PCC Overlays Fabric and Fiber January 8, 2021

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Tech Center

Use of Geotextile Materials for Separation in Concrete Overlay Applications

Use of Geotextile Materials for Separation in Concrete Overlay Applications

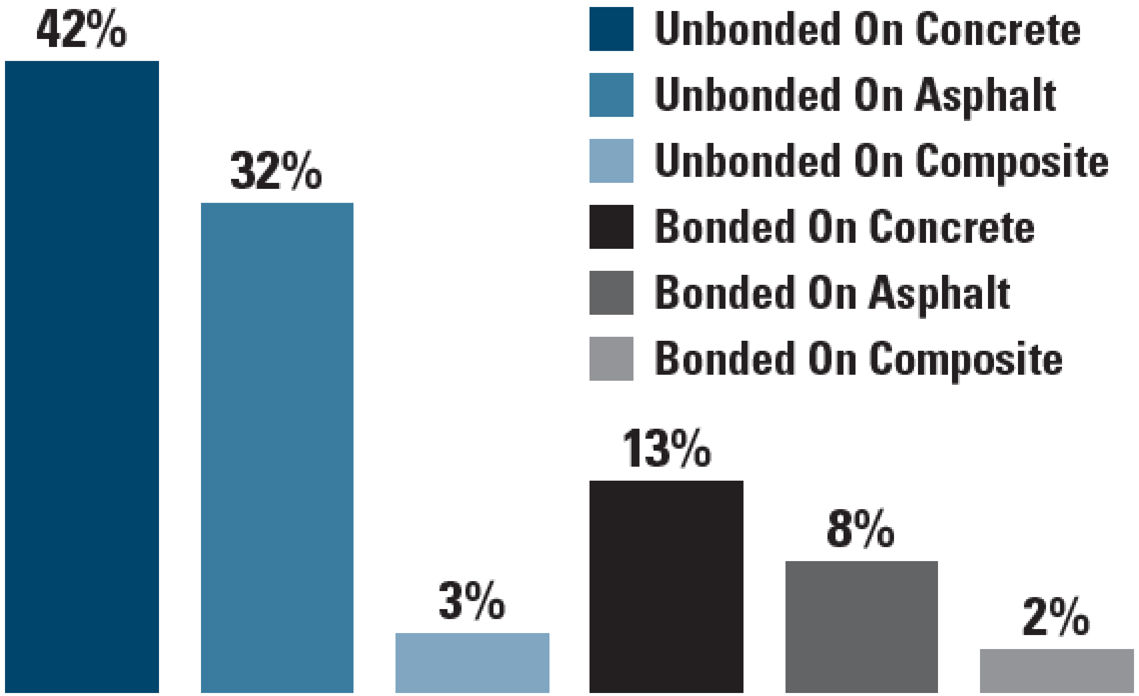
Background – International Practice

- > 40 years of use by German Engineers
- Geotextile fabrics have been used as a separation layer between:
  - full-depth concrete pavements and stiff cement treated bases
  - Concrete overlays over rubblized or crack & seated pavements (not common US practice)
- The current specification in the US was based upon the German Specification

Use of Geotextile Materials for Separation in Concrete Overlay Applications

Background - US Practice

- 2006 International Technology Scanning Program (FHWA , AASHTO, & NCHRP)
  - Identified the technology as potential beneficial for concrete overlay applications
  - Recommended evaluation as an alternative to HMA



After Cackler 2017, National CP Tech Center, based on data from National Concrete Overlay Explorer (ACPA 2014)

Figure 3. Percentage of bonded and unbonded concrete overlays by pavement type constructed from 1900–2010

Use of Geotextile Materials for Separation in Concrete Overlay Applications

Purpose of Separation Materials

- Isolation from movement of the underlying pavement
- Drainage
- Bedding – a cushion of the overlay to reduce
  - Curling and warping stresses
  - Bearing stresses
  - Effects of dynamic traffic loads
  - Prevent keying

Use of Geotextile Materials for Separation in Concrete Overlay Applications

Summary of current specification

Property	Requirements	Test Procedure
Geotextile Type	Nonwoven, needle-punched, no thermal treatment to include calendering*	EN 13249, Annex F (Certification)
Color	Uniform/nominally same color fibers	(Visual Inspection)
Weight (mass per unit area)	≥ 450 g/m² (13.3 oz/yd²) ≥ 500 g/m² (14.7 oz/yd²) ≤ 550 g/m² (16.2 oz/yd²)	ISO 9864 (ASTM D5261)
Thickness under load (pressure)	[a] At 2 kPa (0.29 psi): ≥ 3.0 mm (0.12 in.) [b] At 20 kPa (2.9 psi): ≥ 2.5 mm (0.10 in.) [c] At 200 kPa (29 psi): ≥ 0.10 mm (0.04 in.)	ISO 9863-1 (ASTM D5199)
Wide-width tensile strength	≥ 10 kN/m (685 lb/ft)	ISO 10319 (ASTM D4595)
Wide-width maximum elongation	≤ 130 percent	ISO 10319 (ASTM D4595)
Water permeability in normal direction under load (pressure)	≥ 1 x 10^{-4} m/s (3.3 x 10^{-4} ft/s) at 20 kPa (2.9 psi)	DIN 60500-4 (modified ASTM D5493)
In-plane water permeability (transmissivity) under load (pressure)	[a] ≥ 5 x 10^{-4} m/s (1.6 x 10^{-3} ft/s) at 20 kPa (2.9 psi) [b] ≥ 2 x 10^{-4} m/s (6.6 x 10^{-4} ft/s) at 200 kPa (2.9 psi)	ISO 12958 (ASTM D6574) or ISO 12958 (modified ASTM D4716)
Weather resistance	Retained strength ≥ 60 percent	EN 12224 (ASTM D4355 @ 500 hr exposure for gray, white, or black material only)
Alkali resistance	≥ 96 percent polypropylene/polyethylene	EN 13249, Annex B (Certification)

Use of Geotextile Materials for Separation in Concrete Overlay Applications

First US Project in 2008

- Missouri DOT – Route D
- Clarkson Construction Co.
- Originally built 1986
- 9,300 AADT
- Severe D Cracking

- 45,000 sq. yds.
- 5” thick
- 6’ joint spacing
- 12 & 15 oz Fabrics (with heat treatment)
  - Thermal treated

