



Experimental Study of Strength and Electrochemical corrosion of concrete incorporating Colloidal Nano Silica

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ABSTRACT

Enhancement of durability and reduction of maintenance cost of concrete with the implementation of various approaches has always been a matter of concern to researchers. Colloidal Nano silica (CNS) has received a great deal of interest from researchers with their Significant performance in improving the durability of concrete. This works aims to examine the utility of partial substitution of CNS with 0%,1%,2%,3%,4%,5% by weight of cement in a concrete. The improvement of the durability characteristics linked to resistance for electrochemical corrosion using Electrical Resistivity and Half-cell Potential analysis furthermore the effect of this silica mixture on the compressive strength of concrete under normal and aggressive environment have also been investigated. Based on the maximum compressive strength of concrete the optimal cement substituent ratio have been obtained 2%, 3% CNS. The optimal CNS of cement by optimal percentage of CNS exhibited decreased rate for electrochemical corrosion

Keywords –CNS, Corrosion, Electrical Resistivity, Half-Cell Potential, Strength,

I. INTRODUCTION

Studies in the field of advanced construction materials, such as the use of nanoparticles as cement admixture, have reported significant improvements in the properties of traditional building products. In previous research, various nanoparticles were mixed with cement, and their performance was evaluated. Nanoparticles, such as Nano clay, Al₂O₃, Fe₂O₃, TiO₂, and CaCO₃ were evaluated; however, SiO₂ was the most commonly studied. Nano-silica denotes that small particles comprise an amorphous SiO₂ core with a hydroxylated surface, which makes the substance insoluble in water. The size of the particles can vary between 1–100 nm; therefore, they are small enough to remain suspended in a fluid medium without settling. Parameters, such as specific surface area, particle size, and size distribution can be controlled using the synthesis technique. Nano-silica particles have a high surface area to volume ratio that provides high chemical reactivity. They behave as nucleation centers, contributing to the development of the hydration of ordinary Portland cement (OPC). The addition of Nano-



silica into mortar and concrete mixtures accelerates the hydration process, improving the strength and microstructure characteristics of the OPC. The increase in the initial hydration rate caused by the pozzolanic reaction increases the amount calcium-silicate-hydrate (C-S-H) gel. Cement-based materials containing Nano-silica particles demonstrate an improved performance due to the combined of the filler, nucleation, and pozzolanic reaction.

A) CORROSION

Any process of deterioration and consequent loss of a solid metallic material, through an unwanted chemical or electrochemical attack by its environment, starting at its surface, is called corrosion. Corrosion means the disintegration of a material into its constituent atoms due to chemical reactions with its surroundings. In the most common use of the word, this means a loss of electrons of metals reacting with water and oxygen. Weakening of iron due to oxidation of the iron atoms is a well-known example of electrochemical corrosion. This is commonly known as rusting. This type of damage typically produces oxides) and/or salt(s) of the Experimental study of strength and electrochemical corrosion of concrete incorporating colloidal Nano silica original metal. Corrosion can also refer to other materials than metals, such as ceramics or polymers. Although in this context, the term degradation is more common. Most structural alloys corrode merely from exposure to moisture in the air, but the process can be strongly affected by exposure to certain substances (see below). Corrosion can be concentrated locally to form a pit or crack, or it can extend across a wide area to produce general deterioration. While some efforts to reduce corrosion merely redirect the damage into less visible, less predictable forms, controlled corrosion treatments such as passivation and chromate conversion will increase a material's corrosion resistance.

CAUSES OF CORROSION IN RC STRUCTURES

- Carbonation
- Chloride attack

CARBONATION

Reduction of pH in cover concrete which causes loss of passive oxide layer Low pH caused by reaction of Calcium Hydroxide (Ca(OH)₂) in concrete with atmospheric Carbon Dioxide Carbonation is one of the two main causes of corrosion of steel in concrete, the other is chloride attack. The result of the interaction of carbon dioxide gas in the atmosphere with the alkaline hydroxides in the concrete, the carbonation process effectively drops the pH of the concrete to a level where the steel will corrode. The carbon dioxide dissolves in water to form carbonic acid, which can migrate to the reinforcing steel if the concrete cover is low or if the concrete is of poor quality (open pore structure, low cement content, high water cement ratio, or poor curing of the concrete). Carbonation is more common in old structures, particularly buildings.



