Influence of Colliodal Nano- SiO_2 on durability properties of high strength concrete

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Abstract - High strength concrete (HSC) has become a very popular construction material. Due to its superior strength, toughness, stiffness and durability, the size of HSC structural members can be significantly reduced to obtain same amount of compressive strength as a normal strength concrete. The content of high strength concrete is generally which often leads to higher shrinkage and greater evolution of heat of hydration besides increase in cost. A partial substitution of cement by an industrial waste, such as fly ash is not only economical but also improves the properties of fresh and hardened concrete and enhances durability. Generally, the specification restricts the replacement level of cement with fly ash to about 25-30%.

Nanotechnology is a very active research field and has applications in a number of areas. Nanotechnology has been applied to concrete production and has the potential of improving the performance of concrete. It has been shown to increase the mechanical and durability properties of concrete leading to development of novel and sustainable materials.

In this study the effect of colloidal nano silica at different %, incorporating high strength concrete along with fly ash are studied. The test specimens are cured under a sulphuric medium of Sodium sulphate (Na_2SO_4) and Magnesium sulphate ($MgSO_4$). The test are conducted for 7, 28, 56 days, after 28 days curing in normal water. The results shows that the concrete containing about 20% Fly ash and 3% CNS shows better performance of concrete against sulphate attack.

***Key Words*: Colloidal Nano Silica, High Strength Concrete, Microstructure, Durability property, Mechanical property.**

1. INTRODUCTION

The cement industry becomes one of the most energy consuming industries with the high rate of CO2 emission (5%) every year. Many efforts have been taken to reduce the effect of cement industry on green house gasses by using supplementary cementitious materials, which makes the partial replacement to ordinary Portland cement such as GGBFS, SF, FA, NS etc. out of that one interesting material i.e. nano silica produced from silica sand. Past research work on concrete using nano silica has investigated that improved workability and the strength of the concrete also reduce the overall permeability of the hardened concrete.

Nano material is the smallest particle of size less than 100 nm. (a nanometer, nm, is 10^{-9}m). Nanomaterials are very reactive because of the particles of small size and large surface area and have great potential in improving concrete properties such as, compressive strength and permeability, In short the nano particles can be summarized as follows,

- Nano particles act as fillers in the empty spaces.
- Well distributed nano particles act as crystallization centers of hydrated products increasing hydration rate.
- Nano particles assist towards the formation of small in size Ca(OH)2 crystals and homogeneous clusters of C–S–H composition.
- Nano particles improve the structure of the transition zone between aggregates and paste.

Colloidal nano silica solution denotes small particles consisting of an amorphous SiO_2 core with a hydroxyl-ate the surface, which are insoluble and mono-dispersed in water, and with a particle size of 10 – 100 nm, which are small enough to remain suspended in a fluid medium without settling. The microstructure examinations have verified the finer structure (pore and grain refinement) and the drastically reduced porosity for the specimen containing nano-silica powder or dispersions. It is assumed that the nano-silica has much finer particle size and much greater pozzolanic reactivity than silica fume, thus can act as seeds and pozzolan more effectively.

1.1 LITERATURE REVIEW

In recent years experiments were carried out by adding or replacing nano silica. Here are some previous studies summarize below, **A.M. Said et al** Studied, experimental study was conducted on concrete containing colloidal nano silica with aqueous solution of 50% amorphous silica content. The mean of nano particles was of 35nM. The result showed that, significant improvement in terms of reactivity, strength development, refinement of pore structure and densification of ITZ. **Amrish Nasution et al.** The silica used in the study having size 10-40 nM at different % (0%, 2.5%, 5%, 7.5%, 10%) by cement weight. The result showed that, the nano silica was able to increase the density as well as increase the mechanical properties of concrete. **Min-Hong Zhang et al** water permeability resistant behavior and microstructure of concrete with nano silica was studied. The nano silica can improve the resistant to the penetration. The microstructure of concrete is more uniform and compact as compared to normal concrete. **Binsar Hariandja et al** locally available nano silica used on concrete with size 40-80 nM.

The result shows that combined use of nano silica with silica fume can increases the compressive strength and durability. Based on previous researches, this research is focused on the addition of colloidal in high strength concrete (M80) to improve the mechanical and durability of the concrete.

The colloidal nano silica used in aqueous solution of 15% amorphous silica content with size of particles 5-8 nM. The purpose of this study is to investigate durability property of high strength concrete (M80) under sulphuric medium.