Todd LaTorella, ACPA, MO/KS Chapter

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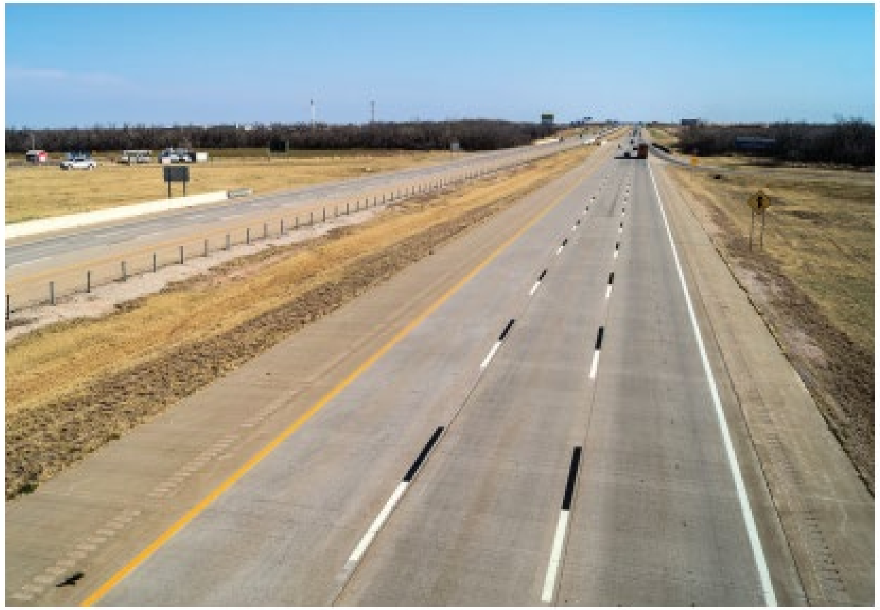
Use of Geotextile Materials for Separation in Concrete Overlay Applications

Second US Project - 2009

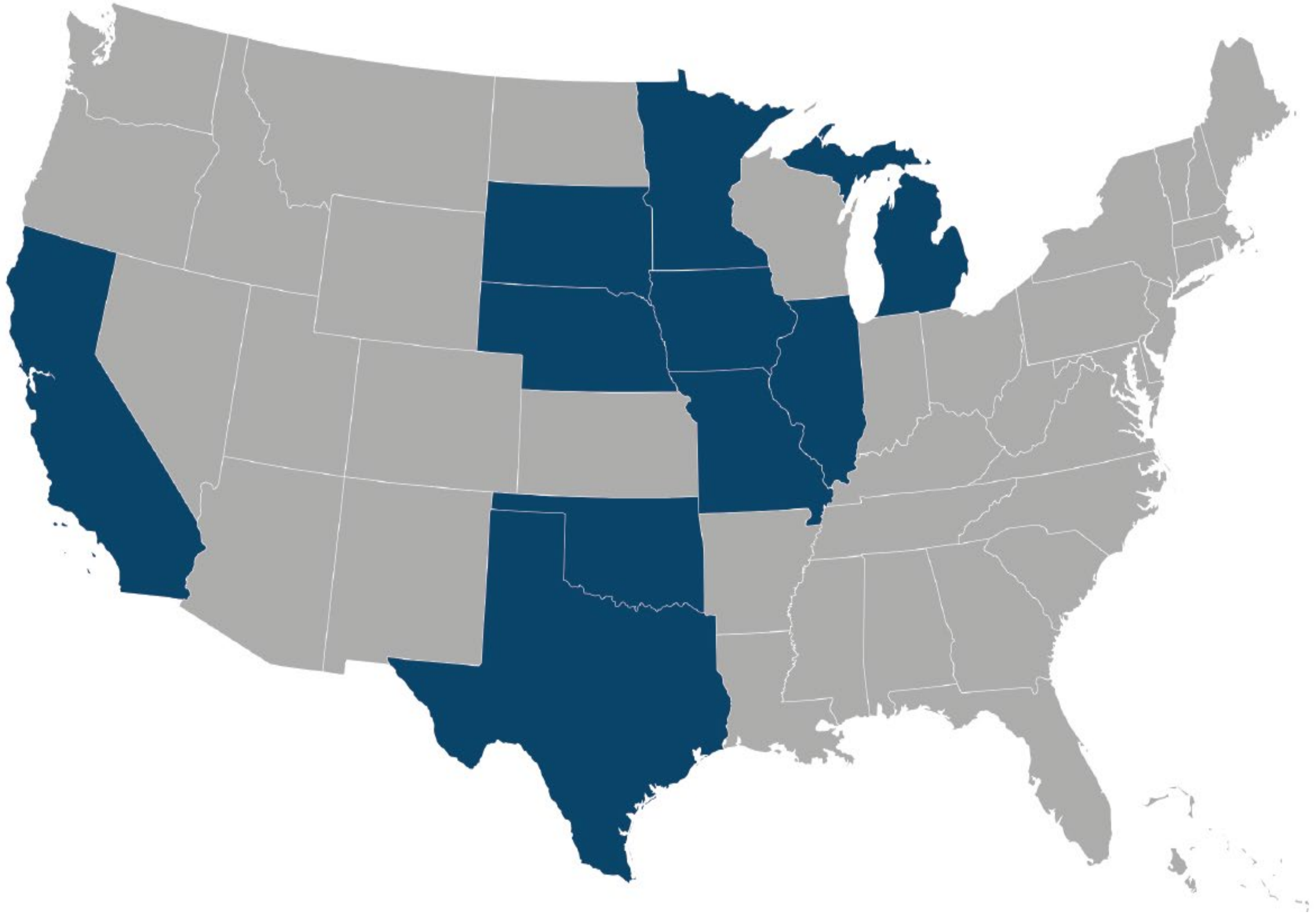
- Oklahoma – I 40
- Duit Construction Co.
- Originally built 1969
- 9” JPCP over 4” asphalt base
- 681,000 sq. yds.
- 10 “ thick
- 15’ joint spacing
- 15 oz Fabric (imported from Germany)



Use of Geotextile Materials for Separation in Concrete Overlay Applications

US Applications

- Since 2008 > 10 m sy (2017)
- Non woven 13 & 15 oz
- JPCP overlay over
  - JPCP
  - CRCP

