.73	7.82	6.95	6.13	5.37	4.67	0.134	0.143	0.154	0.165	0.175	0.186	0.196	0.207
		Avg	**6.37**	**5.92**	**5.43**	**4.95**	**4.49**	**4.05**	**3.63**	**3.24**	**0.116**	**0.123**	**0.130**	**0.138**	**0.145**	**0.153**	**0.160**	**0.168**
		StdDev	**2.48**	**2.32**	**2.13**	**1.95**	**1.76**	**1.58**	**1.42**	**1.26**	**0.047**	**0.043**	**0.040**	**0.037**	**0.036**	**0.035**	**0.036**	**0.038**

Table A.28 *BBR* Mixture Data for M28-Hwy 45/E2-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.08	4.62	4.18	3.78	3.44	3.14	2.87	2.63	0.153	0.149	0.144	0.140	0.135	0.131	0.127	0.122
-		2	3.84	3.62	3.36	3.11	2.86	2.62	2.38	2.16	0.095	0.101	0.109	0.117	0.124	0.132	0.139	0.147
-		3	4.64	4.26	3.82	3.39	2.98	2.58	2.21	1.86	0.130	0.146	0.163	0.181	0.198	0.216	0.234	0.251
-		4	4.15	3.73	3.31	2.93	2.59	2.29	2.03	1.79	0.171	0.172	0.174	0.175	0.177	0.178	0.180	0.181
-		5	5.84	5.32	4.77	4.25	3.76	3.30	2.87	2.48	0.142	0.152	0.162	0.173	0.184	0.194	0.205	0.216
-		6	8.62	7.93	7.16	6.41	5.68	4.98	4.33	3.72	0.126	0.139	0.153	0.168	0.182	0.196	0.210	0.225
-		7	6.81	6.23	5.61	5.00	4.43	3.89	3.39	2.93	0.136	0.146	0.158	0.170	0.181	0.193	0.204	0.216
-		8	4.85	4.57	4.25	3.91	3.57	3.23	2.90	2.58	0.089	0.101	0.113	0.126	0.138	0.151	0.163	0.175
		Avg	**5.48**	**5.04**	**4.56**	**4.10**	**3.66**	**3.25**	**2.87**	**2.52**	**0.130**	**0.138**	**0.147**	**0.156**	**0.165**	**0.174**	**0.183**	**0.192**
		StdDev	**1.58**	**1.44**	**1.29**	**1.14**	**1.00**	**0.86**	**0.74**	**0.62**	**0.028**	**0.025**	**0.024**	**0.025**	**0.028**	**0.032**	**0.037**	**0.043**

Table A.29 *BBR* Mixture Data for M29-FR/E5-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	3.72	3.40	3.05	2.72	2.40	2.10	1.83	1.57	0.139	0.150	0.161	0.173	0.185	0.197	0.209	0.221
-		2	4.73	4.18	3.65	3.17	2.76	2.40	2.08	1.80	0.196	0.198	0.199	0.201	0.203	0.204	0.206	0.208
-		3	5.09	4.45	3.81	3.23	2.72	2.27	1.88	1.54	0.209	0.220	0.232	0.243	0.255	0.267	0.279	0.290
-		4	2.80	2.50	2.21	1.95	1.72	1.51	1.32	1.15	0.174	0.177	0.180	0.183	0.187	0.190	0.193	0.196
-		5	6.69	6.27	5.82	5.38	4.96	4.55	4.17	3.80	0.101	0.106	0.110	0.115	0.120	0.125	0.130	0.135
-		6	4.99	4.46	3.94	3.48	3.08	2.72	2.40	2.12	0.179	0.179	0.179	0.179	0.179	0.179	0.179	0.179
-		7	8.73	8.40	8.01	7.58	7.14	6.68	6.21	5.74	0.057	0.065	0.074	0.083	0.092	0.101	0.110	0.119
-		8	3.59	3.16	2.75	2.40	2.11	1.85	1.64	1.45	0.207	0.203	0.197	0.192	0.187	0.182	0.177	0.171
		Avg	**5.04**	**4.60**	**4.16**	**3.74**	**3.36**	**3.01**	**2.69**	**2.40**	**0.158**	**0.162**	**0.167**	**0.171**	**0.176**	**0.181**	**0.185**	**0.190**
		StdDev	**1.90**	**1.90**	**1.89**	**1.86**	**1.81**	**1.74**	**1.67**	**1.58**	**0.055**	**0.053**	**0.051**	**0.050**	**0.050**	**0.050**	**0.052**	**0.053**

Table A.30 *BBR* Mixture Data for M30-FR/E5-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	1.05	1.04	1.02	1.00	0.97	0.95	0.92	0.89	0.017	0.022	0.027	0.032	0.037	0.042	0.047	0.052
-		2	4.70	4.28	3.83	3.41	3.01	2.64	2.30	1.99	0.145	0.154	0.164	0.174	0.184	0.194	0.203	0.213
-		3	6.44	6.03	5.53	5.00	4.47	3.94	3.42	2.93	0.097	0.115	0.134	0.154	0.173	0.193	0.212	0.232
-		4	5.10	4.63	4.15	3.71	3.30	2.93	2.60	2.29	0.153	0.156	0.161	0.165	0.169	0.173	0.177	0.181
-		5	3.14	2.77	2.41	2.10	1.82	1.58	1.36	1.18	0.196	0.198	0.201	0.203	0.206	0.209	0.211	0.214
-		6	6.02	5.57	5.12	4.69	4.30	3.94	3.61	3.31	0.123	0.124	0.124	0.125	0.126	0.126	0.127	0.128
-		7	6.23	5.95	5.65	5.37	5.10	4.85	4.61	4.38	0.073	0.073	0.073	0.073	0.074	0.074	0.074	0.074
-		8	4.06	3.57	3.08	2.64	2.25	1.91	1.61	1.34	0.202	0.210	0.218	0.226	0.235	0.243	0.252	0.260
-		9	4.67	4.16	3.65	3.18	2.76	2.38	2.04	1.74	0.179	0.186	0.194	0.202	0.210	0.218	0.226	0.234
		Avg	**4.60**	**4.22**	**3.83**	**3.46**	**3.11**	**2.79**	**2.50**	**2.23**	**0.132**	**0.138**	**0.144**	**0.150**	**0.157**	**0.164**	**0.170**	**0.176**
		StdDev	**1.71**	**1.62**	**1.52**	**1.43**	**1.34**	**1.26**	**1.19**	**1.13**	**0.061**	**0.061**	**0.062**	**0.064**	**0.066**	**0.068**	**0.071**	**0.075**

Table A.31 *BBR* Mixture Data for M31-FR/E5-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.43	5.08	4.67	4.23	3.79	3.36	2.94	2.54	0.098	0.114	0.132	0.149	0.167	0.184	0.202	0.219
-		2	5.63	5.12	4.57	4.06	3.58	3.13	2.72	2.35	0.148	0.157	0.167	0.177	0.187	0.197	0.208	0.218
-		3	3.76	3.28	2.82	2.43	2.09	1.80	1.54	1.33	0.216	0.217	0.217	0.217	0.218	0.218	0.219	0.219
-		4	6.41	5.90	5.34	4.79	4.25	3.74	3.26	2.81	0.124	0.137	0.151	0.164	0.178	0.192	0.206	0.220
-		5	4.30	3.91	3.31	2.63	1.97	1.38	0.91	0.56	0.111	0.193	0.284	0.375	0.466	0.557	0.648	0.739
		Avg	**5.11**	**4.66**	**4.14**	**3.63**	**3.14**	**2.68**	**2.27**	**1.92**	**0.139**	**0.164**	**0.190**	**0.216**	**0.243**	**0.270**	**0.297**	**0.323**
		StdDev	**1.07**	**1.05**	**1.04**	**1.04**	**1.04**	**1.03**	**1.00**	**0.94**	**0.047**	**0.042**	**0.061**	**0.092**	**0.126**	**0.161**	**0.197**	**0.233**

Table A.32 *BBR* Mixture Data for M32-Hwy 45/E5-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	4.32	3.84	3.37	2.96	2.60	2.29	2.02	1.78	0.191	0.189	0.188	0.186	0.185	0.183	0.182	0.181
-		2	5.37	4.83	4.27	3.73	3.24	2.78	2.37	2.01	0.163	0.174	0.186	0.199	0.211	0.224	0.237	0.249
-		3	9.65	9.08	8.43	7.75	7.08	6.40	5.74	5.11	0.091	0.102	0.114	0.126	0.138	0.150	0.163	0.175
-		4	4.81	4.26	3.71	3.23	2.80	2.42	2.09	1.80	0.192	0.195	0.199	0.203	0.207	0.211	0.215	0.219
-		5	3.31	3.00	2.68	2.39	2.12	1.89	1.67	1.48	0.159	0.161	0.164	0.166	0.169	0.172	0.174	0.177
-		6	4.42	4.06	3.69	3.37	3.07	2.80	2.55	2.33	0.137	0.136	0.135	0.134	0.133	0.133	0.132	0.131
-		7	3.97	3.64	3.29	2.96	2.64	2.35	2.08	1.83	0.135	0.142	0.150	0.158	0.166	0.174	0.182	0.190
-		8	7.42	7.09	6.68	6.23	5.75	5.26	4.75	4.26	0.066	0.079	0.093	0.108	0.123	0.137	0.152	0.167
		Avg	**5.41**	**4.98**	**4.52**	**4.08**	**3.66**	**3.27**	**2.91**	**2.58**	**0.142**	**0.147**	**0.154**	**0.160**	**0.167**	**0.173**	**0.180**	**0.186**
		StdDev	**2.11**	**2.06**	**1.99**	**1.88**	**1.77**	**1.63**	**1.49**	**1.34**	**0.045**	**0.041**	**0.038**	**0.035**	**0.033**	**0.033**	**0.034**	**0.035**

Table A.33 *BBR* Mixture Data for M33-Hwy 45/E5-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	3.80	3.31	2.81	2.37	1.98	1.64	1.35	1.10	0.217	0.228	0.240	0.252	0.265	0.277	0.289	0.301
-		2	5.83	5.40	4.92	4.44	3.96	3.50	3.07	2.66	0.115	0.128	0.142	0.156	0.170	0.185	0.199	0.213
-		3	4.25	3.85	3.50	3.21	2.99	2.81	2.68	2.58	0.164	0.148	0.131	0.114	0.096	0.079	0.062	0.044
-		4	4.17	3.65	3.14	2.71	2.33	2.01	1.73	1.48	0.212	0.213	0.214	0.215	0.216	0.217	0.218	0.219
-		5	6.95	6.55	6.15	5.79	5.45	5.14	4.86	4.60	0.094	0.092	0.090	0.087	0.085	0.083	0.081	0.078
-		6	2.84	2.64	2.43	2.24	2.06	1.90	1.75	1.61	0.118	0.118	0.118	0.119	0.119	0.119	0.120	0.120
-		7	2.19	2.02	1.85	1.70	1.56	1.44	1.32	1.22	0.129	0.127	0.125	0.123	0.121	0.119	0.117	0.115
-		8	2.53	2.38	2.23	2.10	1.97	1.85	1.74	1.64	0.095	0.093	0.092	0.091	0.089	0.088	0.086	0.085
-		9	6.73	6.05	5.35	4.72	4.14	3.62	3.15	2.73	0.167	0.172	0.179	0.185	0.191	0.198	0.204	0.210
		Avg	**4.37**	**3.98**	**3.60**	**3.25**	**2.94**	**2.66**	**2.41**	**2.18**	**0.146**	**0.147**	**0.148**	**0.149**	**0.150**	**0.152**	**0.153**	**0.154**
		StdDev	**1.78**	**1.65**	**1.52**	**1.41**	**1.31**	**1.22**	**1.16**	**1.10**	**0.047**	**0.049**	**0.052**	**0.057**	**0.064**	**0.070**	**0.077**	**0.085**

Table A.34 *BBR* Mixture Data for M34-Hwy 45/E5-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	10.43	9.94	9.33	8.67	7.96	7.24	6.51	5.79	0.069	0.083	0.099	0.114	0.130	0.145	0.161	0.176
-		2	8.71	7.52	6.40	5.44	4.62	3.93	3.34	2.84	0.233	0.233	0.234	0.234	0.235	0.235	0.235	0.236
-		3	7.30	6.67	5.98	5.31	4.68	4.08	3.53	3.02	0.138	0.150	0.164	0.177	0.190	0.204	0.217	0.231
-		4	6.88	6.18	5.45	4.77	4.14	3.56	3.04	2.57	0.165	0.175	0.187	0.199	0.211	0.223	0.235	0.247
-		5	6.19	5.47	4.75	4.12	3.56	3.06	2.62	2.24	0.194	0.199	0.204	0.209	0.215	0.220	0.225	0.230
-		6	6.83	6.24	5.60	5.00	4.44	3.91	3.43	2.98	0.141	0.150	0.159	0.168	0.177	0.186	0.196	0.205
-		7	5.80	5.27	4.72	4.21	3.74	3.31	2.91	2.55	0.150	0.155	0.162	0.168	0.174	0.181	0.187	0.193
-		8	8.40	7.75	7.07	6.41	5.80	5.22	4.68	4.18	0.126	0.131	0.137	0.143	0.149	0.154	0.160	0.166
-		9	5.71	5.19	4.64	4.13	3.66	3.22	2.81	2.45	0.149	0.156	0.164	0.173	0.181	0.189	0.197	0.206
		Avg	**7.36**	**6.69**	**5.99**	**5.34**	**4.73**	**4.17**	**3.65**	**3.18**	**0.152**	**0.159**	**0.168**	**0.176**	**0.185**	**0.193**	**0.201**	**0.210**
		StdDev	**1.56**	**1.52**	**1.50**	**1.45**	**1.39**	**1.32**	**1.23**	**1.13**	**0.045**	**0.042**	**0.039**	**0.035**	**0.033**	**0.031**	**0.029**	**0.028**

Table A.35 *BBR* Mixture Data for M35-FR/E7-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	8.18	7.84	7.42	6.97	6.48	5.97	5.45	4.93	0.061	0.073	0.086	0.099	0.112	0.125	0.138	0.151
-		2	1.77	1.74	1.71	1.66	1.61	1.55	1.49	1.42	0.023	0.029	0.035	0.042	0.049	0.055	0.062	0.069
-		3	6.86	6.50	6.07	5.62	5.15	4.68	4.21	3.76	0.080	0.092	0.105	0.118	0.132	0.145	0.158	0.172
-		4	5.97	5.62	5.22	4.83	4.44	4.06	3.69	3.34	0.094	0.101	0.109	0.117	0.125	0.133	0.141	0.150
-		5	1.93	1.75	1.59	1.46	1.36	1.28	1.22	1.18	0.166	0.149	0.131	0.113	0.095	0.077	0.059	0.040
-		6	4.05	3.87	3.67	3.46	3.24	3.03	2.81	2.60	0.068	0.075	0.082	0.089	0.096	0.102	0.109	0.116
-		7	7.85	7.27	6.63	6.00	5.40	4.83	4.29	3.78	0.119	0.128	0.138	0.148	0.157	0.167	0.176	0.186
		Avg	**5.23**	**4.94**	**4.62**	**4.29**	**3.95**	**3.63**	**3.31**	**3.00**	**0.087**	**0.092**	**0.098**	**0.104**	**0.109**	**0.115**	**0.120**	**0.126**
		StdDev	**2.68**	**2.53**	**2.34**	**2.15**	**1.95**	**1.75**	**1.55**	**1.35**	**0.046**	**0.039**	**0.035**	**0.033**	**0.034**	**0.039**	**0.046**	**0.054**

