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Effects of temperature variations on the deflections of airfield jointed plain concrete pavements

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ABSTRACT

This paper aims to study the influences of temperature variations on airfield jointed plain concrete pavement (JPCP) deflections. The maximum deflection at the transverse joint (D_0^j), the maximum deflection at the corner of a slab (D_0^c), and the deflection basin at the centre of a slab were considered. The in-situ deflection measurements at three civil airports were conducted over a 24-hour period and numerical simulations for JPCP at a civil airport were performed as well. The results indicate that the temperature change slightly affects the deflection basin at the centre of a slab unless the positive temperature gradient in the slab increases to exceed a certain critical value. But both D_0^j and D_0^c are significantly affected by temperature variations. The results of in-situ tests show that D_0^j (or D_0^c) is almost stable from 1 pm and 5 pm in a day. At other times of one day, there is a strong negative liner correlation between D_0^j (or D_0^c) and the pavement surface temperature during the heating period and the cooling period, respectively. The results of numerical simulations reveal that both D_0^j and D_0^c gradually increase with the increase of the average temperature. The results of numerical simulations also suggest that a critical negative/positive temperature gradient exists at the transverse joint while there is a critical positive temperature gradient at the slab corner. Besides, all the critical temperature gradients are seldom affected by the average temperature. When the temperature gradient exceeds the critical value, D_0^j, D_0^c and all values of the deflection basin have a strong positive linear correlation with the temperature gradient.

1. Introduction

The pavement deflections, which are usually measured by Falling weight deflectometer (FWD), are widely used to evaluate the load-carrying capacity of airfield jointed plain concrete pavement (JPCP), load transfer efficiency (LTE) of joints and voids underneath the slab (CAAC, 2009; FAA, 2011). However, cement concrete has a significant characteristic of thermal expansion and contraction. With temperature variations, the deformation of JPCP slab may vary substantially (Guo and Marsey, 2001; Rufino et al., 2004; Zhao et al., 2017). As a result, the measured pavement deflections would be inconsistent in various temperature conditions, even at the same locations (Guo and Marsey, 2001).

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Uddin et al. (1983) earlier studied the effects of temperature on deflections of continuously reinforced-concrete pavements in Texas, and the results indicated that the temperature differential in the slab significantly affected the slab edge deflection. Subsequently, Gustavo et al. (1987) found that deflections at the mid-span of the slab remained almost constant but the slab edge deflection varied obviously with the temperature differential in the slab. Similarly, Owusu-Antwi et al. (1990) found that temperature gradient had little effect on the slab interior deflection. However, Ozbeki et al. (1985) and Zhao et al. (2007) paradoxically concluded that the temperature gradient in slab had a significant effect on midslab deflections. Vandenbossche (2003) ever found that concrete pavement deflections would be affected by temperature variations and tried to interpreted deflections at the Minnesota Road Research Facility (Mn/Road). Besides, Tang and Yoshitaka (1992) conducted in-situ FWD testing at different daytimes on Haneda airfield pavements, and the results showed that both the maximum deflections at the edge and at the corner varied linearly with the pavement surface temperatures at daytimes. Recently, Nam et al. (2014) also studied the effects of daily pavement surface temperature variations on in-situ pavements deflection by continuous rolling dynamic deflectometer (RDD) measurements. What's more, FAA (2016) suggests conducting FWD at a time when the temperature is relatively constant between the day and night in order to avoid effects of temperature variations.

According to the literatures, most field investigations were conducted during daytime. Practically, it is inevitable to perform the FWD testing on airfield pavements at night. It is meaningful to investigate the influences of round-the-clock temperature variations on airfield JPCP deflections. Another issue to be considered is that the influences of temperature variations on JPCP deflections can be explained in two perspectives: temperature gradient (or temperature differential) and average temperature. On one hand, temperature gradient that exists through the thickness of the slab may cause the slab to curl (Guo and Marsey, 2001). This will affect the support of underlying layers, which has a significant effect on deflections (Uddin et al., 1983; Gustavo et al., 1987; Ozbeki et al., 1985; Zhao et al., 2007; Vandenbossche, 2003). On the other hand, the concrete slab adjusts to average temperature variations by contraction or expansion, resulting horizontal movement of the slab. The horizontal movement of the slab changes the joint opening, which affects LTE especially for aggregate interlock joints (Khazanovich and Gotlif, 2003; Rufino et al., 2004; Kohn et al., 2011). Theoretically, JPCP edge deflections are closely related to LTE. Therefore, further study is essential to better understand the influences of temperature variations on airfield JPCP deflections.

This paper focused on the maximum deflection at the transverse joint, the maximum deflection at the corner of a slab and the deflection basin at the centre of a slab. In-service airfield JPCPs at three civil airports in China were characterized in terms of 24-h continuous deflections measured by FWD. The tested deflections with round-the-clock pavement surface temperatures were statistically analysed. Furthermore, relying on "Pavement Condition Monitoring System (PCMS)" at a civil airport in China (Zhao, 2014), a series of numerical simulations were conducted to study the influences of temperature variations on deflections from two aspects: temperature gradient and average temperature. This work are expected to improve the understanding of the influences of temperature variations on airfield JPCP deflections.

2. Field investigations of pavement deflections

2.1. Site description and testing method

Four pavement types were investigated at three civil Airports (A, B, C) in China, which are illustrated in Fig. 1. The JPCPs in Airport A and C have been used for 10 years and 5 years, respectively. The old JPCP in Airport B has been already used for 8 years and the new JPCP is just used for one year. All investigated slabs are 5 m wide and 5 m long. The transverse joints of all investigated JPCPs are dummy joints. The longitudinal joints in Airport A and B are groove joints while Airport C has tied joints.

This research applied FWD to measure deflections, and the configuration of the sensors and loading plate was illustrated in Fig. 2. The applications of this machine indicate that no reason has been found to challenge the results reliability. Two slabs were randomly selected for each type of JPCP. The FWD testing is illustrated in Fig. 3. Deflections at three locations (transverse joint, slab centre, and slab corner) were tested with the loading of 140 KN and pavement surface temperatures were also recorded at the same time. The testing was performed every hour with the duration of 24 h and testing at certain locations was repeated three times. All testing were conducted on sunny days and the moisture conditions of the slabs were almost stable during the testing period. Therefore, the influences of moisture on deflections can be ignored.

2.2. Analysis of in-situ deflections

According to the related evaluation (CAAC, 2009; FAA, 2011), this paper analysed the maximum deflection at the transverse joint (D_0^j), the maximum deflection at the corner of a slab (D_0^c), and the values (D_0–D_8) of the deflection basin at the centre of a slab. The averaged three deflection (and temperature) measurements were reported as the final result. The Averaged deflections (and temperature) of two investigated slabs were adopted as the typical results for each JPCP type. As an example, results of the old JPCP in Airport B are shown in Fig. 4. It can be found that the values (D_0–D_8) of the deflection basin at the centre of the slab slightly vary with pavement surface temperatures while both D_0^js and D_0^cs change significantly.

To evaluate the strength of the relationship between measured deflections and pavement surface temperatures, Spearman's correlation analyses were carried out. The analysis results for each type of JPCP are given in Table 1. The selected