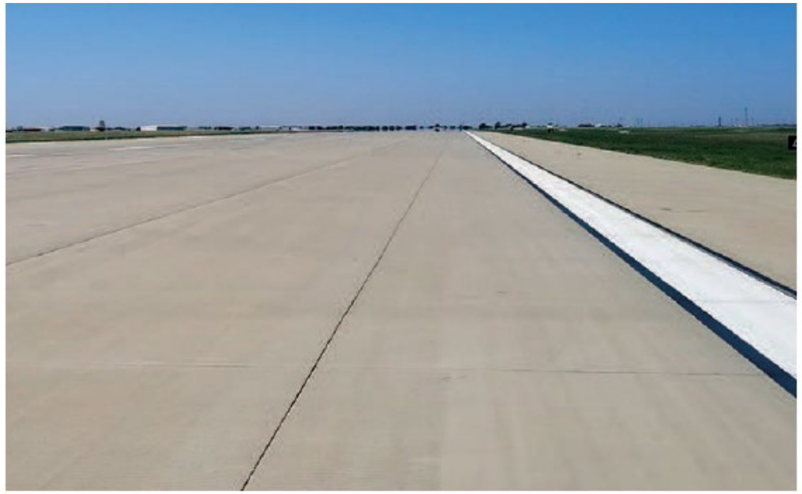


Performance Assessment of Nonwoven Geotextile Materials Used as the Separation Layer for Unbonded Concrete Overlays of Existing Concrete Pavements In the US (Aug. 2018) -

Use of Geotextile Materials for Separation in Concrete Overlay Applications

Summary of US Applications

- Municipal Streets
- County Roads
- Primary Highway
- Interstate Highways
- Airports



Use of Geotextile Materials for Separation in Concrete Overlay Applications

US Performance Overview

- Geotextile separation has worked well for a wide range of overlay thickness and loading
- Eliminates stripping of Asphalt separation layer
- Appears to reduce panel migration
- Adhesives work effectively for securing the fabric
- Can provide significant cost and time savings
- Provides adequate drainage with proper outlets
- Match fabric thickness to the overlay thickness

Use of Geotextile Materials for Separation in Concrete Overlay Applications

US Performance Overview

Can provide significant cost and time savings

- Cost (Iowa bid results 2015-2017)
  - $2.07 - $2.45/ sq. yd. for geotextile fabric
  - $4.86/ sq. yd. for 1” asphalt

- Time
  - Normally eliminates need for subcontract
  - Easier execution for the paving contractor
  - Does not control the paving progress

Use of Geotextile Materials for Separation in Concrete Overlay Applications

- Panel Movement

Dan DeGraaf, Michigan Concrete Association

Figure 6. Panel movement on UBCOC overlay with HMA separation layer

Dan DeGraaf, Michigan Concrete Association

Figure 5. Lack of panel movement shown on 4 in. UBCOC overlay with geotextile separation layer after 6 years of urban traffic

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Stripping may occur in the asphalt interlayer of an unbonded concrete overlay pavement when the interlayer contains trapped water and under repeated heavy truck traffic, results in the water stripping the asphalt binder from the aggregate.

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Iowa Applications

- 20 projects (ICPA database)
- 1,083,966 sq. yds.
- 2013 to date
- 4” – 7” overlay thickness
- 16 county; 4 municipal

Use of Geotextile Materials for Separation in Concrete Overlay Applications

- Ongoing Evaluations
  - Required geotextile thickness on thinner overlays?
  - Is there advantage in UBCOA applications?
  - Color advantage (White, black, gray)
  - Fatigue life/deflections

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Mn Road findings

- 3” overlay with 6’ X 6’ panels
- 8 oz and 16 oz fabrics
- The thinner fabric resulted in
  - > strain
  - > IRI
  - > surface distresses
  - 4 decibels quieter
- Recommended staying with current spec until further studies can examine other thicknesses

Use of Geotextile Materials for Separation in Concrete Overlay Applications

Poweshiek V-18

- Built in 2008 with 2 test sections with geotextile
- Deflection testing in 2018
- Resilient modulus >40%
- Permanent deformation

  < asphalt sections

Use of Geotextile Materials for Separation in Concrete Overlay Applications

Buchanan – D 16

- Built 2020
- 6” UBCOA
- 2 fabrics (6 & 12 oz)
- White and black color
- Will re-test this summer

Use of Geotextile Materials for Separation in Concrete Overlay Applications

- Construction procedures
  - Pre-overlay repairs
  - Placement
    - Anchoring options
- Fabric thickness guidance

Overlay Thickness	Recommended non-woven geotextile thickness
< 5 in.	13.3 oz./yd^2
$\geq$ 5 in.	14.7 oz./yd^2

Use of Geotextile Materials for Separation in Concrete Overlay Applications

- Resources- https://cptechcenter.org/concrete-overlays/
  - Guide Specs
  - Typical Plans
  - Design Procedures
  - Performance History
  - Use of fibers
  - Training materials
    - Handouts
    - Videos

Fiber-Reinforced Concrete Overlays

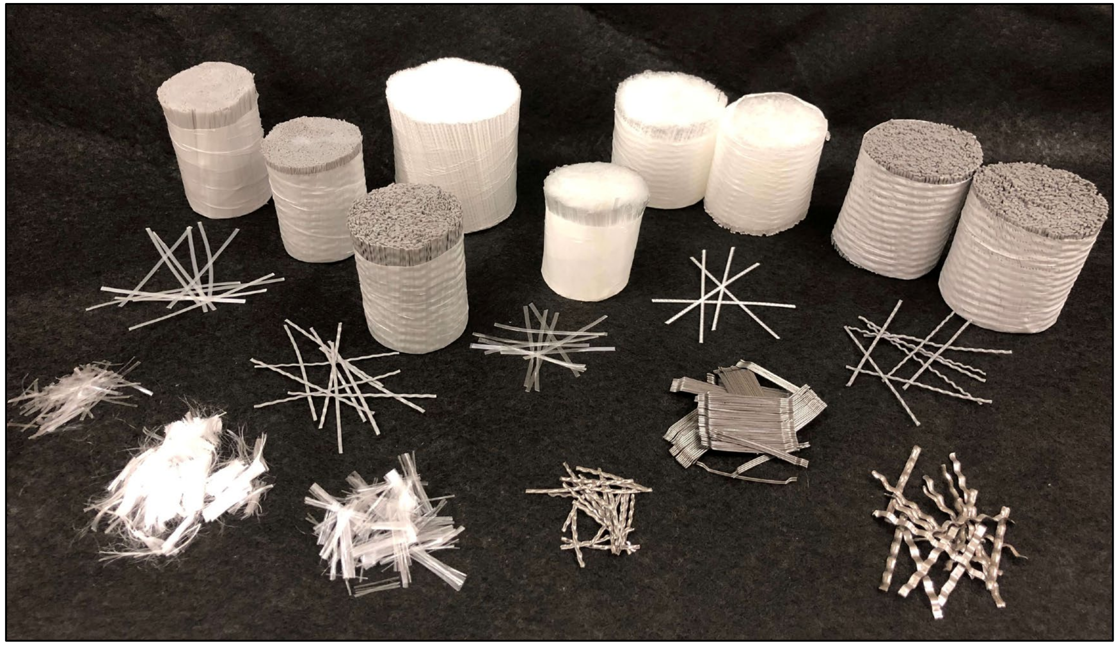
Outline

- Background
- Design and Construction
- Fiber-Reinforced Concrete Overlays in Iowa
  - Recent Projects
  - New Applications and Ideas

Background

What is Fiber-Reinforced Concrete?

