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Aggressive alkaline attack on nano Al_2O_3 blended Ultra High Performance Concrete

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Abstract

In the present research work, the alkaline attack on ultra high performance concrete with different percentage of nano Al_2O_3 powder has been investigated. 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 strength loss of UHPC were measured, after 25% NaOH solution, 25% NaOCl solution and 25% NH_4OH solution for the 30 days, 60 days, 120 days and 180 days of exposure period. The results of this research work clearly showed that 2% nano Al_2O_3 was optimum percentage. it was improve the resistance against the alkaline attack on ultra high performance concrete. Because of the smaller size and higher surface area of nano Al_2O_3 particles play the main role on microstructure and reduced porosity and water transport properties of UHPC.

Keywords: *nano Al_2O_3, Ultra High Performance Concrete, alkaline attack, Sodium Hydroxide attack, Sodium Hypochlorite attack and Ammonium Hydroxide attack.*

1. Introduction

In past two decades, ultra high performance concrete has been developed most promising type of concrete, because of its superior performance in strength and durability[1]–[3]. The efficiency of ultra high performance concrete was depends on the optimum packing density of the mixture [4]. The packing density of UHPC mixture was enhanced by utilization of fine powder to arrest the micro pores on the concrete [5], [6]. Still now the we are utilizing micro particles such as silica fume, bagasse ash, ground granulated blast furnace slag, coal bottom ash, fly ash, gypsums, limestone powder, metakaolin, palm oil fuel ash and rice husk ash for fabrications of UHPC [7]–[22]. In this scope, the inclusion of nano particles was greatly influences properties of UHPC. The small size of nano particles was fill the voids between cement and micro sized supplementary cementing materials of UHPC, thus leading to produce the highly homogeneous cement matrix with more quantity C-S-H gel production. In recent days only limited works has available for utilization of nano materials such as carbon nano fiber, nano $CaCO_3$, nano SiO_2, nano ZrO_2, nano metaclay and nano metakaolin in ultra high strength concrete [23]–[31]. To date, no comprehensive study relating to the replacement of nano Al_2O_3 on aggressive chemical 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 alkaline attack (such as sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack) of specimens measured after the 30^{th} day, 60^{th} day, 120^{th} day and 180^{th} days of exposure period.

2. Materials and methods

In the present study, UHPC was fabricated by using the ingredients of Ordinary Portland Cement 53 grade (conforming to IS 12269-2013 [32]), silica fume (conforming to IS 15388- 2003[33]), quartz powder, nano Al_2O_3 Particles having size of 20-30nm and SSA of 180 m^2/g (produced from SISCO Research Laboratories Pvt. Ltd), river sand, polycarboxylate ether based superplasticizer ASTM C494 Type F, polypropylene fibres of length 20 mm and 38 µm diameter [34]. The Tables 1 shows the mix proportions details of UHPC was developed based ASTM C1856/C1856M-17 [35], the CON mixture was without nano Al_2O_3 particles and other five mixes consist of nano Al_2O_3 particle was replaced by 0.5%, 1%, 1.5%, 2% and 3% weight of cement. The six mixes were mixed with mortar mixture machine and fresh concrete was placed in 50 mm cubes. After 24 hours, demoulded specimens were placed in normal water curing for 28 days

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Table 1 Mix proportion for Nano Al2O3 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

3. Experimentation techniques:

The UHPC were fabricated according to ASTM 1856/C1856-17[35]. The compressive strength of specimens was measured with an average of three 50 x 50 x 50 mm cube specimens tested as per ASTM C109/C10M – 07 [36]. After the curing period, the performance of specimens against the aggressive alkaline chemical attack was tested according to ASTM C 267 – 01 [37]. The rate of chemical attack were measured by change in weight and change in strength of UHPC cube specimens after the 30^{th} day, 60^{th} day, 120^{th} day and 180^{th} days of exposure period in alkaline solutions. In this study 25% sodium hydroxide solution, 20% sodium hypochlorite solution and 20% ammonium hydroxide solution are taken for aggressive alkaline chemical media according to ACI 201.2R-08 [38].

