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Effect of Colloidal Nano Silica on Durability of High Strength Concrete Subjected to Acid Attack

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Abstract: **-- Nanotechnology is one of the most active research areas that relate to number of disciplines including Civil engineering and it may have a great impact on the field of construction materials. The literature survey shows that little is reported to evaluate the durability aspect of HSC (High strength concrete) incorporating Colloidal nano silica (CNS). This paper deals with studying the effect of CNS on durability properties of HSC subjected to acid attack (H2So4, and HCL) by conducting the tests such as Compressive strength, Weight loss, SCM, ESD and linear regression analysis etc. The experimental study is carried out on M 60 grade of concrete with varying percentage of the P-63 grade of fly ash from 5% to 25 % and P-100 grade of fly ash with constant 10 % replacement by weight of cement (b.w.c) also the percentage of CNS varies from 1% to 5% b.w.c The result shows that 20% replacement of cement by fly ash and 3% addition of CNS gives satisfactory results when compared with other mix proportions.**

Key Words - HSC, CNS, Acid attack, weight loss, strength

I. INTRODUCTION

Acid attack generally occurs where the calcium hydroxide is attacked vigorously, although all the Portland cement compounds are susceptible to degradation, acid solutions both mineral (such as sulphuric, hydrochloride, and phosphoric acids) and organic (such as lactic, acetic, formic, tannic and other acids produced in decomposing silage) are about the most aggressive agents to concrete. Depending on the type of acid the attack can be mainly an acid attack, or a combination of acid followed by salt attack. It cannot cause deterioration in the interior of the specimen without the cement paste on the outer portion being completely destroyed. The rate of penetration is thus inversely proportional to the quantity of acid neutralizing material, such as calcium hydroxide, C-S-H gel, and lime stone aggregate. In practice the degree of acid attack increases as acidity increases, attack occurs at values of PH below 6.5 , a PH of less than 4.5 leading to severe attack . The rate of acid attack depends on tne ability of hydrogen ions to be diffused through the cement gel (C-S-H) after calcium hydroxide (Ca (OH) 2) has been dissolved and leached out .

II. MECHANISUM OF ACID ATTACK

The deterioration of concrete due to sulphuric acid consist of two stages, in first stage H2So4 chemically reacts with hydration products such as calcium hydroxide (CH) and calcium silicate hydrates (C-S-H) to form Gypsum (CaSo4.2H2O), in second stage gypsum reacts with hydrated tri calcium alluminate (C3A) to form ettringite (C6AS3H32) and its analogs . the process mentioned below ,

$Ca(OH)_2 + H_2So_4 \rightarrow CaSo_4.2H_2O$

$CaSiO_2.2H_2 + H_2So_4 \rightarrow CaSo_4 + S\ i\ (OH)_2 + H_2O$

$3CaO.Al_2O_3.12\ H_2O + 3(CaSo_4.\ 2H_2O) + 14\ H_2O \rightarrow 3CaO.Al_2O_3 3\ CaSo_4.32\ H_2O$

Both Gypsum and ettringite have low structural stability in composition to the reactants they replace are also responsible for expansion, which initiates cracks.

III. RESEARCH SIGNIFICANCE

The main challenge before the construction industry is to serve the two important needs of the society, namely the protection of the environment and meeting the requirement of developing construction industry. The development of human activity results in environmental degradation. The main challenge is to minimize the degradation to a level consistent with sustainable development. For civil engineers the concept of sustainable development means use of high performance materials with reasonable cost with lowest possible environmental impact, and this is possible only by using waste products in the

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construction industry . One of the product is fly ash, as its volume is increasing worldwide with increasing use of coal and contributing environmental degradation. So one of the major industry like civil engineering works which consumes thousands of tons of cement every year that is the ideal place for economic and safe disposal of million tons of industrial by product fly ash due to its highly pozzolanic and cementitious property. So here an attempt has been made to use CNS along with fly ash, admixtures and retarders to check the durability aspect of HSC and which can be compared with normal concrete (NC) to find out optimum % of CNS to be used in HSC to improve the durability property against acid attack.

