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Analysis of in situ bond strength of bonded concrete overlay

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HIGHLIGHTS

- The vulnerable factor causing poor bonding of bonded concrete overlay is studied.
- The concrete overlay types and the substrate condition induce poor bonding.
- The vulnerable factor causing the poor bonding is the substrate condition.

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ABSTRACT

Cement concrete pavement has become a popular candidate for highway construction in Korea because it is capable of withstand the heavy vehicle traffic. The service life of some highways is close to the end and they require the rehabilitation to extend the service life. Therefore, bonded concrete overlay is a good alternative, since its material properties are similar to the existing concrete pavement. However, it is recently reported that the early distresses occur in bonded concrete overlay and poor bonding between the overlay and the existing pavement is assumed to be the cause of this problem. According to the pre-investigation result in laboratory, there are two factors causing the poor bonding: the concrete overlay types and the substrate condition. The study investigates the vulnerable factor among the two factors based on the analysis of in situ bond strength data of bonded concrete overlay collected from some highways in Korea. As a result, the substrate condition becomes a vulnerable factor influencing the poor bonding and causing the early distress in bonded concrete overlay.

1. Introduction

In Korea, more than sixty percent of highways were constructed with cement concrete pavements due to the economic growth that induces the industrial development and the rise of heavy vehicles. Some pavements are nearly twenty years old and their service life is approaching the end. Due to the increase of traffic loading and the pavement age, some highway sections require the maintenance, rehabilitation and reconstruction. Additionally, bonded concrete overlay (BCO) becomes a good alternative in Korea since its structure was successfully constructed in 1991 on 88-highway of Korea and it gave a satisfied performance in extending the service life [3].

Generally bonded concrete overlay is a thin layer of Portland cement concrete (PCC) [2] and its thickness is typically 76–102 mm [6,11]. This overlay can be applied on the existing pavement with a good condition and free of structural distress [1,4,5]. Bonded concrete overlay (BCO) can improve the riding quality and restore the structural capacity of existing pavement to carry the anticipated future traffic [1,4,5]. The benefits of bonded concrete overlay can be achieved simultaneously with the bonding mechanism. When overlay and existing pavement are well bonded, this new full-depth pavement will behave as a monolithic structure to withstand the curling and loading stresses. Therefore, the bonding between the overlay and the existing pavement is very important to prevent early distresses and secure a future performance. In order to control the bonding quality of bonded concrete overlay construction, most highway agencies have developed individual bond strength criterion. American Concrete Pavement Association (ACPA) suggests 1.4 MPa of shear strength between the overlay and the existing pavement as the bond strength criterion [5]. In case of Canadian Standard, the required bond strength is defined by the shear strength 0.9 MPa [12]. Korea Expressway Corporation (KEC) agency recommends 1.4 MPa of tensile strength as the bond strength criterion [3]. Moreover, Sprinkel and Ozyidirim define bond strength criterion by tensile strength as described in Table 1 [7]. After experiencing the curling and loading stresses, early distresses

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Table 1
Summary of bond strength criteria for bonded concrete overlay.

Testing method	Strength criteria (MPa)		References
Bond strength (Shear)	1.4		[5]
	0.9		[12]
Bond strength (Tensile)	1.4		[3]
	2.1	Excellent	[7]
	1.7–2.1	Very Good	
	1.4–1.7	Good	
	0.7–1.4	Fair	
	0–0.7	Poor	

in bonded concrete overlay are reported and it is assumed to be the cause of poor bonding. Two origins of poor bonding include: bond strength of bonded concrete overlay is smaller than the bond strength criterion, and/or bond stress at the interface is exceed the bond strength [10].

Therefore, this study aims to investigate on the vulnerable factor inducing the poor bonding of bonded concrete overlay based on the evaluation of in situ bond strengths collected from some highways around Korea with bond strength criteria.

