Fibers in Pavements

Shane Underwood, Ph.D.
Assistant Professor,
School of Sustainable Engineering and the Built Environment
Co-Director,
The National Center of Excellence on SMART Innovations
Senior Sustainability Scientist,
Global Institute of Sustainability

November 19, 2014
Arizona Pavements and Materials Conference, Tempe, AZ

Special Session

Special Session

is this new?

how do they work?

what types of fibers are used in PCC/AC?

Fibers in Pavements

do they really improve performance?

so what makes it sustainable?

Straw reinforcement of mud bricks dates back at least 3500 years to the Mesopotamians

1992

VS

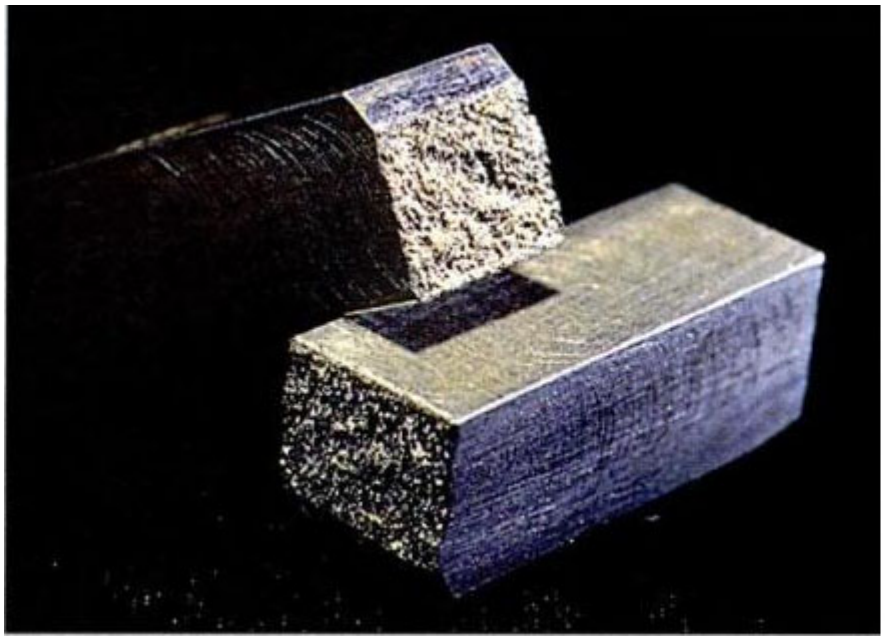
2014

Basic Role of Fibers

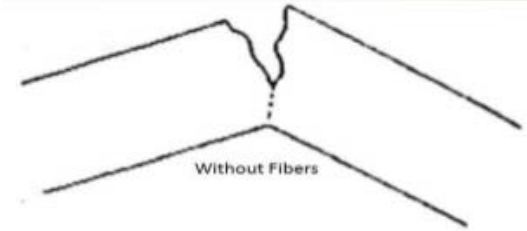
- Portland cement concrete
  - Bridge cracks that develop in PCC.
  - Increase ductility
  - Reduce permeability
- Asphalt concrete
  - Increase viscosity of binding materials and prevent draindown in OGFC and SMA mixtures
  - Improve crack resistance and extend fatigue life

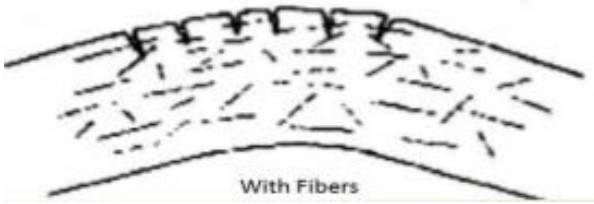
Mechanical Benefits

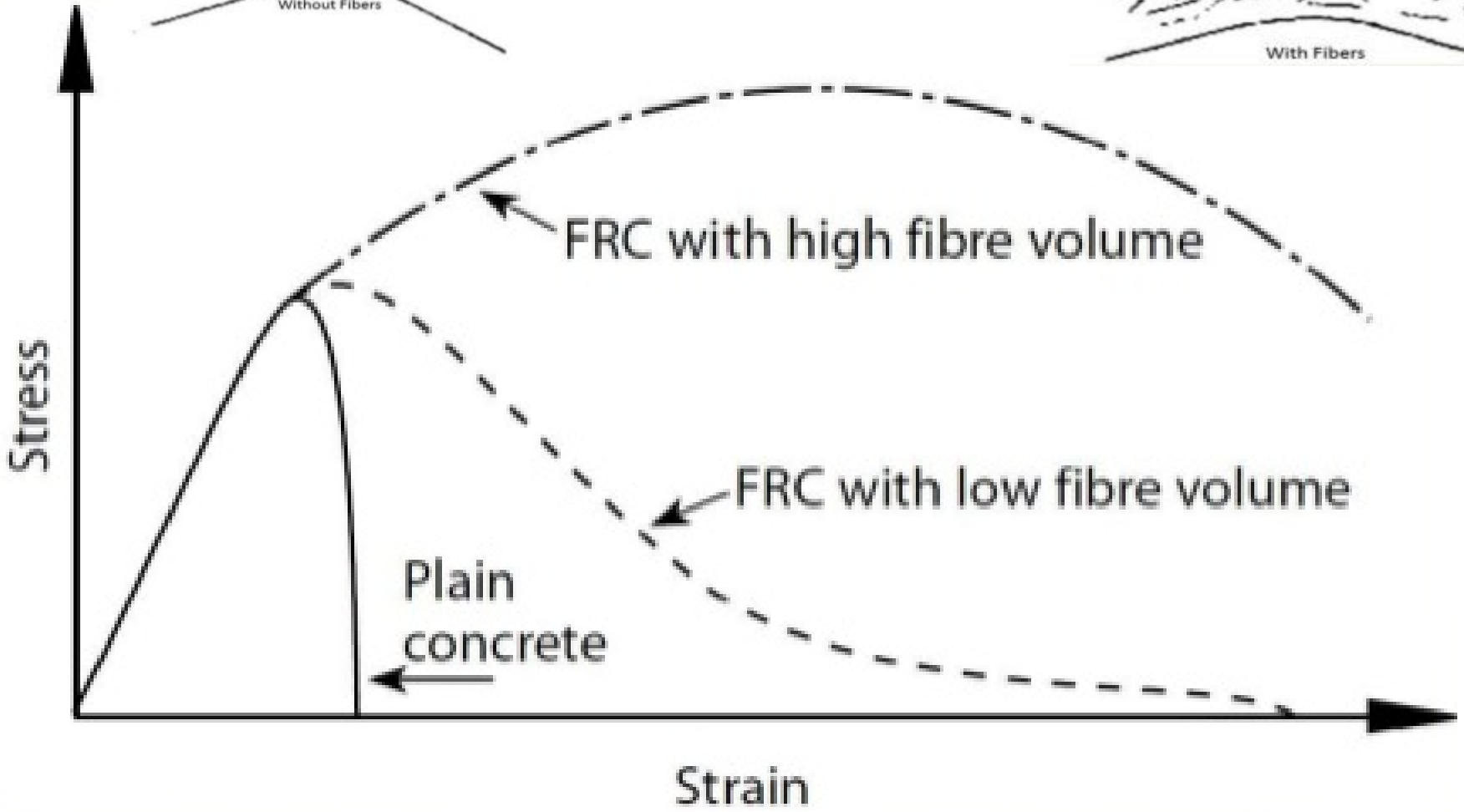
- Toughness is the ability of a material to absorb energy and plasticially deform without fracture
- Resistance of material to fracture when it is stressed



