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Field performance evaluations of partial-depth repairs

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ABSTRACT

Before partial-depth repair using proper materials was implemented, Houston District of Texas Department of Transportation had to repair spalls and punchout constantly in the Continuously Reinforced Concrete Pavement (CRCP) pavements on US290 and SH6. The full-depth repair to address the cracking on US75 did not work well. Spalls, wide, cracks and punchouts due to mid-depth horizontal cracks represent functional and structural distresses in Portland cement concrete pavement. Traditionally, these distresses were repaired by partial-depth repair (PDR). The performance of PDR varies substantially. Two types of polymeric patch materials were used to repair the distresses. Material A is polyurethane-based and Material B is epoxy-based. Material A was used to repair spalls in CRCP. It provided quite satisfactory performance for more than 9 years. Material B was used to repair cracks in jointed concrete pavement and CRCP. Its performance was satisfactory when applied to stable slabs and the loose concrete was completely removed. Compared to full-depth repair (FDR), PDRs utilizing polymeric patch materials are much more cost-effective, and PDR takes much less time than FDR. It is believed that both chip-and-patch and saw-and-patch methods would work as long as the delaminated areas are completely removed and the concrete slabs are stable (e.g. no settlement or movement under moving trucks).

1. Introduction

Spalls have been observed on various highways in Texas, as shown in Fig. 1. Spalls tend to propagate under repeated thermal stresses and/or traffic loadings. They usually start on the pavement surface and lead to the eventual dislodging of concrete. Spalls reduce pavement serviceability, and if left unrepaired, 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]. Compared to full-depth repair (FDR), PDR offers advantages such as less construction cost and time, shorter lane closure and less damage to the existing pavement. The 1998 ACPA manual indicates that spalls and cracks can be corrected by PDR, as long as they are well sealed. It is believed that hairline and narrow cracks still maintain aggregate interlock and can effectively transfer loads. Thus, PDR can be an effective repair method for spalls and cracks, improving functional performance of pavement and extending pavement life. For jointed concrete pavements (JCP) or continuously reinforced concrete pavements (CRCP), PDR offers a less intrusive rehabilitation measure than FDR by keeping the existing longitudinal steel intact, which better preserves the pavement continuity and ride quality [9]. PDR replaces unsound 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. There is not much literature documenting the long-term field performance of different patch materials used for PDR.

It has been reported that 8–10% of all spalls repairs fail within 1 year and 50% of all pavement repairs fail within the first 5 years [15]. Concrete pavements rehabilitated with Hot Mix Asphalt (HMA) patching followed by an HMA overlay were concluded to be effective in the short term, but not in the long term according to Kazmierowski and Sturm [11] who studied a concrete pavement rehabilitation project in Ontario, Canada. In contrast, Diefenderer and Mokarem [7] reported satisfactory performance with an experimental joint reinforced concrete pavement (JRCP) section on I-64 in Virginia, rehabilitated using FDR and PDR with HMA patching material and a 5-in. HMA overlay. Therefore, success with HMA varies, and field evaluations of patching materials are necessary.

The effectiveness of PDR depends largely on the mechanical properties of the repair material used. Desirable properties for patch materials include easy mixing, rapid strength development,

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Fig. 1. Spalls on different highways.

Fig. 2. Partial-depth repair (PDR) and the ability of Material A to bridge the transverse cracks in the concrete.

short curing time, strong bond strength, long term durability, thermal compatibility with the substrate concrete, and reasonable cost. There are a number of patching materials available in the market. Markey et al. [13] performed extensive laboratory and field investigations of 10 patch materials that have been used in Texas and found that polymeric patch materials performed best. Fig. 2 shows that polymeric patch material was able to bridge the transverse cracks in the concrete pavement and demonstrated a high resistance to propagation of cracks. There is a good bond between polymeric patch materials and the substrate concrete.

This paper documents the field performance of two polymeric patching materials used in a number of PDR projects in Texas over the last 9 years. The performance information in this paper is derived from simple visual observations, without in-depth mechanical and chemical investigation. Visual inspection, distress score and ride quality from the Pavement Management Information System (PMIS) was used to assess the long-term field performance of various patching materials.

2. Suitable distress for PDR

There are three types of the distresses that make PDR suitable for a CRCP: (1) spalls (2) wide cracks (3) punchouts due to mid-depth horizontal cracks. These failures are confined to the upper half of the slab. On the other hand, when the distress has progressed to the bottom half of the slab, full-depth repair should be selected. Successful PDR experiences on US290, SH6 and US75 are illustrated in subsequent sections. Fig. 3 illustrates a typical punchout due to a mid-depth horizontal crack. The same figure shows the concrete cut and removed to expose the mid-depth horizontal crack. The spall and punchout are the main distresses of CRCP. The wide crack and spall are the main distress of JCP. The focuses of this paper is to discuss the use of patch material in the repair of partial depth distresses in concrete pavements which include both CRCP and JCP. The following explains the mechanisms of spalls and punchouts due to mid-depth horizontal cracks. Mechanisms of wide cracks can be found in the literature [9].

2.1. Spall

Markey et al. [13] reported that the cause of the spalling has been attributed to several factors, including how the concrete is cured and the use of certain types of siliceous river gravel (SRG) that have a high coefficient of thermal expansion (CTE) and modulus of elasticity (E). High CTE and E cause larger curling and warping stresses for given environmental loading (temperature and moisture variations in concrete), resulting in higher potential for delamination and spalls.

Previous research has shown that delamination occurs at early stages due to differential volume changes in concrete that result from temperature and moisture variations near the surface [10,16]. These cracks are parallel to and at a shallow depth below the surface of the pavement. It is believed that the horizontal cracks form at an early stage due to large evaporation-induced stress gradients that cause shear stresses near the pavement surface. The evaporation and resulting stresses are affected by wind speed, relative humidity, concrete temperature, and air temperature. The critical factors affecting the temperature and moisture gradients in concrete include: (1) concrete placement temperature, (2) composition and amount of cementitious material used in the concrete, (3) effectiveness of curing operations and (4) environmental conditions during and after the concrete placement. Once delamination has formed, it often develops into severe spalls.

The longitudinal joint construction calls for a saw cut to a specific depth. Late or shallow saw cutting of longitudinal joints, and inadequate base support under the concrete slabs have been found to be the causes for wide or irregular cracks [3].

Spalls and wide or irregular cracks are very expensive to repair. Field observations have indicated that some of the repair methods have not been effective, as more repairs are required on a yearly