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CENTER FOR INFRASTRUCTURE ENGINEERING STUDIES

Acquisition of a High-Quality Temperature Chamber

by

David N. Richardson

A University Transportation Center Program at Missouri University of Science & Technology

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16. Abstract With the Missouri Department of Transportation (MoDOT) beginning to implement the new Mechanistic-Empirical (M-E) Design Guide for New and Rehabilitated Pavements, the need exists for various types of testing of hot-mix asphalt (HMA) mixes used by MoDOT in its flexible pavements. In particular, the American Association of State Highway and Transportation Official (AASHTO) test protocol T 322 is utilized to determine HMA properties needed as inputs to pavement distress prediction models within the M-E Pavement Design Guide (MEPDG) Software. The primary properties derived from T 322 are creep compliance and tensile strength. These properties are determined using indirect tension methods and are temperature dependent. Creep compliance is a parameter used in the thermal cracking distress model within the MEPDG Software and is determined at 0, -10, and -20°C while tensile strength is an input to the fatigue cracking distress model and is determined at temperatures ranging fron -20 to +20°C.					
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ACQUISITION OF A HIGH-QUALITY TEMPERATURE CHAMBER

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A temperature chamber with a range of -30°C to 100°C that can be integrated with various dynamic and static loading units has been purchased for construction material research. The equipment will be useful to evaluate the temperature-dependent performance of pavement materials such as asphaltic cement concrete (ACC), portland cement concrete (PCC), unbound granular base aggregates, and roadbed soils. However, specimens of metal, composites, and wood could also be evaluated across a significant range of temperatures.

The chamber was recently used for a Missouri Department of Transportation (MoDOT) project in which various hot-mix asphalt (HMA) mixes were tested to evaluate their low-temperature or thermal cracking properties. In particular, the AASHTO T 322 test protocol was utilized to determine HMA properties needed as inputs to pavement distress prediction models within the new M-E Pavement Design software. The properties derived from T 322 are creep compliance, tensile strength, and Poisson's ratio, all of which are temperature dependent. Creep compliance and tensile strength are parameters used in the thermal cracking distress model within the M-E Pavement Design software and is typically determined at 0, -10, and -20°C while tensile strength is determined at temperatures ranging from -20 to +20°C.

The temperature chamber will be used for materials research by faculty and students at the Missouri University of Science and Technology.



APPENDIX A

DETERMINATION OF CREEP COMPLIANCE AND TENSILE STRENGTH OF HOT-MIX ASPHALT FOR WEARING COURSES IN MISSOURI

MoDOT expressed the desire to have MST perform the T 322 testing on several HMA mixes used in wearing (surface) courses throughout the state. MoDOT needs the T 322 results to calibrate default distress models currently employed in the MEPDG Software. The following appendix is the report submitted to the MoDOT after the T 322 testing was completed with the acquired high-quality temperature chamber sponsored by the University Transportation Center at Missouri University of Science & Technology.

Organizational Results Research Report

April 2008 OR08.018

Determination of Creep Compliance and Tensile Strength of Hot-Mix Asphalt for Wearing Courses in Missouri

Prepared by Missouri University of Science and Technology and Missouri Department of Transportation

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Determination of Creep Compliance and Tensile Strength of Hot-Mix Asphalt for Wearing Courses in Missouri

Prepared for the

Missouri Department of Transportation Organizational Results

By

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Creep compliance and indirect tensile	(IDT) strength of ho	t-mix asphalt (HMA) are the two prir	nary inputs	
to the low-temperature or thermal cra	cking module in the r	new Mechanist	ic-Empirical Pavement	t Design	
Guide (M-E PDG) software. Creep co	ompliance is defined a	as time-depend	ent strain per unit stres	ss, while IDT	
strength is best defined as HMA stren	gth when subjected t	o tension. AAS	SHTO T 322 test proto	col was	
used as reference for this work. Howe	ever in preparation for	r the laboratory	work performed at the	e Missouri	
University of Science and Technolog	y many experts were	consulted as to	how IDT creep/streng	th testing	
and calculations are actually being pe	rformed. Using MoI	OOT supplied to	est specimens, six diffe	erent plant-	
produced wearing (surface) course mi	ixes were tested. Four	r mixes were te	sted at three levels of	percent air	
voids: 4, 6.5, and 9% and two mixes	were tested only at 6.	5% air voids. P	er requirements of the	M-E PDG,	
creep testing was performed at 0, -10,	and -20 degrees Cen	tigrade (°C) an	d IDT strength testing	was	
performed at -10°C. Additional IDT s	trength testing was p	erformed at 4.4	and 21°C (40 and 70	°F) per	
MoDOT's requirements. Poisson's ra	tio was determined fr	om the creep to	esting while tensile fail	lure strain	
was determined from the IDT strength	h testing. Trends such	as increasing	creep compliance and	decreasing	
tensile strength with increasing % air	voids and/or tempera	ture were conf	irmed. The presence of	frecycled	
asphalt pavement (RAP) in a mix tend	led to decrease the cr	eep complianc	e (increase the stiffnes	s) and	
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EXECUTIVE SUMMARY

Creep compliance and indirect tensile (IDT) strength of hot-mix asphalt (HMA) are the two primary inputs to the low-temperature or thermal cracking module in the new Mechanistic-Empirical Pavement Design Guide (M-E PDG) software. Creep compliance is defined as time-dependent strain per unit stress, while IDT strength is best defined by what its name implies: HMA strength when subjected to tension.

The test protocol used as the reference for this work is American Association of State Highway and Transportation Officials (AASHTO) test method T 322. However in preparation for the laboratory work that was performed at the Missouri University of Science and Technology (Missouri S&T), many experts (see Acknowledgements) were consulted as to how IDT creep/strength testing and calculations are actually being performed.

MoDOT supplied the test specimens. Six different plant-produced wearing (surface) course mixes were tested. Four of the mixes were tested at three levels of percent air voids: 4, 6.5, and 9%. The remaining two mixes were tested only at 6.5% air voids. Per requirements of the M-E PDG, creep testing was performed at 0, -10, and -20 degrees Centigrade (°C) (32, 14, and -4 degrees Fahrenheit (°F), respectively) and IDT strength testing was performed at -10°C. Additional IDT strength testing was performed at 4.4 and 21°C (40 and 70 °F, respectively) per MoDOT's requirements. Poisson's ratio was determined from the creep testing while tensile failure strain was determined from the IDT strength testing.

All required results were obtained. Trends such as increasing creep compliance and decreasing tensile strength with increasing % air voids and/or temperature were confirmed. The presence of recycled asphalt pavement (RAP) in a mix tended to decrease the creep compliance (increase the stiffness) and increase the tensile strength compared to similar mixes without RAP.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS II
EXECUTIVE SUMMARY II
TABLE OF CONTENTS III
LIST OF FIGURESV
LIST OF TABLESVII
INTRODUCTION 1
OBJECTIVES
TECHNICAL APPROACH
General3
Materials and Target Specimen Properties3
Specimen Fabrication4
IDT Testing5
Equipment5
Creep Compliance Testing6
Procedure7
Tensile Strength Testing10
Procedure11
Data Reduction13
Creep Compliance
Poisson's Ratio
Tensile Strength and Tensile Failure Strain16
RESULTS AND DISCUSSION 17
Creep Compliance17
Poisson's Ratio

Tensile Strength	. 29
Tensile Failure Strain	. 36
Creep Compliance versus IDT Strength	. 39
CONCLUSIONS	. 40
RECOMMENDATIONS	. 41
REFERENCES	. 42
APPENDIX A: CREEP COMPLIANCE	A
APPENDIX B: TENSILE STRENGTH & TENSILE FAILURE STRAIN	I

LIST OF FIGURES

Figure 1: Test Equipment Setup	6
Figure 2: Instrumented IDT Specimen	7
Figure 3: Pre-Instrumentation Preparation	8
Figure 4: Typical Load vs Time Plot	9
Figure 5: Low Temperature Tensile Strength Testing Configuration	12
Figure 6: Deformation Determination for Creep Compliance Calculations	15
Figure 7: Creep Compliance Comparisons: 6.5% Voids, -20°C	20
Figure 8: Creep Compliance Comparisons: 6.5% Voids, -10°C	20
Figure 9: Creep Compliance Comparisons: 6.5% Voids, 0°C	21
Figure 10: Irregular Thermal Cracking Output: Original Method: 07-123	22
Figure 11: Creep Compliance Master Curve Creation	23
Figure 12: Equivalent Area Concept	24
Figure 13: Equivalent Area vs. Original Method: 07-123	25
Figure 14: Thermal Cracking Output: Equivalent Area Method: 07-123	
Figure 15: 100 Second Creep Compliance @ 6.5% Voids @ -10°C	
Figure 16: IDT Strength vs. % Air Voids: 4 Mixes: 21.1°C	33
Figure 17: IDT Strength vs % Air Voids: 4 Mixes: 4.4°C	
Figure 18: IDT Strength vs % Air Voids: 4 Mixes: -10°C	
Figure 19: IDT Strength vs % Air Voids: 2 Mixes: -10°C	
Figure 20: IDT Strength vs % Air Voids: All Mixes: -10°C	35
Figure 21: IDT Strength: All Mixes @ 6.5% Voids @ -10°C	
Figure 22: 100 Second Creep Compliance vs IDT Strength: -10°C	39
Figure A-23: 4 Mixes @ 4% Voids & -20°C	В
Figure A-24: 6 Mixes @ 6.5% Voids & -20°C	В
Figure A-25: 4 Mixes @ 9% Voids & -20°C	C
Figure A-26: 4 Mixes @ 4% Voids & -10°C	C
Figure A-27: 6 Mixes @ 6.5% Voids & -10°C	D
Figure A-28: 4 Mixes @ 9% Voids & -10°C	D
Figure A-29: 4 Mixes @ 4% Voids & 0°C	E

Figure A-30: 6 Mixes @ 6.5% Voids & 0°C	E
Figure A-31: 4 Mixes @ 9% Voids & 0°C	F
Figure A-32: 07-123 Using Equivalent Area Method	F
Figure A-33: 06-84 @ 4% Voids: Round 2	G
Figure A-34: 06-84 @ 6.5% Voids: Round 2	G
Figure A-35: 06-84 @ 9% Voids: Round 2	H
Figure A-36: 06-101 @ 4% Voids	H
Figure A-37: 06-101 @ 6.5% Voids	I
Figure A-38: 06-101 @ 9% Voids	I
Figure A-39: 06-125 @ 4% Voids	J
Figure A-40: 06-125 @ 6.5% Voids	J
Figure A-41: 06-125 @ 9% Voids	K
Figure A-42: 06-150 @ 4% Voids	K
Figure A-43: 06-150 @ 6.5% Voids	L
Figure A-44: 06-150 @ 9% Voids	L
Figure A-45: 06-105 @ 6.5% Voids	M

LIST OF TABLES

Table 1: HMA Mixes and Target % Air Voids	3
Table 2: Additional Mix Properties	4
Table 3: Creep Compliance: 06-125 (SP125C Limestone)	. 17
Table 4: Creep Compliance: 06-101 (SP125B Dolomite)	. 18
Table 5: Creep Compliance: 06-84 (SP125BSM Porphry)	. 18
Table 6: Creep Compliance: 06-150 (SP125C Limestone)	. 19
Table 7: Creep Compliance: 06-105 (SP125C Dolomite), 07-123 (BP-1 Dolomite).	. 19
Table 8: Equivalent Area vs. Original Method: 07-123	.24
Table 9: Original vs. Stretched Creep Compliance Ranges: 07-123	. 27
Table 10: Poisson's Ratio	. 28
Table 11: Non-instrumented Tensile Strength: -10°C	. 29
Table 12: Instrumented Tensile Strength: 21.1°C	. 30
Table 13: Instrumented Tensile Strength: 4.4°C	. 30
Table 14: Instrumented Tensile Strength: -10°C	. 31
Table 15: All Tensile Strength: -10°C	. 32
Table 16: Tensile Failure Strain: 21.1°C	. 36
Table 17: Tensile Failure Strain: 4.4°C	. 37
Table 18: Tensile Failure Strain: -10°C	. 38
Table B-19: Non-instrumented Data @ -10°C: Part A	II
Table B-20: Non-instrumented Data @ -10°C: Part B	111
Table B-21: Instrumented Data @ 21.1°C: Part A	IV
Table B-22: Instrumented Data @ 21.1°C: Part B	V
Table B-23: Instrumented Data @ 4.4°C: Part A	.VI
Table B-24: Instrumented Data @ 4.4°C: Part B	VII
Table B-25: Instrumented Data @ -10°C: 07-123 & 06-105	VIII
Table B-26: Instrumented Data @ -10°C: 06-84	IX
Table B-27: Instrumented Data @ -10°C: 06-101	Х
Table B-28: Instrumented Data @ -10°C: 06-125	XI
Table B-29: Instrumented Data @ -10°C: 06-150	.XII

INTRODUCTION

With the Missouri Department of Transportation (MoDOT) beginning to fully implement the new Guide for Mechanistic-Empirical (M-E) Design of New and Rehabilitated Pavement Structures (1), the need existed for various types of testing of hot-mix asphalt (HMA) used by MoDOT in its flexible pavements. The American Association of Highway and Transportation Officials (AASHTO) test method T 322-07 (2) is utilized to determine HMA properties that are needed as inputs to the M-E Pavement Design Guide (M-E PDG) software.

Two HMA properties derived from AASHTO T 322-07 are creep compliance and tensile strength. Creep compliance is defined as time-dependent strain per unit stress while indirect tensile (IDT) strength is best defined by what its name implies; HMA strength when subjected to tension. Both properties are determined using the IDT method; i.e. a cylindrically shaped specimen is loaded in compression across its diameter thus indirectly causing tension in opposite directions perpendicular to and beginning at the line of loading. As HMA is considered a visco-elastic material, creep compliance and tensile strength are not only dependent on the HMA mix constituent properties, constituent proportions, and compacted mix properties (e.g. % air voids), both are also temperature dependent. Additionally, creep compliance is dependent on the load/unload duration and tensile strength is dependent on load rate.

The contract was started when T 322-03 (*3*) was the current version for determining creep compliance and tensile strength using IDT methods. T 322-07 was published in the summer of 2007. Some changes to T 322-03 were in response to results published in the National Cooperative Highway Research Program (NCHRP) Report 530 (*4*). Especially in the context of M-E PDG inputs, creep compliance and tensile strength determination has been a moving target and, thus, experts (see Acknowledgements) were contacted in regard to how these properties are actually being obtained in practice. It is fair to say that there were about as many methods promoted and opinions expressed as there were contacts. Nonetheless, T 322-07 was adhered to as closely as possible, with a few exceptions (see Technical Approach section).

MoDOT contracted with Missouri University of Science and Technology (Missouri S&T) to perform the creep compliance and tensile strength testing on several HMA mixes used in wearing (surface) courses throughout the state. Test results are needed by MoDOT to calibrate the M-E PDG thermal (low-temperature) cracking distress models to local conditions; e.g. locally available HMA mix constituents.

OBJECTIVES

The objective of this project is to determine creep compliance, Poisson's ratio, tensile strength, and tensile failure strain of several HMA surface mixes in general accordance with AASHTO T 322-07. The test results will include creep compliance, Poisson's ratio, tensile strength, and tensile failure strain data for six different plant-produced mixes. The specimens, provided by MoDOT, will be tested for creep compliance (and Poisson's ratio) at 0, -10, and -20°C, and for tensile strength at -10, 4.4, and 21°C. Tensile failure strain will be determined for all six mixes at -10°C, and additionally at 4.4 and 21°C on four of the mixes (per MoDOT's requirements). Those same four mixes will be tested at three levels of % air voids: 4, 6.5, and 9%. The remaining two mixes will be tested at 6.5% voids only. All testing will include three replications per treatment combination.

TECHNICAL APPROACH

General

The technical approach included choice of materials and target specimen properties, determination of mix properties, specimen fabrication, determination of actual specimen properties, creep compliance and tensile strength testing, and data reduction.

Materials and Target Specimen Properties

MoDOT sampled six different plant-produced surface mixes, selected the level(s) of % air voids at which each compacted mix would be tested, and fabricated the test specimens for the creep compliance and tensile strength testing. Table 1 gives information about the mixes, the target % air voids of the IDT specimens, and the minimum number of replicate tests (creep and strength) required per treatment combination.

HMA Mix Type	MoDOT ID [Description]	Virgin PG	No. R	eplicate	Tests
	% RAP**	Binder	4%	6.5%	9%
	(Aggregate Type)	Grade	Voids	Voids	Voids
Superpave	06-101 [SP125B]	76-22	3*	3*	3*
	(Dolomite)	(modified)			
Superpave	06-150 [SP125C]	70-22	3*	3*	3*
	10% RAP	(modified)			
	(Limestone)				
Superpave	06-125 [SP125C]	64-22	3*	3*	3*
	(Limestone)				
Superpave	06-105 [SP125C]	70-22		3	
	10% RAP	(modified)			
	(Dolomite)				
Superpave	06-84 [SP125BSM]	76-22	3*	3*	3*
(Stone Matrix)	(Porphry)	(modified)			
Marshall	07-123 [BP-1]	64-22		3	
	20% RAP				
	(Dolomite)				

Table 1: HMA Mixes and Target % Air Voids

*Additional IDT strength testing at 4.4 and 21°C (40 and 70°F, respectively) **Recycled Asphalt Pavement

It is important to point out why it is advantageous to perform more testing at 6.5% air voids than 4 and 9%: the M-E PDG requires that as-constructed properties be used as inputs to the Thermal Cracking module within the software. A level of 6.5% air

voids generally describes the average level of compaction immediately postconstruction. MoDOT's specifications require *in-place* (as-constructed) densities of $94 \pm 2\%$ of theoretical maximum specific gravity (G_{mm}) for Superpave (SP) mixes (i.e. 4 - 8% voids), $\geq 94\%$ of G_{mm} for Stone Matrix Asphalt (SMA) mixes (maximum of 6% voids), and $\geq 92\%$ of G_{mm} for Bituminous Pavement (BP) mixes (maximum of 8% voids). Thus, 6.5% air voids fits nicely within the specifications for all three mix types. Additional testing at 4 and 9% air voids allows for the development of relationships between material properties determined through testing and the level of air voids. Therefore the prediction of material properties can be made at different levels of voids other than those actually used during testing.

Specimen Fabrication

Having obtained the plant-produced mixes, MoDOT Central Lab staff first determined the maximum specific gravity of each mix (G_{mm}) according to test method AASHTO T 209 (5). Having the G_{mm} of each mix and using well established algorithms, the mix weight was determined that would produce a gyratorycompacted specimen 150 mm in diameter, 115 mm in height, and with a void content approximating the target. After the specimens were compacted and had been stored at room temperature overnight, a water-cooled masonry saw was used to first trim off at least 6 mm of height from the top and bottom of the specimen, and then saw the remainder of the specimen in half producing two IDT specimens (each with two parallel sawn faces) 150 mm in diameter and about 50 mm in height (in most cases; there was an exception for one mix). Each IDT specimen was then dried using the CoreDry® device. Bulk specific gravities (G_{mb}) and the actual % air voids of each were then determined using ASTM D 6752 (6) (NOTE: ASTM D 6752, essentially the CoreLok® method, is a deviation from T 322-07 which specifies AASHTO T 166 (7) for G_{mb} determination). Finally, each IDT specimen was measured (4 thickness and 2 diameter measurements taken and then averaged), marked, wrapped in cling wrap, and boxed for delivery to Missouri S&T. Table 2 gives more detailed information about the mixes.

Mix ID	% Virgin Binder	% Binder in RAP	Total % Binder	% Fibers	G _{mm}			
06-101	5.7	NA	5.7	0	2.515			
06-150	5.0	4.8	5.5	0	2.467			
06-125	6.5	NA	6.5	0	2.412			
06-105	5.1	4.8	5.6	0	2.455			
06-84	6.3	NA	6.3	0.3	2.436			
07-123	4.2	5.7	5.3	0	2.501			

Table 2: Additional Mix Properties

IDT Testing

Equipment

Testing for this project was performed using a Tinius-Olsen (T-O) Super L load frame calibrated up to 120,000 lbf. The system is non-dynamic, closed-loop servohydraulic and is computer controlled using the software program MTestWindows by Admet. In addition to the T-O's standard load measurement device (pressure transducer), a new electronic 25,000 lbf, fatigue-rated Tovey load cell (Model FR20-25K) was mounted in-line between the loading table of the T-O and the piston connected to the lower IDT loading platen/strip, as specified in T 322-07. The Tovey load cell was cross-calibrated up to 19,000 lbf using the T-O which had been calibrated by a certified T-O technician approximately 10 months earlier. Just days before IDT testing began, the same T-O technician again calibrated the T-O and noted that no adjustments to the previous calibration were necessary thus verifying the cross-calibration of the Tovey load cell. The T-O load data output is used by the MTestWindows program for control purposes. However, for purposes of calculating creep compliance and tensile strength, the Tovey load data was used because of the load cell's faster response and higher resolution relative to the pressure transducer used in the T-O. Because all data was acquired at a rate of 10 Hz, a faster load cell response was necessary to determine with greater accuracy the time at which maximum loads occurred.

Specimen deformations were measured using new, MTS strain-gauge type extensometers (Model OSDME). The extensometers were factory calibrated for two different full-scale displacement ranges: vertical, 2.000 and 0.2000 mm compression only (utilized during strength and creep testing, respectively); horizontal, ± 0.500 and ± 0.0500 mm compression and tension (utilized during strength and creep testing, respectively). During creep compliance testing, the smaller range was used for increased resolution.

Data acquisition was accomplished using LabView 8.0 by National Instruments. Inputs to data acquisition were the T-O load output and table position, the Tovey load cell, and the four MTS extensometers.

The temperature chamber is MTS model 651.34. The temperature is controllable from -30 to $\pm 0.2^{\circ}$ C. Figure 1 shows the equipment configuration.



Figure 1: Test Equipment Setup

Creep Compliance Testing

Creep compliance is defined in T 322-07 as "the time-dependent strain divided by the applied stress." T 322-07 specifies compacted HMA test specimens that are cylindrically shaped with a diameter of 150 ± 9 mm and a thickness (height) of 38 to 50 mm (typically). A static load is imposed along a diametral axis of the temperature controlled specimen for a specified period of time (usually 100 seconds). Creep compliance testing is non-destructive in that the load is controlled so that the upper linear-elastic boundary of the HMA (typically 500 microstrain) is not exceeded, therefore each specimen can be tested at several temperatures. However, the load must be great enough to cause sufficient horizontal deformation (≥ 0.00125 mm or 33 microstrain based on a 38 mm gauge length) such that noise in the data acquisition process is insignificant. During the loading period, vertical and horizontal deformations are measured on the two sawn, parallel faces of the specimen using four extensometers, two per face (see Figure 2).



Figure 2: Instrumented IDT Specimen

Procedure

Prior to performing the creep testing, gauge points were attached to the IDT specimens using a gluing template and a cyanoacrylate adhesive (see Figures 3(a) through 3(g)). Just before testing a particular IDT specimen, specially modified MTS adapters were mounted onto the gauge points, aligned and secured in preparation for suspending the extensometers between each set of opposing adapters (black for vertical, gray for horizontal). Figures 3(h) and 3(i) show the mounting of the adapters.