Table A.36 *BBR* Mixture Data for M36-FR/E7-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	7.63	7.16	6.60	6.03	5.46	4.89	4.34	3.81	0.096	0.109	0.123	0.137	0.152	0.166	0.180	0.194
-		2	7.47	7.00	6.46	5.90	5.33	4.77	4.22	3.71	0.096	0.109	0.124	0.138	0.153	0.168	0.182	0.197
-		3	6.19	5.85	5.44	5.01	4.57	4.13	3.70	3.28	0.085	0.098	0.111	0.125	0.139	0.152	0.166	0.180
-		4	6.80	6.50	6.11	5.69	5.25	4.78	4.31	3.84	0.065	0.079	0.095	0.111	0.126	0.142	0.158	0.173
-		5	7.32	6.76	6.13	5.49	4.87	4.26	3.69	3.16	0.119	0.134	0.150	0.166	0.183	0.199	0.215	0.232
-		6	4.46	4.13	3.76	3.38	3.01	2.65	2.31	1.99	0.114	0.128	0.144	0.160	0.176	0.192	0.207	0.223
-		7	7.17	6.73	6.22	5.69	5.15	4.62	4.09	3.59	0.093	0.107	0.121	0.136	0.151	0.166	0.180	0.195
-		8	6.77	6.44	5.82	5.01	4.10	3.21	2.39	1.69	0.049	0.112	0.182	0.252	0.321	0.391	0.461	0.531
-		9	9.72	9.13	8.44	7.71	6.98	6.24	5.53	4.84	0.092	0.106	0.122	0.137	0.152	0.168	0.183	0.199
-		10	5.11	4.94	4.76	4.60	4.44	4.30	4.16	4.04	0.055	0.053	0.052	0.050	0.048	0.047	0.045	0.044
		Avg	**6.86**	**6.46**	**5.97**	**5.45**	**4.92**	**4.39**	**3.87**	**3.40**	**0.086**	**0.104**	**0.122**	**0.141**	**0.160**	**0.179**	**0.198**	**0.217**
		StdDev	**1.44**	**1.34**	**1.22**	**1.11**	**1.03**	**0.97**	**0.95**	**0.94**	**0.023**	**0.023**	**0.034**	**0.050**	**0.068**	**0.085**	**0.104**	**0.122**

Table A.37 *BBR* Mixture Data for M37-FR/E7-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.23	4.89	4.50	4.12	3.75	3.38	3.04	2.71	0.104	0.113	0.123	0.133	0.142	0.152	0.162	0.171
-		2	4.89	4.57	4.20	3.83	3.45	3.07	2.71	2.37	0.100	0.114	0.129	0.143	0.158	0.173	0.188	0.203
-		3	7.51	7.07	6.59	6.11	5.64	5.19	4.75	4.32	0.092	0.098	0.105	0.112	0.118	0.125	0.131	0.138
-		4	5.96	5.54	5.07	4.60	4.15	3.70	3.28	2.89	0.111	0.122	0.134	0.145	0.157	0.169	0.180	0.192
-		5	5.93	5.58	5.19	4.81	4.44	4.08	3.74	3.41	0.095	0.100	0.106	0.112	0.118	0.124	0.130	0.137
-		6	7.05	6.61	6.11	5.61	5.10	4.60	4.12	3.66	0.097	0.107	0.119	0.130	0.142	0.154	0.165	0.177
		Avg	**6.10**	**5.71**	**5.28**	**4.85**	**4.42**	**4.00**	**3.61**	**3.23**	**0.100**	**0.109**	**0.119**	**0.129**	**0.139**	**0.150**	**0.159**	**0.170**
		StdDev	**1.02**	**0.97**	**0.92**	**0.87**	**0.83**	**0.79**	**0.75**	**0.71**	**0.007**	**0.009**	**0.012**	**0.014**	**0.018**	**0.021**	**0.024**	**0.027**

Table A.38 *BBR* Mixture Data for M38-Hwy 45/E7-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	8.08	7.55	6.96	6.39	5.83	5.29	4.77	4.28	0.104	0.112	0.120	0.128	0.137	0.145	0.153	0.162
-		2	7.38	6.88	6.35	5.84	5.35	4.89	4.45	4.04	0.109	0.113	0.118	0.123	0.128	0.133	0.138	0.143
-		3	6.21	5.77	5.30	4.84	4.41	4.00	3.62	3.26	0.115	0.121	0.126	0.132	0.137	0.143	0.149	0.154
-		4	7.20	6.80	6.35	5.90	5.47	5.04	4.62	4.22	0.090	0.095	0.102	0.108	0.114	0.121	0.127	0.133
-		5	3.54	3.33	3.09	2.85	2.61	2.38	2.15	1.94	0.093	0.102	0.111	0.121	0.130	0.139	0.149	0.158
		Avg	**6.48**	**6.07**	**5.61**	**5.16**	**4.73**	**4.32**	**3.92**	**3.55**	**0.102**	**0.109**	**0.115**	**0.122**	**0.129**	**0.136**	**0.143**	**0.150**
		StdDev	**1.78**	**1.66**	**1.53**	**1.41**	**1.30**	**1.19**	**1.09**	**0.99**	**0.011**	**0.010**	**0.009**	**0.009**	**0.009**	**0.010**	**0.011**	**0.012**

Table A.39 *BBR* Mixture Data for M39-Hwy 45/E7-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	7.89	7.35	6.73	6.09	5.45	4.83	4.23	3.66	0.105	0.120	0.136	0.152	0.168	0.184	0.200	0.216
-		2	5.69	5.35	4.97	4.57	4.16	3.76	3.37	3.00	0.091	0.102	0.115	0.127	0.139	0.152	0.164	0.177
-		3	5.52	5.11	4.66	4.21	3.77	3.35	2.95	2.57	0.116	0.128	0.140	0.153	0.165	0.178	0.190	0.203
-		4	5.79	5.27	4.70	4.15	3.62	3.12	2.67	2.25	0.143	0.157	0.173	0.189	0.204	0.220	0.236	0.252
-		5	5.95	5.63	5.26	4.86	4.45	4.04	3.64	3.24	0.081	0.093	0.106	0.120	0.133	0.146	0.159	0.172
-		6	6.97	6.45	5.88	5.34	4.82	4.33	3.86	3.43	0.120	0.127	0.135	0.144	0.152	0.160	0.168	0.176
		Avg	**6.30**	**5.86**	**5.37**	**4.87**	**4.38**	**3.91**	**3.45**	**3.03**	**0.109**	**0.121**	**0.134**	**0.148**	**0.160**	**0.173**	**0.186**	**0.199**
		StdDev	**0.93**	**0.87**	**0.80**	**0.74**	**0.68**	**0.63**	**0.58**	**0.53**	**0.022**	**0.022**	**0.023**	**0.024**	**0.026**	**0.027**	**0.029**	**0.031**

Table A.40 *BBR* Mixture Data for M40-Hwy 45/E7-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.20	4.90	4.59	4.28	3.97	3.68	3.40	3.12	0.090	0.094	0.099	0.104	0.108	0.113	0.118	0.123
-		2	6.92	6.51	6.03	5.53	5.01	4.49	3.99	3.50	0.089	0.103	0.119	0.134	0.149	0.164	0.180	0.195
-		3	6.35	5.82	5.25	4.71	4.19	3.70	3.24	2.82	0.134	0.143	0.154	0.164	0.174	0.184	0.195	0.205
-		4	4.08	3.74	3.35	2.97	2.59	2.23	1.89	1.59	0.129	0.147	0.166	0.186	0.206	0.226	0.245	0.265
-		5	4.92	4.52	4.07	3.61	3.17	2.74	2.34	1.97	0.126	0.143	0.162	0.181	0.200	0.219	0.238	0.257
-		6	6.95	6.48	5.97	5.48	5.00	4.54	4.11	3.70	0.108	0.114	0.121	0.128	0.135	0.142	0.149	0.156
-		7	6.35	5.98	5.53	5.05	4.56	4.07	3.59	3.13	0.089	0.104	0.121	0.138	0.155	0.173	0.190	0.207
		Avg	**5.82**	**5.42**	**4.97**	**4.52**	**4.07**	**3.64**	**3.22**	**2.83**	**0.109**	**0.121**	**0.135**	**0.148**	**0.161**	**0.174**	**0.188**	**0.201**
		StdDev	**1.10**	**1.06**	**1.01**	**0.96**	**0.91**	**0.87**	**0.83**	**0.78**	**0.020**	**0.022**	**0.026**	**0.030**	**0.035**	**0.040**	**0.045**	**0.051**

Table A.41 *BBR* Mixture Data for M41-FR/E4-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	7.68	7.32	6.88	6.40	5.91	5.40	4.88	4.38	0.070	0.082	0.096	0.110	0.123	0.137	0.151	0.164
-		2	7.91	7.55	7.13	6.70	6.25	5.80	5.35	4.90	0.070	0.078	0.087	0.095	0.104	0.112	0.121	0.130
-		3	7.94	7.38	6.76	6.15	5.57	5.01	4.47	3.97	0.113	0.122	0.131	0.140	0.149	0.158	0.167	0.177
-		4	6.84	6.55	6.19	5.79	5.36	4.91	4.45	3.99	0.061	0.075	0.089	0.104	0.119	0.134	0.149	0.163
-		5	6.02	5.61	5.14	4.68	4.22	3.77	3.35	2.94	0.107	0.118	0.131	0.143	0.155	0.167	0.179	0.191
-		6	8.06	7.73	7.35	6.94	6.52	6.08	5.64	5.20	0.062	0.069	0.078	0.087	0.095	0.104	0.113	0.121
-		7	13.94	13.16	12.36	11.62	10.94	10.31	9.73	9.19	0.093	0.091	0.089	0.088	0.086	0.085	0.083	0.081
-		8	6.81	6.46	6.07	5.69	5.31	4.94	4.57	4.22	0.082	0.087	0.092	0.097	0.102	0.108	0.113	0.118
		Avg	**8.15**	**7.72**	**7.24**	**6.75**	**6.26**	**5.78**	**5.31**	**4.85**	**0.082**	**0.090**	**0.099**	**0.108**	**0.117**	**0.126**	**0.135**	**0.143**
		StdDev	**2.45**	**2.31**	**2.19**	**2.09**	**2.02**	**1.96**	**1.91**	**1.88**	**0.020**	**0.020**	**0.020**	**0.022**	**0.025**	**0.028**	**0.032**	**0.037**

Table A.42 *BBR* Mixture Data for M42-FR/E4-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.91	5.44	4.92	4.41	3.92	3.45	3.02	2.61	0.128	0.139	0.151	0.164	0.176	0.189	0.201	0.214
-		2	7.96	7.35	6.68	6.04	5.43	4.85	4.30	3.79	0.123	0.132	0.141	0.150	0.159	0.168	0.178	0.187
-		3	2.59	2.48	2.33	2.17	2.00	1.82	1.63	1.45	0.065	0.079	0.096	0.112	0.128	0.145	0.161	0.177
-		4	6.52	6.12	5.66	5.18	4.69	4.21	3.74	3.28	0.094	0.107	0.121	0.135	0.150	0.164	0.178	0.193
-		5	5.30	4.97	4.61	4.27	3.95	3.64	3.34	3.06	0.101	0.105	0.108	0.112	0.116	0.120	0.124	0.128
-		6	4.15	3.87	3.57	3.27	2.99	2.72	2.47	2.23	0.110	0.115	0.121	0.127	0.133	0.139	0.145	0.150
-		7	3.20	3.10	2.98	2.84	2.69	2.52	2.35	2.18	0.044	0.053	0.064	0.074	0.085	0.096	0.106	0.117
-		8	5.72	5.34	4.87	4.37	3.85	3.33	2.83	2.36	0.097	0.120	0.145	0.171	0.196	0.222	0.247	0.273
-		9	4.82	4.61	4.30	3.93	3.51	3.07	2.62	2.19	0.055	0.084	0.116	0.147	0.179	0.211	0.242	0.274
		Avg	**5.13**	**4.81**	**4.44**	**4.05**	**3.67**	**3.29**	**2.92**	**2.57**	**0.091**	**0.104**	**0.118**	**0.132**	**0.147**	**0.162**	**0.176**	**0.190**
		StdDev	**1.66**	**1.51**	**1.34**	**1.18**	**1.03**	**0.91**	**0.79**	**0.70**	**0.030**	**0.027**	**0.027**	**0.030**	**0.035**	**0.041**	**0.049**	**0.056**

Table A.43 *BBR* Mixture Data for M43-FR/E4-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	6.49	6.17	5.81	5.44	5.07	4.69	4.32	3.96	0.076	0.083	0.091	0.099	0.107	0.114	0.122	0.130
-		2	5.59	5.19	4.75	4.32	3.88	3.46	3.06	2.69	0.110	0.121	0.134	0.146	0.158	0.171	0.183	0.195
-		3	6.46	6.22	5.91	5.56	5.18	4.78	4.37	3.95	0.054	0.067	0.081	0.095	0.109	0.123	0.137	0.151
-		4	6.38	5.89	5.37	4.87	4.41	3.97	3.56	3.18	0.125	0.130	0.136	0.142	0.148	0.153	0.159	0.165
-		5	5.55	5.19	4.78	4.37	3.95	3.55	3.16	2.79	0.102	0.113	0.125	0.137	0.149	0.161	0.173	0.185
-		6	5.06	4.44	3.84	3.31	2.84	2.42	2.06	1.75	0.203	0.208	0.213	0.219	0.224	0.230	0.235	0.240
-		7	6.84	6.26	5.65	5.08	4.53	4.03	3.56	3.14	0.138	0.144	0.152	0.159	0.166	0.174	0.181	0.188
		Avg	**6.05**	**5.62**	**5.16**	**4.71**	**4.27**	**3.84**	**3.44**	**3.07**	**0.115**	**0.124**	**0.133**	**0.142**	**0.152**	**0.161**	**0.170**	**0.179**
		StdDev	**0.65**	**0.70**	**0.74**	**0.78**	**0.80**	**0.81**	**0.80**	**0.77**	**0.048**	**0.046**	**0.043**	**0.041**	**0.039**	**0.038**	**0.037**	**0.035**

Table A.44 *BBR* Mixture Data for M44-Hwy 45/E4-R0.91-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.73	5.31	4.84	4.36	3.89	3.43	2.99	2.59	0.114	0.127	0.143	0.158	0.173	0.188	0.204	0.219
-		2	2.66	2.57	2.47	2.35	2.23	2.10	1.97	1.83	0.050	0.058	0.065	0.073	0.081	0.089	0.097	0.105
-		3	6.13	5.88	5.59	5.30	5.01	4.72	4.44	4.15	0.065	0.069	0.074	0.079	0.083	0.088	0.093	0.097
-		4	7.08	6.54	5.96	5.37	4.80	4.26	3.75	3.26	0.119	0.130	0.142	0.155	0.167	0.180	0.192	0.205
-		5	8.53	7.85	7.16	6.53	5.95	5.42	4.94	4.49	0.132	0.133	0.133	0.134	0.134	0.135	0.135	0.136
		Avg	**6.03**	**5.63**	**5.20**	**4.78**	**4.38**	**3.99**	**3.62**	**3.26**	**0.096**	**0.103**	**0.111**	**0.120**	**0.128**	**0.136**	**0.144**	**0.152**
		StdDev	**2.17**	**1.95**	**1.74**	**1.56**	**1.41**	**1.28**	**1.18**	**1.10**	**0.036**	**0.037**	**0.039**	**0.041**	**0.044**	**0.048**	**0.052**	**0.057**

