Evaluation of Fiber-Reinforced Asphalt Pavements – Idaho Case Study

US-30 at Montpelier, Idaho

ITD Project Phase 1 (RP 237) – Lab Evaluation of Materials

Project Team:

UI – Fouad Bayomy (PI), Ahmed Muftah (Grad Student)

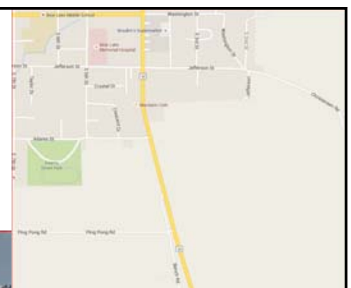
WSU – Haifang Wen (Co-PI), Amir Bahadori (Grad Student)

ITD – Dan Harelson and Jesse Barrus

Project Description

US-30, Montpelier SCL to Dingle Rd.

MP 435.281 – 438.501 (3.22 Miles)



Project Description

The project involves

- Milling and overlaying 0.4 ft of the existing roadway and replace by fiber modified HMA in three sections.
- A non modified 4th section is used as control.
- The four sections are approximately equal in length.
- Construction was completed in August 2014 under ITD contract No. 7868

Project Description

Control Mix

- The non-modified Control mix is a Superpave **SP5** using 47% RAP. Mix Design was developed at NCAT, Auburn, AL.
- As per NCAT results, the virgin binder grade is PG70-28, and the RAP binder is PG64-28. The final PG is **PG70-28**

Summary of Mix Design of Control Mix

JMF as provided in NCAT report:

Follows ITD SP5 Superpave mix with 47% RAP
PG70-28
Pb 4.8%
Pb (RAP) = 2.83%
VTM = 4%
VMA = 13.6
VFA = 70.4%
D/b Ratio = 1.1

Project Description

Fiber Modified Mixes

- The fiber-modified sections adopted the same mix design. No change in the mix volumetrics.
- Three types of fibers were provided:
  - Fiber #1 (aramid and polyolefin fibers) – Vendor #1
  - Fiber #2 (wax treated aramid fiber) – Vendor #2
  - Fiber #3 (glass fibers) – Vendor #3

Project Description

Fiber Modified Mixes

- Addition of fibers at the asphalt plant during construction was in accordance with the manufacturers' specifications
- Fiber contents and methods of adding fibers to the mixtures were established and performed by the fibers' vendors

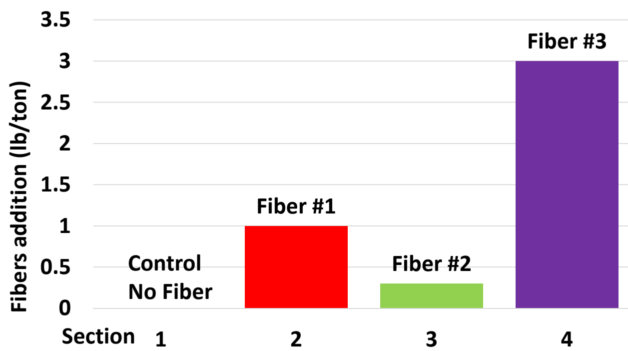
Project Description

Project Sections

The study included 4 sections, approximately equal in length:

- **Section 1 – Unmodified Control section**
- **Section 2 – Fiber #1 with the rate of 1 lb/ton**
- **Section 3 – Fiber #2, rate 1/3 lb/ton**
- **Section 4 – Fiber #3, rate 3 lb/ton**

Fiber Quantities /ton



Construction Data	Section 1	Section 2	Section 3	Section 4
	Control	Fiber #1	Fiber #2	Fiber #3
Mix Placed (tons)	4,861.38	4,083.82	4,221.28	4,249.42
Fibers (lbs)	-	4,260.00	1,193.30	13,195.90
Fiber Content lb/ton	-	1.04	0.28	3.11
Fiber Content, %	-	0.052%	0.014%	0.155%

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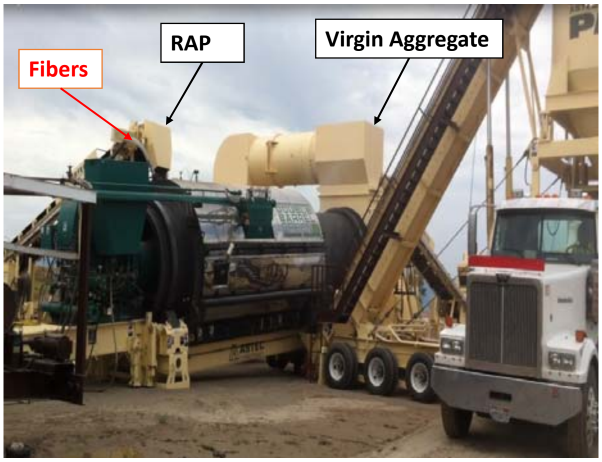
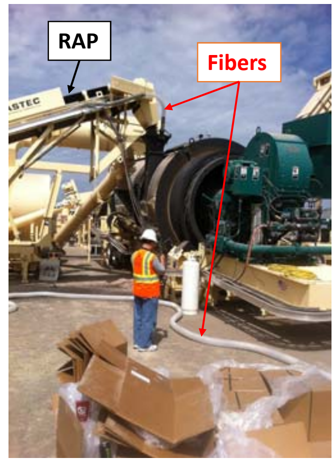
Fibers Addition





