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A COMPARATIVE STUDY ON CHARACTERISATION AND EFFECT OF MICRO SILICA AND NANO SILICA

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ABSTRACT

An attempt has been made in doing a comparative study on characterisation and effect of nano silica and micro silica on the mechanical and durability properties of High Performance Concrete (HPC). The obtained test results on addition of nano silica and micro silica displayed that the compressive strength, tensile strength of HPC was enhanced upon the addition of nano silica and was comparatively higher than micro silica. In the case of opposition against capillary intake, water absorption, voids and volume of permeable pores, concrete with nano silica performed well compared to micro silica. Microstructure examination was achieved using Scanning Electron Microscope (SEM). SEM studies indicated that the microstructure of concrete was improved by uniform distribution of nano silica particles. The proportion of voids existing in case of nano silica is fairly lesser than of micro silica.

Keywords: Nano silica, Micro silica, HPC, SEM.

1. INTRODUCTION

HPC is not a superior kind of concrete. It is composed of the same variety of materials as that of the normal cement concrete. The utilisation of few mineral and chemical admixtures like micro silica and Super plasticizer improves the strength, durability and workability standard to a vast range. High performance concrete has innumerable benefits like enhanced durability characteristics and much lesser cracking than normal strength concrete. Whichever concrete satisfies definite specification proposed to excel constraints of conventional concretes is called as High Performance Concrete. Nano-silica is homogenous in a way that it elevates the density, strikingly the integration between the cement pastes and aggregate. Priyadarshana *et al* (2015) considered the high performance concrete including fly ash, nano silica and micro silica. Li *et al* (2016) mannered the reaction on concrete by limited substitution of cement by micro silica, Therefore, the incorporation of nano-silica and micro silica in concrete ended in higher compressive strength, increment in tensile strength than that of normal concrete to a significant level. Also, the concrete becomes denser with enhanced imperishability properties.

2. MATERIALS AND METHODOLOGY

Binding materials cast-off were Portland Pozzolona cement (PPC), micro silica (MS) and nano silica (NS). The chemical and physical properties are seen in Table-1. The images of Scanning Electron Microscope (SEM) for Micro silica and Nano silica are shown in Figures 1 and 2.

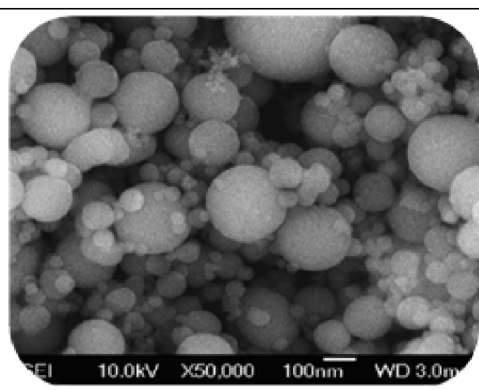
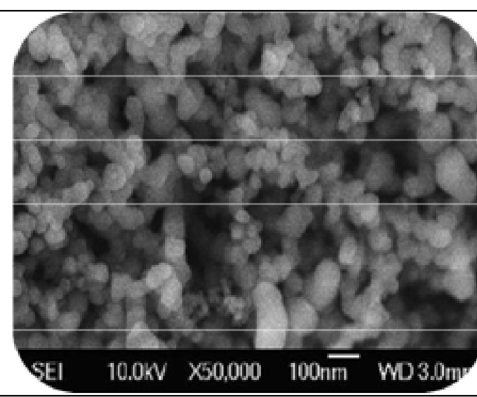


Figure-1. SEM micro silica.



Figurte-2. SEM nano silica.

Table-1. Chemical configuration and physical properties of PPC, MS and NS materials

Properties	Chemical compositions (%)		
	PPC	MS	NS
SiO_2	21.1	96	99.98
Al_2O_3	5.5	2	0.005
Fe_2O_3	3.53	0.6	0.001
CaO	63.51	1	-
MgO	1.02	5	-
SO_3	2.12	2	-
Physical properties			
Specific gravity	3.1	2.34	-
Avg. particle size	13µm	0.1µm	15nm
SSA(m^2/g)	0.38	20	

3. EXPERIMENTAL INVESTIGATIONS

In the present work a high performance concrete grade to acquire a characteristic compressive strength of 70 MPa as per ACI 211.1 - 91 was adopted. The design mix ratio arrived was 1:0.94:1.86 (Cement: Fine aggregate: Coarse aggregate) with water/cement ratio of 0.29 and the workability was established with slump cone test as specified by ASTM C143.

