Kansas Department of Transportation

TECHNICAL SUMMARY

Low-Shrinkage Ultra-High-Performance Concrete

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Introduction

Ultra-high-performance concrete (UHPC) has become increasingly common due to its high strength, rapid strength gain, and considerable durability compared to conventional concrete. These attributes make UHPC desirable for many applications, including in accelerated bridge construction. However, the high cost of UHPC – due in part to the prevalence of proprietary mixtures – has slowed its implementation. Therefore, a primary aim of the current work was to reduce UHPC costs in Kansas by developing a non-proprietary UHPC mixture design using primarily Kansas-based materials. Because the intended application is primarily in joints (pour strips) between precast members in accelerated bridge construction projects, higher priority was placed on rapid strength gain than on high ultimate strength.

UHPC uses high contents of cementitious materials and a low water-to-cementitious materials (w/cm) ratio to achieve its high strength, but these properties also cause it to exhibit more early-age shrinkage than conventional concrete. When UHPC is used for joints between precast members, excessive shrinkage might cause the UHPC to pull away from the precast concrete, exposing the reinforcing bars crossing the joint to moisture, oxygen, and road salts. Consequently, the effectiveness of shrinkage-limiting methods in UHPC must be investigated. This research explored the efficacy of shrinkage reducing admixtures (SRAs), shrinkage compensating admixtures (SCAs), and prewetted lightweight aggregates (LWAs) for internal curing, which all tend to reduce shrinkage of conventional concrete.

Project Description

The first portion of this research focused on the development of a non-proprietary UHPC mixture design using constituent materials readily available in Kansas and a targeted compressive strength of 14 ksi within seven days of mixing. Mixture designs published by Wille and Boisvert-Cotulio (2015) were used as a starting point and then modified to achieve the desired results for early-age strength. The second portion of this research focused on strategies for reducing UHPC shrinkage, including SRAs, SCAs, and LWAs. The effectiveness of these technologies for limiting UHPC shrinkage is reported. A small number of tests were also conducted to document the behavior of the resulting UHPC in compression, tension, and bending.

Project Results

Table 4.1 reports the fresh-state properties measured after mixing, including temperature, slump flow, J-ring, and unit weight. The fresh-state properties of Batch B8–Baseline were measured a second time, 30 minutes after mixing, to simulate the effects of transit time for UHPC mixed off-site. The batches had an average temperature of 78 °F, with a range of 68 to 86 °F. The lowest temperature was measured in Batch B13–SRA1.25% at 68 °F. The two highest temperatures were 86 °F and 82 °F in Batches B4–FlyAsh and B10–SCA6%, respectively. Both batches also had the lowest J-ring results at 15.5 in. and 16 in., respectively, which could be due to their high temperatures. The addition of steel fibers in Batches B7–Fibers2% to B22–3%HF resulted in increased unit weights, except for Batch B16–LWA30%, which had the lowest density (136.8 pcf) due to the high percentage of LWA. Table 4.1 also reports whether segregation was observed. For example, Batches B15–LWA15% and B16–LWA30%, which had LWA at a dosage of 15% and 30% of the weight of cementitious material, respectively, both exhibited segregation in the J-ring tests (Figures 4.1 and 4.2, respectively).

Project Information

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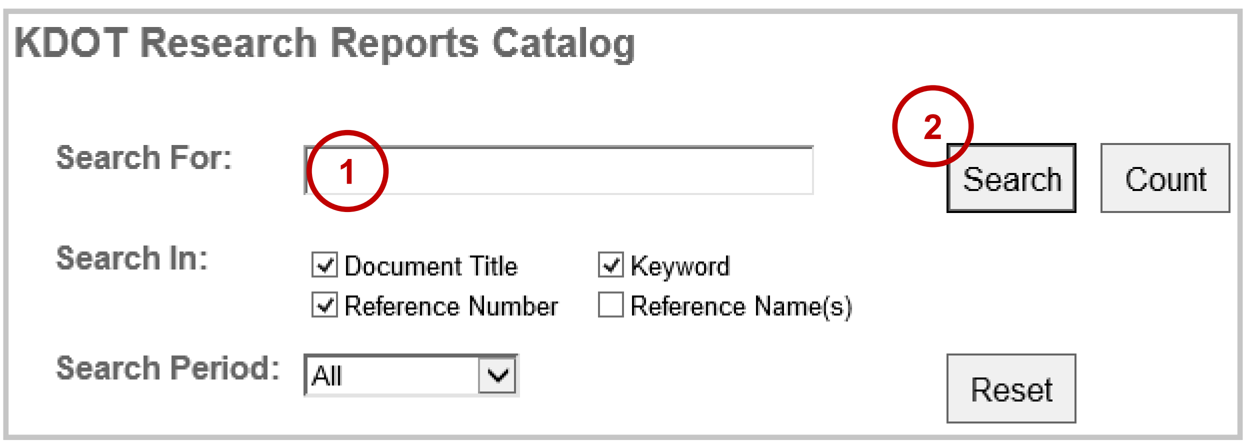

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