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The effects of nano alumina particles replacement on water transport properties of UHPC

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ABSTRACT:

In the present investigation, the water transport properties of ultra high performance concrete (UHPC) containing nano Al_2O_3 particles have been investigated. The cement was partially replaced by 0.5%, 1%, 1.5%, 2% and 3% nano Al_2O_3 particles. The water absorption, volume of permeable voids, water penetration depth under the pressure and Sorptivity of hardened concrete were tested at an age of 28th and 56th days of curing period. The results were revealed that increasing the nano Al_2O_3 particles have found to be reducing the water transport properties of ultra high performance concrete. Because of the filler effect of nano Al_2O_3 particles provide dense packing of cement matrix of UHPC was reduced the porosity.

KEYWORDS: *nano Al_2O_3, ultra high performance concrete, water absorption, the volume of permeable voids, water penetration depth and Sorptivity.*

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1. INTRODUCTION

The application nanotechnology in the construction sector was a surface coating (water repellent, UV production coating etc), effective supplementary cementing materials (Such as nano-SiO_2, nano-$CaCO_3$, nano-TiO_2, and nano-Fe_2O_3, etc.,) and in sensors etc [1]. In recent days, many researchers focusing the utilization of nano Al_2O_3 particles as an effective supplementary cementitious material to enhance the hydration, workability properties, mechanical properties and durability performance of cement paste, mortar and concrete only[2–11]. Still now, only a few studies were available on the utilization of nano Al_2O_3 in ultra high performance concrete [12,13]. The literature of previous works on nanomaterial and UHPC showed that, there is a lack in the studies of water transportation properties of nano Al_2O_3 particles replaced UHPC. The present investigation aims to study the effects of Al_2O_3 particles replacement on water transportation properties (such as water absorption, the volume of permeable voids, water penetration depth under the pressure and sorptivity properties) of UHPC at age of 28 and 56 days.

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.

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
28^{th}d Compressive strength (MPa)	122.65	130.18	136.80	147.02	155.59	145.40

MIXING, CASTING AND CURING

The six series of mixes mixed with mortar mixture machine [19]. Then fresh concrete placed into the 50 x 50 x 50 mm cubes, 150 x 150 x 150 mm cubes and 100 mm diameter and 200mm height cylindrical moulds. After 24 hours, the demoulded specimens were placed in a water curing for up to the age of testing [20].

EXPERIMENTAL TECHNIQUES

The water absorption and volume of permeable voids of UHPC specimens were measured by **Equation (1)** and **Equation (2)**, respectively according to **ASTM C 642 – 06** standard procedures at age of 28th day and 56th day [21]. The water penetration depth of UHPC under the pressure was measured according to the **BS EN 12390-8:2009** standard procedure at age of 28th day and 56th day [22]. The Sorptivity of UHPC was measured at age 28th day according to the ASTM C1585 – 13 [23] and the absorption (I) calculated as per **Equation (3)**.

$$Water\ absorption\ ,\% \ = \frac{(B-A)}{A} * 100$$ **Equation (1)**

$$Volume\ of\ permeable\ pore\ space\ (voids),\% = \frac{(g_2-g_1)}{g_2} * 100$$ **Equation (2)**

$$\text{Sorptivity}\ (I)\ = \frac{m_t}{a*d}$$ **Equation (3)**

Where

A - mass of oven-dried sample in air (g)

B - a mass of surface-dry sample in the air after immersion (g)

g_1 - bulk density (g/mm^3)

g_2 - apparent density (g/mm^3)

I - the absorption (mm)

m_t - the change in specimen mass at the time t (g)

a - the exposed area of the specimen (mm^2)

d - the density of the water (g/mm^3)

Results & Discussions

The water absorption

The water absorption of UHPC specimens tested according to **ASTM C 642 – 06**. Figure 1 shows the effect of nano Al_2O_3 particle replacement on the water absorption properties of UHPC specimen at age of 28th day and 56th day. The maximum water absorption (%) was observed on the CON mix was 0.66% and 0.54% for the 28th day and 56th day respectively in comparison to all other mixes. The minimum water absorption (%) was observed on the 2.0 AL mix was 0.53% and 0.42% for the 28th day and 56th day respectively in comparison to all other mixes.