Specimens

Concrete cube specimens (100 mm x 100 mm x 100 mm) were moulded to study the outcome of micro silica on compressive strength, water absorption, density of concrete at different curing ages. Cylindrical specimens (100 mm diameter and 50 mm height) were moulded to report the durability characteristics such as sorptivity and cylindrical specimens (100 mm diameter and 200 mm height) were cast to study the splitting tensile strength. For testing compressive strength, water absorption (100mm X 100mm X 100mm) of control specimen and specimens with 1%, 2%, 3%, 4% and 5%. A total number of 36 specimens were cast (age = 28 days). Similarly 18 cylindrical specimens of size (50 mm diameter X 100 mm height) and (100 mm diameter X 200 mm height) each for sorptivity tests and split tensile strength were cast.

Compressive strength

As per IS: 516-1959(reaffirmed 2004) the compressive strength was conveyed through, on concrete cubes (150 x 150 x 150 mm) by a Universal Testing Machine (UTM) to acquire the 28- days compressive strength of concrete. In each mix 3 cube specimens were cast. All the specimens were cast in wooden moulds and well compacted. Then they were cured and tested at different ages of concrete for 28 days to understand the effect of age of concrete. Digital compression testing machine of 3000kN capacity with 200kN/min as rate of loading was used to conduct the test assessment of compressive strength.

Splitting tensile strength

Cylinders (100 mm diameter X 200 mm height), were moulded and after casting were immersed in water with curing age of 28 days. After curing, specimens were dried and used for the test. According to the code ASTM C496, this test method consists of exerting a diametrical force along the length of a cylinder at a rate which is within a stipulated range till failure. In order to ensure the specimens are on the same axial place, diametrical lines are drawn on the two ends. The compression testing machine is set for the required range and the plywood strip on the lower plate with the specimen. The specimens are aligned so that the lines marked on the ends are vertical and centred over the bottom plate. Apply the load continuously and the breaking load is noted.

Sorptivity

The cylinder i.e. specimens (100mm diameter x 50 mm height) was prepared. Then the specimens were oven dried at temperature of 100^{o}C and cooled. Once the specimen is cooled, it is kept in a water tub with water level up to 5mm from the base of specimen and the flow from the surrounding surface is head off by securing it properly with repellent coating. The volume of water drawn in was studied at predetermined intermission for the six hours. Sorptivity is a easy approach which is used to measure the amount of capillary suction of concrete when it is brought under the contact of water. The Sorptivity test was performed in guidance with ASTM C 1585 [11]. One surface of the specimen is uncovered while the consumption amount of water is computed by the rise in mass of the specimen. The rate of immersion is the gradient of the befitting line to the plot of absorption square root of time.

$S = I \sqrt{t}$

Where
S is sorptivity,
I is the cumulative infiltration at time, t.

Where
S =Sorptivity in mm, t = Elapsed time in minute. I = $\Delta w/Ad$
ΔW =Change in weight = W2-W1
W1 = Oven dry weight of the cylinder in grams
W2 = Weight of cylinder for every interval
A = Surface area of the specimen through which water penetrated.

Water absorption

Specimens (100 mm X 100 mm), were moulded and submerged in water for 28 days for curing. The samples were oven dried for 24 hours at a temperature of 110 °C up till the mass became consistent and is balanced. The mass procured was recognised as the dry weight (W1) of the cylinder. Then, the samples were submerged in hot water at 85 °C for 5 hours. This weight was noted as the wet weight (W2) of the cylinder.

% Water Absorption = [(W2-W1)/W1] x100
Where,
W1 = Oven dry weight of cylinder in grams
W2 = after 3.5 hours wet weight of cylinder in grams.

