EFFECT OF ELEVATED TEMPERATURE ON CONCRETE CONTAINING NANOSILICA

By

Ahmed Adel Mohamed Radwan

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
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In
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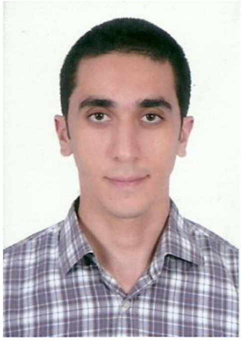

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Title of Thesis:

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Key words: Nano-silica Concrete , Elevated temperature, Polypropylene fibers, compression strength, tensile strength.

Summary:

Elevated temperature has high impact on concrete in its different shapes. This includes the effect on the mechanical properties and the physical change under different temperatures. The main aim of this research is to study the behavior of concrete containing different portions of nano-silica when exposed to different degrees of elevated temperatures and compare it with control high strength concrete without any admixtures. The results showed higher compressive strength for concrete containing nano-silica than that of control under all different degrees of temperatures. The results showed also that the presence of nano-silica in concrete catalyzes the chemical reaction under mild increase in temperature (200°C and 400°C), this leads to higher compression strength at (200°C and 400°C) than that at 30°C. The presence of polypropylene fibers in concrete, which melts down under high temperatures, gives higher compressive strength than concrete that does not contain polypropylene fibers.

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Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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ABSTRACT

The purpose of this research is to provide insight into the effect of elevated temperature on concrete mixes containing nano-silica. The behavior of such concrete is examined after exposure to 4 different degrees of temperatures (30°C, 200°C, 400°C and 800°C) and then tested for compression and indirect tension. Three different sizes of cubes (side length of 10cm, 15cm and 20cm) were tested for the compression test at 3 different ages (3 days, 7 days and 28 days) and at the four previously mentioned temperatures. The indirect tension test was performed on standard cylinders (15cm*30cm) at the age of 28 days at 4 different degrees of temperatures (30°C, 200°C, 400°C and 800°C).

This research study proves that the increase in temperature to 200°C for concrete containing nanosilica catalyzes the hydration reaction which gives higher compressive strength. The higher the nanosilica percentage, the higher the compressive strength gained with the increase in temperature up to 200°C.

Polypropylene fibers are also provided as admixture in two mixes with different dosage of 0.1% and 0.05% of cement weight to examine the effect with presence of nanosilica. Yet the mixes with pure nanosilica gave better performance under elevated temperatures up to 800°C.

At early age (3 days) and higher temperatures the presence of nanosilica with lower percentage (1%) improved the behavior and gave 39% higher strength at 400°C for the 15 cm cubes and 12% higher strength at 400°C for the 10cm cubes.

Based on this research; it can be concluded that curing of nano-silica concrete at temperature of 200°C for 60 minutes in precast concrete factories can increase the strength by 10% to 20% which can be interpreted as a mean of reducing the amount of nano-silica in concrete mixes. This would be a considerable cost saving.

Chapter 1: Introduction

1.1. General:

The nanotechnology revolution improved many of products, services and industries, including the construction industry. Because of the control of dimensions in transitional zone between molecule and atom, the Nano sized (between 1 & 100 nm) materials gain new characteristics when compared to the compared macro material. These characteristics achieved at the Nano-scale makes the material capable of showing highly-advanced performances in magnetism, conductivity, mechanical strength, and optical sensitivity, enabling a range of applications included the electronics, biomedical agents and catalysts. The combination of Nano-materials in construction industry is predictable to enhance essential characteristics of construction materials (e.g., strength, durability etc.). Nanotechnology in construction was once chosen as a top targeted application of nanotechnology which can solve the developing world's largest predicaments.

Concrete is the largest annually produced material among all construction materials, which undergoes extreme improvement in its mechanical properties through adding carbon nanotubes (CNT) or Nano-silica (or Fe_2O_3) to the concrete mixes contain cement and aggregates. Adding 1%wt CNT restrains concrete's crack propagation by acting as nucleating agents, while iron oxide and nano-silica particles (3 to 10%wt) act as filling agents to reinforce concrete.

1.2. Thesis Objective:

As the nanomaterials are subjected to many researches in order to improve concrete mechanical properties, one of the very important parameters is the behavior of the nanomaterials under elevated temperature. There are very few researches that focus on the behavior of Nano-silica concrete subjected to different levels of elevated temperature. This research focuses on the effect of different levels of elevated temperatures on concrete containing nano-silica with different portions in addition of Polypropylene fibers which enhance the behavior of HSC under elevated temperatures. The specimens are examined at different ages of 3days, 7days and 28days and with different sizes of 10cm length cubes, 15cm length cubes and 20cm length cubes.

1.3. Thesis Structure:

The Thesis is divided into the following five chapters:

Chapter (1) Introduction:

This chapter is an introduction to the nanomaterial usage in concrete in general and some of the used nanomaterials in concrete.

Chapter (2) Literature Review:

This chapter reviews some of the previous researches with scope of effect of using nanomaterials on concrete specifications and mechanical properties and once more the effect of high temperature on normal strength concrete and high strength concrete mechanical properties, physical changes and spalling.

Chapter (3) Experimental Work:

This chapter illustrates the used materials in the study with the used portions and the procedures used in the experiment alongside with the used devices in the testing phase. Also, the specimens of each mix design used with different admixture, size, age and temperature.

Chapter (4) Results and Discussions:

This chapter illustrates the effect of the gradual high temperature on each mix with different admixtures, size, age and temperature on the compressive strength and tensile strength.

