Joint Transportation Research Program

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Dowel Bar Retrofit Mix Design and Specification

Introduction

Current INDOT specifications for repair materials to be used in dowel bar retrofit (DBR) applications (Sections 507.08 and 901.07 of INDOT's Book of Specifications) are based, in large part, on the requirements of ASTM C 928 and the manufacturer-provided technical performance data. The objective of this research was to develop a set of performance specifications for patching materials that can be used in dowel bar retrofit repair applications in the state of Indiana.

To accomplish this goal, five commercial rapid-setting repair materials and one custom-developed rapid-setting, self-consolidating concrete were extensively evaluated for different performance characteristics. In addition, the assessment of the influence of production variables on properties of these materials was also conducted. The project was broadly divided in to two phases. Phase I consisted of studies of commercial rapid-setting repair materials and Phase II consisted of development of rapid-setting, self-consolidating concrete (RSSCC).

Phase I was divided into two primary steps. Step 1 involved selection of five commercial rapid-setting repair materials based on compilation of published reports on the performance of existing DBR installations and a list of commercial rapid-setting materials (CRSM) approved for use by different state departments of transportation (DOTs). Optimal mixture proportions for the selected CRSMs were developed using slump flow and the rate of compressive strength development as the criterion. In Step 2, the effect of temperature of mixture ingredients at the time of placement on early age and long-term properties of the selected mixtures were studied. The fresh and hardened concrete properties studied were slump flow, setting time, rate of compressive strength development, slant shear bond strength, cracking potential, freeze-thaw resistance and air-content of hardened concrete.

Phase II was also divided in to two steps. Step 1 involved development of optimal mixture proportions for RSSCC. The focus of Step 2 was on evaluation of robustness of RSSCC to variation in production parameters, such as moisture content of aggregates (for two water-to-cementitious ratios and two types of mixing equipments), aggregate gradation, and the effect of remixing after a period of rest.

Findings

Due to small dimensions of the DBR slot, it was found (by using a mock up) that CRSMs used in this research required the largest amount of extra water to be added to facilitate placement. The measurement of the slump flow instead of the slump gave a good indication of the flowability of the repair concrete, and thus its placeability. The cracking potential of all CRSMs tested in this research was low. All but one CRSM exhibited low resistance to freezing and thawing cycles. When compared to the requirements traditionally used for plain concrete to achieve adequate freeze-thaw resistance, the spacing factor and specific surface values for hardened CRSMs were out of range.

The early-age and long-term performance of CRSMs were found to be affected by the temperature of materials at the time of casting and the ambient temperature at which the repair concrete was cured. All but one CRSM reached the stipulated compressive strength as stated in ASTM C 928 for material temperature condition of 23°C. A similar observation was also be made for material and curing temperature of 40°C. The final setting time and the rate of compressive strength development was low for repair concrete cast with materials at 10°C and cured at the same temperature.

The research conclusively proved that small repair jobs can be successfully completed using RSSCC. The mixing sequence and total mixing time are important factors for achieving a stable RSSCC. A two-step procedure for addition of superplasticizers implemented in the research was found to be beneficial for achieving stable and cohesive RSSCC.

The final RSSCC mixture consisted of a ternary blend of Type III Portland cement, silica fume, and micro-fine fly ash. The total cementitious materials content of this mix was 560 kg/m3 and it required 2.15% of HRWR (by weight of cement) and accelerator dosage of 8.8% (by weight of cement) at water-to-cementitious ratio of 0.31.

The moisture content of aggregates at the time of mixing was found to have played an important role in the robustness of RSSCC. Mixtures having w/cm of 0.36 were more robust and less sensitive to variations in aggregate moisture conditions than those made with w/cm of 0.31.

Implementation

Based on the observed performance of various CRSMs studied in this project it is recommended that the current INDOT specifications and guidelines for repair materials for use in load transfer restoration applications be revised. The summary of main reasons for this recommendation is briefly listed below.

Experimental results showed that the performance criteria currently laid down in the INDOT standards fall short with respect to specifying the following key parameters that influence the durability of the repaired systems:

1. Measurement of workability (in terms of flowability) of the repair concrete
2. Measurement of compressive strength at early ages
3. Measurement of freeze-thaw durability
4. Determination of cracking susceptibility
5. Performance criteria for placement of repair concrete at extreme temperatures (10°C and 40°C)

To achieve stable RSSCC for small batch volumes (1–2 cu. ft.) it is essential that the mixing sequence and mixing time be strictly adhered to. The trial mix procedure should be prepared before the start of the project to optimize the aggregate content and the superplasticizer dosage.

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Dowel bar retrofit across a crack
(Wilson and Toepel, 2002)