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PORTLAND CEMENT CONCRETE
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tech transfer summary

Blended Cements

Improving Concrete Properties Using Environmentally Responsible Mixtures

RESEARCH PROJECT TITLE
Evaluating Properties of Blended Cements for Concrete Pavements

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PRINCIPAL INVESTIGATOR/ CONTACT PERSON
Kejin Wang
Assistant Professor
Department of Civil, Construction and Environmental Engineering
Iowa State University
515-294-2152
kejinw@iastate.edu

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MORE INFORMATION
http://www.pcccenter.iastate.edu/research/detail.cfm?projectID=844170850

PCC CENTER
IOWA STATE UNIVERSITY
2901 South Loop Drive
Suite 3100
Ames, IA 50010-8634
515-294-8103

Objectives

Recent research evaluated the behavior of concrete made with supplementary cementitious materials (SCMs) such as fly ash and ground granulated blast-furnace slag under a variety of conditions. Correlations were found among the source and proportion of the SCMs, curing conditions, concrete set time, maturity, strength development, and cracking potential.

Problem Statement

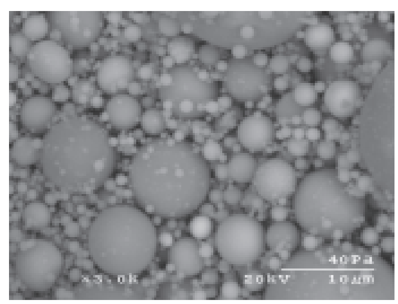
This project was triggered by interest in sustainable development and new environmental regulations on waste disposal. The addition of fly ash, slag, and other industrial byproducts to cements can improve concrete workability, durability, and long-term strength, but a gap in knowledge about the variation in performance of concrete containing SCMs from various sources has limited its use by the PCC paving industry.

Technique Description

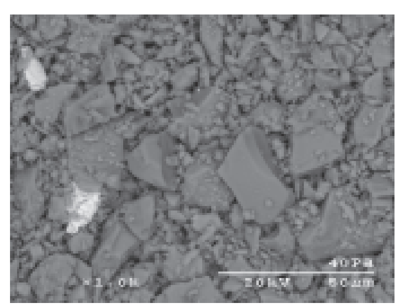
Cement mixtures containing ordinary portland cement (OPC) and at least one SCM are called blended cements. Class C fly ash is often used as a SCM to improve concrete workability and reduce cost, as well as for other technical reasons. Blended cements blended or interground at cement plants are generally more uniform and produce better results than blended concrete mixtures combined at the concrete mixer.

Binary cements contain OPC and one SCM. In this project, the term binary cement is used to refer to blended cements containing OPC and 15% Class C fly ash.

Ternary cements contain OPC and two SCMs. In this project, the term ternary cement is used to refer to blended cements containing OPC, 15% Class C fly ash, and 20%, 25%, or 35% slag.



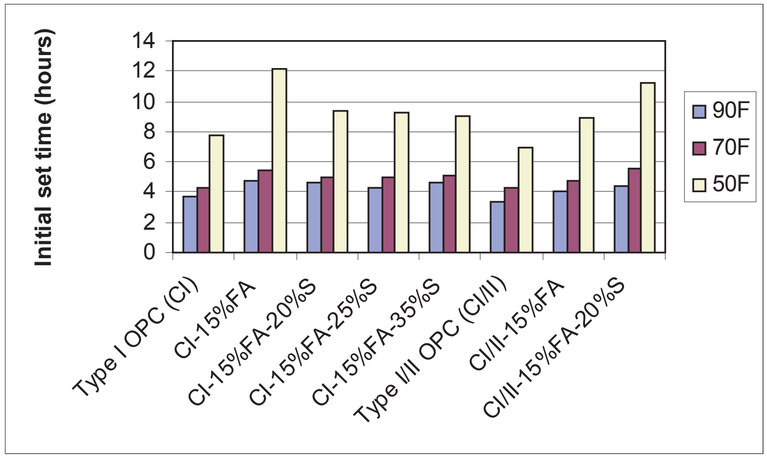
Fly ash viewed through scanning electron microscope