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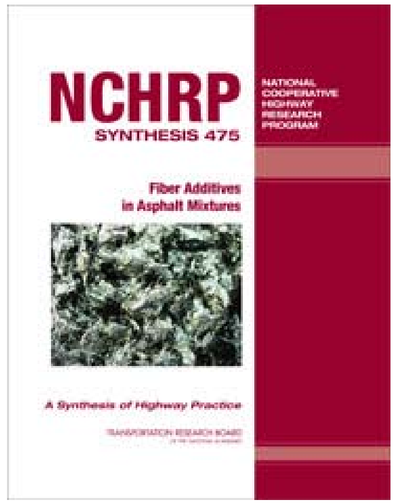
Objectives

- ITD's objective is to rehab the road to address the existing cracking and rutting problems
- The scope of this lab-based phase is limited to material characterization of the placed mixes and to determine whether there are significant changes in mixes' properties upon adding the fibers.
- Field performance monitoring on a yearly basis. At a later stage, the field data collected will be analyzed.

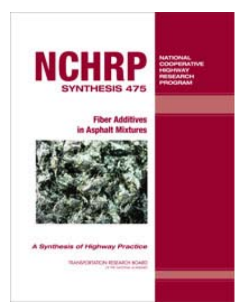
Studies on Fiber-Modified HMA

- NCHRP Synthesis 475 is the most recent synthesis on the use of fibers in asphalt pavements. (released Summer 2015)



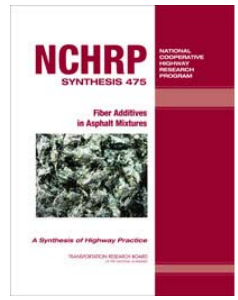
Studies on Fiber-Modified HMA

- **Various Types** of fibers included: cellulose, mineral, synthetic polymer, and glass fibers, as well as some less common fiber types. Recycled fiber materials—such as newsprint, carpet fibers, and recycled tire fibers—have also been used.

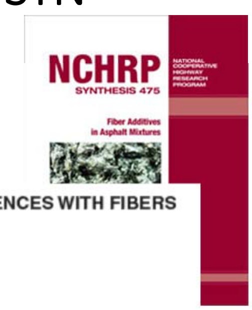


Studies on Fiber-Modified HMA

- Effective use of fibers was to reduce binder **draindown in gap and open-graded mixes** is quite well established, the effects of using fibers for other reasons are less clear.
- Most of the studies on the use of fibers in **dense graded mixes** indicated fiber content about 0.3% by weight of the mix.



Cases Presented on the NCHRP SYN



CASE 1. AGENCY CONSIDERING USE OF FIBERS

CASE 2. AGENCY WITH VARYING FIBER USAGE

CASE 3. CONTRACTORS' EXPERIENCES WITH FIBERS IN ASPHALT MIXTURES

CASE 4. ONGOING RESEARCH ON FIBERS IN DENSE-GRADED ASPHALT

CASE 5. STATE WITH HIGH FIBER USAGE RESEARCHING OTHER APPLICATIONS

Studies on Fiber-Modified HMA

Ohio Project (in-Progress)

- Project included One type: (aramid and polyolefin) fiber-modified overlays over jointed concrete pavements to address **reflective cracking**
- As per the project contact: *"At this time there is no discernible difference in performance between all sections. The data indicates that the fibers have not reduced reflective cracking severity or extent after 3 years in service. Yearly evaluations will continue to be performed."*

ITD – UI Project (RP237)
Lab Evaluation of Materials

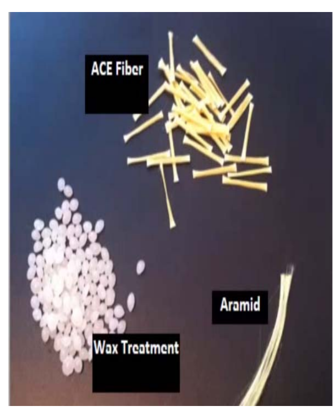
- Properties Types of Fibers Used
- Lab Testing and Results
- Evaluation using ME Software
- Field Performance Evaluation

Fiber #1 (Aramid and Polyolefin)

This fiber is a blend of Aramid and Polyolefin fibers. Both fibers have the same length of ¾” (19mm). The specific gravities are 1.44 and 0.91 respectively. The tensile strength of the aramid fibers is up to 400 ksi and decomposition or break down temperature of 800 ^{o}F. The Polyolefin Fibers has much lower tensile strength of 70 ksi and break down temperature of 315 ^{o}F.

Fiber #2 (Wax Treated Aramid fibers)

Aramid fibers with ¾” (19 mm) in length, a specific gravity of 1.44 with a tensile strength of 400 ksi. The break down temperature is 800 ^{o}F. These fibers are treated with melted wax bath to provide more control of fiber mixing and weighing down the fibers due to its light weight.



Fiber #3 (Glass Fibers)

- The vendor refers to it as Fiber Glass Type E. The fibers length is ½” (13mm) and has a specific gravity of 2.7. The tensile strength is 300 ksi. Melting of the fiber glass is relatively high. For this type of fibers, the melting point is 2075^{o}F. Water absorption is less than 1%

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Lab Testing

1. Rutting Resistance:
   - Dynamic Modulus and Flow Number
   - APA
   - HWTT
2. Fatigue Resistance:
   - IDT (Fatigue)
   - Jc
3. Thermal Resistance:
   - IDT (Thermal)

Lab Testing

1. Rutting Resistance:
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   - IDT (Thermal)

Dynamic Modulus (E*)

AMPT Test Method (AASHTO T 342-11)

- Sample Preparation for E*
  - 2-2.5 hours heating the loose mixes to the compaction temperature
  - Compaction
  - Core and cutting with air voids within 6.5%-7.5%
  - Testing temperatures (40 ^{o}F, 70 ^{o}F, 100 ^{o}F, 130 ^{o}F)
  - Loading frequencies(0.1Hz, 0.5Hz,1Hz, 5Hz, 10Hz, 25Hz).

