Field Investigation into Early Age Behavior of Joint Plain Concrete Pavement

Park, Dae Geun* Suh, Young-Chan** Kim, Hyung-Bae***

ABSTRACT

The temperature variation of the concrete pavement in the early age significantly affects the initiation and propagation of its early age cracks. This implies that the measurement and analysis of early age temperature trend are necessary to examine the causes of early age cracks in the concrete pavement. In this study, it is investigated how the early age temperature trend in the concrete pavement affects the random crack initiation and behaviors of saw-cut joints using the actual construction site which is located at the KHC test road. During 72 hours after placing the concrete pavement, the ambient air temperature and temperatures at the top, middle, and bottom in the concrete pavement were measured and the random crack initiation in concrete slabs and early age behaviors in the joints were surveyed. The investigation results indicate that the first random crack was initiated at one of the slabs placed in the early morning which have higher temperature changes during early 72 hours. In addition, the joints that were saw-cut in the morning were cracked more rapidly than those saw-cut in the afternoon.

Keyword : Concrete Pavement, early age random crack, temperature variation

1. Introduction

Since 88 expressway was constructed, the most of national expressways has been constructed with the concrete pavement. Increasing the expressway network, various researches for improving design, construction, and material properties on the concrete pavement have been more widely conducted. However, the early age characteristics after the placement which is considered as a key factor of the long term performance in the concrete pavement has not been fully investigated.

In this study, the early age concrete pavement behavior was investigated measuring the temperature variation of the concrete pavement slab during early 72 hours after placement using the actual pavement section at the KHC test road (sta. 1+400~1+700). In order to stably measure inside temperatures of the concrete pavement, i-button, a embedded digital temperature sensor was used.

2. Concrete Pavement at the KHC Test Road

2.1 Cross-Section

Figure 1 shows the cross section of the joint plain concrete pavement (JPCP) constructed at the KHC test road for this field study.

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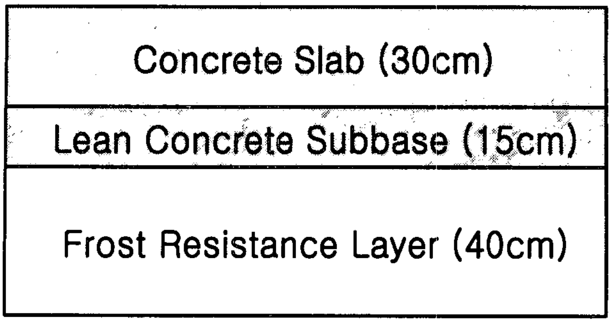


Figure 1 Cross-Section of JPCP at KHC Test Road

2.2 Construction Schedule

The pavement was constructed at the KHC test road on July 18, 2002. Starting at 8 AM with a slipform paver that can pave 2 lanes simultaneously, paving 300 meters long section was completed until 6 PM. The joint spacing was 6 meters and total number of slabs were 50. The curing compound spreading was begun at 10:30 AM.

2.3 Measurement and Survey

The measurement and survey items conducted in this study are listed in Table 1.

Table 1 Measurement and Survey Items

	Temperature Measurement (Air &Slab)	Crack Survey
Purpose	• Examine Temperature Variation • Analyze Causes of Crack Initiation	• Examine the Time of Crack Initiation • Examine Joint Cracking Rate in terms of Construction Time
Method	Digital Sensor (i-Button)	Visual Survey
Interval	10 minute	1~2 hours

2.3.1 Temperature Measurement : i-Button

In order to obtain vertical temperature profile in the concrete slab, a set of i-buttons attached to a small stick was embedded in a point that is 70cm apart from the shoulder between slip-form paving and tinning. Using i-buttons attached to the stick, the top (3cm deep), middle (15cm), bottom (27cm deep) temperatures in the concrete pavement were measured (Figure 2). In order to examine different temperature variations corresponding to different construction time, sets of i-buttons are embedded in 4 different points in construction sequence. The embedment time and location for each point is shown in Figure 3.