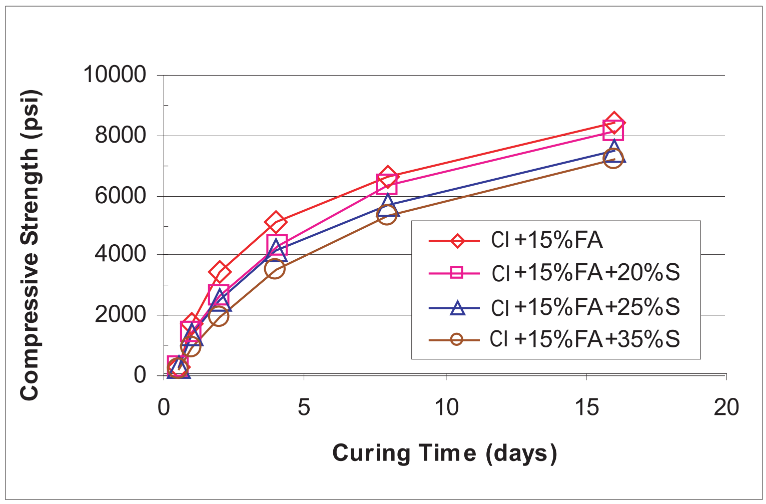
Slag viewed through scanning electron microscope

Key Findings

- Concrete performance varies with the source and proportion of cementitious materials used.
  - o Fly ash can function as a water-reducing agent in cement mixtures. As a result, ternary cement concrete can achieve the same flowability as OPC concrete.
  - o Fly ash replacement in binary cements generally increases paste/concrete set time when compared with OPC concrete.
  - o Slag replacement in ternary cements can either increase or decrease the set time, depending on the type of clinker used when compared with binary cement conrete.
- As SCM content increases, longer curing times or higher curing temperatures may be needed.
  - o SCM concrete often displays slow hydration, accompanied by slow setting and low early-age strength, especially under cold weather conditions.
  - o Due to the effect of curing temperature on the pozzolanic reaction of the material, covering slabs to trap heat, extending curing times, and/or using accelerators is recommended for SCM concrete paving in cold weather conditions.
- SCM concrete can perform comparably to or better than OPC concrete under hot weather conditions.
  - o SCM concrete generally has a lower risk of thermal cracking than OPC concrete because the maximum heat of cement hydration in binary/ternary cement concrete decreases with the amount of SCM replacements.
  - o Under hot weather conditions (90°F), binary/ternary cement concrete has a slightly longer set time than OPC concrete, which permits sufficient time for concrete placing and finishing.
  - o Under hot weather conditions (90°F), ternary and binary cement concretes have comparable strength at the age of about 7 days, but at 14 days ternary cement concrete displays higher strength.
- Traffic opening time of pavement should be based on strength and time-temperature factor (TTF) as follows:



Initial set times of concrete made with Type I and Type I/II OPC and various amounts of fly ash and slag at 90°F, 70°F, and 50°F



Effect of SCMs on mortar strength (Type I OPC cured at 70°F)

  - o A consistent datum temperature should be used in developing the strength-TTF correlation and the TTF-time correlation to determine pavement traffic opening time.
  - o The required TTF value to open pavement to traffic should be based on the strength-TTF correlation of the concrete materials and mix proportions under the field curing conditions. Determining pavement traffic opening time based on the strength-TTF correlation developed at normal weather conditions (70°F) for concrete cured at cold weather conditions (50°F) could result in improper early opening of the pavement.

Potential Benefits of Blended Cements

- Improved concrete workability.
- Lower risk of thermal cracking.
- Improved concrete durability and long-term strength.
- Reduced overall concrete cost.