- Concrete reinforced with discrete, distributed fibers
- Macro-fibers and micro-fibers
- Different materials: steel, glass, synthetic, natural



Images: Sika

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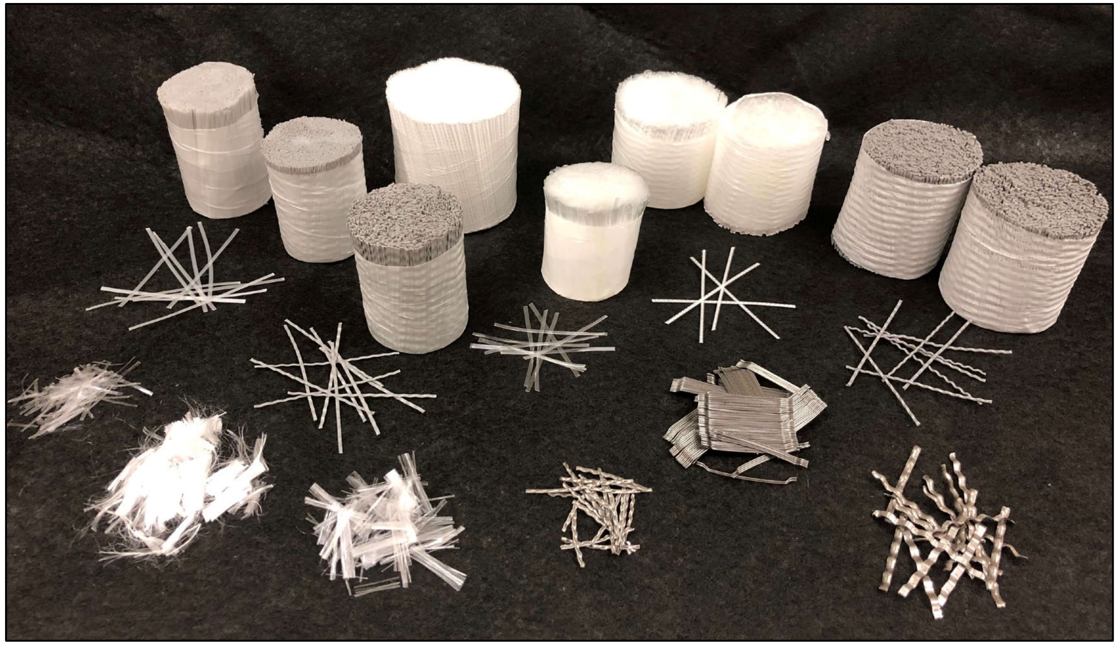
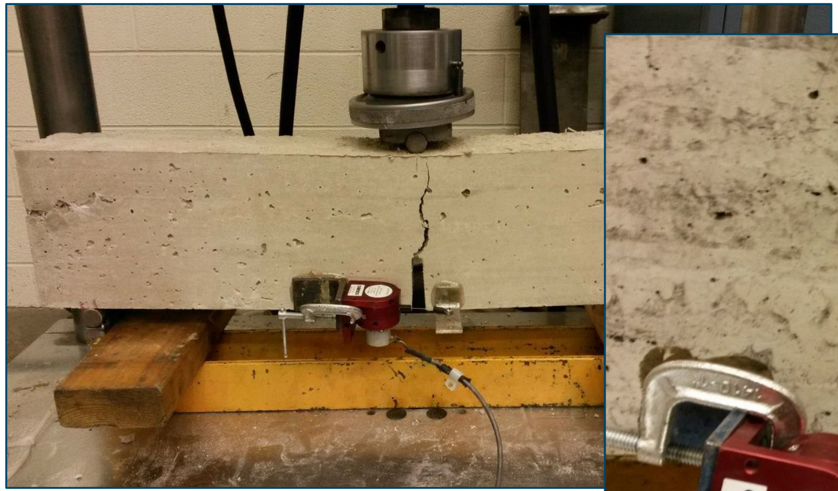


Images: Sika

What is Fiber-Reinforced Concrete?

- Reinforcing with synthetic macro-fibers:
  - Increases the fracture toughness and post-crack load capacity of concrete
  - Does NOT increase compressive, tensile, or flexural strength of concrete

  - Some decrease in workability
  - Reduction in bleeding, plastic shrinkage cracking
  - Reduces crack widths
  - Increases resistance to cracking



Benefits of Fibers in Concrete Pavements

- How the properties of FRC translate to pavement performance:
  - Improves long-term fatigue performance
  - Keeps joints and cracks tight
  - Enhances aggregate interlock
  - Prevents panel movement/sliding
- Design implications:
  - Improves design life/reduces thickness
  - Improves load transfer
  - Allows for longer joint spacings?

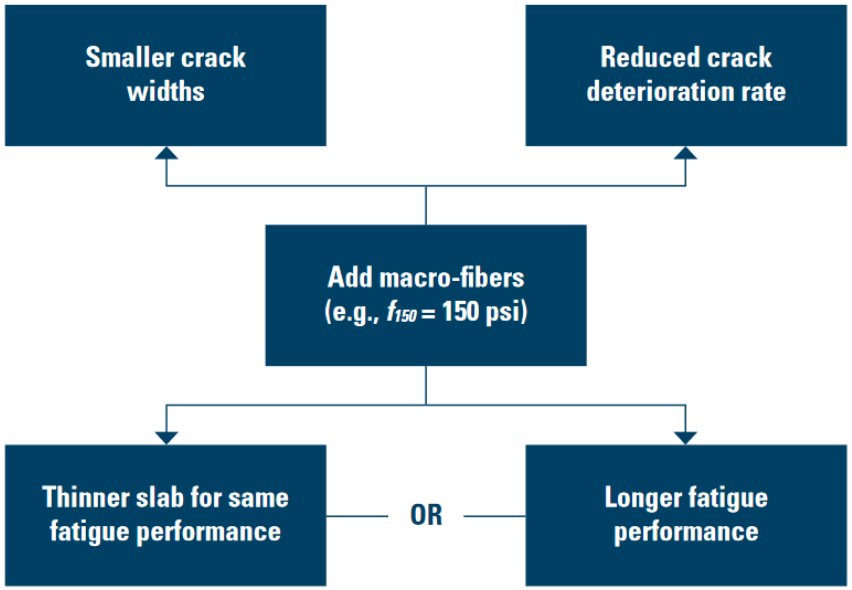


Image: CP Tech Center

Concrete Overlays

- Concrete overlays are a particularly good application for fibers
  - Improves fatigue life of a thin slab
  - Enhances aggregate interlock when the pavement is often too thin to place dowel bars for load transfer

Concrete Overlays

- Fiber-reinforced concrete has been used to construct bonded and unbonded concrete overlays in all types of applications: city streets, county & state highways, and interstate highways

Design and Construction

Designing FRC Overlays

- How do I choose a dosage rate for fibers?
  - A dosage of 3 to 5 lbs/cy of synthetic macro-fibers has been common for concrete overlays, including in Iowa
    - About 0.2 to 0.3% by volume
    - How was this rate determined?