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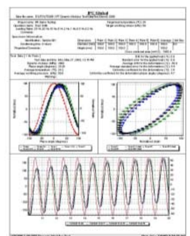
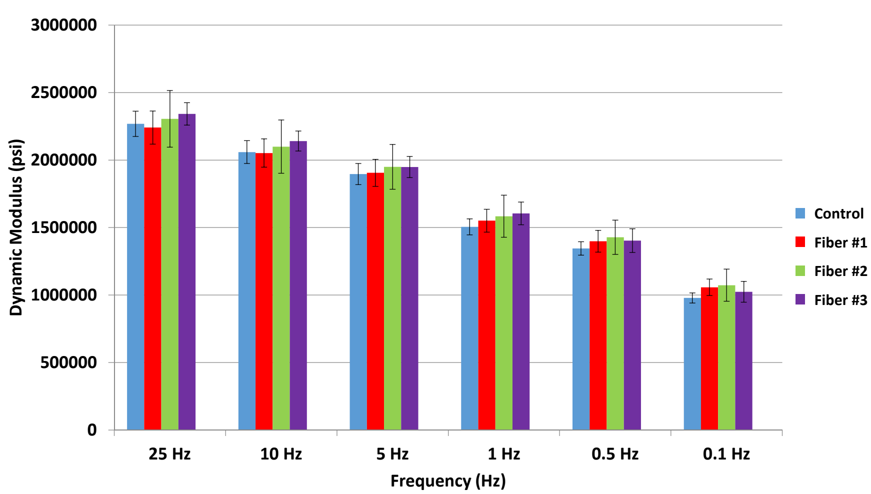
Dynamic Modulus (E*)

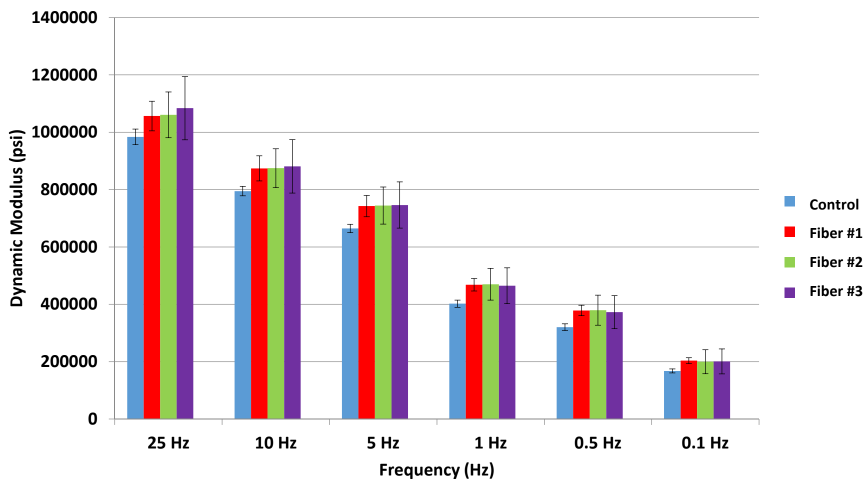
- E* test using AMPT machine, AASHTO T 342-11



Dynamic Modulus Test Results E*(psi) at 40F



Dynamic Modulus Test Results E*(psi) at 70F



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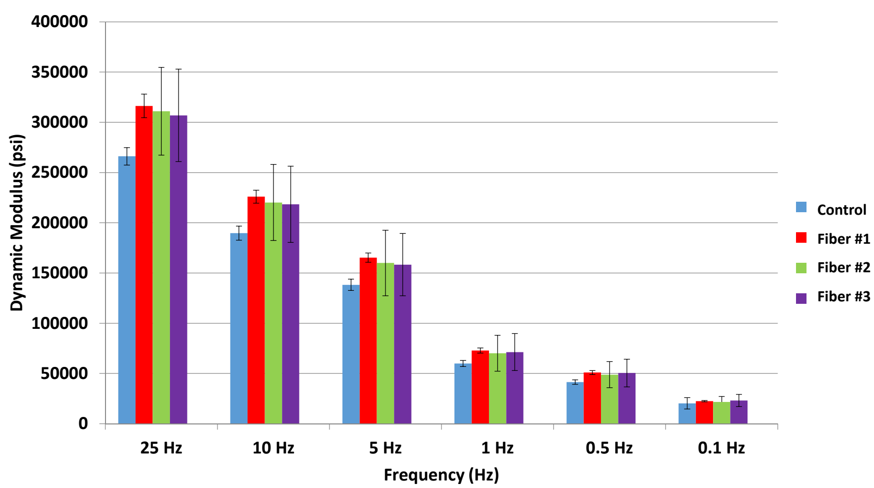
Dynamic Modulus Test Results E*(psi) at 100F