2. METHODOLOGY

Materials required

Cement - The Ordinary Portland Cement (OPC) of 53 grade ultra tech cement is used. It has specific gravity of 3.15. The test conducted on cement was as per IS: 12269-1987.

Fine aggregate - Fine aggregate that is to be used for this entire study of investigation was local river sand confirming to zone-II of IS: 383-1970 and specific gravity is 2.60 and fineness modulus is 3.12.

Coarse aggregate - In the present study, locally available coarse aggregate of maximum size 10mm were used confirming to IS: 2386:1963(Part-III). Its specific gravity is 2.90 and fineness modulus is 6.78.

Water - Potable water confirming to IS: 456-2000 is used for casting and curing.

Nano Silica - High strength means better packing effect between different ingredients of concrete. Hence we used colloidal nano silica that fills the pore spaces of concrete, obtained from "Bee-chem". Chemicals ltd, Kanpur. It has 15-16% nano content which is in the form of water soluble type.

Table-1 Properties of colloidal nano silica

Parameter	Nano Solids	Particle Size	Specific gravity	Viscosity
Value	15-16%	5-8 nM	1.15	10-15 Sec.

Fly Ash - Fly ash of grade P-63 and P-100 are used as partial replacement to the cement. The fly ash is obtained from "DIRK India Pvt. Ldt"., Nashik, Maharashtra. The fly ash is replaced at P-63 (0%, 5%, 10%, 15%, 20%, 25%) and P- 100 at constant rate of 10%.

Admixture - For increasing workability of concrete a super plasticizer,"AURAMIX-400" by FOSROC chemicals, Mumbai is used in this experimental work. Along with retarder "CONPLAST R" manufactured by FOSROC chemicals Mumbai, confirming to IS: 9103-1993.

Mix Design - To investigate the effect of nano silica on the durability and mechanical properties of conventional concrete the mix design is done according to IS 10262:2009.

Table-2 Proportion for Concrete Mix Design (M80)

Materials	Cement	C.A.	F.A.	Water	Admix.
Mass (Kg/m3)	750	1047.6	626.2	142.7	11.25

The above table shows the quantity of material required for (M80) grade of concrete in Kg/m3. Hence the mix proportion then becomes **- 1:0.834:1.396**

Casting of Test Specimen - In this study the specimen of standard cubes (100 X100 X 100mm) were casted.

Mixing - Measured quantities of coarse aggregate and fine aggregate were spaced out over an impervious concrete floor. The dry OPC were spread out on the aggregate and mixed thoroughly in dry state turning the mixture over and over until the uniformity of color was achieved. Water was measured exactly by way and it was thoroughly mixed to obtain homogenous concrete. The mixing shall be done for 10 to 15 minutes.

Placing and Compacting - The cube mould and cylinder moulds are cleaned and all care is taken to avoid irregular dimensions. The joints between the sections of mould were coated with oil and similar coating of mould was applied between the contact surfaces during filling. The mix was placed in 3 layers and the layer was contacted using table vibrator to obtain dense concrete.

Curing - The test specimen cubes were stored in a place free from vibration in moist air at 90% relative humidity and at temperature of 27+/ for 24 ½ hours from the time of addition of water to dry ingredients. After 24 hours the specimens demoulded and immediately immersed in clean, fresh water tank for period of 28 days.

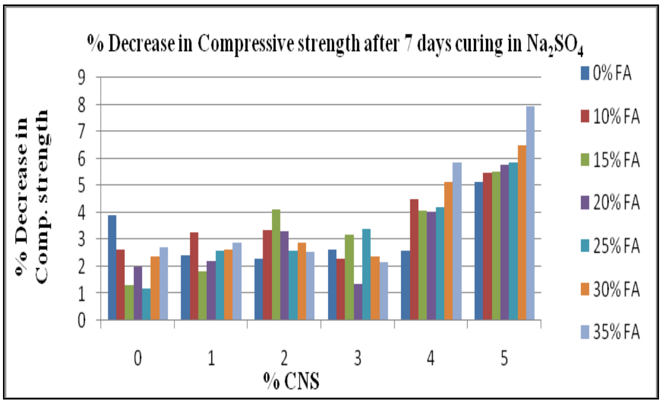
Compressive strength of HSC - Compressive strength of colloidal nano-SiO_2 and fly ash blended cement concrete cubes was determined after 28 days of curing as per I.S. 510-1959.

