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Fiber reinforced polymer patching binder for concrete pavement rehabilitation and repair

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HIGHLIGHTS

- FRPPB has been used successfully to minimize reflective cracking for JCP overlay.
- FRPPB has been used effectively to repair spalls.
- Over 8 years of field monitoring, the performance of FRPPB has been excellent.
- Zero maintenance was need after the FRPPB repair.

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ABSTRACT

Several strategies with Fiber Reinforced Polymer Patching Binder (FRPPB) have been used for the repair of jointed concrete pavements. The primary goal of such repairs is to minimize and delay the reflective cracks through a subsequent overlay. The same material has been used successfully in various districts to repair spalls in continuously reinforced concrete pavement, to fill voids at longitudinal joints, and to repair bridge approach slabs that have significant movement. Field results from US59 indicate that FRPPB can be used effectively to retard reflected cracks in AC overlays over JCP. The responsible engineers are very pleased with the FRPPB performance, as the section has provided excellent ride quality over the last 9 years and has required zero maintenance. Since most movements that cause reflected cracks are near the transverse joint, removing a slot at the transverse joint and filling it with FRPPB has proven to be a viable option for mitigation of reflected cracks. To date, the oldest spall repair has been in service for over 8 years, and is still performing well. FRPPB is able to adhere and adapt to volume changes in the surrounding concrete pavement, and conforms to settled or moving concrete slabs without any crack development.

1. Introduction

Reflective cracking of Asphalt Concrete (AC) overlays on top of jointed concrete pavement (JCP) has long been a problem in pavement rehabilitations [4]. Various types of interlayer systems, fabrics and stress relieving layers have been used around the world to eliminate or slow the development of reflective cracks. These methods and products have had mixed outcomes, and long term performance results are rarely reported.

In addition, spalling is one of the main distresses for concrete pavement and bridge decks of various highway structures. Spalls tend to propagate and widen under repeated thermal stresses and/or traffic loadings. They usually start on the pavement surface and lead to the eventual dislodging of the concrete. Spalls cause poor ride and reduce pavement serviceability. When left unrepaired, they can become hazardous to the traveling public. Partial Depth Repair (PDR) is a common choice for rehabilitating localized spalls and cracks of depth less than one-third to one-half of a concrete slab [1]. PDR can be an effective method for spalls and cracks, improving functional performance of pavement and extending pavement life. PDR offers advantages such as shorter lane closure time, lower cost, and less intrusive damage to the surrounding pavement. PDR replaces unsound and loose concrete, restores the ride quality of the pavement, and deters further deterioration [1]. Although PDR has been used to repair spalls and wide cracks, specifying and selecting the right patch material has been a challenge. Previous studies show that up to 20% PDR failed after 3 to 10 years even with properly construction and good quality control [14,12]. Reasons for several PDR types failure were analyzed, 5 out of 8 most frequent causes of partial depth repair failure are related to

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repair materials according to Wilson et al. [15]. Chen et al. [2] reported satisfactory performance with epoxy-based repair materials and stable slabs. Large relative movement usually was found between different concrete structures near transverse or longitudinal joint and approach slab. When repair boundary covers those areas, repair material needs to be able to withstand horizontal movement and vertical shear as required for joint seals [5]. Compatibility between repair materials and existing pavement is very important to short- and long-term patch performance, especially when the patch is exposed to environmental condition [6]. It has been reported that eight to ten percent of all spall repairs fail within one year, and fifty percent of all pavement repairs fail within the first five years [9]. Concrete pavements rehabilitated with patching material followed by a hot-mix asphalt (HMA) overlay were concluded to be effective in the short term, but not in the long term according to Kazmierowski and Sturm [8], who studied a concrete pavement rehabilitation project in Ontario, Canada. In contrast, Diefenderer and Mokarem [3] reported satisfactory performance with an experimental joint reinforced concrete pavement (JRCP) section on I-64 in Virginia, rehabilitated using full depth repair and PDR with HMA patching material and a 127 mm (5-in.) HMA overlay. Therefore, success with HMA varies, and field evaluations of patching materials are necessary.

Pavement performance information is important for maintenance and rehabilitation activities, as well as overall planning and budgeting purposes. Even though the mechanism that causes reflective cracking is well documented in literatures [10,7,11], transportation agencies can still take advantage of the lessons learned from the study.

The purpose of this paper is to disseminate information gained from over 9-year performance monitoring of Fiber Reinforced Polymer Patching Binder (FRPPB) repairs. This material is aimed at reducing and delaying reflective cracks over JCP. There is a section of US59 which has a 203 mm (8-in.) JCP, originally constructed in the early 1940s. Rehabilitation and maintenance of this section has always been a challenge to the responsible district. Four different treatment sections with FRPPB were selected for this study. Different milling strategies were also tried, from milling the entire existing AC to the bare JCP, to only milling the AC at the joints.