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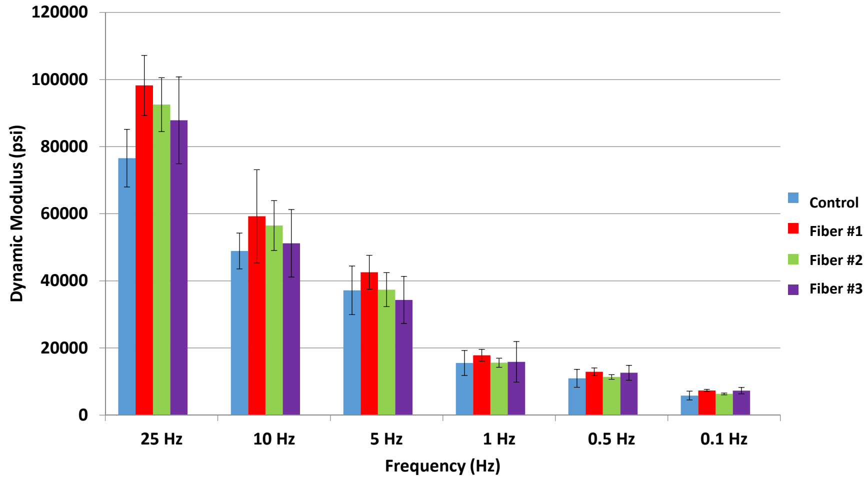
Dynamic Modulus Test Results E*(psi) at 130F



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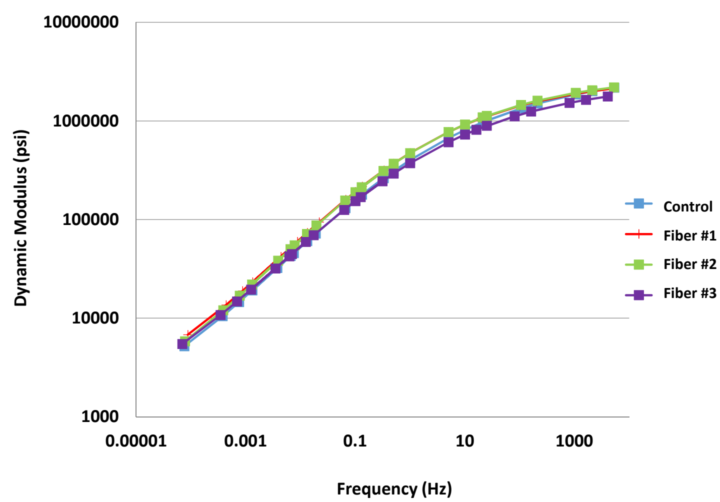
Dynamic Modulus Test Results E*(psi) at 130^{O}F



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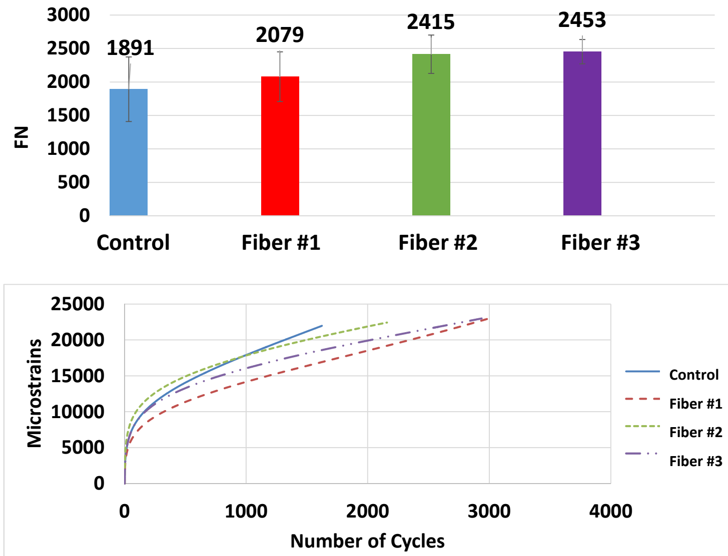
Flow Number Test Results on None Consolidated Samples