Chemical Attack on concrete - To find the effect of chemicals on the mix, the chemical used are Sulphates ($MgSO_4$& Na_2SO_4) with each have been mixed with 5% by weight of water after 28 days curing of the specimen. The samples were kept in various chemicals for 7 days, 28 days and 56 days and then after the effect of above chemicals were studies on percentage weight loss and percentage reduction in compressive strength.

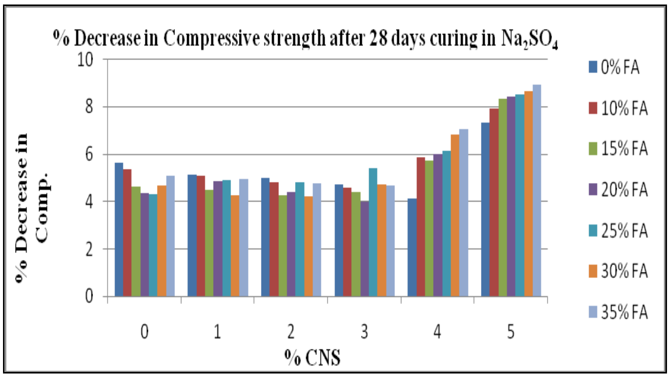
3. EXPERIMENTAL RESULTS

1. Sodium sulphate (Na_2SO_4)

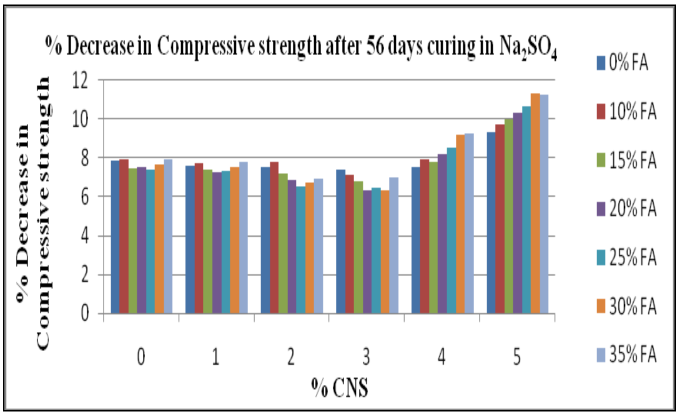
Graph 1 - % Decrease in Compressive strength after 7 days curing in Na_2SO_4



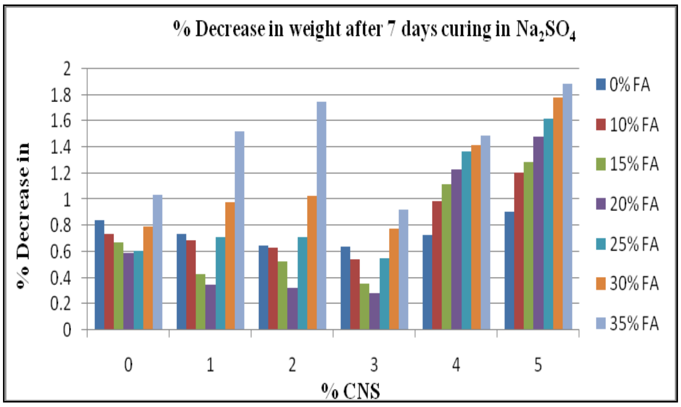
Graph 2 - % Decrease in Compressive strength after 28 days curing in Na_2SO_4



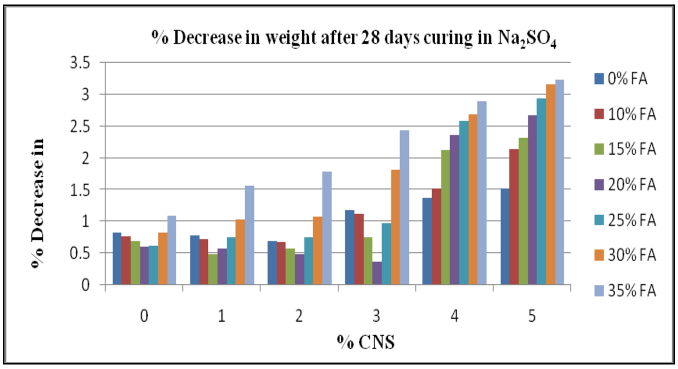
Graph 3 - % Decrease in Compressive strength after 56 days curing in Na_2SO_4



