Experimental Study on the Strength and Durability of High Performance Nano Silica Concrete

G. Ravi Teja, A. Narender Reddy, T. Meena

Abstract*: *The utilization of combination of different mineral admixtures like fly ash (FA), alcoffine (ALC) and nano silica (NS) which are by-products from industries possess pozzalanic nature and is an environmental friendly material in construction industry. The environmental impact can be minimized by making use of many industrial by products in a sustainable manner. The evaluation of strength and durability study was performed using on concrete with FA, ALC and NS as a partial replacement of Ordinary Portland Cement (OPC). The studied parameters were compressive strength, split tensile strength and flexural strength, as well as the durability study that involves water absorption and sorptivity. The combination of FA 25%, ALC 10% and NS 0, 0.5, 1, 2 and 3% was used in partial substitution of cement at by weight. The results show that among different NS content High performance concrete containing 25%-10%-1% FA-AL-NS exhibited the best results for the strength and durability property tests at 7, 28 days for strength and 28, 90 days for durability properties.

Index Terms*: *Fly ash, Alccofine, Nano Silica, Tetranary Blended Concrete

I. INTRODUCTION

Cement is the most widely used binding material in the concrete. Concrete is heterogeneous material made up of cement, fine aggregate, coarse aggregate additional admixtures [1]. In replacement and concrete is the main binding material which has characteristics such as strength and durability [2]. The advancement and utilization of mineral admixtures for concrete can be done in the construction due to cost effective, energy saving and utilization of naturally available materials [3]. One of the main issues with the production with Portland cement is the high amount of greenhouse gas emission that will be produced during the process of cement clinker manufacturing. Mineral admixtures used are fly ash (FA), GGBS, rice husk ash (RHA), Alccofine (ALC) and nano silica (NS) materials etc [4]. Most of these mineral admixtures are used to replace the cement in concrete which can increase the strength and durability properties [5]. In the present study FA, ALC and NS was used as replacement for cement.

Fly ash is a byproduct from the electrical and steam generation plant. FA comprises of the non-burnable mineral of coal and it comprises of fine particles that raise with the gases which posses high pozzolanic nature. Now a day several billion tons of FA is produced all over India. In the present study, the cement was replaced by FA at constant of 25% [6].

Alccofine is a slag based product produced through controlled granulation. These, comprises of high glass content with ultra fine molecule size. The water is decreased however functionality is kept up to 70% substitution and shows great performance in concrete [7]. ALC can be used as good water to enhance the quality parameters and different properties of concrete. In the present study the cement was replaced by ALC at constant of 10% [8].

To enhance the mechanical & durability properties of concrete, further nano materials are also being introduced. But there is very limited work which deals with effect of Nano silica on concrete. Nano silica is nano measured very responsive amorphous silica that helps to improve microstructure of concrete. The main intension of this work is to look at the effect of Nano silica with combination of FA and ALC to the concrete and find the effect of combination of FA-ALC-NS on mechanical and durable properties of High performance concrete (HPC), i.e. compressive strength, split tensile strength, flexural strength, water absorption test and sorptivity test.

II. MATERIALS

A. Cement

Zuari 53 grade cement with specific gravity of 3.12 obtained from nearest store.

B. Course Aggregate

Crushed stones taken from the local quarry with nominal size passing through 20mm and retained on 4.75mm sieve were used as Course aggregate. The specific gravity of aggregate was 2.78.

C. Fine Aggregate

The locally available river sand which is passing through 4.75 mm having specific gravity of 2.68 was used as fine aggregate and it belongs to Zone II.

D. Fly ash

Fly ash used for the present work is class F type obtained from Vijayawada thermal power plant having a specific gravity of 2.3.

Revised Manuscript Received on March 10, 2019.

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E. Alccofine

Alccofine used in this study is a specially processed by-product based on slag with high glass content with high reactivity obtained through the process of controlled granulation having a specific gravity was 2.9 obtained from ACL pvt limited, Goa.

F. Nano silica

Nano silica used in our investigation was amorphous in nature having particle size of 10-40mm and the specific gravity is 1.21 obtained from Beechems pvt ltd, Kanpur.

G. Superplastizer

water reduction chemical admixtures Glenium SKY 8233 was used as superplastizer.

H. Water

Tap water available in our university campus was used in the entire investigation having the ph value of 7.

III. MIX DESIGN

M60 grade of concrete mix design can be done by using ACI 211. 4R-08. The mix ratio for the work done has given in Table 1

Table 1: Mix Design

Materials	Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (Kg/m^3)
Quantity	540.12	625.51	1180.08	162.03

Mix Proportion= 1: 1.16: 2.19 with water cement ration (w/c) of 0.30.