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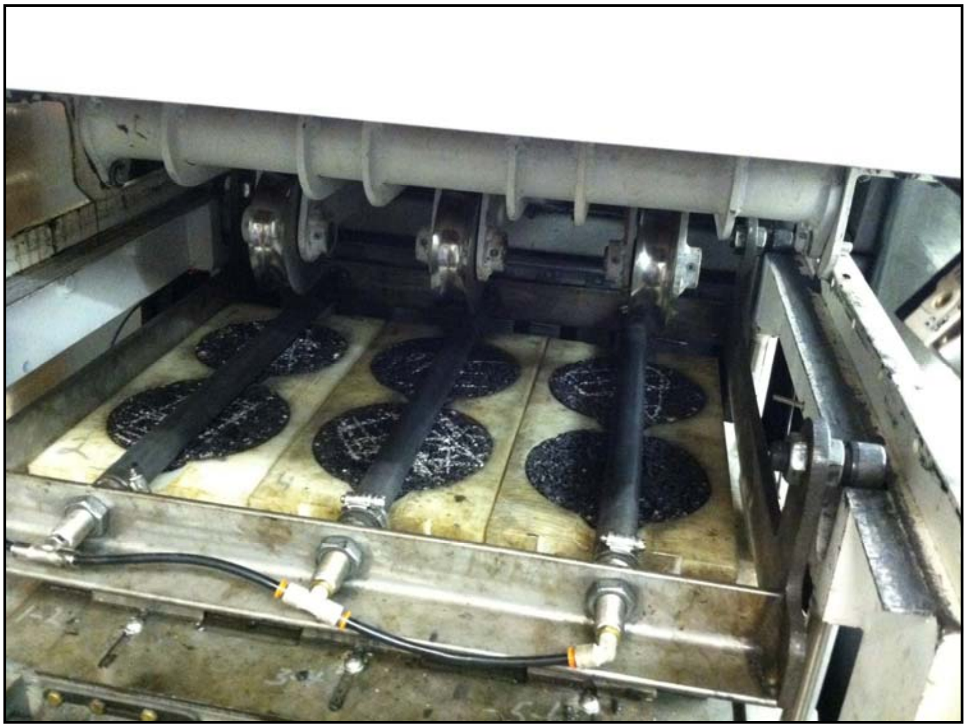
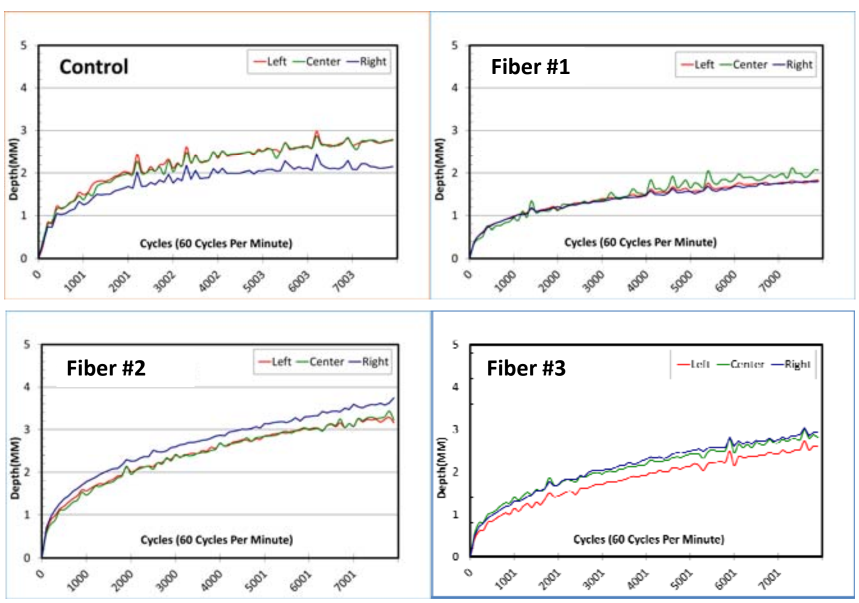
Asphalt Pavement Analyzer (APA)

- The test conducted by Idaho Transportation Department (ITD) in accordance with AASHTO TP 63
- Samples preparation:
  - ✓ Compact the sample to achieve a final air voids of 7±0.5%.
  - ✓Sample height of 4.53 in (115mm)
  - ✓The rolling wheel pass was 60 cycles per minutes for a total number of cycles of 8000.



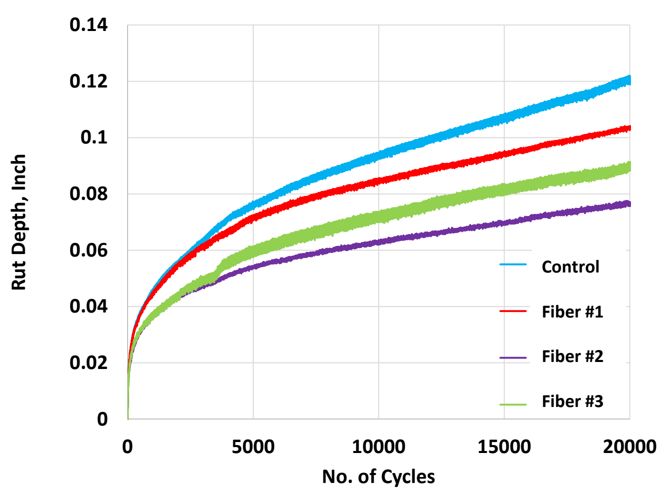
APA Summary of Results



Hamburg Wheel Tracking Test – APA Jr

- The test conducted in accordance with Tex-242-F.
- Samples preparation:
  - ✓ Compact the sample to achieve a final air voids of 7±0.5%.
  - ✓ Sample size of 2.3±0.1 in. in height and 5.9 in. in diameter.
  - ✓ The rolling wheel pass for a total number of cycles of 20,000.

Hamburg Wheel Tracking Test – APA Jr



Lab Testing

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   - APA
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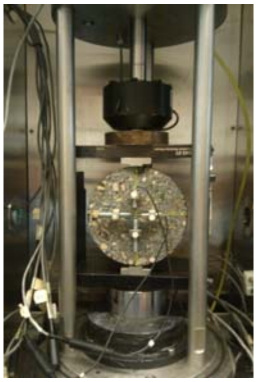
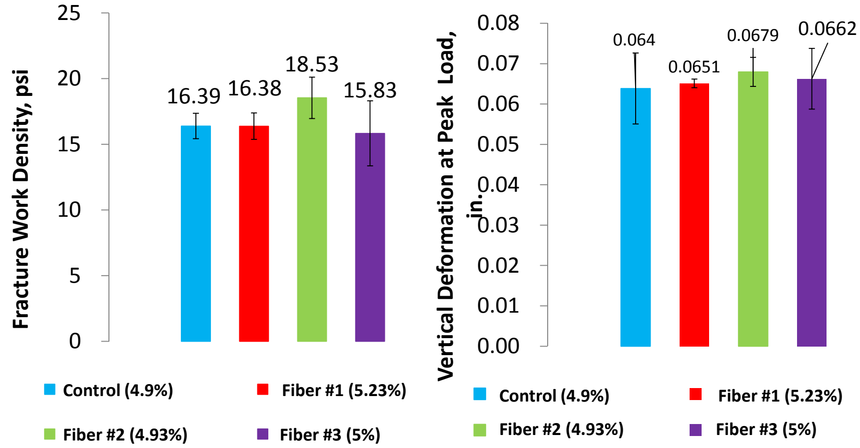
2. Fatigue Resistance:
   - IDT (Fatigue)
   - Jc
3. Thermal Resistance:
   - IDT (Thermal)

Indirect Tension Test:

- The test conducted at 68F.
- Horizontal and Vertical LVDTs to measure the strain.
- Using the Fracture work density to evaluate the sample resistance.
- 3 core samples for each type of mix.