Image: Forta

Designing FRC Overlays

- ASTM C1609 testing to determine residual strength (f_{150})
- The common dosage rate (3 to 5 lbs/cy) for FRC overlays corresponds to f_{150} = 100 to 200 psi for most macro-synthetic fibers

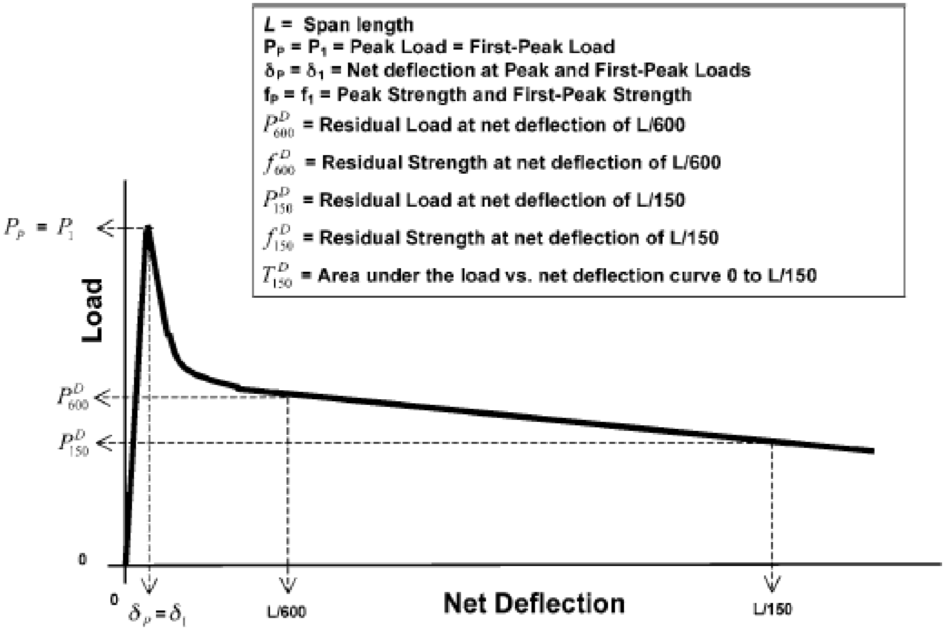
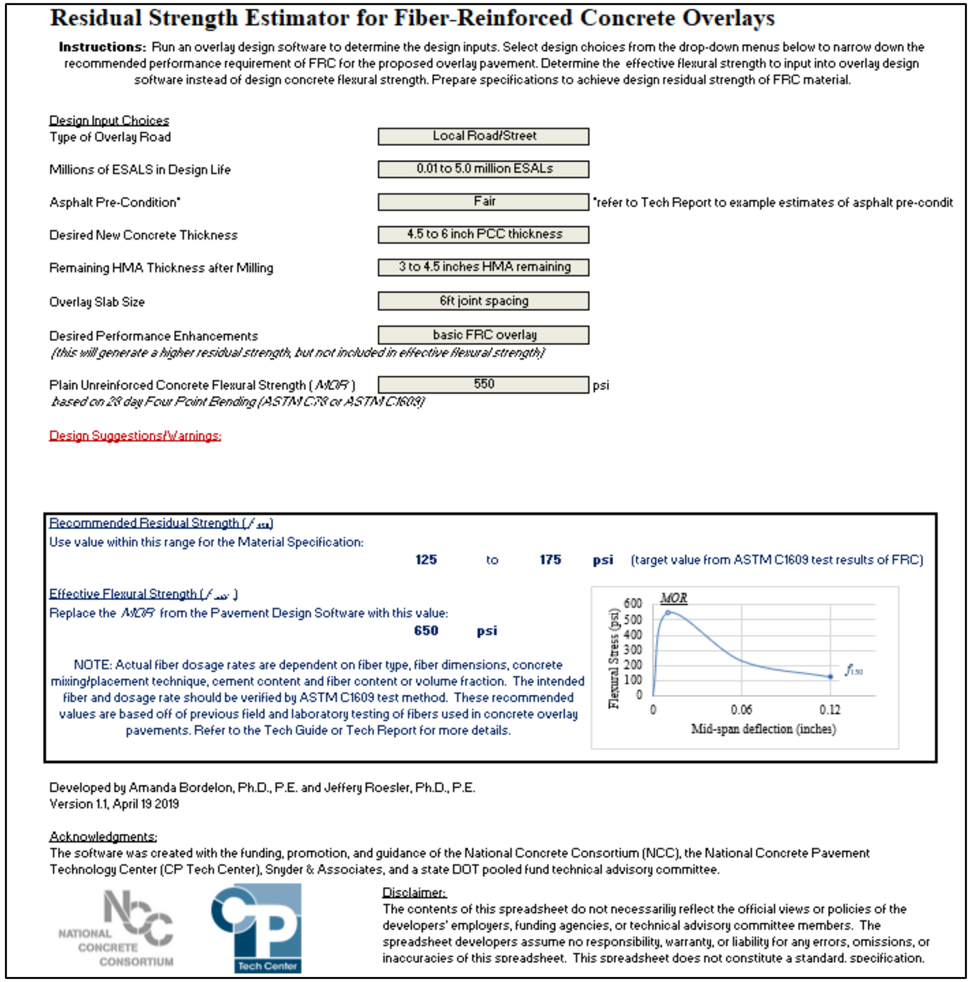


FIG. 3 Example of Parameter Calculations for First-Peak Load Equal to Peak Load (Not to Scale)

Images: CP Tech Center

Designing FRC Overlays

- How does using fibers affect the design?
  - Current practice: add the residual strength to the design flexural strength to produce an effective flexural strength
  - Tool available on CP Tech Center website to help determine a design value for residual strength:
    - https://cptechcenter.org/publications/
    - Click the “Spreadsheets” sub-heading



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.