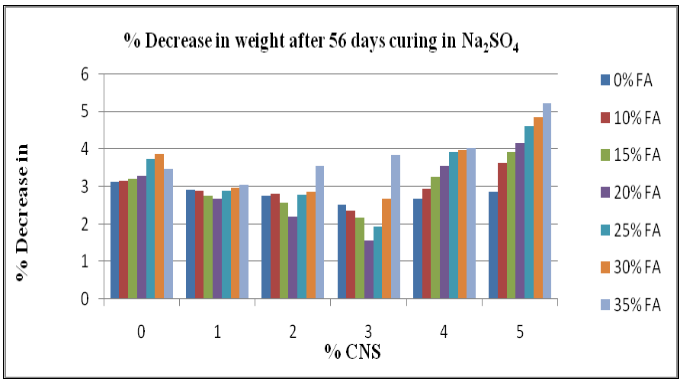
Graph 4 - % Decrease in weight after 7 days curing in Na_2SO_4



Graph 5 - % Decrease in weight after 28 days curing in Na_2SO_4



Graph 6 - % Decrease in weight after 56 days curing in Na_2SO_4

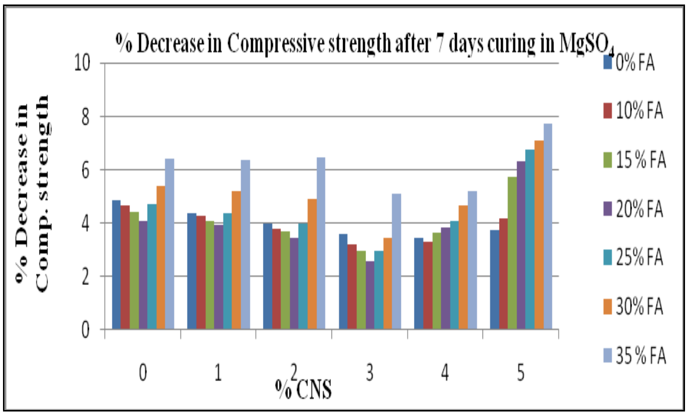


From the experimental result it is found that the percentage decrease in Compressive Strength was observed as 1.15%, 4.19% and 6.33% in Na_2SO_4 w.r.t corresponding mix at 3% addition of CNS and 20% FA replacement, whereas maximum loss beyond this proportion was observed in both solutions.

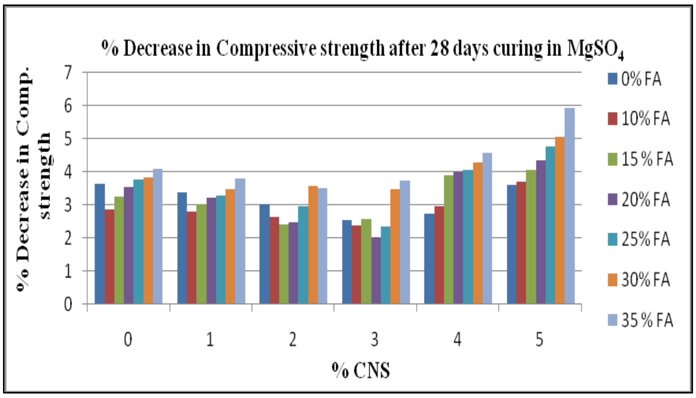
The percentage decrease in weights was observed as 0.28%, 0.47% and 1.56% in Na_2SO_4 w.r.t corresponding mix at 3% addition of CNS and 20% FA replacement, whereas maximum loss beyond this proportion was observed in both solutions.

2. Magnesium sulphate ($MgSO_4$)

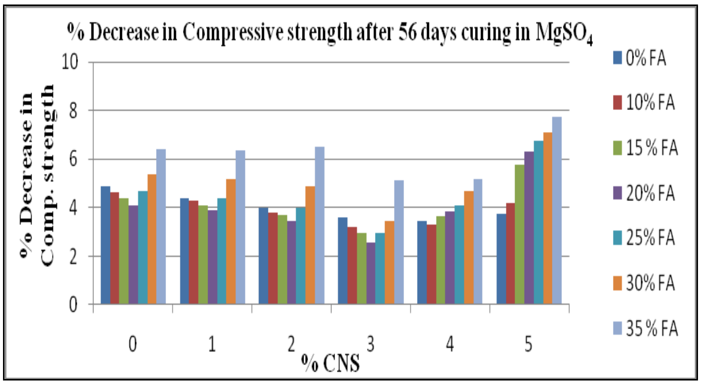
Graph 7 - % Decrease in Compressive strength after 7 days curing in $MgSO_4$