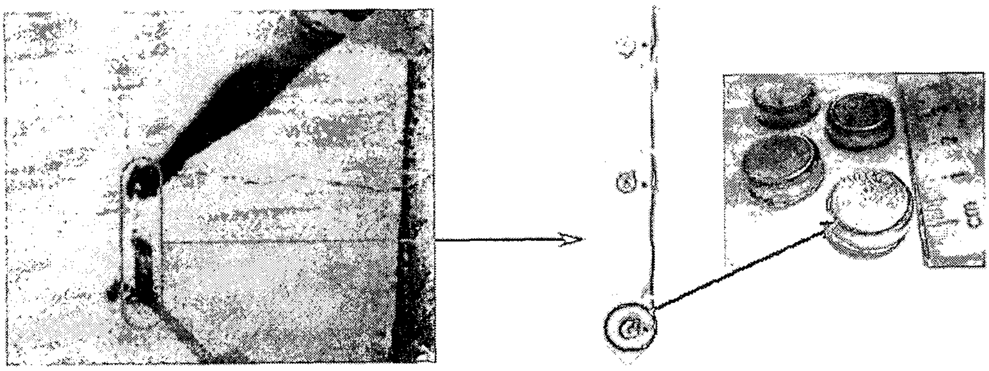


Figure 2 Embedment of i-Button

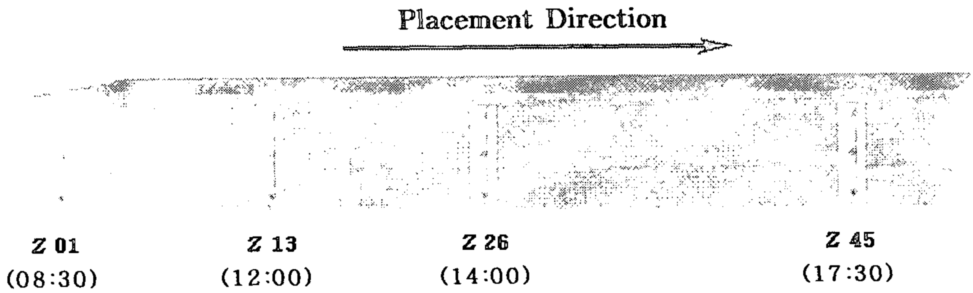


Figure 3 Temperature Measurement Points Selected with Different Construction Time

2.3.2 Crack Survey

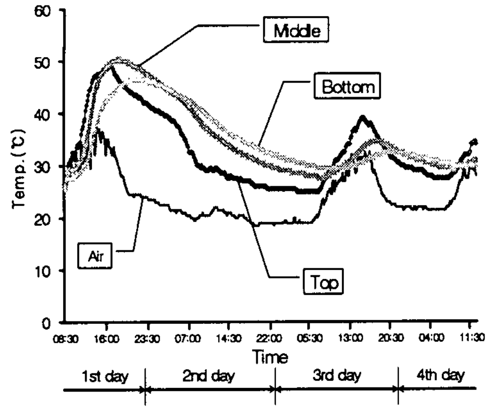
In this concrete pavement construction, the joint saw-cutting was delayed until the first random crack would be created in order to examine its initiation time and location. The survey was intensively conducted during nighttime because in summer the random crack is subject to create in the early morning of the day after the construction date.

3. Analyses and Results

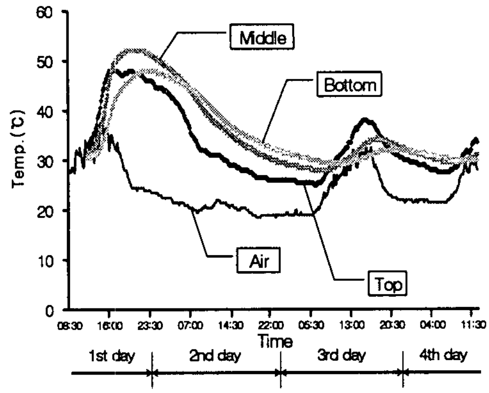
3.1 Temperature Variation for 72 Hours after Concreting

Figure 4 shows that temperature variations in each measurement point. The temperature at the second day was relatively low because it rained all the day. The highest temperature for all measurement points was caught in middle of the concrete slab implying that the heat of hydration in the mid-depth of the concrete slab was less affected by the variation of ambient air temperature than those in the top and bottom of the concrete slab. The lowest temperature in all measurement point was caught in top of the concrete slab. In Z26 and Z45, the peak temperature in top of the slab is much lower than that in middle and bottom of the slab, while in z1 and Z13, the peak temperature in top of the slab is similar to that in middle and bottom of the slab. This means that when the time that the heat of hydration is risen runs into the time that the ambient air temperature is dropping, the temperature in the top of the concrete slab will not much increases.