Toughness







Reference: Cement & Concrete Institute
http://www.cnci.org.za

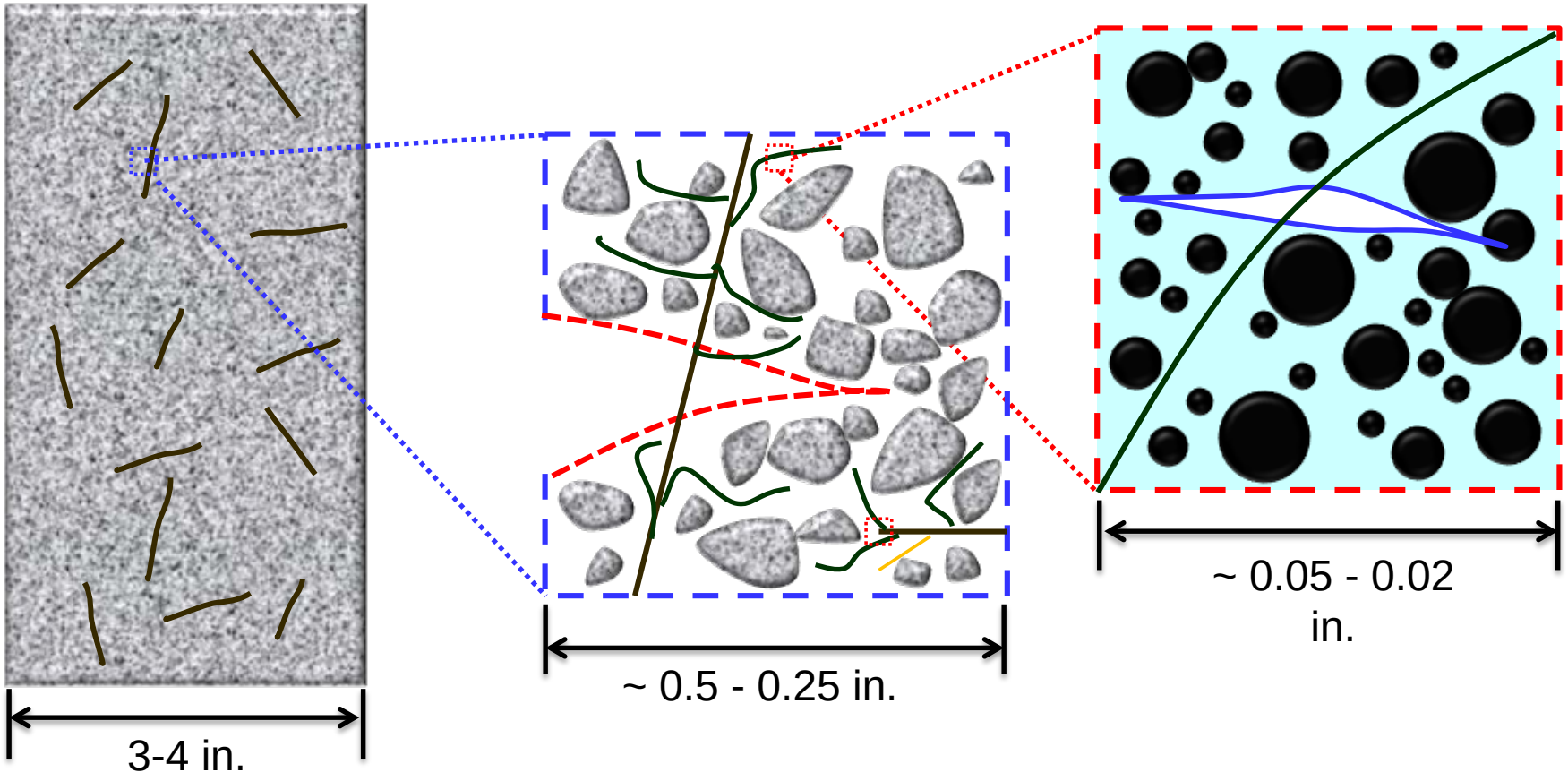
Source: P.K. Mehta and P.J.M. Monteiro, Concrete: Microstructure, Properties, and Materials, Third Edition, Fourth Reprint 2011