Design Input Choices

Type of Overlay Road	Local Road/Street	
Millions of ESALS in Design Life	0.01 to 5.0 million ESALs	
Asphalt Pre-Condition*	Fair	*refer to Tech Report to example estimates of asphalt pre-condit
Desired New Concrete Thickness	4.5 to 6 inch PCC thickness	
Remaining HMA Thickness after Milling	3 to 4.5 inches HMA remaining	
Overlay Slab Size	6ft joint spacing	
Desired Performance Enhancements (this will generate a higher residual strength, but not included in effective flexural strength)	basic FRC overlay	
Plain Unreinforced Concrete Flexural Strength (MOR) based on 28 day Four Point Bending (ASTM C78 or ASTM C1609)	550	psi

Design Suggestions/Warnings:

Recommended Residual Strength (f_{150})
Use value within this range for the Material Specification: **125** to **175** **psi** (target value from ASTM C1609 test results of FRC)

Effective Flexural Strength (f_{eff})
Replace the MOR from the Pavement Design Software with this value: **650** **psi**

NOTE: Actual fiber dosage rates are dependent on fiber type, fiber dimensions, concrete mixing/placement technique, cement content and fiber content or volume fraction. The intended fiber and dosage rate should be verified by ASTM C1609 test method. These recommended values are based off of previous field and laboratory testing of fibers used in concrete overlay pavements. Refer to the Tech Guide or Tech Report for more details.

Developed by Amanda Bordelon, Ph.D., P.E. and Jeffery Roesler, Ph.D., P.E.
Version 1.1, April 19 2019

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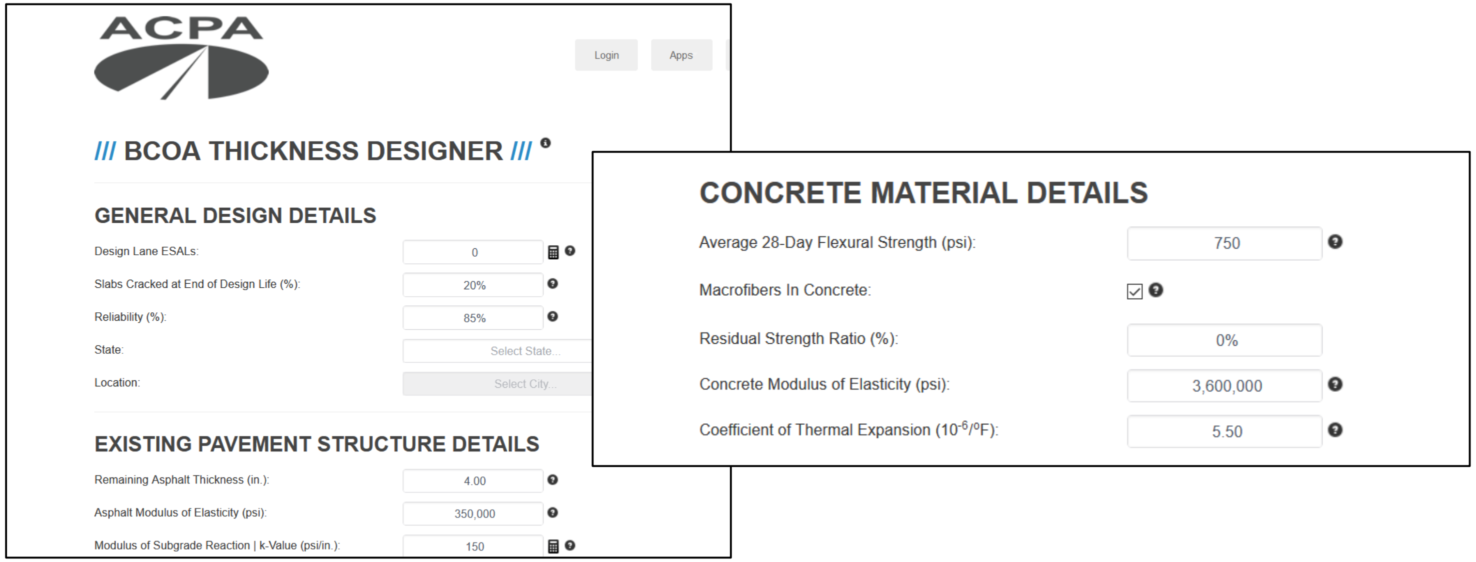
v1.1, Bordelon and Roesler (2019)

Designing FRC Overlays

- You may use this effective flexural strength value in any design tool to obtain an overlay thickness design accounting for fibers
  - Different fiber products – different f_{150} values at different dosage rates
  - In some concrete overlay design tools like BCOA-ME, all you need to do is plug in a fiber dosage rate, and the software adjusts the design accordingly according to its own assumptions



Constructing FRC Overlays

- Construction Considerations
  - Mixing
    - Ensure fibers are well-dispersed
    - May require an increase in mix time
  - Workability
    - May need to adjust admixtures
    - At especially high fiber dosages (> 7 lbs/cy or > 0.5%), may need to increase paste content
  - Finishing

