National Concrete Pavement Technology Center

Field Performance of Fiber-Reinforced Concrete Overlays

tech transfer summary

Investigating the behavior of fiber-reinforced concrete overlays in the field provided insights that will allow for improvements to concrete overlay design and performance.

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RESEARCH PROJECT TITLE
Field Performance of Fiber-Reinforced Concrete Overlays

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The mission of the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University is to unite key transportation stakeholders around the central goal of developing and implementing innovative technology and best practices for sustainable concrete pavement construction and maintenance.

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Background

Iowa leads the United States in the construction of concrete overlays, with nearly 600 projects totaling more than 2,000 centerline miles completed since record-keeping began in the 1970s. In recent years, a growing number of concrete overlay projects in Iowa and around the country have been constructed using fiber-reinforced concrete (FRC), with synthetic macrofibers embedded throughout the concrete mass at typical rates of 0.2% to 0.3% by volume.

Fibers are most commonly used on thin (4 to 6 in.) overlays, including concrete on asphalt–bonded (COA–B), concrete on asphalt–unbonded (COA–U), and concrete on concrete–unbonded (COC–U) overlays.

Reinforcement with synthetic macrofibers primarily benefits overlay performance by resisting crack opening and providing post-crack load carrying capacity, or residual strength. When designing FRC overlays, the residual strength is assumed to enhance the overall flexural fatigue performance of the pavement, allowing for either a reduction in required overlay thickness or an increase in design life relative to a plain, unreinforced overlay.

Problem Statement

The impacts of FRC on crack opening and fatigue life are well understood, but a number of other proposed benefits of using fibers in concrete overlays have not been studied as thoroughly.

Fiber-reinforced concrete overlay in Buchanan County

Past research suggests that fiber reinforcement may enhance aggregate interlock at joints, which could improve load transfer efficiency (LTE), reduce pavement roughness, and mitigate curling and warping potential. These potential benefits are not currently accounted for in any concrete overlay design procedures.

Designers and practitioners are also interested in whether it might be viable to use fibers to extend typical joint spacing designs for concrete overlays. Many thin concrete overlays are constructed with shorter joint spacings (e.g., 6 ft x 6 ft) than conventional pavements (12 ft x 12 ft or greater), which reduces stresses under traffic loads.

However, not all joints activate in overlays with shorter joint spacings, meaning that cracks do not always form beneath all sawcut control joints. Unactivated joints have sometimes been linked to poor performance outcomes, such as dominant joint behavior.

Objective

The primary objective of this study was to more fully characterize the behavior of FRC overlays in the field. A testing program was carried out to conduct a number of measurements, including joint LTE, structural backcalculation, pavement smoothness, curling and warping, and joint activation.

The goal of this field investigation was to obtain a more comprehensive understanding of the performance of various types of concrete overlay designs, both with and without fiber reinforcement.

Research Description

Six different FRC overlay projects constructed in Iowa between 2017 and 2021 were selected for analysis, encompassing three different types of concrete overlays (COA–B, COA–U, COC–U). Three of the six projects included test sections with varying design thicknesses and joint spacings, including sections both with and without fibers. In total, 37 unique overlay sections were included in the field investigation.

Variables included at field investigation sites included the following:

- Overlay type (COA–B, COA–U, and COC–U)
- Overlay thickness (4 and 6 in.)
- Transverse joint spacing (5.5, 6, 9, 11, 12, 15, 20, 30, and 40 ft)
- Fiber dosage rate (0 and 4 lb/yd^3)
- Separation layer (geotextile)

Note that the test sections did not include every combination of each of these variables, and geotextile separation layers were included in all of the COC–U overlay sections and one COA–U overlay section.

