National Concrete Pavement Technology Center

Optimizing Cementitious Content in Concrete Mixtures for Required Performance

tech transfer summary

This study investigates the effects of changing cement content and paste volume on strength and durability.

January 2012

RESEARCH PROJECT TITLE
Optimizing Cementitious Content in Concrete Mixtures for Required Performance

SPONSORS
Federal Highway Administration
DTFH61-06-H-00011 Work Plan 20

PRINCIPAL INVESTIGATOR
Peter Taylor
Associate Director, National Concrete Pavement Technology Center
Iowa State University
515-294-9333
ptaylor@iastate.edu

MORE INFORMATION
www.cptechcenter.org

National CP Tech Center
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-3230

IOWA STATE UNIVERSITY
Institute for Transportation

Problem Statement

Concrete is the most commonly used material for all types of construction, and cement is a primary component. The cement content of a mixture is commonly perceived to control concrete strength. Based on this perception, a minimum cement content is often specified that may exceed the amount needed to achieve the desired strength and durability.

This excess amount of cement content has a negative impact on cost and the environment for the following reasons:

- Cement is the most expensive component in concrete
- Cement contributes about 80 percent of the carbon dioxide (CO_2) burden of a concrete mixture

Although workability is improved by increasing cement content, previous studies suggest that increasing cement content does not necessarily contribute to increasing strength. Increased cement content also causes higher internal temperatures in the concrete during the finishing and curing processes. In addition, the high cement content causes the mixture to become sticky and may lead to increased risk of shrinkage and cracking problems. Therefore, cement content should be balanced to achieve the required performance while minimizing risk of these problems.

Research Goal and Objective

The goal of this project was to help the concrete industry use the right amount of cement with an appropriate water-to-cement (w/c) or water-to-cementitious materials (w/cm) ratio to meet given workability, strength, and durability requirements, and so to optimize carbon dioxide emissions, energy consumption, and costs.

The hypothesis behind this study is that when other parameters are kept constant, concrete properties such as strength and durability will not be improved significantly by adding additional cement after a certain minimum cement content is used. Figure 1 illustrates this hypothesis.

The scope of this study was to investigate strength, chloride penetration, and air permeability as indicators of performance of concrete mixtures with various w/cm and cementitious contents using a variety of binders. Fresh concrete properties such as slump, setting time, and air content were also tested.

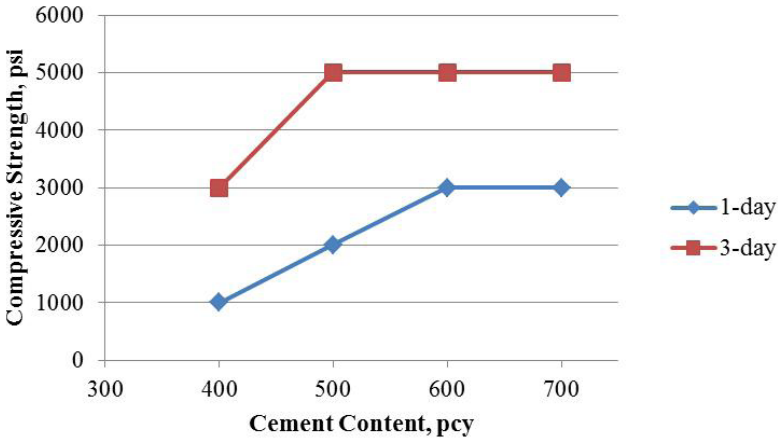

Figure 1. Hypothetical effect of cement content on concrete compressive strength for this study

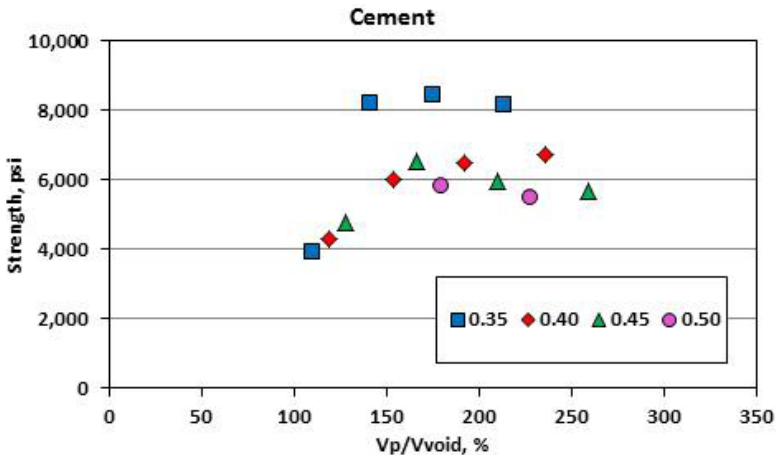

Figure 2. Compressive strength at 28 days as a function of volume of paste divided by the volume of voids in the aggregate system; the data in this figure is consistent with the hypothesis (Figure 1)

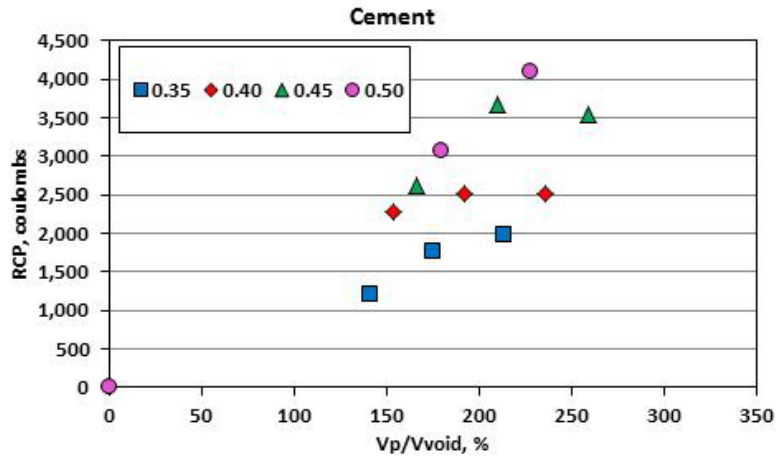

Figure 3. Chloride penetrability at 28 days as a function of volume of paste divided by the volume of voids in the aggregate system

The final report for this project presents and discusses workability, setting time, strength, chloride penetration, and air permeability, and how they are affected by paste content of a mixture.

Key Findings

- About 1.25 to 1.5 times more paste is required than voids between the aggregates to obtain a minimum workability. Below this value, water reducing admixtures are of little benefit. Increasing paste thereafter improved workability.
- For a high cement content, decreasing w/c reduces setting time because cement grains are closer to each other, reducing the time needed for hydration products to become interconnected.
- For a given w/cm, increasing cementitious content does not significantly improve compressive strength once the critical minimum has been provided. The critical value is about 1.5 to two times the voids content of the aggregate system. Figure 2 illustrates this.
- For a given w/cm, increasing paste content increases the chloride penetrability. Figure 3 provides an example.
- For a given w/cm, increasing cement content increases the air permeability.

Implementation Benefits

Reducing excess cement content in concrete mixtures will help to reduce costs as well as the environmental and energy impacts associated with making cement.