PUTTING RESEARCH TO WORK BRIEF

Comparison of Class C Versus Class F Fly Ash for Concrete Pavement

Current Wisconsin Department of Transportation (WisDOT) specifications only permit Class C fly ash for use in Portland cement concrete in pavements. Class F fly ash sources were eliminated from WisDOT specifications in the 1990s due to high values of loss on ignition (LOI), which led to difficulties in establishing and maintaining a proper entrained air void system in the concrete used in paving applications. It is necessary to determine the suitability of current Class C fly ash sources and available Class F sources for use in Portland cement concrete (PCC) in pavements because of potential changes in the production of fly ash related to the coal sources used and new unit operations needed to meet changing air quality standards.

What is the Problem?

There is a mutual interest between WisDOT and industry to increase the number of usable fly ash sources in Wisconsin due to concerns that the availability of Class C fly ash may be reduced due to changing coal sources. Specifically, research is needed to evaluate the feasibility of expanding current specifications to allow for use of Class F fly ash in concrete paving applications. In order for Class F fly ash to be a viable alternative as a supplemental cementitous material, its use must produce mixes that meet current performance standards.

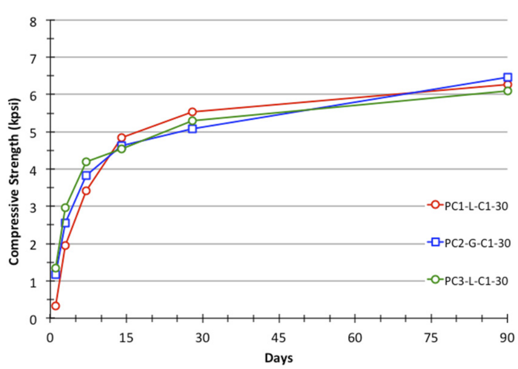
Objectives

The objectives of this research include:

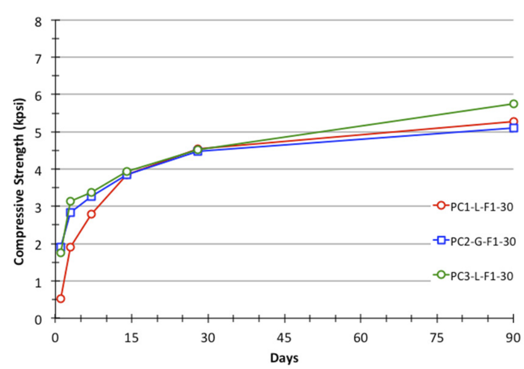
- Evaluating several locally available Class F fly ash sources in terms of their potential to impact air entrainment in paving concrete, in comparison with Class C fly ash sources currently in use.
- Providing mixture design guidance related to acceptable proportions of Class F fly ash that can be used in paving applications without negatively affecting overall performance.

Methods

The materials were first characterized with respect to air entraining admixtures (AEA) adsorption using the foam index test, direct measurement of adsorption and the iodine number test. Next, a partial factorial experiment was conducted to evaluate the mixtures using two different Class C fly ash sources, two different Class F fly ash sources, three different Portland cement sources and two different aggregate sources as primary variables. This resulted in a matrix of 42 concrete mixtures with fly ash and six concrete mixtures without fly ash. The concrete mixtures were tested using standard fresh concrete tests (e.g., slump, unit weight, air content) and semi-adiabatic calorimetry. Hardened concrete tests were also performed, including compressive strength, flexural strength and freeze-thaw durability (in a $CaCl_2$ solution).



(a)



(b)

Plots of Compressive Strength Development Over Time For Concrete Mixtures: (a) Class C Fly Ash Replaced at 30% and (b) Class F Fly Ash Replaced at 30%

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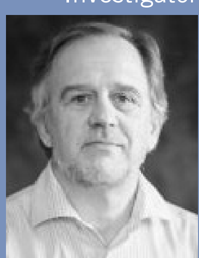

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Results

- The two Class C ash sources had a very low LOI (0.2 percent and 0.3 percent), but the ash with the lower LOI had the second highest adsorption capacity of the four ash sources tested (two Class C and two Class F). For the Class F ashes, the LOI values were 0.1 percent and 2.0 percent, and their adsorption capacity was in proportion to these values. However, the low LOI Class C fly ash had an adsorption capacity comparable to the high LOI Class F fly ash. This result shows the need for characterizing fly ash based on adsorption capacity rather than loss on ignition. With respect to impact on air entrainment, the Class F ash sources tested performed in a manner similar to Class C ash currently being used in Wisconsin.
- The results of calorimetry testing showed both Class C and Class F fly ash sources followed the expected classic behavior. Addition of either type of ash reduced the heat of hydration; the reduction associated with the addition of Class F ash is greater than that with Class C fly ash.
- The results of the freeze-thaw testing showed that most of the concrete mixtures, with and without fly ash, performed well. Only 10 of the 48 mixtures had durability factors less than 80 percent after completion. However, of the 10 mixtures falling below 80 percent, six had the high LOI Class F fly ash in the mixture. Only two mixtures were unable to achieve the full 300 cycles of freeze-thaw testing. Given the harshness of testing in $CaCl_2$ solutions, the mixtures performed well overall.
- Class C and Class F fly ashes reduced compressive and flexural strengths of concrete mixture at early ages. Compared to Class C fly ash, Class F fly ash and concrete with higher ash contents produced more pronounced reductions. Both types of ash showed a decrease in the rate of strength gain. The strengths of concrete mixtures with Class C fly ash were comparable to strengths of the concrete mixtures without fly ash at 14 days. The strengths of concrete mixtures with Class F fly ash were comparable to strengths of the concrete mixtures without fly ash at 90 days.
- Use of fly ash showed a major impact on the results of maturity tests. The maturity level required to achieve a specific strength varied widely with the fly ash content as well as the cement type. Except at early ages (e.g., 1-day), the type of fly ash did not have statistically significant effect on the maturity.

Recommendations

The researchers made the following major recommendations from the results of this research:

- There is strong evidence to support using Class F fly ash in concrete pavement. The use of Class C ash should also continue. With the exception of freeze-thaw testing, the performance of the Class F ash sources tested was comparable to that of the Class C ash sources. Replacement levels of fly ash up to 30 percent can be used without significant changes in fresh or hardened concrete properties. For replacement levels greater than 30 percent, performance testing of the mixtures must be required.
- The existing LOI specification of two percent should be retained, but additional testing should be performed to establish the adsorption capacity of any ash used in paving concrete.
- WisDOT should adopt use of the direct adsorption isotherm test and the coal fly ash iodine number test on a provisional basis. By adopting these tests on a provisional basis, materials providers and contractors can begin developing a knowledge base of the tests, and WisDOT can begin developing a historical database for establishing future specification criteria.
- WisDOT should discontinue freeze-thaw testing using $CaCl_2$ solutions in the test procedure. This results in a harsh testing environment, which extends what is already a harsh test (AASHTO T 161) into a more severe environment. Additionally, $CaCl_2$ solutions are corrosive and result in destruction of freeze-thaw chambers.

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This brief summarizes Project 0092-12-04,
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