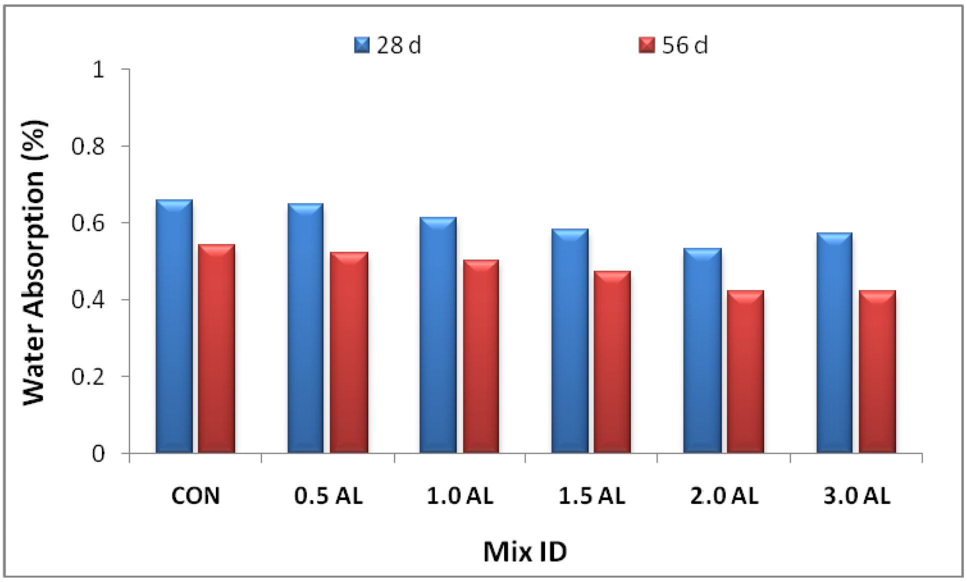

Figure 1 the water absorption

The water permeability – depth of penetration under pressure:

The depth of water penetration under pressure of UHPC mixes tested according to the **BS EN 12390-8:2009**. Figure 2 shows the effect of nano Al_2O_3 particle replacement on the depth of water penetration of UHPC specimens at the age of 28th day and 56th. The maximum depth of water penetration was observed in the CON mix was 1.34mm and 1.08mm for the 28th day and 56th day respectively in comparison to all other mixes. The minimum depth of water penetration was observed in the 2.0 AL mix was 0.96mm and 0.68mm for the 28th day and 56th day respectively in comparison to all other mixes.

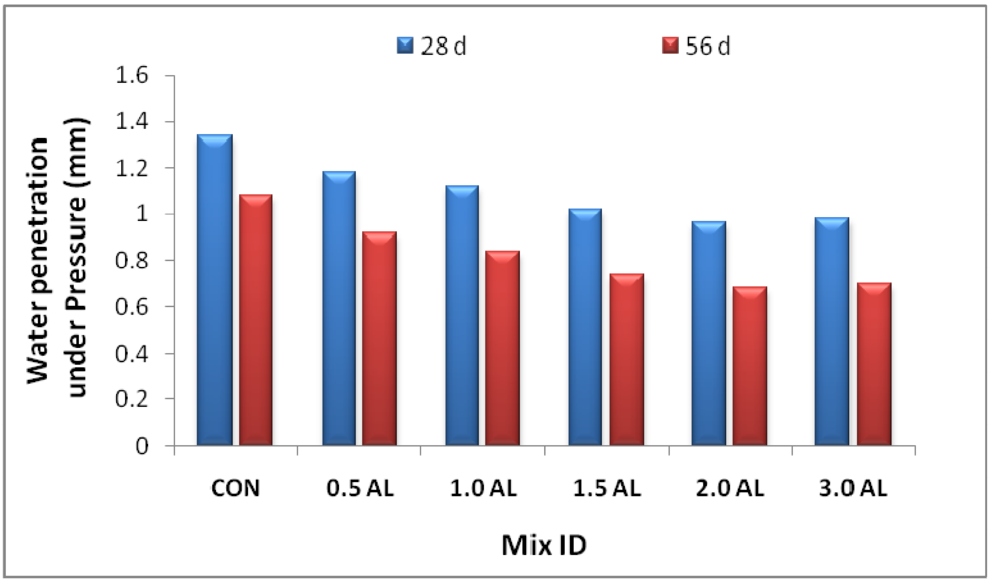

Figure 2 the water permeability – depth of penetration under pressure

The volume of permeable voids

The volume of permeable voids of UHPC mixes tested according to the **ASTM C 642 -06**. Figure 3 shows the effect of nano Al_2O_3 particle replacement on the porosity of UHPC specimens at the age of 28^{th} day and 56^{th} day of curing. The maximum volume of permeable voids was observed on the CON mix was 1.68% and 1.38% for the 28^{th} day and 56^{th} day respectively in comparison to all other mixes. The minimum volume of permeable voids was observed on the 2.0 AL mix was 1.35% and 1.08% for the 28^{th} day and 56^{th} day respectively in comparison to all other mixes.