Table A.45 *BBR* Mixture Data for M45-Hwy 45/E4-R1.36-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	7.12	6.57	5.96	5.37	4.81	4.27	3.76	3.29	0.124	0.134	0.144	0.155	0.166	0.177	0.187	0.198
-		2	6.48	6.20	5.89	5.59	5.30	5.01	4.72	4.44	0.069	0.072	0.074	0.077	0.080	0.083	0.086	0.089
-		3	8.10	7.65	7.11	6.56	6.00	5.44	4.89	4.36	0.087	0.098	0.110	0.123	0.135	0.147	0.160	0.172
-		4	6.87	6.27	5.58	4.88	4.21	3.57	2.99	2.46	0.137	0.157	0.180	0.203	0.225	0.248	0.270	0.293
-		5	6.74	6.36	5.93	5.47	5.02	4.56	4.11	3.68	0.086	0.096	0.108	0.120	0.132	0.143	0.155	0.167
		Avg	**7.06**	**6.61**	**6.09**	**5.57**	**5.07**	**4.57**	**4.09**	**3.65**	**0.101**	**0.111**	**0.123**	**0.136**	**0.148**	**0.160**	**0.172**	**0.184**
		StdDev	**0.62**	**0.60**	**0.59**	**0.61**	**0.66**	**0.71**	**0.77**	**0.82**	**0.029**	**0.034**	**0.040**	**0.047**	**0.053**	**0.060**	**0.066**	**0.073**

Table A.46 *BBR* Mixture Data for M46-Hwy 45/E4-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	8.10	7.65	7.11	6.56	6.00	5.44	4.89	4.36	0.087	0.098	0.110	0.123	0.135	0.147	0.160	0.172
-		2	10.14	9.80	9.43	9.05	8.67	8.29	7.92	7.54	0.053	0.055	0.058	0.060	0.063	0.066	0.068	0.071
-		3	7.94	7.35	6.70	6.05	5.42	4.82	4.25	3.71	0.118	0.129	0.140	0.152	0.164	0.176	0.188	0.200
-		4	8.57	8.03	7.43	6.83	6.23	5.65	5.09	4.56	0.099	0.108	0.117	0.127	0.136	0.146	0.155	0.165
-		5	4.45	4.19	3.91	3.63	3.36	3.09	2.83	2.58	0.090	0.096	0.103	0.110	0.117	0.124	0.131	0.137
-		6	4.38	3.99	3.59	3.21	2.85	2.53	2.22	1.95	0.143	0.150	0.158	0.165	0.173	0.180	0.188	0.196
-		7	6.95	6.44	5.92	5.44	4.99	4.58	4.20	3.84	0.121	0.122	0.122	0.123	0.124	0.125	0.126	0.127
-		8	8.40	7.86	7.25	6.63	6.02	5.42	4.85	4.30	0.101	0.111	0.122	0.134	0.145	0.156	0.168	0.179
-		9	6.40	6.13	5.81	5.46	5.10	4.72	4.34	3.97	0.064	0.073	0.084	0.094	0.105	0.115	0.126	0.136
		Avg	**7.26**	**6.83**	**6.35**	**5.87**	**5.40**	**4.95**	**4.51**	**4.09**	**0.097**	**0.105**	**0.113**	**0.121**	**0.129**	**0.137**	**0.146**	**0.154**
		StdDev	**1.92**	**1.87**	**1.81**	**1.75**	**1.70**	**1.64**	**1.60**	**1.55**	**0.028**	**0.029**	**0.029**	**0.031**	**0.033**	**0.035**	**0.038**	**0.041**

Table A.47 *BBR* Mixture Data for M47-Hwy 45/E3-R1.81-A3

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.94	5.35	4.75	4.19	3.67	3.20	2.78	2.40	0.162	0.170	0.177	0.185	0.193	0.201	0.209	0.217
-		2	11.49	10.98	10.38	9.76	9.12	8.47	7.81	7.17	0.068	0.076	0.085	0.094	0.102	0.111	0.120	0.129
-		3	5.10	4.53	3.96	3.43	2.96	2.53	2.16	1.82	0.183	0.191	0.200	0.210	0.219	0.228	0.238	0.247
-		4	6.94	6.39	5.79	5.20	4.63	4.09	3.59	3.12	0.127	0.137	0.149	0.161	0.172	0.184	0.196	0.208
-		5	12.50	11.98	11.34	10.67	9.96	9.23	8.49	7.76	0.063	0.073	0.083	0.094	0.104	0.115	0.125	0.136
-		6	8.08	7.03	6.00	5.11	4.34	3.67	3.10	2.60	0.220	0.225	0.229	0.234	0.239	0.244	0.248	0.253
-		7	8.62	7.77	6.92	6.15	5.46	4.83	4.27	3.77	0.164	0.166	0.169	0.171	0.174	0.176	0.179	0.182
-		8	3.92	3.57	3.24	2.96	2.72	2.51	2.34	2.18	0.150	0.143	0.135	0.127	0.118	0.110	0.102	0.094
-		9	4.53	3.94	3.39	2.91	2.51	2.17	1.87	1.62	0.222	0.220	0.218	0.216	0.214	0.211	0.209	0.207
-		10	6.05	5.46	4.86	4.30	3.79	3.33	2.91	2.54	0.161	0.167	0.172	0.178	0.184	0.190	0.196	0.201
-		11	6.50	5.62	4.79	4.08	3.48	2.96	2.53	2.15	0.230	0.230	0.231	0.231	0.231	0.231	0.232	0.232
		Avg	**7.24**	**6.60**	**5.95**	**5.34**	**4.79**	**4.27**	**3.80**	**3.38**	**0.159**	**0.163**	**0.168**	**0.173**	**0.177**	**0.182**	**0.187**	**0.191**
		StdDev	**2.74**	**2.72**	**2.67**	**2.61**	**2.51**	**2.39**	**2.25**	**2.11**	**0.057**	**0.054**	**0.052**	**0.050**	**0.050**	**0.049**	**0.050**	**0.051**

Table A.48 *BBR* Mixture Data for M48-Hwy 45/E3-R1.81-A7

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	6.52	6.00	5.46	4.97	4.51	4.08	3.69	3.33	0.132	0.134	0.137	0.139	0.142	0.144	0.147	0.149
-		2	7.85	7.00	6.13	5.32	4.58	3.92	3.32	2.80	0.177	0.187	0.198	0.209	0.221	0.232	0.243	0.254
-		3	6.38	5.59	4.80	4.11	3.49	2.95	2.48	2.07	0.207	0.214	0.222	0.230	0.239	0.247	0.255	0.263
-		4	9.31	8.61	7.84	7.07	6.33	5.62	4.95	4.32	0.119	0.130	0.142	0.154	0.166	0.178	0.190	0.202
-		5	5.44	4.69	3.99	3.39	2.88	2.45	2.08	1.77	0.236	0.236	0.235	0.235	0.234	0.234	0.233	0.233
-		6	9.91	9.45	8.92	8.37	7.81	7.25	6.69	6.14	0.072	0.079	0.087	0.096	0.104	0.112	0.120	0.128
-		7	5.36	4.70	4.06	3.51	3.03	2.62	2.26	1.95	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211
-		8	5.54	5.18	4.82	4.48	4.17	3.88	3.62	3.37	0.106	0.105	0.105	0.104	0.103	0.103	0.102	0.101
-		9	7.71	6.95	6.17	5.47	4.83	4.26	3.74	3.28	0.164	0.168	0.172	0.177	0.181	0.185	0.189	0.193
-		10	12.36	11.24	10.07	8.95	7.91	6.93	6.04	5.23	0.146	0.155	0.164	0.174	0.184	0.194	0.204	0.214
-		11	6.85	6.16	5.45	4.80	4.19	3.64	3.14	2.69	0.163	0.171	0.181	0.190	0.199	0.209	0.218	0.227
		Avg	**7.57**	**6.87**	**6.16**	**5.49**	**4.88**	**4.33**	**3.82**	**3.36**	**0.158**	**0.163**	**0.169**	**0.174**	**0.180**	**0.186**	**0.192**	**0.198**
		StdDev	**2.19**	**2.10**	**1.99**	**1.87**	**1.74**	**1.62**	**1.50**	**1.38**	**0.049**	**0.048**	**0.047**	**0.047**	**0.048**	**0.049**	**0.050**	**0.052**

Table A.49 *BBR* Mixture Data for M49-Hwy 45/E3-R1.81-A14

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.29	5.02	4.69	4.35	4.01	3.66	3.31	2.97	0.080	0.091	0.102	0.114	0.126	0.138	0.150	0.161
-		2	3.99	3.68	3.37	3.08	2.81	2.56	2.33	2.12	0.125	0.127	0.129	0.131	0.133	0.135	0.137	0.140
-		3	5.42	4.96	4.49	4.05	3.64	3.26	2.91	2.59	0.137	0.141	0.146	0.152	0.157	0.162	0.167	0.172
-		4	7.72	7.14	6.51	5.90	5.30	4.73	4.19	3.68	0.118	0.128	0.138	0.149	0.159	0.170	0.181	0.191
-		5	3.21	2.67	2.18	1.78	1.45	1.18	0.96	0.79	0.293	0.293	0.293	0.293	0.293	0.294	0.294	0.294
-		6	0.75	0.73	0.72	0.70	0.68	0.66	0.63	0.61	0.026	0.030	0.035	0.040	0.044	0.049	0.054	0.059
-		7	2.44	2.31	2.15	1.98	1.82	1.65	1.49	1.33	0.086	0.097	0.109	0.120	0.132	0.144	0.156	0.167
-		8	6.45	5.90	5.34	4.81	4.33	3.88	3.47	3.09	0.139	0.143	0.147	0.152	0.156	0.160	0.164	0.168
-		9	0.41	0.41	0.40	0.40	0.39	0.39	0.38	0.37	0.010	0.013	0.016	0.019	0.022	0.025	0.028	0.031
		Avg	**3.96**	**3.65**	**3.32**	**3.01**	**2.71**	**2.44**	**2.19**	**1.95**	**0.113**	**0.118**	**0.124**	**0.130**	**0.136**	**0.142**	**0.148**	**0.154**
		StdDev	**2.50**	**2.31**	**2.11**	**1.91**	**1.72**	**1.54**	**1.38**	**1.21**	**0.082**	**0.081**	**0.079**	**0.078**	**0.077**	**0.077**	**0.076**	**0.076**

Table A.50 *BBR* Mixture Data for M50-Hwy 45/E3-R1.81-A30

			Test Time (sec) and Mixture Stiffness (GPa)								**Test Time (sec) and Mixture m-value**							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	6.41	5.81	5.18	4.59	4.04	3.54	3.07	2.65	0.151	0.160	0.170	0.179	0.189	0.199	0.208	0.218
-		2	7.32	6.73	6.16	5.66	5.23	4.86	4.54	4.27	0.139	0.132	0.124	0.117	0.109	0.102	0.095	0.087
-		3	6.59	5.83	5.03	4.28	3.59	2.97	2.43	1.96	0.186	0.204	0.223	0.243	0.263	0.282	0.302	0.321
-		4	7.03	6.50	5.94	5.40	4.89	4.42	3.97	3.55	0.123	0.128	0.134	0.140	0.145	0.151	0.157	0.163
-		5	9.45	9.09	8.65	8.17	7.65	7.11	6.55	5.99	0.056	0.066	0.077	0.089	0.100	0.112	0.123	0.135
-		6	8.86	8.28	7.66	7.07	6.51	5.98	5.48	5.01	0.107	0.111	0.114	0.117	0.121	0.124	0.128	0.131
-		7	11.26	10.67	9.99	9.28	8.57	7.85	7.14	6.45	0.080	0.090	0.100	0.111	0.121	0.131	0.142	0.152
-		8	4.43	3.86	3.30	2.79	2.33	1.94	1.60	1.30	0.211	0.223	0.236	0.249	0.262	0.274	0.287	0.300
-		9	9.05	8.26	7.42	6.62	5.86	5.15	4.50	3.90	0.141	0.150	0.160	0.170	0.181	0.191	0.201	0.211
		Avg	**7.82**	**7.23**	**6.59**	**5.98**	**5.41**	**4.87**	**4.36**	**3.90**	**0.133**	**0.140**	**0.149**	**0.157**	**0.166**	**0.174**	**0.183**	**0.191**
		StdDev	**2.03**	**2.05**	**2.05**	**2.02**	**1.98**	**1.92**	**1.84**	**1.75**	**0.049**	**0.051**	**0.054**	**0.058**	**0.063**	**0.068**	**0.073**	**0.079**

Table A.51 *BBR* Mixture Data for M51-Hwy 45/E3-R1.81-A45

			Test Time (sec) and Mixture Stiffness (GPa)								**Test Time (sec) and Mixture m-value**							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	5.23	4.71	4.17	3.66	3.19	2.76	2.37	2.02	0.162	0.171	0.182	0.193	0.204	0.215	0.226	0.236
-		2	3.88	3.39	2.92	2.51	2.16	1.85	1.59	1.36	0.214	0.215	0.217	0.218	0.220	0.222	0.223	0.225
-		3	7.56	5.67	4.37	3.57	3.09	2.84	2.76	2.85	0.495	0.419	0.334	0.250	0.166	0.082	-0.003	-0.087
-		4	7.24	6.47	5.68	4.93	4.25	3.64	3.08	2.59	0.173	0.184	0.196	0.208	0.220	0.232	0.244	0.256
-		5	7.49	7.02	6.45	5.84	5.21	4.58	3.96	3.38	0.093	0.112	0.133	0.154	0.175	0.197	0.218	0.239
-		6	4.08	3.57	3.05	2.59	2.17	1.80	1.49	1.21	0.207	0.219	0.233	0.246	0.260	0.273	0.287	0.300
-		7	5.33	4.67	4.02	3.45	2.95	2.52	2.14	1.82	0.209	0.213	0.218	0.222	0.227	0.231	0.236	0.240
		Avg	**5.83**	**5.07**	**4.38**	**3.79**	**3.29**	**2.86**	**2.48**	**2.18**	**0.222**	**0.219**	**0.216**	**0.213**	**0.210**	**0.207**	**0.204**	**0.201**
		StdDev	**1.59**	**1.38**	**1.29**	**1.21**	**1.10**	**0.99**	**0.87**	**0.80**	**0.128**	**0.096**	**0.061**	**0.033**	**0.032**	**0.060**	**0.094**	**0.129**

Table A.52 *BBR* Mixture Data for M52-Hwy 45/E3-R1.81-A60

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
-	A	1	2.51	1.95	1.53	1.24	1.04	0.91	0.82	0.76	0.423	0.377	0.326	0.276	0.226	0.175	0.125	0.074
-		2	10.14	9.57	8.88	8.14	7.38	6.62	5.87	5.14	0.085	0.100	0.116	0.133	0.149	0.166	0.182	0.199
-		3	5.00	4.33	3.68	3.12	2.64	2.23	1.88	1.58	0.228	0.232	0.235	0.239	0.243	0.247	0.250	0.254
-		4	4.83	4.67	4.50	4.32	4.15	3.97	3.80	3.64	0.053	0.055	0.057	0.058	0.060	0.062	0.064	0.066
-		5	10.15	9.45	8.64	7.81	6.99	6.18	5.40	4.67	0.106	0.121	0.137	0.153	0.169	0.186	0.202	0.218
-		6	4.52	3.97	3.41	2.89	2.42	2.00	1.64	1.32	0.197	0.213	0.230	0.247	0.264	0.281	0.298	0.315
-		7	9.66	8.93	8.20	7.53	6.92	6.37	5.86	5.40	0.126	0.124	0.123	0.122	0.121	0.120	0.119	0.117
		8	5.20	4.65	4.08	3.56	3.08	2.65	2.26	1.92	0.174	0.183	0.193	0.203	0.212	0.222	0.232	0.242
		Avg	**6.50**	**5.94**	**5.37**	**4.83**	**4.33**	**3.87**	**3.44**	**3.05**	**0.174**	**0.176**	**0.177**	**0.179**	**0.181**	**0.182**	**0.184**	**0.186**
		StdDev	**3.00**	**2.93**	**2.80**	**2.63**	**2.45**	**2.25**	**2.06**	**1.87**	**0.116**	**0.101**	**0.086**	**0.075**	**0.069**	**0.070**	**0.078**	**0.090**

