Nano-Silica for Enhanced Greener Concrete
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Background

Concrete and Environment
- Concrete, based mainly on Portland cement, is the most used manmade material and the 2nd most used material after water.
- Cement industry, one of the most energy consuming industries, accounts for 5% to 8% of the global CO₂ emissions.
- About 50% of these emissions are caused by the chemical process of cement manufacturing.
- For more than 50 years, different supplementary cementitious materials (SCMs) have been widely tested and used to replace ordinary cement in concrete.
- These materials included fly ash, Ground Granulated Blast Furnace Slag (GGBFS), natural pozzolans and silica fumes (micro silica).
- Fly ash, GGBFS and micro silica, as byproducts, are much more environmentally friendly compared to cement.
- U.S. Green Building Council’s (USGBC) considers using recycled materials or byproducts in concrete a contributing factor to earn points in the LEED program.
- Currently, minimum dosages of SCMs are recommended in concrete mixes by various agencies due to their environmental impact and to improve durability.
- The main concern about fly ash concrete has been always its relatively low early strength and strength gain rate compared to normal concrete.

Nano-Silica
- Nanotechnology is a promising research fields that may significantly improve the mixture design, performance and production of cement-based materials.
- Materials composed of nano-sized particles displays unique physical and chemical properties compared to those with normal particle sizes.
- Silica (SiO₂) is the most abundant mineral in the Earth’s crust and is found on all of its continents like sand and quartz.
- Nano-silica can be found in forms of (1) compacted dry grains and (2) colloidal suspension.

Scope and Objectives

Colloidal nano-silica was added to normal and fly ash concretes with different rates to examine the effect on different concrete performance aspects.

The main objectives of the study is to determine the effect of adding nano-silica on:
- The rate hydration and the reactivity of cement and pozzolans.
- The mechanical properties and strength gain rate (especially for fly ash concrete).
- Durability.
- Microstructure and Porosity.

Materials and Mixtures

<table>
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<tr>
<th>Mixture</th>
<th>Cement</th>
<th>Fly Ash</th>
<th>Effective Nano-Silica</th>
<th>Water</th>
<th>HRWR%</th>
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<tr>
<td>A-0</td>
<td>658</td>
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<td>19.74 (3.0%)</td>
<td>263.2</td>
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</tr>
<tr>
<td>A-1</td>
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<tr>
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<tr>
<td>B-0</td>
<td>460.6</td>
<td>197.4 (30%)</td>
<td>19.74 (3.0%)</td>
<td>263.2</td>
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<tr>
<td>B-1</td>
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<td>223.7</td>
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</tr>
</tbody>
</table>

Mechanical Properties

Hydration and Reactivity

Thermogravimetry, Portlandite (CH) peaks at about 450°C

Microstructure and Porosity

Major Observation

- The overall performance of concrete, with or without fly ash, was significantly improved with the addition of variable dosages of nano-silica.
- Using nano-SiO₂, with fly ash concrete increased its reactivity and overcame the disadvantage of its lower early age strength compared to normal concrete.
- MIP results showed that the total porosity and the threshold pore diameter were significantly lower for mixtures containing nano-silica.
- Thermogravimetry results indicated that the addition of nano-silica led to significant consumption of Portlandite (CH) in the pozzolanic reaction. However, increasing the dosage of nano-silica from 3% to 6% did not increase the consumption of CH.
- MIP results showed that the total porosity and the threshold pore diameter were significantly lower for mixtures containing nano-silica.