IV. RESULTS

A. Compressive Strength

Compressive strength test was carried out at the age of 7 and 28 days. Test was conducted on 100x100x100 mm cubes by using the compression testing machine (CTM) of capacity 2000KN. The load divided by the cross sectional area of the specimen is equal to the cube compressive strength. From the result the strength was increased till 1% replacement of cement by nano silica and then it the strength tends to reduce. The compressive strength increases from 46.2MPa to 57.83MPa for 7 days curing and 64.06MPa to 77.63MPa for 28 days later on it tends to decrease there are shown in table2 and figure2 below. For HPC mix with combination of 25% FA-10% ALC-1% NS compressive strength increased by 25% in 7 days and 21% in 28days curing. The reason behind the increase in strength is due to the quick formation of C–S–H gel in the existence of ultra-high dynamic nano sized silica with high filler effect [9]. Beyond 1% NS content the strength tends to decrease because, the excesses amount of nano silica cause agglomeration in the particle inside the concrete. This may also be due to high utilization of calcium hydroxide during the extra pozzalanic reactions by the nano silica[10].

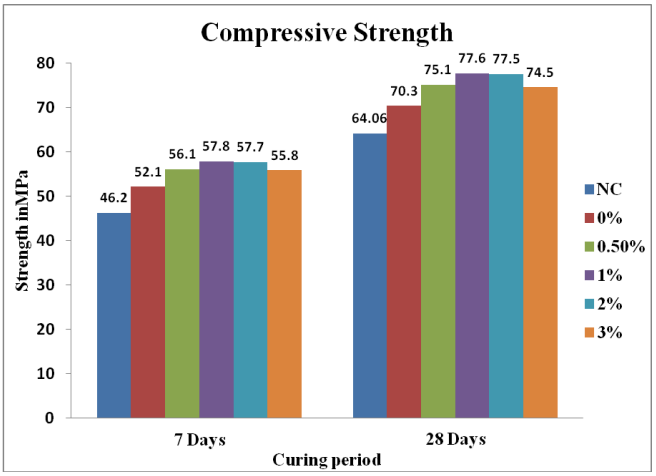

Fig. 1. Compressive strength of the blended concrete

B. Split Tensile Strength

Split tensile strength test was carried out at the age of 7 and 28 days. 200x100 mm Cylinders were tested by using the compression testing machine (CTM) of capacity 2000kN. The split tensile strength increases from 3.75MPa to 4.33MPa for 7 days and 4.52MPa to 4.92MPa for 28days curing. The increase in strength may be due to the nano silica reaction with Ca $(OH)_2$ forming C-S-H gel [11]. The strength increased by 15% in 7 days and 9% in 28days for HPC with combination of 25% FA-10% ALC-1% NS, Beyond 1% NS strength tends to decrease is may be due low water cement proportion of the concrete. The pore filling nature of Nano silica will not allow the water to enter into the concrete because of its high surface area leads to lack of hydration and decrease of the tensile strength [12].

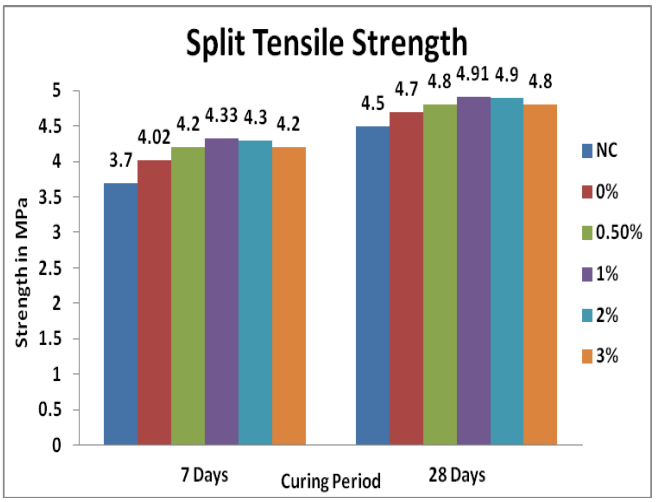

Fig. 2. Split tensile strength of the blended concrete

C. Flexural Strength

Flexural strength test was conducted on beams with size 100x100x500mm by using flexural testing machine of capacity 100kN. The beam is subjected to three point loading. The flexural strength increases till 1% of NS content from 4.9MPa to 5.7MPa for 7 days and 5.8MPa to 6.5MPa for 28 days. The strength increases by 16% in 7 days and 12% in 28 days curing.