4. RESULTS AND DISCUSSIONS

Compressive strength

Table-2 shows the 28 days compressive strength of micro silica and nano silica. It is clearly seen from the table that the strength increases with increasing amount of NS and MS. The benefit in the compressive strength can be associated to the origination of calcium silicate hydrate (C-S-H) gel which is effective than the normal C-H gel. The strength of concrete is increased by micro silica and nano silica which in turn strengthens the bond between the cement and the aggregates

Table-2. Compressive strength of MS and NS.

Specimens	Compressive strength (N/mm^2)	
	MS	NS
Control	71.3	71
1%	74.9	75.8
2%	75.6	77
3%	77.7	79.2
4%	78.3	83.4
5%	80.1	86.6

Figure-3 shows the effect of mixture of MS and NS on compressive strength of concrete. Substitution of cement with micro silica improved the compressive strength up to 12.34% while substitution of cement with nano silica improved compressive strength up to 21.97%. From the comparison it can be concluded that the latter shows better performance.

Split tensile strength

Table-3 exhibits the split tensile strength of concrete with nano silica and, micro silica. The graphs conclude that the substitution of cement with nano and micro silica shows increment in strength. Although, there is no definite reduction in strength with increase in the micro-silica and nano silica content.

Table-3. Splitting tensile strength of MS and NS.

Specimens	Split tensile strength (N/mm^2)	
	MS	NS
Control	9.92	10.05
1%	12.41	15.95
2%	19.89	24.01
3%	26.36	31.5
4%	32.66	38.16
5%	38.01	44.65

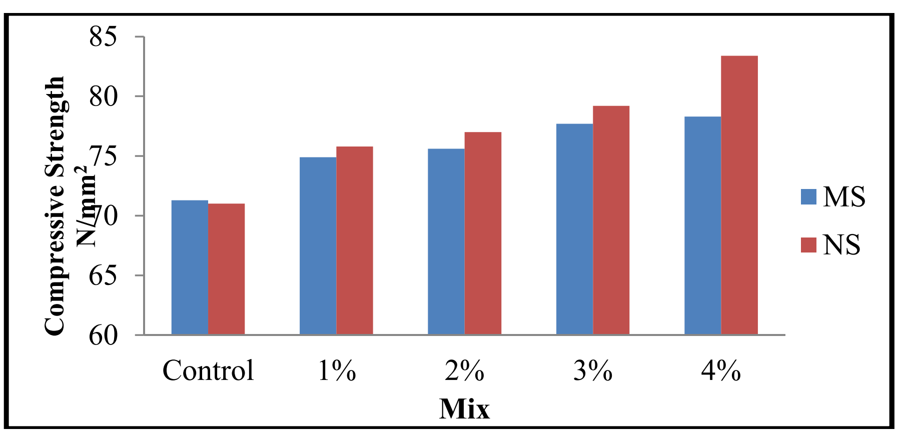


Figure-3. Effect of MS and NS on compressive strength.

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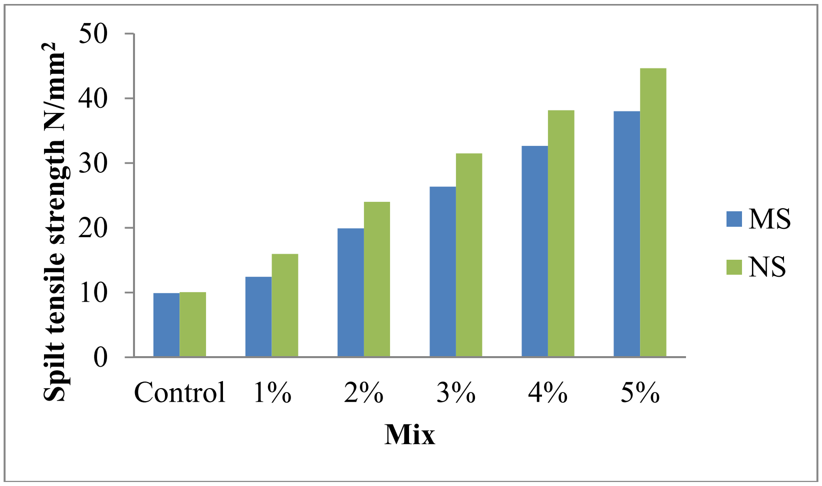

Figure-4. Effect of MS and NS on split tensile strength.

