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Special Session

The University of Arizona

Northern Arizona University

ASU
Special Session
Fibers in Pavements

how do they work?

what types of fibers are used in PCC/AC?

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

Crack Bridging and Toughness

- **Mixture**
- **Mortar Macro-Damage**
- **Mastic/Paste Micro-Damage**

- 3-4 in.
- ~ 0.5 - 0.25 in.
- ~ 0.05 - 0.02 in.
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

Source: Mobasher
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

Test Without Rest Periods

![Diagram showing test setup and strain over time](image-url)
Fatigue Performance of FRAC

**Dynamic Modulus (kPa) vs. Reduced Frequency, fr**
- Fiber-Reinforced
- Control

**Number of Cycles to Failure**
- Fiber-Reinforced
- Control

**Tensile Strain (με)**
- Fiber-Reinforced
- Control

**Tests Without Rest Periods**

Time

Strain

Test Without Rest Periods
Fatigue Performance of FRAC

Research at FHWA

<table>
<thead>
<tr>
<th>Strain, ( \mu\varepsilon )</th>
<th>Penn DOT Mixes</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Fatigue Ratio</td>
</tr>
<tr>
<td></td>
<td>SBS/C</td>
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<tr>
<td>150</td>
<td>4.91</td>
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<tr>
<td>250</td>
<td>3.51</td>
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<td>550</td>
<td>2.08</td>
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<td>650</td>
<td>1.87</td>
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</table>

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

![Graph showing permanent deformation over number of loading cycles.](image-url)
### Summary of Results Report

#### 1 lb/ton Fiber-Reinforced Mixtures

<table>
<thead>
<tr>
<th>Cracking</th>
<th>Rutting</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fatigue Life</strong></td>
<td><strong>Fracture Resistance</strong></td>
</tr>
<tr>
<td>+3 times</td>
<td>+20%</td>
</tr>
</tbody>
</table>
Fatigue Performance of FRAC

Source of Fatigue Improvement

Unaltered Synthetic Fiber

Approximately 10 µm

Agitated Synthetic Fiber

Approximately 100 nm
LCCA Analysis

- Long term benefits of fiber scenario outweigh the conventional asphalt concrete.

- For study case
  - Present net worth savings of 17% or $35,000 per mile/lane over a 50 year period.
  - Equivalent annualized cost difference of up to $1,650 per mile/lane/yr.
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

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