Chapter (5) Conclusions:

This chapter illustrates the high noted conclusions of the experiment and how it may affect the usage of nanomaterials in concrete.

Chapter 2: Literature Review

2.1. Methods of Production of Nanomaterials:-

2.1.1. Sol-Gel method:

The reasonably little amounts of nano-sized materials are adequate to enhance the execution of nano composites. But also, the businesswise implementation of nano-materials relies upon the capacity to produce the nano-materials in enormous amounts also at a feasible cost with respect to the total impact of the nano-product. The technologies that can motivate the mechanical yields of nano-materials contain chemical vapor testimony, plasma angling, chemical vapor testimony, electro deposition, mechanical weakening, sol-gel union and the utilization of normal nano-systems. During preparation advancements, sol-gel blend is a highly utilized "base up" generation technique for nano-sized materials, for instance, nano-silica. The procedure includes the arrangement of a colloidal suspension (sol) and gelation of the sol to shape a system in a nonstop fluid stage (gel). Ordinarily, tetraethoxysilane or trymethylethoxysilane (TEOS /TMOS) are connected as forerunners for blend of nano-silica. Sol-gel development could be expressed in another few stages:

- Hydrolysis of the forerunner.
- Polymerization and condensation of monomers to shape the particles.
- Growth of particles.
- Particles agglomeration, trailed by the arrangement of systems and, consequently, structure of gel.
- Evacuation of the solvents through drying.
- Evacuation of the surface useful gatherings through thermal treatment and acquire the coveted precious stone structure.

Composition of nanosilica can be summarized as in the following chemical reaction:

$$nSi(OC_2H_5)_4 + 2nH_2O \xrightarrow[NH3]{C2H5OH} nSiO_2 + 4nC_2H_5OH$$

There are many parameters which affect the reaction process, including temperature, pH, H2O/Si molar ratio, concentration of reagents, type of catalyst, etc. When properly performed, the process is able to generate perfect spherical nano-particles of silica with size range between 1 and 100 nm.
Processing natural nano-systems, for instance, clay is a likely promising system which is used to manufacture nano-porous materials (of pores around of 10 nm).
Phyllosilicates which consist of silicate tetrahedra alternating layers and aluminum octahedra are used typically. The fabrication includes the use of a pillaring arrangement (generally including polycation [Al13O4(OH)24]7+) to distant the platelets of phyllosilicate. The subsequent intercalated clay is changed over to oxide by thermal treatment.

2.1.2. Mechano-chemical activation:

Mechano-chemical activation of powder particles or mechanical attrition is another strategy used for forming of nano-materials for an industrially large scale. It was effectively utilized to fabricate unique compounds of metals with dissolving points and composites of metal-ceramic of enhanced corrosion resistance and strength.

In the mechanical attrition process, the intermixing of single parts takes place at an atomic scale because of solid state amorphization. The procedure is dominated by both the combination of lattice defects into the crystal structure and the mechanical alloying.

Mechano-chemistry is recognized by high energy ball milling, it stimulates the displacement reactions of solid state. The procedure is being used to fabricate ceramic nano-particles, for example, ZrO_2 and Al_2O_3.

Mechano-chemical activation is as well highly effective technique used to connect the organic functional groups to the inorganic powders surface, for instance, portland cement (i.e. to illustrate the organo-mineral hybridization). Inter-grinding dry modifiers and cement through high-energy milling results in multiple binding materials with enhanced performance. For instance, inter-grinding of cement and an uncommonly chose admixture modifier with high dosage (around 4%) produces a binder with both high strength and decreased water demand. Complex admixture-modifier came out of a strong surfactant and a reactive silica-based sorbent is produced for the enhancement of strength of cement. It is recommended that these modifiers, when included through the process of cement grinding, shape the nano-thick organo-mineral layers on the cement particles surface also the stabilization and enhancement of highly reactive dislocation centers and defective spots.

2.1.3. Synthesis of Colloidal Nano-silica by an Ultrasound Method Based on Alkali Leaching of Silica Fume:

Silica gel is prepared by a known method like dissolution-precipitation process. Based on reaction state, silica fume is reacted with sodium hydroxide solution according to Eq. (1) and the suspension is then clarified. Subsequently, sulfuric acid solution is introduced drop by drop to the generated sodium silicate solution under stirring. When the reaction is done, a white precipitate as silica gel is created, as described by Eq. (2). The acquired gel mixture is then washed by filtered water for many times to remove solutions.

$$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O \qquad (1)$$

$$Na_2SiO_3 + H_2SO_4 \rightarrow SiO_2 + Na_2SO_4 + H_2O \qquad (2)$$

The resulted wet gel is mixed with diluted sodium hydroxide solution for adjusting pH in the range of stable sols. The alkaline wet gel was then irradiated with a Bandelin ultrasonic probe system, HD 3200 with tapered tip KE 76 which is made of titanium alloywith the power and frequency of 30 W and 20 kHz, respectively, to convert silica gel to colloidal nanosilica.

DLS (Dynamic Light Scattering) results show that the average diameter of particles are dramatically reduced from 337.10 nm to 93.27 nm in only 5 minutes of sonication with 60% (in terms of volume) of particles representing sizes below 50 nm. However, continued sonication results in much lower rates of size reduction with evidences of agglomeration. SEM and TEM (Scanning and Transmission Electron Microscopes) studies confirms that most of the silica particles are quite spherical in shape and nano sizes. According to the results of X-ray diffractometry and FTIR spectroscopy, the resulted product consists of pure amorphous nanosilica.