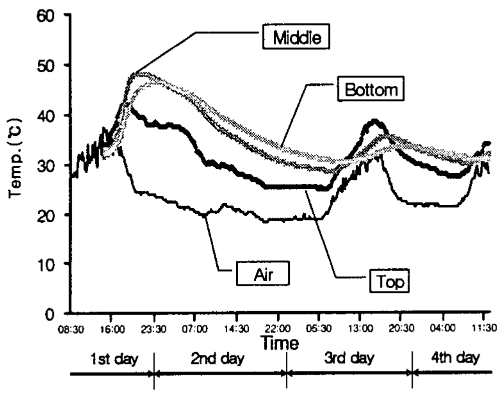
In Figure 5, the variations of temperatures in all measurement points had same trends since 7AM of the second day indicating that the temperature change due to the heat of hydration of portland cement may be ceased.



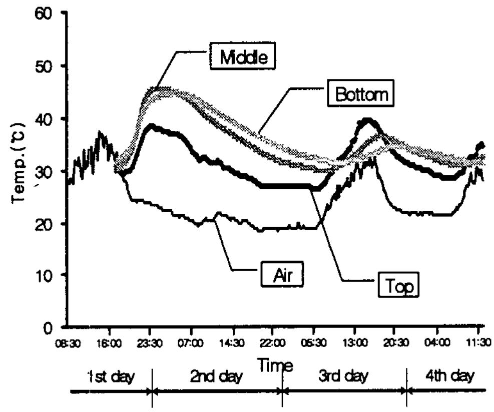
(a) Z 01



(b) Z 13

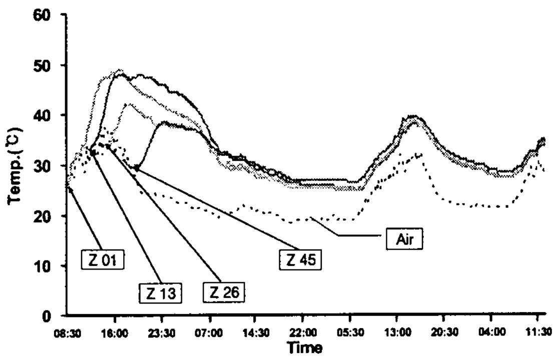


(c) Z 26

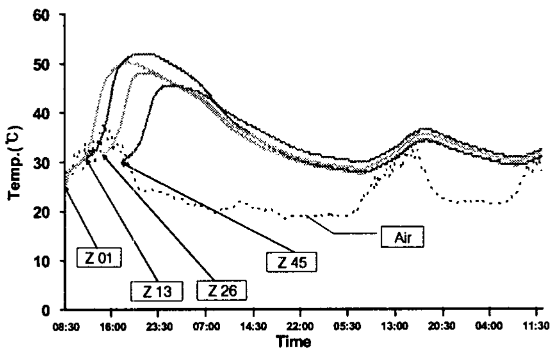


(d) Z 45

Figure 4 Temperature Variation at Each Measurement Point



(a) Top



(b) Middle

Figure 5 Different Temperature Variations based on Placement Time

3.2 Early Age Crack Due to Temperature Change

Figure 6 shows the difference between the peak temperature and the temperature at the first random crack initiation in the concrete slab at each measurement point. The temperature changes in the top, middle, and bottom of the slab at Z01 point, which is concreted in the early morning, is more than 4 times as much as those in Z45. This is because increasing ambient air temperature from morning to afternoon in Z01 accelerated the heat evolution by cement hydration, while decreasing ambient air temperature from afternoon to night in Z13, z26, and Z45 decelerated it. This extreme temperature change in the concrete pavement is a key factor to occur high tensile stress in the early age [Suh, 1991]. When the temperature more rapidly drops from the zero-stress point to the crack initiation point, the concrete slab is