Table A.53 *BBR* Mixture Data for M53-Hwy 45/E3a-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	11.64	10.80	9.89	9.00	8.15	7.34	6.57	5.85	0.116	0.123	0.131	0.139	0.147	0.155	0.163	0.171
1	B2	2	4.95	4.90	4.86	4.83	4.81	4.79	4.78	4.77	0.014	0.013	0.011	0.009	0.007	0.005	0.002	0.000
1	B3	3	4.13	3.95	3.75	3.55	3.34	3.13	2.93	2.73	0.068	0.073	0.078	0.084	0.089	0.095	0.100	0.106
1	B5	4	5.99	5.35	4.68	4.07	3.50	2.99	2.54	2.13	0.175	0.186	0.198	0.209	0.221	0.233	0.245	0.256
2	B1	5	3.33	2.91	2.50	2.15	1.83	1.56	1.33	1.13	0.213	0.216	0.220	0.224	0.227	0.231	0.235	0.239
2	B2	6	7.14	6.71	6.31	5.97	5.68	5.45	5.26	5.11	0.103	0.094	0.085	0.075	0.065	0.056	0.046	0.037
2	B3	7	6.00	5.26	4.57	3.99	3.50	3.09	2.73	2.43	0.213	0.206	0.199	0.192	0.185	0.178	0.171	0.164
2	B4	8	7.02	6.54	6.03	5.55	5.10	4.66	4.25	3.87	0.110	0.114	0.118	0.122	0.126	0.130	0.134	0.138
3	B2	9	4.45	3.85	3.28	2.80	2.39	2.05	1.75	1.50	0.232	0.231	0.229	0.228	0.227	0.225	0.224	0.222
3	B3	10	8.00	7.23	6.48	5.80	5.20	4.66	4.19	3.76	0.161	0.160	0.159	0.158	0.157	0.156	0.155	0.154
4	B2	11	5.42	5.11	4.76	4.40	4.04	3.69	3.34	3.00	0.088	0.098	0.108	0.118	0.128	0.138	0.148	0.159
4	B4	12	6.54	6.02	5.46	4.91	4.40	3.92	3.46	3.04	0.129	0.137	0.146	0.155	0.164	0.173	0.182	0.191
5	B2	13	3.91	3.68	3.46	3.27	3.10	2.95	2.82	2.71	0.098	0.092	0.086	0.080	0.073	0.067	0.061	0.054

Table A.53 Continued

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa) 8	15	30	60	120	240	480	960	Test Time (sec) and Mixture m-value 8	15	30	60	120	240	480	960
5	B3	14	11.37	10.80	10.17	9.54	8.91	8.29	7.69	7.10	0.079	0.084	0.090	0.095	0.101	0.106	0.112	0.118
5	B4	15	8.67	8.30	7.84	7.35	6.83	6.30	5.76	5.22	0.064	0.075	0.087	0.099	0.111	0.124	0.136	0.148
5	B5	16	7.21	6.88	6.49	6.08	5.66	5.23	4.81	4.39	0.071	0.080	0.089	0.099	0.108	0.117	0.127	0.136
6	B2	17	8.63	8.16	7.61	7.05	6.49	5.93	5.38	4.84	0.086	0.095	0.105	0.115	0.125	0.135	0.146	0.156
6	B4	18	5.24	4.62	4.01	3.48	3.02	2.61	2.26	1.96	0.202	0.203	0.204	0.205	0.207	0.208	0.209	0.210
6	B5	19	5.18	4.62	4.06	3.55	3.10	2.69	2.33	2.01	0.180	0.185	0.190	0.195	0.201	0.206	0.211	0.216
7	B3	20	4.60	3.97	3.36	2.83	2.37	1.98	1.64	1.36	0.230	0.236	0.243	0.251	0.258	0.265	0.272	0.280
7	B4	21	2.78	2.36	1.96	1.63	1.35	1.12	0.93	0.77	0.263	0.265	0.267	0.268	0.270	0.272	0.274	0.276
8	B3	22	4.04	3.59	3.15	2.76	2.41	2.11	1.83	1.59	0.185	0.187	0.190	0.193	0.195	0.198	0.201	0.203
8	B5	23	3.05	2.66	2.28	1.95	1.66	1.41	1.19	1.00	0.214	0.219	0.224	0.230	0.235	0.241	0.246	0.251
9	B4	24	4.60	4.04	3.50	3.02	2.61	2.24	1.92	1.64	0.202	0.206	0.209	0.213	0.217	0.221	0.224	0.228
10	B5	25	4.84	4.52	4.17	3.81	3.45	3.10	2.76	2.44	0.102	0.112	0.124	0.136	0.148	0.160	0.172	0.184
		Avg	**5.95**	**5.47**	**4.99**	**4.53**	**4.12**	**3.73**	**3.38**	**3.05**	**0.144**	**0.148**	**0.152**	**0.156**	**0.160**	**0.164**	**0.168**	**0.172**
		StdDev	**2.34**	**2.26**	**2.18**	**2.09**	**1.99**	**1.89**	**1.79**	**1.69**	**0.067**	**0.066**	**0.066**	**0.066**	**0.067**	**0.068**	**0.070**	**0.072**

Table A.54 *BBR* Mixture Data for M54-Hwy 45/E3a-R1.81-A7

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	5.02	4.42	3.80	3.24	2.74	2.29	1.90	1.56	0.197	0.209	0.223	0.236	0.250	0.264	0.277	0.291
1	B3	2	7.17	6.72	6.28	5.90	5.57	5.27	5.02	4.79	0.106	0.100	0.094	0.088	0.081	0.075	0.069	0.062
1	B4	3	4.35	4.03	3.68	3.35	3.04	2.75	2.48	2.22	0.121	0.126	0.132	0.137	0.143	0.148	0.154	0.160
2	B1	4	3.39	3.31	3.21	3.10	2.97	2.84	2.70	2.55	0.034	0.040	0.048	0.055	0.062	0.070	0.077	0.085
2	B4	5	2.32	2.17	2.00	1.82	1.65	1.48	1.31	1.16	0.101	0.113	0.126	0.138	0.151	0.164	0.176	0.189
2	B5	6	2.67	2.53	2.35	2.17	1.99	1.80	1.61	1.43	0.081	0.094	0.108	0.122	0.137	0.151	0.165	0.180
3	B1	7	6.18	5.79	5.35	4.92	4.49	4.08	3.68	3.30	0.101	0.109	0.118	0.127	0.135	0.144	0.153	0.162
3	B4	8	9.70	8.90	8.12	7.43	6.83	6.29	5.82	5.40	0.140	0.135	0.130	0.125	0.120	0.115	0.110	0.105
4	B1	9	2.85	2.70	2.53	2.33	2.13	1.92	1.72	1.52	0.075	0.090	0.106	0.122	0.139	0.155	0.171	0.188
4	B3	10	3.32	3.20	3.06	2.92	2.78	2.64	2.50	2.36	0.059	0.062	0.066	0.069	0.073	0.077	0.080	0.084
4	B4	11	2.80	2.63	2.42	2.21	1.99	1.78	1.56	1.36	0.094	0.109	0.125	0.142	0.158	0.174	0.191	0.207
5	B1	12	2.01	1.95	1.88	1.79	1.70	1.60	1.50	1.40	0.043	0.052	0.062	0.071	0.081	0.090	0.100	0.110
5	B2	13	3.39	3.29	3.18	3.06	2.93	2.80	2.66	2.52	0.042	0.047	0.053	0.059	0.065	0.070	0.076	0.082

Table A.54 Continued

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
5	B3	14	2.72	2.57	2.41	2.24	2.08	1.92	1.76	1.60	0.084	0.091	0.099	0.106	0.114	0.121	0.129	0.136
5	B4	15	2.99	2.84	2.66	2.47	2.27	2.06	1.85	1.64	0.072	0.086	0.101	0.116	0.132	0.147	0.162	0.177
6	B1	16	3.12	3.02	2.92	2.82	2.73	2.64	2.56	2.48	0.050	0.050	0.049	0.048	0.048	0.047	0.046	0.046
6	B5	17	2.81	2.71	2.59	2.45	2.30	2.15	1.99	1.83	0.051	0.061	0.072	0.083	0.094	0.106	0.117	0.128
7	B1	18	3.11	3.00	2.88	2.76	2.64	2.53	2.41	2.30	0.056	0.058	0.060	0.062	0.065	0.067	0.069	0.071
7	B2	19	2.22	2.02	1.84	1.69	1.59	1.50	1.44	1.41	0.163	0.145	0.126	0.106	0.087	0.067	0.048	0.028
7	B3	20	2.30	2.20	2.06	1.90	1.73	1.55	1.37	1.19	0.064	0.083	0.105	0.126	0.147	0.169	0.190	0.212
8	B2	21	2.75	2.68	2.59	2.50	2.39	2.27	2.15	2.02	0.036	0.043	0.051	0.059	0.068	0.076	0.084	0.092
8	B4	22	2.60	2.46	2.28	2.09	1.90	1.70	1.51	1.32	0.085	0.100	0.116	0.133	0.149	0.165	0.182	0.198
8	B5	23	3.57	3.43	3.26	3.08	2.88	2.68	2.47	2.26	0.058	0.068	0.079	0.090	0.101	0.112	0.123	0.134
9	B3	24	2.47	2.39	2.29	2.17	2.04	1.90	1.76	1.62	0.047	0.058	0.070	0.082	0.094	0.107	0.119	0.131
9	B4	25	3.05	3.00	2.93	2.85	2.75	2.63	2.51	2.38	0.020	0.029	0.038	0.047	0.056	0.066	0.075	0.084
9	B5	26	2.61	2.55	2.48	2.39	2.30	2.21	2.10	2.00	0.035	0.040	0.046	0.052	0.059	0.065	0.071	0.077
10	B4	27	3.74	3.68	3.60	3.52	3.45	3.38	3.31	3.24	0.030	0.030	0.030	0.030	0.031	0.031	0.031	0.031
10	B5	28	3.61	3.55	3.48	3.41	3.34	3.26	3.19	3.11	0.027	0.028	0.029	0.031	0.032	0.033	0.034	0.036
		Avg	**3.53**	**3.35**	**3.15**	**2.95**	**2.76**	**2.57**	**2.39**	**2.21**	**0.074**	**0.081**	**0.088**	**0.095**	**0.103**	**0.110**	**0.117**	**0.125**
		StdDev	**1.67**	**1.52**	**1.38**	**1.27**	**1.18**	**1.11**	**1.06**	**1.02**	**0.043**	**0.042**	**0.042**	**0.045**	**0.048**	**0.053**	**0.059**	**0.065**

Table A.55 *BBR* Mixture Data for M55-Hwy 45/E3a-R1.81-A30

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	4.45	4.14	3.80	3.48	3.17	2.87	2.59	2.32	0.112	0.118	0.125	0.132	0.139	0.145	0.152	0.159
1	B2	2	6.32	5.61	4.98	4.47	4.06	3.73	3.46	3.26	0.196	0.181	0.164	0.147	0.131	0.114	0.097	0.081
1	B5	3	12.64	11.58	10.46	9.39	8.37	7.41	6.52	5.70	0.134	0.142	0.152	0.161	0.170	0.180	0.189	0.198
2	B1	4	8.83	8.30	7.64	6.94	6.21	5.49	4.78	4.10	0.090	0.109	0.129	0.149	0.170	0.190	0.210	0.231
2	B2	5	4.94	4.27	3.66	3.14	2.71	2.35	2.04	1.78	0.232	0.227	0.222	0.216	0.211	0.205	0.200	0.195
2	B3	6	4.09	3.63	3.17	2.75	2.38	2.04	1.75	1.48	0.186	0.193	0.200	0.208	0.215	0.223	0.230	0.237
2	B4	7	2.55	2.18	1.88	1.66	1.49	1.38	1.30	1.26	0.263	0.233	0.199	0.166	0.132	0.098	0.065	0.031
2	B5	8	5.55	5.29	5.02	4.75	4.49	4.25	4.01	3.78	0.075	0.076	0.078	0.080	0.081	0.083	0.084	0.086
3	B1	9	6.50	5.96	5.38	4.83	4.30	3.81	3.35	2.92	0.133	0.142	0.152	0.162	0.171	0.181	0.191	0.201
3	B3	10	4.72	4.39	4.01	3.63	3.24	2.87	2.51	2.18	0.108	0.122	0.137	0.153	0.168	0.184	0.199	0.215
3	B4	11	8.40	8.08	7.72	7.34	6.96	6.58	6.19	5.80	0.059	0.064	0.069	0.074	0.080	0.085	0.090	0.096
4	B2	12	5.54	4.91	4.28	3.70	3.19	2.72	2.32	1.96	0.187	0.195	0.204	0.213	0.222	0.230	0.239	0.248
		Avg	**6.21**	**5.70**	**5.17**	**4.67**	**4.21**	**3.79**	**3.40**	**3.05**	**0.148**	**0.150**	**0.153**	**0.155**	**0.158**	**0.160**	**0.162**	**0.165**
		StdDev	**2.68**	**2.54**	**2.37**	**2.20**	**2.02**	**1.85**	**1.69**	**1.54**	**0.064**	**0.056**	**0.049**	**0.046**	**0.047**	**0.053**	**0.062**	**0.073**

Table A.56 *BBR* Mixture Data for M56-Hwy 45/E3a-R1.81-A60

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	4.33	4.16	3.96	3.76	3.56	3.37	3.18	2.99	0.065	0.068	0.072	0.076	0.080	0.083	0.087	0.091
1	B2	2	3.42	3.07	2.72	2.39	2.10	1.84	1.60	1.39	0.170	0.175	0.180	0.186	0.191	0.197	0.202	0.208
1	B3	3	8.81	8.34	7.82	7.29	6.76	6.23	5.72	5.22	0.083	0.090	0.098	0.105	0.113	0.120	0.128	0.136
2	B1	4	6.08	5.53	4.95	4.41	3.91	3.45	3.04	2.65	0.150	0.156	0.163	0.170	0.176	0.183	0.190	0.197
2	B2	5	10.64	9.96	9.20	8.46	7.75	7.05	6.39	5.75	0.103	0.110	0.117	0.124	0.132	0.139	0.147	0.154
2	B4	6	6.56	6.11	5.60	5.09	4.59	4.10	3.64	3.20	0.109	0.120	0.132	0.143	0.155	0.167	0.179	0.190
2	B5	7	10.51	9.68	8.82	8.01	7.25	6.54	5.88	5.27	0.127	0.132	0.137	0.141	0.146	0.151	0.156	0.161
3	B1	8	7.05	6.69	6.24	5.74	5.22	4.68	4.14	3.61	0.075	0.092	0.110	0.129	0.148	0.167	0.186	0.205
3	B3	9	8.54	8.07	7.56	7.04	6.53	6.02	5.53	5.06	0.086	0.092	0.099	0.106	0.112	0.119	0.126	0.133
4	B2	10	1.78	1.76	1.73	1.69	1.65	1.60	1.54	1.48	0.018	0.024	0.030	0.036	0.041	0.047	0.053	0.059
4	B3	11	5.86	5.34	4.86	4.46	4.13	3.85	3.62	3.43	0.152	0.141	0.130	0.118	0.107	0.095	0.084	0.072
4	B5	12	3.07	2.99	2.90	2.80	2.69	2.57	2.44	2.31	0.036	0.042	0.049	0.055	0.062	0.069	0.076	0.083
		Avg	**6.39**	**5.98**	**5.53**	**5.10**	**4.68**	**4.28**	**3.89**	**3.53**	**0.098**	**0.104**	**0.110**	**0.116**	**0.122**	**0.128**	**0.135**	**0.141**
		StdDev	**2.89**	**2.68**	**2.46**	**2.25**	**2.05**	**1.85**	**1.67**	**1.50**	**0.047**	**0.045**	**0.044**	**0.044**	**0.045**	**0.047**	**0.050**	**0.054**