Crack Bridging and Toughness

Mixture

Mortar
Macro-Damage

Mastic/Paste
Micro-Damage

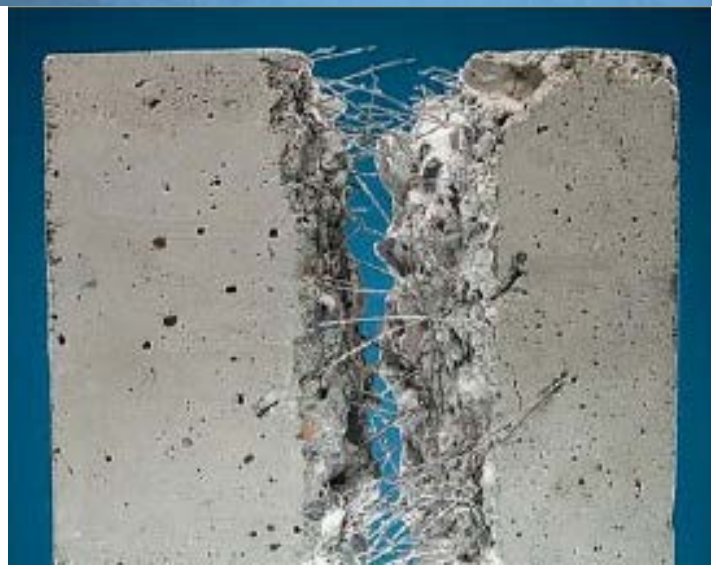


Fibers used in Portland Cement Concrete

- Steel fibers
- Glass fibers
- Carbon fibers
- Cellulose fibers
- Polypropylene
- Nylon fibers

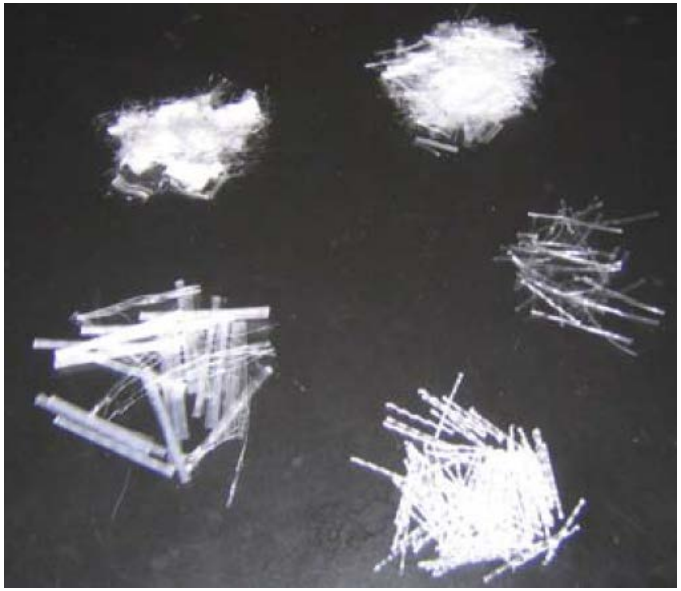
Steel Fibers

- Added between approximately 33 and 265 lb/cy
  - 0.25% and 2.0% by volume
- 0.017 to 0.04 in. diameter
- 0.5 in. to 2.5 in. length
  - Longer = better reinforcement
  - Shorter = better workability
- Improve abrasion and impact resistance



Synthetic Fibers

- Man-made fibers from petrochemical and textile industries
  - Acrylic, aramid, carbon, nylon, polyolefin
- Primary use in ultra-thin whitetopping
  - Typical dosage = 3 lb/cy fibrillated polypropylene
- Benefits
  - Reduce plastic shrinkage, increased toughness, reduced settlement of aggregate particles

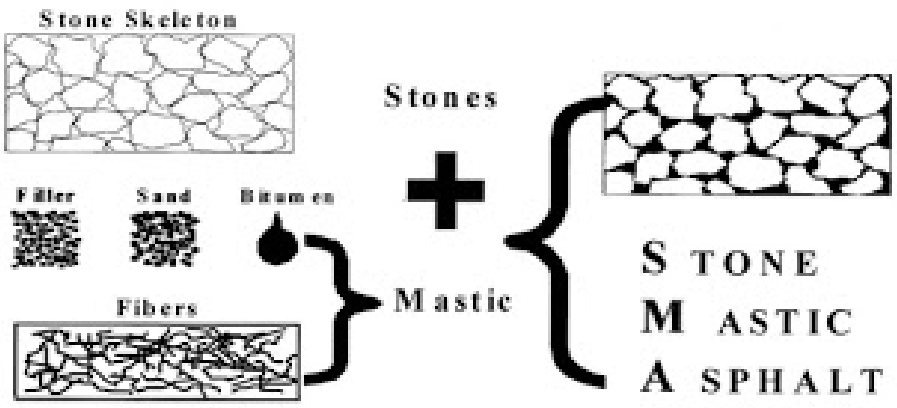


Fibers used in Asphalt Concrete

- Natural
  - Cotton, cellulose, coconut, bamboo
- Non-Synthetic
  - Asbestos, glass, carbon, mineral fiber
- Synthetic
  - Polypropylene, polyester, aramid

