

EFFECTS OF ELEVATED TEMPERATURE ATTACK ON NANO – Al_2O_3 PARTICLES BLENDED ULTRA HIGH PERFORMANCE CONCRETE

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Abstract

Keywords:

ultra high performance concrete; nano Al_2O_3 ; Elevated temperature attack; weight loss; strength loss.

In the present investigation, the thermal resistance behavior of ultra high performance concrete (UHPC) containing nano Al_2O_3 particles has been investigated at the age of 56th day. A partially cement was partially replaced by 0.5 %, 1 %, 1.5 %, 2 % and 3 % nano Al_2O_3 particles. The change in weight and change in compressive strength of the produced specimens were measured, after 4 hours exposed in elevated temperature about 300°C, 600°C and 900°C at a rate of heating 10 °C/min. After the 4-hours of soaking period, the exposed samples were examined at both micro and macro scales to explore the colour transformations, change in weight, change in strength, cracking and spalling behavior of UHPC at 300°C, 600°C and 900°C. The 2% of nano Al_2O_3 particles improved spalling resistance compared with all other mix proportions. The obtained result reveals that, 2% of nano Al_2O_3 particles efficiently used in UHPC performed better in elevated temperature.

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1. Introduction

The ultra high performance concrete efficiency was maximized by optimizing the packing density of the mixture, thus resulting in self consolidation of the fresh concrete mixture and higher packing density of concrete [1]. The uniform microstructure was achieved by eliminating the coarse particle from the mixture and with the proper grain size distribution binder and filler materials leads to optimize the packing UHPC [2]. Nowadays, the production of UHPC with very high homogeneous is possible at very low water – binder ratio, because the use of new generation polymers based high range water reducing admixtures[3]. Due to optimization UHPC ingredients have outstanding rheological properties at the fresh mix is allowing a self-consolidating mix of UHPC [4]. Therefore, UHPC noticeably improved resistance against severe environmental conditions, blast loading, and impact loading, that was improved structural resistance and durability of concrete structures [5], [6]. At present scenario, using of nano Al_2O_3 in concrete has developed due to its unique performance on the cement matrix. The inclusion of nano Al_2O_3 particles leads to enhance the mechanical and durability performance of cement paste [7], mortar [8]–[10], concrete [11], self compacting concrete [12], high performance concrete. Therefore nano Al_2O_3 particles high activity was depended on the size and specific surface area of nano Al_2O_3 particles. The fusions of ultra-high performance concrete (UHPC) and nanotechnology are a key to create a next generation nano-based ultra-high performance concrete with superior durability properties in aggressive environmental conditions[13]. In recent days, many researchers focusing utilization of nano Al_2O_3 particles in cement paste, mortar and concrete. The literature of previous works on nanomaterial and UHPC showed that there is a lack in the studies of the effect of elevated temperature attack in nano Al_2O_3 particles replaced ultra high performance concretes. The present investigation aims to study the effects of Al_2O_3 particles replacement on elevated temperature attack (300°C, 600 °C and 900 °C for 4 hours) by the loss in mass and average strength loss of UHPC at the age of 56th day.

2. Materials and methods

The OPC-53 grade cement [14], silica fume [15], Quartz powder, nano Al_2O_3 (size 20-30nm and surface area of 180 m^2/g), River sand, Polypropylene fibers [16], Polycarboxylic ether super-plasticizer [17] were used for fabrication of UHPC. The six different mixture proportions, was developed based ASTM C1856/C1856M-17 guideline [18]. The CON mixture was without nano Al_2O_3 particles and other five mixture proportions were containing 0.5%, 1%, 1.5%, 2% and 3%

nano Al_2O_3 replaced by weight of cement. Tables 1, show the mixture proportions details of six series mix. The six series of mixes mixed with mortar mixture machine [19]. Then fresh concrete placed into the 50 x 50 x 50 mm cubes. After 24 hours, the demoulded specimens were placed in a water curing for 28 days [20].

Table 1 the mixture proportions by weight of cement

Ingredient	CON	0.5 AL	1.0 AL	1.5 AL	2.0 AL	3.0 AL
Cement	1	0.995	0.99	0.985	0.98	0.97
Silica Fume	0.30	0.30	0.30	0.30	0.30	0.30
Nano Al_2O_3	0	0.005	0.01	0.015	0.020	0.030
Quartz Powder	0.430	0.430	0.430	0.430	0.430	0.430
Sand	2.183	2.183	2.183	2.183	2.183	2.183
Water	0.24	0.24	0.24	0.24	0.24	0.24
Superplasticizer	0.04	0.04	0.04	0.04	0.04	0.04
PP Fibers	0.004	0.004	0.004	0.004	0.004	0.004

3. Experimental Techniques:

The change in compressive strength and weight of the UHPC specimens were measured, after 4 hours exposed in elevated temperature about 300°C, 600°C and 900°C at a rate of 10 °C/min [21]. The effect elevated temperature attack on the change in compressive strength and weight of UHPC was calculated by **Equation (15)** and **Equation (16)** according to the BS EN 13381-3 [22] standard procedure at age of 56th day. Figure 1 shows test setup for elevated temperature attack.

$$\text{Change in compressive strength \%} = \frac{S_2 - S_1}{S_1} \quad \text{Equation (15)}$$

$$\text{Change in Weight Change \%} = \frac{W - C}{C} \quad \text{Equation (16)}$$

Where

S_1 - Average compressive strength before exposure (N/mm^2)