IV. MATERIAL USED

A] Cement—In present research work Ultra tech OPC of 53 grade is used, the cement has been tested in accordance with Indian standards confirming to I.S. 12629-1989. The specific gravity of cement is 3.15

B] Fly ash- The fly ash used in present work is of grade P-63 and P-100 supplied by Dirk India Pvt .Ltd Nasik .The physical and chemical properties are as mentioned in table -1 below

Table 1- Physical and Chemical properties of Fly Ash

Test No	Test	Unit	I.S Specification	Pozzocrete P-63	Pozzocrete P-100
1	Fineness by Blaine's Permeability	m2/Kg	320	400	610
2	25 micron residue	%	Not Specified	---	0.08
3	45 micron residue	%	34	10.0	Traces
4	Lime reactivity	N/mm2	4.5	5.5	7.0
5	Moisture Content	%	2.0	0.5	0.5
6	Autoclave Expansion	%	0.8 %	0.1 %	0.1 %
7	Compressive Strength at 28 days % of plain cement mortar	%	80	90	95
8	Loss on Ignition	%	5	2.5	2.5
9	SiO2+ Al2O3+Fe2O3	%	70 min. by mass	90	90.0
10	SiO2	%	35 min by mass	50	60.35
11	MgO	%	4 max. by mass	4.0	4.0
12	SO3	%	3 max. by mass	2.0	2.0
13	Na2O	%	1.5 max. by mass	1.5	1.5
14	Total Chlorides	%	0.05max. by mass	0.05	0.05

C] Fine Aggregate—The fine aggregate used in this experiential work is procured locally from Pravara River in Maharashtra and it is tested according to I.S 2386-1963and I.S.383-1970, the sand confirming to Zone-II with fineness modulus of 3.45 and specific gravity 2.60

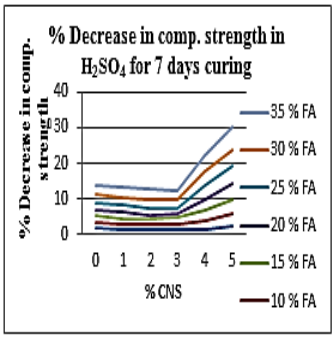
D] Coarse Aggregate-Locally available coarse aggregate having maximum size 10mm is used in present work, the aggregates are tested as per I.S.2386-1963, the specific gravity found to be 2.77 and fineness modulus of 6.78 .

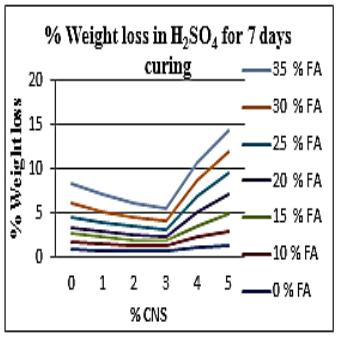
E] Super plasticizer – Master Glenium Sky-8855 with constant dose of 1.5 % manufactured by BASF Chemicals, Mumbai is used as water reducing agent and to improve workability of fly ash concrete along with retarder Master Pozzolith-44R

F] Colloidal Nano-Silica—CNS with particle size 5-8 nm with specific gravity 1.15 having solid content 15-16% is used as supplied by Bee-Chem. Pvt.Ltd. Kanpur (India)

5. Experimental Programme – In this experimentation an attempt has been made to find out the effect of acid attack on properties of HSC produced by replacing cement by fly ash in various percentage of P-63 grade of fly ash varying from 5 % to 25% in increment of 5% along with P-100 grade with constant 10% replacement b.w.c, locally available sand, coarse aggregate were used in this experimentation. Also to improve the properties of hardened concrete Colloidal Nano silica is used varying from 1 % to 5% Mix design of M60 grade of concrete is done in accordance with I.S 10262-1982 and I.S 10262-2009 with W/C ratio of 0.22 and mix proportion of 1:1.05:1.37 to find out the effect of acid attack on compressive strength, weight loss and visual observations for which specimens of 150mmx150mmx150mm were casted. The specimens were kept in 5% solutions of H2So4 and HCL solutions for 7, 28, and 56 days after curing in normal water for 28 days. The PH of solution was 4.5 and 4.0 in H2So4 and HCL solutions respectively and it is maintained throughout.