4. Results and Discussion

4.1 Alkaline solution attack:

The rate of attack of alkaline solution on nano Al_2O_3 Ultra High Performance Concrete mixes were measured by change in weight and change in strength after the exposure period in alkaline solutions such as 25% sodium hydroxide solution, 20% sodium hypochlorite solution and 20% ammonium hydroxide solution.

The weight loss and strength loss of UHPC mixes such as CON, 0.5 AL, 1.0 AL, 1.5 AL, 2.0 AL and 3.0 AL were examined at the age of 30^{th} day, 60^{th} day, 120^{th} day and 180^{th} day of alkaline solution curing. The deteriorated specimens after the 30^{th} day, 60^{th} day, 120^{th} day and 180^{th} days of exposure period in 25% sodium hydroxide solution, 20% sodium hypochlorite solution and 20% ammonium hydroxide solution was shown in Figure 1.

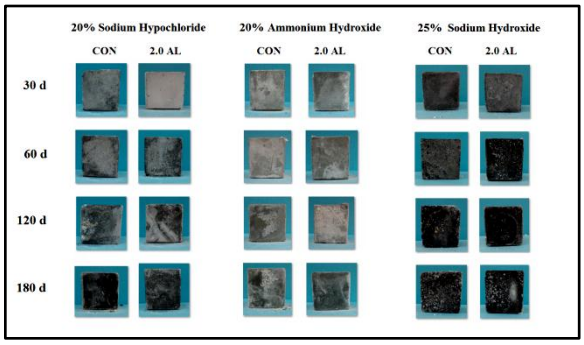

Figure 1 the deteriorated specimens after the 30th day, 60th day, 120th day and 180th days of exposed alkaline attack

4.2 Weight loss:

Figure 2 show that the effects of nano Al_2O_3 particle replacement on weight loss behavior of UHPC specimens exposed to aggressive alkaline chemicals attack. The test results reveal that out off six serious mixes, the CON mix suffered more and 2.0 AL mix was suffered less in alkaline attack, comparatively from at all ages of exposure period. After 30days of exposure period, the weight loss for CON mix and 2.0 AL was measured 0.45% and 0.27%, 0.33% and 0.18%, 0.57% and 0.37% for sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack, respectively in comparison to water cured specimens. After 60days of exposure period, the weight loss for CON mix and 2.0 AL was measured 0.87% and 0.56%, 0.61% and 0.33%, 1.02% and 0.68% for sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack, respectively in comparison to water cured specimens. After 120days of exposure period, the weight loss for CON mix and 2.0 AL was measured 1.65% and 1.12%, 1.23% and 0.74%, 2.14% and 1.31% for sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack, respectively in comparison to water cured specimens. After 180days of exposure

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period, the weight loss for CON mix and 2.0 AL was measured 2.53% and 1.48%, 1.87% and 1.04%, 3.28% and 1.93% for sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack, respectively in comparison to water cured specimens.

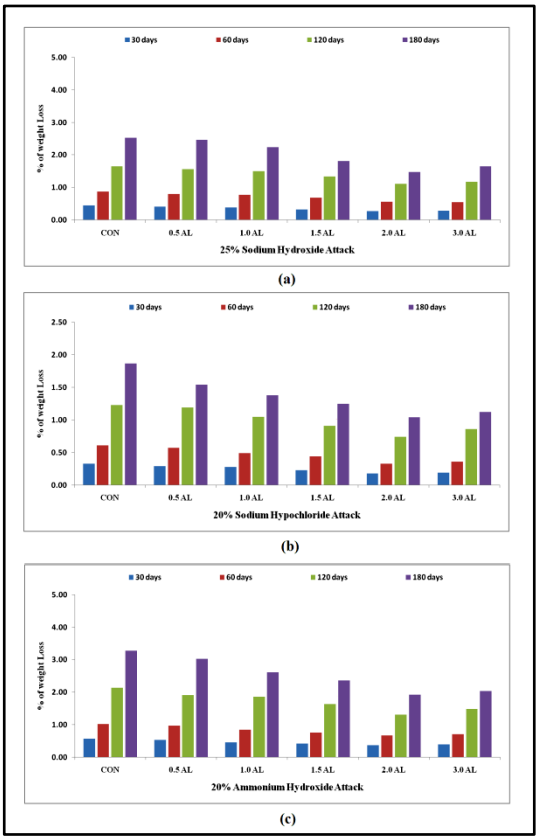

Figure 2 the weight loss due to (a) sodium hydroxide attack, (b) sodium hypochlorite attack and (c) ammonium hydroxide attack