Three replicate test specimens were inserted into the temperature chamber: one that was instrumented with the extensiometers and placed on the lower loading strip (as shown in Figure 2), and two that were not. The chamber was turned on and the temperature control set to -21°C. Per recommendations in NCHRP Report 530, specimen temperature was monitored by using a dummy IDT specimen within the chamber that had a type K thermocouple embedded at its 3-dimensional center. Thus, the chamber temperature was necessarily set at the target test temperature ± 1.0 °C in order to obtain an internal specimen temperature that was within ± 0.5 °C of the target temperature (as indicated by the type K thermocouple) before any testing was performed. The basic procedure for creep testing was as follows:

1. Perform a 100 second IDT creep test at -20°C on specimen #1 of the set of three replicates that represent a particular treatment combination of mix type

and level of % air voids. Although not specified or even addressed in T 322-07, the static creep load should be applied as quickly as possible, with minimum overshoot, and then stabilized to $\pm 2\%$ of the creep load as quickly as possible. Figure 4 shows a typical load versus time plot. NOTE: Data was acquired at a rate of 10 Hz throughout the entire creep test.



Figure 3: Pre-Instrumentation Preparation

- 2. After removal of the static load, continue to record deformations (rebound) of specimen #1 for at least an additional 100 seconds
- 3. Repeat steps 1 and 2 on specimens #2 and #3. NOTE: In between the testing of each specimen, the adapters/extensometers had to be moved from one specimen to the next, and this was done outside of the chamber. During this time, the door to the chamber was left open (thus shutting off the temperature chamber) so that the temperature of the dummy specimen (left inside the chamber) would more closely reflect the temperature of the specimen that was about to be tested. Once the next specimen was instrumented and aligned on the IDT test fixture lower loading strip, the door would be closed, the temperature chamber energized, and testing would not resume until the

dummy specimen temperature was again within $\pm 0.5^{\circ}$ C of the target temperature.

4. Once testing is completed at -20°C, repeat steps 1 through 3 at 0°C and then again at -10°C, all with the same three specimens.

Thus, the same three specimens were tested at all temperatures in the following order: 1, 2, 3 (at -20°C), 3, 2, 1 (at 0°C), then 1, 2, 3 (at -10°C). On average, it took about 12 hours to perform the creep testing for one set of replicates. Most of that time was spent waiting for the temperature of the dummy specimen (as indicated by the type K thermocouple) to stabilize at the desired test temperature, $\pm 0.5^{\circ}C$.





The use of a thermocouple-instrumented dummy specimen to determine test specimen temperatures was a deviation from T 322-07. Section 11.3 states to "lower the temperature of the environmental chamber to the test temperature and, once the test temperature ± 0.5 °C is achieved, allow each specimen to remain at the test temperature from 3 ± 1 hours prior to testing." The problem with the method specified in T 322-07 is that the door to the chamber is open for approximately 5 minutes while the adapters/extensometers are being transferred to the next specimen, thus the chamber and the specimens warm up. Upon closing the door and turning the chamber back on, the chamber will come back to test temperature much faster than the specimens; i.e. there is no guarantee that the instrumented test

specimen is actually at the test temperature unless internal specimen temperature is monitored, which was done during the testing in this study. As indicated earlier, creep testing of a set of three replicate specimens was accomplished, on average, in about 12 hours therefore no specimens were left at or below 0°C for more than 24 hours, per the restriction specified in T 322-07 Section 11.3.

Tensile Strength Testing

The tensile strength testing portion of T 322-07 is a destructive test; i.e. the specimen is loaded until tensile failure occurs and the specimen cannot be used again. The specimen temperature is first stabilized at the target temperature and then loaded at a rate of 12.5 mm of vertical ram movement per minute. Tensile failure has been defined to have taken place with the *first* occurrence of one of the following two conditions: 1) the maximum load is reached or 2) the difference between the vertical (y) and horizontal (x) deformations (on either face) reaches a peak. The load (and time) at which the y-x differential peaks was defined in T 322-03 as "first failure." T 322-03 states, "This value [stress at first failure] is less than or equal to the ultimate stress realized by the specimen and is determined by analyzing deformations on both sides of each specimen." However, T 322-07 has discontinued the use of the "first failure" definition and specifies the maximum load recorded during testing to be used in calculating tensile strength. Tensile strength is calculated as a function of the load at tensile failure and the specimen dimensions. Tensile failure strain is calculated as simply the horizontal strain at tensile failure; i.e. the horizontal deformation occurring between the initial application of load and tensile failure, divided by the gauge length (38 mm during this project).

MoDOT's stated need for tensile failure strain data caused concern from the start of the project because it requires the recording of vertical and horizontal deformations during the IDT strength testing procedure which could lead to damage of the extensometers. The mode of tensile failure is temperature dependent; i.e. the lower the temperature, the higher the probability that the specimen will fail catastrophically and suddenly fracture in half, everything else remaining constant.

This issue of instrumented specimens during strength testing is one of the curiosities of T 322. T 322-07 Section 11.5 states, "After the creep tests have been completed at each temperature, determine the tensile strength by applying a load to the specimen at a rate of 12.5 mm of ram (vertical) movement per minute. *Record the vertical and horizontal deformations on both ends of the specimen and the load, until the load starts to decrease*." The italicized sentence was also in T 322-03. However, the "first failure" definition has been removed from T 322-07 and determination of "first failure" was the only reason to record vertical and horizontal deformations during strength testing (i.e. monitor the y-x differential). Nowhere in T 322-07 are the deformations obtained during strength testing used for any calculation or analysis purposes.

Some experts assert that, provided the technician is very careful, tensile failure strain can be determined without damaging the equipment, even at very low temperatures. However, these same experts acknowledge that damage to deformation measurement devices has occurred. NCHRP Report 530 recommends not performing IDT strength testing while the specimen is instrumented. In that report, an equation was developed that transforms "uncorrected" IDT strength (i.e. strength calculated as a function of maximum load) into a "corrected" or true tensile strength (i.e. that strength calculated using the "first failure" definition). The relationship looks to have been developed using 16 data points and resulted in a R² value of 74%.

Tensile Strength = $(0.78 \times IDT Strength) + 38$

(1)

where:

Tensile Strength = strength corrected to first failure IDT Strength = strength calculated as a function of maximum load

The need for "first failure" tensile strength stems from the fact that the procedure outlined in T 322-03 was used during the national calibration of the thermal cracking distress model in the M-E PDG. Appendix HH of the M-E PDG documentation (*8*) goes into great detail about the IDT procedure and how "first failure" represents the true tensile strength of a HMA mixture at low temperatures better than simply using the maximum load. Thus, the argument is that any local calibration of the thermal cracking model should also be performed using the "first failure" concept.

Procedure

In light of the previous discussion about concerns over damaging or destroying the extensometers, the tensile strength and tensile failure strain data was collected in a sequence such that the probability of damage was minimum at the beginning and maximum at the end, thus ensuring the maximum amount of valid data across the entire testing program. The sequence was as follows:

- Immediately following the creep compliance testing of a particular set of replicate specimens at -10°C, that same set of specimens was tested for tensile strength but they were not instrumented for deformation measurements. Because specimens were not instrumented, maximum load was used for calculation purposes.
- 2. Once all of the creep compliance and non-instrumented tensile strength testing was complete, another round of tensile strength testing was performed on the four mixes selected for testing at 21°C (70°F) but those specimens were instrumented with the extensometers. Due to instrumentation, the "first failure" concept was used for calculation purposes.
- 3. Following completion of the instrumented tensile strength testing at 21°C, another round of instrumented tensile strength testing was performed on the

same four mixes but at 4.4°C (40°F). Again, "first failure" was used during calculations.

4. Finally, instrumented tensile strength testing was performed on all six mixes at -10°C. Once again, "first failure" was used during calculations.

To try and minimize any shock or movement of the specimen during the instrumented, lower temperature tensile strength testing, a set of foam rubber "book ends" were constructed that were placed on either side of the specimen during testing. Figure 5 shows this configuration.



Figure 5: Low Temperature Tensile Strength Testing Configuration

The tensile strength testing was performed per T 322-07 in that the specimens were loaded at a rate of 12.5 mm of ram (vertical) movement per minute. The extensometers were configured for the larger range at which they had been calibrated such that deformations could be measured to a maximum of 2.000 mm vertically and 1.000 mm horizontally (\pm 0.500 mm).

Data Reduction

Creep Compliance

Creep compliance is calculated as a function of the horizontal and vertical deformations, the gauge length over which these deformations are measured, the dimensions of the test specimen, and the magnitude of the static load. Creep compliance determination, as defined in T 322-07, is given as follows:

$$D(t) = \frac{\Delta X_{tm, t} \times D_{avg} \times b_{avg}}{P_{avg} \times GL} \times C_{cmpl}$$
(2)

where:

 $D(t) = creep compliance at time t (kPa)^{-1}$

GL = gauge length in meters (0.038 meters for 150 mm diameter specimens) D_{avg} = average diameter of all specimens [typically 3] (nearest 0.001 meter) b_{avg} = average thickness of all specimens [typically 3] (nearest 0.001 meter) P_{avg} = average creep load (kN)

 $\Delta X_{tm,t}$ = trimmed mean of the normalized, horizontal deformations (nearest 0.001 meter) of all specimen faces [typically 6] at time t

$$C_{cmpl} = correction \ factor = 0.6354 \times \left(\frac{X}{Y}\right)^{-1} - 0.332$$
(3)

where:

 $\frac{X}{Y}$ = absolute value of the ratio of the normalized, trimmed mean of the horizontal

deformations (i.e. $\Delta X_{tm,t}$) to the normalized, trimmed mean of the vertical deformations (i.e. $\Delta Y_{tm,t}$) at a time corresponding to $\frac{1}{2}$ the total creep test time [typically 50 seconds] for all specimen faces

Equation 3 gives a non-dimensional correction factor that accounts for horizontal and vertical stress correction factors, and horizontal specimen bulging during loading (8, 9). Equation 3 restrictions are given by Equation 4:

$$\left[0.704 - 0.213 \left(\frac{b_{\text{avg}}}{D_{\text{avg}}}\right)\right] \le C_{\text{cmpl}} \le \left[1.566 - 0.195 \left(\frac{b_{\text{avg}}}{D_{\text{avg}}}\right)\right]$$
(4)

Normalization of the measured vertical and horizontal deformations of a specific specimen face is accomplished by multiplying said deformations by a constant that is a function of specimen dimensions and the creep load:

Normalization Constant =
$$\frac{b_n}{b_{avg}} \times \frac{D_n}{D_{avg}} \times \frac{P_{avg}}{P_n}$$
 (5)

where:

 b_n , D_n , and P_n = thickness, diameter, and creep load of specimen n, respectively.

The trimmed mean of the normalized deformations (i.e. $\Delta X_{tm,t}$ and $\Delta Y_{tm,t}$) is simply the average of the remaining values (usually 4) after the maximum and minimum values have been discarded.

Creep compliance values needed for input into the M-E PDG Thermal Cracking module are calculated at 1, 2, 5, 10, 20, 50, and 100 seconds of loading, at -20, -10, and 0°C. The first major step is to determine the deformations at these times during testing at each of the temperatures.

Upon inspection of the raw acquired data, one first identifies the points in time at which 1) the load is first applied to the specimen and 2) the load stabilizes to $\pm 2\%$ of the target creep load. In viscoelastic theory, the load versus time profile for creep testing is a step function; i.e. the load is applied instantaneously, held constant for the desired length of time, and then removed instantaneously. However, instantaneous loading in the real world is impossible. Under ideal real-world conditions the elapsed time between the initial application of load and stabilization at the creep load ($\pm 2\%$) would be 0.1 second or less, based on the opinions of experts. However due to equipment limitations, elapsed load "ramp" time (i.e. the elapsed time between initial application of the load and the stabilization of the load to $\pm 2\%$ of the target creep load) during this study averaged 3 seconds.

Per recommendations by Harold Von Quintus, MoDOT's consultant on calibration of the M-E PDG, creep compliance at 1 second, for example, would be calculated using deformations recorded 1 second *after* the load stabilized to $\pm 2\%$ of the target creep load; i.e. the point in time at which the load stabilized to $\pm 2\%$ of the target creep load would be considered t_{zero}. In essence, a true creep load profile was being assumed. All creep compliance values at different times, t, are calculated relative to t_{zero}. Designated as the "original" method throughout the remainder of this paper, the methodology described above is shown in Figure 6 using a time-abbreviated dataset. Deformations are designated as North or South (i.e. the face of the specimen the deformations are associated with), and Vertical or Horizontal.

Note that in this particular dataset, the load "drooped" to the lower limit (target creep load – 2%) immediately following the very brief overshoot, and stayed there for several seconds before fully stabilizing at the target creep load of 2000 pounds. This phenomenon occurred quite often but not all of the time, and seemed to result from a combination of the tuning of the T-O servo-hydraulic gains (i.e. Proportional, Integral, and Derivative gains or PID's), the particular specimen and test temperature, and inherent peculiarities of the T-O system. It should also be noted that although the indication is that deformations at the specified times are used for calculation of creep compliance, an average deformation value based on several deformations that straddle the specified time line was actually used for creep compliance calculations. This averaging of several values (a minimum of two and a maximum of nine) was done to account for noise in the data. For example, if the South Horizontal deformation value at 5 seconds was being determined, horizontal deformations on the south face of the specimen at 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, and 5.4 seconds were averaged. However to determine the deformation at t_{zero}, a smaller number of values were averaged because the absolute value of the change in deformation per 0.1 second was usually greater than at later times.



Figure 6: Deformation Determination for Creep Compliance Calculations

Poisson's Ratio

Poisson's ratio, v, is calculated as follows:

$$\nu = -0.10 + 1.480 \left(\frac{X}{Y}\right)^2 - 0.778 \left(\frac{b_{\text{avg}}}{D_{\text{avg}}}\right)^2 \left(\frac{X}{Y}\right)^2$$
(6)

where:

 $0.05 \le v \le 0.50$

Tensile Strength and Tensile Failure Strain

Calculation of tensile strength per T 322-07 is given by Equation 7.

$$S_{t,n} = \frac{2 \times P_{f,n}}{\pi \times b_n \times D_n}$$
(7)

where:

 $S_{t,n}$ = tensile strength of specimen, n P_{f,n} = maximum load observed for specimen, n

As the "first failure" concept was utilized during IDT strength testing, calculation of tensile strength would be accomplished using Equation 7 but $P_{f,n}$ would be the load associated with the maximum y-x differential or the maximum load, whichever occurred first. The average tensile strength for a particular set of replicate specimens is also an input to the Thermal Cracking Module of the M-E PDG.

Tensile failure strain is calculated as follows:

$$\varepsilon_{\rm tf} = \frac{\Delta X_{\rm f}}{{\rm GL}} \times 10^6 \tag{8}$$

where:

 ϵ_{tf} = tensile failure strain (microstrain) ΔX_f = the horizontal deformation (10⁻⁶ mm) at failure. GL = gauge length in mm (38 for 150 mm diameter specimens)

RESULTS AND DISCUSSION

Creep Compliance

The creep compliance results are given in Tables 3 through 7. Creep compliance values are given in two different units: psi⁻¹ (needed for input into the M-E PDG Thermal Cracking Module) and GPa⁻¹. Plots generated for comparison purposes are given in Figures 7 through 9 showing creep compliance results for mixes compacted to 6.5% voids. A complete set of plots are given in Appendix A.

	0.001	e e inipilari	001 00 120				
Temp	Time	06-125 (V	oids = 4%)	06-125 (Vo	ids = 6.5%)	06-125 (V	oids = 9%)
(deg C)	(sec)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)
	1	2.5035E-07	0.03631	3.0510E-07	0.04425	3.3867E-07	0.04912
	2	2.5648E-07	0.03720	3.0997E-07	0.04496	3.4573E-07	0.05014
	5	2.6933E-07	0.03906	3.2352E-07	0.04692	3.5754E-07	0.05186
-20	10	2.8235E-07	0.04095	3.4009E-07	0.04933	3.7427E-07	0.05428
	20	2.9128E-07	0.04225	3.6010E-07	0.05223	3.9264E-07	0.05695
	50	3.1535E-07	0.04574	3.8300E-07	0.05555	4.1835E-07	0.06068
	100	3.2748E-07	0.04750	4.1431E-07	0.06009	4.4649E-07	0.06476
	1	3.3791E-07	0.04901	3.6567E-07	0.05304	4.1683E-07	0.06046
-10	2	3.4928E-07	0.05066	3.8180E-07	0.05538	4.2892E-07	0.06221
	5	3.7034E-07	0.05371	4.0938E-07	0.05938	4.5714E-07	0.06630
	10	3.9875E-07	0.05783	4.4683E-07	0.06481	4.9356E-07	0.07159
	20	4.2747E-07	0.06200	4.8141E-07	0.06982	5.3069E-07	0.07697
	50	4.7736E-07	0.06924	5.4865E-07	0.07957	5.9145E-07	0.08578
	100	5.2629E-07	0.07633	6.0627E-07	0.08793	6.4465E-07	0.09350
	1	5.3193E-07	0.07715	5.6385E-07	0.08178	6.7142E-07	0.09738
	2	5.6947E-07	0.08260	6.0557E-07	0.08783	7.1841E-07	0.10420
0	5	6.3890E-07	0.09266	6.9872E-07	0.10134	8.1813E-07	0.11866
	10	7.1948E-07	0.10435	8.0840E-07	0.11725	9.3953E-07	0.13627
	20	8.2759E-07	0.12003	9.5273E-07	0.13818	1.0931E-06	0.15854
	50	1.0377E-06	0.15051	1.2298E-06	0.17837	1.3791E-06	0.20002
	100	1.2568E-06	0.18228	1.5379E-06	0.22305	1.6955E-06	0.24591

Table 3: Creep Compliance: 06-125 (SP125C Limestone)

Temp	Time	06-101 (V	oids = 4%)	06-101 (Vo	06-101 (Voids = 6.5%)		06-101 (Voids = 9%)	
(deg C)	(sec)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)	
	1	2.1272E-07	0.03085	2.4003E-07	0.03481	2.8444E-07	0.04125	
	2	2.1606E-07	0.03134	2.4822E-07	0.03600	2.8698E-07	0.04162	
	5	2.2259E-07	0.03228	2.5550E-07	0.03706	2.9960E-07	0.04345	
-20	10	2.3511E-07	0.03410	2.6741E-07	0.03878	3.1585E-07	0.04581	
	20	2.4617E-07	0.03570	2.7939E-07	0.04052	3.3516E-07	0.04861	
	50	2.6328E-07	0.03819	2.9706E-07	0.04308	3.5140E-07	0.05097	
	100	2.7380E-07	0.03971	3.1193E-07	0.04524	3.7558E-07	0.05447	
	1	2.6071E-07	0.03781	3.0755E-07	0.04461	3.7287E-07	0.05408	
	2	2.6953E-07	0.03909	3.2101E-07	0.04656	3.8817E-07	0.05630	
	5	2.8765E-07	0.04172	3.4047E-07	0.04938	4.1282E-07	0.05987	
-10	10	3.0762E-07	0.04462	3.6382E-07	0.05277	4.3411E-07	0.06296	
	20	3.2653E-07	0.04736	3.9391E-07	0.05713	4.6853E-07	0.06795	
	50	3.6785E-07	0.05335	4.3838E-07	0.06358	5.1935E-07	0.07533	
	100	4.0278E-07	0.05842	4.7890E-07	0.06946	5.6973E-07	0.08263	
	1	3.8947E-07	0.05649	4.3942E-07	0.06373	4.8861E-07	0.07087	
	2	4.1800E-07	0.06063	4.7132E-07	0.06836	5.2329E-07	0.07590	
0	5	4.7754E-07	0.06926	5.3036E-07	0.07692	5.9067E-07	0.08567	
	10	5.4781E-07	0.07945	5.9919E-07	0.08690	6.7225E-07	0.09750	
	20	6.3849E-07	0.09261	6.9474E-07	0.10076	7.7699E-07	0.11269	
	50	8.0632E-07	0.11695	8.6604E-07	0.12561	9.5867E-07	0.13904	
	100	9.8017E-07	0.14216	1.0474E-06	0.15192	1.1556E-06	0.16761	

Table 4: Creep Compliance: 06-101 (SP125B Dolomite)

Table 5: Creep Compliance: 06-84 (SP125BSM Porphry)

Temp	Time	06-84 (Vo	oids = 4%)	06-84 (Voi	06-84 (Voids = 6.5%)		06-84 (Voids = 9%)	
(deg C)	(sec)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)	
	1	2.5426E-07	0.03688	2.9047E-07	0.04213	3.6340E-07	0.05271	
	2	2.6128E-07	0.03790	2.9604E-07	0.04294	3.6774E-07	0.05334	
	5	2.7030E-07	0.03920	3.0591E-07	0.04437	3.8061E-07	0.05520	
-20	10	2.8330E-07	0.04109	3.2202E-07	0.04670	3.9955E-07	0.05795	
	20	2.9398E-07	0.04264	3.4097E-07	0.04945	4.2072E-07	0.06102	
	50	3.1146E-07	0.04517	3.6314E-07	0.05267	4.4901E-07	0.06512	
	100	3.2883E-07	0.04769	3.8628E-07	0.05603	4.7240E-07	0.06852	
	1	3.5706E-07	0.05179	3.5774E-07	0.05189	5.0654E-07	0.07347	
	2	3.6484E-07	0.05291	3.7019E-07	0.05369	5.1945E-07	0.07534	
	5	3.8548E-07	0.05591	3.9085E-07	0.05669	5.4379E-07	0.07887	
-10	10	4.0867E-07	0.05927	4.1908E-07	0.06078	5.8552E-07	0.08492	
	20	4.4271E-07	0.06421	4.6059E-07	0.06680	6.3365E-07	0.09190	
	50	4.8753E-07	0.07071	5.0960E-07	0.07391	7.1346E-07	0.10348	
	100	5.4001E-07	0.07832	5.6664E-07	0.08218	7.9126E-07	0.11476	
	1	4.9589E-07	0.07192	4.9558E-07	0.07188	7.4524E-07	0.10809	
	2	5.2990E-07	0.07686	5.2614E-07	0.07631	8.0206E-07	0.11633	
0	5	5.9431E-07	0.08620	5.9778E-07	0.08670	9.1754E-07	0.13308	
	10	6.7615E-07	0.09807	6.8427E-07	0.09924	1.0566E-06	0.15324	
	20	7.7898E-07	0.11298	8.0170E-07	0.11628	1.2460E-06	0.18072	
	50	9.6964E-07	0.14063	1.0148E-06	0.14719	1.6149E-06	0.23423	
	100	1.1634E-06	0.16874	1.2521E-06	0.18161	2.0361E-06	0.29531	