S_2 - Average compressive strength after exposure to elevated temperature (N/mm^2)

C - Conditioned weight of specimen (g)

W - Weight of specimen after exposure to elevated temperature (g)



Figure 1 Test setup for elevated temperature attack

3. Results and discussions:

The elevated temperature attack of UHPC mixes was tested according to the standard procedure of BS EN 13381-3 at age of 56th day. The effect of nano Al_2O_3 particle replacement on the loss in mass and loss in strength of nano Al_2O_3 blended UHPC was shown in Figure 2 and Figure 3 respectively, after the UHPC specimens were 4 hours exposed to the elevated temperature of 300°C, 600°C, and 900°C in Muffle furnace. After the 4 hours of exposure period in elevated temperature, the maximum mass loss and loss in strength observed for CON mix was 7.94% and 12.01%, 19.05% and 28.94%, and 28.81% and 60.08%, respectively at an elevated temperature of 300°C, 600°C, and 900°C. The minimum mass loss and loss in strength observed for 2.0 AL mix was 4.94% and 7.48%, 11.86% and 18.01%, and 17.93% and 37.39%, respectively at an elevated temperature of 300°C, 600°C, and 900°C. Because of filler effect nano Al_2O_3 particles leads to resistance against the elevated temperature attack in UHPC [23].

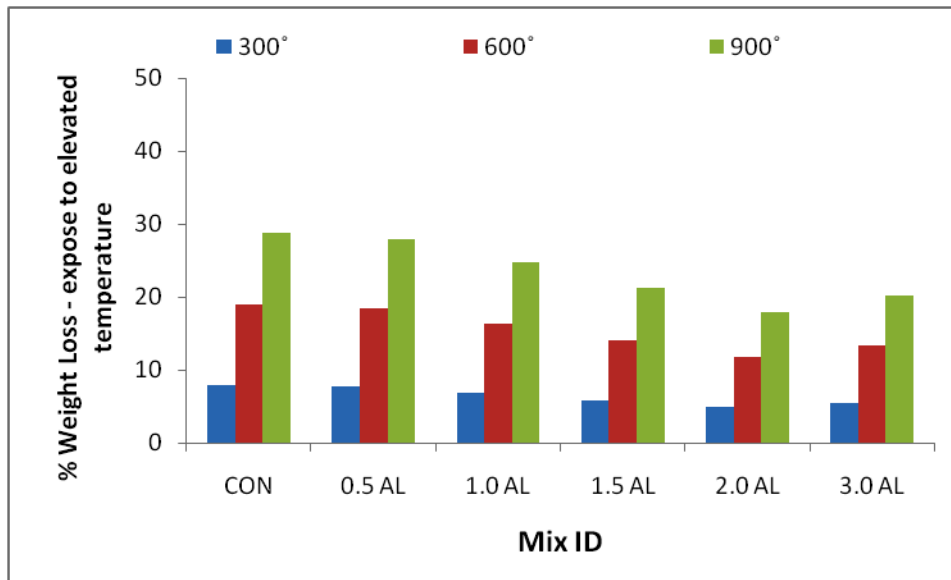


Figure 2 the weight loss of expose to elevated temperature

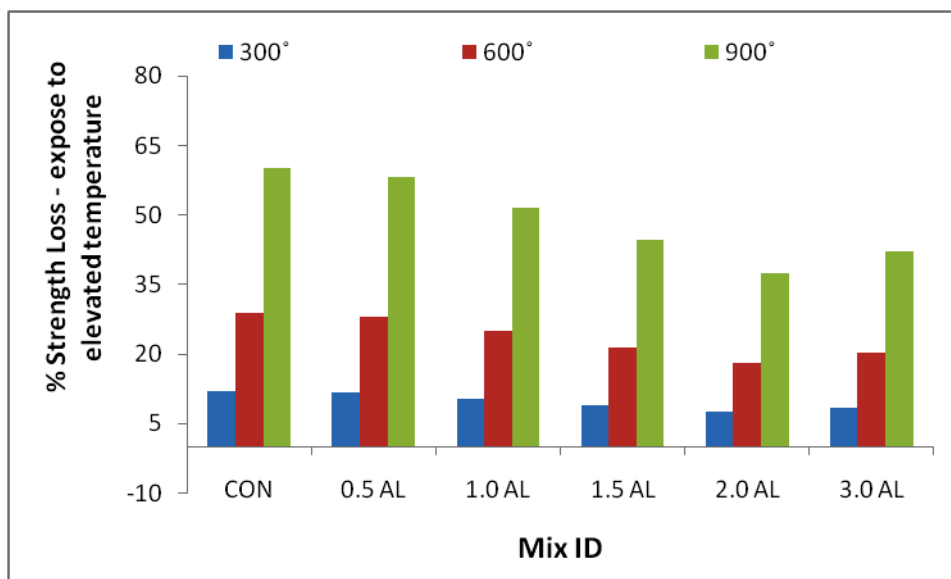


Figure 3 the strength loss of expose to elevated temperature

4. Conclusion:

The results reveal that the thermal resistance and spalling resistance of the specimens were increasing with the nanoparticles content. The inclusion of nano Al_2O_3 particles in UHPC cement matrix was act as the pore-filling material, increased surface hardness and resistance against spalling at elevated temperature attack. Because of small particle size and high surface area of nano Al_2O_3 particles play the main role in the packing of nano Al_2O_3 has reduced the porosity and improves homogeneous microstructure of concrete.

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