4.3 Strength loss:

Figure 3 show that the effects of nano Al_2O_3 particle replacement on strength loss behavior of UHPC specimens exposed to aggressive alkaline solution attack. The test results reveal that out off six serious mixes, the CON mix suffered more and 2.0 AL mix was suffered less in alkaline attack, comparatively at all ages of exposure period. After 30days of exposure period, the average compressive strength loss for CON mix and 2.0 AL was measured 2.33% and 1.78%, 2.14% and 1.65%, 2.56% and 1.94% for sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack, respectively in comparison to water cured specimens. After 60days of exposure period, the average compressive strength loss for CON mix and 2.0 AL was measured 3.81% and 2.87%, 3.44% and 2.61%, 4.26% and 3.13% for sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack, respectively in comparison to water cured specimens. After 120days of exposure period, the average compressive strength loss for CON mix and 2.0 AL was measured 6.51% and 4.83%, 5.80% and 4.37%, 7.41% and 5.40% for sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack, respectively in comparison to water cured specimens.

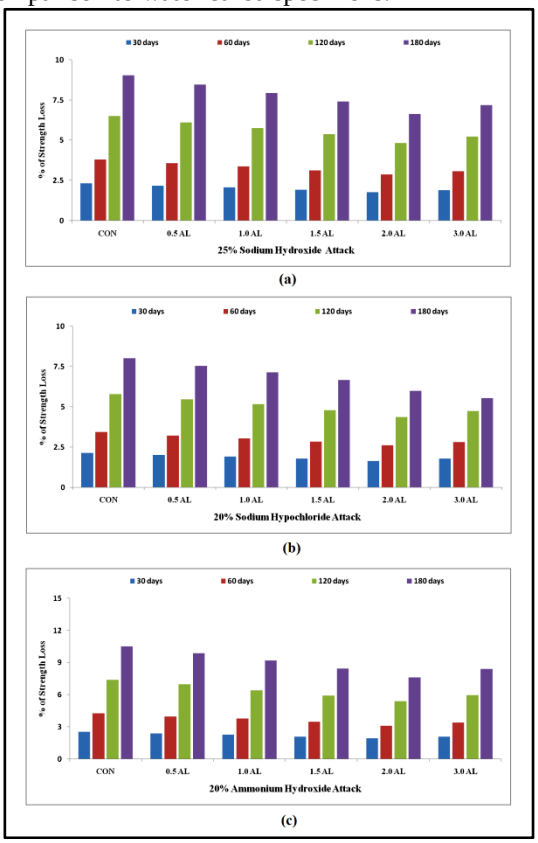

Figure 3 the strength loss due to (a) sodium hydroxide attack, (b) sodium hypochlorite attack and (c) ammonium hydroxide attack

After 180days of exposure period, the average compressive strength loss for CON mix and 2.0 AL was measured 9.03% and 6.63%, 8.03% and 5.99%, 10.50% and 7.63% for sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack, respectively in comparison to water cured specimens.

5. Conclusions

This study explored the effects of nano Al_2O_3 particle on the sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack of ultra high performance concrete. The inclusions nano Al_2O_3 particle acts as a pore filling material, nucleation sites for C-S-H gel formation and aluminosilicate type gel in cement matrix. The high retention in strength loss and weight loss was observed in 2% nano Al_2O_3 particle contained specimens. Besides the complexuation of UHPC cement matrix by nano Al_2O_3 particle was lead to improve the denser microstructure and production layer for aggressive chemical attacks. The test results reveals that the inclusion of nano Al_2O_3

particle particles hinder the further ingress of aggressive chemical and reduce the leaching characteristics of cement matrix in sodium hydroxide attack, sodium hypochlorite attack and ammonium hydroxide attack.

References

[1] M. Schmidt, E. Fehling, and C. Geisenhanslüke, *Proceedings of the International Symposium on Ultra High Performance Concrete*, no. 3. 2004.

