TEXAS STATE UNIVERSITY SAN MARCOS
The rising STAR of Texas

PROJECT SUMMARY

Texas Department of Transportation

0-7017: Use of Rapid Setting Hydraulic Cements (RSHC) for Structural Applications

Background

Construction and replacement of infrastructure assets results in costly road closures. Rapid setting hydraulic cements (RSHCs), like calcium sulfoaluminate (CSA) cement and calcium aluminate cement (CAC), can dramatically reduce the time needed for construction. These cements are beginning to gain the attention of various stakeholders in the cement and concrete industry owing to their remarkable properties and notably lower carbon footprint compared to ordinary portland cement (OPC) and other traditional infrastructure materials. Currently, the use of CSA and CAC cement is often limited to rapid repair applications and other special applications where their exclusive qualities are required. Although there are hardly any records of their use in new structural applications, recent advances in these cements have shown great potential to be successfully used in producing structural-grade concrete. The possibility of harnessing their rapid strength gain abilities in reducing the duration of in-situ concrete activities during construction, thereby truncating construction project delivery time was of particularly interest to TxDOT. However, the lack of long-term durability performance data of their use in concrete in various environmental conditions has deterred their adoption for use in new structural applications. This research evaluated the short- and long-term durability performance of these binders as it relates to key durability issues associated with reinforced concrete.

What the Researchers Did

There are a variety of rapid setting cement systems available with a range of different formulations. The research work described in this report, however, was limited to ettringite-based cement systems (e.g., CSA and CAC) either as the primary binder (i.e., pure cement), or a blend with portland cement and/or other mineral additives. This comprehensive project included ten (10) various types of ettringite-based cement systems categorized as pure cement (i.e., cements that are not blended with any other material), proprietary blends (i.e., cements pre-blended with other materials during production), and lab produced blends (i.e., combinations of cement produced in the lab). These cements were then evaluated for their short- and long-term performance that are relevant for the design of structural class concrete. The comprehensive experimental work involved a suite of fresh, hardened, and durability performance tests on paste, mortar, and concrete samples. Additionally, testing involved standardized and modified procedures to determine effectiveness and robustness of current laboratory test method to predict performance of these unique binder systems. Finally, corresponding field specimens were placed in various durability-related tests (e.g., ASR, Chloride, and Carbonation) to link performance under real-world conditions with lab results.

What They Found

A Significant laboratory and field data were generated during the course of this project. Although some of the tests are ongoing and may require additional time to validate the performance of RSHCs in various aggressive environments, some general observation can be made at this time:

•When comparing between CSA and CAC binder types in terms of mechanical strength, mechanical

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properties (compressive, tensile, and modulus) were generally higher in CSAs, especially at early-ages (e.g., < 7days) when all mixture proportions remain equal (e.g., w/c and binder content). The only exception were blended cements containing CSA with OPC which significantly impacted early-age strength at the expense of long-term strength.

•With the exception of blended cements containing CSA or CAC with OPC, very little mechanical strength was observed in test specimens beyond 28 days of curing. In fact, most mixtures did not observe a relatively substantial increase in strength beyond 7 days of curing.

•When evaluated in an accelerated carbonation testing chamber, all RHSCs under this program showed significantly lower carbonation resistance when compared to OPC at an equivalent w/c ratio and curing age. While carbonation depth decreased for all mixtures as the curing age increased, there was not much difference in carbonation depth between the 24-hour and 7-day cured samples, especially in samples produced with CSA cements.

•On the other hand, when evaluated for natural concrete carbonation outdoors in Texas, the performance of RSHCs was dependent on exposure type. Samples placed outdoors and exposed to precipitation had a markedly higher resistance to carbonation compared to samples placed in sheltered conditions. For application where carbonation-induced corrosion is a concern, care must be taken on the type of exposure and outdoor conditions the concrete will be exposed to minimize the potential for distress.

•With the exception of a few CSA cement types, the corrosion potential in RSHC concrete appears to be comparable to OPC after 3 years of exposure. Bulk-chloride diffusion test showed that these cements had much lower chloride binding capacity compared to CAC and OPC systems.

•While permeability testing such as electrical bulk resistivity and rapid chloride penetration (RCP) showed moderate to high resistivity compared to OPCs at all ages, poor correlation was observed in performance with the various durability related testing. Special care should be taken when using these methods to assess RSHC concrete permeability and its ability to perform in particular aggressive environments (e.g., marine/chlorides).

What This Means

This study showed that RSHC concrete can be designed to meet structural class specifications in terms of fresh (i.e., workability and working time) and hardened properties (early- and/or later-age strength). However, information is still needed to fully understand their performance in various durability-related distresses. In particular, more work is needed to understand their potential implication in chloride- and carbonation-induced corrosion. While many RSHCs showed potential in being capable of meeting durability performance, time is still needed to discern their behavior in these conditions, especially under long-term service conditions (i.e., cracked and carbonated RSHC concrete). Nonetheless, opportunities may arise for some RSHCs to be used in targeted structural applications that can achieve durability requirements.

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