Florida Department of Transportation Research

Effects of Blast Furnace Slag Characteristics on Durability of Cementitious Systems for Florida Concrete Structures

September 2019

Project Number
BDV25-977-28

Project Manager
Harvey DeFord
FDOT Materials Office

Principal Investigator
Abla Zayed
University of South Florida

Current Situation

Concrete is a mixture of relatively simple ingredients – portland cement, water, sand, and aggregate – but the chemistry of these ingredients is quite complex, as are the effects of the ingredients and their chemistry on the performance of the final concrete. Much research has been done in order to understand the effects of variations in the basic ingredients of concrete as well as other materials (admixtures) on the strength and durability of concrete. The result has been a very refined understanding of concrete and formulas that produce very strong and durable concrete. A common admixture is ground-granulated blast furnace slag (GGBFS), a nonmetallic byproduct of iron refining. GGBFS is a combination of calcium oxide, magnesium oxide, silicate, and aluminate. Concrete formulas that include GGBFS have improved strength and durability, but recent field tests have indicated that higher temperatures are occurring in the curing concrete, which can result in expansion and cracking.

Excessive curing temperatures in large concrete structures can result in cracking and less durability.

Research Objectives

Cement mixtures containing GGBFS were tested to assess their cracking potential and sulfate durability, especially with regard to aggressive environments.

Project Activities

Eight GGBFSs were selected for the project. Three were selected for their low, medium, and high aluminate content. Three additional slags, ground to different degrees of fineness, were used to test the effect of fineness. Two more slags, with different sulfate content, were used in a limited number of experiments. The four cements selected had similar fineness and silicate content, but differed in alkali and aluminate content.

The as-received materials were tested for their physical, chemical, and mineralogical composition, using Blaine fineness, particle size distribution, specific gravity, X-ray fluorescence, and X-ray diffraction coupled with Rietveld refinement. Mixtures were tested at the cement+water (paste), cement+water+sand (mortar), and cement+water+sand+aggregate (concrete) stages, using a variety of tests, including sulfate durability, pore size distribution, X-ray diffraction, cracking index, and others.

Study findings indicated the significance of three GGBFS properties on slag-blended concrete cracking potential: alumina content, alumina-to-magnesia ratio, and fineness. Higher alumina content, higher slag fineness, and higher alumina-to-magnesia ratio resulted in higher cracking potential. Additionally, increasing slag alumina, alumina-to-magnesia ratio, and fineness had a negative effect on sulfate durability of the slag-blended cementitious systems.

Project Benefits

A better understanding of the relationship between slag properties and the properties of concrete made with it will help ensure more durable concrete structures.

For more information, please see www.fdot.gov/research/.