subject to undergo a higher volume contraction to introduce the random crack with a high tensile stress which is larger than the developed strength of the slab as shown in Figure 7. Therefore, the higher temperature change in the concrete pavement can yield higher probability of random cracking.. In this construction, the first random crack was initiated at the 5th slab (placement time : 9 AM) at around 6:00 AM the second day after the placement of concrete slabs. It was slightly different from our prediction in which the first random crack had been expected to be in the first slab that had the most temperature change. This is because the first slab has a free edge where some free movement can occur and relatively lower internal stress is developed, while 5th slab has no free slab movement and the free strain is fully translated into the internal axial stress. From a related study to this field investigation, the time for the first random crack initiation was estimated using a computer program predicting the strength and stress of an early-age concrete pavement (72 hour after placement), which is called HIPERPAV (HIgh PERformance PAVing software). As shown in. Figure 8, the prediction result also indicates that the first random crack at the 5th slab would be initiated at around 6 AM.

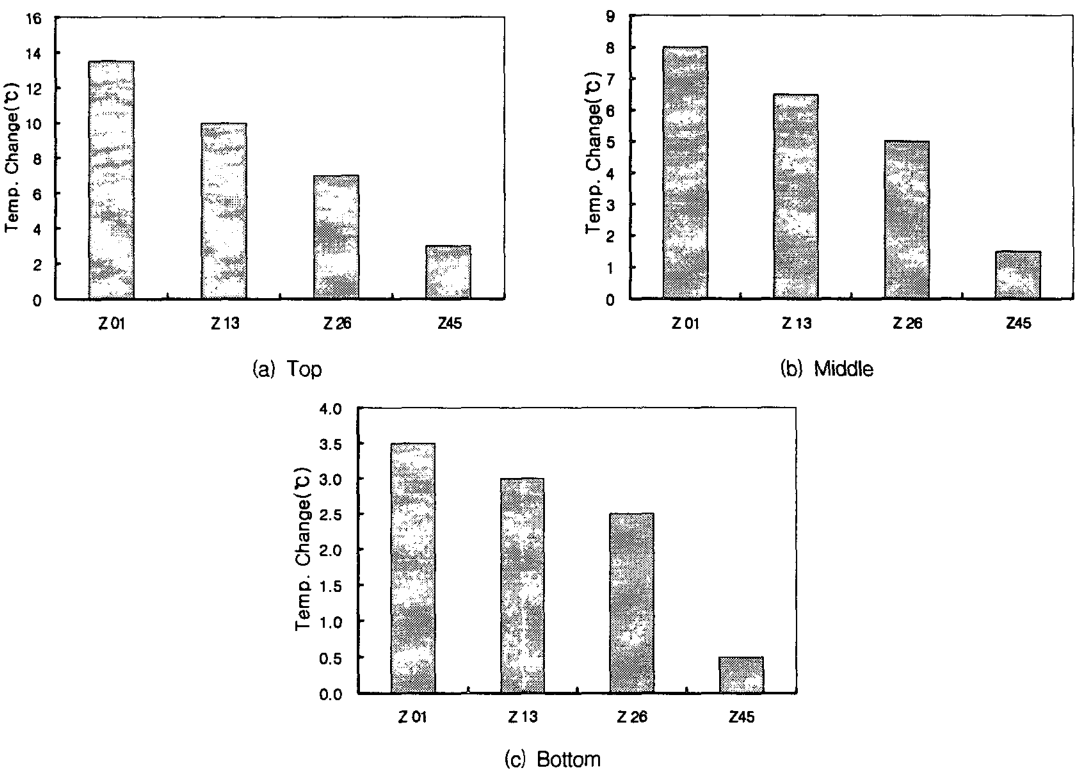


Figure 6 Temperature Change from the peak point to the first crack initiation in Each Measurement Point

