Fiber Reinforced Concrete for Pavement Overlays

Jeffery Roesler, Ph.D., P.E., University of Illinois Urbana-Champaign

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  • National Concrete Pavement Technology Center (Iowa State)
    • Peter Taylor, Steve Tritsch, etc.
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    • Jerod Gross, Dale Harrington
FRC Overlay Project - Main Tasks

1) Develop *software tool* for calculating fiber performance for concrete overlays (Residual Strength Estimator)
   - Functional class, traffic, existing asphalt condition, bond condition, concrete/asphalt thickness; New concrete strength and proposed slab size
   - Recommend residual strength for FRC (ASTM C 1609)

2) Develop *Tech Briefs*
   - FRC for concrete overlays (8 pp)
   - Overview of FRC Bridge Decks (4 pp)

3) Detailed *Reports* on FRC overlays and decks

4) Deliver *three 60-minute webinar* on FRC & pavement overlays.
Fiber Type (Size)

Micro-Fibers
• Material:
  • Synthetic, natural or glass fibers
• Dosage:
  • 0.05 to 0.2% by volume
  • 0.75 to 3 lb/cy
• Fiber dimensions:
  • Diameter < 0.012 inch
  • Length < 0.5 inch

Macro-Fibers
• Material:
  • Synthetic or steel
• Dosage:
  • 0.2 to 0.5% by volume
  • 3 to 8 lb/cy (synthetic) or 25 to 75 lb/cy (steel)
• Fiber dimensions:
  • Diameter > 0.012 inch
  • Length 0.5 to 2.5 inches
Monotonic Load-Deflection of FRC Slab

*Plain vs Macro Synthetic Fibers*

![Graph showing load deflection for plain and macro synthetic fiber slabs.](image)

- **Plain**
- **0.48% Synthetic Macro Fiber**
- **0.32% Synthetic Macro Fiber**
MACRO-Fiber Reinforcement Benefits for Concrete Pavements & Overlays

• **Increase** in *structural capacity* of slab
  • Can reduce required slab thickness for overlays

• Maintain crack/joint widths

• Non-uniform (variable) support condition

• Tie *longitudinal* / transverse contraction joints
  • **Avoid slab migration**

• Extend overlay serviceability
  • Reduce deterioration rates after initial cracking
  • slab deflect ↑ and displace more easily
  • Thin concrete overlays deteriorate more rapidly under traffic

• Macro-fibers are *NOT* necessary on every concrete pavement project
Fiber-Reinforced Concrete for Pavement Overlays: Technical Overview Report

• General overview of macrofibers in concrete pavements
• Macrofibers types available
• Effect on fresh and hardened properties
• Test methods to specify macrofibers for overlays
• Construction best practices & guidelines
• Residual Strength Estimator software overview

https://cptechcenter.org/publications/
FRC Pavement Overlay Report: T.O.C.

https://cptechcenter.org/publications/

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References

Appendix A – Description of Residual Strength Estimator Software for FRC Concrete Overlay
Common FRC Overlay Questions/Comments

1. When should I consider macro-fibers in a concrete overlay?
2. How do macro-fibers affect contraction joints?
3. How do I quantify the existing pavement condition in the FRC overlay design?
4. What is the difference between bonded and unbonded overlays with FRC?
5. What macro-fiber dosage is required for a concrete overlay?
6. Do I need to update the concrete mixture design for addition of macro-fibers?
7. What specific fiber type should I use and do I need to consider the fiber type when determining the fiber dosage?
8. Will I have corrosion issues if I use steel fibers?

https://cptechcenter.org/publications/
Fiber-Reinforce Concrete Overlay Tech Brief

1. Tech Brief - FRC for Pavement Overlays (8 pages)
   - Fiber types, mixture proportions, properties, slab performance, structural design, construction, testing, residual strength

-Fiber types, mixture proportions, properties, slab performance, structural design, construction, testing, residual strength

ASTM C1609-12
Concrete Mixture changes for FRC Overlay

• Batching/mixing
  • Trial concrete mixture should be made first
  • At < 0.5% volume fraction of fibers, typically no need to change batching/mixing
    • Slump loss may occur.
  • Fiber Balling may occur if:
    • Fibers added too quickly
    • Fiber volume too high
    • Fibers already clumped (in delivery bags)
    • Mixer inefficient or worn blades
    • Mixture too stiff
    • Concrete mixed too long after fibers added
    • Mix sequencing - fibers added to mixer before other ingredients