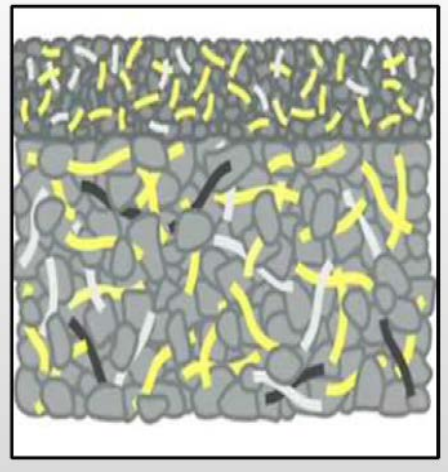
Cellulose and Mineral Fibers in Asphalt Concrete

- Pellitized or loose fibers
- Approximately 0.2 in. length
- Dosage of 0.3-0.4% of total mixture mass
- Used to primarily control draindown in SMA, OGFC, and Porous Asphalt



Synthetic Fibers in Asphalt Concrete

- Single type or blends to reinforce asphalt concrete matrix.
  - Polypropylene
  - Polypropylene + Aramid
- Dosed at 1 lb of fiber per ton of mix



Synthetic Fibers in Asphalt Concrete

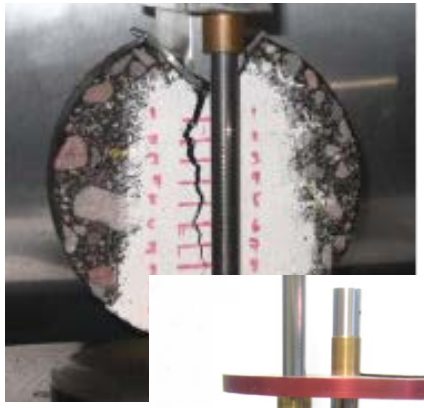
Introduction

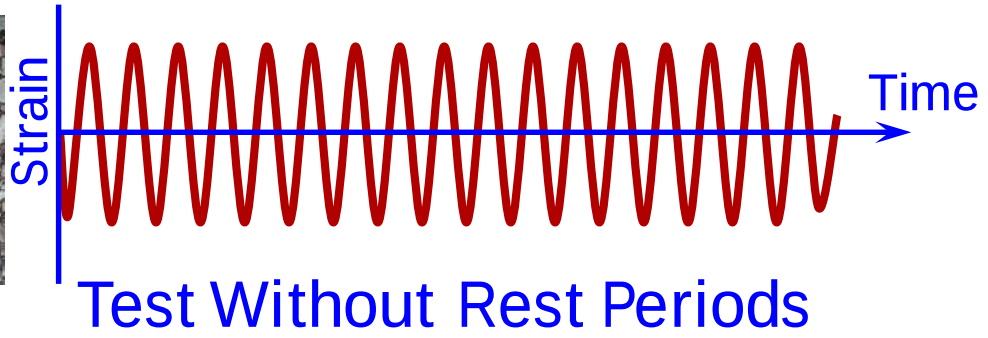
Synthetic Fibers in Asphalt Concrete

Introduction

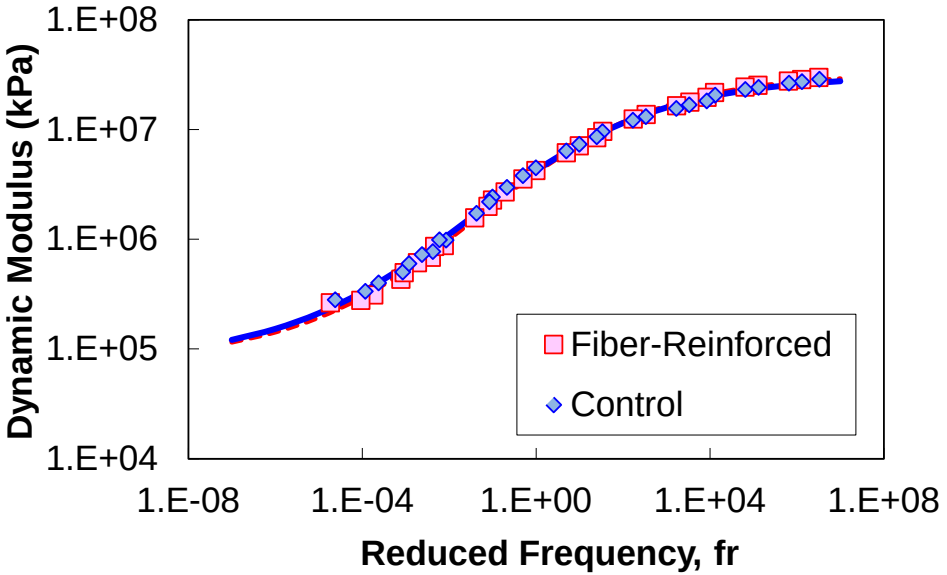
Testing Program

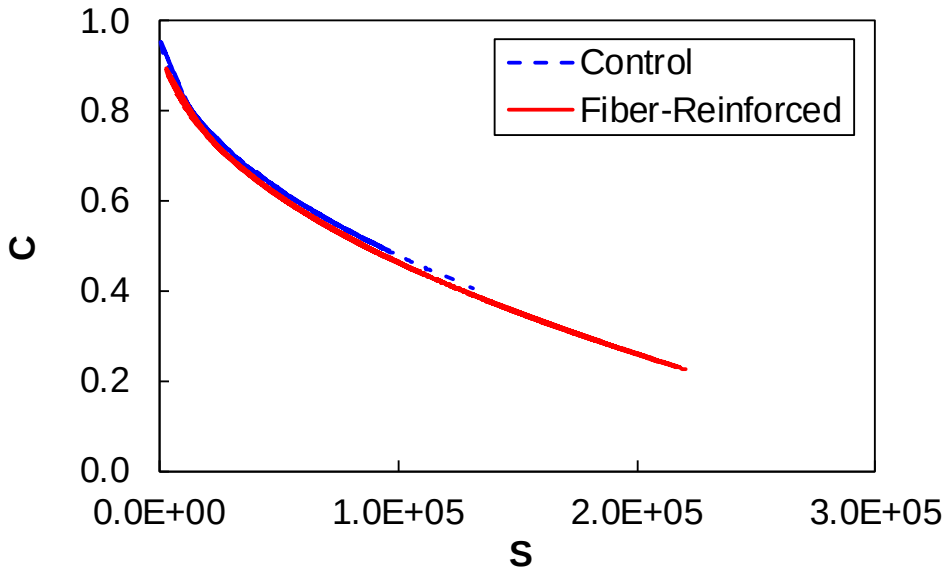
- Dynamic modulus
  - AASHTO T-342
- Fracture
  - C* fracture test
- Axial fatigue
- Permanent deformation
  - Flow number

