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Hydration characteristic, thermal expansion and microstructure of cement containing nano-silica

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HIGHLIGHTS

- NS increases the water demand and consequently retards the setting process.
- The values of pH and free lime decrease with increasing NS% content.
- Chemically combined water contents increase with increasing NS% content, due to the pozzolanic reaction of NS.
- Microstructure and mechanical properties improved with increasing NS up to 3.0% and then slightly up to 5%.
- Thermal expansion coefficient of hydrated cement pastes containing 3% NS increases with curing time.

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ABSTRACT

The effect of nano-silica (NS) on the hydration characteristics, thermal expansion and microstructure of cement pastes and mortars was studied. OPC was replaced with NS up to 6.0%. The presence of NS increases the required water of standard consistency and elongated the setting times. The results of chemically combined water, free portlandite, pH, bulk density, compressive strength and thermal expansion showed that NS contents up to 5.0 mass% improve the physico-chemical and mechanical properties of cements. NS behaves not only as filler to improve the microstructure, but also as an activator to promote the pozzolanic reaction, which enhances the formation of hydrated products. It was concluded that partially substitution of OPC up to 5 mass% NS improves the mechanical and microstructural characteristics in comparison with the neat OPC paste up to 90 days.

1. Introduction

Recently, nanotechnology has attracted a considerable scientific interest due to the new potential uses of particles in nanoscale, which can change the concrete world. Nano-materials improve the concrete characteristics [1,2].

Nano-particles (NPs) showed unique physical and chemical properties different from those of the conventional materials [2]. There is a great interest in replacing NPs in concrete structure to improve the chemical and physico-mechanical properties of concrete [1,3].

NPs were used either to replace part of the cements [1,2]. The addition of NPs improves the performance of cement, in fresh mixtures, an improvement of rheological properties has been recorded and in the hardened state, the compressive strength was increased [4]. Nano-silica act as nuclei for promoting the hydration of cement phases (i.e., β-C_2S and C_3S), it acts as a nucleation site, which accelerates the cement hydration [5,6].

The greater reactivity of NPs is attributed to the high purity and high specific surface area. Some researchers have recorded an increased in the water demand for mixing of the cements and concretes to give the same workability [7–9].

The most common NPs used in cement production are nano-sized SiO_2 (NS), TiO_2 (NT), Al_2O_3 (NA), Fe_2O_3 (NF), ZnO_2 (NZ), and carbon nano-tubes [10,11].

The role of the NPs can be summarized as follows: (i) NPs not only act as fillers to improve the microstructure, but also as an activator to promote pozzolanic reactions [12], (ii) act as a nucleation site for

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