• If Mix adjustment required: Add water reducer or ↑ Paste content.
2. Tech Brief - Overview of Fiber-Reinforced Concrete Bridge Decks (4 pgs)

https://intrans.iastate.edu/app/uploads/2019/03/FRC_bridge_decks_ovw_TB.pdf
FRC Overlay Project – Webinars (60 min.)

https://cptechcenter.org/recorded-webinars/

1. Fiber Reinforced Concrete Overview for Concrete Pavement and Overlays
   General overview of fibers used for concrete pavements with an emphasis on macro-fibers and their effect on concrete properties and pavement construction.
   • https://vimeo.com/297350236

2. Effect of Macrofibers on Behavior and Performance of Concrete Slabs and Overlays
   Review the significant findings of macro-fiber addition to concrete slabs on grade, which include the increase in plain concrete slab capacity, reduction in crack widths, and increase in pavement performance.
   • https://vimeo.com/299518241

3. Overview of Macrofiber Software and Guidelines for Concrete Overlay Design
   Provide an overview of the macro-fiber software for determining the recommended fiber reinforced concrete residual strength values for application to concrete overlay design.
   • https://vimeo.com/304860866
Residual Strength Estimator for Fiber-Reinforced Concrete Overlays

**Instructions:** Run an overlay design software to determine the design inputs. Select design choices from the drop-down menus below to narrow down the recommended performance requirement of FRC for the proposed overlay pavement. Determine the effective flexural strength to input into overlay design software instead of design concrete flexural strength. Prepare specifications to achieve design residual strength of FRC material.

<table>
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<tr>
<th>Design Input Choices</th>
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<tr>
<td>Type of Overlay Road</td>
<td>Arterial</td>
</tr>
<tr>
<td>Millions of ESALS in Design Life</td>
<td>0.01 to 5.0 million ESALs</td>
</tr>
<tr>
<td>Asphalt Pre-Condition*</td>
<td>Fair</td>
</tr>
<tr>
<td>Desired New Concrete Thickness</td>
<td>4.5 to 6 inch PCC thickness</td>
</tr>
<tr>
<td>Remaining HMA Thickness after Milling</td>
<td>4.5 to 6 inches HMA remaining</td>
</tr>
<tr>
<td>Overlay Slab Size</td>
<td>6ft joint spacing</td>
</tr>
<tr>
<td>Desired Performance Enhancements</td>
<td>basic FRC overlay</td>
</tr>
<tr>
<td>(this will generate a higher residual strength, but not included in effective flexural strength)</td>
<td></td>
</tr>
<tr>
<td>Plain Unreinforced Concrete Flexural Strength (MOR)</td>
<td>550 psi</td>
</tr>
<tr>
<td>based on 28 day Four Point Bending (ASTM C78 or ASTM C1699)</td>
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Effective Flexural Strength Equation

\[ MOR' = MOR + f_{150} \]

- \( MOR \) = plain concrete flexural strength
- \( f_{150} \) = residual strength
- \( MOR' \) = effective (modified) flexural strength of FRC

\[ f_{150} = 125 \text{ psi (FRC mix for example)} \]
\[ MOR = 625 \text{ psi (ASTM C78 at 28 days)} \]
\[ MOR' = 625 \text{ psi} + 125 \text{ psi} = 750 \text{ psi} \]

\[ \text{Stress Ratio (SR)} = \frac{\text{Total Stress(MOR)}}{MOR'} = \frac{\sigma}{MOR + f_{150}} \]

- Fatigue Life: \( \log N_f = 17.61 - 17.61 \frac{\sigma}{MOR'} \)

Note:
\[ f_{150} = f_{150}^{150} \]

Altoubat et al. (2007)
Bordelon and Roesler (2012)
Questions & Further Information

• Contact:
  • Jeffery Roesler, Ph.D., P.E., University of Illinois Urbana Champaign
    jroesler@Illinois.edu
  • CPTech Center https://cptechcenter.org