Bridge Deck Overlays using Ultra-High Performance Concrete

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Developing ultra-high-performance concrete (UHPC) produced with local materials for bridge deck overlay applications

Overlays are placed on existing concrete bridge decks for reasons that include increasing cover for the deck reinforcing steel, improving ride ability, and improving skid resistance. The goal of this project is to develop overlay technologies that can increase the service life of the overlay and extend the service life of the underlying concrete deck using ultra-high performance concrete (UHPC) produced with local materials. UHPC is an advanced fiber reinforced composite material characterized by compressive strengths greater than 17,000 psi (120 MPa) at 28 days. Using UHPC as an overlay material has potential advantages over other materials that include its high strength and exceptional durability. Effectiveness of an overlay is governed by the bond strength between the overlay material and the existing concrete deck, shrinkage, and cracking properties of the overlay material of the overlay and substrate materials. Therefore, to assess the potential of UHPC as an overlay material, the investigation focuses on the strength of the bond between the UHPC and the normal strength concrete (NSC) substrate, which is greatly influenced by the surface roughness at the UHPC and NSC interface

Problem Statement

Typical concrete overlay materials include latex-modified concrete, low slump dense concrete, and polyester polymer concrete. However, each of these materials have drawbacks that have lead designers to question the cost effectiveness of using them in overlays.

To increase the service lives of bridge deck overlays, and subsequently the underlying concrete deck, this research project is investigating the possibility of using UHPC to overlay existing concrete bridge decks. UHPC produced with local materials has been shown to have exceptional durability and strength properties, as shown in Figure 1, that have the potential to greatly improve the sustainability of overlaying concrete bridge decks by extending the service lives of both the overlay and the concrete deck.

Summary

Effectiveness of an overlay greatly depends on the bond strength between the overlay material and the existing concrete deck, shrinkage, and cracking properties of the overlay material. S lant shear and split cylinder specimens that consist of one-half UHPC and one-half NSC substrate material are used to measure the bond strength between the UHPC and NSC, as shown in Figure 2. NSC with a water-to- cementitious materials ratio of 0.45 was used to form the substrate material.

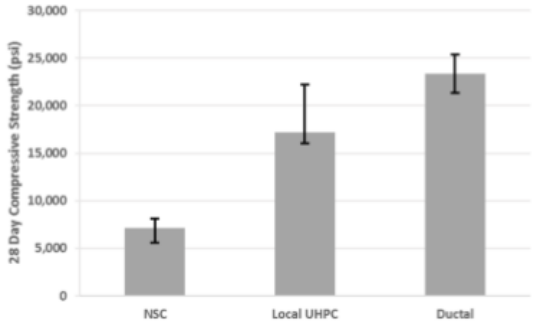

Figure 1. Typical compressive strengths of normal strength concrete, UHPC produced with local materials, and Ductal® (a pre-packaged, proprietary UHPC mixture).

The substrate was stored in a wet room for 28 days, then textured by grinding to a depth of 0.04 to 0.08 in. (1-2 mm.) to mimic surface preparation of concrete bridge decks. Bonding agents were not used because the nano-particles in the UHPC provide sufficient bond with the textured NSC.

UHPC for the overlay mixture was tested for workability by conducting a slump and spread test for every mixture. Compressive strength of UHPC is measured using 4x4 in. (100x100 mm.) cube specimens. The shrinkage of the UHPC overlay mixture is being studied in the fresh and early-age

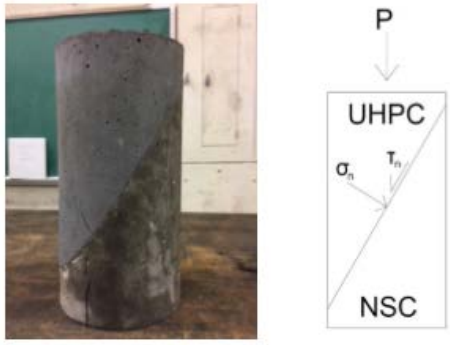

Figure 2. Split cylinder sample and stress state induced during compression test.

stages using a 6x6x24 in. (152x152x609 mm) beam mold with two linearly variable displacement transducers (LVDT). The LVDTs are placed against a metal hanger that is embedded 1 inch (25 mm) into the UHPC. As the specimen experiences shrinkage, the LVDTs record the displacement.

Findings

A UHPC mixture with a 28-day compressive strength of 17,220 psi (118.8 MPa) was used for the slant-shear, split cylinder, and split prism tests. Table 1 presents sample results from the slant-shear tests along with the shear stress and normal stress calculated at failure.

Table 1. Slant shear test results.

Type	Specimen	Strength (ksi)	Shear stress (ksi)	Normal stress (ksi)	Failure
Over Textured	1	6.54	2.83	1.64	Bond Failure
	2	7.29	3.16	1.82	Substrate Failure
	3	5.89	2.55	1.47	Bond Failure
	4	7.38	3.20	1.85	Substrate Failure
	5	7.28	3.15	1.82	Substrate Failure
	6	7.83	3.39	1.96	Substrate Failure
Slightly Textured	1	2.97	1.29	0.74	Bond Failure
	2	2.39	1.03	0.60	Bond Failure
	3	3.12	1.35	0.78	Bond Failure
	4	1.89	0.82	0.47	Bond Failure
	5	3.30	1.43	0.83	Bond Failure
	6	3.07	1.33	0.77	Bond Failure

According to the American Concrete Institute's Guide for Selection of Materials for the Repair of Concrete, a 7-day bond shear strength must be greater than 1000 psi (6.9 MPa) to be acceptable.According to this criterion, all samples met this performance requirement satisfactorily, as even the under textured specimens provided adequate bond strength.

The shrinkage test results of a 6x6x24 inch (150x150x600 mm) UHPC beam specimen. The total shrinkage during the 7-day test was nearly 1800 micro strain, as shown in Figure 3. This strain level is consistent with other tests conducted on UHPC specimens. Based on the preliminary results of this study, UHPC appears to have the potential to be used as an overlay material as long it has proper workability and the substrate surface is adequately prepared.

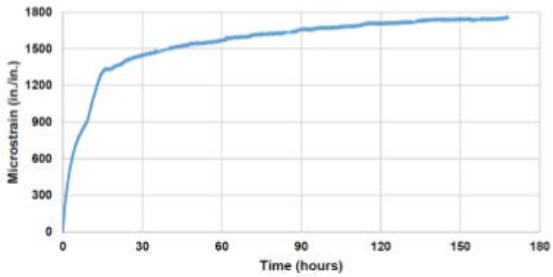

Figure 3. Early-age shrinkage results for UHPC.

Impacts

The goal of this proposed project is to develop overlay technologies using UHPC produced with local materials that can increase the service life of the overlay and reduce maintenance costs during that service life.This technology will also extend the service life of the underlying concrete deck.UHPC is promising as an overlay material because it has been shown to have exceptional durability and strength properties.

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