IOWA STATE UNIVERSITY
Materials Analysis and Research Laboratory

Alkali Content of Fly Ash: Measuring and Testing Strategies for Compliance

tech transfer summary

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RESEARCH PROJECT TITLE
Alkali Content of Fly Ash:
Measuring and Testing Strategies for Compliance

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The Materials Analysis and Research Laboratory, one of the core facilities supported by the Office of Biotechnology at Iowa State University, offers chemical and physical characterization of a wide variety of materials to support university research and teaching programs. For outside agencies, the laboratory also conducts research on materials-related problems.

This study investigated the test methods used to determine the alkali content of fly ash. It also evaluated if high-alkali fly ash exacerbates alkali-silica reaction in laboratory tests and field concrete.

Background

Sodium and potassium are the common alkalis present in fly ash. Excessive amounts of fly ash alkalis can cause efflorescence problems in concrete products and raise concern about the effectiveness of the fly ash to mitigate alkali-silica reaction (ASR). Fly ash marketing agencies occasionally provide materials that just miss the criteria for alkali content given in Iowa DOT IM 491.17. Since usage is only from an approved list (certified sources) this leads to disputes that can be difficult to resolve. This is especially problematic when the alkali content of a given source of fly ash only changes by a small amount, but the change causes the source to exceed a specification limit.

Problem Statement

The available alkali test takes approximately 35 days for execution and reporting. Hence, in many instances the fly ash has already been incorporated into concrete before the test results are available. This complicates the job of the fly ash marketing agencies and it leads to disputes with fly ash users who often are concerned with accepting projects that contain materials that fail to meet specification limits.

Objectives

The objectives of this research project were to:

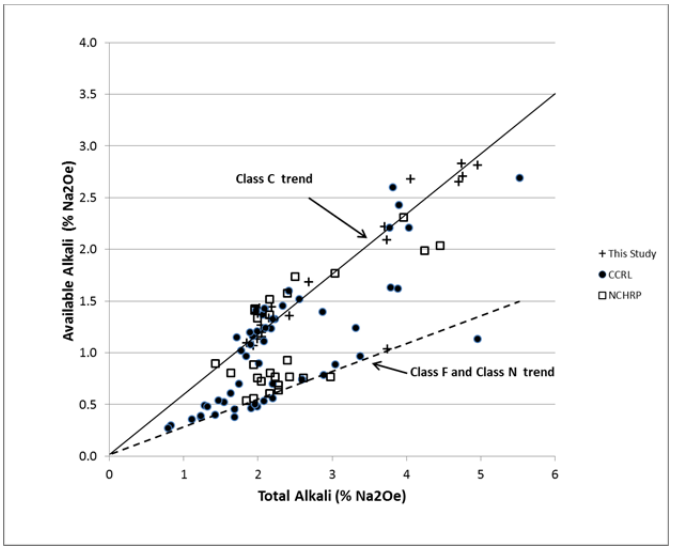
- Determine if and how, new emission control rules will impact Midwest power plants and fly ash production
- Determine if high-alkali fly ash exacerbates the occurrence of ASR in laboratory test specimens
- Determine a faster method for determining the available alkali content of fly ash
- Evaluate field concrete containing high-alkali fly ash to see if ASR is more prevalent

Research Methodology

The research plan consisted of a lab study and a field study. The lab study focused on the available alkali test and how fly ash alkali content impacts common performance tests (mortar-bar expansion tests). Twenty-one fly ash samples were evaluated during the testing. The field study focused on the inspection and testing of selected, well documented pavement sites that contained moderately reactive fine aggregate and high-alkali fly ash from Ottumwa Generating Station (OGS). A total of nine pavement sites were selected to be evaluated.

Findings and Conclusions

- Recent changes (or proposed changes) in environmental regulations will impact all coal-burning power plants in the United States of America. The major impacts will be due to the implementation of the Mercury and Air Toxics Standards (MATS) and the Clean Power Plan (CPP). MATS retrofits are currently in progress and will be completed by about 2016. The future of the CPP is currently uncertain, but the rule is expected to be finalized in June 2015. Due to the controversy of the rule, many legal challenges are expected and this could delay the effective date of the rule.
- High-alkali fly ash did not exacerbate the occurrence of ASR in laboratory test specimens. Mortar-bar expansion tests indicated that performance can be improved (lower measured expansions) by using more fly ash (higher replacement levels), a fly ash containing a higher value of the sum-of-the-oxides (more siliceous), and blended cements. In this study, the Type IP cement performed the best of the three cements that were studied. The available alkali content of the fly ash generally did not produce the best correlations to measured expansions; this was especially true if one was allowed to change fly ash replacement level.
- Mortar-bar expansion tests, conducted in accordance with Iowa DOT IM 491.17, did not fail any fly ash samples due to excessive expansion. However, four of these fly ash samples had available alkali contents exceeding 2.5% (the maximum limit via chemical testing). Comparison of the Iowa DOT failure criterion for mortar-bar expansion with other specifications (both ASTM and AASHTO) indicated that it needs to be re-evaluated.
- The available alkali test is prone to experimental errors that lead to poor agreement between testing labs. The strong linear relationship between available alkali and total alkali contents for Class C fly ashes (see below), provides a quicker and more precise method for estimating the available alkali content.



Relationship between total alkali and available alkali for fly ash

- High-alkali fly ash from Ottumwa Generating Station was not conclusively linked to ASR problems at any field site. It was used in pavements that had both good and poor performance. Sites 2, 5 and 9 all contained OGS fly ash but did not exhibit significant ASR-related distress in the petrographic exams.
- Examination of pavement cores indicated that Wayland sand is an ASR-sensitive aggregate. Four of the six sites that used this sand exhibited microcracking that could be attributed to specific fine aggregate particles. In the remaining two sites that used Wayland sand, minimal cracking was noted but ASR gel was noted in both cores. The most common reactive components consisted of shale, chert and hydrous chert. Occasionally greywacke and meta-granite were also found near gel deposits.

Research Implementation

- It is recommended that the available alkali test be replaced with the total alkali test. This will reduce the time required to produce a test result from about 28 days to about one hour.
- The DOT needs to adopt a simpler strategy to calibrate their available alkali model for Class C fly ash. It is recommended that they set the slope of the calibration curve to 0.66 and set the intercept to zero. CCRL pozzolan samples 38 and 47 can be used to evaluate the performance of the model.
- IM497.17 has served the Iowa DOT for over 20 years. Changes need to be made to bring it up-to-date. However, it is recommended to postpone any major changes until after the current (and proposed) EPA regulations are implemented because that would avoid making multiple changes that could confuse users. The following changes are recommended in the interim:

  - The specification limits in that document need to be changed to reflect the change to total alkali content. This means that the low limit should be changed to 2.3% and the high limit should be changed to 3.8%.
  - The Iowa DOT failure criterion for the mortar-bar expansion test needs to be re-evaluated. The test is performed very infrequently (less than one time per year), and has not failed any source of fly ash so it could be removed from the IM without much impact.

- Wayland sand is an ASR-sensitive aggregate. It is recommended that preventative measures be used when utilizing this aggregate in concrete mixtures.