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Performance of UHPC containing nano Al_2O_3 particles exposed to seawater

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Abstract— the present research work deals about seawater attack of ultra high performance concrete (UHPC) with different percentage of nano Al_2O_3 powder has been investigated at the age of 30 days, 60 days, 120 days and 180 days exposure period. The cement was partially replaced by nano Al_2O_3 powder at 0.5 %, 1 %, 1.5 %, 2 %, and 3 % by weight. The change in weight and change in strength loss of UHPC were measured, after sea water attack for the 30 days, 60 days, 120 days and 180 days of the exposure period. The results of this research work clearly showed that nano Al_2O_3 was optimum replacement improved the resistance against the Seawater attack in UHPC. Because of the smaller size and higher surface area of nano Al_2O_3 particles play the main role in microstructure and reduced porosity and water transport properties of UHPC.

Keywords— Ultra High Performance Concrete, nano Al_2O_3, seawater attack, strength loss and weight loss

I. INTRODUCTION

The efficiency of UHPC was maximized by optimizing the particle packing density of the mixture, thus resulting in ultra high consolidation of the concrete mixture and higher packing density of concrete [1]–[3]. The homogeneous of concrete microstructure was achieved by eliminations of a coarse particle from the mixture and with the proper grain size distribution of leads to optimize the particle packing UHPC [4]. Now, the production of UHPC with very high homogeneous is possible at very low water – binder ratio, because of the use of new generation polymers based superplasticizers [5]–[7]. Due to optimization UHPC ingredients have outstanding rheological properties at the fresh mix is allowing a self-consolidating mix of UHPC [8]. Therefore, UHPC noticeably improved resistance against severe environmental conditions, blast loading, and impact loading, that was improved structural resistance and durability of concrete structures [9]–[13]. In recent years, 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 [14]–[17], mortar [18]–[25], normal strength concrete [26]–[29], self compacting concrete [30]–[32], 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 chemical environmental conditions[33]. To date, no comprehensive study relating to the replacement of nano Al_2O_3 on seawater attack of ultra high performance concrete has been undertaken. The present investigation aims to study the effects of Al_2O_3 particles replacement in UHPC on seawater attack of specimens measured after the 30^{th} day, 60^{th} day, 120^{th} day and 180^{th} days of the exposure period.

II. MATERIALS AND METHODS

The OPC-53 grade cement [34], silica fume [35], Quartz powder, nano Al_2O_3 (size 20-30nm and surface area of 180 m^2/g), River sand, Polypropylene fibers [36], Polycarboxylic ether super-plasticizer [37] were used for fabrication of UHPC. The six different mixture proportions, was developed based ASTM C1856/C1856M-17 guideline [38]. 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 [39]. Then fresh concrete placed into the 50x50x50 mm cubes. After 24 hours, the demoulded specimens were placed in a water curing for 28 days [40].

Table 1 The mix proportion for nano Al_2O_3 blended UHPC

Mix ID	**Cement**	**Silica Fume**	**Nano Al_2O_3**	**Sand**	**Quartz Powder**	**w/b Ratio**	**PCE**	**Fiber**	**Compressive Strength (28^{th} day)**
CON	1	0.30	0	2.183	0.430	0.24	0.04	0.004	122.65
0.5AL	0.995	0.30	0.005	2.183	0.430	0.24	0.04	0.004	130.18
1.0 AL	0.99	0.30	0.01	2.183	0.430	0.24	0.04	0.004	136.8
1.5 AL	0.985	0.30	0.015	2.183	0.430	0.24	0.04	0.004	147.02
2.0 AL	0.98	0.30	0.02	2.183	0.430	0.24	0.04	0.004	155.59
3.0 AL	0.97	0.30	0.03	2.183	0.430	0.24	0.04	0.004	145.40

III. RESULTS AND DISCUSSION

The rate of attack of Seawater on UHPC mixes was measured by change in weight and change in strength after the 30 days, 60 days, 120 days and 180 days exposure in Seawater [41], [42]. The deteriorated specimens after the 30 days, 60 days, 120 days and 180 days of exposure period in Seawater were shown in Figure.1.

