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Causes and controls of cracking at bridge deck overlay with very-early strength latex-modified concrete

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HIGHLIGHTS

- VES-LMC has a high risk of thermal cracking in early age.
- Cracking control methods for VES-LMC were suggested.
- A verification program of field application was performed.

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ABSTRACT

Very-early strength latex-modified concrete (hereafter, VES-LMC) was developed by focusing on workability and strength development for early opening to the traffic after three hours of concrete placement. This study was designed to analyze the causes of map and transverse cracking in VES-LMC and to provide control methods for minimizing the occurrence of cracks at a field in Korea. The results are as follow:

The map cracks of bridge deck overlays with VES-LMC were caused by initial plastic shrinkage cracking within a few hours after placement, by improper and delayed curing (use of curing compound that was delayed until after tining), and were propagated into visible wider cracks within a week. It was also concluded that the property of VES-LMC with minimal bleed accelerated these plastic shrinkage cracks. This was verified by a nomograph relating air temperature, relative humidity, concrete temperature, and wind speed to evaporation rate. To prevent map cracking of the bridge deck overlay with VES-LMC, the recommendations are to apply curing compound as soon as possible after placement and before tining concrete, and reapply curing compound after tining. The prevention methods should focus on VES-LMC material properties affecting the susceptibility of a concrete overlay to prevent transverse cracking. Recommendations on VES-LMC material properties to reduce cracking included the following: as low early strength concrete as possible; low amount of VES cement; low hydration temperature; minimum cement paste volumes and free shrinkage. A verification program of field application was performed in order to prove the effectiveness of prevention methods of map cracking and transverse cracking. The proposed preventions against map and transverse cracking were verified because no cracks occurred until 3 months after overlay placement.

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1. Introduction

Very-early strength latex-modified concrete was developed by focusing on workability and strength development for early opening to the traffic after three hours of concrete placement, and thus possible fast-tracking [1]. Fast-tracking can reduce traffic congestion caused by repair jobs. Also, the increased durability, resistance to permeation, lower maintenance, and lower total costs compared to repair alternatives are all benefits delivered in a VES-LMC system [2]. VES-LMC could be used at repair jobs of concrete bridge deck overlay and concrete pavement repairs.

Because VES-LMC is overlaid on existing slab, the bridge slab acts as a confinement. Thus, the early behavior of VES-LMC such as dry shrinkage, autogenous shrinkage and thermal deformation is confined accordingly. VES-LMC undergoes volumetric changes, and excessive volumetric change can cause cracking under this kind of confinement condition [3]. Additionally, the construction

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method and equipment as well as the difference in the curing method can magnify the occurrence of cracking. This type of cracking acts as the direct factor to lower the durability of a concrete structure.

Cracking in VES-LMC can be largely classified into three types: map cracking, transverse cracking, and longitudinal cracking. The causes for the map cracking are known to be plastic shrinkage cracking, alkali–silica reaction and freeze–thawing reaction, etc. Moreover, the map cracking in VES-LMC propagates within 15 days of the concrete placement, and its main cause is known to be plastic shrinkage cracking. The second common cracking type is transverse cracking, and is caused by the combination of thermal stress and dry shrinkage. The third shrinkage type, longitudinal cracking, occur the least frequently [4].

The purpose of this study was to show the typical crack types and analyze the causes of map and transverse cracking in VES-LMC and to provide control methods for minimizing the occurrence of cracks at fields. The proposed prevention of cracking was verified at another field application program. The results of this study will help the field engineer and researcher to better understand the causes and prevention of cracks in bridge deck overlays with very-early-strength latex-modified concrete.

2. Examples of cracking in VES-LMC

2.1. Map cracking

Fig. 1(a) shows an example of a map cracking, which took place at a typical pattern on a bridge overlaid with VES-LMC in Korea. Fig. 1(b) shows the map cracking at Braddock Road Bridge of Route 620 of Virginia in the United States, which is one of the very first overlays by RS-LMC (Rapid Setting Latex Modified Concrete) in the USA [5]. The surface of the bridge is grooved, and it is deemed that it was overlaid by an inexperienced constructor during the initial application of the RSLMC, causing severe cracking. However, it has no debonding and/or pop-out. Such problems as inadequate bonding with the repairing body, the quality of the concrete during its procurement, and poor curing condition can cause the map cracking.