Constructing FRC Overlays

- Paving

Constructing FRC Overlays

- Paving

Constructing FRC Overlays

- Paving

FRC Overlays in Iowa

FRC Overlays in Iowa

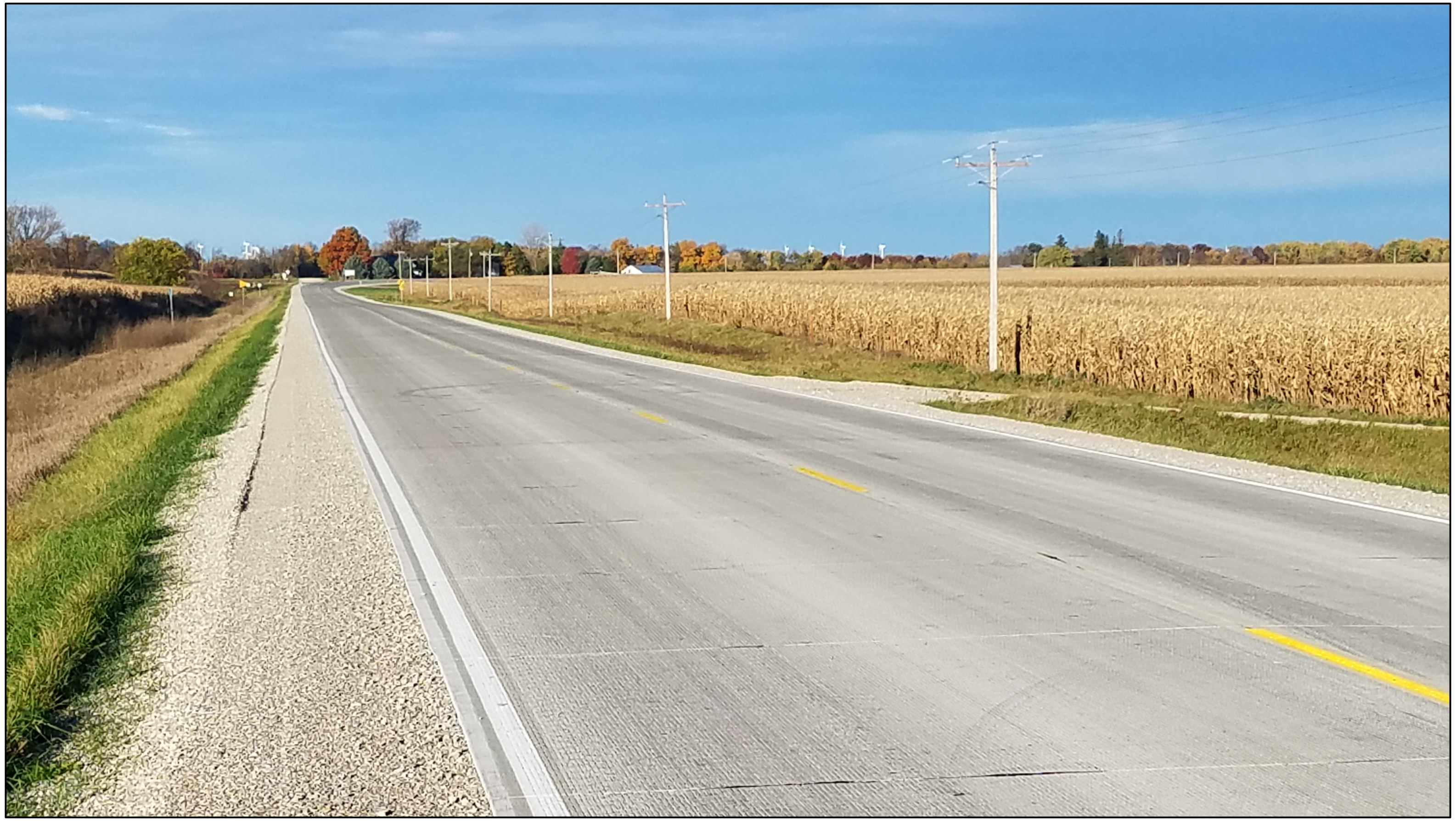
- Micro-fibers on experimental concrete overlays 1970s to 1990s
  - Greene County
  - IA 21, Iowa County (1994)
- First test sections with synthetic macro-fibers on state highways in the early 2000s
  - IA 13, Delaware County (2002):
  - 3 lbs/cy dosage rate

FRC Overlays in Iowa

- Later in 2000s and into 2010s, adoption of fibers began on thin concrete overlays on city streets
  - Le Mars (2010-2018):

FRC Overlays in Iowa

- Most recently, more FRC overlays on county highways
  - Mitchell County (2017):
  - 4 lbs/cy fibers



New Applications and Ideas

- FRC overlays with synthetic macro-fibers have performed well in Iowa and across the US dating back to the 2000s
- Over time, fiber products continue to improve in performance and mixing characteristics
- What new ideas are out there for concrete overlay applications?

New Applications and Ideas

- Optimizing Joint Spacing
  - Thin concrete overlays (4 to 6 inches) commonly have short joint spacing
  - Cracks don't always form beneath joints right away on these thinner overlays, which could be a problem
    - Additional cost & maintenance for design that may not work as intended
    - Potential for dominant joint behavior

New Applications and Ideas

- Can we better optimize joint spacing design for low-volume roads?
  - Are shorter slabs always necessary?
  - Will cracks consistently form beneath joints as designed?
  - Can we measure differences/impact on curling behavior, ride quality?
  - Do fibers help with the ability to potentially extend joint spacing?

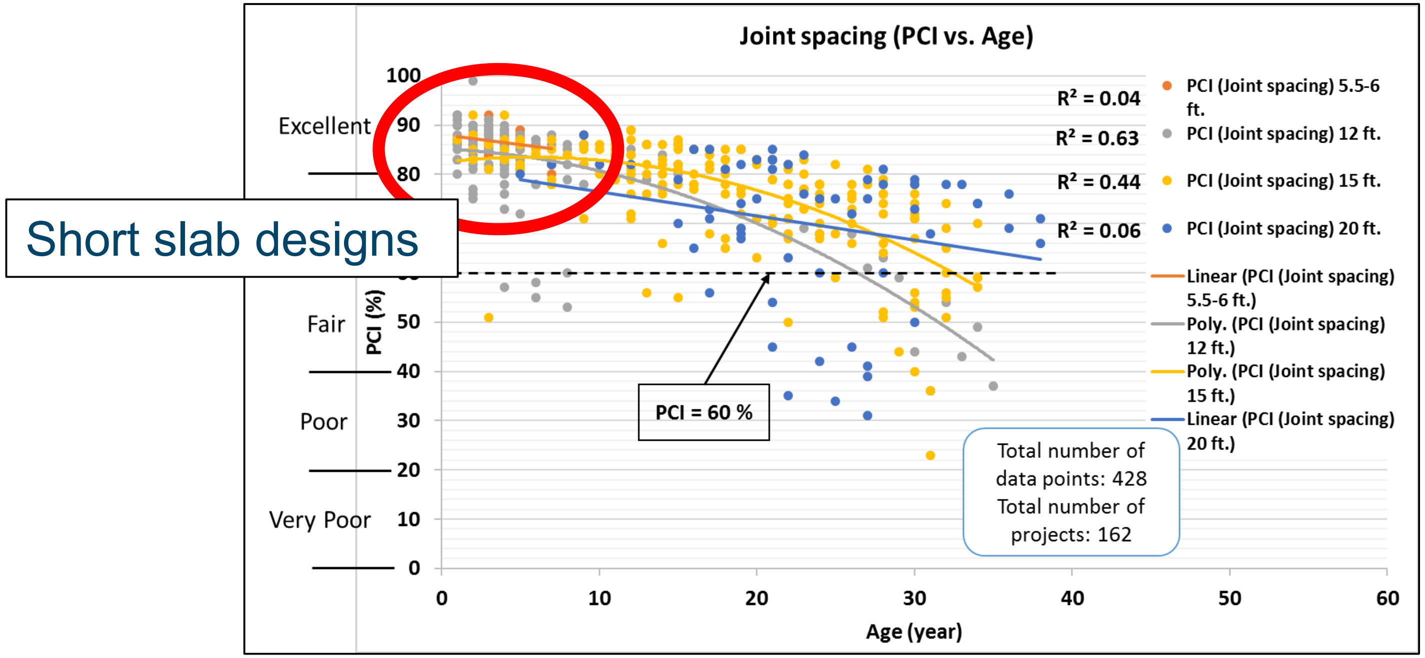
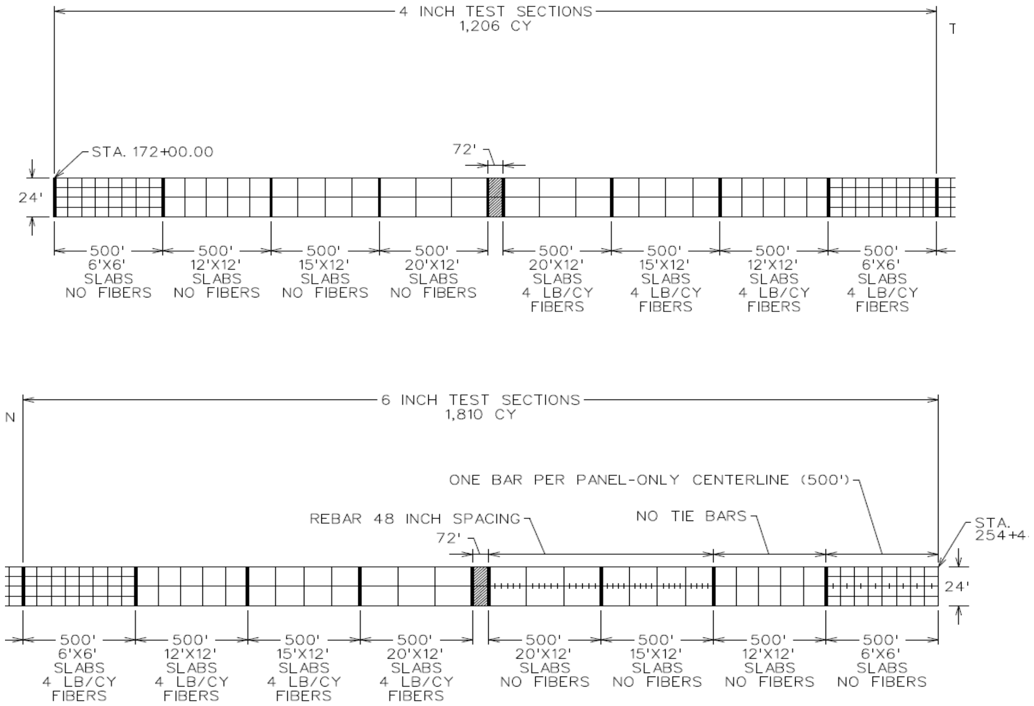