2. Research strategy

In this study, the bond strength criterion 1.4 MPa recommended by Korea Expressway Corporation is used to evaluate bonding strength of bonded concrete overlay [3]. Initially, it is necessary to define the main issues affecting the poor bonding of bonded concrete overlay based on the experiment in laboratory. In this experimental pre-investigation, the samples of various concrete overlay materials were constructed on the substrate specimens that have different performance conditions. Average bond strength of each concrete overlay was measured and evaluated with the bond strength criterion. As a result, the main factors causing the poor bonding of bonded concrete overlay are identified. When these factors are determined, the main purpose of this research is to identify the most vulnerable factor inducing the poor bonding. Therefore, it is essential to gather the information such as the in situ bond strength and the failure modes of bonded concrete overlay constructed on some highways in Korea. According to this information, the percentage of projects having the bond strength less than 1.4 MPa must be computed and the occurrence percentages of each failure modes are also defined.

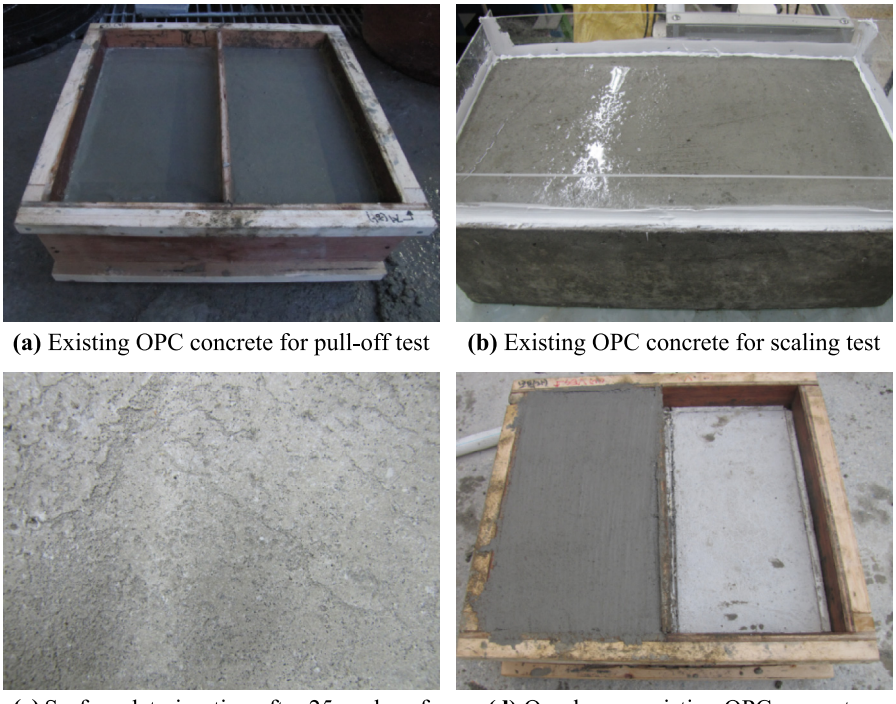
3. Pre-investigation of bonded concrete overlay in laboratory

3.1. Specimen preparation and bond strength measurement

The investigation aims to determine the main possible factors causing the poor bonding of bonded concrete overlay by evaluating the bond strengths measured by direct tensile test (pull-off test) of KS F2762 standard [13]. In this experiment, there are four different types of concrete overlay to be studied: Ordinary Portland Cement

Table 2
Mixture proportions of concrete overlays [10].

Overlay material	G_{max} (mm)	Slump (cm)	Air (%)	W/B (%)	S/a (%)	Content (kg/m^3)				
						Water	Binder	Fine Agg.	Coarse Agg.	Other
OPC (30–35 MPa)	13, 25	4	6	45	42	148.5	330	759	1067	AE Water Reducing Agent (Bx0.3%)
URHC	13	8	3–6	40	35	160	400	631	1172	AE Water Reducing Agent (Bx0.3%), Retarder (Bx03%)
URH-LMC	13	16–22	3–6	38	55	74	360	960	787	Latex 115
URH-APMC	13	15–17	6	36	44	106	390	756	979	Acrylic Polymer 66 AE (Bx0.03%)



(a) Existing OPC concrete for pull-off test

(b) Existing OPC concrete for scaling test

(c) Surface deterioration after 25 cycles of scaling test

(d) Overlay on existing OPC concrete

Fig. 1. Specimen preparation process.