Water absorption

When comparing nano silica results with the obtained micro silica. Nano silica also possesses the reduction in water absorption. The percentage of voids present in nano silica in much lower when compared to micro silica. Consequently, it can be inferred that the nano silica increases the strength of concrete and also the bond between the cement paste and the aggregates which results in less number of voids.

Table-4. Water absorption of NS and MS.

Specimen	Number	Initial weight (kg)	Oven dry weight (kg)	Weight after immersion (kg)	Gain %	Average gain %
Control	1	2.832	2.803	2.856	1.92	1.85
	2	2.824	2.796	2.846	1.79	
1%	1	2.768	2.749	2.797	1.76	1.745
	2	2.816	2.788	2.836	1.73	
2%	1	2.82	2.796	2.84	1.75	1.73
	2	2.792	2.785	2.832	1.71	
3%	1	2.98	2.683	2.727	1.66	1.63
	2	2.89	2.602	2.643	1.6	
4%	1	2.8	2.565	2.6	1.59	1.58
	2	2.722	2.452	2.488	1.57	
5%	1	2.88	2.581	2.619	1.53	1.49
	2	2.69	2.43	2.465	1.46	

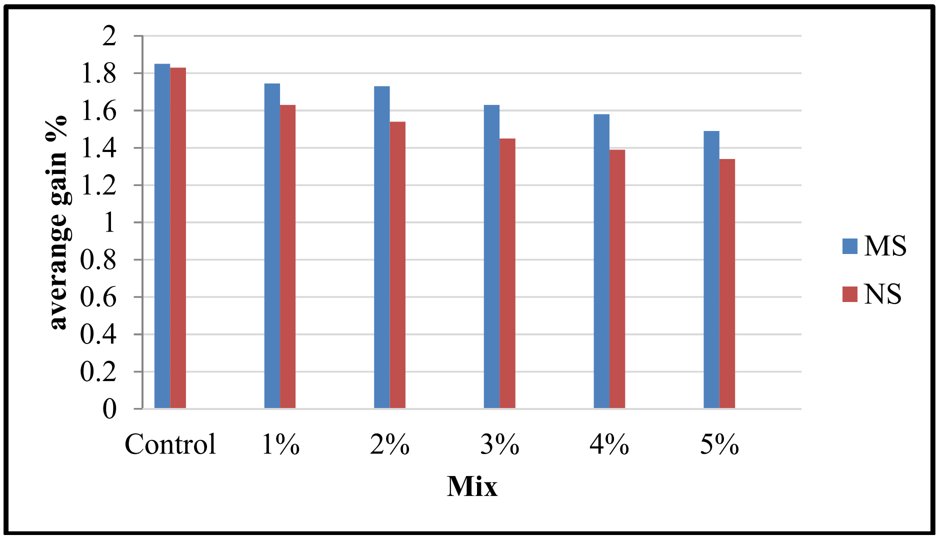

Figure-5. Effect of MS and NS on water absorption.

Sorptivity

It is very evident that even with small amount of MS and NS can effectively reduce concrete sorptivity which is attributed to the filler effect of micro silica besides the pozzolanic reaction between micro silica and calcium hydroxide induced throughout the hydration of cement. When micro silica could show good improvement in sorptivity, nano silica overpowered micro silica by showing drastic change. The amount of water absorbed is lesser in concrete with nano silica than micro silica.