IDT Fracture Test at 68°F



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Fatigue Life Prediction

Bottom-UP Fatigue Life Prediction Model (ALF)

$$N_f = 3.75 \times 10^{-5} \left(\frac{1}{\varepsilon_t}\right)^{0.147} (FWD)^{1.92} h^{0.135}$$ **(Wen-2013)**

Fatigue Life for Different Sections

Mix	N_f
Control	211493
Fiber #1	209702
Fiber #2	267156
Fiber #3	197193

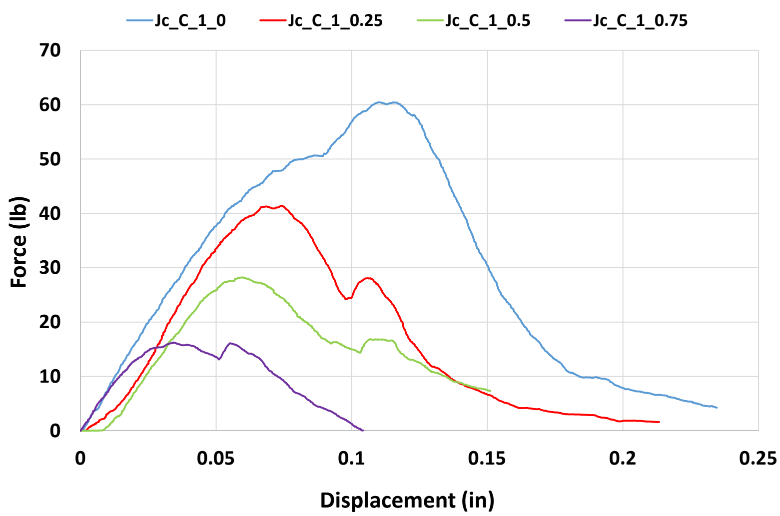
J_c test

- It is a fracture toughness parameter
- It is determined in a Semi Circular Notched Bending Fracture (SCNBF).
- Samples preparation:
  - Compact the sample to achieve
  - a final air voids of 4%.
  - Each sample was sliced into
  - 4-quarter specimens.
  - One of the quarters was left
  - un-notched, the other three
  - quarters were notched to
  - 0.25, 0.5, 0.75 inches.

J_c test cont.

- A ramp load with a constant vertical deformation rate of 0.01 in/min. was applied until fracture occurred.
- Draw the relationship between the applied load and the displacement.
- Determine the strain energy (U)
  which is the area underneath
  the load-deformation curve
  divided U by the thickness
  of the sample.

J_c test



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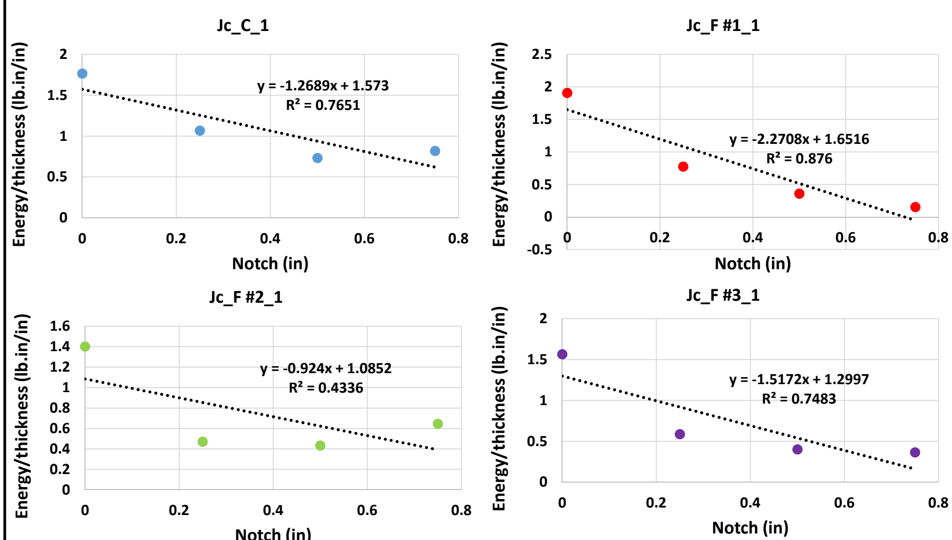
J_c test Results



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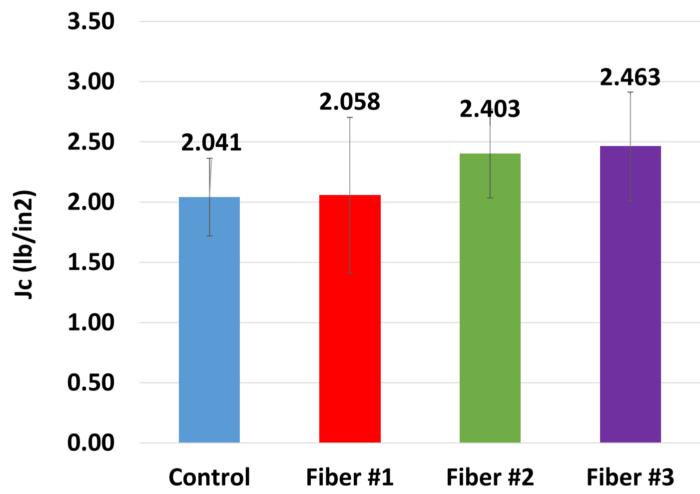
J_c test results

