Evaluating Micro-Structure, Hydration and Thermal Expansions of Cement Containing Nano-Silica

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Abstract

This study reported that the addition of nano-silica enhances the mechanical characteristics of concrete as its compressive, flexural and tensile split strengths are increased. As a comparison mixture to equate it along with nano-modified concrete, ordinary samples of Portland cement (OPC) have been utilized. Herein, up to 6.0 percent of OPC has been substituted by nanosilica. In fact, the introduction of nanosilica improves mechanical and microstructural characteristics of concrete by significantly (28 to 35%). The finding therefore, indicated that partly replacing OPC with up to 5 percent nanosilica increases the mechanical and microstructural properties cured up to ninety days as opposed to the standard OPC mix.

Keywords: Nano-particles, nano-silica, fly ash, concrete, compressive strength.

Introduction

Most modern and propelled components for the structural production are required in the construction industry. Cement is among the major materials that the construction frameworks have used in huge volumes but increased production of concrete contributes to degradation of climate. The main technique consists of decreasing cement mixture in mortar and replacing cement with some other pozzolanic products like silica nano-silica and silica fumes, thus minimizing environmental pollution. There are no extensive studies on the use of Nano-Silica and its effects in concrete materials. The present research is trying for showcasing that how significant nS applications could be with special reference to cement concrete. The research is also attempting to understand the properties of nS so that suitability for concrete can be checked. Recent researches show rarity of the studies which covered the usage of Nano silica and fly ash in concrete.
It is significant to note that surface area gets escalated at the same time there is a reduction in the pores once particles of Nano silica are getting applied resulting ultimately to a very strong mix of concrete. Shakmenko et al., 2013; Jafarbeglou et al., 2015 conducted a test relating to Water absorption along with compressive strength. The test got conducted wherein application of Nano silica was done and the method that got used was the method of sol-gel. Wang et al. (2004) stated that earlier it was the colloidal form of Nano silica in the concrete which carries more compressive strength when compared to another form that is powder form of Nano silica. Later however equality in strength has been observed both in case of colloidal as well as powder Nano silica.

**Nanotechnology in Construction**

Nano science and Nanotechnology have become topics of extensive interest and research among many scientists worldwide since 1990’s [Gupta & Jayatissa, 2003]. Here the nano-particle as the name itself suggest are particles which is so small that to measure the size nano-meters (nm) is brought into account. As far as nanotechnology is concerned, it means the synthesis of nano-particles which is having some unique feature that ultimately suits specific industries such as medicine, agriculture, etc. Particle size should mandatorily be lesser than 200-nm. This present decade has not witnessed just the quality improvisation but also the extension of the life of the products.

In all these years multiple nano materials have been tested to see the behavior of the specific material with regard to concrete. But yet the best output was achieved when nano-silica got used. The reason that has been deciphered for it be the most suitable is due to its Pozzolanic properties. Due to the said property it has been concluded that reaction happens with calcium hydroxide (Ca(OH)2) crystals of Nano Silica. This after reaction got arranged in a zone which is termed as the interfacial transition zone (ITZ). The arrangement post reaction is taking place between hardened OPC paste and aggregates, finally resulting into C–S–H gel [Abyan et al., 2013]. Yet in another research Qing et al. similar results have been found with regard to Nano-silica. They concluded that nano silica which is having more Pozzolanic properties in comparison to silica fume leading to more strength. Nano-SiO 2 can improve the pressure-sensitive properties of cement mortar [Ghasemi et al., 2010].

**Effects of Nano-Silica**

It is to be noted as being stated by Givi et al., 2011 that the role as being played by nano particles is not just of filler but also helps in improving the micro structure and further
activating the pozzolanic reaction. The experiment was conducted by Said & Zeidan (2009) where in 30% fly ash has been added in place of the cement. There were two cases that has been studied. In the first case Colloidal Nano silica is having the normal ingredients of concrete with fly ash. The second case is that of wherein there is no fly ash.