6. Test Results and Discussion –





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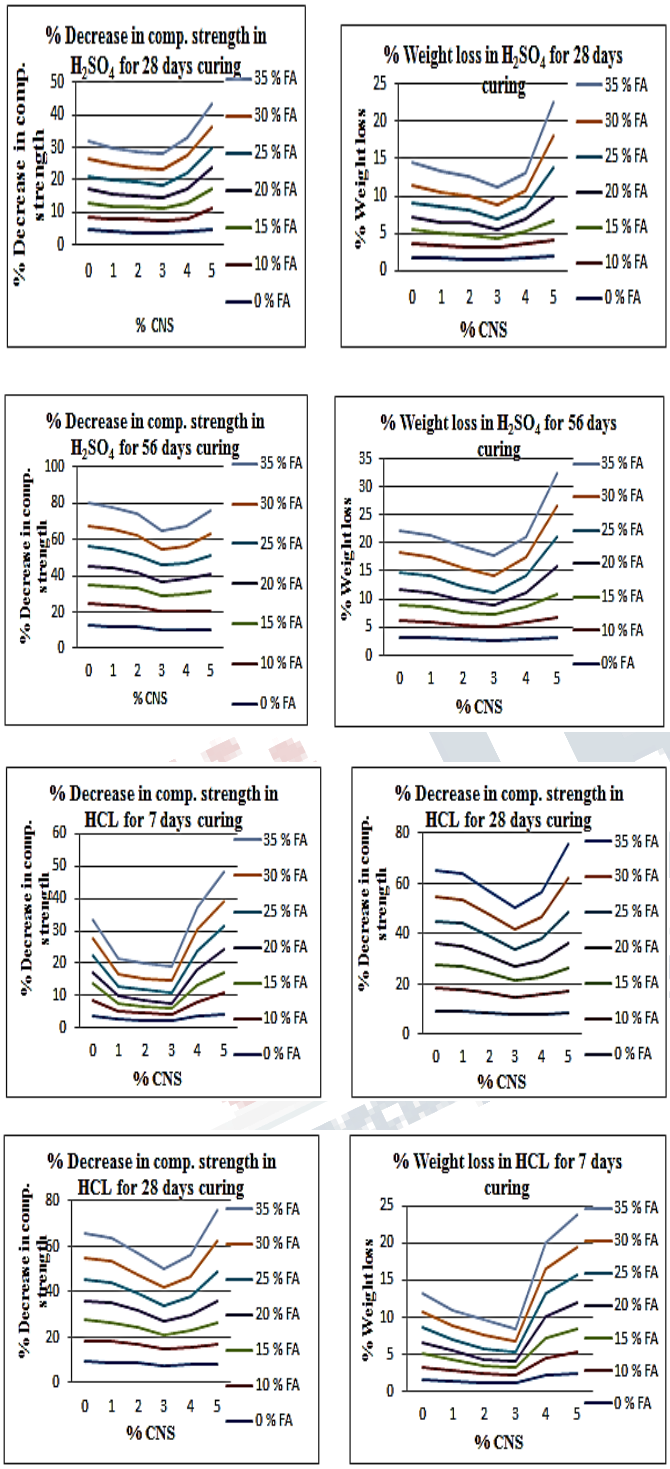
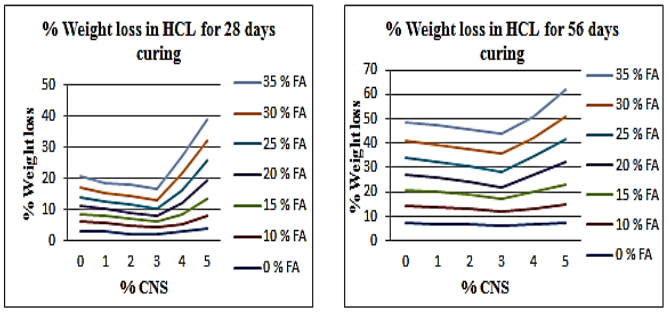


Fig 1- % decrease in compressive strength and weigh loss at various % of FA and % CNS



6. Visual observations

In this deterioration was observed initially at the top surface edges of specimen and which has progressed along the sides up to the bottom edge, as time of exposure progresses deterioration was observed on all edges, and finally spalling of surface at the sides was predominant which form of failure is. After 28 days the side surface spelled off the core leading to weakening and delamination of the top and bottom surfaces but which was negligible in mix when 20 % FA and 3% CNS was added as it gives good particle packing density. Scaling is predominant in H2So4 than the HCL (fig-2 and fig-3)