Temp	Time	06-150 (Voids = 4%)		06-150 (Voids = 6.5%)		06-150 (Voids = 9%)	
(deg C)	(sec)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)
-20	1	2.3270E-07	0.03375	2.7471E-07	0.03984	3.2558E-07	0.04722
	2	2.3364E-07	0.03389	2.7942E-07	0.04053	3.3127E-07	0.04805
	5	2.4020E-07	0.03484	2.8612E-07	0.04150	3.4147E-07	0.04953
	10	2.5333E-07	0.03674	2.9530E-07	0.04283	3.5699E-07	0.05178
	20	2.6562E-07	0.03853	3.0936E-07	0.04487	3.7511E-07	0.05441
	50	2.7686E-07	0.04016	3.2931E-07	0.04776	4.0184E-07	0.05828
	100	2.9248E-07	0.04242	3.4894E-07	0.05061	4.2234E-07	0.06126
-10	1	2.7076E-07	0.03927	3.4397E-07	0.04989	3.9128E-07	0.05675
	2	2.7845E-07	0.04039	3.5229E-07	0.05109	4.0149E-07	0.05823
	5	2.9297E-07	0.04249	3.7356E-07	0.05418	4.2930E-07	0.06227
	10	3.1444E-07	0.04560	4.0236E-07	0.05836	4.6357E-07	0.06724
	20	3.3663E-07	0.04882	4.2599E-07	0.06179	4.9991E-07	0.07251
	50	3.7557E-07	0.05447	4.7964E-07	0.06957	5.6571E-07	0.08205
	100	4.0644E-07	0.05895	5.2053E-07	0.07550	6.1993E-07	0.08991
0	1	3.6693E-07	0.05322	4.8603E-07	0.07049	6.5130E-07	0.09446
	2	3.8964E-07	0.05651	5.1387E-07	0.07453	6.9116E-07	0.10024
	5	4.2905E-07	0.06223	5.8161E-07	0.08436	7.8421E-07	0.11374
	10	4.7953E-07	0.06955	6.6901E-07	0.09703	8.9981E-07	0.13051
	20	5.4656E-07	0.07927	7.8147E-07	0.11334	1.0633E-06	0.15422
	50	6.6964E-07	0.09712	9.9636E-07	0.14451	1.3820E-06	0.20044
	100	8.0373E-07	0.11657	1.2394E-06	0.17976	1.7543E-06	0.25444

Table 6: Creep Compliance: 06-150 (SP125C Limestone)

Table 7: Creep Compliance: 06-105 (SP125C Dolomite), 07-123 (BP-1 Dolomite)

Temp	Time	06-105 (Vo	ids = 6.5%)	07-123 (Voids = 6.5%)		
(deg C)	(sec)	D(t) (1/psi)	D(t) (1/Gpa)	D(t) (1/psi)	D(t) (1/Gpa)	
-20	1	2.7026E-07	0.03920	2.4423E-07	0.03542	
	2	2.7292E-07	0.03958	2.5001E-07	0.03626	
	5	2.8299E-07	0.04104	2.5685E-07	0.03725	
	10	2.9788E-07	0.04320	2.6911E-07	0.03903	
	20	3.0996E-07	0.04496	2.7338E-07	0.03965	
	50	3.2931E-07	0.04776	2.9386E-07	0.04262	
	100	3.4218E-07	0.04963	3.0554E-07	0.04431	
	1	3.2643E-07	0.04734	3.0469E-07	0.04419	
	2	3.4122E-07	0.04949	3.1069E-07	0.04506	
	5	3.5722E-07	0.05181	3.2346E-07	0.04691	
-10	10	3.7983E-07	0.05509	3.4429E-07	0.04994	
	20	4.1038E-07	0.05952	3.6472E-07	0.05290	
	50	4.4907E-07	0.06513	4.0189E-07	0.05829	
	100	4.8786E-07	0.07076	4.2199E-07	0.06120	
	1	4.3592E-07	0.06323	4.0019E-07	0.05804	
	2	4.5828E-07	0.06647	4.2175E-07	0.06117	
	5	5.0714E-07	0.07355	4.6055E-07	0.06680	
0	10	5.6857E-07	0.08246	5.0619E-07	0.07342	
	20	6.4142E-07	0.09303	5.6527E-07	0.08199	
	50	7.7507E-07	0.11241	6.6626E-07	0.09663	
	100	9.1212E-07	0.13229	7.7447E-07	0.11233	



Figure 7: Creep Compliance Comparisons: 6.5% Voids, -20°C



Figure 8: Creep Compliance Comparisons: 6.5% Voids, -10°C



Figure 9: Creep Compliance Comparisons: 6.5% Voids, 0°C

Two rounds of IDT creep testing of the BP-1 (07-123) mix were performed because the first round of creep testing was performed with an insufficient load. The load during the first round of testing produced initial horizontal deformations that did not meet the lower limit of ~33 microstrain. So, although six replicate specimens were tested for tensile strength, only the last 3 replicate specimens (round 2) were used to calculate creep compliance.

There were also two rounds of IDT creep testing on 06-84, the SMA mix. The first round of testing resulted in creep compliance values for the 4% voids specimens that were greater than the 6.5% voids specimens, backward from the expected trend. The non-uniform void distribution in the SMA specimens resulted in one face of the sawn specimen sometimes possessing large exposed voids while the opposite face was much smoother. It is speculated that this difference in face texture could have been the cause of the unexpected trend. The second round of creep testing produced expected results and those values are the ones reported in Table 5. There was not a second round of tensile strength testing immediately following the second round of creep testing.

At 6.5% air voids and at all three test temperatures, 07-123 is the stiffest or least compliant of the six mixes investigated, whereas 06-125 is the most compliant. This result dramatically shows the effect that RAP has on creep compliance. Both 07-123 and 06-125 utilize PG64-22 as the virgin binder yet they are at the extremes, at least

as it pertains to creep compliance, largely due to the fact that 07-123 has 20% RAP and 06-125 has none.

The usage of RAP in a mix is not directly addressed in the M-E PDG although some work has been done in this area (*10*). To properly account for its inclusion in a mix, a Level 1 analysis of the mix and binder should be performed; e.g. extracted RAP binder and the blended binder would need to be characterized. Estimations based on comparisons such as those shown in Figures 7 – 9 could be helpful in Level 2 and 3 designs. For example, at -20°C, 07-123 (PG64-22 virgin binder, 20% RAP) and 06-101 (PG76-22 binder, 0% RAP) have very similar creep compliance curves.

As a follow-up check on the creep compliance values listed in Tables 3 – 7, the M-E PDG software was utilized. An example new flexible pavement design (for the Dallas, Texas area) that is included in Version 1.0 of the software was used as the baseline design. Each set of creep compliance values and the associated average tensile strength from the present study were substituted into the Thermal Cracking Module of the software, they were identified as Level 1 inputs, and the analysis was performed. The purpose was to make sure that the creep compliance values as calculated would run in the software without any errors in the thermal cracking output. Only the 07-123 creep compliance values using the original calculation method produced errors in the thermal cracking output. Figure 10 shows the resultant thermal cracking plot.



Thermal Cracking: Total Length Vs Time

Figure 10: Irregular Thermal Cracking Output: Original Method: 07-123

An investigation into the reason for the error (extreme stair-step increases in thermal cracking beginning around 100 months) was undertaken. It seems that a relatively
small range (the difference between the maximum and minimum values) of creep compliance per temperature can produce problems in the algorithm used to create the master creep compliance curve (the full explanation of which is beyond the scope of this paper) by limiting the amount of overlap created when the -10°C and the 0°C creep compliance – time curves are shifted to the right in time to extend the -20°C curve thereby creating one continuous, creep compliance – reduced time master curve. The general process is shown in Figure 11 using the 07-123 data calculated using the original method.



Figure 11: Creep Compliance Master Curve Creation

This conclusion was reached using two different types of analyses: one was based on creep compliance values calculated using a different method for determining t_{zero} , and the other was based on arbitrarily increasing the range of creep compliance values for the 07-123 mix at -10 and 0°C.

The alternative method for determining t_{zero} is based on an "equivalent area" concept where at some time, t, the area under the load versus time curve of a noninstantaneous ramp load is equal to the area under a true creep load profile at time, t'. This concept was first suggested to the authors by James Sherwood of the FHWA. Later, Harold Von Quintus verified that this concept has been used in the past, particularly in an earlier flexible pavement analysis program called VESYS. However, published documentation of the equivalent area concept as applied specifically to non-instantaneous creep loading has yet to be found. Figure 12 shows this concept in calculating creep compliance at 1 second.



Figure 12: Equivalent Area Concept

Table 8 shows creep compliance values for 07-123 calculated using the equivalent area method and the "original" method described earlier.

Table 8: Equivalent Area vs. Original Method: 07-123

		Creep Compliance (1/psi)									
Time	Temp = ·	-20degC	Temp =	-10degC	Temp = 0degC						
(sec)	Equiv. Area	Original	Equiv. Area	Original	Equiv. Area	Original					
1	2.4430E-07	2.4423E-07	2.9033E-07	3.0469E-07	3.5911E-07	4.0019E-07					
2	2.4356E-07	2.5001E-07	3.0246E-07	3.1069E-07	3.9380E-07	4.2175E-07					
5	2.5001E-07	2.5685E-07	3.2053E-07	3.2346E-07	4.4563E-07	4.6055E-07					
10	2.5918E-07	2.6911E-07	3.3988E-07	3.4429E-07	4.9442E-07	5.0619E-07					
20	2.7571E-07	2.7338E-07	3.6380E-07	3.6472E-07	5.5972E-07	5.6527E-07					
50	2.9128E-07	2.9386E-07	4.0019E-07	4.0189E-07	6.6436E-07	6.6626E-07					
100	3.0674E-07	3.0554E-07	4.2673E-07	4.2199E-07	7.7751E-07	7.7447E-07					
Range	6.3187E-08	6.1304E-08	1.3641E-07	1.1730E-07	4.1840E-07	3.7427E-07					
% of Equiv	. Area Range	97.0%		86.0%		89.5%					

The first item to point out in Table 8 is the anomalous values of creep compliance for the equivalent area method at -20°C and at 1 and 2 seconds; the value at 1 second is actually larger than that at 2 seconds which is contrary to the expected trend. Upon closer inspection of the data, this anomaly is due to the fact that deformations at 1 second using the equivalent area method more closely coincide with the "knee" of the load – time curve or that area where the overshoot occurs, not ~1 second after the overshoot as is the case when using the original method. Thus for this one particular anomaly, deformations at 1 second were actually larger than at 2 seconds simply because the load due to the very brief overshoot was greater than the load at 2 seconds.

A second observation in looking at Table 8 is the fact that the equivalent area method gives smaller creep compliance values, in general. This is due to the shifting of the time line by about 1 second. In the original method of calculating creep compliance, t = 1 second always occurred about 1 second *after the overshoot*. In the equivalent area method, t = 1 second generally *coincided with the overshoot*, thus there is about a 1 second difference between the two methods with the equivalent area method using smaller deformations and resulting in smaller creep compliance values, in general. Figure 13 graphically depicts the differences between the two methods. As can be seen, the lines essentially lay on top of one another, especially at the 100 second interval.



Figure 13: Equivalent Area vs. Original Method: 07-123

Getting back to the issue of the error in the thermal cracking output shown in Figure 10, the range of creep compliance values for the two calculation methods is shown in Table 8 and clearly indicates that the equivalent area method results in a greater range. The first clue that range had an impact on the algorithm in the Thermal Cracking Module came when the creep compliance values calculated using the equivalent area method (larger range) were input into the Thermal Cracking Module and ran error-free. Output from that analysis is shown in Figure 14. The "Thermal Crack Length" line is near zero and flat across the design period which is logical, as thermal cracking is probably not a major concern in Dallas, Texas due to its climate. It should be noted that the other 13 sets of creep compliance/IDT strength values produced thermal cracking output similar to Figure 14 when using the original method for calculating creep compliance.



Thermal Cracking: Total Length Vs Time

Figure 14: Thermal Cracking Output: Equivalent Area Method: 07-123

To double-check the theory that the creep compliance range could impact the Thermal Cracking Module algorithm, the creep compliance values calculated using the original method were modified by incrementally increasing the compliance values for -10 and 0°C resulting in a larger, "stretched" range for these two temperatures but having the original value at 1 second of creep. This stretching only increased the overlap (as depicted in Figure 11) of the -10 and 0°C curves and the upper limit of the 0°C curve. Table 9 shows this methodology.

	Creep Compliance (1/psi)									
Time	Temp =	-20degC	Temp =	-10degC	Temp = 0degC					
(sec)	Original	Stretched*	Original	Stretched	Original	Stretched				
1	2.4423E-07	2.4423E-07	3.0469E-07	3.0469E-07	4.0019E-07	4.0019E-07				
2	2.5001E-07	2.5001E-07	3.1069E-07	3.1224E-07	4.2175E-07	4.2513E-07				
5	2.5685E-07	2.5685E-07	3.2346E-07	3.2669E-07	4.6055E-07	4.6516E-07				
10	2.6911E-07	2.6911E-07	3.4429E-07	3.4946E-07	5.0619E-07	5.1227E-07				
20	2.7338E-07	2.7338E-07	3.6472E-07	3.7202E-07	5.6527E-07	5.7318E-07				
50	2.9386E-07	2.9386E-07	4.0189E-07	4.1194E-07	6.6626E-07	6.7692E-07				
100	3.0554E-07	3.0554E-07	4.2199E-07	4.3465E-07	7.7447E-07	7.8841E-07				
Range	6.1304E-08	6.1304E-08	1.1730E-07	1.2996E-07	3.7427E-07	3.8821E-07				
% of Original Range		100.0%		110.8%		103.7%				

 Table 9: Original vs. Stretched Creep Compliance Ranges: 07-123

*This column is the same as the original

The stretched values (larger ranges for -10 and 0°C curves) were input into the Thermal Cracking Module and it also ran error-free thus confirming that the range of the creep compliance values per temperature has an impact on the proper operation of the Thermal Cracking Module algorithm.

Having determined that there is a problem running the M-E PDG thermal cracking analysis with the 07-123 creep compliance values calculated using the original method, it is recommended that the values determined using the equivalent area method (Table 8) be used when needed. A graph showing creep compliance values at 100 seconds, 6.5% voids, and at -10°C is given in Figure 15 for purposes of comparing mixes. Note that the 07-123 material (20% RAP) would still have the lowest creep compliance of all six mix types even though 07-123 creep compliance was calculated using the equivalent area method.



Figure 15: 100 Second Creep Compliance @ 6.5% Voids @ -10°C

Poisson's Ratio

Although not an input in the M-E PDG Thermal Cracking Module, Poisson's ratio is an Asphalt Materials Properties input in the M-E PDG and can be entered directly or estimated from other properties. Table 10 gives the Poisson's ratio values calculated using the procedure described in the Data Reduction section.

Table 10): Poisson':	s Ratio					
Temp	07-123	06-84	06-84	06-84	06-101	06-101	06-101
(Deg C)	6.5% voids	4% voids	6.5% voids	9% voids	4% voids	6.5% voids	9% voids
-20	0.210	0.279	0.245	0.224	0.242	0.240	0.178
-10	0.243	0.229	0.301	0.206	0.302	0.266	0.182
0	0.323	0.330	0.393	0.293	0.365	0.351	0.270
	06-105	06-125	06-125	06-125	06-150	06-150	06-150
_	6.5% voids	4% voids	6.5% voids	9% voids	4% voids	6.5% voids	9% voids
-20	0.246	0.306	0.223	0.212	0.295	0.243	0.216
-10	0.243	0.273	0.288	0.249	0.349	0.269	0.267
0	0.351	0.302	0.337	0.291	0.438	0.352	0.283

In general, the Poisson's ratio values in Table 10 increase with increasing temperature. However, there are four instances that do not follow this trend. Also, Poisson's ratio decreases with increasing % air voids at -20°C, but it does not always follow this trend at the higher temperatures.

Tensile Strength

All of the IDT strength testing as outlined in a previous section of this report was completed successfully. Summaries of the tensile strength results for the non-instrumented testing at -10°C, the instrumented testing at 21.1°C, the instrumented testing at 4.4°C, the instrumented testing at -10°C, and all testing at -10°C are given in Tables 11 - 15, respectively. More detailed tables are given in Appendix B.

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Mix ID	Number of	Average Air	St	SD*	CV**	Equation 1
	Replicates	Voids (%)	(psi)	(psi)	(%)	Correction (psi)
07-123	6	6.5	612	87.2	14.2	515
06-105	3	6.5	616	18.2	3.0	519
06-84	3	4.0	738	22.9	3.1	614
06-84	3	6.5	620	24.4	3.9	522
06-84	3	9.0	525	22.7	4.3	447
06-101	3	4.0	841	42.8	5.1	694
06-101	3	6.5	663	16.1	2.4	555
06-101	3	9.0	601	12.8	2.1	507
06-125	3	4.0	696	31.1	4.5	581
06-125	3	6.5	623	10.0	1.6	524
06-125	3	9.0	532	11.2	2.1	453
06-150	3	4.0	786	48.8	6.2	651
06-150	3	6.5	674	30.3	4.5	564
06-150	3	9.0	599	21.1	3.5	505

Table 11: Non-instrumented Tensile Strength: -10°C

*Sample standard deviation

**Sample coefficient of variation

Table 11 shows the expected trend of tensile strength as a function of % air voids: the strength decreases with increasing voids. The strength values for mixes compacted to 6.5% voids are fairly consistent ranging from 612 to 674 psi. Mix 07-123 (BP1) shows a highly variable tensile strength which is not too surprising as it is the lowest quality mix with the highest percentage of RAP (20%). Also, remember that there were two rounds of creep testing on 07-123 which is why 6 specimens were tested for non-instrumented IDT strength. Also included in Table 11 are values calculated using Equation 1, the equation presented in the NCHRP 530 Report that purportedly corrects IDT strength test results to true tensile strength.

Mix ID	No. Replicates	Average Air Voids (%)	S _t (psi)	SD (psi)	CV (%)
06-84	3	4.0	195	9.1	4.7
06-84	3	6.5	166	11.9	7.2
06-84	3	9.1	140	7.4	5.3
06-101	3	4.0	225	13.3	5.9
06-101	3	6.5	226	10.6	4.7
06-101	3	9.0	171	11.3	6.6
06-125	3	4.1	158	8.0	5.1
06-125	3	6.5	135	9.0	6.7
06-125	3	9.0	130	6.1	4.7
06-150	3	4.1	184	5.0	2.7
06-150	3	6.8	153	1.9	1.2
06-150	3	9.0	132	5.7	4.3

Table 12: Instrumented Tensile Strength: 21.1°C

Table 12 shows one anomaly in that the 06-101 mix IDT strength did not vary between 4.0 and 6.5% air voids. This could be due to the fact that 06-101 uses a highly modified binder, PG76-22. However, this anomaly could also be due to variability among the replicates, as indicated by the statistics which show high CV values across all three levels of air voids.

No. Replicates CV (%) Mix ID Average Air Voids (%) S_t (psi) SD (psi) 06-84 4.0 3 460 18.8 4.1 3 06-84 6.5 419 23.2 5.5 3 06-84 9.0 341 3.0 0.9 06-101 3 4.0 543 27.0 5.0 3 06-101 6.4 492 22.6 4.6 3 06-101 9.0 401 28.5 7.1 3 06-125 4.1 465 5.8 1.2 3 06-125 6.4 380 18.0 4.7 3 06-125 9.0 335 3.9 1.2 3 4.1 4.2 06-150 520 21.9 3 06-150 6.8 438 16.5 3.8 06-150 3 9.0 388 17.0 4.4

Table 13: Instrumented Tensile Strength: 4.4°C

Table 13 shows the expected trend of decreasing IDT strength with increasing voids. The 06-101 mix again shows consistently higher variability among the replicates of all mixes in Table 13 at all levels of air voids.

Mix ID	No. Replicates	Average Air Voids (%)	S _t (psi)	SD (psi)	CV (%)
07-123	3	6.8	594*	59.6	10.0
06-105	3	6.5	571	35.2	6.2
06-84	3	4.1	697	19.2	2.8
06-84	3	6.5	618	46.7	7.6
06-84	3	9.0	551	58.0	10.5
06-101	3	4.0	773	15.4	2.0
06-101	3	6.5	625*	39.7	6.4
06-101	3	9.0	573	15.2	2.6
06-125	3	4.0	587*	36.1	6.1
06-125	3	6.5	509*	108.8	21.4
06-125	3	9.0	484*	37.1	7.7
06-150	3	4.0	780*	47.5	6.1
06-150	3	6.6	630*	20.0	3.2
06-150	3	9.0	550*	15.8	2.9

Table 14: Instrumented Tensile Strength: -10°C

*Based on one or more instances of a maximum y-x differential occurring prior to the maximum load being reached

Of the instrumented IDT strength testing at three different temperatures, "first failure" as a result of maximum y-x differentials occurring prior to obtaining the maximum load was present only during the testing at -10°C. Of the 42 specimens represented in Table 14, 11 "failed" prior to the maximum load being reached. The amount of time that transpired between the maximum y-x differential and the maximum load ranged from 0.1 to 0.6 seconds. It should be noted that a data acquisition rate of ~20 Hz was depicted in the M-E PDG Appendix HH when describing the "first failure" due to a maximum y-x differential phenomenon. Therefore, while the data acquisition rate of 10 Hz as specified in T 322-07 for creep testing was used in this study, more accurate determinations of "first failure" may have been possible at higher acquisition rates.

Mix ID	No. Replicates	Average Air Voids (%)	S _t (psi)	SD (psi)	CV (%)
07-123	9	6.6	606*	75.6	12.5
06-105	6	6.5	594	35.3	5.9
06-84	6	4.0	717	29.5	4.1
06-84	6	6.5	619	33.4	5.4
06-84	6	9.0	538	41.9	7.8
06-101	6	4.0	807	47.2	5.8
06-101	6	6.5	644*	34.3	5.3
06-101	6	9.0	587	19.6	3.3
06-125	6	4.0	641*	66.8	10.7
06-125	6	6.5	566*	93.4	16.5
06-125	6	9.0	508*	36.0	7.1
06-150	6	4.0	783*	43.2	5.5
06-150	6	6.5	652*	33.3	5.1
06-150	6	9.0	575*	31.3	5.4

Table 15: All Tensile Strength: -10°C

*Based on one or more instances of a maximum y-x differential occurring prior to the maximum load being reached

Figures 16 through 21 graphically depict the results of the IDT strength testing performed in this study. Table 15 combines the results of all IDT strength testing performed at -10°C. The expected trend of decreasing strength with increasing voids is present. Statistically speaking, data in Table 15 is probably more accurate than Tables 11 and 14 due to the increased number of replicate specimens. For comparison purposes one could look at information reported in NCHRP 530 and ASTM D 6931-07 (*11*) where Anderson and McGennis (*12*) reported a CV value of 7% for IDT strength testing of 3 replicate 150 mm diameter specimens at -10°C using a load rate of 12.5 mm/min, and tested at two levels of % voids: 6.5 and 7.5%.







Figure 17: IDT Strength vs % Air Voids: 4 Mixes: 4.4°C



Figure 18: IDT Strength vs % Air Voids: 4 Mixes: -10°C



Figure 19: IDT Strength vs % Air Voids: 2 Mixes: -10°C



Figure 20: IDT Strength vs % Air Voids: All Mixes: -10°C



Figure 21: IDT Strength: All Mixes @ 6.5% Voids @ -10°C

Tensile Failure Strain

The tensile failure strain results determined using horizontal deformations recorded during the instrumented IDT strength testing are given in Tables 16 - 18. The results are expressed in microstrain based on a 38 mm gauge length.