Table A.57 *BBR* Mixture Data for M57-FR/E3-R0.91-A7

			Test Time (sec) and Mixture Stiffness (GPa)								**Test Time (sec) and Mixture m-value**							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	9.12	8.49	7.81	7.16	6.53	5.92	5.35	4.81	0.110	0.116	0.123	0.130	0.137	0.144	0.151	0.157
1	B2	2	8.19	7.83	7.41	6.96	6.49	6.02	5.54	5.06	0.067	0.075	0.085	0.095	0.105	0.115	0.125	0.135
1	B3	3	5.45	5.07	4.63	4.19	3.76	3.35	2.95	2.58	0.112	0.124	0.137	0.150	0.163	0.176	0.189	0.202
1	B5	4	7.24	6.33	5.54	4.93	4.45	4.08	3.79	3.58	0.222	0.203	0.181	0.159	0.137	0.115	0.093	0.071
2	B1	5	4.52	4.29	4.02	3.74	3.45	3.15	2.86	2.57	0.078	0.088	0.100	0.111	0.123	0.134	0.146	0.157
2	B2	6	4.53	4.16	3.75	3.36	2.98	2.63	2.30	1.99	0.132	0.142	0.154	0.165	0.177	0.188	0.200	0.211
2	B3	7	6.35	5.60	4.83	4.13	3.51	2.95	2.45	2.03	0.194	0.206	0.219	0.231	0.244	0.257	0.270	0.283
2	B4	8	9.01	8.33	7.59	6.86	6.17	5.50	4.87	4.29	0.120	0.130	0.140	0.150	0.160	0.170	0.180	0.190
2	B5	9	6.20	5.54	4.87	4.26	3.70	3.20	2.75	2.35	0.175	0.183	0.191	0.199	0.207	0.215	0.223	0.231
		Avg	**6.73**	**6.18**	**5.61**	**5.07**	**4.56**	**4.09**	**3.65**	**3.25**	**0.134**	**0.141**	**0.148**	**0.154**	**0.161**	**0.168**	**0.175**	**0.182**
		StdDev	**1.77**	**1.67**	**1.59**	**1.51**	**1.43**	**1.36**	**1.28**	**1.21**	**0.052**	**0.047**	**0.043**	**0.042**	**0.043**	**0.047**	**0.053**	**0.061**

Table A.58 *BBR* Mixture Data for M58-FR/E3-R1.36-A7

			Test Time (sec) and Mixture Stiffness (GPa)								**Test Time (sec) and Mixture m-value**							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	9.01	8.59	8.07	7.52	6.95	6.35	5.76	5.17	0.070	0.082	0.095	0.109	0.122	0.135	0.148	0.162
1	B3	2	4.63	4.14	3.64	3.17	2.75	2.37	2.03	1.72	0.174	0.182	0.192	0.201	0.210	0.220	0.229	0.238
1	B5	3	12.02	10.79	9.55	8.44	7.44	6.54	5.73	5.02	0.171	0.174	0.177	0.181	0.184	0.187	0.191	0.194
2	B1	4	8.40	7.60	6.84	6.18	5.61	5.12	4.70	4.33	0.162	0.156	0.149	0.142	0.135	0.128	0.121	0.114
2	B2	5	8.01	7.60	7.15	6.70	6.26	5.82	5.40	4.99	0.081	0.086	0.091	0.096	0.101	0.106	0.112	0.117
2	B3	6	8.59	7.83	6.99	6.17	5.39	4.65	3.97	3.35	0.141	0.156	0.172	0.188	0.204	0.220	0.236	0.252
2	B4	7	10.11	9.68	9.20	8.72	8.25	7.78	7.31	6.85	0.067	0.071	0.075	0.079	0.083	0.087	0.091	0.095
2	B5	8	9.29	8.42	7.53	6.70	5.95	5.26	4.63	4.06	0.154	0.159	0.164	0.170	0.175	0.181	0.186	0.191
		Avg	**8.76**	**8.08**	**7.37**	**6.70**	**6.08**	**5.49**	**4.94**	**4.44**	**0.128**	**0.133**	**0.139**	**0.146**	**0.152**	**0.158**	**0.164**	**0.170**
		StdDev	**2.09**	**1.94**	**1.81**	**1.72**	**1.65**	**1.60**	**1.54**	**1.50**	**0.047**	**0.045**	**0.045**	**0.046**	**0.048**	**0.051**	**0.054**	**0.059**

Table A.59 *BBR* Mixture Data for M59-FR/E3-R1.81-A7

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa) 8	15	30	60	120	240	480	960	Test Time (sec) and Mixture m-value 8	15	30	60	120	240	480	960
1	B1	1	8.31	7.47	6.65	5.94	5.31	4.77	4.29	3.87	0.172	0.169	0.165	0.162	0.158	0.154	0.151	0.147
1	B3	2	4.57	4.11	3.68	3.33	3.04	2.80	2.61	2.46	0.178	0.165	0.151	0.137	0.124	0.110	0.096	0.082
1	B4	3	6.37	5.62	4.86	4.18	3.58	3.05	2.58	2.17	0.196	0.204	0.212	0.221	0.229	0.238	0.246	0.255
1	B5	4	6.90	6.23	5.56	4.96	4.41	3.92	3.48	3.08	0.160	0.162	0.165	0.167	0.169	0.172	0.174	0.177
2	B2	5	5.15	4.73	4.29	3.87	3.48	3.10	2.76	2.44	0.131	0.137	0.145	0.152	0.159	0.167	0.174	0.181
2	B3	6	5.48	5.23	4.94	4.64	4.33	4.02	3.70	3.40	0.070	0.078	0.086	0.095	0.104	0.112	0.121	0.129
2	B4	7	6.15	5.50	4.83	4.21	3.64	3.12	2.66	2.25	0.173	0.183	0.193	0.204	0.215	0.226	0.237	0.248
		Avg	**6.13**	**5.56**	**4.97**	**4.45**	**3.97**	**3.54**	**3.15**	**2.81**	**0.154**	**0.157**	**0.160**	**0.163**	**0.165**	**0.168**	**0.171**	**0.174**
		StdDev	**1.24**	**1.08**	**0.94**	**0.84**	**0.76**	**0.71**	**0.67**	**0.65**	**0.042**	**0.040**	**0.040**	**0.042**	**0.045**	**0.050**	**0.056**	**0.062**

Table A.60 *BBR* Mixture Data for M60-FR/E1-R0.91-A7

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa) 8	15	30	60	120	240	480	960	Test Time (sec) and Mixture m-value 8	15	30	60	120	240	480	960
1	B1	1	4.43	4.04	3.61	3.19	2.78	2.40	2.05	1.73	0.139	0.154	0.171	0.187	0.204	0.220	0.236	0.253
1	B2	2	7.65	7.27	6.84	6.39	5.93	5.47	5.01	4.56	0.076	0.085	0.094	0.103	0.112	0.121	0.131	0.140
1	B4	3	3.09	3.00	2.90	2.80	2.70	2.60	2.50	2.41	0.046	0.048	0.050	0.052	0.053	0.055	0.057	0.058
1	B5	4	6.39	6.05	5.65	5.25	4.85	4.45	4.05	3.67	0.085	0.093	0.102	0.111	0.120	0.129	0.138	0.147
2	B1	5	8.40	8.00	7.50	6.96	6.40	5.82	5.25	4.68	0.072	0.085	0.100	0.114	0.129	0.143	0.158	0.172
2	B3	6	5.73	5.22	4.69	4.20	3.74	3.31	2.92	2.57	0.145	0.151	0.157	0.164	0.171	0.177	0.184	0.191
2	B4	7	8.59	8.12	7.58	7.00	6.41	5.81	5.22	4.65	0.082	0.094	0.107	0.121	0.134	0.147	0.161	0.174
2	B5	8	6.09	5.50	4.88	4.30	3.76	3.25	2.80	2.39	0.156	0.166	0.178	0.189	0.201	0.212	0.223	0.235
		Avg	**6.30**	**5.90**	**5.46**	**5.01**	**4.57**	**4.14**	**3.73**	**3.33**	**0.100**	**0.110**	**0.120**	**0.130**	**0.141**	**0.151**	**0.161**	**0.171**
		StdDev	**1.91**	**1.84**	**1.75**	**1.65**	**1.54**	**1.43**	**1.32**	**1.20**	**0.041**	**0.042**	**0.044**	**0.047**	**0.050**	**0.053**	**0.056**	**0.060**

Table A.61 *BBR* Mixture Data for M61-FR/E1-R1.36-A7

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	6.83	6.25	5.65	5.09	4.56	4.07	3.62	3.21	0.137	0.143	0.149	0.155	0.161	0.167	0.173	0.179
1	B2	2	6.76	6.39	5.96	5.51	5.05	4.59	4.14	3.70	0.084	0.095	0.107	0.119	0.131	0.144	0.156	0.168
1	B3	3	5.36	4.96	4.52	4.08	3.65	3.25	2.86	2.50	0.118	0.129	0.141	0.153	0.165	0.177	0.189	0.201
1	B4	4	7.55	6.92	6.24	5.58	4.94	4.33	3.77	3.25	0.132	0.144	0.156	0.169	0.182	0.194	0.207	0.220
2	B1	5	9.11	8.57	8.03	7.54	7.09	6.68	6.30	5.96	0.097	0.095	0.092	0.090	0.088	0.085	0.083	0.080
2	B2	6	7.23	6.68	6.07	5.47	4.89	4.33	3.80	3.30	0.120	0.131	0.144	0.157	0.169	0.182	0.195	0.207
2	B3	7	6.97	6.48	5.92	5.38	4.85	4.33	3.84	3.38	0.113	0.123	0.134	0.145	0.156	0.167	0.178	0.190
2	B4	8	3.86	3.47	3.07	2.70	2.36	2.04	1.76	1.50	0.163	0.172	0.181	0.191	0.201	0.211	0.221	0.231
		Avg	**6.71**	**6.22**	**5.68**	**5.17**	**4.67**	**4.20**	**3.76**	**3.35**	**0.121**	**0.129**	**0.138**	**0.147**	**0.157**	**0.166**	**0.175**	**0.185**
		StdDev	**1.55**	**1.49**	**1.43**	**1.38**	**1.34**	**1.31**	**1.28**	**1.26**	**0.024**	**0.026**	**0.028**	**0.031**	**0.034**	**0.038**	**0.042**	**0.047**

Table A.62 *BBR* Mixture Data for M62-FR/E1-R1.81-A7

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	6.77	6.27	5.75	5.28	4.84	4.44	4.06	3.72	0.122	0.123	0.124	0.125	0.125	0.126	0.127	0.128
1	B2	2	7.55	6.80	6.05	5.36	4.74	4.18	3.67	3.22	0.164	0.167	0.172	0.176	0.180	0.184	0.188	0.193
1	B3	3	8.69	8.13	7.52	6.91	6.31	5.73	5.18	4.65	0.102	0.110	0.118	0.126	0.134	0.143	0.151	0.159
1	B4	4	7.73	7.37	6.97	6.58	6.20	5.82	5.46	5.10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	B1	5	9.21	8.64	8.03	7.44	6.88	6.34	5.82	5.34	0.101	0.104	0.108	0.112	0.116	0.120	0.123	0.127
2	B3	6	10.01	9.47	8.96	8.55	8.21	7.95	7.75	7.61	0.094	0.084	0.074	0.063	0.052	0.042	0.031	0.020
2	B4	7	8.07	7.48	6.87	6.30	5.76	5.26	4.79	4.36	0.119	0.121	0.124	0.127	0.130	0.133	0.136	0.139
2	B5	8	10.10	9.51	8.87	8.24	7.62	7.02	6.44	5.89	0.093	0.098	0.104	0.109	0.115	0.121	0.127	0.133
		Avg	**8.52**	**7.96**	**7.38**	**6.83**	**6.32**	**5.84**	**5.40**	**4.99**	**0.099**	**0.101**	**0.103**	**0.105**	**0.107**	**0.109**	**0.110**	**0.112**
		StdDev	**1.20**	**1.19**	**1.20**	**1.21**	**1.23**	**1.26**	**1.31**	**1.37**	**0.046**	**0.048**	**0.050**	**0.052**	**0.055**	**0.059**	**0.063**	**0.067**

Table A.63 *BBR* Mixture Data for M63-FR/E2-R0.91-A7

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	4.12	3.81	3.51	3.23	2.97	2.74	2.54	2.35	0.124	0.123	0.121	0.119	0.117	0.115	0.113	0.111
1	B2	2	6.77	6.39	5.95	5.51	5.07	4.64	4.22	3.82	0.090	0.098	0.106	0.115	0.124	0.132	0.141	0.150
1	B3	3	8.34	7.62	6.84	6.10	5.39	4.72	4.11	3.54	0.138	0.149	0.161	0.172	0.184	0.196	0.208	0.219
1	B4	4	6.10	5.62	5.12	4.63	4.17	3.74	3.33	2.96	0.126	0.133	0.140	0.147	0.154	0.162	0.169	0.176
2	B3	5	2.02	1.95	1.87	1.78	1.68	1.58	1.48	1.37	0.051	0.059	0.067	0.076	0.084	0.093	0.101	0.110
2	B4	6	4.70	4.30	3.87	3.45	3.06	2.69	2.34	2.02	0.136	0.147	0.158	0.170	0.181	0.193	0.204	0.216
2	B5	7	6.60	6.10	5.55	5.00	4.46	3.95	3.46	3.01	0.119	0.131	0.144	0.157	0.170	0.183	0.196	0.209
		Avg	**5.52**	**5.11**	**4.67**	**4.24**	**3.83**	**3.44**	**3.07**	**2.72**	**0.112**	**0.120**	**0.128**	**0.137**	**0.145**	**0.153**	**0.162**	**0.170**
		StdDev	**2.08**	**1.89**	**1.69**	**1.50**	**1.32**	**1.15**	**1.00**	**0.86**	**0.031**	**0.032**	**0.033**	**0.035**	**0.038**	**0.041**	**0.044**	**0.048**

Table A.64 *BBR* Mixture Data for M64-FR/E2-R1.81-A7

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B2	1		3.68	3.41	3.13	2.86	2.60	2.35	2.12	1.90	0.115	0.121	0.128	0.134	0.141	0.148	0.155
1	B3	2		6.20	5.82	5.38	4.94	4.48	4.04	3.60	3.19	0.094	0.106	0.119	0.132	0.145	0.158	0.170
1	B5	3		4.26	3.96	3.61	3.26	2.91	2.57	2.25	1.94	0.112	0.125	0.141	0.156	0.171	0.186	0.202
2	B1	4		3.27	3.08	2.84	2.59	2.34	2.08	1.83	1.59	0.089	0.105	0.123	0.141	0.159	0.177	0.195
2	B5	5		3.88	3.50	3.09	2.70	2.33	1.99	1.68	1.40	0.158	0.172	0.188	0.204	0.220	0.236	0.252
		Avg		**4.26**	**3.95**	**3.61**	**3.27**	**2.93**	**2.61**	**2.30**	**2.00**	**0.114**	**0.126**	**0.140**	**0.153**	**0.167**	**0.181**	**0.195**
		StdDev		**1.14**	**1.09**	**1.03**	**0.97**	**0.90**	**0.83**	**0.76**	**0.70**	**0.027**	**0.027**	**0.028**	**0.030**	**0.032**	**0.034**	**0.037**