Fig-2-Specimens after HCL Attack

Fig-3- Specimens after H2So4 Attack

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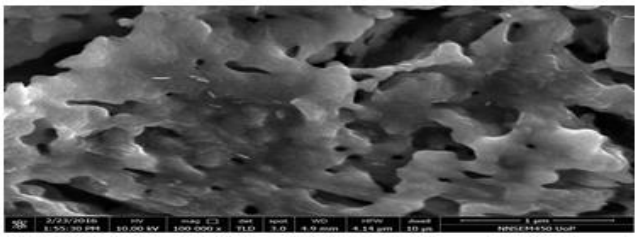
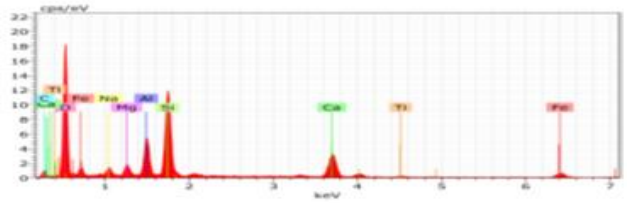
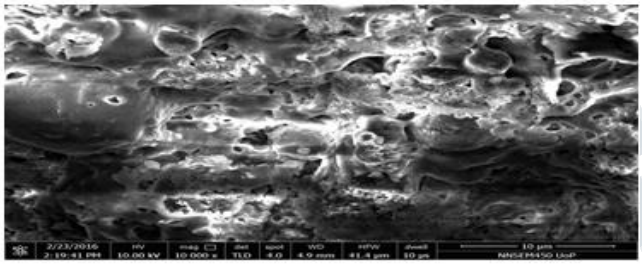
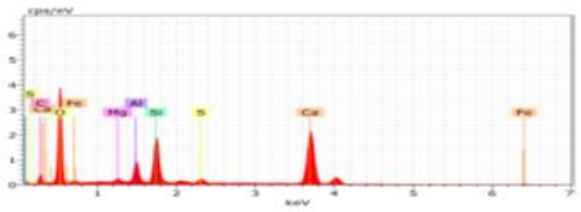