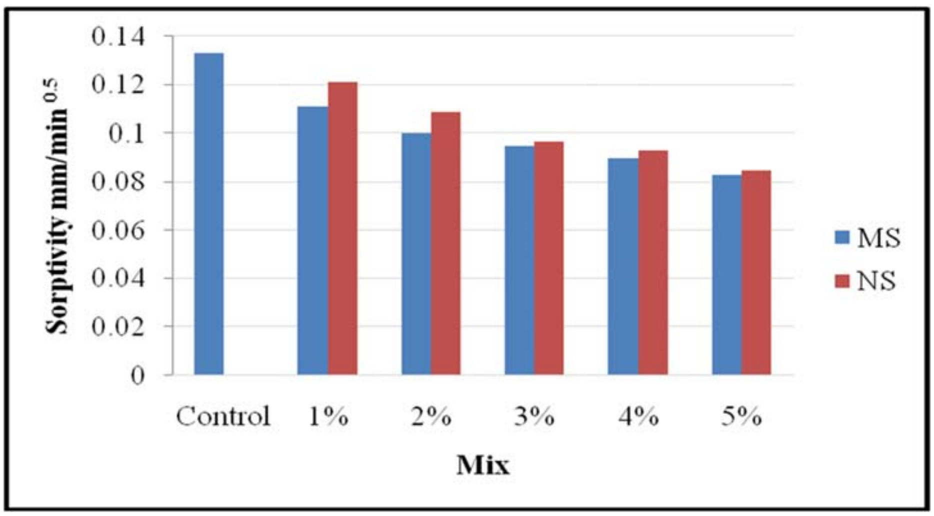

Figure-6. Effect of MS and NS on sorptivity.

XRD analysis

The XRD pattern of the sample with micro silica and nano silica are shown in Figures 7 and 8. From the Figures 7 and 8, it is seen that the major component present in the sample is silica content due to the peak on 2 angles of 27°. The peak indicates that the silica content is of crystalline nature and the broad parts will generally indicate that the elements are amorphous in nature.

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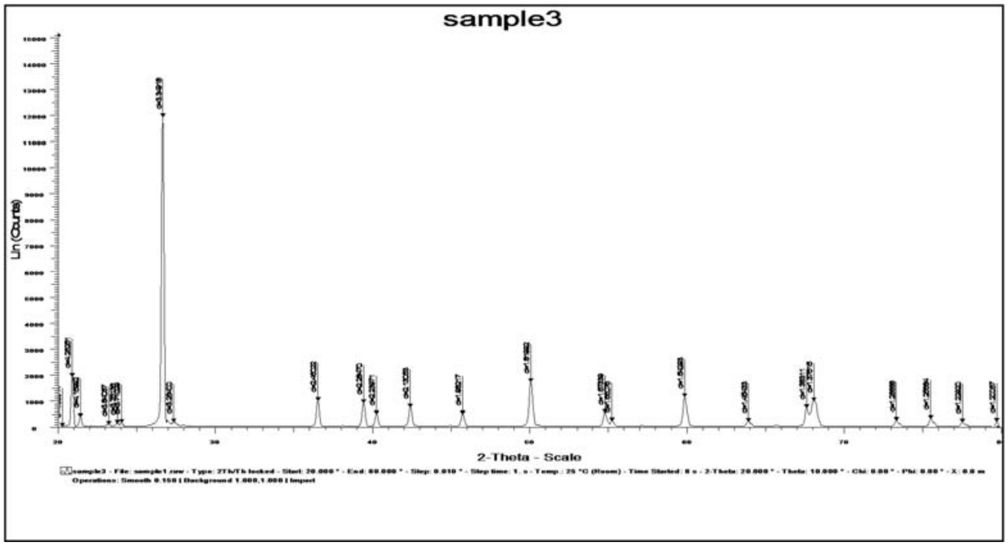

Figure-7. XRD graph of micro-silica.