The outcomes confirmed that there is an improvisation of reaction due to Nano silica and fly ash in concrete. This is further leading to increase of strength. It has been found during the experiments that once nano silica got added it enhances calcium silicate hydrate gel with high stiffness. It has been observed that if we are increasing the Nano silica by 18% Calcium silicate gel is increasing by 50%. Mondal et al. (2010) in their research studied properties of silica fume and Nano silica in concrete and found that once the Nano silica is mixed it results into high stiffness of C-S-H.

**Literature Review**

Researches by Supit et al. (2015) and Qing et al. (2007) have applied nano-particles in cement and concrete and had applied nano-oxides, to be specific SiO$_2$ as well as Fe$_2$O$_3$.

Kamal et al., (2012) took a research relating to compressive strength of Portland cement pastes and mortars. The Portland cement pastes and mortars were having Cu-Zn nano-ferrite. They concluded that for nano-ferrite to be one percent of cement by weight there is an increment of compressive strength of cement paste and mortar by 45 percent.

In the research which got carried out by Zaki and Ragab in the year of 2009 the impact of NS on the SCC was studied. NS in this research got used in various proportions as replacements (0.5%, 0.7% and 1%) for cementitious materials. Compressive strength got calculated in different duration that is of 7 days, 28 days, 90 days and 365 days. They found that higher compressive strengths is similar and is not depending on the duration of observation.

In the research of Li et al. (2015), the researchers went into studying the effect of adding nano-silica to the concretes. They found that nano-silica (NS) concretes needs extra water to retain similar output. Further adding nano-silica caused increment in compressive, splitting as well as flexural strengths significantly with high cement content and low w/c ratio. Moreover by adding nano-silica by 5%, there is an addition of 50% in compressive strength in 7-days and 40% in 28-days when compared with the same concrete without nano-silica.
Materials and Method

The present research involves two cases. In case one concrete will be without nano particles and case two is concrete with the nano particles. The experiment will attempt to analyses the performance with special reference to concrete for both of the cases. The particular of Cement has been coordinating as that of being referenced to IS 8112:1989. As restricting issue, common portland cement grade 43 was taken. Sand that was utilized for the exploration intention was consistent to IS 383:1970. It was guaranteed that water/cover proportion stays 0.5 simultaneously a cement substance of 380 kg/m 3 were utilized for M 30 grade of concrete. The aggregates utilized in this exploration work comprised of Crushed dolomite, siliceous sand, just as Granite. To keep away from the impact of fine materials in the coarse total, it was washed 48 hours before being utilized and left to dry.

The concrete in the present investigation is 1% of Acrylic polymer along with 1% and 2% of Nano Silica content were likewise utilized in concrete. The molds were loaded up with concrete and compacted by a table vibrator to guarantee that no huge air voids are shaped and legitimate compaction was accomplished. After 24 ± 4 h, the 3D square examples were de-formed and were drenched in water for restoring. Traditional concrete solid shapes, chamber examples were tried in pressure testing machine to discover compressive quality, split rigidity, modulus of flexibility estimations of concrete at different periods of restoring, for example, 28, 56 and 90 days. 2% of Nano SiO2 was included with concrete for discovering modulus of flexibility utilizing the chambers. Chamber examples were tried in pressure testing machine for compressive strain esteems. The particular gravity of the considerable number of materials are given in Table 1. The concrete for small scale structure investigation utilizing Scanning Electron Microscopy (SEM) are given in Figures 4.

Results and Discussion

To study the effect of Nano-silica on the compressive strength of geopolymer paste, a set of ratios (Nano-silica/mould) ranged from 1% to 5% by weight of mould as shown in Table 1. Table 1 and figure 1 shows strength with different parameters during different time frame. The time frame as indicated in the table 1 is that of twenty eight days, fifty six days and ninty days. Table 2 is indicating Modulus of Elasticity of concrete samples. Figure 2: FTIR spectrum of samples containing NS 3% hydrated for 90 days. Figure 3: Evaluating thermal expansion of samples containing various N-SiO2 concentrations and hydrated for 28 days.
Figure 4: SEM images of sample containing 6% NS cured at 28 days.