CHLORIDE ATTACK

Caused by chlorides breaking up passive oxide layer The moisture in concrete pores will act as electrolyte, and the area adjacent to concentration of chloride ions on the reinforcement steel will become cathode initiates corrosion. The mechanism of chloride-induced corrosion of steel embedded in concrete, the ingress of chlorides into the concrete, and the threshold chloride content for corrosion to occur are discussed. The binding of chloride ions by cement compounds and the associated effect of using different cements, both Portland and blended, as well as other factors influencing corrosion, are considered. Tests for the penetrability of concrete to chlorides are described. Finally, the prevention of corrosion is discussed. Experimental study of strength and electrochemical corrosion of concrete incorporating colloidal Nano silica

B) OBJECTIVE

1. Structural improvements such as per strength and durability of concrete cube with a series of experiment.
2. The main of this study is to find electrochemical corrosion of concrete incorporating colloidal Nano silica.
3. In structure effect of colloidal Nano silica on durability and corrosion rate of steel reinforcement embedded in high performance concrete.

C) COLLOIDAL NANO SILICA

In the most general terms colloidal silica is a dispersion of amorphous silicon dioxide (silica) particles in water. These amorphous silica particles are produced by polymerizing silica nuclei from silicate solutions under alkaline conditions to form Nano meter sized silica sols with high surface area. A charge is then induced on the silica nanoparticle surface that allows the silica particles to repel one another and form a stable dispersion, or colloid.

Colloidal Silica Characteristics

Colloidal silicas are produced in a variety of grades that range in a number of factors. Particle size typically varies from 5nm to 40nm, and particle size distribution can vary from narrow to wide depending on the manufacturing process. Standard colloidal silica is stable at a pH from 8 - 10.5 and carries an anionic surface charge that is stabilized with sodium or ammonium. In certain grades, some of the silicon atoms in the silica particle are replaced with aluminate ions to allow for enhanced stability in a wider pH range, usually 3.5 - 10.5

How Nanotechnology Can Change

Construction Materials The majority of recent nanotechnology research in construction has focused on the structure of cement-based materials and their fracture mechanisms. New advanced equipment makes it possible to observe a structure at its atomic level. Moreover the strength, hardness and other basic properties of microscopic and Nanoscopic phases of materials can be measured.²⁴ Atomic force microscopy (AFM) has been



applied to the investigation of the amorphous C-S-H gel structure. This has led to the discovery that this product has a highly ordered structure at the Nano silica.

Concrete with Nanoparticles

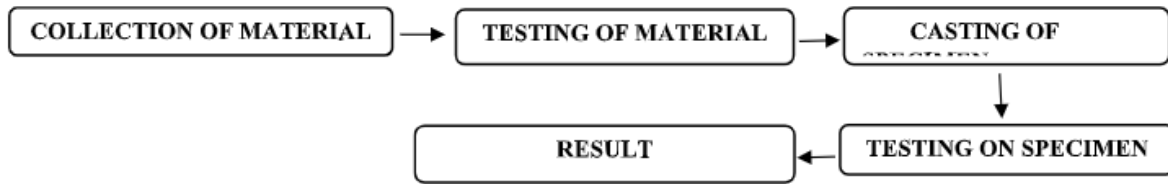
Mechanical properties of cement mortars with Nano-iron-oxide and Nano-silica were studied by Li et al.³⁸ Experimental results demonstrated an increase in compressive and flexural strengths of mortars that contained nanoparticles. It was found that increased Nano-silica content improved the strength of the mortars. A laboratory study of high-volume fly-ash high-strength concrete that incorporated Nano-silica was performed by Li.⁴² Investigation of the hydration process confirmed that the pozzolanic activity of fly-ash can be significantly improved by the application of a Nano-silica. It was concluded that the use of Nano-silica led to increased early age and ultimate strength of high-volume fly-ash concrete.