ID	Specimen	Voids	Average	e Failure Strain (microstrain)				
	No.	(%)	Voids	North	South	Average		
06-84	13	4.0		96	178			
06-84	20	4.4	4.0	172	163	180		
06-84	21	3.6		267	203			
06-84	16	6.4		176	80			
06-84	19	6.5	6.5	105	211	153		
06-84	20	6.6		142	203			
06-84	2	9.3		89	172			
06-84	13	9.2	9.1	247	228	180		
06-84	28	8.7		130	211			
06-101	2	3.9		80	211			
06-101	6	4.1	4.0	189	133	150		
06-101	22	4.1		118	170			
06-101	18	6.1		285	160			
06-101	20	6.8	6.5	90	92	129		
06-101	27	6.5		52	95			
06-101	2	8.9		128	179			
06-101	21	9.1	9.0	145	268	183		
06-101	28	9.1		222	154			
06-125	14	3.9		162	168			
06-125	25	4.1	4.1	181	258	193		
06-125	26	4.3		151	238			
06-125	10	6.2		286	308			
06-125	19	6.9	6.5	185	199	227		
06-125	29	6.3		168	213			
06-125	5	9.4		80	176			
06-125	16	9.0	9.0	287	195	180		
06-125	28	8.6		197	149			
06-150	7	4.1		159	233			
06-150	14	4.1	4.1	157	213	179		
06-150	17	4.0		179	133			
06-150	23	6.8		195	264			
06-150	8	6.8	6.8	213	240	228		
06-150	21	6.7		177	283			
06-150	18	9.0		147	310			
06-150	25	8.9	9.0	225	346	266		
06-150	24	9.2		225	343			

Table 16: Tensile Failure Strain: 21.1°C

At 21.1°C (70°F), all failure strains coincided with the maximum load. Of particular interest is the lack of an obvious trend relating failure strain to % air voids for each mix.

ID	Specimen	Voids	Average	e Failure Strain (microstrain)			
	No.	(%)	Voids	North	South	Average	
06-84	6	4.3		60	42		
06-84	8	3.7	4.0	79	46	63	
06-84	24	4.0		104	50		
06-84	2	6.6		90	32		
06-84	9	6.4	6.5	29	65	54	
06-84	18	6.5		39	69		
06-84	1	9.3		51	86		
06-84	23	9.0	9.0	37	104	66	
06-84	25	8.8		78	37		
06-101	18	4.2		53	53		
06-101	20	4.0	4.0	108	45	69	
06-101	23	3.8		22	131		
06-101	1	6.6		29	120		
06-101	14	6.2	6.4	79	66	64	
06-101	25	6.5		14	77		
06-101	7	9.0		48	45		
06-101	22	8.9	9.0	31	78	52	
06-101	25	9.1		19	91		
06-125	6	3.9		41	69		
06-125	10	4.1	4.1	49	39	51	
06-125	13	4.3		64	47		
06-125	13	6.8		23	95		
06-125	26	6.3	6.4	30	65	50	
06-125	28	6.2		66	22		
06-125	9	9.2		54	43		
06-125	11	9.0	9.0	53	40	48	
06-125	20	8.7		65	32		
06-150	4	4.1		41	111		
06-150	19	4.1	4.1	64	105	85	
06-150	20	4.0		43	146		
06-150	2	6.8		33	105		
06-150	7	6.8	6.8	85	43	61	
06-150	12	6.9		32	70		
06-150	8	9.3		71	47		
06-150	9	9.1	9.0	65	38	58	
06-150	13	8.7		89	35		

Table 17: Tensile Failure Strain: 4.4°C

At 4.4°C (40°F), all failure strains again coincided with the maximum load. Again there is the lack of a definite trend relating failure strain to % air voids for each mix although for all except 06-84, the average failure strain for all six faces decreases with increasing % air voids. Once again the open-graded nature of 06-84, the SMA mix, may contribute to variability enough to cause the non-conformist trend.

ID	Specimen	Voids	Average	e Failure Strain (microstrain)							
	No.	(%)	Voids	At Ma	aximum l	_oad	At ((Y - X) pe	ak		
				North	South	Average	North	South	Average		
07-123	16	6.8		15	14		15	14			
07-123	17	6.7	6.8	18	5	12	18	6*	12		
07-123	18	6.8		6	15		6	15			
06-105	3	6.1		22	20						
06-105	8	7.0	6.5	10	15	18					
06-105	9	6.4		2	36						
06-84	4	4.0		15	24						
06-84	7	4.1	4.1	13	18	18					
06-84	23	4.1		8	28						
06-84	12	6.7		41	13						
06-84	15	6.5	6.5	17	22	27					
06-84	23	6.3		8	59						
06-84	11	9.2		30	13						
06-84	26	9.0	9.0	26	17	24					
06-84	27	8.8		11	47						
06-101	1	3.8		10	17						
06-101	3	4.2	4.0	9	25	16					
06-101	13	4.0		5	31						
06-101	8	6.7		1	52		4*	52			
06-101	16	6.5	6.5	11	16	17	11	16	18		
06-101	26	6.2		7	17		7	17			
06-101	8	9.0		30	8						
06-101	11	9.2	9.0	11	37	22					
06-101	26	8.8		22	23						
06-125	4	3.9		25	20		25	20			
06-125	5	4.0	4.0	5	28	18	6*	28	18		
06-125	8	4.1		4	25		4*	25			
06-125	2	6.4		1	42		2*	42			
06-125	5	6.6	6.5	1	35	19	3*	35	20		
06-125	25	6.5		14	23		14	23			
06-125	2	9.1		8	26		8	26			
06-125	10	9.0	9.0	6	32	18	6*	32	18		
06-125	12	8.9		2	31		2*	31			
06-150	10	4.2		13	22		13	22			
06-150	13	4.0	4.0	6	31	17	6*	31	17		
06-150	26	3.9		12	18		12	18			
06-150	5	6.6		5	21		5	21			
06-150	13	6.5	6.6	6	28	15	6	28	15		
06-150	14	6.7		20	11		20	11*			
06-150	5	9.1		6	33		7*	33			
06-150	6	8.7	9.0	21	16	19	21	16	19		
06-150	17	9.2		4	31		4	31			

Table 18: Tensile Failure Strain: -10°C

*Indicates an occurrence of first failure as a result of the peak y-x differential occurring prior to the maximum load being reached

At -10°C, only the 06-105 and the 06-84 mixes did not experience any peak y-x differential occurrences prior to the maximum load being reached. Mix 06-125 experienced the most "first failures" by peak y-x differential in that, for each level of air voids, two of the six observations were peak y-x differentials. Of the eight cases where means were calculated for both sets of failure strain (at the maximum load and at the peak y-x differential), only 06-101 at 6.5% voids and 06-125 at 6.5% voids resulted in slightly different mean values at the reporting precision selected. Once again, there is no apparent trend between failure strain and % air voids within a mix. More detailed tables are included in Appendix B.

Creep Compliance versus IDT Strength

Although extensive regression analyses could not be performed due to a lack of binder/mixture properties data, a simple correlation between creep compliance and IDT strength does exist and is shown in Figure 22.



Figure 22: 100 Second Creep Compliance vs IDT Strength: -10°C

CONCLUSIONS

Expected trends such as increasing creep compliance and decreasing tensile strength with increasing % air voids and/or temperature were confirmed for all six mixes. And, there is an inverse relationship between creep compliance and IDT strength. However, Poisson's ratio did not always follow a definitive trend relative to % air voids or temperature. Also, tensile failure strain did not exhibit a consistent trend relative to % air voids but it did decrease with decreasing temperature in all cases.

One could conclude that the presence of recycled asphalt pavement (RAP) in a mix tends to decrease the creep compliance and increase the tensile strength compared to a mix without RAP but with the same virgin binder grade, everything else being somewhat equal. This is shown in Figures 15 and 21 by comparing 07-123 (PG64-22, 20% RAP) and 06-125 (PG64-22, 0% RAP). This conclusion is based on the assumption that the binder in the RAP is harder than the virgin binder, thereby increasing the viscosity of the blend. However, the conclusion may not hold if the RAP binder, although age-hardened, is actually softer than the virgin binder.

Figures 15 and 21 also indicate, though, that a clear trend cannot be determined due to the lack of mixes that could be compared in the same manner as 07-123 and 06-125. It does make sense that 06-125 (PG64-22 binder) had the lowest IDT and the greatest creep compliance. Beyond that, the combined influence of RAP and higher PG grades is indistinct because the effect of RAP on the blended binder viscosity characteristics is dependent on many factors.

The Marshall type mix, 07-123 (BP-1) and the Stone Matrix Asphalt (SMA) mix, 06-84, presented the most challenges in the IDT testing. 07-123 turned out to be the stiffest or least compliant mix of the six tested. It also produced highly variable tensile strength results. It is assumed that the non-uniform void distribution of the 06-84 mix played a part in producing a round of problematic creep compliance tests in which the specimens prepared at 4% air voids were more compliant or less stiff than the specimens prepared at 6.5%.

Although not related to the objectives of the work, it is clear that there still needs to be work done on the test method, T 322-07. More detail is required in regard to the IDT creep loading procedure and reducing the raw creep compliance data.

RECOMMENDATIONS

More work is needed to better understand the effects that recycled materials have on the binder/mix properties as they relate to creep compliance and tensile strength. MoDOT has recently increased the allowable percentage of RAP and also allows the usage of recycled asphalt shingles (RAS) in HMA. The binder in RAP and RAS is usually much stiffer than the virgin binder and this poses challenges not only to the mix designer but the pavement designer as well. A fuller understanding of the effects of RAP and RAS in HMA would require an experimental program to be performed in the laboratory so that the various factors could be controlled and/or monitored better than if the mixes were plant-produced.

In the draft final version of the Recommended Practice for Local Calibration of the M-E Pavement Design Guide (13), it is recommended that a minimum of 25 pavement test sections be analyzed for non-load related cracking; e.g. thermal cracking. It is also suggested that measured distress data for each pavement section cover at least 10 years of service. Thus, the combination of 25 pavement sections and 10 years of data per section may not correspond well with the plant-produced mixtures that were investigated in this study; i.e. RAP and SMA mixtures are relatively new and there may not be sufficient pavement sections available in Missouri to produce a reliable calibration – validation of the M-E PDG thermal cracking distress models. An alternative to using plant-produced mixes would be to obtain cores from the selected pavement sections and perform IDT creep/strength tests (along with other material characterization tests) on the cores, similar to the work that was done in the state of Montana (*14*).

IDT creep/strength test data is not only used for calibration – validation purposes, but becomes part of an "input library" for the M-E PDG. As new mix types are adopted by MoDOT, the thermal cracking parameters of creep compliance, tensile strength, and tensile failure strain should, at some point, be determined. MoDOT could perform a further refinement of the thermal cracking distress model parameters once a sufficient number of new mixes have accumulated.

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APPENDIX A: CREEP COMPLIANCE



Figure A-24: 6 Mixes @ 6.5% Voids & -20°C



Figure A-26: 4 Mixes @ 4% Voids & -10°C







Figure A-28: 4 Mixes @ 9% Voids & -10°C



Figure A-29: 4 Mixes @ 4% Voids & 0°C



Figure A-30: 6 Mixes @ 6.5% Voids & 0°C





Figure A-32: 07-123 Using Equivalent Area Method



Figure A-34: 06-84 @ 6.5% Voids: Round 2



Figure A-35: 06-84 @ 9% Voids: Round 2



Figure A-36: 06-101 @ 4% Voids



Figure A-38: 06-101 @ 9% Voids



Figure A-40: 06-125 @ 6.5% Voids





Figure A-42: 06-150 @ 4% Voids





Figure A-44: 06-150 @ 9% Voids



Figure A-45: 06-105 @ 6.5% Voids

APPENDIX B: TENSILE STRENGTH & TENSILE FAILURE STRAIN

Mix Type BP1 RAP %AC 5.7 Virigin AC 4.2 %/Fibers 0.0 Specime Gmb Z/S Diameter Temp Pf.n St. Tensile Strength No. (m) (m) </th <th>IVIIX Designa</th> <th>ation</th> <th>07-123</th> <th>%RAP</th> <th></th> <th>20.0</th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th> <th></th>	IVIIX Designa	ation	07-123	%RAP		20.0										
Wrigh Binder Grade PC64-22 Total %AC 5.3 Syvirgin AC 2.501	Mix Type		BP1	RAP %AC		5.7										
%Virgin AC 4.2 %Fibres 0.0 Gmm 2.501 Specimen Gmb (%) Thickness Diameter Term PLn Xin Avg St St SD St CV Stn Avg St 12 2.333 6.5 1.991 (m) (m) (m) (m) (m) (gs)	Virgin Binde	er Grade	PG64-22	Total %AC		5.3										
Gmm 2.501 CMLRP 530 Correction Specimen Gmb Voids Thickness Diameter Temp Ptn Stn Avg. St StSD StCV Stn Avg. St 3 2.333 6.5 1.991 50.6 5.895 144, 7 1.00 1322, 8 723 (ps)	%Virgin AC		4.2	%Fibers		0.0					1	Fensile Stre	ngth			
Specimen Grb. Voids Thickness Diameter Temp Pi.n St.n Avg. St. St St. D St.CV St.n (ps) (ps) <t< td=""><td>Gmm</td><td></td><td>2.501</td><td></td><td></td><td></td><td></td><td></td><td></td><td>AAS</td><td>SHTO T 322</td><td>2-07</td><td></td><td>NCHRP 530</td><td>Correction</td></t<>	Gmm		2.501							AAS	SHTO T 322	2-07		NCHRP 530	Correction	
No. (%) (m) (mm) (mn) (m	Specimen	Gmb	Voids	Thick	iness	Diam	neter	Temp	Pf,n	St,n	Avg. St	St SD	St CV	St,n	Avg. St	
2 2.333 6.7 1.991 50.6 6.5895 149.7 -10.0 1322.8 723 11.3% 544 Average 2.338 6.5 1.994 50.6 5.899 149.8 -9.6 10645.8 576 487 487 Average 2.334 6.7 1.994 50.6 5.897 149.8 -9.6 10645.8 576 98.1 17.0% 513 487 Average 2.344 6.3 2.001 50.8 5.899 149.8 -9.6 1206.4 609 576 98.1 17.0% 513 487 Average 2.340 6.5 1.997 50.7 5.899 149.8 -9.5 Izuto1.4 653 142.% 515 Mix Tope SP125C RAP %AC 4.8 -9.5 Izuto1.4 612 87.2 14.2% 515 Mix Tope SP125C RAP %AC 4.8 -9.5 Statistics for All 6 612 87.2 14.2%	No.		(%)	(in)	(mm)	(in)	(mm)	(deg C)	(lbf)	(psi)	(psi)	(psi)	(%)	(psi)	(psi)	
3 2.338 6.5 1.991 50.6 5.899 149.8 -9.7 111337.3 647 649 73.2 11.3% 543 544 Average 2.338 6.5 1.992 50.6 5.897 149.8 -9.6 10645.8 576 98.1 17.0% 513 487 13 2.242 6.4 1.997 50.7 5.897 149.8 -9.6 11216.4 663 576 98.1 17.0% 513 487 Average 2.340 6.5 1.997 50.7 5.898 149.8 -9.5 12101.4 653 612 87.2 142.% 515 Mix Designation 06-105 %RAP 0.08 5.898 149.8 -9.5 Statistics for All 6 612 87.2 14.2% 515 Mix Designation 06-105 %RAP 0.00 7.00 7.00 NCHRP 530 Correction 6001 612 87.2 14.2% 515 Specimen Gmb Voids Thickness 0.10 149.4 -9.5 9610.6 601	2	2.333	6.7	1.991	50.6	5.895	149.7	-10.0	13322.8	723				602		
14 2.342 6.3 1.994 50.6 5.899 1.49.8 -9.6 1064.58 576 487 5 2.334 6.7 1.994 50.6 5.897 1.49.8 -9.6 808.6 466 576 98.1 17.0% 513 447 Average 2.344 6.3 2.001 50.8 5.899 149.8 -9.6 11264.6 609 576 98.1 17.0% 513 487 Average 2.340 6.5 1.997 50.7 5.899 149.8 -9.5 Statistics for AII 6 612 87.2 14.2% 547 Mix Type SP12SC RAP %AC 4.8 -9.5 Statistics for AII 6 612 87.2 14.2% 547 Gmm 2.455 Total %AC 5.6 51 %Fibers 0.0 Statistics for AII 6 601 87.2 14.2% 567 14.2% 567 51.5 515 515 515 515 516 567	3	2.338	6.5	1.991	50.6	5.898	149.8	-9.7	11937.3	647	649	73.2	11.3%	543	544	
Average 2.338 6.5 1.992 50.6 5.897 149.8 -9.8 5 2.334 6.7 1.994 50.6 5.901 149.9 -9.6 11264.6 609 576 98.1 17.0% 513 487 Average 2.344 6.3 2.001 50.8 5.899 149.8 -9.6 11264.6 609 576 98.1 17.0% 513 487 Average 2.340 6.5 1.997 50.7 5.899 149.8 -9.5 Statistics for All 6 612 87.2 14.2% 515 Mix Designation 06-105 %RAP 10.0 fmmm 149.8 -9.5 Statistics for All 6 612 87.2 14.2% 515 Mix Designation 06-105 %RAP 10.0 fmmm (mm) (mm) fmm fmm <t< td=""><td>14</td><td>2.342</td><td>6.3</td><td>1.994</td><td>50.6</td><td>5.899</td><td>149.8</td><td>-9.6</td><td>10645.8</td><td>576</td><td></td><td></td><td></td><td>487</td><td></td></t<>	14	2.342	6.3	1.994	50.6	5.899	149.8	-9.6	10645.8	576				487		
5 2.334 6.7 1.994 50.6 5.901 149.8 -9.5 858.6 465 98.1 17.0% 513 401 15 2.344 6.3 2.001 50.8 5.898 149.8 -9.5 12101.4 653 576 98.1 17.0% 513 487 Average 2.340 6.5 1.997 50.7 5.898 149.8 -9.5 Statistics for All 6 612 87.2 14.2% 515 Mix Designation 06-105 %RAP 10.0 No. 6.10 87.2 14.2% 515 Mix Type SP125C RAP %AC 4.8 -9.5 Statistics for All 6 612 87.2 14.2% 515 Specimen Gmb Voids Thickness Diameter Termp Pf.n St. V St SD St CV St.n Avg.St 2 2.290 6.7 1.72 43.7 5.92 150.4 -9.5 9784.5 612 616	Average	2.338	6.5	1.992	50.6	5.897	149.8	-9.8								
13 2.342 6.4 1.997 50.7 5.897 149.8 -9.6 11264.6 609 576 98.1 17.0% 513 487 Average 2.340 6.5 1.997 50.7 5.899 149.8 -9.5 Statistics for All 6 612 87.2 14.2% 515 Mix Designation 06-105 %RAP 10.0 RAP %AC 4.8 17.0% 515 515 Mix Type SP125C Total %AC 5.6 9.7 5.99 149.8 -9.5 Statistics for All 6 612 87.2 14.2% 515 Mix Type SP125C Total %AC 5.8 6.5 1.72 43.7 5.92 150.4 -9.5 9610.6 601 (psi) (psi) (psi) (psi) (psi) (psi) 534 515 519 Average 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 9784.5 612 616 18.2 3.0% 515 519 Average 2.295 6.5 1.72 43.7 5	5	2.334	6.7	1.994	50.6	5.901	149.9	-9.5	8598.6	465				401		
15 2.344 6.3 2.001 50.8 5.898 149.8 -9.5 12101.4 653 547 Mix Designation 06-105 %RAP 50.7 5.899 149.8 -9.5 Statistics for All 6 612 87.2 14.2% 515 Mix Type SP12C RAP %AC 4.8 -0.0	13	2.342	6.4	1.997	50.7	5.897	149.8	-9.6	11264.6	609	576	98.1	17.0%	513	487	
Average 2.340 6.5 1.997 50.7 5.899 149.8 -9.5 Statistics for All 6 612 87.2 14.2% 515 Mix Designation 06-105 %RAP 10.0 RAP %AC 4.8 7.1	15	2.344	6.3	2.001	50.8	5.898	149.8	-9.5	12101.4	653				547		
Mix Designation Wix Type %GAP PG70-22 10.0 RAP %AC 4.8 Total %AC 5.6 Sectionen Specimen Gmm 2.455 Thickness Diameter Temp Pf.n St.n Avg.St St St D St CV St.n Avg.St St St D St CV St.n Avg.St St St D St CV St.n Avg.St (psi)	Average	2.340	6.5	1.997	50.7	5.899	149.8	-9.5	Statistics for	or All 6	612	87.2	14.2%		515	
Mix Designation 06-105 SP125C %RAP SP125C 10.0 RAP %AC 4.8 4.8 Virgin Alcer Grade Gmm 2.455 %Fibers 0.0 Tensile Strength NCHRP 530 Correction Specimen Specimen Gmb Voids Thickness Diameter Temp Pf.n St.n Avg. St St SD St CV St,n Avg. St 2.290 6.7 1.72 43.7 5.92 150.4 -9.5 9610.6 601 psi) (psi) (ps																
Mix Type SP125C RAP %AC 4.8 Virgin Binder Grade PG70-22 Total %AC 5.6 Specimen Gmm 2.455 Thickness Diameter Temp No. (%) (in) (mm) (in) (mm) (ipsi) 2 2.290 6.7 1.72 43.7 5.92 150.4 -9.5 9610.6 601 18.2 3.0% 515 519 1 2.301 6.5 1.72 43.7 5.92 150.4 -9.5 9610.6 601 618 18.2 3.0% 515 519 Average 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 9784.5 612 616 18.2 3.0% 515 519 Average 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 9784.5 612 616 18.2 3.0% 515 519 Mix Type SPCTocar PG76-22 Total %AC 0.0 0.0 No. No. NO. ASHTO T 322-07 N	Mix Designa	ation	06-105	%RAP		10.0										
Virgin Einder Grade PG70-22 Total %AC 5.6 %Virgin AC 5.1 %Fibers 0.0 Specimen Gmb Voids Thickness Diameter Temp (lbl / (psi) (psi) (psi) (%) (k) Avg. St St SD St CV St, n Avg. St Avg. St St SD St CV St, n Avg. St St SD St CV St	Mix Type		SP125C	RAP %AC		4.8										
%Virgin AC 5.1 %Fibers 0.0 Gmm 2.455 Thickness Diameter Temp AASHTO T 322-07 NCHRP 530 Correction Specimen Gmb Voids Thickness Diameter Temp Aug. St St SD St CV St n Avg. St 2 2.290 6.7 1.72 43.7 5.92 150.4 -9.5 9610.6 601 (psi) (psi) (psi) 507 515 519 11 2.301 6.3 1.72 43.7 5.92 150.4 -9.5 10178.2 636 612 616 18.2 3.0% 515 519 Average 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 10178.2 636 612 616 18.2 3.0% 534 Average 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 10178.2 636 150.0 507 534 534 534	Virgin Binde	er Grade	PG70-22	Total %AC		5.6										
Gmm 2.455 AASHTO T 322-07 NCHRP 530 Correction Specimen Gmb Voids Thickness Diameter Temp Pf,n St,n Avg. St St SD St CV St,n Avg. St 2 2.290 6.7 1.72 43.7 5.92 150.4 -9.5 9610.6 601 (psi) (%) (psi) (%) (psi) (%) (psi) (%) (psi) (psi) (%) 507	%Virgin AC		5.1	%Fibers		0.0					1	Fensile Stre	ngth			
Specimen No. Gmb Voids (%) Thickness Diameter (mm) Temp (deg C) Pf, n (bt) St, n (psi) Avg. St (psi) St CV (psi) St, N (psi) Avg. St (psi) St CV (%) St, n (psi) Avg. St (psi) St CV (psi) St, N (psi) Avg. St (psi) Mag. St (psi) Avg. St (psi) St CV (psi) St, N (psi) CV (psi) CV (psi) CV (psi) CV (psi) CV (psi) CV (psi) CV (psi) St CV (psi)	Gmm		2.455							AAS	SHTO T 322	2-07	<u> </u>	NCHRP 530	Correction	
No. (%) (in) (ini) (mm) (ini) (mi)	Specimen	Gmb	Voids	Thick	iness	Diam	neter	Temp	Pf.n	St.n	Ava. St	St SD	St CV	St.n	Ava. St	
No. Off Total Total <thtotal< th=""> Total Tota</thtotal<>	No.		(%)	(in)	(mm)	(in)	(mm)	(deg C)	(lbf)	(psi)	(psi)	(psi)	(%)	(psi)	(psi)	
5 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 9784.5 612 616 18.2 3.0% 515 519 11 2.301 6.3 1.72 43.7 5.92 150.4 -9.5 10178.2 636 616 18.2 3.0% 515 519 Average 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 10178.2 636 616 18.2 3.0% 515 519 Average 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 Mix Designation 06-84 %RAP 0.0 <	2	2,290	6.7	1.72	43.7	5.92	150.4	-9.5	9610.6	601	(1-0-)	(F)	(,*)	507	(F)	
11 2.301 6.3 1.72 43.7 5.92 150.4 -9.5 10178.2 636 534 534 Average 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 10178.2 636 534 534 Mix Designation 06-84 %RAP 0.0	5	2.295	6.5	1.72	43.7	5.92	150.4	-9.5	9784.5	612	616	18.2	3.0%	515	519	
Average 2.295 6.5 1.72 43.7 5.92 150.4 -9.5 Mix Designation 06-84 %RAP 0.0	11	2.301	6.3	1.72	43.7	5.92	150.4	-9.5	10178.2	636		-		534		
Mix Designation 06-84 %RAP 0.0 Mix Type SP125BSM RAP %AC 0.0 Virgin Binder Grade PG76-22 Total %AC 6.3 %Virgin AC 6.3 %Fibers 0.3 Gmm 2.436 AASHTO T 322-07 NCHRP 530 Correction Specimen Gmb Voids Thickness Diameter Temp No. (%) (in) (mm) (in) (mm) (deg C) (lbf) (psi) (psi) (psi) (psi) (psi) (psi) (psi) 627 642 644 642 642 642 642 642 642 642 642 642 644 644 644 644 644 644 644 644 6444 644 6444 644	Average	2.295	6.5	1.72	43.7	5.92	150.4	-9.5			1					
Mix Designation 06-84 Mix Type %RAP 0.0 RAP %AC 0.0 RAP %AC									-							
Mix Type SP125BSM RAP %AC 0.0 Virgin Binder Grade PG76-22 Total %AC 6.3 %Virgin AC 6.3 %Fibers 0.3 Specimen Cmm 2.336 Thickness Diameter Temp Pf.n St.n Avg. St St SD St CV St.n Avg. St (%) (%) (psi) (ps	Mix Designa	ation	06-84	%RAP		0.0										
Virgin Binder Grade PG76-22 Total %AC 6.3 %/Fibers 0.3 Gmm 2.436 Thickness Diameter Temp Pf.n Str. N Avg. St St SD St CV Stn Avg. St Specimen Gmb Voids Thickness Diameter Temp Pf.n Str. N (psi)	Mix Type		SP125BSM	RAP %AC		0.0										
%Virgin AC 6.3 %Fibers 0.3 Gmm 2.436 AASHTO T 322-07 NCHRP 530 Correction Specimen Gmb Voids Thickness Diameter Temp Pf,n St,n Avg. St St SD St CV St,n Avg. St 2 2.344 3.8 1.990 50.5 5.903 149.9 -9.7 13924.6 755 627 627 627 627 627 627 627 627 627 621 614 624 614 627 627 621 614 627 627 627 627 627 627 627 627 627 627 627 621 614 614 627 627 621 614 624 614 627 627 627 621 614 621 614 621 614 621 614 621 614 621 614 621 614 621 614 621 614 621	Virgin Binde	er Grade	PG76-22	Total %AC		6.3										
AASHTO T 322-07 NCHRP 530 Correction Specimen No. Gmb Voids (%) Thickness Diameter Temp Pf.n St.n Avg. St St SD St CV St.n Avg. St 2 2.344 3.8 1.990 50.5 5.903 149.9 -9.7 13924.6 755 627 627 621 614 3 2.339 4.0 1.997 50.7 5.905 150.0 -9.5 13849.5 748 738 22.9 3.1% 621 614 Average 2.339 4.0 1.995 50.7 5.905 150.0 -9.6 13204.3 712 8 22.9 3.1% 621 614 Average 2.339 4.0 1.995 50.7 5.905 150.0 -9.6 638 620 24.4 3.9% 506 522 11 2.272 6.7 1.985 50.4 5.896 149.8 -9.6 1088.7 592 <td< td=""><td>%Virgin AC</td><td></td><td>6.3</td><td>%Fibers</td><td></td><td>0.3</td><td></td><td></td><td></td><td></td><td>-</td><td>Censile Stre</td><td>nath</td><td></td><td></td></td<>	%Virgin AC		6.3	%Fibers		0.3					-	Censile Stre	nath			
Specimen No. Gmb Voids (%) Thickness Diameter Temp (mm) Pf,n (deg C) St,n (bf) Avg. St (psi) St SD (psi) St CV (%) St,n (psi) Avg. St (psi) 2 2.344 3.8 1.990 50.5 5.903 149.9 -9.7 13924.6 755 627 627 621 614 3 2.339 4.0 1.997 50.7 5.905 150.0 -9.6 13204.3 712 31 627 621 614 4 2.334 4.2 1.999 50.8 5.905 150.0 -9.6 13204.3 712 536 536 4 2.272 6.7 1.995 50.7 5.905 150.0 -9.6 10888.7 592 620 24.4 3.9% 500 522 11 2.272 6.7 1.985 50.4 5.896 149.9 -9.7 11538.1 630 24.4 3.9% 500 522 24.4 3.9% 500	Gmm		2,436							AAS	SHTO T 322	2-07		NCHRP 530) Correction	
No. (%) (in) (mm) (in) (mm) (deg C) (ib) (psi) (psi)<	Specimen	Gmb	Voids	Thick	iness	Diam	neter	Temp	Pfn	Stn	Ava St	St SD	St CV	Stn	Ava St	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	No	0	(%)	(in)	(mm)	(in)	(mm)	(deg C)	(lbf)	(nsi)	(psi)	(nsi)	(%)	(psi)	(nsi)	
3 2.339 4.0 1.997 50.7 5.905 150.0 -9.5 1349.5 748 738 22.9 3.1% 621 614 16 2.334 4.2 1.999 50.8 5.906 150.0 -9.6 13204.3 712 503 593 614 Average 2.339 4.0 1.995 50.7 5.905 150.0 -9.6 13204.3 712 50.7 593 Average 2.339 4.0 1.995 50.7 5.905 149.7 -9.5 11626.0 638 2.28 6.3 1.967 50.0 5.895 149.7 -9.5 11626.0 638 2.27 6.7 1.985 50.4 5.896 149.8 -9.6 1088.7 592 620 24.4 3.9% 500 522 14 2.277 6.5 1.976 50.2 5.897 149.8 -9.6 149.8 -9.6 149.8 -9.6 149.8 -9.6 149.8	2	2.344	3.8	1.990	50.5	5,903	149.9	-9.7	13924.6	755	(1-0-)	(1)	(, .)	627	(F *)	
16 2.334 4.2 1.995 50.8 5.906 150.0 -9.6 13204.3 712 513 513 Average 2.339 4.0 1.995 50.7 5.905 150.0 -9.6 13204.3 712 503 500 522 500 503 503 500 522 503 149.9 -9.7 11538.1 630 529 529 529 529 529 529 529 529 529 529 529 529	3	2 339	4.0	1 997	50.7	5 905	150.0	-9.5	13849.5	748	738	22.9	3.1%	621	614	
Average 2.339 4.0 1.995 50.0 5.905 150.0 -9.6 112 121	16	2 334	4.2	1 999	50.8	5 906	150.0	-9.6	13204.3	712			0.170	593	0	
Average 2.287 6.3 1.967 50.0 5.896 149.7 -9.5 11626.0 638 536	Average	2 339	4.0	1 995	50.7	5 905	150.0	-9.6	1020110					000		
1 2.202 6.5 1.057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 1.1057 50.5 52.6 52.7 1.1057 52.5 52.7 1.1057 52.5 52.7 1.1057 <th 1.1057<="" td="" thr<=""><td>7 7</td><td>2 282</td><td>6.3</td><td>1.967</td><td>50.0</td><td>5 895</td><td>149.7</td><td>-9.5</td><td>11626.0</td><td>638</td><td></td><td></td><td></td><td>536</td><td></td></th>	<td>7 7</td> <td>2 282</td> <td>6.3</td> <td>1.967</td> <td>50.0</td> <td>5 895</td> <td>149.7</td> <td>-9.5</td> <td>11626.0</td> <td>638</td> <td></td> <td></td> <td></td> <td>536</td> <td></td>	7 7	2 282	6.3	1.967	50.0	5 895	149.7	-9.5	11626.0	638				536	
11 2.277 6.5 1.976 5.907 149.9 -9.7 1038.1 630 21.7 5.30 529 Average 2.277 6.5 1.976 50.2 5.897 149.8 -9.6 6 2.211 9.2 1.984 50.4 5.907 150.0 -9.8 9439.1 513 14 2.222 8.8 1.991 50.6 5.907 150.0 -10.3 10172.1 551 525 22.7 4.3% 468 447	11	2 272	6.7	1 985	50.4	5 896	149.8	-9.6	10888.7	592	620	24.4	3.9%	500	522	
Average 2.217 6.5 1.976 50.2 5.897 149.8 -9.6 50.2 5.897 149.8 -9.6 6 2.211 9.2 1.984 50.4 5.907 150.0 -9.8 9439.1 513 438 14 2.222 8.8 1.991 50.6 5.907 150.0 -10.3 101271 551 525 22.7 4.3% 468 447	14	2 277	6.5	1.000	50.2	5 901	140.0	-9.7	11538.1	630	020	27.7	0.070	529	022	
Average 2.2.7 0.5 1.610 0.62 0.601 1.405 0.6 0.610 <th0.610< th=""> <th0.61< td=""><td>Average</td><td>2 277</td><td>6.5</td><td>1.976</td><td>50.2</td><td>5 897</td><td>149.8</td><td>-9.6</td><td>11000.1</td><td>000</td><td></td><td></td><td></td><td>020</td><td></td></th0.61<></th0.610<>	Average	2 277	6.5	1.976	50.2	5 897	149.8	-9.6	11000.1	000				020		
	6 (Nonage	2.211	9.2	1.970	50.2	5 907	150.0	-9.0	9439.1	513				438		
	14	2.211	9.2 9.9	1 901	50.4	5 905	150.0	-10.3	10172 1	551	525	22.7	4 3%	450	417	
1 19 2217 9 9 1 983 504 5996 150 9 930 9 510	14	2.222	0.0 Q ()	1 983	50.0	5 906	150.0	-10.3	9390.9	510	525	22.1	ч.J /0	436		
Average 2 217 9 01 1986 50.4 5 906 150.0 -10.0	Average	2 217	0.0 0.0	1 986	50.4	5 906	150.0	-10.0	0000.0	510			H	-300		