[2] E. Fehling, M. Schmidt, and S. Sturwald, *Proceedings of the Second International Symposium on Ultra High Performance Concrete*, vol. 53. 2008.

[3] M. Schmidt, E. Fehling, C. Glotzbach, S. Fröhlich, and S. Piotrowski, *Proceedings of Hipermat 2012 3rd International Symposium on UHPC and Nanotechnology for High Performance Construction Materials*, no. 19. 2012.

[4] M. G. Sohail *et al.*, "Advancements in Concrete Mix Designs: High-Performance and Ultrahigh-Performance Concretes from 1970 to 2016," *J. Mater. Civ. Eng.*, vol. 30, no. 3, p. 4017310, 2018.

[5] F. de Larrard and T. Sedran, "Optimization of Ultra-High-Performance concrete by the use of a packing model," *Cem. Concr. Res.*, vol. 24, no. 6, pp. 997–1009, 1994.

[6] A. Arora *et al.*, "Microstructural packing- and rheology-based binder selection and characterization for Ultra-high Performance Concrete (UHPC)," *Cem. Concr. Res.*, vol. 103, no. February, pp. 179–190, 2018.

[7] H. Yazici, H. Yiğiter, A. Ş. Karabulut, and B. Baradan, "Utilization of fly ash and ground granulated blast furnace slag as an alternative silica source in reactive powder concrete," *Fuel*, vol. 87, no. 12, pp. 2401–2407, 2008.

[8] M. Safiuddin, J. S. West, and K. A. Soudki, "Hardened properties of self-consolidating high performance concrete including rice husk ash," *Cem. Concr. Compos.*, vol. 32, no. 9, pp. 708–717, 2010.

[9] C. Schröfl, M. Gruber, and J. Plank, "Preferential adsorption of polycarboxylate superplasticizers on cement and silica fume in ultra-high performance concrete (UHPC)," *Cem. Concr. Res.*, vol. 42, no. 11, pp. 1401–1408, 2012.

[10] M. A. A. Aldahdooh, N. Muhamad Bunnori, and M. A. Megat Johari, "Development of green ultra-high performance fiber reinforced concrete containing ultrafine palm oil fuel ash," *Constr. Build. Mater.*, vol. 48, pp. 379–389, 2013.

[11] Y. Y. Chen, B. L. A. Tuan, and C. L. Hwang, "Effect of paste amount on the properties of self-consolidating concrete containing fly ash and slag," *Constr. Build. Mater.*, vol. 47, pp. 340–346, 2013.

[12] V. T. A. Van, C. Rößler, D. D. Bui, and H. M. Ludwig, "Rice husk ash as both pozzolanic admixture and internal curing agent in ultra-high performance concrete," *Cem. Concr. Compos.*, vol. 53, pp. 270–278, 2014.

[13] T. Oertel, F. Hutter, U. Helbig, and G. Sextl, "Amorphous silica in ultra-high performance concrete: First hour of hydration," *Cem. Concr. Res.*, vol. 58, pp. 131–142, 2014.

[14] Z. D. Rong, W. Sun, H. J. Xiao, and W. Wang, "Effect of silica fume and fly ash on hydration and microstructure evolution of cement based composites at low water-binder ratios," *Constr. Build. Mater.*, vol. 51, pp. 446–450, 2014.

[15] M. Gesoglu, E. Güneyisi, A. H. Nahhab, and H. Yazici, "Properties of ultra-high performance fiber reinforced cementitious composites made with gypsum-contaminated aggregates and cured at normal and elevated temperatures," *Constr. Build. Mater.*, vol. 93, pp. 427–438, 2015.

[16] W. Li, Z. Huang, F. Cao, Z. Sun, and S. P. Shah, "Effects of nano-silica and nano-limestone on flowability and mechanical properties of ultra-high-performance concrete matrix," *Constr. Build. Mater.*, vol. 95, pp. 366–374, 2015.

[17] A. Tafraoui, G. Escadeillas, and T. Vidal, "Durability of the Ultra High Performances Concrete containing metakaolin," *Constr. Build. Mater.*, vol. 112, pp. 980–987, 2016.

[18] Z. Li, "Drying shrinkage prediction of paste containing meta-kaolin and ultrafine fly ash for developing ultra-high performance concrete," *Mater. Today Commun.*, vol. 6, pp. 74–80, 2016.

