National Concrete Pavement Technology Center

Development of Performance Properties of Ternary Mixtures: Laboratory Study on Concrete

tech transfer summary

This research project is a comprehensive study of how supplementary cementitious materials can be used to improve the performance of concrete mixtures.

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RESEARCH PROJECT TITLE
Development of Performance Properties of Ternary Mixtures: Laboratory Study on Concrete

SPONSORS
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The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

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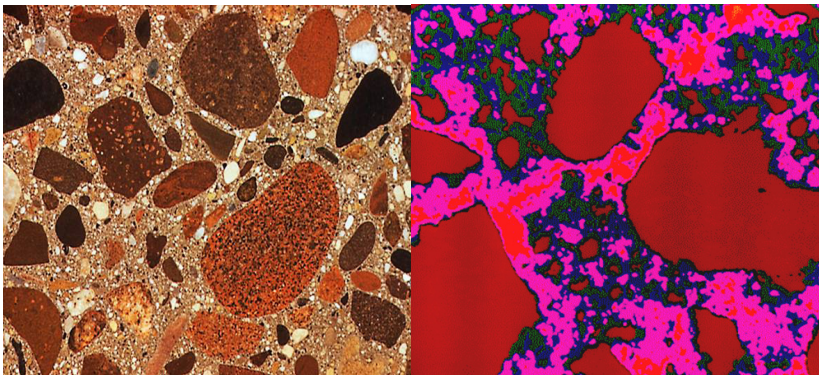
Problem Statement

Supplementary cementitious materials (SCMs), such as fly ash, ground granulated blast-furnace slag (GGBFS), natural pozzolans, calcined kaolinite, and silica fume, have become common parts of modern concrete practice. The blending of two or three cementitious materials to optimize durability, strength, or economics provides owners, engineers, materials suppliers, and contractors with substantial advantages over mixtures containing only portland cement. However, these advances in concrete technology and engineering have not been adequately captured in the specifications of concrete.

Usage is often curtailed because of prescriptive concerns or historical comparisons about how materials should perform. In addition, SCMs can exhibit significant variation in chemical and physical properties, within both a given source and, more commonly, between sources.

Users need specific guidance to assist them in defining the performance requirements for a concrete application and the selection of optimal proportions of the cementitious materials needed to produce the required durable concrete.The selection process is complicated by the fact that blended cements are currently available in selected regions. Both portland and blended cements have already been optimized by the manufacturer to provide specific properties (such as setting time, shrinkage, and strength gain). The addition of SCMs (as binary, ternary, or even more complex mixtures) can alter these properties, and, hence, has the potential to impact the overall performance and applications of concrete.

Research is needed to identify and quantify the major factors that govern mixture performance with multiple SCMs. The focus of the research should be directed at ensuring that the use of these various materials always has a positive impact on the overall durability of the concrete.



Concrete slice (left) and false color concrete image (right)

Project Goals

The goal of this project is to provide the quantitative information needed to make sound engineering judgments pertaining to the selection and use of supplementary cementitious materials (SCMs) in conjunction with portland or blended cement. This will lead to a more effective utilization of supplementary materials and/or blended cements, enhancing the life-cycle performance and minimizing the cost of transportation pavements and structures.

The efforts of this work were directed at producing test results to support the following specific goals:

- Provide quantitative guidance for ternary mixtures that can be used to enhance the performance of structural and pavement concrete
- Provide a solution to the cold weather issues that are currently restricting the use of blended cements and/or SCMs
- Identify how to best use ternary mixes when rapid strength gain is needed
- Develop performance-based specifications for concrete used in transportation pavements and structures

Research Approach

This concrete phase of the study used the information obtained from the paste and mortar work to select a range of materials and dosages to investigate the effects of cold, hot, and ambient environmental conditions for use in concrete mixtures. The thrust of this phase was to build on the data from the previous work, and test concrete mixtures to evaluate the performance characteristics of pavement and structural mixtures.

The materials used in both phases were identical, so that the mortar test results could be directly compared to the test results obtained from concrete test specimens. This comparison is needed to provide information pertaining to the selection of appropriate mixture design and performance tests for specification development. It was desirable to develop mixture design tests using the behavior of mortar specimens that translate well into the performance of concrete. The results of this phase were performance-based measures for concrete in transportation applications.

A subsequent phase will be field demonstrations, in which contractors and states will have on-site technical support for using ternary mixtures. After each trial, the performance-based specifications will be reviewed and revised if necessary. The National Concrete Pavement Technology Center (National CP Tech Center) at Iowa State University (ISU) will seek to help conduct at least one project for each participant state using its mobile research laboratory.

Key Findings

This study investigated the age-related distress mechanisms in ternary blended cementitious materials in concrete and any related barriers to using ternary blended cementitious materials in ready mix concrete. While this is not a final for the entire project report, preliminary findings from this phase of the study, will extend into the final phase of the study.

- There are no technical barriers that exist when using most ternary blended cement mixtures. The mixtures can be designed to meet state requirements and outperform ordinary portland cement concrete (PCC) mixtures.
- Ternary blended cement concrete mixtures greatly reduce the carbon dioxide and other greenhouse gas emissions related to the concrete industry. These mixtures can save more than 10,000 tons of carbon dioxide from being emitted into the atmosphere for just 10 miles of a six-lane concrete pavement.
- The initial cost of a ternary blended cement concrete pavement is dependent on the SCMs used and their proximity to the project location. The initial cost can generally be lowered if fly ash or GGBFS is used. Life cycle costs of ternary blended cement mixtures containing these materials, as well as silica fume, metakaolin and other pozzolans are also reduced.
- The interaction between SCMs varies depending on different materials that are used. Optimum combinations will vary with the selection of materials and relative quantities of each constituent in the concrete mixture. The most efficient means of optimizing a ternary concrete mixture is through trial batching using the mixture designs in this report as a starting point.
- Ready mix plants can receive a return of their investment of adding additional silos for storage of SCMs if they provide fly ash. If they blend on site, the investment in the silo and associated equipment can be recovered in less than 10,000 yd3 of concrete.
- Pre-blended cements can be beneficial because the SCMs are well distributed and the gypsum content has been optimized during the cement production. These cements also meet all applicable standards. There is no capital investment by the ready mix producers from using pre-blended cements.
- States should update their specification to remove limitations on total SCMs and use performance-based tests to determine acceptable concrete mixture properties.
- Different SCMs are appropriate for general use and others for special projects. Different SCMs are also appropriate for different environments. Each state should use SCMs that best suit the project and its environment.