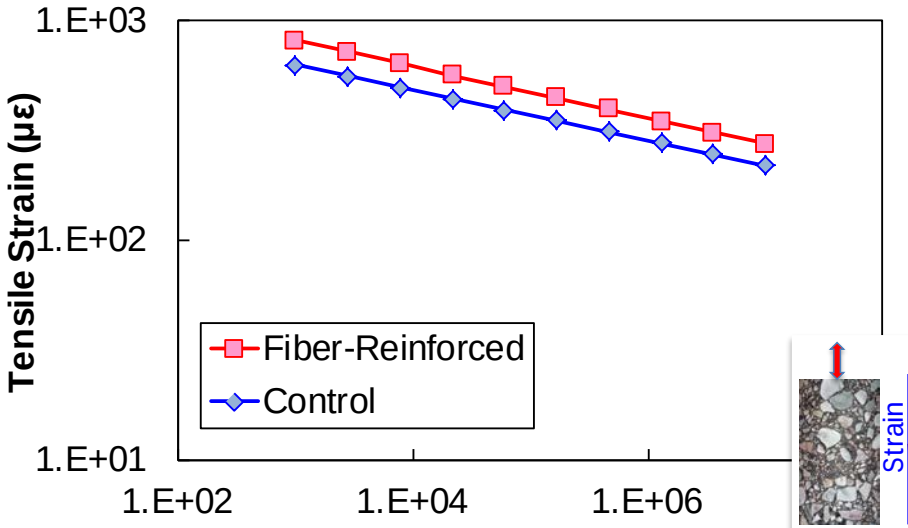


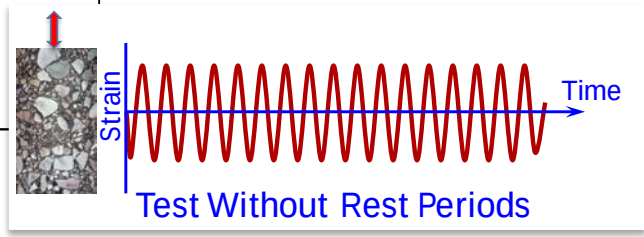


Fatigue Performance of FRAC



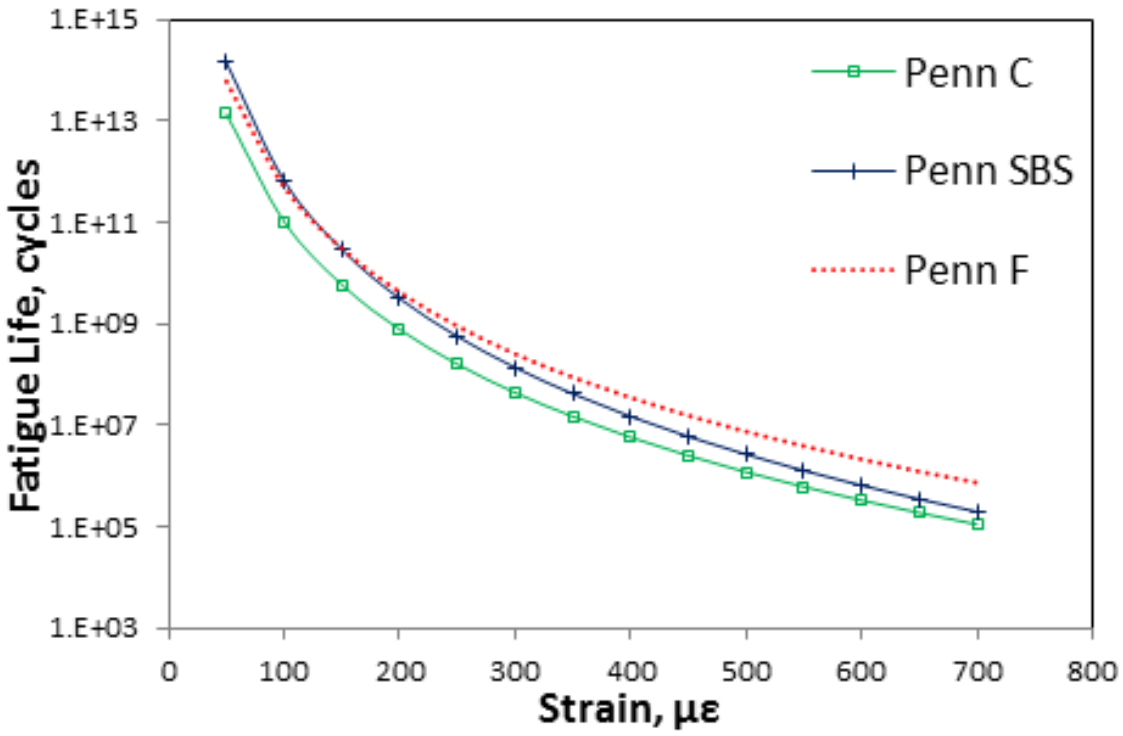






Fatigue Performance of FRAC

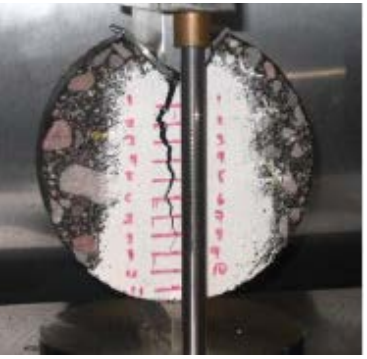
