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Correlating laboratory and full-scale reflective cracking tests for airfield pavements

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HIGHLIGHTS

- Laboratory and full-scale tests were studied to evaluate reflective cracking.
- A customized Overlay Tester (COT) and Cyclic Disc-Compact Tension (CDCT) tests were used for laboratory testing.
- A set of shift factors were developed to correlate full-scale test data to laboratory test results.

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ABSTRACT

Asphalt overlays minimize moisture infiltration and help in restoring the smoothness and structure of existing airfield concrete pavements, but due to reflective cracking, the new asphalt overlay often fails before achieving its design life. In airfields, the potential for reflective cracking presents a major challenge for rigid pavement rehabilitation involving asphalt overlays. To assist airport engineers and others concerned with the temperature-induced reflection cracks, several full-scale test pavements have been constructed, instrumented, and tested at the Federal Aviation Administration (FAA) National Airport Pavement Test Facility (NAPTF). The main objective of this study was to identify and develop correlations between full-scale and laboratory reflective cracking tests. A customized Overlay Tester (COT) and Cyclic Disc-Shaped Compact Tension (CDCT) Test were used evaluate the fracture and fatigue performance of hot mix asphalt (HMA) materials at low temperatures. The COT was conducted at the same conditions as the full-scale tests and test results were analyzed using several parameters. Temperature effect was pronounced in strain parameters (initial strain, failure strain, and strain at $N_{f(NLC)}$). Further fatigue parameters ($N_{f(crack)}$ and $N_{f(NLC)}$) indicated a swifter deterioration of HMA mixture at a higher displacement (cooling) rate. Fracture parameter (Gf_{ini}) was found to decrease with the increase of displacement rate due to the brittleness of HMA at low temperatures as excepted. A two-term exponential function from the CDCT tests demonstrated the fracture behavior of HMA under cyclic loading. The released energy rate factor (R2) correlated well with the fatigue life. Finally, a set of shift factors were derived between the full-scale, OT, and CDCT tests. Valuable data obtained from this study provides immediate support to the future FAA reflective cracking research.

1. Introduction

Hot mix asphalt (HMA) is primarily used as an overlying material over a Portland cement concrete (PCC) pavement as it is economical when compared to PCC rehabilitation or other alternatives. However, because of the PCC pavements' existing poor condition, many HMA overlays are exposed to extreme movements [6]. The opening and closing of joints and/or cracks induced by daily temperature changes and vehicle loading contribute to the rapid propagation of the subsurface defects through the overlay to the surface. This type of distress is usually known as reflective cracking. In other words, reflective cracking is the cracks that occur in HMA pavements directly over any underlying crack or joints. Fig. 1 illustrates the two mechanisms, which causes reflective cracking in the pavements. As shown in Fig. 1(a), the horizontal movement of the slab is usually due to temperature changes that cause tensile and bending stresses to develop in the overlay. Further, the vertical movement at the joint/crack area (Fig. 1(b))

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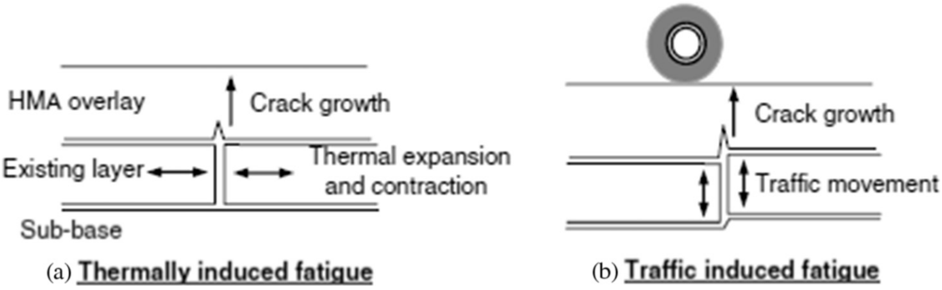

Fig. 1. Mechanisms of reflective cracking [23].

is primarily load induced and creates shear and tensile stresses within the overlay.

In airfields, the potential for reflective cracking presents a major challenge for rigid pavement rehabilitation involving asphalt overlays. Reflective cracking has been studied by several researchers [6,12,24,41], but very few research have been done on reflective cracking especially for airfields [33–36]. A series of full-scale testing has been conducted at the Federal Aviation Administration (FAA) National Airport Pavement Test Facility (NAPTF) to address reflective cracking for airfields [37–40] for HMA overlaid rigid pavements as the current FAA Advisory Circular does not address this failure mode [10].

