Fiber Reinforced Bridge Decks

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Acknowledgements

• Dr. Jeffery Roesler, P.E.
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About Myself

• B.S. Ceramic and Material Science Engineering
  – Clemson University
• M.S., PhD Civil Engineering
  – University of Illinois Urbana-Champaign
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• Assistant Professor at The University of Alabama
• Registered Professional Engineer in four states
Outline

• Fiber Reinforced Concrete Bridge Decks
  – Field Projects
  – Specification Language
By the end of this presentation

• You will know a little more about FRC bridge decks
• You will know the fiber types and common dosages for bridge decks
• You will NOT know the exact dosage to add to your bridge deck concrete mixture
• You will NOT know the single best fiber to use in any and all situations
Just putting this out there

I’m not going to talk about UHPC
Fiber Types (ASTM C1116)

• **Type I: Steel**
  – Must meet ASTM A820

• **Type II: Glass**
  – Alkali-resistant glass must meet ASTM C1666

• **Type III: Synthetic (plastic)**
  – Only polyolefin have a specification: ASTM D7508

• **Type IV: Natural**
  – Only cellulose have a specification: ASTM D7357
Rust

• Will I have corrosion with steel fibers?
  – Yes
  – No
  – Generally limited to surface exposed fibers
  – Extensive literature review performed by Marcos-Meson et al. 2018
Photo: Armen Amirkhanian
What fiber dosage do I use?

• Depends on a lot of factors!
• We must characterize the **performance** of the selected fiber
  – Prescriptive specifications for exact fiber dosages are not ideal and do not capture the variations between fiber types
• Typical ranges for FRC decks
  – Steel: min. 70 lbs/yd$^3$ (min. 0.6% by volume)
  – Synthetic: 3 – 8 lbs/yd$^3$ (0.2% - 0.6% by volume)
Why FRC bridge decks?

• No cracking
• Enhanced structural capacity
• Remove rebar
FRC Bridge Decks

- 2000: Virginia (Ozyildirim 2005)
  - 8.75 lbs/yd³ synthetic fibers

<table>
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<tr>
<th>Year</th>
<th>Air Temp. (°F)</th>
<th>Deck</th>
<th>Length (ft)</th>
<th>Width (mm)</th>
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<td></td>
<td>Fiber</td>
<td>59</td>
<td>0.29</td>
</tr>
</tbody>
</table>
FRC Bridge Decks

• 2006-07: Chicago (Alhassan and Ashur 2012)
  – 3 lbs/yd³ synthetic fibers

From: Armen Amirkhanian
FRC Bridge Decks

• 2007: California (Maggenti et al. 2013)
  – 3 lbs/yd³ synthetic fibers
  – SRA
  – Almost no visible cracking after 5 years of service
FRC Bridge Decks

• 2017: Missouri (Khayat and Abdelrazik 2019)
  – 66 lbs/yd$^3$ steel fibers
  – Expansive compound
  – After 10 months, only hairline cracking visible
FRC Bridge Decks

• 2018: High Bridge in St. Paul, Minnesota
  – 5 lbs/yd³ synthetic fibers

From: Forta Corporation
FRC Bridge Decks With No Rebar

- 1995: Canada (Newhook and Mufti 1996)
  - 9 lbs/yd$^3$ synthetic fibers
  - No reinforcing bars
  - 8” thick deck

From: Newhook and Mufti 1996
FRC Bridge Decks With No Rebar

• 1995: Canada (Newhook and Mufti 1996)
  – 9 lbs/yd$^3$ synthetic fibers
  – No reinforcing bars
  – 8” thick deck

From: Forta Corporation
FRC Bridge Decks

From: Amirkhanian and Roesler 2019
Example Specifications: Oregon

Use synthetic fiber reinforcing from the QPL and according to Section 02045 in all bridge deck and silica fume overlay concrete. Use synthetic fiber reinforcing according to the manufacturer’s recommendations at the rate designated on the QPL. Fiber packaging is not allowed in the mixed concrete.
Example Specifications: Oregon

From: Armen Amirkhanian
Example Specifications: Delaware

...concrete for decks require the use of nonferrous reinforcement fibers at a rate of 1.5 pounds per cubic yard.
Example Specifications: Utah

• Use 4 lb/yd$^3$ of concrete mix
• Provide a minimum flexural strength ratio $(R_{e,3})$ of 25 percent when tested according to ASTM C 1609.
Example Specifications: Kansas

• Provide fibers, which when tested using the procedure described in subsection 1722.4b., result in a minimum equivalent flexural strength \( f_{e,3} \) of:
  
  • Minimum required \( f_{e,3} = 140 + .015 (x – 4000) \) psi
  
  • In the above equation, \( x \) is the average concrete compressive strength as defined in subsection 1722.4b.(2)(c).

• Provide fibers, which when tested using the procedure described in subsection 1722.4b., result in a minimum strength ratio \( R_{e,3} \) of 25%.
Example Specifications: Mississippi

...an approved synthetic structural fiber meeting the requirements of Subsection 711.04 shall be incorporated into the mixture at **1.25 times the approved dosage rate.**
Example Specifications: Missouri

The steel fiber dosage rate shall be 80 pounds per cubic yard of concrete.
Example Specifications: Minnesota

Minimum 25% $R^D_{T,150}$ as specified in ASTM C1609 and minimum reduction greater than 85% of crack reduction ratio (CRR) as specified in ASTM C1579

From: Henkensiefken et al. 2010
Example Specifications: Rhode Island

Fiber density shall be a **minimum of 50 million individual fibers per pound**. Concrete shall be mixed for a minimum of 20 minutes at the required mixing speed once the fibers are added.
Summary

• FRC decks almost always utilize steel or synthetic fibers
• FRC decks almost always have fewer and tighter cracks compared to traditional PCC
• Any specifications related to FRC decks should be performance based and not prescriptive
• State-of-the-practice not at point to use fibers to replace steel rebar on a “regular” basis
Questions?

Fiber-reinforced Concrete Pavement Overlays: Technical Overview
Jeffery Roesler, Amanda Bordelon, Alexander Brand, Armen Amirkhanian

Overview of Fiber-Reinforced Concrete Bridge Decks
Armen Amirkhanian and Jeffery Roesler

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