In addition, several PDR projects (ranging in age from 3 to 8 years) using the same FRPPB material were monitored and the performances were documented. The performance of FRPPB for reducing and delaying reflective cracks, filling the voids (due to lane separation) at longitudinal joints, and spalling repair are presented in the following sections. The results presented in the paper for the FRPPB material was from the same manufacture.

2. Material and installation

The repair material presented in this paper is a hot applied polymer modified binder consisting of bitumen (36%), polymers, graded fillers, granite aggregates, steel fibers, and fiberglass fibers. It also incorporates a recycled tire rubber that provides an impermeable, void-free solid at ambient temperatures. This material is henceforth referred to as the Fiber Reinforced Polymer Patching Binder (FRPPB). The current TxDOT [13] material specification for patching spalls in concrete pavement (DMS 6170) is presented in Table 1. The FRPPB utilized in this study met the DMS 6170 specifications, and its material properties are given in Table 2. Although results are from several different projects of different ages, they all used material from the same manufacturer, under the commercial name "Fibrecrete".

To prolong the life of the repair, all delaminated or debonded material needs to be removed, down to the solid substrate before FRPPB is applied. There are two common ways to remove the loose material for spall repair preparation (1) saw and chip (2) milling. The saw and chip method generally costs more than the milling method when small spot repairs are made. This is because a mill can follow the profile of a typical damaged area fairly closely, grinding it without much unnecessary loss of material. Since vertical saw cuts are used in the saw & chip method, a rectangular volume is removed, which must be replaced with a greater quantity of patch material. Depending on the dimensions of the repair area, the saw and chip method generally requires 2–27% more patch material than the milling method. Fig. 1 illustrates the difference between the two methods.

Fig. 2 illustrates the spalled areas (with a repair perimeter drawn) that are to be sawn and chipped. The completed spall repairs are also shown. No compaction is required to install the FRPPB material.

To enhance the patch material's bond, the manufacturer, Fibrecrete, recommends that after removing all the loose material, the hole or slot should be heated and a primer should be applied, as shown in Fig. 3. If the repair depth exceeds 51 mm (2 in.), the manufacturer recommends using bulking stone (with 100% aggregate passing 25 mm (1 in.) and 90% of aggregates between 12.7 mm (0.5 in.) and 25 mm (1 in.)) to enhance the load bearing capacity. To improve the surface friction, a topping stone with aggregate size of between #8 and #30 sieves is used. Topping stone and bulking stone should be heated before they are applied.

Table 2
Material characteristics for fiber reinforced polymer patching binder.

Binder properties	Method	Requirement
Bond	ASTM D 5329	Pass, 3 cycles @ −29 °C 50% extension
Cone penetration	ASTM D 5329	15 pen units min @ 4 °C
Ductility	AASHTO T51	40 cm min @ 25 °C
Flow	ASTM D 5329	3 mm max @ 60 °C @ 5 h
Resilience	ASTM D 5329	40% min @ 25 °C
Softening point	AASHTO T53	82 °C min
Flash point	AASHTO T48	410°F min

3. Retarding reflected cracking of AC overlays on JCP

3.1. Pavement sections

The 8-in. jointed JCP was originally constructed in the early 1940s. Traffic along US59 in this area is about 26,000 vehicles per day. The percentage of trucks is relatively high at 26%. Due to the high percentage of trucks, the expected 80 kN (18-kip) Equivalent Single Axle Loads (ESALs) count over a 20-yr period (starting 2013) is in the range of 42 million. There are total of four sections. Different strategies with different milling depth and different slot dimensions were utilized to gain knowledge on retarding the reflected cracks on the AC overlay on top of JCP. This consisted of milling the entire existing AC to the bare JCP, to only milling part of the AC at the joints.

Table 1
Current TxDOT material specification for patching spalls in concrete pavement (DMS 6170).

Test	Method	Type I
Gel time, min.	Tex-614-J, Testing Epoxy Materials	5 minimum–60 maximum
Wet bond strength to concrete, psi	Tex-618-J, Testing Elastomeric Concrete	100 minimum
Compressive strength 24 h psi	ASTM "C 579, Standard test methods for compressive strength of chemical-resistant mortars, grouts, monolithic surfacings and polymer concretes"	200 minimum
Compressive stress @ 0.1 in., 7 days, psi	Tex-618-J, Testing Elastomeric Concrete	200 minimum
Resilience, %	Tex-618-J, Testing Elastomeric Concrete	90 minimum
Thermal compatibility one cycle is 8 h @ 60 °C followed by 16 h @ −21 °C determine results after 9 cycles	ASTM "C884/C884M, Standard test method for thermal compatibility between concrete and an epoxy-resin overlay," with modifications	No delamination or cracking

Type I is a flexible material with high resilience properties.