Texas A&M Transportation Institute

Texas Department of Transportation

PROJECT SUMMARY REPORT

0-6958: Developing Performance Specifications for High-Performance Concrete

Background

The Texas Department of Transportation (TxDOT) employs Class S high-performance concrete (HPC) for cast-in-place (CIP) bridge deck construction. TxDOT considers prescriptive Mix Design Options 1–5 and 8 (Item 421—Hydraulic Cement Concrete, TxDOT 2014), primarily developed for alkali-silica reaction (ASR) mitigation, as HPC. These options focus on achieving high strength (the main design criterion) by maintaining low w/cm and specifying limits for ASTM C1202–based permeability.

However, doubts remain about whether these options adequately provide the long-term durability performance often needed when HPC is specified. Current specifications do not specify threshold limits for key performance indicators related to shrinkage, transport properties, chloride, and freeze-thaw (F/T) durability of HPC that are needed due to Texas's diverse geographical, climatic/environmental, and exposure conditions.

The main objective of this project was to develop HPC performance specifications to ensure adequate durability performance matching with exposure conditions.

What the Researchers Did

The researchers evaluated critical durability indicators of selected in-service HPC bridge deck mixtures through a combined approach of field (visual and nondestructive testing) investigations, laboratory evaluation of field cores and reproduced in-service mixtures, and service life evaluation. Next, a comprehensive laboratory evaluation of eight Class S HPC mixtures (selective current field mixtures and additional formulations per guidelines in Options 1–5) was conducted using standard and innovative testing methods.

Subsequently, researchers developed a simplified, user-friendly Excel tool (the TxDOT Tool) to facilitate rapid durability-based performance evaluations of HPC mixtures using resistivity measurements and mix design parameters as the main inputs during mix design and trial batch stages. Additional activities were conducted to reach Technology Readiness Level 8, such as:

- Field evaluation of the selected projects (including resistivity measurements of the field mixtures for field-cast and lab-cast specimens, TxDOT Tool–based performance predictions, and selective validation testing).
- Establishment of within-laboratory variability and inter-laboratory repeatability of the resistivity method.

What They Found

Traditional methods for optimizing the supplementary cementitious material (SCM) dosage for ASR mitigation involve long-term performance testing across multiple replacement levels. This research developed a chemical screening tool (CST) for rapid estimation of optimal SCM dosage (1–2 days) by leveraging the concrete pore solution and aggregate reactivity relationship. Rapid estimation of SCM dosage by the CST was effective in verifying the dosage determined by ASTM C1567 and sorting out the SCMs that need further validation by the accelerated concrete cylinder test method (AASHTO TP142). This performance-based approach diminishes reliance on laborious ASR tests and offers substantial time and cost savings for industry and department of transportation (DOT) stakeholders.

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The current HPC mixtures showed optimized drying shrinkage (DS) performance. A threshold value of 400 µs at 28 days (requiring further validation) was proposed as a DS limit. However, the binary/ternary mixtures with silica fume (SF) and low w/cm ratios (0.40–0.42) showed high autogenous shrinkage. This feature, combined with relatively high thermal strains from early-morning placements, likely caused early-age cracking in certain Amarillo bridge decks with a ternary SF mixture.

Resistivity measurements followed by formation factor estimates (FF = resistivity * pore solution conductivity [PSC]) were very useful in characterizing mixture-specific transport properties. The research established FF-based transport properties' relationships for direct predictions of HPC mixtures' diffusion and sorptivity coefficients, negating the need for laborious performance tests (C1556 and C1585) and enabling rapid in-field chloride and F/T service life assessment.

The reliability of resistivity measurements depends on selecting the appropriate curing regimen. Recent specifications for concrete resistivity tests recommend a single simulated pore solution (SPS) curing to eliminate the need for PSC determination and simplify FF determination. However, this study showed that SPS does not uniformly represent PSC across various HPC mixtures, thus prompting the development of a matching pore solution (MPS) curing regimen. MPS aligns curing solutions closer to the mixture's actual PSC, thereby reducing variability in resistivity measurements and improving the reliability in estimating FF and FF-based transport properties. The resistivity methods met within-laboratory and between-laboratory repeatability requirements based on measuring resistivity (both surface and bulk resistivity) with SPS curing and normal conditioning (NC)/accelerated conditioning (AC) for one mixture by two laboratories.

What This Means

The developed TxDOT Tool aids DOT practitioners and contractors in conducting rapid durability-based performance evaluations of Class S CIP HPC bridge deck mixtures at design, trial batch, and/or field batch stages in four distinct areas: ASR mitigation, shrinkage, resistance to chloride ion ingress, and F/T durability.

Guidelines were also developed for comprehensive performance evaluation of HPC mixtures (covering these aspects) through:

- The TxDOT Tool application.
- Recommendations for appropriate curing and conditioning selection for resistivity tests.
- Selective ASR and shrinkage testing to validate the tool's predictions.

The TxDOT Tool effectively evaluates the durability performance of the studied HPC mixtures using 91-day resistivity measurements with NC. However, when the suitability of 28-day resistivity tests under AC (laboratory or field) for rapid assessments was explored, the TxDOT Tool could classify performance adequately but did not provide acceptable performance evaluation for HPC mixtures. Future work should:

- Validate the acceptability of 28-day resistivity measurements with AC for performance classification and durability-based performance evaluation.
- Expand the field program to establish the validity of using field-cast specimens for quality assurance/quality control.
- Broaden inter-laboratory resistivity research by including more mix types, lab participation, and spreadsheet development for resistivity input correction (device configuration, specimen geometry, etc.) and analysis.

For More Information

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