Research at FHWA



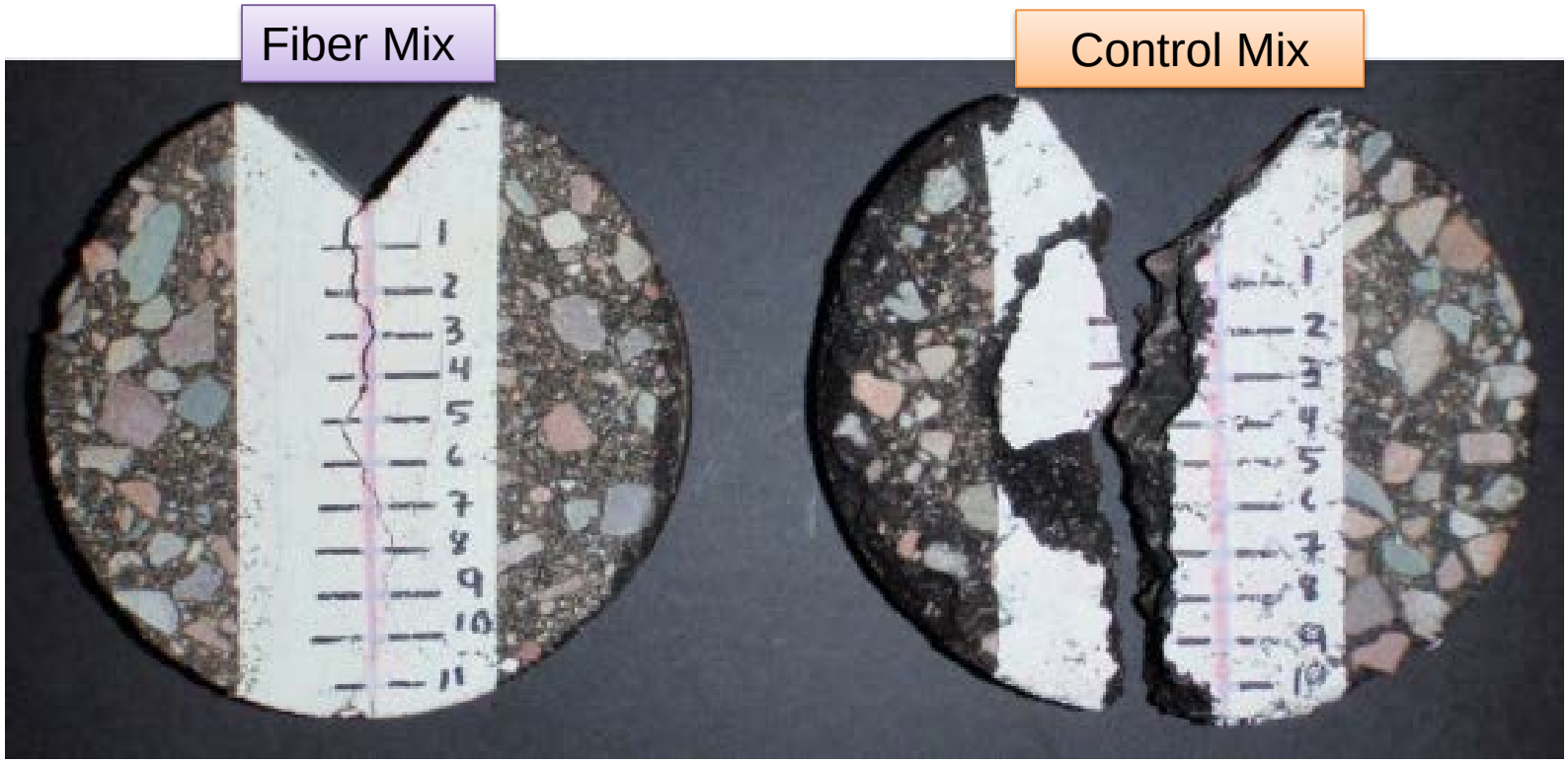
Strain, με	Penn DOT Mixes	
	Fatigue Ratio	
	SBS/C	F/C
150	4.91	5.17
250	3.51	5.61
350	2.81	5.92
450	2.38	6.16
550	2.08	6.37
650	1.87	6.54