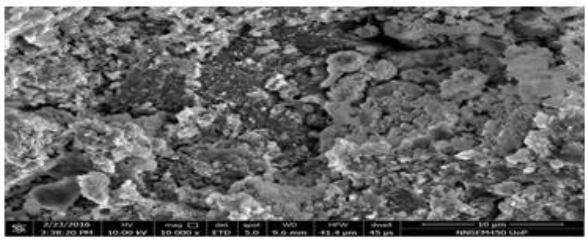


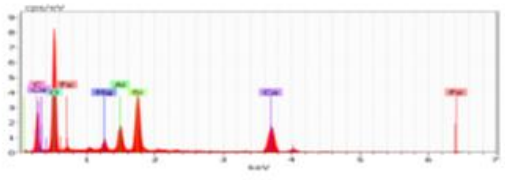
SCM Image in after 7 days in H2SO4





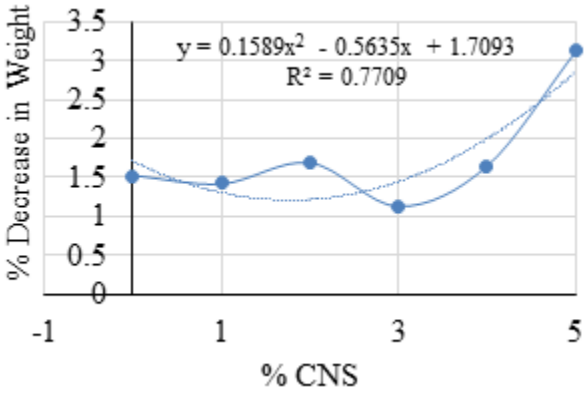
SCM Image in after 28 days in H2SO4





SCM Image in after 56 days in H2SO4

7 Regression Analysis



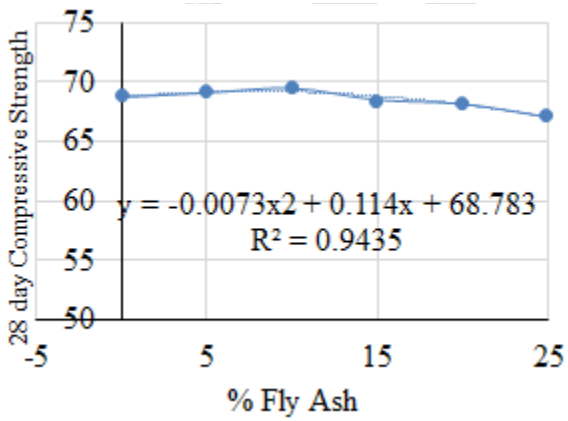


Fig-5- Regression Analysis

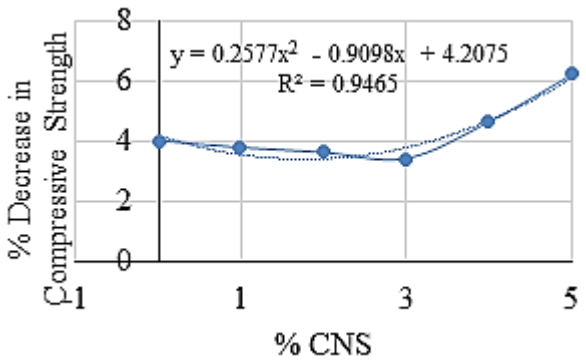


Fig-5- Regression Analysis

8 SCM and EDS analysis – The SCM images and EDS report shows massive formation of gypsum along with significant presence of M-S-H. The C-S-H is considerably reduced indicates decomposition of C-S-H to M-S-H .The gypsum formation may be attributed to reaction between FA and CNS with the CH librated by the hydration of Portland cement also

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decomposition of FA on C-S-H. The decomposition of C-S-H by FA leads to formation of gypsum and loss of C-S-H binder .The SEM observations shows that as the curing period increases in acid medium then micro structural characteristics of the sample goes on changing also as the replacement level of FA increases from 10 % to 35% the reactivity of CNS with varying percentage also changes and good and compact microstructure was observed at 3% addition of CNS and 20 % FA replacement (b.w.c) which indicates that interfacial transition zone is more strong and which gives minimum weight loss and percentage decrease in compressive strength. The above morphological differences at 7, 28, and 56 days curing in acid medium is shown in fig (4)

Regression Analysis- A Sample regression analysis for % decrease in weight , 28days compressive strength and % decrease in compressive strength after 28 days attack of HCL as shown in fig (5) which indicates for all the mixes of % variation of FA and CNS the results obtained experimentally are within limit as the regression factor has satisfactory values

V. CONCLUSIONS

1) From experiment it is observed that percentage weight loss in H2SO4 at 3% CNS content and with 20% FA replacement are 0.55%, 1.13% and 1.82% and loss in compressive strength are 1.06%, 3.44% and 7.94% for 7, 28 and 56 days respectively which are less as compared with others. Then there after that is beyond 4% CNS and 20% FA content the loss observed to be more.

2) Whereas percentage loss in compressive strength in HCL was observed as 1.39%, 5.94%, 10.78% and weight loss was 0.87%, 1.73%, 4.59% at 7, 28 and 56 days respectively for 3% CNS content and 20 % FA content, so if the two acids are compared it was observed that the loss is less in H2SO4 as compared to HCL.

3) The Acid detoriation in normal concrete and CNS added concrete is characterized by scaling, spalling and softening rather than expansion and cracking as reduction in strength is not much after 56 days of acid attack.

4) The Sulfuric acid mainly attack on hydration products of concrete , as in initial stage up to 15 % replacement of FA cement content is more which develops more hydration products which are available to react with sulfuric acid which is responsible for degradation concrete.

5) In HSC as the w/c ratio is low which produces durable concrete sustainable to various chemical and physical attack and as due to addition of nano particles the particle packing density (PPD) increases which gives minimum loss at 3% addition of CNS.

6) When the concrete exposed to constant concentration of acid the degradation is directly proportional to surface area exposed to acid attack.

7) For validating the results combination of chemical and microbiological tests are necessary

8) As far as durability properties are concerned the FA and CNS reduces the water permeability, adsorption this may be due to filler effect of CNS particles which has reduced porosity of concrete.

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