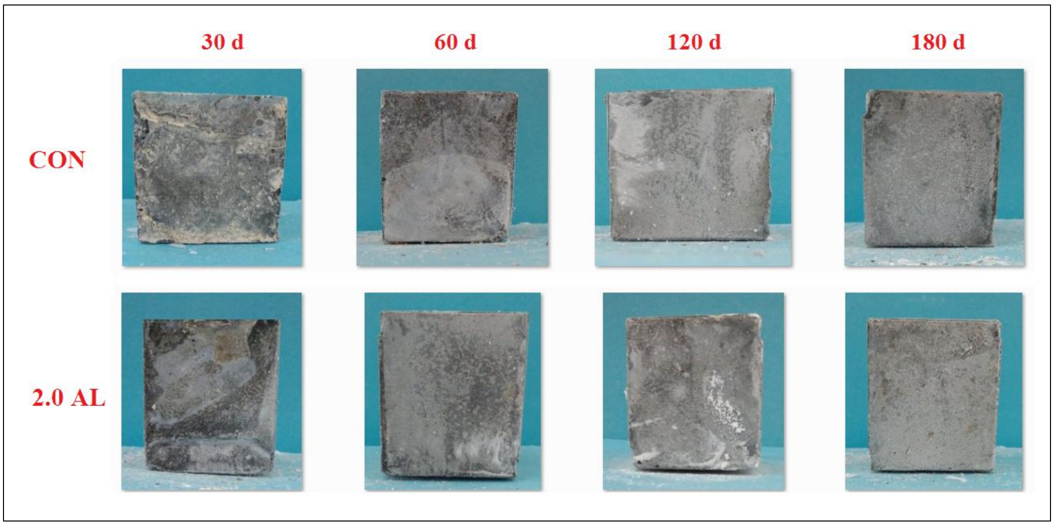

Figure 1 the deterioration of specimens due to seawater attack

Weight loss:
Figure 2 shows that weight loss due to Seawater attack of nano Al_2O_3 blended UHPC concrete specimens, after 30 days in Seawater curing the weight loss was measured 0.36%, 0.32%, 0.28%, 0.24%, 0.21% and 0.23% for the mix proportions CON, 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL, respectively. After 60 days of exposure period in Seawater, the weight loss was measured 0.67%, 0.63%, 0.54%, 0.46%, 0.38% and 0.42% for the mix proportions of CON, 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL, respectively. The weight loss after 120th days of exposure period in Seawater was found 1.32%, 1.21%, 1.07%, 0.94%, 0.73% and 0.79% for the mix proportions of CON, 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL, respectively. The weight loss after 180 day of exposure period in Seawater was found 2.02%, 1.87%, 1.70%, 1.43%, 1.15% and 1.27% for the mix proportions of CON, 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL, respectively. Test results revealed that CON mix suffered maximum weight loss in comparison to all other mix proportions of 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL at all ages.