Energy under the whole curve



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Lab Testing

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   - Dynamic Modulus and Flow Number
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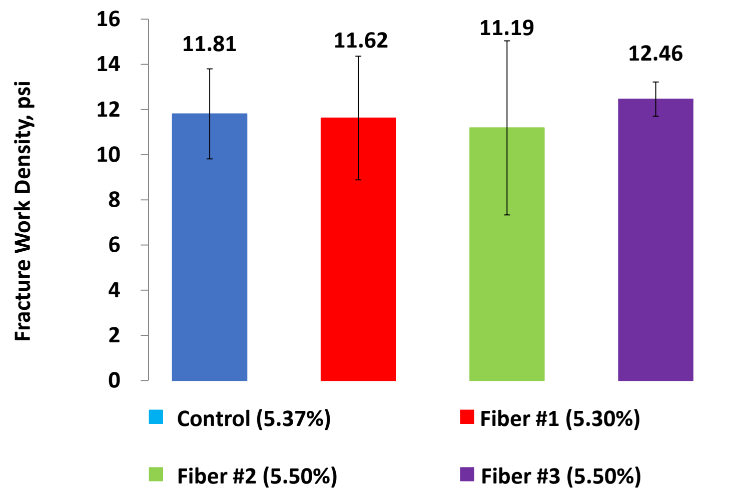
   - Jc
3. Thermal Resistance:
   - IDT (Thermal)

Fracture Work Density at 14°F



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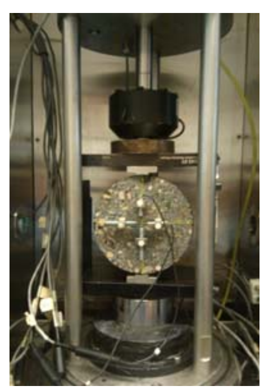
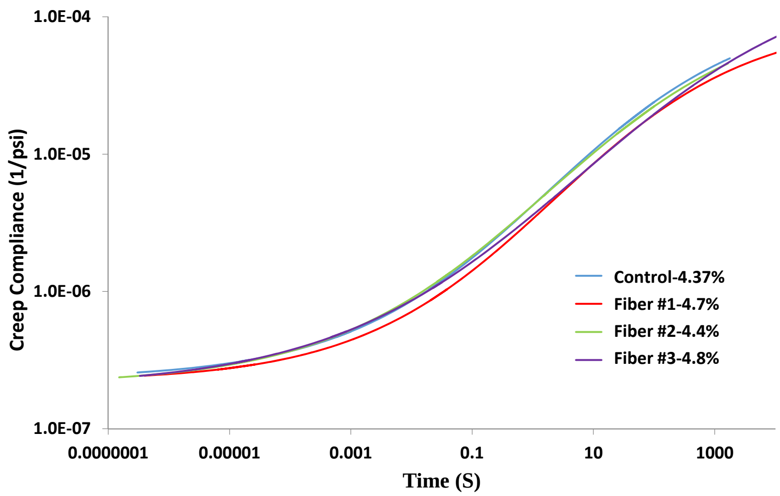
IDT Creep Compliance

- AASHTO T322-07
- A constant load for 100s for 100s
- Six temperatures (-4, 14, 32, 50, 68, 86 °F)
- Temperatures increasing from low to high
- 3 Samples for each type of mix



Creep Compliance Master Curves at 68° F Reference Temperature



Fiber Content and Distribution of Fibers in the Mix

Lab extraction

X-Ray Tomography

Lab Extraction

A side study done in the lab to determine the actual fiber content in the fiber-modified mixes

- Follow the extraction method as per AASHTO T-164
- Ignition Oven at 650 °C
- Lab modification to separate the fibers by floating

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Investigation of Fiber Content in Asphalt Mixes:

AASHTO T-164 :
Extraction of asphalt binder from mixtures
With chemical solvent

Step 1

Asphalt Mix Sample (Binder+Aggregate+Fiber) → Aggregate +Fiber

Proposed Extraction methods

Using ignition oven at 650°C

Step 2

Aggregate +Fiber → Aggregate

Loss of fine aggregate during ignition
Results were not accurate (high fiber content)

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❖ **Modification of proposed method (Step 2):**

Aggregate
+
Fiber

1-Washing of aggregate (Similar to AASHTO T 11-05)

2-Sieving to separate coarse aggregate which trap fiber

Sample with medium size aggregate
+
Fiber

Sample with medium size aggregate
+
Fiber

Use of Calcium Chloride to separate fiber and aggregate

Floating fiber

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Results of Lab Extraction Method:

Fibers #2 (Average of 3 samples)

Asphalt content based on mix weight	**4.9%**
Target AC	**4.8%**
Weight of fiber	**0.38 g**
Fiber content (proposed method)	**0.0172%**
Fiber content based on mix design	**0.015%**

Aggregate +Fiber (Step 1)