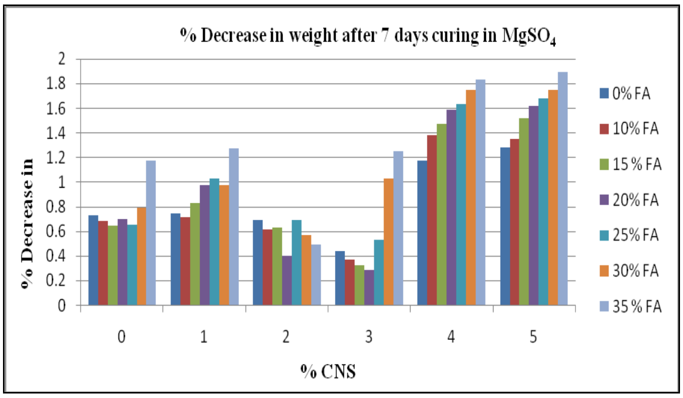
Graph 8 - % Decrease in Compressive strength after 28 days curing in $MgSO_4$



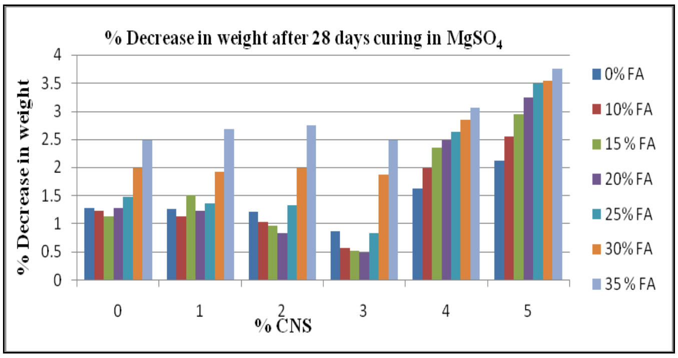
Graph 9 - % Decrease in Compressive strength after 56 days curing in $MgSO_4$



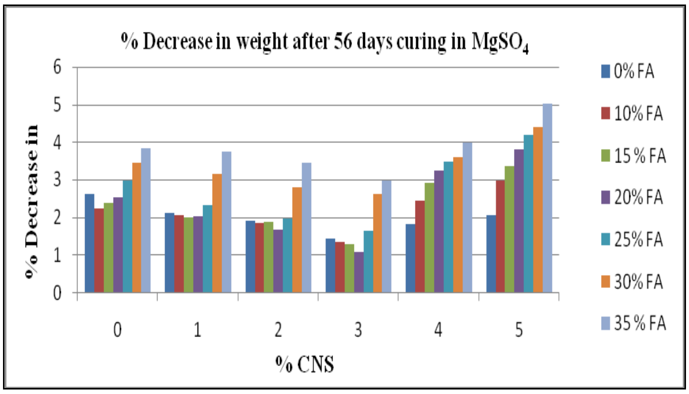
Graph 10 - % Decrease in weight after 7 days curing in $MgSO_4$



Graph 11 - % Decrease in weight after 28 days curing in $MgSO_4$



Graph 12 - % Decrease in weight after 56 days curing in $MgSO_4$



From the experimental result it is found that the percentage decrease in Compressive Strength was observed as 2.52%, 2.03% and 2.56% in $MgSO_4$ w.r.t corresponding mix at 3% addition of CNS and 20% FA replacement, whereas maximum loss beyond this proportion was observed in both solutions.

The percentage decrease in weights was observed as 0.30%, 0.48% and 1.08% in w.r.t corresponding mix at 3% addition of CNS and 20% FA replacement, whereas maximum loss beyond this proportion was observed in both solutions.

COLCLUSION

The reduction in the compressive strength and weight of concrete specimen containing 0%, 1%, 2%, 3%, 4% and 5% colloidal Nano-SiO2 are investigated.

- The minimum loss in compressive strength of concrete is observed at cement replacement by 10% (P-63 FA)+ 10%(P-100 FA) + 3% CNS in 5% solution of Na_2SO_4 is 1.15%, 4.19% and 6.33% w.r.t to corresponding concrete and weight loss was observed as 0.28%, 0.47% and 1.56% w.r.t reference mix for 7, 28 and 56 days curing in the solution.
- The minimum loss in compressive strength of concrete is observed at cement replacement by 10% (P-63 FA)+ 10% (P-100 FA) + 3% CNS in 5% solution of $MgSO_4$ is 2.52%, 2.03% and 2.56% w.r.t to corresponding concrete and weight loss was observed as 0.30%, 0.48% and 1.08% w.r.t reference mix for 7, 28 and 56 days curing in the solution.

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