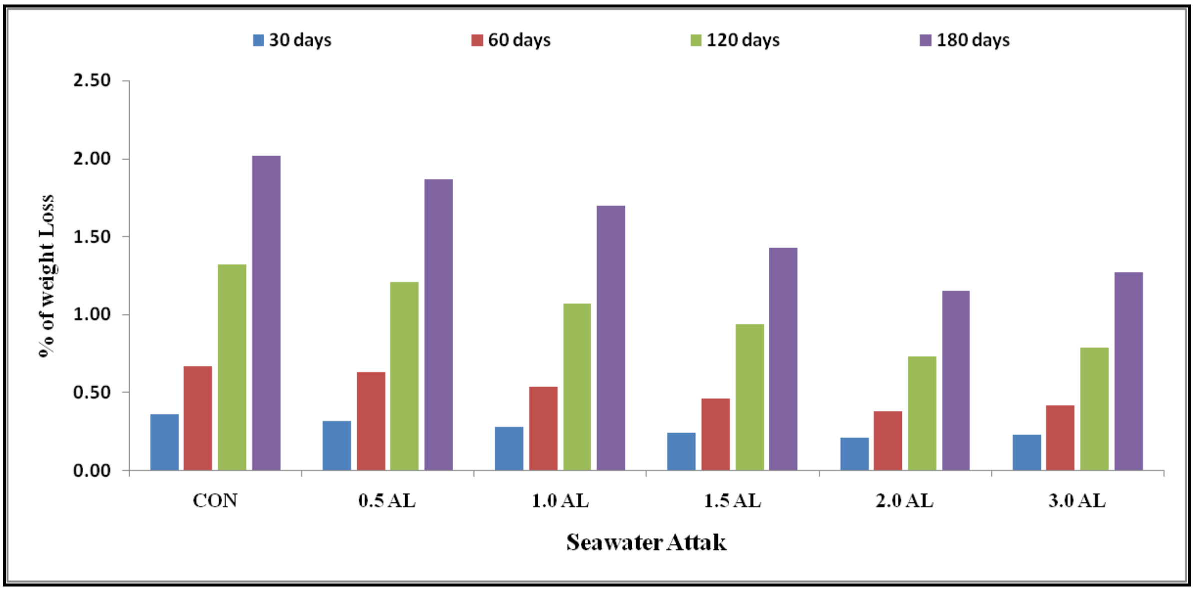

Figure 2 the weight loss of specimens due to seawater attack

Strength loss:
Figure 3 shows that the rate of attack of Seawater on UHPC specimen's compressive strength loss was measured, after curing in Seawater for 30 days, 60 days, 120 days and 180 days of the exposure period. After 30 days in Seawater curing, the average strength loss of UHPC mixes such as CON, 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL was measured as 2.17%, 2.05%, 1.93%, 1.80%, 1.67% and 1.79%, respectively. After 60 days in Seawater exposure period, the average

strength loss of UHPC mixes such as CON, 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL was measured as 3.48%, 3.28%, 3.09%, 2.85%, 2.64% and 2.83%, respectively. After 120 days in Seawater exposure period, the average strength loss of UHPC mixes such as CON, 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL was measured as 5.87%, 5.53%, 5.20%, 4.84%, 4.42% and 4.75%, respectively. After a period of 180 days exposure to Seawater, the average strength loss of UHPC mix proportions such as CON, 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL was measured 8.19%, 7.71%, 7.23%, 6.77%, 6.21% and 6.62%, respectively. The maximum strength loss was observed in CON mix, whereas minimum loss noticed in concrete mix 2.0 AL at all ages.

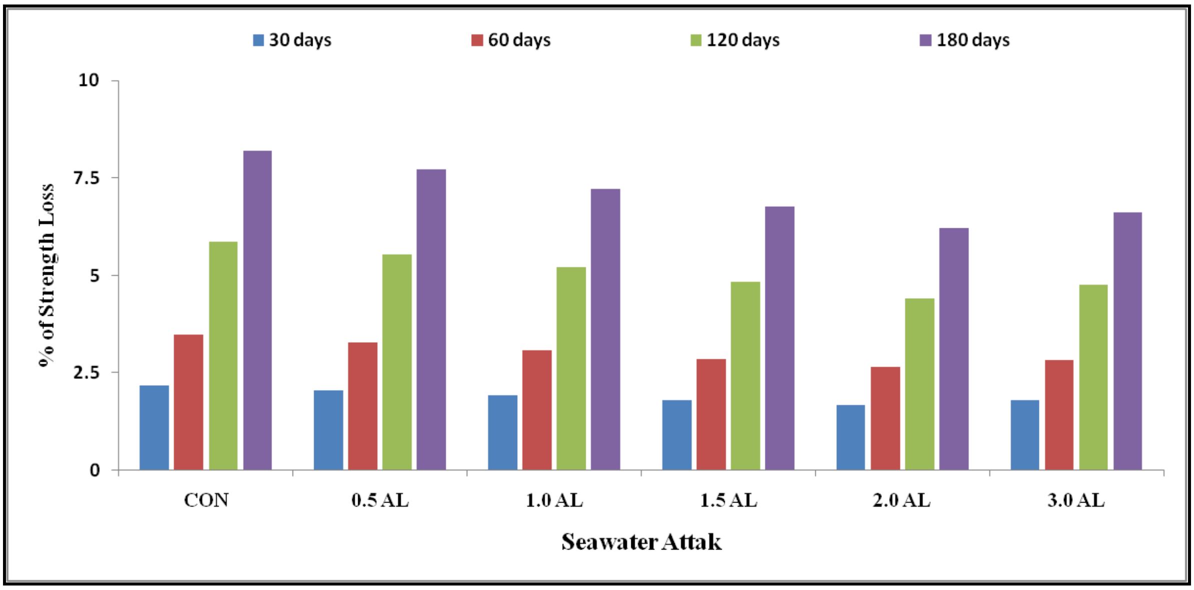

Figure 3 the strength loss of specimens due to seawater attack

IV. CONCLUSIONS

The inclusion of nano Al_2O_3 particles leads to resistance against the sea water penetration of the cement matrix. The 2.0 AL mix was suffered the minimum weight loss and strength loss against the seawater attack. Due to filler effects of nano Al_2O_3 particles was reduced the water transport properties of cement matrix and reduced the porosity on nano blended UHPC.

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