Collected fiber after step 2

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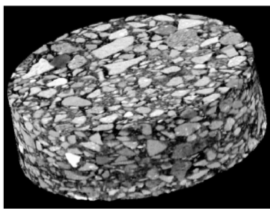
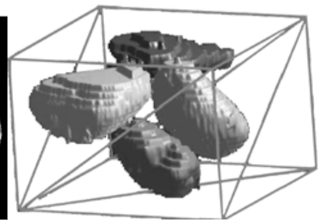
X-Ray Tomography
(in-progress)

- Imaging techniques is efficient approach to characterize the microstructure of the HMA


Gopalakrishnan et al. (2007)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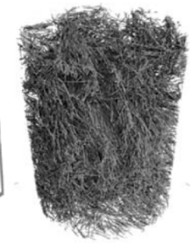
Krause et al. (2009)

- X-ray CT has been used to detect the cracks in asphalt mixes

AASHTOWare ME Design input data

- The pavement structure: 4.8 in. new HMA, 4.8 in. old existing HMA, 7.2 in crushed base, 19.2 in. crushed sub-base.
- Mix class: SP5, ¾ NMAS.
- R values = 80 and 60 for base and subgrade.
- AADT, Vehicle class distribution, and adjustment factors provided by ITD.
- Reliability of 90% used.

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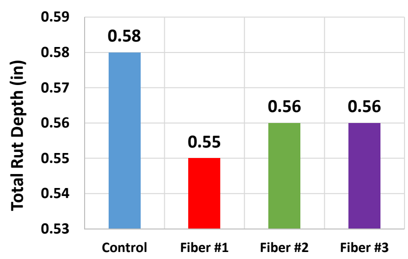
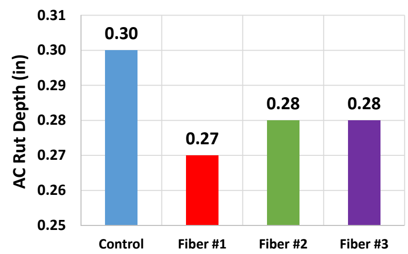
AASHTOWare ME Design Analysis

Predicted Rutting





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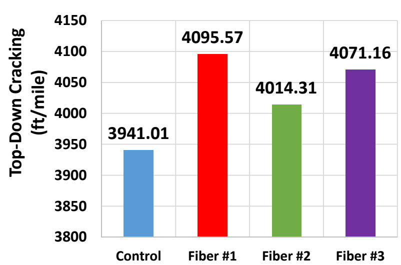
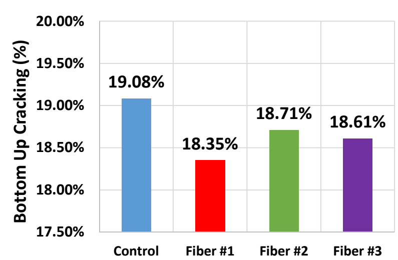
AASHTOWare ME Design Analysis

Predicted Fatigue Cracking





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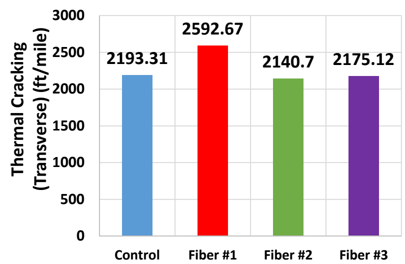
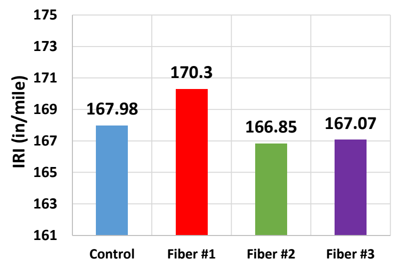
AASHTOWare ME Design Analysis

Predicted Thermal Cracking and IRI





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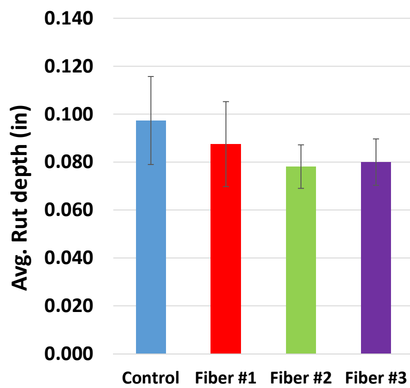
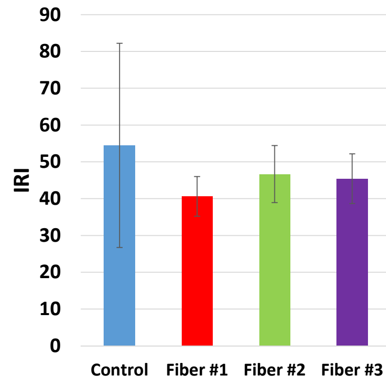
Summary of Results

- **<u>Lab Evaluation</u>** concluded that there is no significant difference among the performance of the fiber modified mixes. Statistical Analysis of ANCOVA showed No significant differences were observed.
- **<u>AASHTOWare ME</u>** Pavement Design software also revealed that mixes perform the same in terms of Rutting resistance, Fatigue cracking resistance, and thermal cracking resistance.

Field Performance of the Constructed Sections (First year)





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Epilog

Inland ASCE Pavement Committee – APAO position paper on use of Aramid Fibers in Asphalt (July 2014)

"We have encouraged local agencies to treat this technology as experimental and to include control sections in all of their projects so differences in performance can be determined. We do not recommend reducing thickness because in our view the research does not justify doing so at this point.."

We Concur with this recommendation………

Thank you

Questions?