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Performance evaluation of bonded concrete overlay

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HIGHLIGHTS

- This study investigates the service life of BCO based on analysis of distress data.
- Measured service life showed a good relationship with predicted service life.
- The maximum bond stress may exceed the bond strength given the critical conditions.
- Potential source of early distress is excessive bond stress at the BCO interface.

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ABSTRACT

Asphalt concrete overlay rather than bonded concrete overlay is used as a typical rehabilitation method for deteriorated concrete pavement in Korea, since asphalt concrete overlay requires a shorter construction time. Asphalt concrete overlay on existing concrete pavement, however, often undergoes various types of early distress, such as reflection cracking, pothole and rutting due to the different physical characteristics between the asphalt concrete overlay and the existing concrete pavement. Recently, bonded concrete overlay has been considered as a possible alternative, since its material properties are similar to existing concrete pavements in Korea. This study investigates the service life of bonded concrete overlay based on an analysis of distress data in USA LTPP sections. Although a considerable numbers of early distressed sections were found, the measured service life shows a good relationship with the predicted service life by the AASHTO design method when early distressed sections are excluded from the comparison. Generally, poor construction or bonding is doubted as the major cause of early distress in bonded concrete overlay. In this study, another potential source of early distress that occurs due to excessive bond stress in spite of the achievement of an adequate level of bond strength is investigated by a numerical analysis. The result of this study indicates that the bond stress may exceed the bond strength in the critical conditions of a high coefficient of thermal expansion of the overlay material and a thin overlay thickness.

1. Introduction

In Korea, cement concrete pavements has steadily been constructed and expanded due to rapid industrial development and increasing number of heavy vehicles, especially since the '88-Highway' was built in 1984 [2]. More than sixty percent of highways were constructed with cement concrete in Korea. However, deteriorated concrete pavements have required maintenance, rehabilitation, and reconstruction since service life of most concrete pavements ends close to 20 years under heavy traffic conditions. Bonded overlays made both of cement concrete and asphalt concrete can been used to extend the service life of deteriorated concrete pavement [3].

The rapid rehabilitation of deteriorated concrete pavement needs to be ensured to prevent traffic jams on the highways of Korea. Due to the fast construction, asphalt concrete overlay has been used as a typical rehabilitation method for deteriorated concrete pavement. However, asphalt concrete overlay on existing concrete pavement experiences various forms of early distress, such as reflection cracking, pothole and rutting, which may occur due to the different physical characteristics between the asphalt concrete overlay and the existing concrete pavement. Therefore, deteriorated concrete pavement requires effective rehabilitation methods. Bonded concrete overlay has been recently assessed as a viable alternative, since the overlay material properties are similar to those of existing concrete pavement [4]. Recently, the use of bonded concrete overlay with ultra-rapid hardening cement has increased in an effort to ensure the early traffic opening of

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highways in Korea [5]. Bonded concrete overlay has advantages in terms of structural performance, as the overlay layer and the existing pavement perform as a monolithic layer. Bonding between the overlay layer and the existing pavement is essential to prevent early distress and to secure good performance. The bonding property ensures that the overlay and existing pavement perform as one original pavement that continues to carry a significant portion of the traffic and environmental loading. Early distress in bonded concrete overlay is caused by poor bonding that has two possible causes: the bond strength of the bonded concrete overlay is less than the quality control criteria, and/or the bond stress at the interface of the bonded concrete overlay is exceed the bond strength criteria. Therefore, it is important to ensure a suitable level of bond strength for good performance of the bonded concrete overlay. The bond strength should be greater than the normal tensile stress and horizontal shear stress due to traffic and environmental loading at the bond interface.

This study investigates the service life of bonded concrete overlay and potential factors influencing the service life using the LTPP database in the United States. In addition, three-dimensional finite analyses are performed to investigate the possibility of occurrence of excessive bond stress that may cause early distress.

Table 1
General performance data description of SPS-7.

State	Section	Overlay thickness (cm)	Existing pavement thickness (cm)	Composite modulus of subgrade reaction (MN/m^3)	Type of existing pavement	Cumulative ESAL ($\times 10^6$)	Cumulative years of record
19	703	10	20	326	CRCP	10.0	11
19	707	16	20	326	CRCP	9.6	11
19	708	13	20	326	CRCP	9.7	11
19	709	14	20	326	CRCP	9.9	11
22	702	9	19	543	CRCP	0.5	2
22	705	10	21	570	CRCP	0.5	2
22	706	15	20	570	CRCP	0.5	2
22	707	15	21	597	CRCP	0.5	2
22	709	14	19	570	CRCP	0.5	2
27	703	9	19	326	CRCP	0.8	3
27	704	8	21	380	CRCP	0.8	3
27	706	13	20	380	CRCP	0.8	3
27	707	13	20	380	CRCP	0.8	3
27	708	14	18	380	CRCP	0.8	5
27	709	12	20	380	CRCP	0.8	3
29	702	10	19	244	JPCP	2.1	8
29	703	8	20	190	JPCP	8.4	14
29	704	9	21	190	JPCP	8.3	14
29	705	8	21	217	JPCP	8.2	14
29	706	14	21	–	JPCP	3.0	9
29	707	12	21	–	JPCP	2.9	9
29	708	12	20	244	JPCP	8.0	14
29	709	13	20	217	JPCP	8.0	14
29	760	10	20	–	JPCP	8.2	14

Table 2
PCI change depending on progress years.

State	Section	0 year	1 year	2 year	3 year	4 year	5 year	6 year	7 year	8 year	9 year	10 year	11 year	12 year	13 year	14 year	15 year	△PCI/year	R^2
19	703	100	100						92									−1.2	0.98
19	707	100	100						99									−0.2	0.98
19	708	100	100						94									−0.9	0.98
19	709	100	100						93									−1.1	0.98
22	702	100	100		100		93											−1.3	0.68
22	705	100	100		90		91											−2.2	0.78
22	706	100	100		67		63											−8.6	0.88
22	707	100	98		52		51											−11.4	0.85
22	709	100	98		90		91											−2.0	0.80
27	703	100		100	98		98			100							96	−0.2	0.53
27	704	100		100	100		100			100							93	−0.5	0.74
27	706	100		100	100		97										59	−3.0	0.94
27	707	100		100	98		92										76	−1.7	0.98
27	708	100		100	100		74										71	−2.1	0.67
27	709	100			100		100										93	−0.5	0.90
29	702	100	100	98	98	99	98			98			95					−0.4	0.75
29	703	100	100	97	92	96	85			85			83					−1.7	0.82
29	704	100	96	97	96	58	97			47			44					−5.7	0.71
29	705	100	100	93	90	88	91			59			55					−4.5	0.91
29	706	100	100	93	88		92			73								−3.2	0.85
29	707	63	60	91	68	65	91			90								3.4	0.39
29	708	100	100	88	88	92	88			94			84					−1.0	0.39
29	709	100	100	93	75	97	93			97			98					0.2	0.01
29	760	100	100	92	91	97	90			90			66					−2.6	0.76