[19] W. Huang, H. Kazemi-Kamyab, W. Sun, and K. Scrivener, "Effect of cement substitution by limestone on the hydration and microstructural development of ultra-high performance concrete (UHPC)," *Cem. Concr. Compos.*, vol. 77, pp. 86–101, 2017.

[20] S. Pyo and H. K. Kim, "Fresh and hardened properties of ultra-high performance concrete incorporating coal bottom ash and slag powder," *Constr. Build. Mater.*, vol. 131, pp. 459–466, 2017.

[21] W. Huang, H. Kazemi-Kamyab, W. Sun, and K. Scrivener, "Effect of replacement of silica fume with calcined clay on the hydration and microstructural development of eco-UHPFRC," *Mater. Des.*, vol. 121, pp. 36–46, 2017.

[22] S. A. Zareei, F. Ameri, and N. Bahrami, "Microstructure, strength, and durability of eco-friendly concretes containing sugarcane bagasse ash," *Constr. Build. Mater.*, vol. 184, pp. 258–268, 2018.

[23] B. B. W. Jo, C. H. Kim, and J. H. Lim, "Investigations on the development of powder concrete with nano-SiO2 particles," *KSCE J. Civ. Eng.*, vol. 11, no. 1, pp. 37–42, 2007.

[24] J. Camiletti, A. M. Soliman, and M. L. Nehdi, "Effect of nano-calcium carbonate on early-age properties of ultra-high-performance concrete," *Mag. Concr. Res.*, vol. 65, no. 5, pp. 297–307, 2013.

[25] J. Camiletti, A. M. Soliman, and M. L. Nehdi, "Effects of nano- and micro-limestone addition

on early-age properties of ultra-high-performance concrete," *Mater. Struct. Constr.*, vol. 46, no. 6, pp. 881–898, 2013.

[26] R. Yu, P. Spiesz, and H. J. H. Brouwers, "Effect of nano-silica on the hydration and microstructure development of Ultra-High Performance Concrete (UHPC) with a low binder amount," *Constr. Build. Mater.*, vol. 65, pp. 140–150, 2014.

[27] L. Ahmed Sbia, A. Peyvandi, P. Soroushian, J. Lu, and A. M. Balachandra, "Enhancement of Ultrahigh Performance Concrete Material Properties with Carbon Nanofiber," *Adv. Civ. Eng.*, vol. 2014, 2014.

[28] D. Wang, C. Shi, Z. Wu, L. Wu, S. Xiang, and X. Pan, "Effects of nanomaterials on hardening of cement – silica fume – fly ash-based ultra-high-strength concrete," *Adv. Cem. Res.*, pp. 1–12, 2016.

[29] M. S. Muhd Norhasri, M. S. Hamidah, A. Mohd Fadzil, and O. Megawati, "Inclusion of nano metakaolin as additive in ultra high performance concrete (UHPC)," *Constr. Build. Mater.*, vol. 127, pp. 167–175, 2016.

[30] B. Han *et al.*, "Reactive powder concrete reinforced with nano SiO2-coated TiO2," *Constr. Build. Mater.*, vol. 148, pp. 104–112, 2017.

[31] M. S. M. Norhasri, M. S. Hamidah, and A. M. Fadzil, "Inclusion of nano metaclayed as additive in ultra high performance concrete (UHPC)," *Constr. Build. Mater.*, vol. 201, pp. 590–598, 2019.

[32] IS-12269, "Ordinary Portland Cement, 53 Grade-Specification," 2013.

[33] IS 15388, "Specification for Silica Fume," 2003.

[34] BS EN 14889-2, "Fibres for concrete- Part 2: Polymer fibres - Definitions, specifications and conformity," 2006.

[35] ASTM C1856/C1856M − 17, "Standard Practice for Fabricating and Testing Specimens of Ultra-High Performance Concrete," pp. 1–4, 2018.

[36] ASTM-C109/C109M-07, "Compressive Strength of Hydraulic Cement Mortars (Using 2-in . or [50-mm] Cube Specimens)." .

[37] ASTM C267, "Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacings and Polymer Concretes," 2001.

[38] ACI 201.2R, "Guide to Durable Concrete," 2008.