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Experimental evaluation of crack width movement of continuously reinforced concrete pavement under environmental load

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HIGHLIGHTS

- Crack width movements in CRCP under temperature changes are measured in situ.
- Crack width movements along the 3D directions are comprehensively analyzed.
- Effects of crack spacing and crack occurrence time on crack width are evaluated.
- Effects of steel ratio and base layer type of CRCP on crack width are investigated.
- Suggestions to improve CRCP performance concerning crack width are proposed.

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ABSTRACT

This study investigates movements of transverse crack width of the continuously reinforced concrete pavement (CRCP) subjected to environmental loads such as changes in temperature. To this end, in-situ experiments were carried out at several highway CRCP sections. The crack width movements were analyzed along the vertical, transverse and longitudinal directions to comprehensively understand the crack width behaviors of CRCP. The effects of design related variables such as steel ratio and base layer type and performance related variables such as crack spacing and crack occurrence time on crack width movements were evaluated. Based on the findings from this comprehensive experimental study concerning crack widths, suggestions were proposed to improve the performance of CRCP.

1. Introduction

The continuously reinforced concrete pavement (CRCP), one of typical rigid pavement types, is subjected to environmental loads such as changes in temperature and moisture, similar to other road pavements. The continuously placed longitudinal steel bars in the CRCP slab coupled with the friction between concrete slab and base layer would resist the contraction behavior of the CRCP slab due to temperature drop and drying shrinkage of concrete. As the applied tensile stresses in the concrete slab reach the tensile strength of concrete, cracks will finally occur in the transverse direction of the concrete slab. The longitudinal steel bars in CRCP are designed to hold the naturally formed transverse cracks tightly to ensure structural continuity of pavement and to mitigate penetration of water and dust at cracks. Since in CRCP there are no artificial transverse joints used in the jointed concrete pavement (JCP), distresses such as spalling and faulting and reduction in load transfer efficiency at joints are not concerns. Due to its outstanding long-term performance such as little distresses and higher load transfer efficiencies at naturally formed transverse cracks, CRCPs are widely used in many countries [1–8].

To assure excellent long-term performance of CRCP, one of the most important factors that should be considered is the width of naturally formed allowable transverse crack. The transverse crack width is not always constant and varies due to environmental loads such as temperature and moisture changes as illustrated in Fig. 1. The crack width movements may be affected by a lot of factors such as the slab depth, crack occurrence time, steel ratio, steel depth, crack spacing, friction at slab bottom, transverse and

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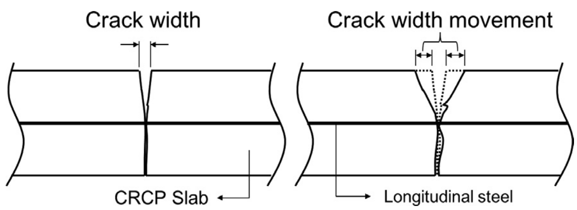

Fig. 1. Crack width movements at transverse cracks of CRCP.

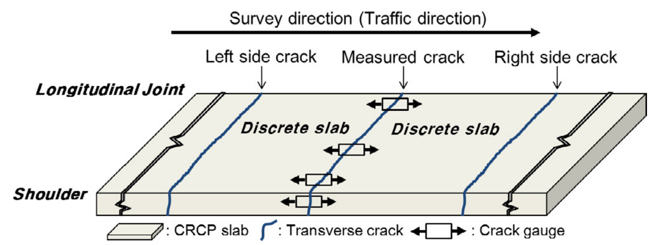

Fig. 2. Crack width measurement condition.

longitudinal locations, etc. The crack width and its movements should be retained as smaller as possible toward better performance of CRCP. For instance, due to the formation of small crack width movements, limited reflection cracking in asphalt or concrete overlays on existing old CRCP [9,10] as well as good performance of composite pavements of asphalt layer on CRCP [11–13] have been observed. Even though the crack width is used as one of important design variables of CRCP [14,15], the relationships between crack width and other variables are not clearly verified based on in-situ tests [16–20]. Therefore, comprehensive studies to understand crack width behaviors of CRCP are needed.