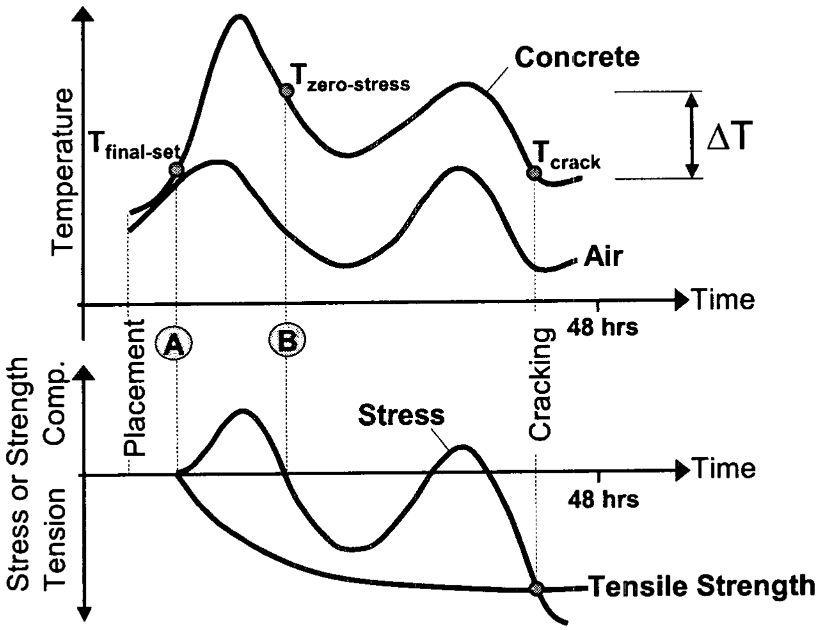


Figure 7 Effect of Temperature Change on Stress and Strength Development [McCullough, 1999]

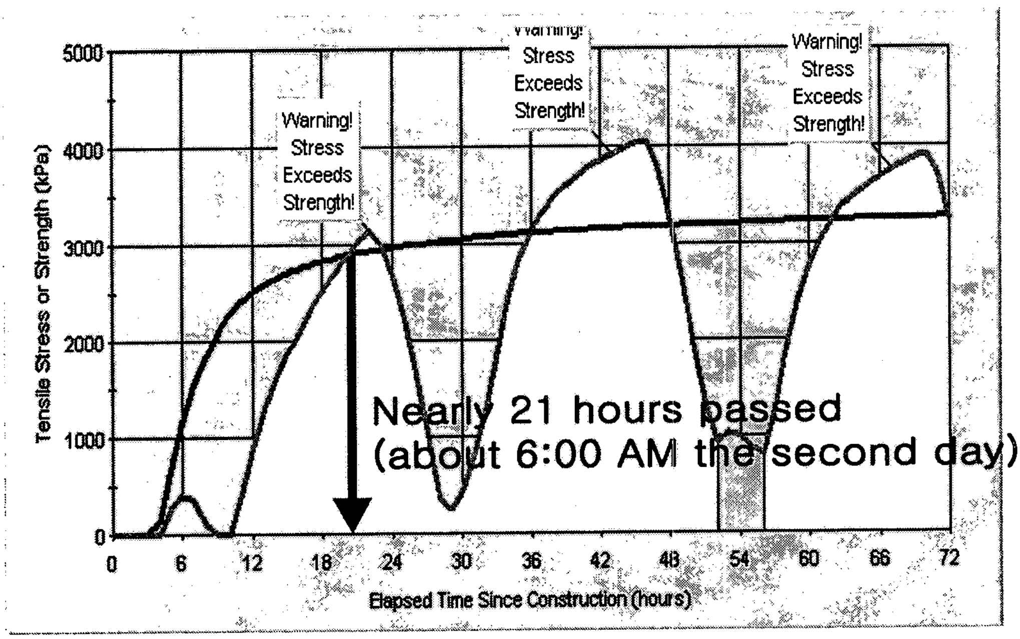


Figure 8 Effect of Temperature Change on Stress and Strength Development

3.3 Placement Time and Joint Crack

As mentioned above, right after the first random crack was initiated, the saw-cuttings of the joints were conducted in placement sequence. Figure 8 shows the proportion of cracked joints from all saw-cut slabs and crack creation time after saw-cutting at each joint. This figure indicates the joints in early placed slabs were more rapidly cracked than the joints in latter placed slabs. If 2:30 PM at which the air temperature reached the peak is assumed a diverging time between early and latter placements, 21 of 30 joints (70%) in early placed slabs were cracked within 72 hours after saw-cutting, while 5 of 20 joints (25%) in latter placed slabs after saw-cutting were cracked within the same period. This result can be explained with the same interpretation that was used for the initiation of the first random crack in the concrete slab. Namely, the higher temperature change of the concrete slab in the early age may lead more rapid crack creation.