Table A.65 *BBR* Mixture Data for M65-Plant Mix/E0-R0.00-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	5.47	5.08	4.61	4.13	3.64	3.17	2.71	2.29	0.110	0.129	0.150	0.170	0.191	0.212	0.232	0.253
1	B2	2	4.30	4.07	3.77	3.45	3.11	2.77	2.43	2.10	0.081	0.099	0.119	0.139	0.159	0.179	0.199	0.219
1	B3	3	5.66	5.27	4.82	4.34	3.86	3.39	2.94	2.51	0.103	0.121	0.140	0.159	0.178	0.198	0.217	0.236
1	B4	4	7.01	6.56	6.01	5.41	4.80	4.20	3.61	3.05	0.095	0.115	0.138	0.161	0.184	0.207	0.229	0.252
1	B5	5	5.33	4.98	4.59	4.19	3.79	3.40	3.02	2.66	0.101	0.112	0.125	0.138	0.151	0.164	0.177	0.190
2	B1	6	2.90	2.67	2.36	2.02	1.67	1.33	1.02	0.76	0.106	0.152	0.202	0.252	0.302	0.352	0.402	0.452
2	B2	7	4.37	4.08	3.72	3.35	2.96	2.58	2.21	1.87	0.100	0.120	0.143	0.165	0.188	0.210	0.233	0.256
2	B3	8	3.93	3.74	3.50	3.24	2.95	2.65	2.35	2.06	0.068	0.086	0.105	0.124	0.143	0.163	0.182	0.201
2	B4	9	3.93	3.74	3.50	3.24	2.95	2.65	2.35	2.06	0.068	0.086	0.105	0.124	0.143	0.163	0.182	0.201
2	B5	10	4.44	4.21	3.91	3.59	3.24	2.89	2.54	2.21	0.077	0.095	0.115	0.135	0.155	0.175	0.195	0.215
3	B1	11	4.75	4.44	4.07	3.67	3.25	2.84	2.44	2.06	0.094	0.115	0.138	0.161	0.184	0.208	0.231	0.254
3	B2	12	3.57	3.30	2.98	2.66	2.34	2.03	1.74	1.47	0.116	0.134	0.154	0.174	0.194	0.214	0.234	0.255
3	B3	13	4.57	4.24	3.87	3.47	3.08	2.69	2.32	1.98	0.107	0.125	0.145	0.164	0.184	0.203	0.223	0.242
3	B4	14	5.00	4.62	4.17	3.71	3.24	2.78	2.36	1.96	0.114	0.136	0.159	0.182	0.206	0.229	0.253	0.276
3	B5	15	5.00	4.62	4.17	3.71	3.24	2.78	2.36	1.96	0.114	0.136	0.159	0.182	0.206	0.229	0.253	0.276

Table A.65 Continued

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
4	B1	16	5.25	4.89	4.49	4.11	3.73	3.38	3.04	2.71	0.111	0.118	0.126	0.134	0.141	0.149	0.157	0.165
4	B2	17	4.06	3.65	3.25	2.89	2.57	2.29	2.04	1.82	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168
4	B3	18	4.25	4.02	3.71	3.38	3.03	2.67	2.31	1.97	0.080	0.101	0.125	0.148	0.171	0.194	0.217	0.240
4	B4	19	5.77	5.40	4.95	4.47	3.98	3.50	3.03	2.58	0.096	0.115	0.136	0.157	0.177	0.198	0.219	0.239
4	B5	20	3.12	2.93	2.72	2.51	2.30	2.10	1.91	1.72	0.096	0.104	0.112	0.120	0.128	0.136	0.144	0.152
5	B1	21	5.38	4.99	4.57	4.17	3.79	3.43	3.09	2.78	0.118	0.123	0.129	0.135	0.141	0.147	0.152	0.158
5	B2	22	3.73	3.50	3.23	2.96	2.69	2.43	2.17	1.92	0.095	0.107	0.119	0.132	0.145	0.157	0.170	0.182
5	B3	23	4.76	4.34	3.83	3.29	2.77	2.27	1.82	1.42	0.132	0.164	0.198	0.233	0.268	0.303	0.337	0.372
5	B4	24	5.27	4.92	4.48	4.00	3.50	3.00	2.53	2.09	0.096	0.122	0.150	0.178	0.206	0.235	0.263	0.291
5	B5	25	5.28	4.91	4.47	4.02	3.55	3.10	2.67	2.26	0.106	0.124	0.145	0.166	0.187	0.208	0.228	0.249
6	B1	26	3.72	3.38	2.99	2.61	2.24	1.89	1.57	1.29	0.144	0.164	0.187	0.209	0.232	0.254	0.276	0.299
6	B2	27	4.93	4.61	4.25	3.88	3.52	3.17	2.83	2.51	0.102	0.112	0.124	0.135	0.147	0.158	0.169	0.181
6	B3	28	4.18	3.93	3.63	3.30	2.97	2.65	2.32	2.02	0.091	0.107	0.125	0.143	0.160	0.178	0.196	0.214
6	B4	29	4.69	4.43	4.11	3.77	3.42	3.06	2.70	2.36	0.081	0.098	0.116	0.133	0.151	0.169	0.187	0.205
6	B5	30	4.69	4.43	4.11	3.77	3.42	3.06	2.70	2.36	0.081	0.098	0.116	0.133	0.151	0.169	0.187	0.205
		Avg	**4.64**	**4.33**	**3.96**	**3.58**	**3.19**	**2.81**	**2.44**	**2.09**	**0.102**	**0.120**	**0.139**	**0.158**	**0.178**	**0.198**	**0.217**	**0.237**
		StdDev	**0.86**	**0.80**	**0.74**	**0.68**	**0.62**	**0.57**	**0.52**	**0.47**	**0.021**	**0.022**	**0.025**	**0.031**	**0.038**	**0.046**	**0.054**	**0.063**

Table A.66 *BBR* Mixture Data for M66-Plant Mix/E0-R0.00-A7

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	4.69	4.37	4.01	3.64	3.28	2.93	2.59	2.27	0.107	0.118	0.131	0.144	0.157	0.170	0.183	0.196
1	B2	2	3.78	3.55	3.29	3.03	2.77	2.51	2.26	2.02	0.095	0.105	0.115	0.125	0.135	0.146	0.156	0.166
1	B3	3	5.67	5.28	4.83	4.35	3.87	3.39	2.93	2.50	0.103	0.121	0.140	0.160	0.180	0.199	0.219	0.239
1	B4	4	4.16	3.95	3.70	3.44	3.17	2.90	2.62	2.36	0.075	0.087	0.099	0.112	0.124	0.137	0.149	0.162
1	B5	5	4.95	4.70	4.38	4.03	3.66	3.28	2.91	2.54	0.077	0.093	0.111	0.129	0.147	0.166	0.184	0.202
2	B1	6	5.25	4.93	4.56	4.16	3.75	3.34	2.95	2.57	0.091	0.107	0.124	0.140	0.157	0.174	0.191	0.208
2	B2	7	6.06	5.66	5.20	4.72	4.23	3.75	3.29	2.85	0.100	0.115	0.132	0.149	0.165	0.182	0.199	0.216
2	B3	8	1.47	1.45	1.41	1.37	1.33	1.29	1.23	1.18	0.024	0.030	0.036	0.042	0.049	0.055	0.061	0.068
2	B4	9	6.11	5.66	5.16	4.65	4.15	3.67	3.21	2.78	0.115	0.128	0.142	0.157	0.171	0.186	0.200	0.215
2	B5	10	4.37	4.10	3.78	3.43	3.08	2.73	2.39	2.06	0.093	0.110	0.128	0.147	0.165	0.184	0.202	0.221
3	B1	11	1.36	1.35	1.32	1.30	1.26	1.23	1.19	1.14	0.016	0.021	0.027	0.033	0.039	0.046	0.052	0.058
3	B2	12	5.80	5.39	4.91	4.42	3.93	3.46	3.00	2.58	0.110	0.126	0.143	0.160	0.177	0.194	0.212	0.229
3	B4	13	3.44	3.25	3.04	2.82	2.60	2.38	2.17	1.96	0.085	0.093	0.103	0.113	0.122	0.132	0.141	0.151

Table A.66 Continued

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa) 8	15	30	60	120	240	480	960	Test Time (sec) and Mixture m-value 8	15	30	60	120	240	480	960
3	B5	14	5.60	5.15	4.66	4.19	3.74	3.32	2.92	2.55	0.128	0.138	0.148	0.159	0.169	0.180	0.190	0.200
4	B1	15	5.64	5.29	4.86	4.42	3.96	3.51	3.06	2.64	0.094	0.111	0.129	0.148	0.167	0.186	0.205	0.223
4	B2	16	3.95	3.73	3.47	3.19	2.90	2.61	2.32	2.04	0.083	0.097	0.113	0.129	0.145	0.161	0.177	0.193
4	B3	17	5.86	5.45	4.98	4.50	4.02	3.55	3.09	2.66	0.106	0.121	0.138	0.155	0.172	0.189	0.206	0.223
4	B4	18	4.73	4.44	4.09	3.74	3.38	3.03	2.68	2.35	0.095	0.108	0.123	0.138	0.153	0.168	0.183	0.198
4	B5	19	6.32	5.91	5.42	4.89	4.35	3.82	3.30	2.81	0.097	0.116	0.137	0.158	0.178	0.199	0.220	0.241
5	B2	20	6.19	5.77	5.28	4.78	4.27	3.76	3.28	2.82	0.103	0.119	0.137	0.154	0.172	0.190	0.208	0.226
5	B3	21	3.66	3.44	3.18	2.91	2.62	2.34	2.06	1.79	0.089	0.105	0.122	0.140	0.157	0.175	0.192	0.210
5	B5	22	5.06	4.76	4.40	4.02	3.62	3.23	2.84	2.47	0.089	0.105	0.122	0.140	0.158	0.176	0.193	0.211
6	B2	23	5.25	4.80	4.34	3.91	3.51	3.14	2.81	2.50	0.140	0.144	0.148	0.153	0.157	0.162	0.166	0.171
6	B3	24	3.93	3.76	3.53	3.28	3.01	2.73	2.45	2.17	0.065	0.080	0.098	0.115	0.132	0.149	0.167	0.184
6	B4	25	3.70	3.46	3.17	2.85	2.52	2.19	1.88	1.58	0.094	0.116	0.140	0.165	0.189	0.213	0.237	0.262
6	B5	26	5.58	5.23	4.81	4.38	3.93	3.49	3.06	2.65	0.096	0.112	0.129	0.146	0.164	0.181	0.198	0.216
		Avg	**4.71**	**4.42**	**4.07**	**3.71**	**3.34**	**2.98**	**2.63**	**2.30**	**0.091**	**0.105**	**0.120**	**0.135**	**0.150**	**0.165**	**0.180**	**0.196**
		StdDev	**1.31**	**1.20**	**1.07**	**0.94**	**0.81**	**0.69**	**0.57**	**0.47**	**0.026**	**0.027**	**0.030**	**0.032**	**0.035**	**0.039**	**0.043**	**0.047**

Table A.67 *BBR* Mixture Data for M67-Plant Mix/E0-R0.00-A30

			Test Time (sec) and Mixture Stiffness (GPa)								**Test Time (sec) and Mixture m-value**							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	2.22	2.15	2.07	1.97	1.85	1.72	1.59	1.45	0.038	0.051	0.066	0.081	0.095	0.110	0.124	0.139
1	B2	2	2.38	2.32	2.24	2.15	2.04	1.91	1.78	1.65	0.033	0.045	0.058	0.070	0.083	0.095	0.108	0.121
1	B3	3	2.90	2.81	2.69	2.55	2.39	2.22	2.04	1.85	0.042	0.056	0.071	0.086	0.100	0.115	0.130	0.145
1	B4	4	2.52	2.45	2.36	2.26	2.14	2.02	1.89	1.75	0.038	0.048	0.059	0.069	0.080	0.091	0.102	0.113
1	B5	5	2.57	2.50	2.39	2.25	2.10	1.92	1.74	1.56	0.039	0.056	0.075	0.094	0.113	0.133	0.152	0.171
2	B1	6	2.00	1.96	1.91	1.84	1.77	1.69	1.60	1.51	0.025	0.034	0.044	0.054	0.063	0.073	0.083	0.092
2	B2	7	2.79	2.72	2.64	2.53	2.42	2.29	2.15	2.01	0.032	0.042	0.052	0.063	0.073	0.084	0.094	0.105
2	B3	8	2.26	2.18	2.07	1.94	1.79	1.63	1.46	1.30	0.047	0.065	0.085	0.105	0.125	0.145	0.164	0.184
2	B4	9	2.83	2.75	2.64	2.51	2.36	2.20	2.04	1.86	0.041	0.053	0.066	0.080	0.093	0.107	0.120	0.134
2	B5	10	2.35	2.28	2.18	2.08	1.97	1.85	1.73	1.60	0.046	0.055	0.065	0.075	0.085	0.095	0.104	0.114
		Avg	**2.48**	**2.41**	**2.32**	**2.21**	**2.08**	**1.95**	**1.80**	**1.65**	**0.038**	**0.051**	**0.064**	**0.078**	**0.091**	**0.105**	**0.118**	**0.132**
		StdDev	**0.29**	**0.28**	**0.27**	**0.26**	**0.25**	**0.23**	**0.22**	**0.22**	**0.007**	**0.009**	**0.012**	**0.015**	**0.018**	**0.022**	**0.025**	**0.029**

Table A.68 *BBR* Mixture Data for M68-Plant Mix/E0-R0.00-A60

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	5.94	5.67	5.34	4.99	4.62	4.24	3.86	3.49	0.069	0.080	0.092	0.105	0.117	0.129	0.141	0.153
1	B2	2	5.79	5.48	5.12	4.74	4.36	3.97	3.59	3.22	0.082	0.092	0.104	0.116	0.128	0.140	0.152	0.164
1	B4	3	2.32	2.26	2.19	2.10	2.01	1.91	1.81	1.70	0.038	0.045	0.053	0.061	0.069	0.077	0.085	0.093
1	B5	4	4.61	4.35	4.03	3.68	3.31	2.93	2.56	2.21	0.082	0.101	0.122	0.142	0.163	0.184	0.204	0.225
2	B1	5	5.64	5.28	4.86	4.42	3.99	3.56	3.14	2.74	0.099	0.112	0.127	0.143	0.158	0.173	0.188	0.203
2	B2	6	5.53	5.23	4.87	4.48	4.08	3.66	3.25	2.85	0.079	0.094	0.112	0.129	0.146	0.163	0.181	0.198
2	B3	7	5.28	5.05	4.78	4.48	4.18	3.87	3.56	3.25	0.067	0.076	0.086	0.096	0.106	0.116	0.126	0.136
2	B4	8	6.68	6.31	5.83	5.31	4.77	4.21	3.67	3.15	0.082	0.102	0.124	0.146	0.167	0.189	0.211	0.233
2	B5	9	7.47	7.04	6.54	6.00	5.46	4.91	4.36	3.84	0.086	0.100	0.115	0.130	0.146	0.161	0.176	0.192
		Avg	**5.47**	**5.19**	**4.84**	**4.47**	**4.09**	**3.70**	**3.31**	**2.94**	**0.076**	**0.089**	**0.104**	**0.119**	**0.133**	**0.148**	**0.163**	**0.177**
		StdDev	**1.44**	**1.34**	**1.22**	**1.10**	**0.98**	**0.86**	**0.75**	**0.66**	**0.017**	**0.020**	**0.024**	**0.028**	**0.032**	**0.036**	**0.041**	**0.045**