Figure: Gross et al. (2017)

New Applications and Ideas

- FRC test sections built in Mitchell & Buchanan Counties (2017-18)
  - 4 and 6 inch overlay sections, 4 lbs/cy fibers
  - Joint spacing varying from 6 ft x 6 ft up to 20 ft transverse
  - Joint activation monitored from construction to one year



New Applications and Ideas

- Results so far:
  - Most of the joints are cracking as intended (approaching 100% activated joints through 1.5 years)
  - The section with the fewest joints activated was 4 inch overlay with fibers and 6 ft x 6 ft slabs (70% activated)
  - Future testing and performance monitoring will help fully understand impacts of joint spacing and fiber-reinforcement

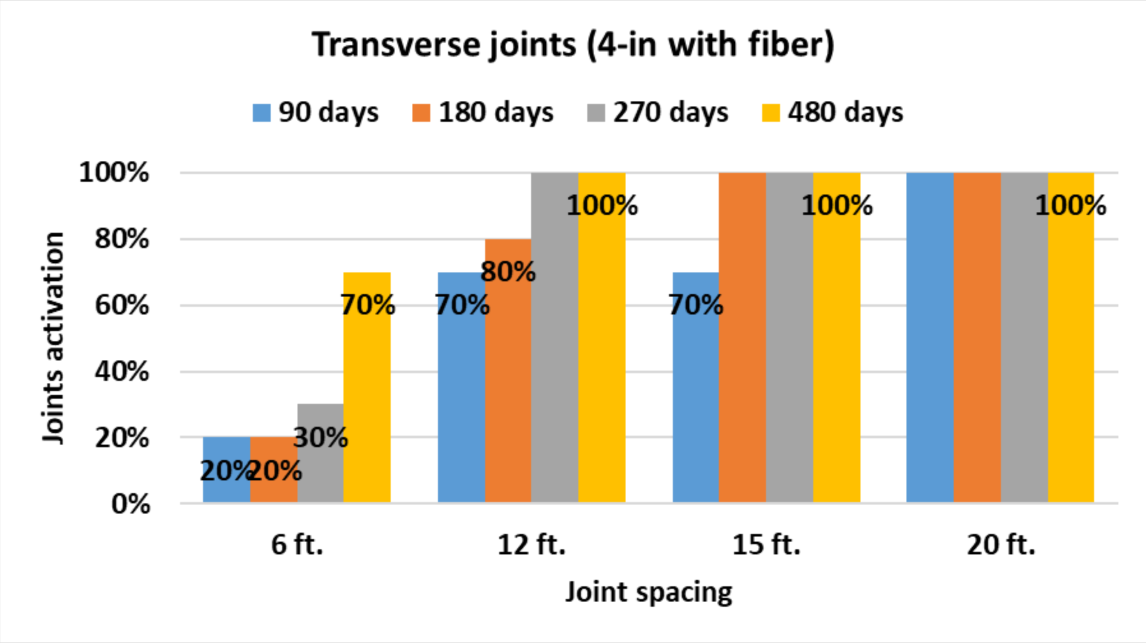


Figure: Gross et al. (2019)

New Applications and Ideas

- If not all joints crack right away, especially when using fibers, maybe early loading of the slab can help activate the joints?
  - US 63, Minnesota:

New Applications and Ideas

- What if we increased fiber dosage rate and let the pavement crack on its own?
- Worth County test section (2019)
  - 6 inch FRC overlay, typical 4 lbs/cy and 12 ft x 12 ft joint spacing
  - 7.5 lbs/cy fibers for test section
  - Increased cementitious content from 570 to 640 lbs
  - No transverse sawed joints in the test section – pavement allowed to crack on its own

New Applications and Ideas

- Paved in October 2019
- Initially: 7 transverse cracks in 636 ft section

New Applications and Ideas

- Cracks developed progressively throughout the year
- Earlier/larger cracks filled
- By December 2020: 24 total transverse cracks
  - Average crack spacing = 26.5 ft
  - Average crack width = 0.036 inches (~1/32 inch)
  - Widest cracks = 0.08 inches (~1/12 inch)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