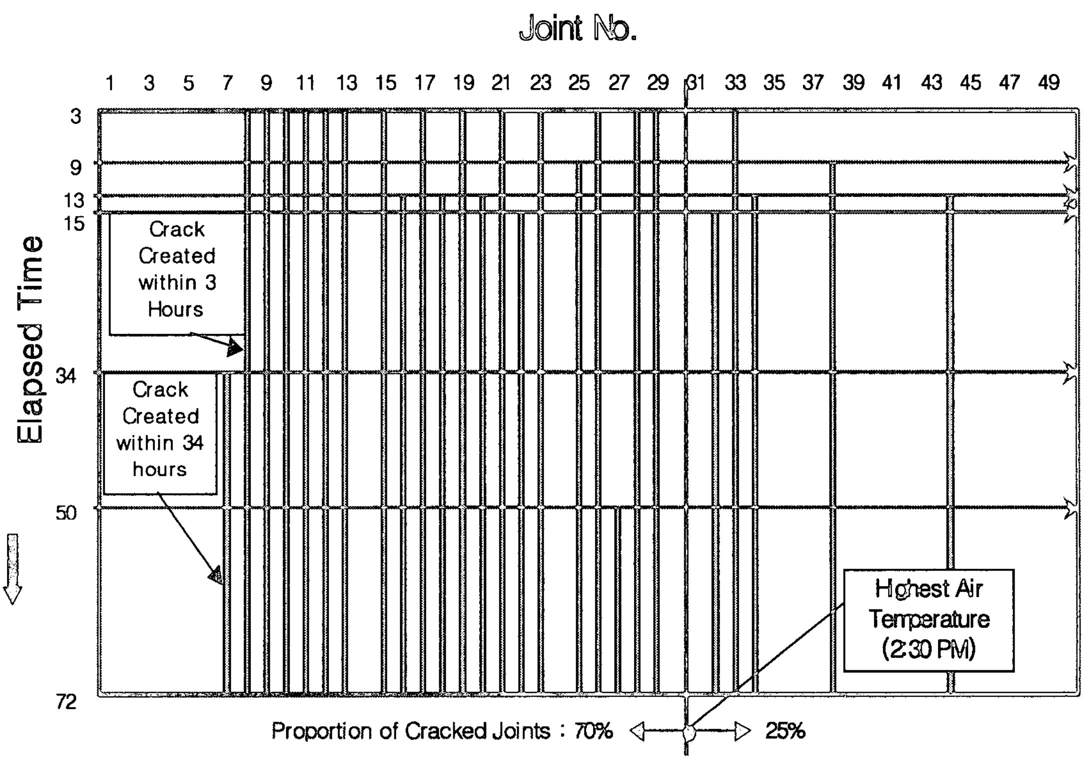


Figure 9 Proportion of Cracked Joints in Placement Sequence

4. Conclusion

In this study, the early age concrete pavement behavior was investigated measuring the temperature variation of the concrete pavement slab during early 72 hours after placement using the actual pavement section at the KHC test road (sta. 1+400~1+700). The inside temperatures of the concrete pavement slab were measured with a certain interval using i-button, a digital temperature sensor, and random crack initiation and early age behavior in the joints were visually surveyed. From this fie이 investigation, following conclusions were made.

1) The first random crack was initiated at the 5th slab (placement time : 9 AM) at around 6:00 AM the second day after the placement of concrete slabs. This slab has higher temperature changes from the peak temperature point to the

crack initiation point which makes the concrete slab undergo a higher volume contraction to introduce the random crack with a high tensile stress which is larger than the developed strength of the slab and has no free slab movement developing higher internal axial stress.

2) In this study, 300 meters long concrete pavement section was constructed. The section was saw-cut per 6 meters and divided into 50 slabs. Among the joints in these slabs, 26 joints were cracked within 72 hours after saw-cutting. The joints saw-cut in early placed slabs were more rapidly cracked than the joints saw-cut in latter placed slabs. This result can be explained with the same interpretation that was used for the initiation of the first random crack in the concrete slab. Namely, the higher temperature change of the concrete slab in the early age may lead more rapid crack creation.

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