Behaviors of Fiber Reinforced Cement Composite Thin Overlay under Restrained Shrinkage

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Summary

Restrained shrinkage and cracking behaviors of fiber reinforced cement composite (FRCC) overlay containing polyethylene and hooked steel fibers were investigated. The specimens, consisting of thin overlay cast on top of reinforced concrete base, were subjected to drying condition since the time of casting under the condition of high wind, high temperature, and low humidity. Free drying shrinkage and crack widths were monitored for 60 days. The experimental results showed that drying shrinkage was unaffected by the addition of fibers at low dosages. However, fibers reduced both the number of cracks and crack widths on the overlay layers compared to plain mortar overlay, with or without steel mesh reinforcement. Fibers were also effective in reducing the delamination of overlay from the concrete substrate. Polyethylene fibers were found to be more effective than hooked steel fibers in controlling shrinkage cracking.

Keywords: Fiber Reinforced Cement Composite (FRCC), Plastic Shrinkage, Drying Shrinkage, Crack, Overlay.

1. Introduction

One common method of repairing deteriorated bridge deck and pavement is to overlay with new wearing surface, either asphalt or cementitious concrete. However, cementitious overlay often has poor durability as it is prone to cracking, delamination, and spalling under restrained shrinkage.

Fiber reinforced cement composite (FRCC) overlays generally offer several advantages to plain concrete overlay including reduced cracking tendency under restrained shrinkage, control of crack widths, and increased ductility. However, the performances of such overlay strongly depend on the fiber types, amount of fibers, and matrix types. Different fiber mechanical properties and fiber geometries affect plastic and drying shrinkages differently and the effects of plastic shrinkage on the drying shrinkage at later time are not fully understood.

In this paper, laboratory tests of thin FRCC overlays containing steel hooked fibers and polyethylene fibers are presented. The overlays were subjected to restrained shrinkage caused by continuous water losses from the time of the casting until the age of 60 days under accelerated drying conditions.

2. Experimental Program

In order to evaluate the performance of FRCC overlay under restrained shrinkage, overlay specimens as shown in Figure 1 were used. The specimen consisted of 150×150×1000 mm reinforced concrete base with 25 mm overlay cast on top. The overlay layers were cast over hardened bases and cured under accelerated drying condition (T = 45±2 °C, RH = 50±5 %) to induce plastic and drying shrinkages. Two specimens were made for each mixture. Crack widths were measured at the age of 1, 7, 14, 28, and 60 days using a crack microscope.

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In addition, three companion free shrinkage specimens, 75×75×350 mm prism, were cast at the same time as the overlay layer and cured under the same condition. Shrinkage strains were measured at the same time as the crack measurements.

Two types of fibers were studied, steel hooked fibers and polyethylene fibers. Table 1 summarizes the specimen details. Two control specimens were made, one was plain mortar (CT0), and the other was plain mortar with steel mesh reinforcement (15 mm spacing, 0.66% volume ratio). The same mortar mixture was used for all the specimens.

3. Results and Conclusions

It was found that the free drying shrinkage of the FRCC mixtures and plain mortar were not substantially different due to the low volume of fibers.

However, the FRCC specimens showed significantly smaller crack widths and total crack area compared with plain mortar specimens, as shown in Figure 2. Specimens with steel mesh reinforcement showed comparable crack area as FRCC with 0.5% steel fiber. Increasing steel fiber content decreases the total crack area as well as the maximum crack width. Cracks occurred during the first day and increased in widths and lengths mostly during the first 14 days. On the other hand, FRCC specimens with polyethylene fibers between 0.25%-1.0% did not crack for 60 days.

It was also observed that FRCC specimens exhibited less delamination under the restrained shrinkage. Both mortar overlay specimens (with or without steel reinforcement) completely delaminated from the base. Whereas FRCC overlays remained largely attached to the base. Polyethylene fibers were more effective than the steel fibers in controlling the delaminations.

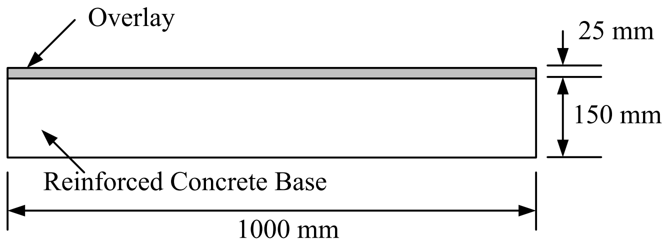

Fig. 1: Overlay Specimen Details

Table 1: Specimen Details

Specimen Designation	Fiber Type	Volume of Fiber (%)
CT0	-	-
CTS	-	-
ST0.5	Hooked Steel	0.5
ST1.0	Hooked Steel	1.0
ST1.5	Hooked Steel	1.5
PE0.25	Polyethylene	0.25
PE0.5	Polyethylene	0.5
PE1.0	Polyethylene	1.0

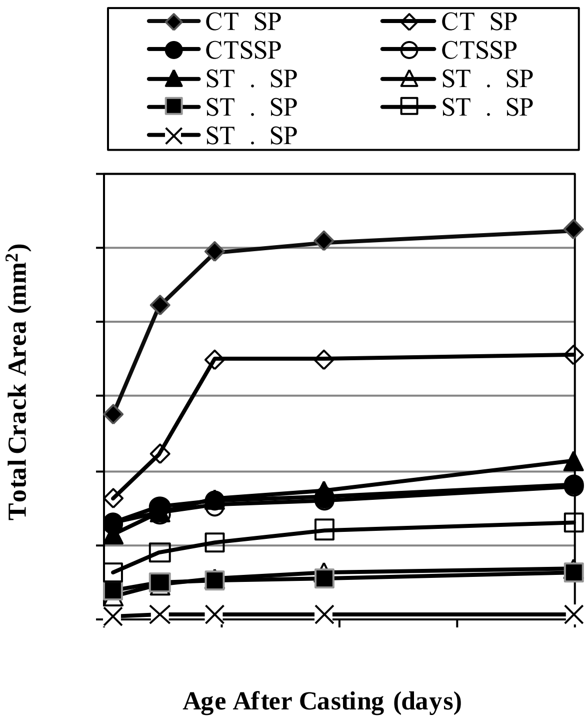

Fig. 2: Total Crack Area vs. Time