ABSTRACT

Huang, Dan., Purdue University, August 2022. The Impact of Curing Temperature on the Hydration, Microstructure, Mechanical Properties, and Durability of Nanomodified Cementitious Composites.
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The study focused on examining the effects of using nanoadditives (nano-TiO_2 and colloidal silica) on the hydration kinetics, microstructure, mechanical properties, and durability of concretes, especially those containing fly ash and slag and cured at low (4°C) temperature.

The results of the Vicat and isothermal calorimetery (IC) tests suggest that the addition of nano-TiO_2 accelerates the hydration process of pastes. In addition, the results of the thermogravimetric analysis (TGA) indicated that the addition of nano-TiO_2 increased the amount of hydration products in the pastes, with more notable increases observed in fly ash pastes. Moreover, X-ray diffraction (XRD) results revealed that the addition of nano-TiO_2 reduced the mean size of calcium hydroxide (CH) crystals.

The interfacial transition zone (ITZ) of concretes with nano-TiO_2 was found to be less cracked and less porous when compared to that of concrete without nano-TiO_2. Furthermore, the energy dispersive X-ray (EDX) analyses of the outer hydration products around partially hydrated cement particles in fly ash concretes with nano-TiO_2 revealed reduction in the values of Ca/Si atomic ratios when compared to the reference fly ash concrete. The image analysis results of the concrete air void system indicated slightly reduced air content, increased specific surface area (SSA), and decreased spacing factor (SF) in concretes with added nano-TiO_2.

The addition of nano-TiO_2 was also found to enhance the compressive and flexural strengths of mortars and concretes. Nano-TiO_2 also improved the resistivity and formation factor values of concretes containing fly ash. Moreover, the total volume of pores, as well as the values of water absorption, were also reduced as a result of addition of nano-TiO_2. This was true for all types of concretes (i.e., with or without SCMs). Finally, the use of nano-TiO_2 seemed to be more beneficial with respect to improving the scaling and freeze-thaw resistance of fly ash concretes compared to cement-only and slag concretes.

Concretes with added nanosilica (colloidal silica) also developed higher compressive and flexural strengths when compared to reference concrete. Moreover, the total pores and permeability of concretes decreased due to the addition of nanosilica while the improvement in

scaling resistance of these concretes was only slight. Furthermore, concretes with nanosilica were found to have higher percentage of finer air voids compared to reference concretes. Finally, the ITZ of concretes with nanosilica was found to have fewer defects and cracks compared to the reference concrete.

In summary, this dissertation presents the results of a study on the multi-scale behavior of nanomodified concretes with and without SCMs cured at both room and low temperatures. Knowledge gained from this study would be helpful in developing concretes with denser and less porous microstructure, a more refined and better-distributed air void system, improved strength, reduced permeability, and enhanced scaling and freeze-thaw resistance, especially in cases when involving the use of SCMs and exposure to low early-age temperatures.