The testing regime carried out at each site included the following:

- Performance prediction using pavement design software
- Visual distress survey
- Ultrasonic tomography for joint activation (MIRA)
- Falling weight deflectometer (FWD) testing for joint LTE and structural backcalculation
- High-speed surface profiling for pavement smoothness and curling/warping

ACPA, used with permission

MIRA testing for joint activation

FWD testing for joint LTE

High-speed surface profiling system for pavement smoothness and curling/warping measurements

Key Findings

The results of this investigation produced a number of interesting findings three to seven years after construction of the field sections:

- Fiber-reinforced sections had fewer cracked slabs than corresponding sections without fiber reinforcement, consistent with performance predictions and expectations.
- The use of fibers appeared to prevent mid-slab transverse cracking in overlays with extended (30 ft, 40 ft) joint spacing designs. Mid-slab cracking occurred in nearly 100% of the corresponding slabs without fibers.
- The use of fibers did not appear to demonstrate any improvements in terms of joint LTE, pavement smoothness, or curling/warping behavior. There were no statistically significant differences between sections with and without fiber reinforcement in terms of performance indicators such as joint LTE, International Roughness Index (IRI), or a metric developed to assess the degree of curling and warping (Curvature IRI).
- Decreasing transverse joint spacing from longer designs (i.e., 11 ft or greater) to shorter designs (e.g., 5.5 to 6 ft) generally improved joint LTE, although the magnitude of these differences was not large at all sites.
- Thickness and joint spacing design did not appear to affect pavement smoothness or curling/warping behavior.
- Joint LTE was significantly better in COA–B and COA–U overlays compared to COC–U overlays, as well as a COA–U overlay section that was constructed with a geotextile separation layer.
- The COA–B and conventional COA–U overlays also demonstrated enhanced structural capacity and lower deflections under loading, indicating that both types of overlays benefitted from bonding to the underlying asphalt independent of whether they were designed as bonded or unbonded overlays.
- A number of COC–U overlay sections, as well as the COA–U overlay with a geotextile separation layer, demonstrated poor joint LTE (50% or below) just five to six years after construction.
- Unactivated joints were present in each of the overlay sections with shorter joint spacing designs (e.g., 5.5 to 6 ft), with joint activation rates ranging from 40% to 80%. Joint activation rates were 100% for nearly every section with a joint spacing of 9 ft or greater. That said, the presence of unactivated joints did not predict poor performance in terms of joint LTE or correlate with any other negative performance outcomes.

Key Recommendations

The results of this field investigation supplied considerable insight into concrete overlay behavior and may have a number of important implications for future concrete overlay design and construction:

- Fiber reinforcement did not improve the performance of concrete overlays in terms of load transfer, smoothness, or curling/warping behavior at the ages (three to seven years) and dosage rates (0 to 4 lb/yd^3) considered in this study. Therefore, it does not appear that these factors need to be considered in the design of FRC overlays unless improvements are realized at later ages or at higher dosage rates.
- Unactivated joints in overlays with shorter joint spacing designs (5.5 to 6 ft) were not correlated with any negative performance outcomes. Therefore, it does not appear that concerns about unactivated joints should guide or affect selection of a joint spacing design.
- Regardless of whether the concrete on asphalt overlays in this study were designed as bonded (COA–B) or unbonded (COA–U), they all demonstrated improved LTE and enhanced structural capacity relative to the COC–U overlays and the COA–U overlay with a geotextile separation layer. Therefore, it appears that it may be useful to consider the bond to the underlying asphalt layer in the design of all concrete on asphalt overlays.

Implementation Readiness and Benefits

The findings and recommendations of this study can be immediately useful to state and local agencies in Iowa looking to improve and optimize the design of concrete overlays, both with and without fiber reinforcement. Better understanding the benefits and limitations of using fibers to improve overlay performance can also assist agencies in determining the most cost-effective use cases moving forward.

The results of this study should further be helpful to agencies in the evaluation of their existing concrete overlays, providing insight into the relative performance of different types of overlay designs in their network and suggesting adjustments that could be made to typical existing designs.