Table B-19: Non-instrumented Data @ -10°C: Part A Mix Designation 07-123 %RAP 20.0
Wix Design	auon	00-101	/0INAF		0.0									
Mix Type		SP125B	RAP %AC		0.0									
Virgin Bind	er Grade	PG76-22	Total %AC		5.7									
%Virgin AC	>	5.7	%Fibers		0.0					٦	Fensile Stre	ength		
Gmm		2.515			-				AAS	SHTO T 322	2-07		NCHRP 530	Correction
Specimen	Gmb	Voids	Thick	iness	Dian	neter	Temp	Pf.n	St.n	Ava. St	St SD	St CV	St.n	Ava. St
No.		(%)	(in)	(mm)	(in)	(mm)	(deg C)	(lbf)	(psi)	(psi)	(psi)	(%)	(psi)	(psi)
4	2 421	38	1 985	50.4	5 895	149 7	-9.9	15002.8	816	(1- 0-1)	(F #1)	(,*)	675	(1)
7	2 / 15	4.0	2 006	51.0	5 896	1/0.8	-10.0	16547.0	801	8/1	12.8	5 1%	733	694
11	2.410	4.0	2.000	50.0	5 907	140.0	10.0	15152.0	917	041	42.0	0.170	675	004
Average	2.410	4.2	2.003	50.9	5.097	149.0	-10.0	highlighted	oollo oro T	iniua Olaan	voluoo		075	
Average	2.413	4.0	1.990	50.7	5.090	149.0	-10.0	10215 1		inius-Oisen	values		560	
2	2.332	0.5	1.900	50.5	5.696	149.0	-9.0	12315.1	009	000	10.1	0.40/	500	
10	2.347	6.7	1.989	50.5	5.903	149.9	-9.7	11901.9	645	663	16.1	2.4%	541	200
17	2.357	6.3	1.999	50.8	5.904	150.0	-9.8	12535.4	6/6				565	
Average	2.352	6.5	1.992	50.6	5.902	149.9	-9.8							
4	2.284	9.2	1.992	50.6	5.903	149.9	-9.8	10836.2	587				496	
6	2.288	9.0	1.989	50.5	5.902	149.9	-9.6	11270.8	611	601	12.8	2.1%	515	507
18	2.294	8.8	1.994	50.6	5.908	150.1	-10.0	11196.9	605				510	
Average	2.289	9.0	1.992	50.6	5.904	150.0	-9.8							
Mix Design	ation	06-125	%RAP		0.0									
Mix Type		SP125C	RAP %AC		0.0									
Virgin Bind	er Grade	PG64-22	Total %AC		6.5									
%Virgin AC	;	6.5	%Fibers		0.0						ensile Stre	enath		
Gmm		2 412							۵۵۹	SHTO T 322	2-07		NCHRP 530	Correction
Specimon	Gmb	Voide	Thick	(0000	Dian	otor	Tomp	Dfn	Str		 	St CV	St n	Avg St
Specifien	Gillb	(0/)	(in)	(mm)	(in)	(mm)	(deg C)	(lbf)	(noi)	Avg. St	3(3D (noi)	(0/)	(noi)	Avg. St
INU.	0.045	(70)	(11)	(1111)	(11)	(1111)	(deg C)	(101)	(psi)	(psi)	(psi)	(%)	(psi)	(psi)
1	2.315	4.0	1.976	50.2	5.908	150.1	-9.6	12191.2	600	000		4 50/	557	504
20	2.321	3.8	2.001	50.8	5.904	150.0	-9.9	13492.4	/2/	696	31.1	4.5%	605	581
24	2.331	4.2	2.004	50.9	5.906	150.0	-9.9	12926.6	695				580	
Average	2.322	4.0	1.994	50.6	5.906	150.0	-9.8							
18	2.249	6.7	1.998	50.7	5.911	150.1	-9.7	11544.2	622				523	
23	2.260	6.3	1.991	50.6	5.903	149.9	-9.6	11703.5	634	623	10.0	1.6%	532	524
24	2.255	6.5	1.961	49.8	5.911	150.1	-9.7	11181.0	614				517	
Average	2.255	6.5	1.983	50.4	5.908	150.1	-9.7						-	
4	2.190	9.2	2.001	50.8	5.912	150.2	-9.6	9657.6	520				443	
6	2.196	9.0	1.989	50.5	5.908	150.1	-9.5	9892.0	536	532	11.2	2.1%	456	453
8	2.200	8.8	1.970	50.0	5.909	150.1	-9.6	9896.2	541				460	
Average	2.195	9.0	1.987	50.5	5.910	150.1	-9.6							
								4						
Mix Design	ation	06-150	%RAP		10.0									
Mix Type	ation	SP125C	RAP %AC		4.8									
Virgin Bind	or Grado	PG70-22	Total %AC		5.5									
		10/0-22	% Eiboro		0.0					-	Concilo Stro	nath		
%virgin AC	,	5.0	%FIDelS		0.0							ingin		0
Gmm		2.467							AAS	SHIU I 322	2-07		NCHRP 530	Correction
Specimen	Gmb	Voids	Thick	ness	Dian	neter	Temp	Pf,n	St,n	Avg. St	St SD	St CV	St,n	Avg. St
No.		(%)	(in)	(mm)	(in)	(mm)	(deg C)	(lbf)	(psi)	(psi)	(psi)	(%)	(psi)	(psi)
2	2.364	4.2	1.980	50.3	5.904	150.0	-9.5	13949.6	760				631	
6	2.369	4.0	1.973	50.1	5.901	149.9	-9.6	13838.6	757	786	48.8	6.2%	628	651
11	2.370	3.9	1.987	50.5	5.900	149.9	-9.5	15516.3	843				695	
Average	2.368	4.0	1.980	50.3	5.902	149.9	-9.5	highlighted	cells are T	inius-Olsen	values			
4	2,301	6.7	1,985	50.4	5,906	150.0	-9.6	11771.2	639				537	
9	2.313	6.2	1,981	50.3	5,901	149.9	-9.6	12719 1	693	674	30.3	4.5%	578	564
11	2 307	6.5	1 978	50.0	5 907	150.0	0.0 A P_	12675 2	601	0/4	00.0		577	504
Average	2 307	6.5	1 981	50.2	5 905	150.0	-0.6	12010.2	001				511	
1 1	2.307	0.3	1.001	50.3	5 011	150.0	-9.0	11340.0	620				501	
	2.240	9.2	1.3/1	50.1	J.311	150.1	-9.0	10000 0	500	500	24.4	3 50/	521	FOF
11	2.249	8.8	1.974	50.1	5.916	150.3	-10.3	10908.2	599	599	21.1	3.5%	505	505
. 40	0.045	0.0	4 070		E GAO	A		1/1/ //					4000	
19	2.245	9.0	1.970	50.0	5.918	150.3	-9.6	10575.6	577				488	

Mix Designation 06-101 %RAP 0.0 0.0

| | | Failure Strain (microstrain) | | orth South Average | orth South Average
96 178 137 | orth South Average
96 178 137
172 163 167 | South Average 96 178 137 172 163 167 267 203 235 | Nth South Average 96 178 137 172 173 167 267 263 233 | Nrth South Average 96 178 137 172 163 267 267 203 2367 176 80 128 | Nth South Average 96 178 137 172 163 167 267 203 236 176 80 128 176 80 128 176 211 168 176 211 168 | Nth South Average 96 178 137 172 163 167 267 203 236 176 80 180 176 80 128 176 211 158 175 211 158 167 203 172 | Nrth South Average 96 178 137 917 163 165 267 203 236 267 203 236 176 80 128 165 211 166 105 211 168 105 211 158 105 211 158 142 203 158 | Nrth South Average 96 178 137 172 163 267 267 203 2367 176 80 128 105 211 160 176 80 128 105 211 168 142 203 173 89 172 130 | Nrth South Average 96 178 137 172 163 267 267 203 236 176 80 128 105 211 168 176 80 128 105 211 168 142 203 153 89 172 153 89 172 153
 | Nrth South Average 96 178 137 172 163 267 267 203 236 176 80 128 176 203 128 166 211 169 176 203 172 142 203 173 89 172 153 89 172 130 247 228 238 130 211 153 | Nrth South Average 96 178 137 172 163 267 267 203 236 176 80 128 106 211 168 142 203 172 89 172 153 89 172 153 130 238 172 142 203 172 130 238 172 141 238 172 142 203 173 143 217 153 130 211 170 130 211 170 | Nrth South Average 96 178 137 172 163 265 267 203 236 176 80 128 105 211 158 142 203 153 89 172 153 137 213 236 2147 228 238 130 211 153 131 172 130 132 172 130 247 228 238 130 211 170 130 211 170 | Nrth South Average 96 178 137 172 163 267 267 203 163 176 80 128 106 211 168 142 203 172 89 172 163 137 238 172 130 217 153 141 203 172 130 217 173 131 172 130 247 228 238 130 211 170

 | Nrth South Average 96 178 137 96 178 137 172 163 235 267 203 235 176 80 128 176 211 160 142 203 155 247 203 152 247 211 150 130 211 172 130 211 172 130 211 172 130 211 172 130 211 170 130 211 170 130 211 170