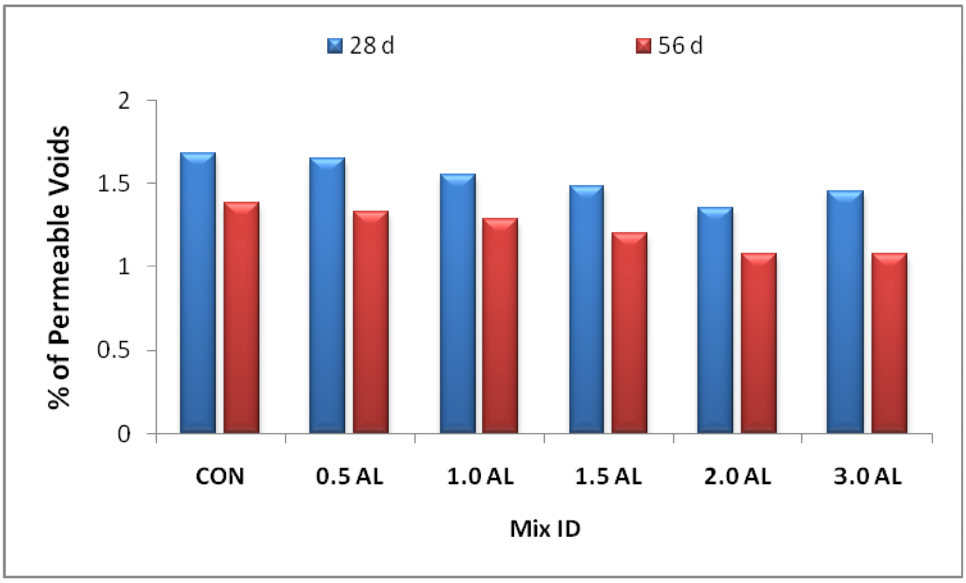

Figure 3 the volume of permeable voids

The sorptivity:

The water sorption properties of UHPC mixes were tested according to the **ASTM C1585 − 13**. Figure 3 shows the effect of nano Al_2O_3 particle replacement on the absorption (I) of UHPC specimens at the age of 28^{th} day. The maximum absorption (I) was observed on the CON mix was 1.89mm, comparatively from other mix proportions. The minimum absorption (I) was observed on the 2.0 AL mix was 1.60mm, comparatively from other mix proportions.

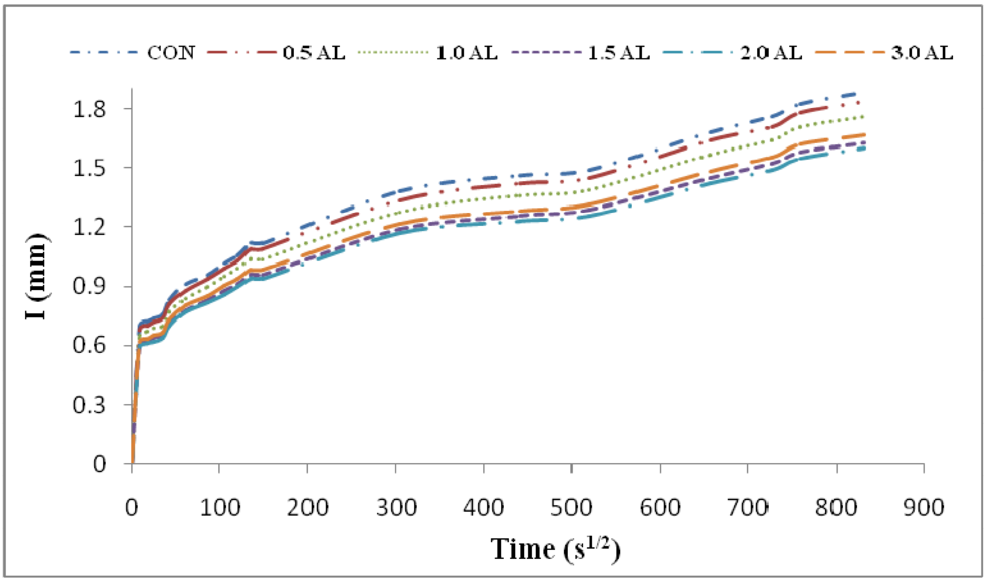

Figure 4 the sorptivity

CONCLUSIONS:

The enhancement resistance against the water transport properties of the specimens was increasing with the nano particles content and age of curing. Results reveal that the inclusion of nano Al_2O_3 particles in ultra high performance concrete cement matrix was act as the pore-filling material and increases resistance against the water transport properties such as water absorption, the volume of permeable voids, water penetration depth under the pressure and sorptivity properties of ultra high performance concrete. This may due to well-optimized UHPC mixture containing nano Al_2O_3 particle was improved the better packing, reduces the micropores and making the cement matrix into the homogenous matrix of ultra high performance concrete, because of due to the smaller size and high surface area of nano Al_2O_3.

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