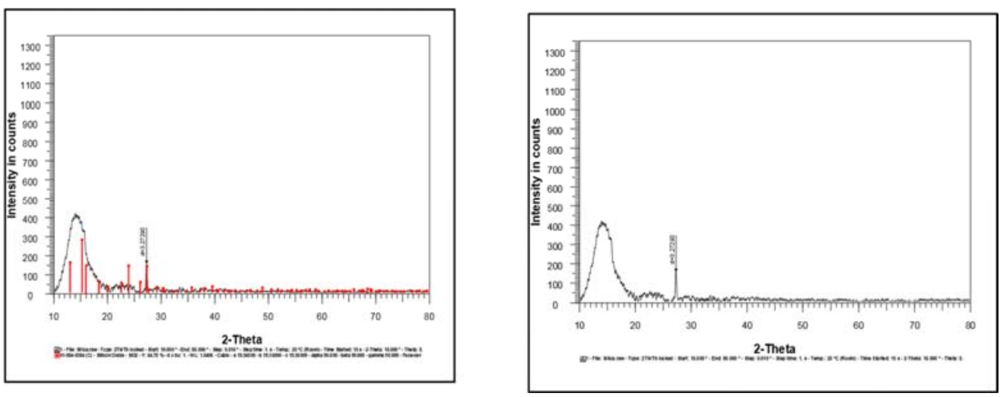

Figure-8. XRD analysis of nano silica.

Scanning electron microscopy analysis

The quantity of origination of CH is decreased with addition of micro silica in concrete. C-S-H is formulated due to the pozzolanic reaction of Micro silica. Due to its formation the microstructure gets more dense and composed to that of normal concrete. The SEM images indicate the nano particles are spherical in shape. From Figure-11, it is seen that the concrete with nano silica possesses dense and more organized structure with less number of Ca $(OH)_2$ crystals and small sized pores. Nano silica takes in calcium hydroxide crystal which fills the pores thereby increasing the strength and upgrades the blend area and cement paste structures. From Figures 9 and 10, it is seen the C-S-H crystal are identified as needle like form and short bundles. P-A (paste-aggregate) bonding is responsible for high early strength and concrete with micro silica showed significant improvement. The pozzolanic reaction by Ca $(OH)_2$ makes the microstructure of concrete denser and homogenous than normal concrete and formation of C-S-H leads to filling the pore system and improves the microstructure of mortar by the effect of densification.

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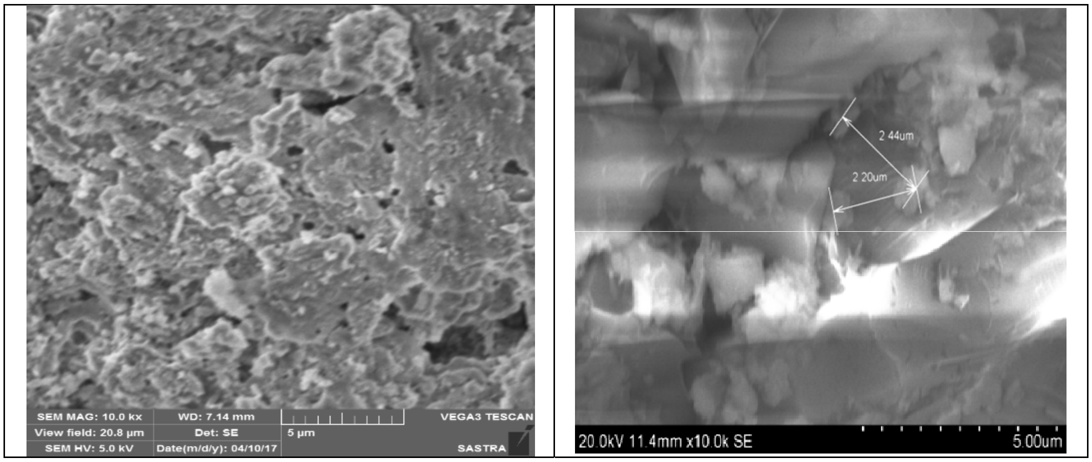

Figure-9. 1% Micro silica and nano silica.