 | Nrth South Average 96 178 137 96 178 137 177 163 236 176 80 128 176 213 126 106 213 156 107 203 158 108 172 163 247 228 238 130 211 170 130 213 163 130 213 163 130 211 170 130 211 170 130 211 170 | Nith South Average 96 178 137 96 178 167 177 203 236 176 80 128 165 211 128 166 211 128 167 203 156 140 211 128 141 203 152 142 203 153 143 211 153 153 153 153 141 203 153 143 211 170 150 211 170 150 211 170 150 211 170 150 211 170 | South Average 96 178 137 177 203 236 176 80 128 105 211 158 142 203 156 247 203 172 130 211 158 130 211 173 130 211 170 130 211 180 130 211 170 130 211 170 130 211 180 130 211 170 130 211 180
 | Inth South Average 96 178 137 172 163 236 267 203 236 105 211 168 142 203 153 247 203 153 247 228 238 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 130 211 170 141 200 180 <th>South Average 96 178 137 172 137 137 267 203 236 105 211 158 142 203 153 247 203 153 247 228 238 130 211 170 211 172 130 247 228 238 130 211 170 130 211 170 140 2014 2014 150 211 140 161 2014 Average 170 211 146</th> <th>Nth South Average 96 178 137 96 178 137 175 163 160 176 80 128 105 213 155 116 213 155 117 203 156 118 172 130 247 228 238 130 211 170 130 211 180 130 211 180 130 211 180 130 211 180 130 211 446 130 211 146 180 133 161</th> <th>Fouth South Average 96 178 137 96 178 137 177 203 236 176 80 128 1405 201 128 1405 203 156 1405 203 156 140 238 172 140 211 170 130 211 170 130 211 170 130 211 180 130 211 170 130 211 170 130 211 170 130 211 170 141 170 144</th> <th>South
 Average 96 178 137 96 178 137 177 203 236 176 80 128 142 203 156 142 203 153 142 203 173 247 203 173 130 211 170 130 211 170 130 211 180 130 211 180 130 211 180 130 211 180 130 211 180 130 211 180 146 204h Average 118 131 146 118 170 146 118 170 146 118 170 146</th> <th>South Average 96 178 137 172 163 236 175 203 236 105 211 158 142 203 153 247 203 153 247 228 238 130 211 170 247 228 238 130 211 170 130 211 170 130 211 170 131 211 146 146 South Average 161 170 146 189 211 146 189 211 146 189 211 146 180 211 146 180 211 146 180 213 150 285 160 223</th> <th>South Average 96 178 137 96 178 137 172 163 160 176 80 128 166 213 155 175 203 156 176 80 128 176 213 155 80 172 130 130 211 170 130 211 170 130 211 180 130 211 180 130 211 146 131 133 161 118 133 161 118 133 161 118 170 213 286 133 161 133 161 144 286 133 161 133 150 233 286 133 161</th> <th>Fouth South Average 96 178 137 96 178 137 177 203 235 176 80 128 176 80 128 175 203 235 176 80 128 170 130 156 130 213 155 247 228 238 130 211 170 130 211 180 nth South Average 130 211 144 133 161 144 118 170 144 118 170 144 118 170 161 286 95 7.4</th> <th>Fouth South Average 96 178 137 177 203 160 176 80 128 140 140 140 141 203 163 145 203 160 140 211 158 140 213 153 141 203 173 130 211 170 130 211 180 130 211 180 141 170 141 180 131 141 180 131 141 180 131 141 180 131 141 180 131 141 180 130 213 286 160 233 191 150 233 290 92 93 92 92 126 123 123 123</th> <th>Average Average 96 178 137 177 265 138 176 80 128 105 211 165 142 203 158 142 203 158 142 203 153 247 228 238 130 211 170 130 211 170 130 211 180 141 204h Average 89 172 146 130 211 180 146 204h Average 80 211 146 118 170 146 118 170 146 286 160 223 90 92 92 146 128 170 146 128 170 150 128 173 153 128 179 15</th> <th>South Average 96 178 137 96 178 137 175 203 235 175 203 153 1405 201 128 141 203 155 141 203 155 141 203 156 1405 203 156 130 2128 130 130 211 170 130 211 146 180 133 161 180 133 161 180 211 146 180 211 146 180 211 146 180 133 161 180 211 146 286 160 223 290 92 91 262 95 74 145 268 206</th> <th>Fouth South Average 96 178 137 175 203 235 167 203 235 106 211 166 105 213 156 106 211 156 107 203 133 108 172 203 247 203 110 247 211 170 130 211 170 130 211 170 130 211 144 130 211 144 133 161 144 118 170 144 118 170 144 118 170 144 129 211 144 211 170 144 118 170 144 128 170 153 128 170 123 128 179 163</th> | South Average 96 178 137 172 137 137 267 203 236 105 211 158 142 203 153 247 203 153 247 228 238 130 211 170 211 172 130 247 228 238 130 211 170 130 211 170 140 2014 2014 150 211 140 161 2014 Average 170 211 146 | Nth South Average 96 178 137 96 178 137 175 163 160 176 80 128 105 213 155 116 213 155 117 203 156 118 172 130 247 228 238 130 211 170 130 211 180 130 211 180 130 211 180 130 211 180 130 211 446 130 211 146 180 133 161
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 | / Number 10016.5013 E 3.6625E-03 E 1.0135E-02 Avera 6.6533E-02 Avera 8.6526E-03 E 7% E.6728E-03 8.5375E-03 E 7% 5.3775E-03 8.33855E-03 2 9.3906E-03 E 9.3908E-03 E 4.9517E-03 E 1.0015 Avera 1.0016-03 E 3.3065E-03 E 1.0012 E 1.0014 1 | Number 7% 5.5313E.03 6 3.6625E.03 6 5 3 1.0135E.02 7 Avera 3 5.3776E.03 3.97356E.03 3 3 9% 9.33656E.03 8 3 1.0135E.02 7 Avera 4 1.33656E.03 8 9 3066E.03 8 9% 9.33666E.03 8 4 9 1.01676E.03 8 4 9 9 1.01676E.03 8 9 30506E.03 8 3.05306E.03 8 3 305306E.03 8 3.05306E.03 8 7 17822E.03 8
 | / numeronia / Numeronia 3.6626E-03 6.5313E-03 6.5313E-02 7.8656E-02 6.5726E-03 6.5776E-03 6.5776E-03 9.3965E-03 9.3965E-03 9.3965E-03 9.3965E-03 9.3965E-03 9.3055E-03 9% 7.1752E-03 4.4972E-03 | 7% 5.5313E03 6 7% 6.5313E03 6 1.0135E02 7 7 6.6578E03 6 7 7% 5.3776E03 6 3.3355E03 7 4 3.3355 1.00141 1 1 1.012603 9 4 3.175E03 9 4 4.9517E03 9 4 4.9517E03 1 4 4.9517E03 1 4 4.9517E03 1 4 4.9517E03 1 4 | / Initial contained 7% 5.5313E6-03 5.5313E6-02 7.0135E-02 7.0135 8.0530E-02 8.0530E-02 | / Initiation 7% 5.5313E.03 6 3.6625E.03 6 5 3.6625E.03 6 5 1.0135E.02 7 Avera 6.6573E.03 6 5 3.9735E.03 5 3 3.9735E.03 7 4 3.9736E.03 8 3 3.93665C.03 8 3 3.93665C.03 8 4 4.9517E.03 8 4 3.0530E.03 8 3 3.0530E.03 8 4 4.4972E.03 8 4 7 1.0839E.03 8 7 3.42177E.03 8 | / Innumental / Norm 3.6625E-03 6.5313E-03 1.0135E-02 1 3.955E-03 6.6728E-03 6.6573EE-03 6.53776E-03 9.3095E-03 6.93266-03 9.3095E-03 6.93066-03 9.3095E-03 6.49712E-03 9.3050E-03 6.4972E-03 9.44972E-03 6.4972E-03 9.34016-03 6.43472E-03 1.08622E-03 6.34016 | Number Number 7% 5.5313E5 03 6.55313E5 03 5.5373E5 03 1.01355 03 5.3775E 03 8.6525 3.89735E 03 5.3775E 03 8.65728E 3.33255E 03 5.3775E 03 5.3775E 9% 3.3055E 03 3.33255E 3.97365 3.97365 3.97365 9% 3.0502E 3 3.33555E 3.97365 3.97365 3.97365 9% 7.17822E 3.03 4.4972E 3.03 5.34275E 3.41377 7% 1.08392E 3.41377E 3.8875 3.41377E 3.41377E 3.41377E 3.413772E 3.41377E 3.413772E 3.41377 | Number Number 7% 6.5313E03 6 6.65315E03 6 5 1.0135E02 7 Averal Averal Averal 4 3.0625E03 6 5 3.10135E013 7 Averal 3.33255E03 6 3 3.33255E03 8 9 3.33255E03 8 9 4.9517E03 8 4 1.0853E01 7 Avera 1.0553E013 8 4 1.17822E03 8 4 1.10839E.03 6 7 1.1582E03 8 4 1.0833E.03 6 7 1.0833E.03 6 7 1.0832E.03 6 7 1.0833E.03 6 1 1.0832E.03 6 3 1.10832E.03 6 3 1.10832E.03 6 3
 | / Innthe mination 7% 6.6313E603 6 3.6626E03 6 6.6313E602 7 6.65313E603 6 6.6728E03 6 7% 6.6728E03 7 Averal 3.33856E03 7 4 6 3.33856E03 7 8 3 3 3.33856E03 8 3 3 3 4 4.9517E03 8 3 3 3 4 | / Innthicumation 7% 6.5313E.03 6 1.0135E.02 7 1.0135E.02 7 6.5313E.03 6.5313E.03 6 6 1.0135E.02 3.39735E.03 6 6 8.5375E.03 3.39365E.03 6 6 9% 3.30536E.03 6 7 6 9% 3.30565E.03 6 7 6 9% 3.30565E.03 6 7 6 9% 3.05076.03 6 8 4 1.005076.03 6 7 1 8 9% 7.1782E.03 6 3 8 1.0082.03 7 3 8 3 8.40726.03 6 3 3 8 7.17822E.03 6 3 8 3 8.40726.03 6 3 3 3 8.419726.03 7 3 8 3 |
| | | 10 00 | סט – טַכּי | (%) (iii |) (%)
(%) | 9.1 | 9.1 4.7% | 9.1 4.7% | 9.1 4.7% | 9.1 4.7%
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 | 9.1 4.7%
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11.9 7.2%
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| nsile Strength | SHTO T 322-07 | i
i
i | 740 ST - 27 S | Avg. St St St
(psi) (psi | Avg. St | Avg. St St St St
(psi) (psi)
195 | Avg. St | Avg. St | Avg. St | Avg. St. St. St. St. St. St. St. St. St. St | Avg. St. St St St St (psi) (ps | Avg. St. St St St (psi)
(psi) (psi) (psi)
195
166 1 | Avg. St. St St St (psi)
(psi)
195
166
166 | Avg. St. St St St (psi)
(psi)
195
186
140
140 | Avg. St. St St St (psi)
(psi) (psi) (psi)
195
166
140 | Avg. St. St
 | Avg. St. St | Avg. St. St St St St (psi)
195 196 140 140

 | Avg. St. St St St St (psi)
195 196 140 140
 | Avg. St
 | Avg. St | Avg. St
 | Avg. St
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(psi) (psi) (psi)
195
140
140
140
140
225 (psi) (psi) (psi) (psi) | Avg. St. St St St St (psi) (ps | Avg. St | Avg. St
 | Avg. St St St St St St St (psi) (psi | Avg. St. St | Avg. St. St | Avg. St | Avg. St | Avg. St. St. St. St. St. (psi) |
| Tens | ASH | of,n St,n / | | lbf) (psi) | (bf) (psi)
3774.6 204 | lbf) (psi)
3774.6 204
3682.5 194 | lbf) (psi)
3774.6 204
3582.5 194
3429.6 186 | lbf) (psi)
3774.6 204
3682.5 194
3429.6 186 | [bf) (psi) 3774.6 204 3582.5 194 3429.6 186 3135.9 171 | [bf) (psi) 3774.6 204 3682.5 194 3429.6 186 3135.9 171 3217.6 174 | [bf) (ps) 3774.6 204 582.5 194 3429.6 186 3135.9 171 2217.6 171 2217.6 152 | [bf) (psi) 3774.6 204 362.5 194 3429.6 186 3135.9 171 2217.6 171 2217.6 152 | [bf) (psi) 3774.6 204 5682.5 194 3135.9 171 217.6 171 217.6 171 2213.6 171 2213.5 152 | [bf) (psi) 3774.6 204 3632.5 194 3135.9 171 217.6 171 217.6 171 2213.6 171 213.5 171 217.6 171 217.6 174 2213.2 135 2613.2 135 2765.0 149
 | (bf) (ps) 3774.6 204 5682.5 194 3135.9 171 3135.9 171 220.4 152 276.5 136 276.0 149 2613.2 136 2603.9 137 | [bf) (psi) 3774.6 204 3682.5 194 3135.9 171 220.4 152 277.6 171 2717.6 174 2736.9 171 2790.4 152 2513.2 136 2765.0 137 2603.9 137 | (bf) (ps) 3774.6 204 5682.5 194 3135.9 171 2201.4 171 2217.6 174 2217.6 174 2765.0 135 2613.2 136 2603.9 137 | (bf) (ps) 3774.6 204 5682.5 194 3135.9 171 3135.9 171 2217.6 174 2213.2 135 2765.0 14 2765.0 135 2613.2 135 2603.9 137

 | (bf) (ps) 3774.6 204 5582.5 194 3135.9 171 3135.9 171 277.6 174 276.0 135 276.0 14 2763.0 135 2613.2 135 2603.9 137

 | (bf) (ps) 3774.6 204 3582.5 194 3592.5 134 3217.6 171 2217.6 174 2217.6 174 2217.6 174 2217.6 174 2213.2 135 2563.9 137 2603.9 137 7ens 7ens | [bf) (psi) 3774.6 204 3582.5 194 3135.9 171 3135.9 171 2014.6 174 2135.9 171 2135.9 174 2135.9 174 2513.2 135 2603.9 137 Zens.5 137 ASH ASH | Table (psi) (psi) 3774.6 204 194 3632.5 194 171 3135.9 171 134 2017.6 174 152 2765.0 149 266 2603.9 137 168 2603.9 137 7 7,n St,n /
 | Tens Tens Tens 1774.6 204 194 1373.6 194 134 13135.9 171 134 13135.9 171 174 2717.6 174 152 2613.2 135 134 2765.0 137 137 2603.9 137 149 2603.9 137 149 2603.9 137 149 160 (ps) 137
 | Table (psi) (psi) 3774.6 204 184 3632.5 184 134.9 3135.9 171 174 2717.6 174 174 2765.0 136 137 2613.2 136 137 2603.9 137 2683.9 76.0 149 7 76.0 288.3 240 | Ibf) (ps) (ps) 3774.6 204 3582.5 194 3582.5 194 3573.6 171 3217.6 171 2217.6 171 2217.6 171 2217.6 171 2217.6 171 2203.9 171 2563.9 171 2663.9 137 768.9 137 768.9 137 768.9 278.4 758.5 137 749. 7 708.9 222 200 222
 | Ibf) (ps) (ps) 3774.6 204 3582.5 194 3628.5 135.9 171 134 3135.9 171 152 174 2017.6 174 152 149 2513.2 136 137 149 2603.9 137 2603 137 160 869.3 2240 137 7603.9 137 240 137 1609.3 240 240 149 76.0 867.8 214 2240 | Ibf) (ps) (ps) 3774.6 204 3735.9 171 3135.9 171 217.6 174 2790.4 152 2613.2 135 2765.0 149 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 | Ibf) (psi) 3774.6 204 3135.9 1171 3135.9 171 2017.6 174 2017.6 174 2013.2 135 2513.2 135 2613.2 135 2613.3 171 2765.0 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 240 2603.9 240 2605.8 214 3952.5 214 | Ibf) (ps) (ps) 3774.6 204 3582.5 194 3582.5 194 3592.5 194 3217.6 171 2217.6 171 2217.6 171 2217.6 171 2217.6 171 2217.6 171 2217.6 171 2217.6 171 2214 234 25603.9 137 7mn ASH 7mn St, n 7mn ASH 2503.9 214 252.6 214 252.6 234 | Ibf) (ps) (ps) 3774.6 204 3582.5 194 3582.5 135.9 171 134 2017.6 174 152 154 2217.6 174 152 154 2217.6 174 152 154 2563.9 137 149 149 2603.9 137 240 149 7 8863.3 2240 137 1098.9 2240 137 240 1099.9 234 137 241 1055 234 234 234 255.6 234 234 234 255.6 234 234 234 | Table (psi) (psi) 3774.6 204 3682.5 194 3135.9 171 217.6 174 2217.6 174 2513.2 135 2563.9 171 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 263.9 137 264.0 214 274.0 214 265.9 214 214 234 214 234 | Ibf) (psi) (psi) 3135.9 171 204 3135.9 171 134 2017.6 134 154 2017.6 174 154 2017.6 171 154 2013.2
 135.9 171 217.6 174 152 2513.2 135 136 2603.9 137 240 16h (psi) / 1696.9 214 230 3952.6 214 231 3198.3 173 231 3198.3 173 231 | Ibf) (psi) (psi) 3135.9 171 194 3135.9 171 114 2017.6 174 174 2017.6 174 174 2013.2 135.9 171 213.5.9 171 149 2503.9 137 240 2603.9 137 240 2603.9 137 240 2765.9 137 240 2603.9 214 234 2763.9 214 233 2763.9 214 231 2741.4 230 234 238.3 173 238 3198.3 173 231 | Ibf) (ps) (ps) 3774.6 204 3552.5 194 3520.4 194 3217.6 171 2217.6 174 2217.6 174 2217.6 174 2217.6 174 2217.6 174 2217.6 174 2217.6 137 2563.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2603.9 137 2503 2240 2504 234 2505.8 214 2536 214 2536 214 2536 214 2536 214 2536 231 2536 231 2538 173 2538 173 |
| | | Temp Pf,r | | iai) (n bab) (ibi) | 9.8 21.2 377 | 9.8 21.2 377
9.8 21.2 377
9.8 21.0 355 | 9.8 21.2 377
9.8 21.2 377
9.8 21.0 358
9.8 20.9 342 | 1 (009 U) (10)
3.8 21.2 377
3.8 21.0 355
3.8 20.9 342
3.8 21.0 35 | 0 (10) (10) (10) (10) (10) (10) (10) (10 | 1 (eeg C) (m) 9.8 21.2 377 9.8 21.2 377 9.8 21.0 368 9.8 20.9 345 9.8 21.0 36 9.8 21.0 36 9.8 21.0 36 9.8 21.0 36 9.8 21.0 36 9.8 21.0 313 9.8 21.0 313 9.8 21.2 313 | 1 1 100 | 1 (leg U) (leg U) (leg U) 38 21.2 37.7 37.7 38 21.1 37.7 37.7 38 21.0 34.7 34.7 38 21.0 34.7 34.7 39 21.1 21.2 31.7 31 21.2 31.7 31.7 31 21.2 31.7 31.7 31 21.2 31.7 31.7 32 32 32.1 32.1 33 21.2 31.7 31.7 34 21.2 31.7 31.7 35 21.2 27.1 27.1 35 21.2 27.1 27.1 | 0 | 0 0000
0000 00000 0000 0000 0 | 1 10000 1000 1000 1 | 1 10000 1000 1000 1 | 1 10000 1000 1000 1 | 1 10 11 <th11< th=""> 11 11 11<td>1 1000 1000 1000 1000 1000 1000 1000 1000 2000 366 2012 377 366 2013 367 <t< td=""><td>0 1000 1000 1000 1000 1000 1000 20</td><td>0 1000 1000 1000 1000 1000 1000 1000 273 237 236 237 237 236 237 237 236 237 236 237 236 237 236 237 236 236 237 236 236 237 236 236 237 236 236 237 236 236 237 236 236 237 236 236 237
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| е РС/6-22 Iotai
Б 3 % Fib | 2.436 | b Voids | | i) - (%) - (%) | 338 (%) () | 338 (%) (!
338 4.0 (!
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338 4.0 | (%) (%) (%) (%) (%) (%) (%) (%) (%) (%) | (%) (%) (%) (%) (%) (%) (%) (%) (%) (%) | 338 (%) (0) 338 4.0 1 329 3.4.4 3 339 3.4.6 3 230 6.4.0 6 276 6.5 5 276 6.6 6 | 338 (%) (1) 338 4.0 (1) 349 3.6 3.6 349 3.6 3.6 2800 6.4 6.5 2778 6.5 5.5 2778 6.5 5.5 | 338 (%) (338 4.0 (339 3.45 3.6 330 5.6 5.5 2778 6.6 5.5 278 6.5 5.5 279 9.3 9.3 | 338 40 338 40 338 40 339 349 339 358 339 368 339 368 339 368 339 368 339 368 339 368 3368 4.0 2778 6.6 2778 6.6 2778 6.5 279 9.3 2712 9.3 278 6.5
 | 338 (%) (338 4.0 (338 4.0 (338 4.0 (338 4.0 (338 5.6 (2776 6.5 (2778 6.5 (2778 6.5 (2778 6.5 (2718 6.5 (273 9.3 (273 8.7 (| 338 (%) 0 338 4.0 0 339 3.6 4.0 339 5.6 5.6 2776 6.6 5.6 212 9.3 3.1 215 9.1 9.1 | (%) (%) (%) (%) (%) (%) (%) (%) (%) (%) | (%) (%) (%) (%) (%) (%) (%) (%) (%) (%)

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 | (%) (0) (0) 338 4.0 1 349 3.4 3.4 349 3.6 4.0 230 6.4 3.6 230 6.4 3.6 230 6.4 3.6 230 6.4 3.6 231 8.7 3.7 212 9.1 8.7 215 9.1 8.7 06-101 %RP 8.7 05-101 %RP 7.7 | (%) (0) (0) 338 4.0 1 349 3.6 4.0 349 3.6 3.6 280 6.4 6.4 280 6.5 3.6 280 6.5 3.6 209 9.3 9.3 212 9.1 8.7 215 9.1 8.7 06-101 %R4 8.7 05126B 7 701 215 9.1 2.5 215 2.5.7 %11 | 338 (%) (0) 338 4.4 0 349 3.6 3.4 280 6.4 0 280 6.4 0 200 9.3 6.5 209 9.3 0 212 9.1 0 212 9.1 7 213 8.7 7 214 9.3 1 212 9.1 7 213 8.7 7 214 9.1 7 215 9.1 7 215 9.1 7 215 9.1 7 215 9.1 7 215 101 1 215 1 7 215 1 1
 | 338 (%) (0) 338 4.0 10 349 3.6 3.6 339 4.0 3.6 339 5.6 5.6 209 9.3 2.12 215 9.1 9.1 215 9.1 7.12 215 8.7 7.12 215 9.1 7.12 215 9.1 7.12 8 7.125 8.7 7.15 9.1 7.14 8 7.15 9.1 9.1 7.15 9.1 101 %RA 8.7 105 9.1 7.14 10 0.5 7.15 10 1.0 1.0 10 1.0 1.0 10 1.0 1.0 10 1.0 1.0 10 1.0 1.0 10 1.0 1.0 10 1.0 1.0
 | 338 (%) (0) 338 4.4 3.6 349 3.6 4.0 338 4.0 3.6 338 4.0 6.4 338 6.4 6.6 2200 6.6 6.6 2212 9.3 8.7 2212 9.1 8.7 2213 8.7 7.8 2115 9.1 8.7 06-101 8.7 8.7 06-101 8.7 10tal 1 2.515 9.1 0.101 8.7 10tal 1 7.8 10tal 1 7.8 10tal 1 7.8 10tal | 338 (%) (0) 338 4.0 10 338 4.0 3.6 338 4.0 3.6 338 4.0 3.6 338 6.5 3.6 200 6.5 5.6 209 9.3 8.7 215 9.1 8.7 06-101 % % 06-101 % 7.7 06-101 % 7.12 112 215 9.1 06-101 % 7.12 113 % % 113 4.1 4.1
 | 338 (%) (0) 338 4.0 20 349 3.6 4.0 280 6.4 3.6 280 6.4 3.6 280 6.5 3.6 2778 6.5 3.6 2778 6.5 5.6 2710 6.5 5.7 2711 8.7 7 212 9.1 8.7 215 9.1 8.7 215 9.1 8.7 215 9.1 8.7 215 9.1 8.4 215 9.1 8.4 215 9.1 8.4 215 1.1 8.4 213 3.9 0 413 4.1 4.1 | 338 (%) (0) 338 4.0 10 339 3.4 3.6 339 3.6 3.6 200 6.4 0 201 6.5 0 202 9.3 6.5 203 9.3 6.5 203 9.3 7.8 212 9.1 8.7 212 9.1 8.7 212 9.1 7.4 212 9.1 7.4 215 9.1 7.4 1 7.1 9.1 1 1.1 7.4 1 1.1 3.9 1 1.1 4.1 | 338 4.0 10 338 4.4 3.6 349 3.6 4.0 338 4.0 3.6 338 4.0 3.6 338 4.0 6.4 2200 6.6 6.6 2212 9.3 8.7 2212 9.1 8.7 2212 9.1 8.7 2213 8.7 7.04 06-101 %F.8 8.7 215 9.1 1.04 8 7.7 %F.8 06-101 %F.8 8.7 112 2.5 7.6 113 4.1 4.1 413 4.1 4.1 3614 6.1 6.1 | 338 40 10 338 4,40 3,6 338 4,40 3,6 338 4,0 10,1 2278 6,6 5,6 2212 2212 9,1 2215 9,1 7,12 215 9,1 8,7 215 9,1 8,7 215 9,1 8,7 215 9,1 8,7 215 9,1 8,7 215 9,1 8,7 215 9,1 8,7 1,1 8,7 8,7 1,1 3,9 1,0 1,1 8,7 1,0 1,1 8,6 1,0 1,1 4,1 4,1 3,1 6,8 6,1 3,1 6,8 6,1 | 338 4.0 0 338 4.4 4.0 338 4.4 3.6 338 4.0 3.6 200 6.4 3.6 201 2.278 6.5 201 9.3 9.2 215 9.1 7.1 215 9.1 8.7 215 9.1 8.7 215 9.1 8.7 215 9.1 8.7 215 9.1 8.7 215 9.1 8.7 215 9.1 8.7 211 8.7 8.7 215 9.1 8.7 211 8.7 8.1 211 4.1 4.1 3355 6.5 7.7 355 6.5 6.5 | 338 (%) (0) 338 4.0 (0) 339 3.4 3.6 339 3.6 3.6 200 6.4 3.6 201 6.5 3.6 202 9.3 8.4 203 9.3 4.0 212 9.1 8.7 215 9.1 8.7 215 9.1 8.7 215 7 8.7 214 3.3 4.1 215 7 8.7 214 4.1 8.8 2515 7 8.1 3.3 4.1 4.1 3.3 6.5 6.5 333 6.5 6.5 | 338 (%) (0) 338 4.0 10 339 3.4 3.6 339 3.6 3.6 200 6.4 3.6 201 6.5 3.6 202 9.3 6.5
 203 9.3 6.5 203 9.3 7.8 212 9.1 8.7 212 9.1 8.7 215 9.1 7.7 215 9.1 7.4 11 7.1 9.1 11 7.3 3.9 11 7.3 3.9 11 7.3 3.9 11 7.3 3.9 11 7.3 3.9 11 7.3 4.1 11 7.3 4.1 11 7.3 5.7 11 7.3 5.7 12 8.9 6.5 13 6.5 5.7 <tr< td=""><td>338 40 10 338 440 40 338 440 36 338 440 36 338 65 36 200 65 36 201 93 66 202 200 93 203 87 7 215 91 87 215 91 87 215 91 87 215 91 87 214 413 41 413 41 41 335 65 68 345 66 66 345 66 66 345 66 91 345 66 91</td><td>338 40 10 338 4.0 4.0 338 4.0 3.6 338 4.0 3.6 338 5.4 3.6 338 6.5 3.6 338 6.5 3.6 338 6.5 3.6 338 6.5 3.6 338 6.5 3.6 338 6.5 3.1 341 2.55 8.7 413 4.1 4.1 414 4.1 4.1 4.14 4.1 4.1 4.14 4.1 4.1 4.14 4.1 4.1 2.515 6.5 7 353 6.5 6.5 353 6.5 6.1 9.1 9.1 9.1</td></tr<> | 338 40 10 338 440 40 338 440 36 338 440 36 338 65 36 200 65 36 201 93 66 202 200 93 203 87 7 215 91 87 215 91 87 215 91 87 215 91 87 214 413 41 413 41 41 335 65 68 345 66 66 345 66 66 345 66 91 345 66 91 | 338 40 10 338 4.0 4.0 338 4.0 3.6 338 4.0 3.6 338 5.4 3.6 338 6.5 3.6 338 6.5 3.6 338 6.5 3.6 338 6.5 3.6 338 6.5 3.6 338 6.5 3.1 341 2.55 8.7 413 4.1 4.1 414 4.1 4.1 4.14 4.1 4.1 4.14 4.1 4.1 4.14 4.1 4.1 2.515 6.5 7 353 6.5 6.5 353 6.5 6.1 9.1 9.1 9.1 |
| %Vinnin AC | Gmm | Specimen Gmb | | No. | No.
13 2.35 | No.
13 2.35
20 2.32 | No.
13
20
21
23
23
21
23 | No. 13 2.35
20 2.35
21 2.32
Average 2.33 | No.
13 2.35
20 2.35
21 2.35
Average 2.35
16 2.28 | No.
13 2.35
21 2.35
21 2.34
Average 2.37
19 2.27 | N0.
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Table B-21: Instrumented Data @ 21.1°C: Part A