Table A.69 *BBR* Mixture Data for M69-Plant Mix/E3a-R1.81-A0

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	2.89	2.45	2.05	1.71	1.43	1.20	1.00	0.84	0.263	0.261	0.260	0.259	0.257	0.256	0.254	0.253
1	B2	2	3.82	3.41	2.96	2.54	2.15	1.79	1.47	1.19	0.173	0.191	0.212	0.232	0.253	0.273	0.294	0.314
1	B3	3	5.67	5.15	4.56	3.97	3.40	2.86	2.37	1.93	0.142	0.164	0.188	0.212	0.236	0.260	0.284	0.308
1	B4	4	5.35	4.86	4.34	3.84	3.38	2.96	2.57	2.21	0.150	0.159	0.169	0.179	0.189	0.200	0.210	0.220
1	B5	5	6.12	5.50	4.84	4.20	3.60	3.05	2.55	2.11	0.162	0.178	0.195	0.213	0.230	0.248	0.265	0.282
2	B1	6	6.83	6.26	5.60	4.93	4.28	3.65	3.07	2.54	0.129	0.149	0.172	0.195	0.217	0.240	0.262	0.285
2	B2	7	3.89	3.47	3.06	2.68	2.34	2.04	1.77	1.52	0.175	0.181	0.187	0.192	0.198	0.204	0.210	0.216
2	B3	8	5.34	4.83	4.27	3.73	3.22	2.75	2.31	1.92	0.152	0.168	0.186	0.204	0.222	0.240	0.258	0.275
2	B4	9	5.13	4.64	4.10	3.58	3.07	2.61	2.18	1.80	0.151	0.169	0.188	0.208	0.227	0.247	0.266	0.286
2	B5	10	4.91	4.55	4.13	3.68	3.24	2.80	2.39	2.01	0.110	0.130	0.152	0.175	0.197	0.219	0.242	0.264
3	B1	11	5.39	4.86	4.31	3.79	3.31	2.86	2.46	2.10	0.159	0.169	0.180	0.191	0.202	0.213	0.224	0.235
3	B2	12	4.21	3.83	3.41	3.00	2.59	2.21	1.86	1.54	0.138	0.157	0.178	0.199	0.220	0.241	0.262	0.283
3	B3	13	4.78	4.23	3.64	3.07	2.55	2.08	1.67	1.31	0.182	0.205	0.231	0.256	0.282	0.307	0.333	0.358
3	B4	14	4.33	3.96	3.54	3.12	2.72	2.33	1.98	1.65	0.133	0.151	0.171	0.191	0.210	0.230	0.250	0.269
3	B5	15	5.46	4.98	4.42	3.86	3.32	2.80	2.33	1.91	0.138	0.159	0.183	0.207	0.230	0.254	0.278	0.301

Table A.69 Continued

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
			8	15	30	60	120	240	480	960	8	15	30	60	120	240	480	960
4	B1	16	4.66	4.22	3.76	3.32	2.91	2.53	2.18	1.87	0.152	0.162	0.174	0.185	0.196	0.207	0.219	0.230
4	B2	17	3.62	3.18	2.70	2.26	1.86	1.50	1.19	0.92	0.196	0.219	0.245	0.271	0.297	0.323	0.349	0.374
4	B3	18	5.59	5.07	4.49	3.92	3.37	2.86	2.39	1.97	0.145	0.164	0.186	0.207	0.228	0.249	0.270	0.292
4	B4	19	4.25	3.90	3.50	3.10	2.72	2.35	2.00	1.69	0.129	0.146	0.164	0.183	0.201	0.220	0.238	0.257
4	B5	20	2.93	2.51	2.11	1.77	1.48	1.24	1.03	0.85	0.243	0.247	0.251	0.255	0.259	0.263	0.268	0.272
5	B1	21	4.70	4.26	3.76	3.26	2.78	2.33	1.92	1.56	0.145	0.168	0.192	0.217	0.242	0.266	0.291	0.315
5	B2	22	4.59	4.22	3.78	3.35	2.93	2.52	2.14	1.79	0.127	0.145	0.165	0.185	0.205	0.225	0.245	0.265
5	B3	23	4.59	4.18	3.70	3.22	2.75	2.31	1.90	1.54	0.137	0.161	0.188	0.214	0.241	0.267	0.294	0.320
5	B4	24	5.35	4.89	4.36	3.83	3.32	2.83	2.38	1.97	0.134	0.153	0.175	0.197	0.218	0.240	0.261	0.283
5	B5	25	5.03	4.49	3.90	3.35	2.83	2.36	1.94	1.57	0.173	0.191	0.211	0.231	0.252	0.272	0.292	0.312
6	B1	26	4.23	3.83	3.42	3.02	2.65	2.31	2.00	1.72	0.152	0.162	0.172	0.183	0.193	0.203	0.214	0.224
6	B2	27	4.62	4.19	3.70	3.22	2.76	2.34	1.95	1.60	0.148	0.168	0.189	0.210	0.232	0.253	0.274	0.296
6	B3	28	2.18	1.91	1.63	1.37	1.14	0.93	0.75	0.59	0.200	0.219	0.240	0.260	0.281	0.302	0.323	0.344
6	B4	29	3.97	3.62	3.23	2.83	2.45	2.09	1.75	1.44	0.135	0.155	0.177	0.199	0.221	0.243	0.265	0.288
6	B5	30	3.21	2.92	2.59	2.25	1.92	1.61	1.32	1.06	0.135	0.160	0.188	0.215	0.243	0.271	0.299	0.327
		Avg	**4.59**	**4.15**	**3.66**	**3.19**	**2.75**	**2.34**	**1.96**	**1.62**	**0.157**	**0.174**	**0.192**	**0.211**	**0.229**	**0.248**	**0.266**	**0.285**
		StdDev	**1.01**	**0.95**	**0.87**	**0.78**	**0.69**	**0.61**	**0.52**	**0.45**	**0.033**	**0.030**	**0.027**	**0.027**	**0.028**	**0.030**	**0.034**	**0.039**

Table A.70 *BBR* Mixture Data for M70-Plant Mix/E3a-R1.81-A7

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	5.00	4.54	4.03	3.53	3.04	2.59	2.17	1.79	0.143	0.162	0.182	0.203	0.223	0.244	0.264	0.285
1	B2	2	5.27	4.79	4.24	3.70	3.17	2.68	2.23	1.83	0.143	0.163	0.186	0.209	0.231	0.254	0.277	0.299
1	B3	3	5.68	5.06	4.38	3.72	3.12	2.57	2.08	1.66	0.175	0.197	0.221	0.245	0.269	0.292	0.316	0.340
1	B4	4	1.91	1.84	1.74	1.63	1.50	1.37	1.24	1.11	0.056	0.071	0.088	0.105	0.122	0.139	0.156	0.173
1	B5	5	4.78	4.38	3.92	3.46	3.00	2.58	2.18	1.81	0.131	0.150	0.171	0.191	0.212	0.233	0.254	0.275
2	B1	6	4.57	4.12	3.61	3.11	2.62	2.17	1.77	1.41	0.152	0.176	0.204	0.231	0.258	0.285	0.312	0.340
2	B2	7	4.03	3.70	3.32	2.94	2.56	2.20	1.87	1.56	0.126	0.145	0.166	0.187	0.208	0.230	0.251	0.272
2	B3	8	3.95	3.61	3.22	2.84	2.47	2.12	1.79	1.49	0.134	0.152	0.172	0.192	0.212	0.232	0.252	0.272
2	B4	9	3.13	2.84	2.49	2.11	1.74	1.39	1.08	0.82	0.135	0.173	0.215	0.258	0.300	0.343	0.385	0.427
2	B5	10	3.34	2.93	2.47	2.02	1.61	1.24	0.93	0.68	0.190	0.227	0.268	0.309	0.350	0.391	0.432	0.473
3	B1	11	4.15	3.81	3.42	3.04	2.66	2.31	1.97	1.66	0.129	0.145	0.163	0.181	0.199	0.217	0.235	0.253
3	B2	12	4.15	3.81	3.42	3.04	2.66	2.31	1.97	1.66	0.129	0.145	0.163	0.181	0.199	0.217	0.235	0.253
3	B3	13	2.70	2.37	2.00	1.65	1.34	1.05	0.81	0.61	0.194	0.224	0.258	0.292	0.326	0.360	0.394	0.428
3	B4	14	2.08	1.80	1.51	1.25	1.01	0.81	0.64	0.50	0.223	0.243	0.265	0.287	0.309	0.332	0.354	0.376
3	B5	15	4.11	3.74	3.30	2.86	2.43	2.02	1.65	1.32	0.138	0.164	0.193	0.222	0.250	0.279	0.308	0.337

Table A.70 Continued

Core	SP	Rep	Test Time (sec) and Mixture Stiffness (GPa) 8	15	30	60	120	240	480	960	Test Time (sec) and Mixture m-value 8	15	30	60	120	240	480	960
4	B1	16	4.48	4.04	3.54	3.05	2.58	2.14	1.74	1.39	0.151	0.175	0.202	0.230	0.257	0.284	0.311	0.338
4	B2	17	3.29	2.93	2.53	2.14	1.77	1.43	1.13	0.88	0.170	0.198	0.228	0.259	0.289	0.319	0.350	0.380
4	B3	18	3.89	3.55	3.15	2.75	2.36	1.99	1.65	1.34	0.137	0.159	0.184	0.209	0.234	0.259	0.284	0.308
4	B4	19	3.63	3.23	2.85	2.51	2.22	1.96	1.74	1.54	0.186	0.184	0.182	0.180	0.179	0.177	0.175	0.173
4	B5	20	5.02	4.51	3.93	3.37	2.84	2.35	1.90	1.52	0.160	0.184	0.210	0.236	0.262	0.288	0.314	0.340
5	B1	21	2.43	2.31	2.17	2.01	1.84	1.66	1.48	1.30	0.066	0.083	0.102	0.120	0.138	0.157	0.175	0.194
5	B2	22	3.39	3.03	2.64	2.28	1.95	1.66	1.39	1.15	0.176	0.189	0.203	0.217	0.232	0.246	0.260	0.274
5	B3	23	2.62	2.33	2.02	1.71	1.42	1.15	0.92	0.72	0.168	0.195	0.225	0.254	0.284	0.314	0.343	0.373
5	B4	24	4.08	3.64	3.15	2.66	2.21	1.79	1.42	1.10	0.167	0.195	0.226	0.257	0.287	0.318	0.349	0.380
5	B5	25	5.23	4.79	4.30	3.80	3.32	2.87	2.44	2.05	0.130	0.147	0.166	0.186	0.205	0.224	0.243	0.262
6	B1	26	6.22	5.69	5.11	4.53	3.96	3.43	2.93	2.47	0.133	0.148	0.166	0.183	0.200	0.218	0.235	0.252
6	B3	27	4.35	3.98	3.54	3.09	2.64	2.22	1.83	1.48	0.131	0.156	0.183	0.210	0.238	0.265	0.292	0.319
6	B4	28	3.99	3.65	3.24	2.83	2.42	2.03	1.67	1.35	0.130	0.155	0.183	0.212	0.240	0.268	0.296	0.324
6	B5	29	4.97	4.50	3.97	3.43	2.92	2.43	1.99	1.60	0.144	0.169	0.195	0.222	0.249	0.276	0.303	0.330
		Avg	**4.02**	**3.64**	**3.21**	**2.80**	**2.39**	**2.02**	**1.68**	**1.37**	**0.146**	**0.168**	**0.192**	**0.216**	**0.240**	**0.264**	**0.288**	**0.312**
		StdDev	**1.06**	**0.97**	**0.87**	**0.77**	**0.68**	**0.59**	**0.52**	**0.45**	**0.034**	**0.036**	**0.040**	**0.045**	**0.051**	**0.058**	**0.065**	**0.072**

Table A.71 *BBR* Mixture Data for M71-Plant Mix/E3a-R1.81-A30

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	2.93	2.71	2.47	2.24	2.01	1.79	1.58	1.39	0.119	0.129	0.139	0.150	0.161	0.171	0.182	0.193
1	B2	2	3.78	3.44	3.07	2.71	2.36	2.03	1.73	1.45	0.140	0.156	0.173	0.190	0.208	0.225	0.243	0.260
1	B3	3	3.26	2.98	2.67	2.35	2.04	1.74	1.46	1.21	0.130	0.150	0.173	0.195	0.217	0.239	0.262	0.284
1	B5	4	4.43	4.03	3.58	3.12	2.68	2.26	1.87	1.53	0.139	0.161	0.185	0.209	0.233	0.258	0.282	0.306
2	B2	5	2.85	2.57	2.25	1.92	1.59	1.29	1.03	0.79	0.147	0.178	0.213	0.248	0.283	0.318	0.352	0.387
2	B3	6	3.84	3.50	3.13	2.75	2.39	2.04	1.73	1.44	0.136	0.154	0.174	0.194	0.214	0.234	0.254	0.274
2	B4	7	4.36	3.98	3.54	3.10	2.68	2.27	1.89	1.55	0.135	0.156	0.179	0.203	0.226	0.249	0.273	0.296
2	B5	8	4.67	4.28	3.83	3.37	2.91	2.48	2.07	1.70	0.126	0.148	0.173	0.197	0.222	0.246	0.271	0.295
		Avg	**3.77**	**3.44**	**3.07**	**2.70**	**2.33**	**1.99**	**1.67**	**1.38**	**0.134**	**0.154**	**0.176**	**0.198**	**0.221**	**0.243**	**0.265**	**0.287**
		StdDev	**0.70**	**0.64**	**0.57**	**0.50**	**0.43**	**0.38**	**0.32**	**0.28**	**0.009**	**0.014**	**0.020**	**0.027**	**0.033**	**0.041**	**0.047**	**0.054**

Table A.72 *BBR* Mixture Data for M72-Plant Mix/E3a-R1.81-A60

			Test Time (sec) and Mixture Stiffness (GPa)								Test Time (sec) and Mixture m-value							
Core	**SP**	**Rep**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**	**8**	**15**	**30**	**60**	**120**	**240**	**480**	**960**
1	B1	1	0.37	0.37	0.37	0.36	0.36	0.36	0.35	0.35	0.005	0.008	0.011	0.013	0.016	0.019	0.022	0.025
1	B2	2	4.61	4.16	3.65	3.15	2.67	2.23	1.83	1.48	0.154	0.176	0.200	0.224	0.249	0.273	0.297	0.321
1	B4	3	4.19	3.79	3.33	2.88	2.44	2.03	1.66	1.34	0.148	0.172	0.198	0.224	0.251	0.277	0.303	0.329
2	B2	4	5.22	4.88	4.48	4.07	3.67	3.27	2.88	2.52	0.102	0.115	0.130	0.144	0.159	0.174	0.188	0.203
2	B3	5	2.48	2.31	2.11	1.89	1.66	1.44	1.22	1.02	0.099	0.122	0.147	0.172	0.197	0.222	0.247	0.272
2	B5	6	5.87	5.34	4.75	4.18	3.62	3.09	2.61	2.17	0.141	0.159	0.178	0.197	0.216	0.236	0.255	0.274
		Avg	**3.79**	**3.48**	**3.12**	**2.76**	**2.40**	**2.07**	**1.76**	**1.48**	**0.108**	**0.125**	**0.144**	**0.162**	**0.181**	**0.200**	**0.219**	**0.237**
		StdDev	**2.03**	**1.84**	**1.64**	**1.44**	**1.26**	**1.08**	**0.92**	**0.78**	**0.056**	**0.063**	**0.071**	**0.079**	**0.088**	**0.096**	**0.105**	**0.113**