Li and Gibson, 2014

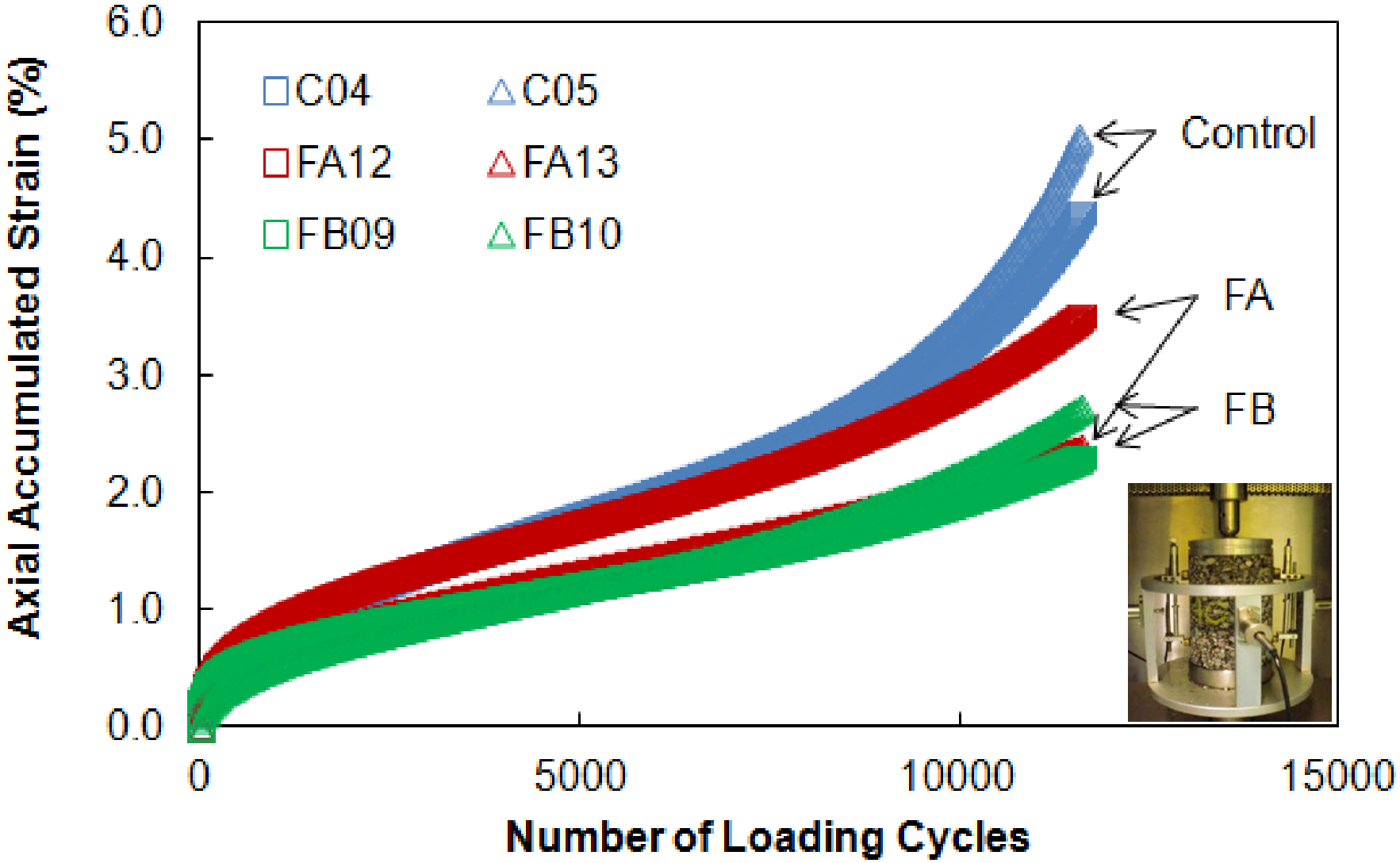
Fracture Performance of FRAC



- Up to 50% increase in peak strength
- Fracture energy increases of up to 40%



Permanent Deformation in FRAC



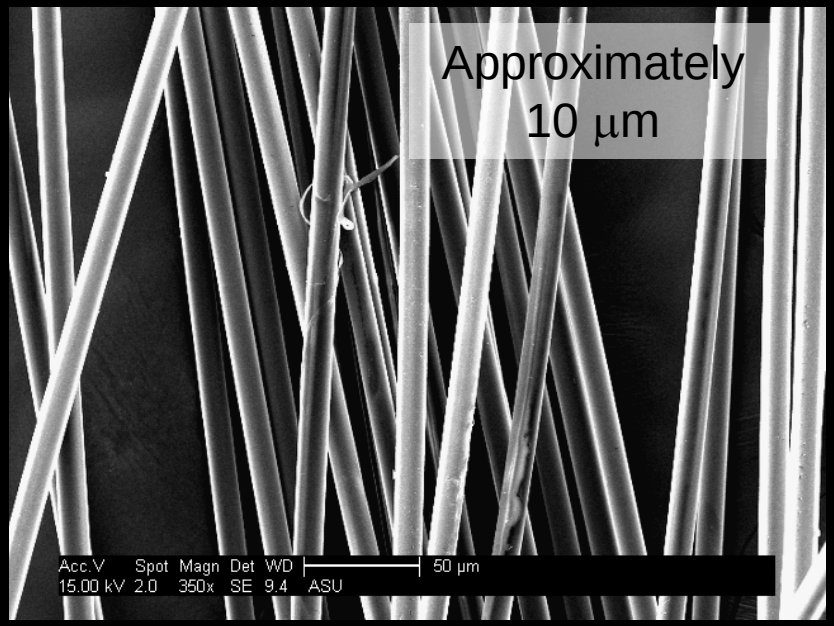
Summary of Results Report

1 lb/ton Fiber-Reinforced Mixtures			
Cracking		Rutting	
Fatigue Life	Fracture Resistance	Flow Number	Permanent Strain at Flow
+3 times	+20%	+2 times	-33%