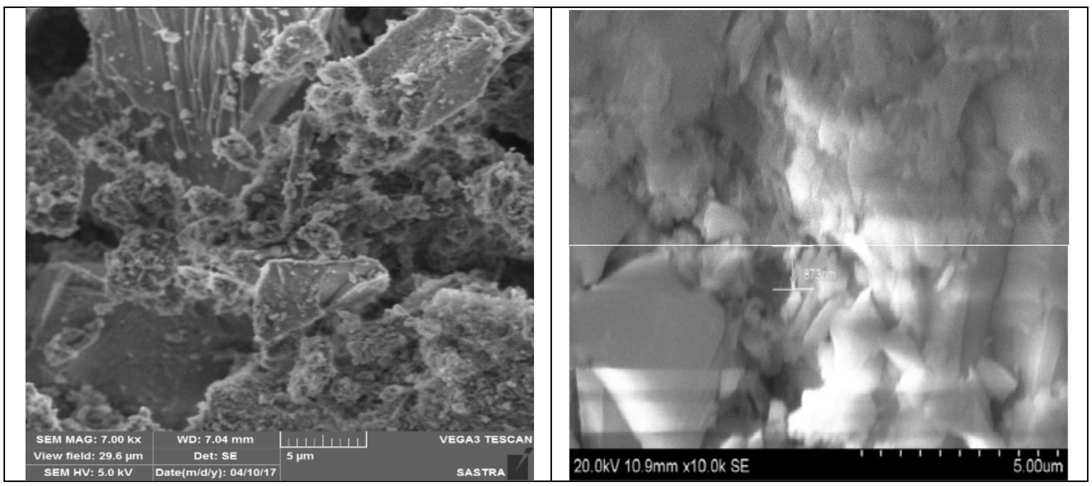

Figure-10. 2% Micro silica and nano silica.

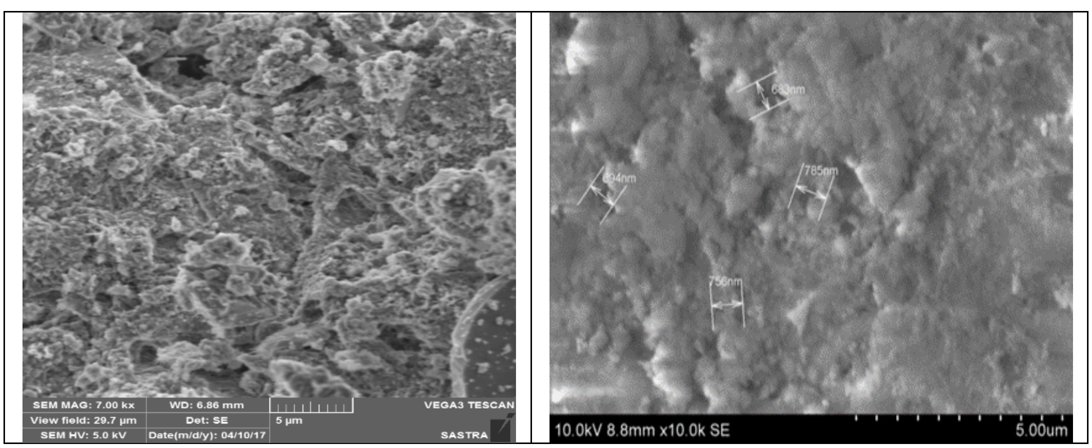

Figure-11. 3% Micro silica and nano silica.

5. CONCLUSIONS

- The compressive strength had an impact with substitution of cement with micro and nano silica to some extent regardless of its percentage.
- The compressive strength increased in the order of 5.05%, 6.03%, 8.9%, 9.81% and 12.34% respectively on the addition of micro silica and 6.76%, 7.99%, 11.5%, 17.46% and 21.97% respectively on the replacement of nano silica from the control specimen.

- The results obtained from the split tensile test have also showed an increase upon the addition of micro silica and nano silica.
- Addition of micro silica and nano silica as substitute showed increment and improved the resistance in terms of durability characteristics.
- It was also to be noted that addition of MS and NS reduces the water absorption in the order of 1.85%, 1.745% 1.73%, 1.63%, 1.58% and 1.49% respectively for control, 1%, 2%, 3%, 4% and 5% and hence volume of permeable pores was also reduced.
- In the case of opposition against capillary suction, water absorption, voids and volume of permeable pores, concrete with nano silica performed well compared to micro silica.
- By considering effect of compressive strength, durability characteristics, it is concluded that concrete with nano silica was found to be the better replacement material from the limited experiments conducted.

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