Joint Transportation Research Program

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Superabsorbent Polymers for Internally Cured Concrete

Introduction

This project investigates the use of superabsorbent polymer (SAP) particles as internal curing agents in cementitious mixtures that are currently specified for INDOT applications, such as bridge decks and full-depth patching of concrete pavements. A materials-centric research approach was employed to identify suitable commercial SAP formulations for use in internally cured concrete mixtures as well as to develop successful methods of implementation and evaluation of fresh and hardened SAP-cured mixtures.

A series of laboratory-based experiments were designed to determine the following: (1) the effects of such variables as cement chemistry and type, use of chemical admixtures, and use of slag cement on the absorption of commercial SAP; (2) successful batching sequences and adjustments for SAP-cured mixes; (3) the impact of SAP on early-age properties of cementitious mixtures; and (4) whether SAP-mortar mixtures had sufficient workability to be pumped.

SAP absorption was measured gravimetrically during immersion in simulated pore fluids prepared using three cements of different chemical compositions and the following two different types: (1) systems containing slag cement and (2) systems with and without (high range) water reducing admixture ((HR)WRA), and air entraining (AE) admixture. The following properties (measurements) were determined as a function of SAP composition and batching parameters for mortars and concretes: workability (slump, flow retention); strength (compression and flexural tests); consistency (air content); volumetric stability (warping, autogenous shrinkage, drying shrinkage); cracking tendency (restrained ring test); and pumpability (time trials with recirculating pump). Cement pastes were used for measurements of degree of hydration (isothermal calorimetry, non-evaporable water). The microstructure of internally cured paste and mortar samples was analyzed, and thermogravimetric analysis was performed on pastes with different cements cured with and without SAP and with and without external curing compound.

Findings

- A SAP dosage of 0.2% by weight of binder was used in this project with SAP added as dry particles less than 0.3 mm in size. Concrete properties were found to be insensitive to whether SAP was added with the cement or with the aggregate in batching sequence. Results indicated that no extra water needs to be added to mixtures containing SAP to account for water absorption by SAP particles. In such cases, workability should be adjusted using (HR)WRA to ensure the target slump value.
- Different commercial SAP formulations composed of acrylate- and acrylamide-based crosslinked polymers displayed different absorption capacities and swelling kinetics when immersed in simulated pore solutions instead of pure water. While SAP absorption was slightly to moderately sensitive to cement chemistry and type, the presence of water reducing and air entraining admixtures did not affect SAP absorption behavior.
- SAP-containing mortars with higher w/c values (≥0.49) displayed accelerated compressive and flexural strength gains compared to SAP-free

mortar. This is consistent with the accelerated hydration observed via calorimetry for SAP-containing pastes and signifies that SAP internal curing could be employed in situations when rapid strength development is desired. Additionally, SAP and external curing compound displayed similar increases in CH formation when used together or separately across cement chemistries and types.

- Warping and drying shrinkage of SAP-containing pastes were greater when extra water was added to the mixtures. Both SAP formulations were effective in reducing autogenous shrinkage. Additionally, SAP can be used to decrease cracking tendency of both high and low w/c mixes.
- Mortars containing SAP were pumpable, indicating that SAP internal curing is feasible for field application.

Implementation

While field trials are still needed, the laboratory outcomes of this project suggest that the use of SAP internal curing agents would lead to the formation of concrete mixtures with improved hydration, accelerated strength gain, greater volumetric stability and improved cracking resistance while maintaining sufficient workability to be pumped and placed without sacrificing compressive or flexural strength. Laboratory results also indicate that incorporation of SAP in fresh concrete mixes would have similar hydration benefits as the application of curing compound after concrete has set (this aspect should be verified under field exposure conditions). Mixture composition adjustments should prioritize the use of (HR)WRA instead of extra water to attain a target slump value, as addition of extra water will almost always lead to reductions in strength, increased warping, and higher levels of drying shrinkage. At the recommended dosage of 0.2% dry SAP by weight of binder, approximately one pound of SAP would be needed per cubic yard of concrete, potentially delivered in dissolvable bags similar to those used by industry to introduce other types of admixtures.

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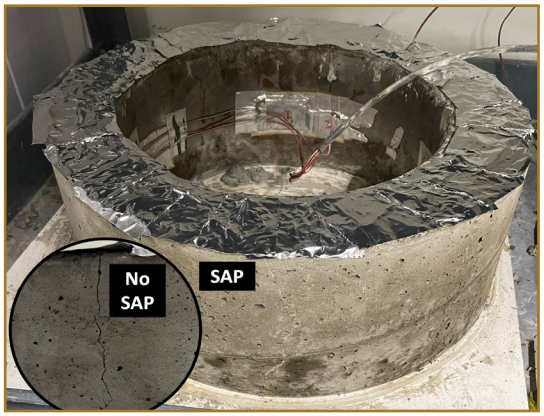
Mortar flow table testing was used to characterize SAP's effect on flow. Here, a 0.42 w/c mortar containing SAP and 0.5% HRWRA flowed 93%.



Ring testing of cracking tendency under restrained shrinkage. The 0.35 w/c Type I mortar with SAP ring is uncracked, while the inset shows a 0.35 w/c Type I mortar of the same age which has cracked.