The objective of this study is to investigate comprehensively movements of transverse crack width of CRCP subjected to environmental loads such as changes in temperature. To this end, full-scale field experiments are carried out at several highway CRCP sections. Using the measurement data, the crack width movements are analyzed along the vertical, transverse and longitudinal directions to thoroughly understand the crack width behaviors of CRCP. In addition, the effects of design related variables such as steel ratio and base layer type and performance related variables such as crack spacing and crack occurrence time on crack width movements are evaluated. By considering the characteristics of crack width movements obtained in this study, suggestions are proposed to improve the performance of CRCP.

2. Field experiments

A series of field tests was conducted to measure the crack width movements at several subsections of two different highway CRCP sections. The main difference between the two CRCP sections lies in the composition of underlying layers. A CRCP section has an asphalt bond breaker layer between the concrete slab and lean concrete base (referred to as A-CRCP herein), and the other has a lean concrete base directly beneath the concrete slab (referred to as L-CRCP herein). The measurement of crack width movement is performed at a selected crack when that crack and both the next cracks all propagate completely through the depth of slab. The next crack from the selected crack in the traffic direction is defined as the right side crack, and that in the opposite direction the left side crack as shown in Fig. 2. It is noted that if the crack width movements are measured as soon as cracks form, the crack width movements will be affected by both the drying shrinkage of concrete and temperature changes. In this study, however, since the measurements are performed at several year old CRCP sections, the drying shrinkage effect can be negligibly smaller and the crack width movements will mainly be affected by temperature changes.

2.1. A-CRCP test section

The A-CRCP section that includes an asphalt bond breaker layer beneath the concrete slab was constructed at the Korea Expressway Corporation Test Road (KECTR) in 2002 [21]. The A-CRCP section is 390 m long and composed of three different subsections depending on the steel ratio. The C1, C2, and C3 subsections have the steel ratios of 0.6%, 0.7%, and 0.8%, respectively. The longitudinal steel bars locate at the mid depth of the concrete slab and the thicknesses of the concrete slab, asphalt bond breaker, and lean concrete base are 300 mm, 50 mm, and 150 mm, respectively.

Crack surveys were conducted periodically at the A-CRCP section just after concrete placement to record the locations and occurrence times of cracks. Table 1 lists crack survey times and crack numbering method. The first number of a crack represents the crack survey number and the second number shows the sequence of crack occurrence at a selected crack survey time. For instance, Crack 5-3 designates the crack that was revealed first at the 5th crack survey performed in May 2005 and was the 3rd newly discovered crack from the beginning location of crack survey at the 5th crack survey.

The measurements of the crack width movement at the A-CRCP section were performed at the C1 and C3 subsections as shown in Fig. 3. At the C1 subsection, the crack width movements along the depth of slab were measured. At the C3 subsection, the crack widths were measured in the summer and winter at the selected cracks to investigate the seasonal effect of the crack width movement. In addition, since the C1 and C3 subsections have different steel ratios and are closed to the free end terminal and the anchor lugs, respectively, the effects of steel ratio and longitudinal location on the crack width movement were investigated by comparing measurement data.

At the C1 subsection, the crack width movements were measured at three cracks of 4-1, 1-17, and 1-23 as shown in Fig. 4 at the side of slab after removing part of shoulder pavement. The cracks 1-17 and 1-23 occurred soon after concrete placement and the average crack spacings to adjacent cracks are 1.75 m and 1.35 m, respectively, as shown in Table 2. The crack 4-1 formed 2 years later and the average crack spacing to adjacent cracks is 0.9 m. At Cracks 1-17 and 1-23, the measurement gages were installed at four different depths of slab, which were 250, 180, 130, and 70 mm from the bottom of slab, in order to evaluate the crack width movements depending on the vertical location of slab. The temperature measurement sensors were also installed at the top, mid depth, and bottom of slab to acquire temperature variations through slab depth.

Table 1
Survey of crack occurrence at A-CRCP.

Survey No.	Survey Time	Crack No.
A-CRCP placement	October 2002	–
1	After paving	1-n
2	September 2003	2-n
3	July 2004	3-n
4	October 2004	4-n
5	May 2005	5-n
6	October 2007	6-n
7	September 2010	7-n
8	May 2011	8-n
9	August 2012	9-n
10	May 2014	10-n
11	December 2014	11-n