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			strain)	Average	16	21	19	19	29	19	19	22	12	24	17	18						strain)	Average	19	18	15	17	22	22	23	22	22	38	28	26
			rain (micro	South	168	258	238		308	199	213		176	195	149							rain (micro	South	233	213	133		264	240	283		310	346	343	
			Failure Sti	North	162	181	151		286	185	168		80	287	197							Failure Sti	North	159	157	179		195	213	177		147	225	225	
			s (mm)	Average	5.2807E-03	3.3334E-03	7.3891E-03	7.3344E-03	1.1297E-02	7.2923E-03	7.2450E-03	3.6114E-03	4.8512E-03	9.1497E-03	5.5755E-03	5.8588E-03						s (mm)	Average	7.4526E-03	7.0199E-03	5.9390E-03	5.8038E-03	8.7131E-03	3.5960E-03	3.7367E-03	3.6820E-03	3.6911E-03	1.0840E-02	1.0786E-02	1.0106E-02
			al Deformation	South	6.4012E-03	9.7883E-03	9.0398E-03	age	1.1707E-02	7.5513E-03	8.1031E-03	age (6.6704E-03	7.4115E-03	5.6799E-03	age (al Deformation	South	8.8484E-03	8.0853E-03	5.0729E-03	age (1.0033E-02	9.1102E-03	1.0757E-02	age (1.1797E-02	1.3138E-02	1.3036E-02	age
			Horizont	North	6.1602E-03	6.8785E-03	5.7384E-03	Aver	1.0887E-02	7.0332E-03	6.3868E-03	Aver	3.0320E-03	1.0888E-02	7.4711E-03	Aver						Horizont	North	6.0567E-03	5.9546E-03	6.8051E-03	Aver	7.3935E-03	8.0818E-03	6.7169E-03	Aver	5.5853E-03	8.5425E-03	8.5356E-03	Aver
			StC<	(%)		5.1%				6.7%				4.7%								오 장	(%)		2.7%				1.2%				4.3%		
	ų	20	St SD	(isd)		8.0				9.0				<u>6</u> .1						ų	20	St SD	(isd)		5.0				1.9				5.7		
	sile Strengt	HTO T 322-	Avg. St	(bsi)		158				135				130						sile Strengt	HTO T 322-	Avg. St	(Isd)		184				153				132		
	Ten	AASI	st'n	(bsi)	166	151	156		126	134	144		137	125	129					Ten	AASI	۲, مع	(Isd)	179	184	189		151	155	154		134	125	136	
			Pf,n	(lbf)	3081.8	2742.1	2766.9		2342.7	2456.5	2670.7		2539.2	2329.4	2380.9							Pf,n	(lpl)	3314.9	3366.5	3470.5		2800.4	2868.6	2835.1		2457.1	2322.1	2513.8	
			Temp	(deg C)	21.1	21.2	21.3	21.2	21.2	21.3	21.0	21.2	21.3	21.3	21.1	21.2					I	Temp	(deg C)	21.3	21.3	21.3	21.3	21.5	21.4	21.4	21.4	21.2	21.5	21.3	21.3
			eter	(mm)	150.1	149.9	149.9	149.9	149.9	150.2	150.1	150.1	150.3	150.2	150.1	150.2						eter	(mm)	149.9	149.9	149.9	149.9	150.0	150.0	150.0	150.0	150.2	150.4	150.4	150.4
0.0 0.0	0.0		Diam	(in)	5.908	5.900	5.902	5.903	5.902	5.915	5.911	5.909	5.919	5.913	5.909	5.914	10.0	4.8	5.5	0:0		Diam	(iii)	5.901	5.900	5.902	5.901	5.906	5.904	5.904	5.905	5.913	5.923	5.922	5.919
			ess	(mm)	50.7	49.8	48.7	49.8	50.8	50.2	50.6	50.5	50.6	50.9	50.5	50.7						ess	(mm)	50.7	50.2	50.3	50.4	50.6	50.6	50.5	50.6	50.2	50.6	50.4	50.4
6RAP 2AP %AC otal %AC	6Fibers		Thickn	(in)	1.996	1.962	1.918	1.959	2.000	1.976	1.993	1.990	1.991	2.002	1.990	1.994	6RAP	RAP %AC	otal %AC	6Fibers		Thickn	(u)	1.998	1.978	1.981	1.986	1.993	1.993	1.988	1.991	1.975	1.991	1.986	1.984
6-125 9 P125C F 664-22 T	6.59	2.412	Voids	(%)	9.9 9	4.1	4.3	4.1	6.2	6.9	6.3	6.9	9.4	9.0	8.6	9.0	5-150 3	P125C F	G70-22 T	5.0 9	2.467	Voids	(%)	4.1	4.1	4.0	4.1	6.8	6.8	6.7	6.9	9.0	8.9	9.2	9.0
ion Grade P. V. Q.			Gmb		2.318	2.314	2.308	2.313	2.262	2.245	2.261	2.256	2.186	2.195	2.206	2.196	tion 0(S	Grade P			Gmb		2.365	2.365	2.368	2.366	2.300	2.299	2.302	2.300	2.245	2.247	2.241	2.244
Mix Designat Mix Type Virgin Binder	%Virgin AC	Gmm	Specimen	No.	14	25	26	Average	10	19	29	Average	2	16	38	Average	Mix Designat	Mix Type	Virgin Binder	%Virgin AC	Gmm	Specimen	No.	2	14	17	Average	23	œ	21	Average	18	25	24	Average

Table B-22: Instrumented Data @ 21.1°C: Part B

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			strain)	Average	51	63	77	63	61	47	54	54	69	71	57	99							strain)	Average	ន	76	17	69	74	73	46	64	46	54	55	52
			train (micro	South	42	46	50		32	65	69		98	104	37								train (micro	South	ន	45	131		120	66	77		45	82	91	
			Failure St	North	60	79	104		06	29	39		51	37	78								Failure St	North	23	108	22		29	79	14		48	31	19	
			s (mm)	Average	1.9376E-03	2.3770E-03	2.9094E-03	2.4080E-03	2.3257E-03	1.7961E-03	2.0445E-03	2.0554E-03	2.6166E-03	2.6878E-03	2.1846E-03	2.4963E-03							s (mm)	Average	2.0119E-03	2.8954E-03	2.9081E-03	2.6051E-03	2.8188E-03	2.7622E-03	1.7326E-03	2.4379E-03	1.7551E-03	2.0710E-03	2.0848E-03	1.9703E-03
			I Deformation	South	1.6101E-03	1.7412E-03	1.8839E-03	age	1.2129E-03	2.4821E-03	2.6228E-03	age	3.2783E-03	3.9655E-03	1.3945E-03	age							I Deformation	South	2.0213E-03	1.6964E-03	4.9787E-03	age	4.5516E-03	2.5218E-03	2.9275E-03	age	1.6972E-03	2.9698E-03	3.4605E-03	age
			Horizonta	North	2.2650E-03	3.0128E-03	3.9349E-03	Aven	3.4384E-03	1.1101E-03	1.4662E-03	Aven	1.9550E-03	1.4100E-03	2.9748E-03	Aven							Horizonta	North	2.0025E-03	4.0944E-03	8.3754E-04	Aven	1.0861E-03	3.0026E-03	5.3766E-04	Aver	1.8130E-03	1.1722E-03	7.0913E-04	Aven
			2 ₹	(%)		4.1%				5.5%				0.9%			•						2 25	(%)		5.0%				4.6%				7.1%		
	th	-07	st SD	(Isd)		18.8				23.2				3.0							th	-07	St SD	(Isd)		27.0				22.6				28.5		
	sile Streng	HTO T 322-	Avg. St	(isd)		460				419				341							sile Streng	HTO T 322	Avg. St	(isd)		543				492				401		
	Ten	AAS	с, б	(isd)	441	461	478		403	410	446		344	340	338						Ten	AAS	ч, С	(isd)	571	517	542		490	515	470		427	407	371	
			Pf,n	(lql)	8119.5	8555.3	8855.0		7418.0	7571.4	8145.8		6376.5	6275.0	6255.1								Pf,n	(lpt)	10548.7	9595.3	9908.4		9028.9	9528.2	8716.4		7828.2	7547.2	6871.1	
			Temp	(deg C)	4.7	4.7	4.7	4.7	4.6	4.7	4.7	4.7	4.7	4.6	4.7	4.7				I			Temp	(deg C)	4.5	4.7	4.6	4.6	4.7	4.7	4.7	4.7	4.6	4.9	4.9	4.8
			eter	(mm)	149.7	149.9	149.9	149.8	150.0	149.9	149.7	149.9	149.9	150.0	150.1	150.0							eter	(mm)	149.9	149.7	149.8	149.8	149.9	150.0	149.9	149.9	149.9	150.0	149.7	149.9
0.0	0.3		Diam	(iii)	5.895	5.901	5.900	5.899	5.906	5.903	5.895	5.901	5.902	5.907	5.911	5.907		0.0	0.0	5.7	0.0		Diam	(ii)	5.900	5.894	5.896	5.897	5.902	5.904	5.900	5.902	5.903	5.905	5.895	5.901
			less	(mm)	50.5	50.9	50.7	50.7	50.4	50.6	50.1	50.4	50.8	50.5	50.7	50.7							less	(mm)	50.7	51.0	50.2	50.6	50.4	50.7	50.9	50.7	50.2	50.8	50.9	50.6
%RAP RAP %AC Total %AC	%Fibers		Thickr	(ui)	1.989	2.004	1.997	1.997	1.986	1.994	1.973	1.984	2.001	1.988	1.995	1.995		%RAP	RAP %AC	Total %AC	%Fibers		Thickr	(iii)	1.995	2.006	1.975	1.992	1.986	1.996	2.003	1.995	1.978	1.999	2.002	1.993
06-84 SP125BSM F 0676-22 1	6.3	2.436	Voids	(%)	4.3	3.7	4.0	4.0	6.6	6.4	6.5	6.9	9.3	9.0	8.0	9.0		36-101 5	SP125B F	DG76-22	5.7 5	2.515	Voids	(%)	4.2	4.0	3.8	4.0	6.6	6.2	6.5	6.4	9.0	8.9	9.1	9.0
r Grade P			Gmb		2.330	2.346	2.339	2.338	2.276	2.281	2.277	2.278	2.209	2.216	2.223	2.216		ition C		r Grade F			Gmb		2.410	2.413	2.419	2.414	2.350	2.359	2.351	2.353	2.289	2.291	2.287	2.289
Mix Designa Mix Type Virgin Bindel	%Virgin AC	Gmm	Specimen	No.	9	00	24	Average	2	0	18	Average	~	23	25	Average		Mix Designa	Mix Type	Virgin Binde	%Virgin AC	Gmm	Specimen	No.	18	2	23	Average	~	14	25	Average	7	2	25	Average

Table B-23: Instrumented Data @ 4.4°C: Part A

Table		<u>-כ</u>	<u> </u>	4	.	11	<u>5</u>	ιu	111	IC	;	ιe	u		10	110	2	e	-	ŧ.'	+		•		<u>a</u>	ι										
			istrain)	Average	55	44	55	51	69	47	44	50	48	46	49	48							istrain)	Average	76	84	96	85	69	64	51	61	59	52	62	58
			train (micro	South	69	39	47		95	65	22		43	40	32								train (micro	South	111	105	146		105	43	70		47	38	35	
		:	Failure S	North	41	49	64		23	30	99		54	53	65								Failure S	North	41	64	43		33	85	32		71	65	68	
			ns (mm)	Average	2.0809E-03	1.6758E-03	2.1085E-03	1.9551E-03	2.2365E-03	1.8029E-03	1.6845E-03	1.9080E-03	1.8422E-03	1.7616E-03	1.8569E-03	1.8202E-03							ns (mm)	Average	2.8959E-03	3.2041E-03	3.5928E-03	3.2309E-03	2.6224E-03	2.4252E-03	1.9367E-03	2.3281E-03	2.2357E-03	1.9622E-03	2.3582E-03	2.1854E-03
			al Deformatio	South	2.6032E-03	1.4787E-03	1.7993E-03	rage	3.5948E-03	2.4524E-03	8.4765E-04	rage	1.6390E-03	1.5196E-03	1.2316E-03	rage	1						al Deformatio	South	4.2285E-03	3.9886E-03	5.5593E-03	rage	3.9871E-03	1.6358E-03	2.6478E-03	rage	1.7769E-03	1.4490E-03	1.3244E-03	rage
			Horizont	North	1.5585E-03	1.8730E-03	2.4177E-03	Ave	8.7816E-04	1.1535E-03	2.5214E-03	Ave	2.0454E-03	2.0037E-03	2.4821E-03	Ave							Horizont	North	1.5633E-03	2.4197E-03	1.6263E-03	Ave	1.2578E-03	3.2145E-03	1.2256E-03	Ave	2.6945E-03	2.4755E-03	3.3920E-03	Ave
			े ठ	(%)		1.2%				4.7%				1.2%									st c<	(%)		4.2%				3.8%				4.4%		
	th		25 75	(isd)		5.8				18.0				3.9							th	20	St SD	(isd)		21.9				16.5				17.0		
	sile Streng	HTO T 322.	Avg. St	(psi)		465				R				999 999							sile Streng	HTO T 322	Avg. St	(isd)		520				438				Ř		
	Ten	ASI	د تة	(psi)	461	464	472		384	361	396		33	ĝ	336						Ten	AASI	r, S	(isd)	494	23	535		446	419	448		378	407	378	
		i	r, t	(lpt)	8466.2	8970.3	8820.8		7068.2	6719.7	7304.1		6147.1	6276.8	6214.6								Pf,n	(lpl)	9078.4	9788.8	9741.2		8182.4	7669.9	8243.4		6873.0	7528.1	6941.6	
			lemp	(deg C)	4.3	4.6	4.6	4.5	4.6	4.6	4.6	4.6	4.3	4.4	4.6	4.4							Temp	(deg C)	4.4	4.6	4.7	4.6	4.7	4.7	4.8	4.7	4.4	4.7	4.7	4.6
			eter	(mm)	149.9	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.3	150.2	150.1	150.2							eter	(mm)	149.9	149.8	149.8	149.8	150.0	150.2	150.0	150.0	150.2	150.1	150.1	150.1
0.0 0.0 6.5	0.0	i	Diam	(iii)	5.903	5.905	5.906	5.905	5.907	5.906	5.904	5.906	5.918	5.915	5.911	5.915		10.0	4.8	5.5	0:0		Diam	(ui)	5.900	5.899	5.897	5.899	5.904	5.913	5.904	5.907	5.915	5.908	5.909	5.911
			less	(mm)	50.3	53.0	51.2	51.5	50.4	51.0	50.5	50.7	50.7	50.6	50.6	50.7							less	(mm)	50.3	50.6	50.0	50.3	50.2	50.1	50.4	50.2	49.7	50.6	50.3	50.2
%RAP RAP %AC Total %AC	%Fibers	i	Thickr	(iii)	1.982	2.085	2.015	2.027	1.986	2.009	1.989	1.995	1.997	1.993	1.994	1.995		%RAP	RAP %AC	Total %AC	%Fibers		Thickr	(ui)	1.981	1.994	1.967	1.981	1.978	1.973	1.984	1.978	1.956	1.991	1.979	1.975
06-125 SP125C	6.5	2.412	Voids	(%)	6.E	4.1	4.3	4.1	6.9	6.3	6.2	6.4	9.2	9.0	8.7	0.6		06-150	SP125C	-G70-22	5.0	2.467	Voids	(%)	4.1	4.1	4.0	4.1	6.9	6.9	6.9	6.9	6.9	9.1	8.7	9.0
fion (Grade P			Gmb		2.319	2.312	2.308	2.313	2.248	2.259	2.263	2.257	2.190	2.194	2.203	2.196		tion (r Grade			Gmb		2.365	2.367	2.370	2.367	2.299	2.298	2.296	2.298	2.237	2.244	2.252	2.244
Mix Designa Mix Type Virgin Binder	%Virgin AC	Gmm	Specimen	No.	Q	10	13	Average	10	26	28	Average	0	1	20	Average		Mix Designa	Mix Type	Virgin Binder	%Virgin AC	Gmm	Specimen	No.	4	19	20	Average	2	7	12	Average	œ	0	<u>0</u>	Average

Table B-24: Instrumented Data @ 4.4°C: Part B

Ιċ	11)(e		-2	:0	•		IS	u	uı	116	JI	π	e	L	$\boldsymbol{\nu}$	a	ld	. (y	-	10)		•	01	-	<u> </u>	<u>_</u>	0	κU	0	- 1	U	S			
					St CV	(%)		10.0%				eak		Average	15	12	11	12							Stc∕	(%)		iQ/AIG#		Γ	- Included and a second se	dar	Average				i0//IC#	e line as t	5
				2-03	St SD	(isd)		59.6			in)	(Y - X) ре		South	14	9	15	rage						2-03	St SD	(Isd)		0.0		(9	2	ad (? - ⊥)	South				rage	the sam	eformatio
				HTO T 32	Avg. St	(psi)		594			microstrai	At		North	15	18	9	Ave						HTO T 32	Avg. St	(isi)		0		microstra	A+	ζ	North				Ave	eading on	rizontal d
				AAS	st'n	(psi)	640	527	617		e Strain (i	ad		Average	15	11	11	12						AAS	st'n	(Isd)	0	00		e Strain (190	Average	21	13	19	18	n as the r	al and ho
					Pf,n	(lbf)	11828.6	9754	11345.8		Failur	ximum Lo		South	14	5	15	ge							Pf,n	(lpl)				Failur	vine in a	אוננותננו בת	South	20	15	36	ge	ation take	een vertic
				Correction	Avg. St	(bsi)		505				At Ma		North	15	18	٩	Avera						Correction	Avg. St	(isd)		483			At Me		North	22	10	2	Avera	ntal deforma	erence betw
			e Strength	NCHRP 530	st,n	(psi)	537	460	519					Average	6673E-04	.5613E-04	1.0067E-04	I.7451E-04					e Strength	NCHRP 530	st'n	(isd)	515	467	0 0				Average				i0//I0#	nding horizo	aximum diffi
			Tensil	_	S S	(%)		8.6%				(Y - X) peak		South	.5008E-04 5	.1715E-04 4	.8208E-04 4	Je 4					Tensil	_	S S	(%)		6.2%			V V Nacol	(1 - A) peak	South				Je P	ш	μ
					St SD	(isd)		51.3			nations (mm)	Åt		North	.8338E-04 5	.9512E-04 2	.1927E-04 5	Avera							S SD	(isd)		35.2		nations (mm)	14V	ζ	North				Avera		
				HTO T 322-07	Avg. St	(bsi)		599			zontal Deforn			Average	.6673E-04 5	.3674E-04 6	.0067E-04 2	.6805E-04						HTO T 322-07	Avg. St	(isi)		571		zontal Deform			Average	.9612E-04	.7766E-04	.2223E-04	.6534E-04	failure	
				AAS	st'n	(bsi)	640	542	617		Hori	aximum Loac		South	.5008E-04 5	.7837E-04 4	.8208E-04 4	ge 4						AAS	st,n	(isd)	612	125	B	Hori	avimum loos	מאוווועווו בטמו	South	.7491E-04 7	6931E-04 4	.3777E-03 7	ge 6	stance of first	
					Pf,n	(lpt)	11828.6	10024.4	11345.8			At M		North	.8338E-04 5	(.9512E-04 1	1927E-04 E	Avera							Pf,n	(lpt)	9839.5	8791.5	C:0000		V4 4V	ž	North	(.1733E-04 7	(.8602E-04 E	.6730E-05	Avera	dicates an in	
		I			Temp	(deg C)	-9.9	-9.7	-10.0	-9.9			Temp	(deg C)	-9.9	9.7 8	-10.0	6.6-							Temp	(deg C)	-9.7	۰.0 ۲.0	0.01		1	Temp	(qeid C)	-9.7 8	-9.7	-10.0 6	8.0- 0	.9	
					ter	(mm)	149.9	149.9	150.0	149.9		-	ter	(mm)	149.9	149.9	150.0	149.9							ter	(mm)	150.4	150.1	150.4			ter	(mm)	150.4	150.1	150.4	150.3		
20.0).c	с. С.	0.0		Diamet	(in)	5.901	5.901	5.905	5.902			Diamet	(in)	5.901	5.901	5.905	5.902		10.0	4.8	5.6	0.0		Diamet	(in)	5.92	5.91	5.92			Diamet	(iii)	5.92	5.91	5.92	5.92		
					SS	(mm)	50.7	50.7	50.4	50.6			SS	(mm)	50.7	50.7	50.4	50.6							SS	(mm)	43.9	49.7	43.9			ss	(mm)	43.9	43.7	43.9	43.9		
RAP S 2 2 3 2	PH %AC	tal %AC	Fibers		Thickne	(in)	1.995	1.997	1.983	1.992			Thickne	(in)	1.995	1.997	1.983	1.992		RAP	AP %AC	tal %AC	Fibers		Thickne	(in)	1.73	1.72	2 22			Thickne	(iii)	1.73	1.72	1.73	1.73		
123		64-22 To	4.2 %	2.501	Voids	(%)	6.9	6.7	6.9	6.8			Voids	(%)	6.9	6.7	6.9	6.8		105 %	125C R/	570-22 To	5.1 %	2.455	Voids	(%)	6.1	0.7	5 G			Voids	(%)	6.1	7.0	6.4	6.5		
-20 -20 -10		Grade PG			Gmb		2.331	2.333	2.331	2.332			Gmb		2.331	2.333	2.331	2.332		o D E	R	Brade PG			Gmb		2.306	2.282	2.23/ 2.25/			Gmb		2.306	2.282	2.297	2.295		
Mix Designatic	Mix Lype	Virgin Binder (%Virgin AC	Gmm	Specimen	No.	16	17	18	Average		-	Specimen	No.	16	17	18	Average		Mix Designatic	Mix Type	Virgin Binder (%Virgin AC	Gmm	Specimen	No.	m	<u> </u>	Average	- C		Specimen	No.	m	8	6	Average		