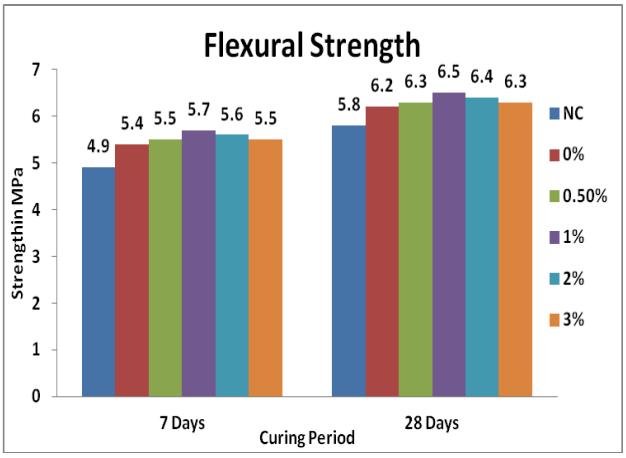

Fig. 3. Flexural strength of the blended concrete

D. Water Absorption

Water absorption test was done on 100x100x100 mm size cube for the ages 28 and 90 days. The average amount of water penetrated into the voids is calculated. The specimen will be kept in oven for 24 hours and then kept in curing tank for 48 hours and the water absorption percentage is calculated. The water absorption decreases from 3.28% to 2.35% for 28 days and 2.67% to 1.81% for 90 days for nano silica upto 1% Beyond 1% the absorption percentage tends to increase slightly. The lower absorption percentage till 1% NS is may be due to the pore filling nature of nano silica helps in improving the pore structure [7]. Beyond 1% as the nano silica content increases the slurry density increase leads to increase in slurry permeability leads to leaching out of materials led to increase in pores in concrete[5].

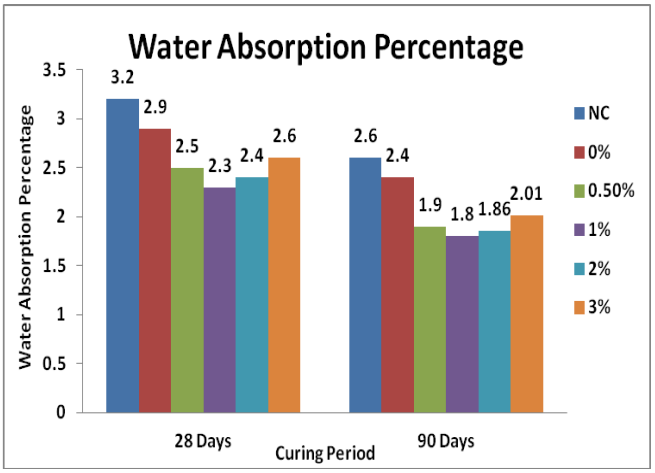

Fig. 4. Water absorption percentage of the blended concrete

E. Sorptivity

Sorptivity test was conducted on 100x50mm size specimen for 28 and 90 days curing period. Sorptivity test estimates the rate of entrance of water into the pores of concrete by capillary suction. The amount of water infiltrating over a period of time from 30 min was decided from the specimen weight. In the sorptivity value decreases from 0.13 $mm^3/mm^2/min$ to 0.09 $mm^3/mm^2/min$ for 28 days and 0.118 $mm^3/mm^2/min$ for 0.074 $mm^3/mm^2/min$ for 90 days at 1 % NS content Beyond 1% NS content the sorptivity value tends to increase.

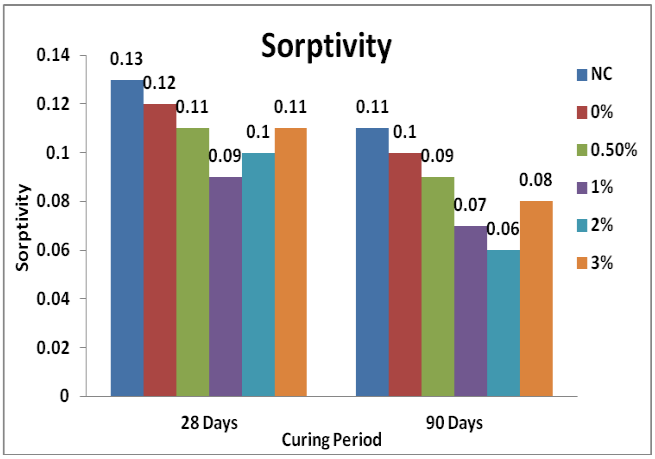

Fig. 5. Sorptivity of the blended concrete

V. CONCLUSION

Based on work done so far and experimental results that the Nano silica included with concrete has exhibited properties given below:

- The results showed that there is an considerable improvement in the mechanical properties and durability properties by the addition of nano silica to tetranary blended concrete.
- The mechanical properties and durability properties of M60 grade concrete increased with an increase of Nano silica content upto 1% and it is subject to the availability of free calcium hydroxide.
- The increment in Compressive Strength, Split Tensile Strength and Flexural Strength of Nano concrete was linear and achieved higher strength at combination of 64% cement, 25% Fly ash, 10% Alccofine and 1% Nano Silica.
- Beyond 1% NS the strength and durability tends to reduce, beyond 1% Nano Silica the strength and durability tends to decrease because of quantity of Nano Silica higher which may cause liberation out of lime quantity during the hydration process, excess amount of NS leaches out result in decreasing in pore bond strength.

ACKNOWLEDGMENT

The Authors would like to Thank VIT-Vellore for providing the required facilitates for performing the experimental work.

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