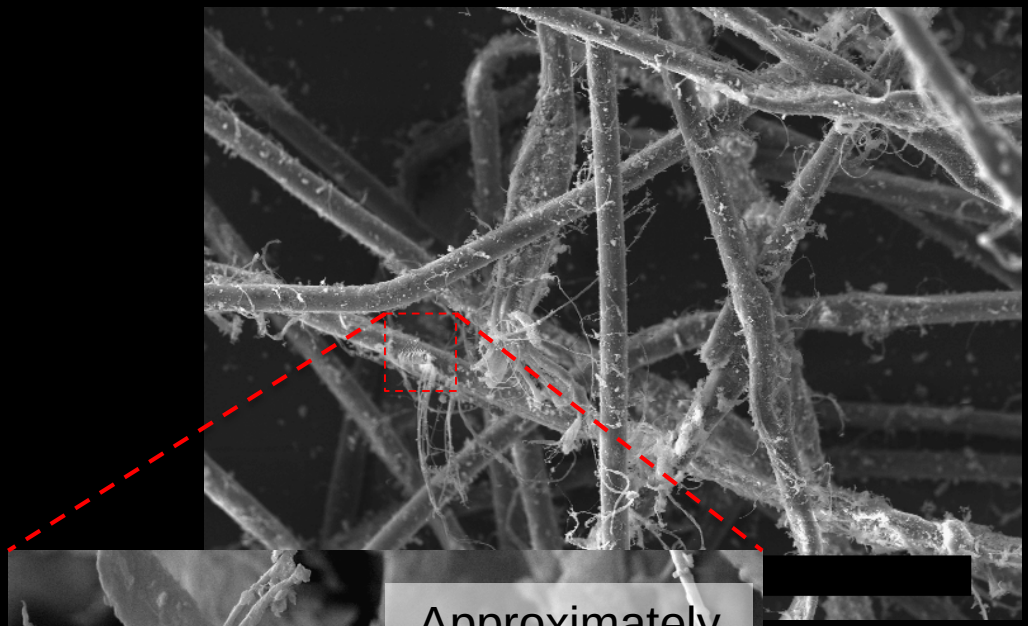
Fatigue Performance of FRAC

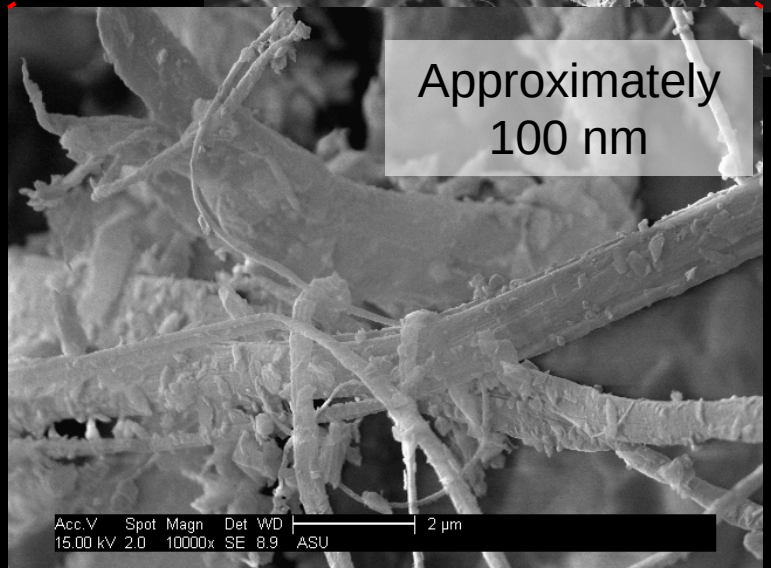
Source of Fatigue Improvement

Unaltered Synthetic Fiber



Agitated Synthetic Fiber

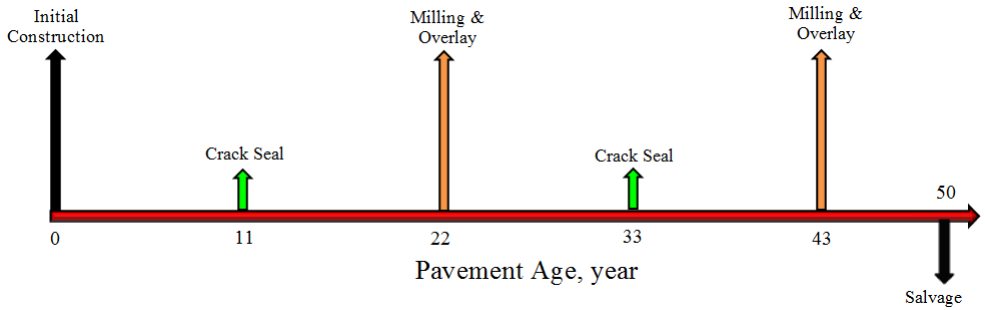




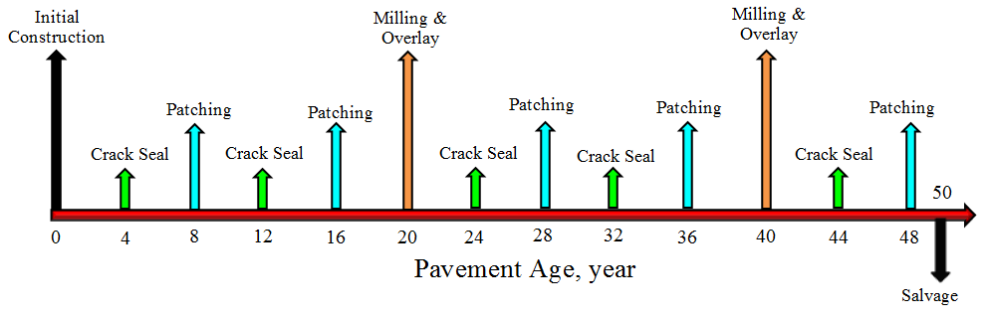
LCCA Analysis

- Long term benefits of fiber scenario outweigh the conventional asphalt concrete.
- For study case
  - Present net worth savings of 17% or $35,0000 per mile/lane over a 50 year period
  - Equivalent annualized cost difference of up to **$1,650 per mile/lane/yr**.

FRAC



Conventional



Wrap-Up

- Fibers are used in paving materials for multiple purposes.
  - To improve cracking resistance
  - To improve abrasion resistance
  - Stabilize the binding structure
- Fibers used in PCC are primarily steel and synthetic.
- Fibers used in AC are primarily cellulose and mineral fibers and synthetic fibers.

Wrap-Up

- Improvements in fatigue and permanent deformation results from the addition of poly-aramid fiber blends in asphalt concrete.
- Poly-aramid fibers do provide a reinforcement effect that maintain material integrity higher levels of microdamage and ultimately extend the fatigue life of the material.


Thank You
Shane.Underwood@asu.edu