Table B-25: Instrumented Data @ -10°C: 07-123 & 06-105

	-	_	_	_	_		_			_	_		<u> </u>	_	_			_	_	_		_	_	_	_	_	_	_	_	_		_		
			St C<	8		iQ/AIC#				iQ/AIC#				iQ/AIC#				eak		Average				i0//I0#				i0//IC#				i0//IC#	ne line as t	Ę
		22-03	St SD	(lsd)		00				0.0				0.0			iin)	id (x - J) i		South				erage				erage				erage	n the sam	leformatio
		:HTO T 32	Avg. St	(bsl)		_				_							microstra	At		North				Ave				Ave				Ave	eading or	rizontal d
		AAS	ч, С	(bsi)	0	_	0				0		0		0		e Strain (bad		Average	19	5	18	18	27	20	ŝ	27	21	21	29	24	n as the r	al and ho
			Pf,n	(lql)													Failur	ximum Lo		South	24	9	28	ge	13	22	<u>6</u>	ge	13	17	47	ge	ation take	reen vertic
		Correction	Avg. St	(Isd)		581				520				467				At Ma		North	15	Ω	8	Avera	41	17	8	Avera	R	28	11	Avera	ntal deform:	erence betw
	le Strength	NCHRP 530	ч Ђ	(Isd)	566	596	583		544	478	537		460	427	516					Average				#DIV/0#				i0//I0#				i0/\I0#	Ending horizo	naximum diffe
	Tensi		상장	(%)		2.8%				7.6%				10.5%			0	t (Y - X) peak		South				age				age				age		-
		20	St SD	(isd)		19.2				46.7				58.0			mations (mm	A		North				Avera				Avera				Avera		
		SHTO T 322-0	Avg. St	(isd)		697				618				551			rizontal Defor	p		Average	7.3578E-04	5.8724E-04	6.9973E-04	6.7425E-04	1.0159E-03	7.4102E-04	1.2698E-03	1.0089E-03	8.1171E-04	8.1447E-04	1.1058E-03	9.1067E-04	st failure	
		AAS	ct'u	(isd)	677	715	669		649	564	640		540	498	613		θH	Aaximum Los		South	9.0662E-04	6.7086E-04	1.0770E-03	age	4.9095E-04	8.5322E-04	2.2304E-03	age	5.0068E-04	6.3455E-04	1.7759E-03	age	nstance of fir	
			Pf,n	(lpl)	12406.6	13244.0	12665.4		12029.4	10446.8	11782.8		9998.2	9164.4	11355.0			Ath		North	5.6494E-04	5.0361E-04	3.2247E-04	Avera	1.5408E-03	6.2882E-04	3.0918E-04	Aver	1.1227E-03	9.9439E-04	4.3575E-04	Avera	ndicates an i	
ľ			Temp	(deg C)	-10.0	-10.0	-10.0	-10.0	-10.0	-10.1	-10.0	-10.0	-10.2	-9.7	-9.9	-9.9			Temp	(deg C)	-10.0	-10.0	-10.0	-10.0	-10.0	-10.1	-10.0	-10.0	-10.2	-9.7	-9.9	-9.9		
			ieter	(mm)	149.8	149.8	149.8	149.8	150.2	149.8	149.8	149.9	150.0	150.0	150.0	150.0			ieter	(mm)	149.8	149.8	149.8	149.8	150.2	149.8	149.8	149.9	150.0	150.0	150.0	150.0		
0.0	0.3		Diam	(ui)	5.898	5.897	5.899	5.898	5.912	5.899	5.899	5.903	5.906	5.905	5.905	5.905			Dian	(ii)	5.898	5.897	5.899	5.898	5.912	5.899	5.899	5.903	5.906	5.905	5.905	5.905		
			ness	(mm)	50.3	50.8	49.7	50.2	50.7	50.8	50.5	50.6	50.6	50.4	50.7	50.6			ness	(mm)	50.3	50.8	49.7	50.2	50.7	50.8	50.5	50.6	50.6	50.4	50.7	50.6		
%RAP RAP %AC Total %AC	%Fibers		Thick	(ui)	1.979	2.000	1.956	1.978	1.995	1.999	1.988	1.994	1.994	1.983	1.997	1.991			Thick	(iii)	1.979	2.000	1.956	1.978	1.995	1.999	1.988	1.994	1.994	1.983	1.997	1.991		
)6-84 SP125BSM >G76-22	6.3	2.436	Voids	(%)	4.0	4.1	4.1	4.1	6.7	6.9	6.3	6.5	9.2	9.0	8.8	9.0			Voids	(%)	4.0	4.1	4.1	4.1	6.7	6.5	6.3	6.9	9.2	9.0	8.8	9.0		
ation [r Grade F			Gmb		2.340	2.336	2.337	2.338	2.274	2.278	2.282	2.278	2.211	2.217	2.223	2.217			Gmb		2.340	2.336	2.337	2.338	2.274	2.278	2.282	2.278	2.211	2.217	2.223	2.217		
Mix Designa Mix Type Virgin Binde	%Virgin AC	Gmm	Specimen	No.	4	7	23	Average	12	15	23	Average	11	26	27	Average			Specimen	No.	4	2	23	Average	12	15	23	Average	11	26	27	Average		

Table B-26: Instrumented Data @ -10°C: 06-84

			S S	(%)		iQ/AIQ#				6.4%				iQ/NQ#				ak	-	Average				#DIV/0	28	14	12	18				#DIV/0	e line as t	_
		50	St SD	(psi)		0.0				39.7				0.0			(эd (X - Y		South				age	52	16	17	age				age	the sam	formation
		FO T 322	wg. St	(bsi)		0				625				0			crostrair	At (North				Avera	4	11	2	Avera				Avera	ding on .	ontal de
		AASH	St,n A	(bsi)	0	0	0		580	642	654		0	0	0		Strain (mi	_		verage	14	17	18	16	26	14	12	17	19	24	22	22	as the rea	and horiz
			Pf,n	(lbf)					3792.8	1903.1	2119.8						Failure (num Loac		South A	17	25	9		52	16	17		ω	37	23		in taken a	n vertical
		orrection	Avg. St	(isd)		641			11	535 1	=			485				At Maxin		North	10	6	Q	Average	+	11	2	Average	œ	11	22	Average	tal deformatic	ence betwee
	e Strength	JCHRP 530 C	St,n	(bsi)	655	632	636		519	538	548		497	485	473					Average				i0//JC#	.0626E-03	.1768E-04	.4297E-04	.7441E-04				i0//JC#	nding horizom	aximum differ
	Tensile	2	st CV	(%)		2.0%				3.0%				2.6%				(Y - X) peak		South				ge	.9705E-03 1	0.1440E-04 5	(.3165E-04 4	ge 6				ge	Ē	В
		7	St SD	(isd)		15.4				18.9				15.2			nations (mm)	At		North				Avera	1.5470E-04 1	4.2096E-04 E	2.5428E-04	Avera				Avera		
		3HTO T 322-0	Avg. St	(isd)		2773				637				573			izontal Deforr	p		Average	5.1327E-04	5.4116E-04	6.9534E-04	5.1659E-04	9.9712E-04 1	5.1768E-04	4.4297E-04	5.5259E-04	7.1238E-04	9.1571E-04	3.4683E-04	3.2497E-04	st failure	
		AAS	ч t	(isi)	262	761	767		617	642	654		588	574	558		Hoi	Aaximum Loa		South	6.6074E-04	9.4584E-04	1.1824E-03	ige I	1.9705E-03	6.1440E-04	6.3165E-04	ige	2.9886E-04	1.4178E-03	8.5893E-04	ige i	nstance of firs	
			Pf,n	(lpl)	14584.4	14113.2	14212.0		11481.9	11903.1	12119.8		10875.9	10505.4	10282.0			At N		North	3.6580E-04	3.3648E-04	2.0830E-04	Avera	2.3756E-05	4.2096E-04	2.5428E-04	Avera	1.1259E-03	4.1363E-04	8.3473E-04	Avera	ndicates an ii	
			Temp	(deg C)	6.6	0, 0,	9.9- 9.9	6.6-	-10.3	-10.0	9.9- 9.9	-10.1	-10.0	-10.0	-9.9	-10.0			Temp	(deg C)	-9.9	9.6	-9.9	-9.9	-10.3	-10.0	9.9	-10.1	-10.0	-10.0	-9.9	-10.0		
			neter	(mm)	149.7	149.8	149.8	149.8	150.0	150.0	149.8	149.9	150.0	149.8	149.9	149.9			neter	(mm)	149.7	149.8	149.8	149.8	150.0	150.0	149.8	149.9	150.0	149.8	149.9	149.9		
0.0 0.0 5.7	0.0		Diam	(in)	5.894	5.898	5.896	5.896	5.906	5.906	5.896	5.903	5.904	5.897	5.903	5.901			Dian	(iii)	5.894	5.898	5.896	5.896	5.906	5.906	5.896	5.903	5.904	5.897	5.903	5.901		
			ness	(mm)	50.6	50.8	50.8	50.7	51.0	50.8	50.9	50.9	50.6	50.2	50.5	50.4			ness	(mm)	50.6	50.8	50.8	50.7	51.0	50.8	50.9	50.9	50.6	50.2	50.5	50.4		
%RAP RAP %AC Total %AC	%Fibers		Thick	(in)	1.993	2.001	2.000	1.998	2.007	2.000	2.002	2.003	1.993	1.977	1.987	1.986			Thick	(ii)	1.993	2.001	2.000	1.998	2.007	2.000	2.002	2.003	1.993	1.977	1.987	1.986		
06-101 SP125B PG76-22	5.7	2.515	Voids	(%)	3.0	4.2	4.0	4.0	6.7	6.5	6.2	6.5	9.0	9.2	8.8	9.0			Voids	(%)	3.8	4.2	4.0	4.0	6.7	6.5	6.2	6.5	9.0	9.2	8.8	9.0		
tion r Grade			Gmb		2.421	2.409	2.414	2.415	2.347	2.350	2.358	2.352	2.289	2.283	2.293	2.288			Gmb		2.421	2.409	2.414	2.415	2.347	2.350	2.358	2.352	2.289	2.283	2.293	2.288		
Mix Designa Mix Type Virain Binder	%Virgin AC	Gmm	Specimen	No.	-	m	13	Average	8	16	26	Average	00	11	26	Average			Specimen	No.	-	m	13	Average	œ	16	26	Average	8	1	26	Average		

Table B-27: Instrumented Data @ -10°C: 06-101

			st cV	(%)		6.1%				21.4%				7.7%				ž		Average	22	17	15	18	23	19	18	20	17	19	17	18	line as t	
		8	St SD	(bsi)		36.1				108.8				37.1			_	Y - X) pea		South /	20	28	25	ge	42	35	23	ge [26	32	31	ge	he same	ormation
		TO T 322	≜vg. St	(isd)		587				20				484			icrostrain	At (North	25	9	4	Avera	2	З	14	Avera	80	9	2	Avera	ading on t	zontal def
		AASH	, L, n	(psi)	621	290	549		499	405	622		508	502	441		Strain (m	p		Average	22	17	14	18	21	18	18	19	17	19	16	18	as the re:	I and hori:
			Pf,n	(lbf)	11541.1	10870.4	10057.4		9270.6	7528.8	11350.7		9449.5	9273.7	8245.8		Failure	mum Loa		South /	20	28	25		42	35	23		26	32	31		ion taken	en vertica
		orrection	≜wg. St	(psi)		200				454				418				At Maxi		North	25	5	4	Averagi	-	1	14	Averagi	8	9	2	Averagi	al deformat	ence betwe
	Strength	:HRP 530 C(st'n	(bsi)	522	506	473		443	396	523		435	435	385					verage	302E-04	965E-04	460E-04	242E-04	536E-04	894E-04	155E-04	528E-04	470E-04	245E-04	364E-04	360E-04	ling horizont	kimum differe
	Tensile (N	>			5.4%				5.5%				.5%				l peak		h A	E-04 8.4	E-03 6.4	E-04 5.5	6.9	E-03 8.3	E-03 7.3	E-04 6.9	7.5	E-03 6.5	E-03 7.3	E-03 6.3	6.7	End	(ema)
			0 87	(%)		<u>-</u>				<u>۳</u>				~			(mi	At (Y - X)		Sout	1 7.4703	1.0819	t 9.4319I	erage	5 1.58091	1.3453	1 8.5754	erage	1.0037	1.22971	5 1.1773	erage		
		20	St SD	(psi)		32.0				82.8				36.5			irmations (m			North	9.3901E-04	2.1738E-04	1.6601E-04	9WA	8.9861E-05	1.3262E-04	5.2556E-04	9MA AMB	3.0568E-04	2.3520E-04	8.9952E-05	Ave		
		SHTO T 322	Avg. St	(isd)		593				533				487			irizontal Defo	ad		Average	8.4302E-04	6.4009E-04	5.4254E-04	6.7522E-04	8.0297E-04	6.9106E-04	6.9155E-04	7.2853E-04	6.5470E-04	7.2540E-04	6.1865E-04	6.6625E-04	st failure	
		88 8	st,n	(psi)	621	009	558		519	458	622		508	509	445		Ĭ	Maximum Lo		South	7.4703E-04	1.0819E-03	9.4319E-04	age	1.5809E-03	1.3453E-03	8.5754E-04	age	1.0037E-03	1.2297E-03	1.1773E-03	age	nstance of fil	
			Pf,n	(lbf)	11541.1	11042.5	10220.9		9655.2	8515.0	11350.7		9449.5	9393.9	8319.1			At 1		North	9.3901E-04	1.9826E-04	1.4188E-04	Aven	2.5085E-05	3.6860E-05	5.2556E-04	Aven	3.0568E-04	2.2111E-04	5.9978E-05	Aven	ndicates an i	
			Temp	(deg C)	-9.9	-10.0	-10.1	-10.0	-10.0	6.6-	-10.1	-10.0	-10.0	-10.0	-10.1	-10.0			Temp	(deg C)	6.6-	-10.0	-10.1	-10.0	-10.0	6.6	-10.1	-10.0	-10.0	-10.0	-10.1	-10.0	.=	
			er	(mm)	150.1	149.9	150.0	150.0	150.2	150.3	150.0	150.2	150.3	150.0	150.7	150.3			er	(mm)	150.1	149.9	150.0	150.0	150.2	150.3	150.0	150.2	150.3	150.0	150.7	150.3		
0.0	0.0		Diamet	(in)	5.910	5.903	5.907	5.907	5.912	5.919	5.905	5.912	5.917	5.906	5.932	5.918			Diamet	(in)	5.910	5.903	5.907	5.907	5.912	5.919	5.905	5.912	5.917	5.906	5.932	5.918		
			ess	(mm)	50.9	50.4	50.1	50.5	50.9	50.7	50.0	50.5	50.8	50.5	50.9	50.8			ess	(mm)	50.9	50.4	50.1	50.5	50.9	50.7	50.0	50.5	50.8	50.5	50.9	50.8		
%RAP RAP %AC fotal %AC	%Fibers		Thickn	(in)	2.002	1.986	1.974	1.987	2.002	1.998	1.967	1.989	2.000	1.990	2.005	1.998			Thickn	(m)	2.002	1.986	1.974	1.987	2.002	1.998	1.967	1.989	2.000	1.990	2.005	1.998		
6-125 P125C 664-22	6.5	2.412	Voids	(%)	3.9	4.0	4.1	4.0	6.4	6.6	6.5	6.5	9.1	9.0	8.9	9.0			Voids	(%)	9.0 0	4.0	4.1	4.0	6.4	6.6	6.5	6.5	9.1	9.0	8.9	9.0		
tion Grade D			Gmb		2.317	2.315	2.314	2.315	2.257	2.254	2.254	2.255	2.192	2.196	2.197	2.195			Gmb		2.317	2.315	2.314	2.315	2.257	2.254	2.254	2.255	2.192	2.196	2.197	2.195		
Mix Designat Mix Type Virain Binder	%Virgin AC	Gmm	Specimen	No.	4	5 G	00	Average	2	ŋ	25	Average	2	0	12	Average			Specimen	No.	4	ۍ	00	Average	2	ŋ	25	Average	2	0	12	Average		

Table B-28: Instrumented Data @ -10°C: 06-125

			St C<	(%)		6.1%				3.2%				2.9%				¥		Average	17	19	15	17	13	17	15	15	20	19	17	19	line as t	
		ę	St SD	(psi)		47.5				20.0				15.8			_	(- X) pea		South /	22	31	18	ge [21	28	11	ge	33	16	31	ge	he same	ormation
		TO T 322	Avg. St	(psi)		280				630				550			icrostrain	At (North	13	6	12	Avera	S	9	20	Avera	7	21	4	Avera	ading on t	contal def
		AASH	st'n	(psi)	829	734	775		607	639	644		535	567	550		Strain (m	7		werage	17	18	15	17	13	17	15	15	20	19	17	19	as the rea	and horiz
			Pf,n	(lbf)	5159.9	3601.7	4315.2		1184.7	1751.7	1793.2		9779.1	0421.8	0193.5		Failure	mum Loa		South 4	22	31	18		21	28	11		33	16	31		on taken	en vertical
		rection	ĝ ĝ	(bsi)	~	648	-		-	2 23	-			467	-			At Maxi		Jorth	13	9	12	Average	S	9	20	Average	9	21	4	Average	deformati	ice betwee
	ngth	P 530 Cor	٩ ٩) (685	617	643		512	536	545		456	480	467					ge b	E-04	horizontal	um differen											
	nsile Strei	NCHR	τ̈́	(psi														ak		Avera	4 6.5284	3 7.0841	4 5.7799	6.4641	4 4.8946	8 6.5204	4 5.8729	5.7626	3 7.6447	4 7.1375	8 6.5976	7.1266	Ending	maximu
	Ter		N S	(%)		5.69				3.5%				2.89			(t (Y - X) pe		South	8.2024E-0	1.1759E-00	6.9265E-0	age	7.9069E-0	1.0721E-00	4.1198E-04	age	1.2611E-00	6.1273E-0	1.1786E-00	age		
		21	St SD	(isi)		43.6				22.0				15.5			mations (mm	¥		North	4.8545E-04	2.4096E-04	4.6333E-04	Avera	1.8824E-04	2.3198E-04	7.6259E-04	Avera	2.6786E-04	8.1478E-04	1.4092E-04	Avera		
		3HTO T 322-C	Avg. St	(isd)		782				632				551			izontal Defor	P		Average	5.5284E-04	5.9754E-04	5.7799E-04	5.4279E-04	4.8946E-04	5.5204E-04	5.8307E-04	5.7486E-04	7.4798E-04	7.1375E-04	5.5976E-04	7.0717E-04	t failure	
		AAS	ч Ю	(isd)	829	743	775		607	633	649		535	567	550		Ηο	faximum Loa		South	3.2024E-04	1.1759E-03	5.9265E-04	ige [1	7.9069E-04	1.0721E-03	4.0355E-04	ie e	1.2611E-03	5.1273E-04	1.1786E-03	de	istance of firs	
			Pf,n	(lpt)	15159.9	13757.3	14315.2		11184.7	11751.7	11887.8		9789.4	10421.8	10193.5			At N		North	1.8545E-04	2.1924E-04	1.6333E-04	Avers	1.8824E-04	2.3198E-04	7.6259E-04	Avers	2.3487E-04	8.1478E-04	I.4092E-04	Avers	ndicates an in	
			Temp	(deg C)	-10.0	-10.1	-9.9	-10.0	9.6-	9.6	-9.7	9.6	-10.3	6.6-	-9.9	-10.0			Temp	(deg C)	-10.0	-10.1	. 6.6-	-10.0	8.6-	8.6	-9.7	-9.8	-10.3	6.6-	6.6-	-10.0	.=	
			ter	(mm)	149.9	149.8	149.8	149.8	150.1	150.0	149.9	150.0	150.4	150.0	150.2	150.2			ter	(mm)	149.9	149.8	149.8	149.8	150.1	150.0	149.9	150.0	150.4	150.0	150.2	150.2		
10.0 5.5	0.0		Diame	(in)	5.900	5.898	5.899	5.899	5.908	5.905	5.901	5.905	5.923	5.906	5.915	5.915			Diame	(iii)	5.900	5.898	5.899	5.899	5.908	5.905	5.901	5.905	5.923	5.906	5.915	5.915		
			ss	(mm)	50.1	50.8	50.6	50.5	50.4	50.4	50.2	50.3	49.9	50.4	50.7	50.3			ss	(mm)	50.1	50.8	50.6	50.5	50.4	50.4	50.2	50.3	49.9	50.4	50.7	50.3		
SRAP AP %AC otal %AC	Fibers		Thickne	(in)	1.973	1.999	1.993	1.988	1.985	1.983	1.975	1.981	1.965	1.983	1.996	1.981			Thickne	(ii)	1.973	1.999	1.993	1.988	1.985	1.983	1.975	1.981	1.965	1.983	1.996	1.981		
-150 %	5.0 %	2.467	Voids	(%)	4.2	4.0	9.6 E	4.0	6.6	6.5	6.7	6.6	9.1	8.7	9.2	9.0			Voids	(%)	4.2	4.0	3.9	4.0	6.6	6.5	6.7	6.6	9.1	8.7	9.2	9.0		
n 06 Yrade PG			Gmb		2.363	2.369	2.371	2.368	2.303	2.307	2.302	2.304	2.244	2.251	2.240	2.245			Gmb		2.363	2.369	2.371	2.368	2.303	2.307	2.302	2.304	2.244	2.251	2.240	2.245		
Mix Designatic Mix Type Virgin Binder G	%Virgin AC	Gmm	Specimen	No.	10	13	26	Average	9	13	14	Average	5	9	17	Average			Specimen	No.	10	13	26	Average	ç	13	14	Average	ç	9	17	Average		

Table B-29: Instrumented Data @ -10°C: 06-150





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