Many researchers [11,2,8,19,32,3,7,1,14,5,13,17,20,21] have studied fracture and fatigue of HMA in the laboratory to understand the failure mechanism. In particular, two test methods – Cyclic Disc-Compact Tension (CDCT) Test and Texas Overlay Tester (OT) – seems useful for reflective cracking research. The CDCT test was recently introduced by [9] to facilitate the cyclic fracture test. Further, the Texas OT [28] has been used by many researchers [15,18,31,42–44] to study reflective cracking in the laboratory as it simulates the horizontal joint movements in the joint/crack vicinity of PCC pavements. Recently, the OT was customized to better understand the cracking resistance of asphalt mixtures [22]. This customized OT (COT) was developed with a similar mechanism to the full-scale tests conducted at the FAA-NAPTF. As full-scale tests are expensive and time-consuming, an effort to correlate the full-scale test data to laboratory test data is proposed in this paper. The main objectives of the study were:

- Characterize the fracture and fatigue performance of HMA mixtures using COT and CDCT test .
- Assess cooling effects on the crack propagation using the COT.
- Identify fatigue and fracture parameters that can correlate laboratory to full-scale tests.

2. Experimental plan

2.1. Full-scale testing

Several full-scale reflective cracking tests have been conducted at the FAA NAPTF. As shown in Fig. 2, the test pavement consisted of two 1.5-m wide HMA overlay sections atop two 305-mm thick, 4.6 × 4.6-m concrete slabs. A thin tack coat of neat PG 64-22 asphalt was applied on the milled concrete surface to prevent interface slippage and secondary cracks. Both sections had the same materials, Table 1 shows the aggregate gradation and volumetric of the HMA mixture (Performance Grade (PG) 64-22) as per P-401 specifications. Crack initiation and propagation were captured by instrumentation sensors. During the overlay paving, H-type asphalt strain gages (EG) were installed at the bottom of each lift. Once the pavement temperature stabilized, surface strain gages (SG) were installed at the various locations on the pavement surface and edges. The section plans for the full-scale tests is shown in Fig. 3. Two different overlay thickness (127 mm and 178 mm) were used as seen in Fig. 3(b). Data from only the 127-mm thick overlay was used in this paper. Note that all sensors were directly above and perpendicular to the PCC joint. Thermocouples were installed at three depths (surface, mid-depth, and bottom) in the overlay to acquire the temperature profile.

The full-scale tests were operated using the Temperature Effect Simulation System (TESS), which consists of hydraulic and temperature units [33]. The temperature unit was designed to maintain the overlay bottom temperature at 0° C, which was identified as the critical temperature. The function of the hydraulic unit was to generate forces that create precise and repeatable horizontal displacement to simulate joint opening and closing induced by

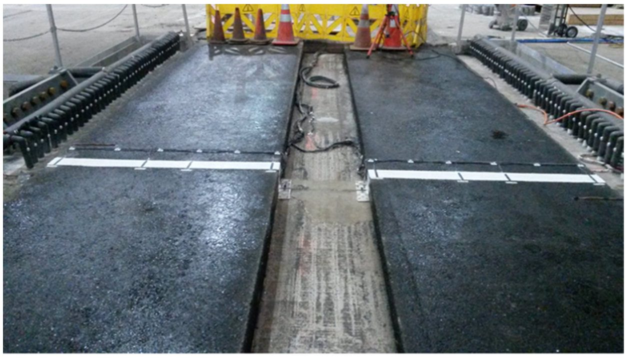

Fig. 2. Full-scale test pavement.

Table 1
Aggregate gradation and volumetrics of studied HMA mixture.

Sieve size (mm)	Cumulative passing (%)	
	Blended aggregates	P-401 specifications
19	100	100.0
12.5	95.4	79–99
9.5	87.5	66–88
4.76	62.9	48–68
2.36	36.9	33–53
1.18	22.3	20–40
0.6	15.1	14–30
0.3	11.8	9–21
0.15	8.9	6–16
0.075	5.9	3–6
Maximum specific gravity	2.628	–
Bulk specific gravity	2.535	–
Optimum asphalt content (AC) (%)	5	4.5–7.0
Air voids (AV) (%)	3.4	2.8–4.2
Voids in mineral aggregates (VMA) (%)	15.4	≥15.0