APPENDIX B

INDIRECT TENSILE TEST DATA

Table B.1 Original *IDT* Data for Hwy 45-150 mm

Rep	Sample Height (in)	Max Load (lbs)	St (psi)	St (kPa)	Time to Peak Load (sec)
1	1.69	3,213	205.5	1,417	1.834
2	1.55	3,710	258.5	1,782	1.800
3	1.60	3,392	227.9	1,571	1.566
4	1.62	3,927	261.0	1,799	2.300
5	1.56	2,084	143.8	991	2.633
6	1.53	3,079	217.4	1,499	2.900
7	1.54	2,652	185.5	1,279	2.667
8	1.56	3,288	227.3	1,567	2.033
9	1.52	2,172	153.7	1,060	1.767
10	1.65	3,028	198.0	1,365	3.900
11	1.57	2,925	201.4	1,389	4.067
12	1.61	3,876	259.5	1,789	4.500
13	1.55	4,241	295.3	2,036	1.833
14	1.52	2,627	185.9	1,282	1.667
15	1.66	3,865	250.6	1,728	2.066
16	1.48	2,901	211.4	1,458	1.634
17	1.42	2,465	186.9	1,289	2.266
18	1.41	3,465	264.7	1,825	2.033
19	1.58	4,505	307.9	2,123	1.667
20	1.40	3,100	238.1	1,642	4.300
21	1.62	3,421	228.3	1,574	2.967
22	1.55	2,261	157.6	1,087	1.200
23	1.70	2,956	187.0	1,289	4.433
24	1.44	1,816	136.3	940	2.467
25	1.65	3,483	227.7	1,570	1.966
26	1.56	2,748	189.9	1,310	2.466
27	1.73	4,270	266.2	1,836	2.167
28	1.47	3,426	251.0	1,730	2.434
29	1.53	2,521	177.1	1,221	1.134
30	*1.76*	*5,841*	*357.7*	*2,467*	*3.167*
Avg (All Data)	**1.57**	**3,242**	**222.0**	**1,530**	**2.461**
Std Dev (All Data)	**0.09**	**831.5**	**50.2**	**346.1**	**0.944**
Avg (No Outliers)	**1.56**	**3,152**	**217.3**	**1,498**	**2.437**
Std Dev (No Outliers)	**0.09**	**683.0**	**43.9**	**302.8**	**0.951**

Note: Italicized Replicates Indicate Outliers Removed

Table B.2 Re-Tested *IDT* Data for Hwy 45-150 mm

Rep	Sample Height (in)	Max Load (lbs)	St (psi)	St (kPa)	Time to Peak Load (sec)
1	1.50	2,795	201.1	1,387	2.866
2	1.49	4,150	300.9	2,075	2.800
3	1.56	4,377	302.5	2,086	2.467
4	1.55	2,948	205.4	1,416	4.167
5	1.59	3,668	249.2	1,718	2.700
6	1.51	3,920	279.4	1,927	1.934
7	1.63	4,848	320.3	2,209	2.900
8	1.50	2,892	208.2	1,435	1.100
9	1.56	3,269	226.2	1,559	1.467
10	1.52	3,203	227.3	1,567	2.000
11	1.43	2,349	177.3	1,223	2.000
12	1.53	3,544	250.0	1,723	1.500
13	1.58	3,618	247.4	1,706	2.733
14	1.40	2,674	205.8	1,419	2.500
15	1.55	4,229	294.9	2,033	1.366
16	1.52	3,095	218.8	1,508	1.966
17	1.41	2,791	213.9	1,475	2.567
18	1.40	2,777	214.3	1,478	2.666
19	1.36	2,836	224.1	1,545	2.933
20	1.55	3,514	245.0	1,689	4.733
21	1.55	3,421	238.7	1,646	4.900
22	1.55	3,825	265.6	1,831	2.534
23	1.56	4,361	302.0	2,083	2.866
24	1.52	3,575	253.1	1,745	1.367
25	1.53	3,137	220.9	1,523	2.200
26	1.43	2,815	211.7	1,460	1.534
27	1.73	5,609	349.0	2,407	2.333
28	1.55	4,201	292.8	2,019	3.034
29	1.58	2,870	196.3	1,353	2.133
30	1.55	4,175	291.0	2,007	2.167
Avg (All Data)	**1.52**	**3,516**	**247.8**	**1,708**	**2.481**
Std Dev (All Data)	**0.08**	**741.7**	**42.9**	**295.7**	**0.903**
Avg (No Outliers)	**1.52**	**3,516**	**247.8**	**1,708**	**2.481**
Std Dev (No Outliers)	**0.08**	**741.7**	**42.9**	**295.7**	**0.903**

Table B.3 *IDT* Data for Hwy 45-100 mm

Rep	Sample Height (in)	Max Load (lbs)	St (psi)	St (kPa)	Time to Peak Load (sec)
1	1.47	2,681	295.2	2,035	3.533
2	1.53	2,390	253.3	1,746	2.200
3	1.47	2,199	242.6	1,672	1.567
4	1.52	2,635	280.0	1,931	1.500
5	1.50	2,766	297.7	2,053	1.700
6	1.72	2,733	256.2	1,767	1.533
7	*1.67*	*4,193*	*406.7*	*2,804*	*2.200*
8	1.67	3,385	327.3	2,257	1.400
9	1.70	2,717	258.5	1,782	1.733
10	1.68	2,748	265.0	1,827	1.300
11	1.48	2,231	244.3	1,685	1.500
12	1.43	2,266	256.6	1,769	2.033
13	1.53	2,740	289.2	1,994	1.366
14	1.48	2,478	270.2	1,863	1.400
15	1.49	2,470	268.2	1,849	1.200
16	1.37	2,137	252.3	1,740	2.100
17	1.36	2,633	312.8	2,156	2.100
18	1.35	2,747	329.3	2,271	1.667
19	1.34	2,733	329.8	2,274	2.300
20	1.66	3,486	339.8	2,343	2.100
21	1.65	3,295	323.0	2,227	1.566
22	1.69	2,613	249.8	1,723	1.634
23	1.67	2,662	258.0	1,779	1.766
24	1.67	2,545	245.8	1,695	1.267
25	1.48	2,609	285.8	1,971	1.100
26	1.52	2,796	298.4	2,057	1.400
27	1.48	2,054	224.6	1,549	1.200
28	1.53	2,524	266.8	1,839	3.067
29	1.48	2,375	259.3	1,788	2.167
30	1.49	2,385	258.5	1,783	2.866
Avg (All Data)	**1.54**	**2,674**	**281.5**	**1,941**	**1.816**
Std Dev (All Data)	**0.12**	**437.5**	**38.7**	**267.2**	**0.575**
Avg (No Outliers)	**1.53**	**2,622**	**277.2**	**1,911**	**1.802**
Std Dev (No Outliers)	**0.11**	**336.2**	**31.2**	**215.4**	**0.581**

Note: Italicized Replicates Indicate Outliers Removed

Table B.4 *IDT* Data for FR-150 mm

Rep	Sample Height	Max Load	St (psi)	St (kPa)	Time to Peak

	(in)	(lbs)			Load (sec)
1	*1.83*	*3,376*	*198.9*	*1,372*	*6.367*
2	1.78	5,234	317.2	2,187	3.167
3	1.68	4,435	284.6	1,962	2.700
4	1.82	4,613	273.7	1,887	2.300
5	1.70	4,483	283.7	1,956	3.467
6	*1.82*	*5,842*	*345.7*	*2,384*	*3.934*
7	1.74	4,412	272.8	1,881	3.134
8	1.71	4,903	309.4	2,134	4.734
9	1.79	4,650	279.7	1,929	2.734
10	1.62	4,348	290.0	1,999	3.066
11	1.66	4,334	281.3	1,939	3.000
12	1.70	4,101	259.7	1,790	3.466
13	*1.69*	*3,089*	*196.6*	*1,355*	*2.000*
14	1.68	3,576	229.9	1,585	2.367
15	1.68	4,315	276.5	1,906	2.766
16	1.64	3,669	240.8	1,660	2.433
17	1.74	4,224	261.2	1,801	3.200
18	1.68	4,619	296.7	2,045	1.700
19	1.63	3,835	253.2	1,746	3.033
20	1.74	4,494	278.8	1,922	2.900
21	1.64	3,672	241.5	1,665	4.300
22	1.69	4,013	256.2	1,766	2.800
23	1.71	4,810	302.7	2,087	3.866
24	1.68	3,694	237.5	1,637	2.000
25	1.72	4,636	290.7	2,004	2.633
26	1.68	4,437	285.4	1,968	2.566
27	1.58	4,565	311.5	2,148	2.500
28	1.59	3,385	229.3	1,581	2.467
29	*1.75*	*3,103*	*191.3*	*1,319*	*2.600*
30	1.73	4,231	262.9	1,813	3.133
Avg (All Data)	**1.70**	**4,236**	**268.0**	**1,848**	**3.044**
Std Dev (All Data)	**0.06**	**616.0**	**36.2**	**249.8**	**0.916**
Avg (No Outliers)	**1.69**	**4,296**	**273.3**	**1,885**	**2.940**
Std Dev (No Outliers)	**0.06**	**447.0**	**24.9**	**171.8**	**0.661**

Note: Italicized Replicates Indicate Outliers Removed

Table B.5 *IDT* Data for FR-100 mm

Rep	Sample Height (in)	Max Load (lbs)	St (psi)	St (kPa)	Time to Peak Load (sec)

1	1.80	3,282	294.5	2,030	1.400
2	1.80	3,908	350.7	2,418	1.767
3	1.78	3,705	336.5	2,320	2.733
4	1.79	2,829	254.9	1,757	1.367
5	1.79	2,901	261.9	1,806	1.134
6	1.82	2,916	259.5	1,789	2.033
7	1.80	2,705	243.6	1,680	1.500
8	1.79	2,567	231.6	1,597	1.200
9	1.81	2,983	266.8	1,840	1.666
10	1.80	3,456	310.5	2,141	2.100
11	1.80	2,386	214.3	1,477	1.167
12	1.78	2,299	208.5	1,438	1.300
13	1.82	3,218	286.1	1,973	1.266
14	1.80	3,557	319.7	2,204	2.500
15	1.82	3,649	324.8	2,239	1.667
16	1.76	2,690	247.0	1,703	1.267
17	1.76	3,212	294.3	2,029	1.133
18	1.77	3,310	301.7	2,080	0.967
19	1.76	3,362	308.2	2,125	1.600
20	1.76	2,642	242.1	1,669	1.433
21	1.82	3,403	302.3	2,085	1.667
22	1.83	3,788	335.2	2,311	1.233
23	1.84	3,577	313.7	2,163	2.333
24	1.83	3,179	281.1	1,938	1.734
25	1.75	2,877	266.1	1,835	1.200
26	1.78	3,144	286.4	1,975	1.400
27	1.76	2,409	221.6	1,528	1.567
28	1.79	3,100	280.8	1,936	1.934
29	1.76	3,148	289.3	1,994	1.800
30	1.73	3,414	318.7	2,198	2.066
Avg (All Data)	**1.79**	**3,121**	**281.8**	**1,943**	**1.604**
Std Dev (All Data)	**0.03**	**430.5**	**37.8**	**260.6**	**0.434**
Avg (No Outliers)	**1.79**	**3,121**	**281.8**	**1,943**	**1.604**
Std Dev (No Outliers)	**0.03**	**430.5**	**37.8**	**260.6**	**0.434**

Table B.6 *IDT* Data for Plant Mix-150 mm

Rep	Sample Height (in)	Max Load (lbs)	St (psi)	St (kPa)	Time to Peak Load (sec)
1	2.95	13,522	493.9	3,405	1.833

2	2.94	13,196	483.4	3,333	1.700
3	2.94	14,918	547.1	3,773	2.034
4	2.94	14,112	518.0	3,572	1.667
5	2.94	14,609	535.8	3,694	1.867
6	2.93	16,739	615.8	4,246	2.033
7	2.93	12,673	465.8	3,212	1.734
8	2.93	16,784	617.2	4,256	1.934
9	2.94	16,015	587.9	4,054	1.734
10	2.93	12,606	463.2	3,194	1.667
11	2.93	12,099	444.7	3,066	1.667
12	2.94	13,434	493.3	3,401	1.733
13	2.93	13,460	495.7	3,418	1.634
14	2.94	11,949	438.7	3,025	2.266
15	2.94	15,836	581.5	4,009	1.700
16	2.94	15,388	563.7	3,887	1.666
17	2.93	15,075	554.0	3,820	2.400
18	2.94	13,947	510.6	3,520	2.000
19	2.94	12,902	473.2	3,263	1.867
20	2.94	13,827	507.2	3,497	2.833
21	2.94	13,529	496.2	3,422	2.167
22	2.94	16,066	589.6	4,065	1.834
23	2.94	16,240	594.6	4,100	1.966
24	2.94	11,906	436.6	3,010	2.033
25	2.94	15,224	559.1	3,855	1.900
26	2.94	12,294	451.2	3,111	1.834
27	2.93	15,801	580.7	4,004	1.900
28	2.93	13,834	508.1	3,503	1.867
29	2.96	14,745	536.9	3,702	1.800
30	2.93	14,578	537.0	3,703	2.267
Avg (All Data)	**2.94**	**14,244**	**522.7**	**3,604**	**1.918**
Std Dev (All Data)	**0.01**	**1,461.3**	**53.7**	**370.4**	**0.262**
Avg (No Outliers)	**2.94**	**14,244**	**522.7**	**3,604**	**1.918**
Std Dev (No Outliers)	**0.01**	**1,461.3**	**53.7**	**370.4**	**0.262**

Table B.7 *IDT* Data for Plant Mix-100 mm

Rep	**Sample Height (in)**	**Max Load (lbs)**	**St (psi)**	**St (kPa)**	**Time to Peak Load (sec)**
1	1.53	4,422	468.4	3,229	1.667
2	1.47	3,662	402.4	2,774	0.068

3	1.42	3,820	434.6	2,997	6.034
4	1.58	3,818	391.4	2,699	6.500
5	1.47	4,640	509.9	3,516	1.600
6	1.51	4,374	468.5	3,230	1.300
7	1.63	5,367	533.6	3,679	1.833
8	1.35	4,651	557.6	3,845	1.567
9	1.51	4,190	449.7	3,101	1.667
10	1.47	2,750	302.6	2,087	1.200
11	1.31	4,570	563.7	3,887	2.167
12	1.67	3,213	311.8	2,150	n/a
13	1.49	5,165	559.7	3,859	3.900
14	1.48	4,459	486.3	3,353	1.766
15	1.63	4,123	408.8	2,818	1.400
16	1.34	3,382	408.9	2,820	6.400
17	1.33	3,704	451.1	3,110	1.800
18	1.68	3,575	343.6	2,369	1.534
19	1.52	4,875	519.4	3,581	2.766
20	1.48	2,606	285.0	1,965	1.767
21	1.59	5,736	584.6	4,031	4.133
22	1.38	4,143	484.1	3,338	2.133
23	1.55	3,392	354.6	2,445	n/a
24	1.42	3,497	397.7	2,742	6.500
25	1.56	3,617	374.1	2,580	2.066
26	1.41	4,691	538.7	3,715	3.533
27	1.56	4,525	470.2	3,242	1.667
28	1.41	3,045	349.7	2,411	3.100
29	1.35	3,662	439.9	3,033	2.234
30	1.63	3,540	350.9	2,419	2.066
Avg (All Data)	**1.49**	**4,040.5**	**440.1**	**3,034**	**2.656**
Std Dev (All Data)	**0.11**	**752.7**	**84.0**	**579.4**	**1.751**
Avg (No Outliers)	**1.49**	**4,040.5**	**440.1**	**3,034**	**2.656**
Std Dev (No Outliers)	**0.11**	**752.7**	**84.0**	**579.4**	**1.751**