Table 1.1: specification of CNS use in concrete

Appearance	White Coloured thin liquid
Solid silica content	30%
Specific gravity	1.2
pH	9.3
Titration Alkali	0.42
Silica soda	84% w/w
Particle Diameter	20-30
Specific Area	410-430

II. MATERIALS AND METHODOLOGY

To carry out the present work we have used the following work flow:



A)Material selected and number of specimen casted:

Following materials are selected for forming the required number of beam, cylinder and cubes

1. **Cement:** - AMBUJA Cement Opc 53 Grade.
2. **Sand:** - Sand Of Pravara River.
3. **Aggregate:-**Obtain Aggregate Locally Available Size 20mm.
4. **Colloidal Nano silica 30% silica:-**IntexobiochemPvt Ltd , Palghar.
5. **Steel bar:** -10mm dia. mild steel bar .

As the above materials are selected for casting the of cubes and beam. Following number of cubes and beam are casted and keep for curing of 28 days and 56 days in salt water. For the present work we have to provide 25mm , 40mm, 50mm, cover of steel bar in concrete beam .specimen of normal concrete with the addition of CNS in the normal concrete. The mixing of CNS is taken in the percentage of by weight of cement. In the 0%,1%,2%,3%,4%,and 5%by the weight of cement in concrete and the number of specimen casted are given in following table:

Table 2.1: Number of Specimen Casted

Sr No.	CNS Content	cube	beam
1	0%	6	6
2	1%	6	6
3	2%	6	6
4	3%	6	6
5	4%	6	6
6	5%	6	6

B) Testing on Concrete:

- a) **Compressive strength** -The testing was carried out on 150x150x150 mm size cube as per IS516-1959.This testing have help us to find out the Compressive strength of cubes when addition proportional quantity of CNS in the concrete
- b) **Half-cell Potential measurement** - The testing was carried out on 700x150x150 mm size Beam as per IS516-1959. This test help to find out the probability of corrosion.
- c) **visual inspection** -The testing was carried out on 700x150x150 mm size Beam as per IS516-1959. In this test to saw corrosion in mild steel bar .



d) concrete resistivity measurement - The testing was carried out on 700x150x150 mm size Beam as per IS516-1959. This test help to find out the electrical resistivity.

e)LCR -The testing was carried out on 700x150x150 mm size Beam as per IS516-1959.in this test find the potential,current,and resistance in corroded mild steel bar.

Experimental Study:

In this paper the methodology for casting the specimen and after curing period the testing of specimen is defined in the following steps, so we can measure the strength and corrosion of the specimen,

Step 1: Place cube and beam at the universal testing Machine to be tested.

Step 2: Apply ultimate load on concrete cube incorporating CNS proportion.

Step 3: Observe and record the compressive strength of the concrete cube.

Step 4: Then to exposed the steel bar in concrete beam for testing of half-cell potential test.

Step 5: In this beam to carried out resistivity after step 4.

Step 6: Apply ultimate load on beam .

Step 7: visual inspection on concrete filled CNS beam and separate the steel bar .

Step 8: After will got current ,potential and resistance on mild steel bar .

With the help of above steps we have calculated the different strength and corrosion of the concrete incorporating CNS and the results achieved through this work are explained in the next chapter.

III. RESULT AND DISCUSSION

The impact of Nano particle on the compressive strength of concrete with the percentage of CNS has shown in below table

Compressive strength for samples CNS0,CNS1,CNS2,CNS3,CNS4,CNS5 Percentage of by weight of cement .in that CNS3% specimen has got optimum compressive strength .the optimal CNS of cement by optimal percentage of CNS exhibited decreased rate for electrochemicalcorrosion:

Compressive strength test(For Cubes):

Table 3.1: Results obtained for compression strength test

Specimens	Compressive strength (Mpa)28 Days	Compressive strength (Mpa)56 Days
CNS0	27.1	27.9
CNS1	30	31.2
CNS2	31.3	32.7
CNS3	32.1	33.5



CNS4	31.6	32.8
CNS5	30.7	32

Half -cell potential test (For Beam):