Table 1: Evaluating strength of M30 grade of concrete (N/mm²)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>28days</th>
<th>56days</th>
<th>90days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete i.e. conventionally used</td>
<td>38.60</td>
<td>39.90</td>
<td>41.63</td>
</tr>
<tr>
<td>Concrete that has 1% of nano-S</td>
<td>43.28</td>
<td>46.10</td>
<td>51.27</td>
</tr>
<tr>
<td>Concrete that has 30% of fly ash</td>
<td>38.60</td>
<td>43.30</td>
<td>47.00</td>
</tr>
<tr>
<td>Concrete that has 50% of fly ash</td>
<td>35.53</td>
<td>36.33</td>
<td>40.10</td>
</tr>
<tr>
<td>Concrete that has 75% of fly ash</td>
<td>29.40</td>
<td>36.87</td>
<td>37.70</td>
</tr>
<tr>
<td>Concrete that has 30% of fly ash in addition to 1% of NS</td>
<td>40.90</td>
<td>45.97</td>
<td>50.16</td>
</tr>
<tr>
<td>Concrete that has 50% of fly ash in addition to 1% of NS</td>
<td>37.95</td>
<td>39.55</td>
<td>45.75</td>
</tr>
<tr>
<td>Concrete that has 75% of fly ash in addition to 1% of NS</td>
<td>36.20</td>
<td>40.50</td>
<td>43.75</td>
</tr>
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</table>

Table 2: Modulus of Elasticity of concrete samples

<table>
<thead>
<tr>
<th>Parameters</th>
<th>28day x10⁴</th>
<th>56days x10⁴</th>
<th>90days x10⁴</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete i.e. conventionally used with 2% of NS</td>
<td>5.01</td>
<td>8.50</td>
<td>11.25</td>
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<tr>
<td>Concrete wherein 30% of cement is getting replaced with fly ash and has 2% of NS</td>
<td>4.01</td>
<td>8.40</td>
<td>9.11</td>
</tr>
<tr>
<td>Concrete wherein 30% of cement is getting replaced with fly ash and has 2% of NS</td>
<td>3.52</td>
<td>4.93</td>
<td>8.63</td>
</tr>
<tr>
<td>Concrete wherein 30% of cement is getting replaced with fly ash and has 2% of NS</td>
<td>1.89</td>
<td>4.26</td>
<td>6.39</td>
</tr>
</tbody>
</table>
Figure 1: Evaluating strength of concrete

Figure 2: FTIR spectrum of samples containing NS 3% hydrated for 90 days

Figure 3: Evaluating thermal expansion of samples containing various N-SiO₂ concentrations and hydrated for 28 days
Adding NS causes the change in the behavior relating to hydration as well as morphology that got shaped into hydrated by product resulting out from the cement pastes. Fig. 4 showed SEM micrographs of cement pastes containing 6.0 mass% NS hydrated for 28 days. Here it is the Calcium hydrate which got changed in the form of Calcium Silicate Hydrate (CSH) gel. It happened once Nano silica is added in the range of micron and Nano.

Conclusion

In the current study, the effect of adding Nano-silica to geopolymer and OPC concrete was investigated. Firstly, trial preliminary mixes were prepared to obtain highest compression mix. By addition of NS along with nano fly ash it has been found that there is an improvisation in compressive strength of concrete. pH value decreased while percentage of NS got increased. The increase in NS percentage also lead to increase of water content which is chemically combined. It has further been found that there is an improvisation in the mechanical property of the cement which was getting researched.

References


lime solution on the properties of SiO2 nanoparticles binary blended concrete. Composites Part B: Engineering, 42(3), 562-569.