Map cracks were not found the first day after placement of the VES-LMC but after three to seven days were visible on the surface of the overlay, having a multi-direction pattern of fine cracks that did not penetrate much below the surface and were usually a cosmetic problem only. They were difficult to see, except when the surface had been wet and then allowed to dry; the fine cracks were visible until they dried. Map cracks were found where the overlay had been improperly tined and near expansion joints.

Map cracks could be a kind of plastic shrinkage cracking which develops when water evaporates from the surface of freshly placed concrete faster than it is replaced by bleed water. Due to the restraint provided by the concrete below the drying surface layer, tensile stresses develop in the weak, stiffening plastic concrete, resulting in shallow cracks of varying depth [6].

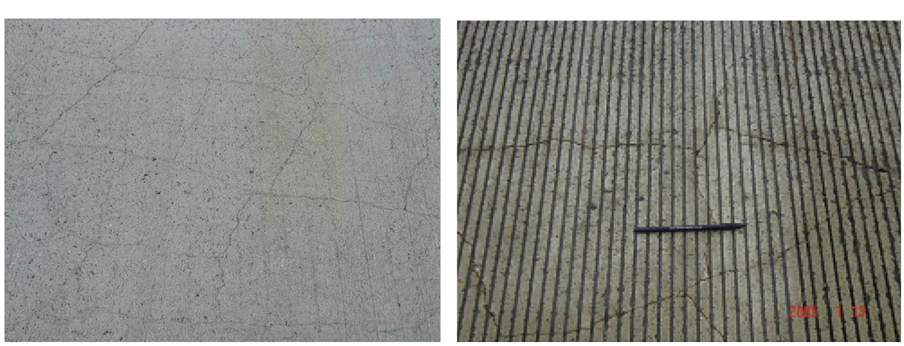
2.2. Transverse cracking

Fig. 2(a) is a picture of the transverse cracking, which took place on a bridge repaired with VES-LMC in Korea. The cracking took place at a constant space in the direction of the traffic, and the cracking was observed to start from the shoulder of the bridge and to propagate to the traffic lane. Fig. 2(b) is a picture of the transverse cracking at Backlick Road Bridge of Route 617 in Virginia. RS-LMC was applied on the bridge for the repair. Although transverse cracking was observed at five locations with the spacing of 2–3 m in-between, the cracking was not severe overall [5]. This bridge was constructed by Wagman Company in the USA, and the quality of the overlay is evaluated to be excellent. This fact indicates the quality of concrete depends greatly on the quality management of the concrete at the field, which is often regarded as the indicator of the technical expertise of a construction company dealing with concrete overlay.

Transverse cracks are perpendicular to the direction of traffic. Their spaces were close as 1.0–1.5 m. Transverse cracking started from the edge of the center barrier. Transverse cracking was not found visibly after one day of concrete placement but was found after 30–90 days, having a pattern of fine and shallow cracks. The cracks were usually clearly visible. This is construed due to the fact that a structural cracking occurs because the transverse confinement at the shoulder is greater than that at the traffic lane.

Transverse cracking can be developed at the bridge deck overlay with VES-LMC when longitudinal tensile stresses in the deck exceed the tensile strength of the VES-LMC. These tensile stresses are caused by temperature changes in the concrete, concrete shrinkage, and sometimes bending from self-weight and traffic loads. It is important to realize that cracking may often be the result of the cumulative effects of many different causes. A combination of shrinkage and thermal stresses causes most transverse bridge deck cracking [4].

There are many research reports on transverse cracking [7,8]. There are various causes for transverse cracking, but it is caused mostly by thermal stress and shrinkage in a confined state. Transverse cracking is a structural cracking and is predicted to a certain degree. Recently, Departments of Transportation in the USA conducted an investigation of cracking in over 100,000 bridges and reported that the long-term cracking of the bridges is most influenced by early transverse cracking. They reported that it is caused mainly by thermal stress and/or dry shrinkage [4].



(a) VES-LMC Overlay in Korea (b) Route 620 in Virginia, US

Fig. 1. Examples of map cracking.

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