Table 3.2: Results obtained for half –cell potential test

Specimens	CNS0	CNS1	CNS2	CNS3	CNS4	CNS5
28 Days	-280	-130	-125	-80	-107	-113
56 Days	-305	-148	-135	-98	-110	-120

Electrical resistivitytest(for beam):

Table 3.3: Results obtained for Electrical resistivity test(for beam)

Specimens	CNS0	CNS1	CNS2	CNS3	CNS4	CNS5
28 Days	6	10	10.3	11.8	10.7	10.2
56 Days	7.5	10.5	11.5	13	12.5	12

IV. CONCLUSION

1. The effects of CNS mixing Cement weight replacement method applied in this study are summarized as being caused by two main reasons.

a. One is that the substitution of the CNS with the weight of the mixing cement promotes the homogeneous dispersion effect of the Nano-silica particles, promoting the pozzolanic reaction, the nucleation effect, and the filler effect.

b. The other is the reduction effect of w/b caused by replacing the dense CNS than the mixing water.

2. Colloidal Nano silica improve compressive strength.
3. It has highest resistance for electrochemical corrosion.
4. Its prevents concrete against corrosion.

Fig.3.1.Comparative study between Compressive strength of cube Specimen for 28 days and 56 days curing

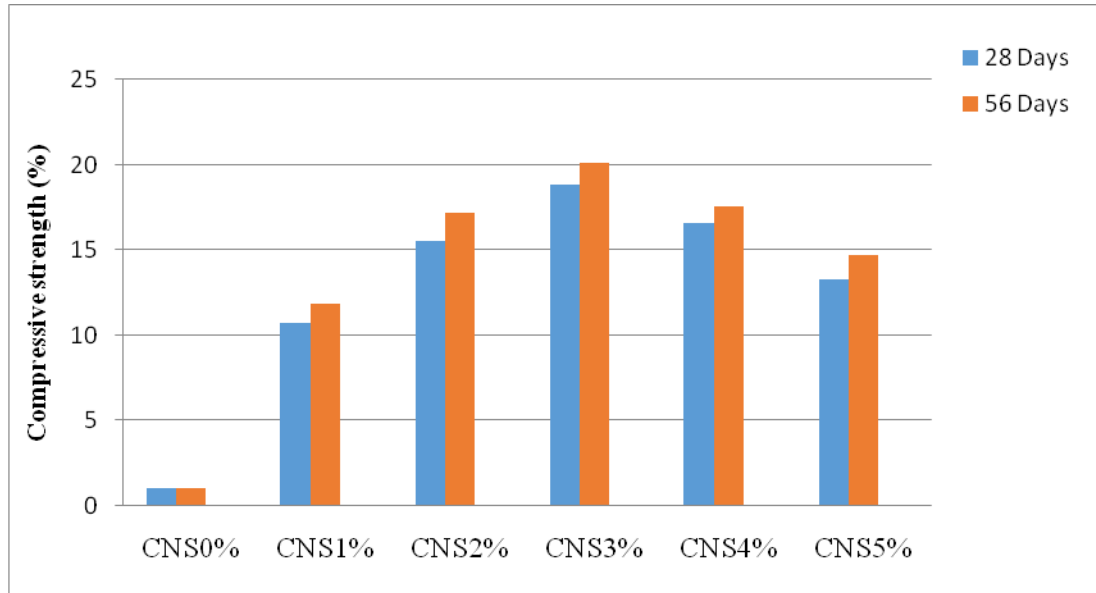


Fig.3.2.Half –cell potential test

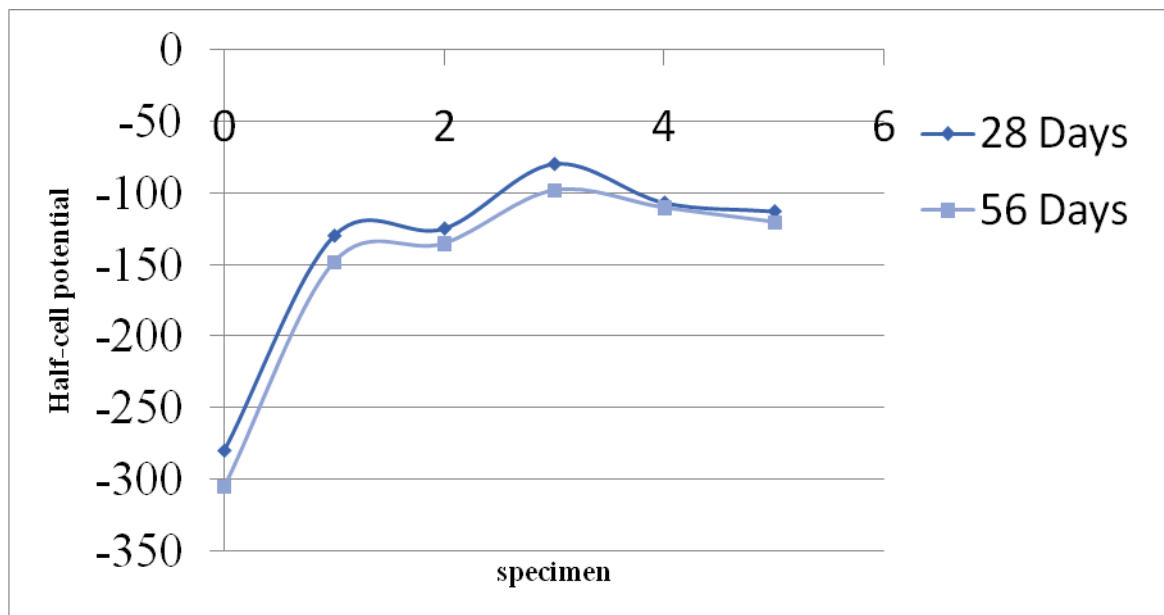
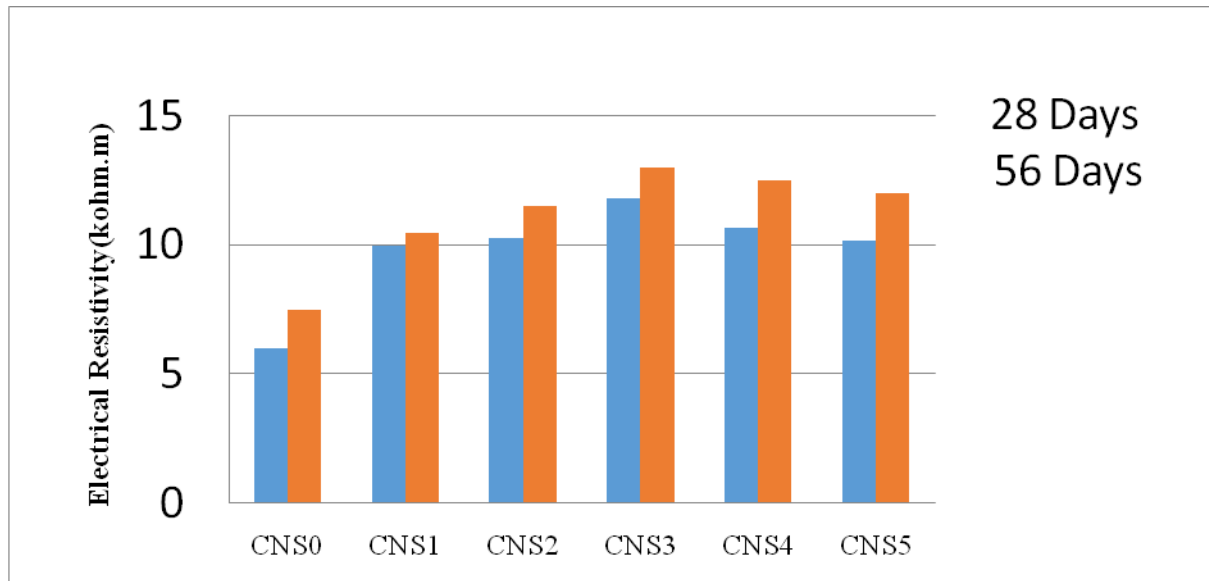


Fig.3.3.Electrical Resistivity



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