National Concrete Pavement Technology Center

Homogeneity of PCC Materials and Mixes

tech transfer summary

Documenting the uniformity of raw materials, plastic concrete properties, and hardened concrete was a major function of this project.

Objectives

- Define the characteristics of a "good" concrete mix as it relates to the mixture supplied to the slipform paver on grade
- Investigate effects of the key parameters of concrete mixing on fresh concrete properties (such as uniformity and workability) under laboratory conditions that replicate different material combinations, mixing times, and mixing methods

Problem Statement

Severe environmental conditions, coupled with the routine use of deicing chemicals and increasing traffic volume, place extreme demands on portland cement concrete (PCC) pavements. Although engineers have in many instances been able to design PCC pavements that met these challenges, there have been some reports of premature deterioration that could not be attributed to a single specific cause. Such deterioration often appeared to be the result of problems that arose because of plastic concrete problems (mixture incompatibilities) and/or construction practices (construction-related distress or CRD).

Both the complexity of modern concrete mixtures and local environmental conditions can influence the outcome of paving projects. Hence, research is needed on the characterization of basic concrete materials (i.e., uniformity before and after mixing), identifying potential incompatibility problems, and optimizing mixture proportion. These are key factors for increasing the durability of concrete pavements.

In addition, the strong push for the use of supplementary cementitious materials (SCMs) in the concrete industry has magnified concerns about product homogeneity, a characteristic which can complicate field operations and in turn impact performance. Bulk chemical composition for portland cements and fly ash often gives a good indication of material homogeneity. However, such measurements are less meaningful for blended cements, because the blending process tends to obscure changes in the base materials.

Research Description

This research project investigated important variables that impact the homogeneity and rheology of concrete mixtures.

Data collected in the field study documented cementitious material properties, plastic concrete properties, and hardened concrete properties.

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RESEARCH PROJECT TITLE
Materials and Mix Optimization Procedures for PCC Pavements

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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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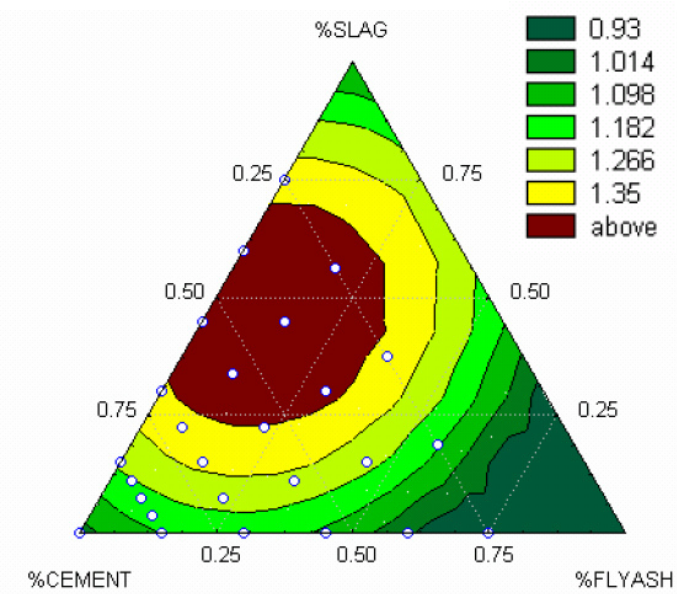
Key Findings

- The results of the field studies indicated that the quality management concrete (QMC) mixtures used in Iowa generally exhibited good uniformity and good to excellent workability. Hardened concrete properties (compressive strength and hardened air content) were also satisfactory.
- The homogeneity of raw cementitious materials that were used on the projects could not be monitored by the investigators as closely as was desired. However, the information that was gathered indicated that the bulk chemical composition of most materials streams was reasonably uniform. Specific minerals phases in the cementitious materials were less uniform than the bulk chemical composition. This suggests that some manufacturing processes could be improved to provide a more homogeneous materials stream to construction projects.
- Of the six projects in this study, only one contractor reported mixture-related problems. However, testing indicated that the cementitious materials were functioning adequately and that the problem likely resulted from extreme weather conditions (a heat index of approximately 110 degrees) and a relatively harsh mixture.
- The results of the laboratory study indicated that ternary mixtures show significant promise for improving the performance of concrete mixtures.



Ternary diagram illustrating relative mortar strength after 180 days of curing

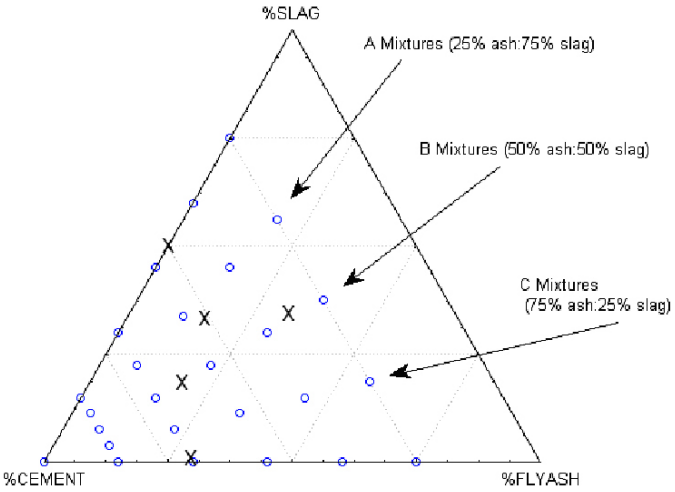


Illustration of the paste, mortar, and concrete mixtures made for the study

- The lab study also verified the results from prior projects that have indicated that bassanite ($CaSO_4 \cdot \frac{1}{2}H_2O$) is typically the major sulfate phase that is present in portland cements and blended cements in Iowa. This trait causes cements to exhibit premature stiffening problems (false set) in laboratory testing. Fly ash helps to reduce the impact of false set in most instances. The premature stiffening problem can also be alleviated by increasing the water–cement ratio of the mixture and providing a remix cycle for the mixture.

Implementation Benefits

The data collected provided adequate information to characterize a "good" paving mix. The information colleted in this research project provides a more rational basis for explaining discrepancies between theoretical performance (ideal, laboratory) and actual field performance (service life) of concrete pavement supplemented with SCMs.

Implementation Readiness

Since no evidence of premature distress has been observed in the last decade, it appears that the development and implementation of the QMC mixture program in Iowa has resolved previous problems. Other states may derive benefit from the results of this research.

In addition, future uniformity requirements will hopefully progress to the level of measuring actual mineral phases or glass components to give a more precise estimate of the uniformity of the active ingredient(s) in the material and how that uniformity impacts constructability and pavement durability.