Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 6, June 2021: 971- 979

Durability of High Performance Concrete Containing Nano Silica Using Rapid Chloride Permeability Test

C.K.Sridhar[a], Dr S.B.Vanakudre[b]

[a]Associate Professor, Department of Civil Engineering, KLS Vishwanath Rao Deshpande Institute of Technology , Haliyal, Karnataka, India
[b]Retd Principal, SDM College of Engineering & Technology, Dharwad, Karnataka, India

Abstract

Till the end of 20th century, scientists and engineers emphasized in developing high strength materials without considering the performance of the structures in different environmental conditions. Corrosion of reinforced steal in marine structures, bridges, water retaining structures, etc. is due to ingress of chloride ion which is present in water. This is one of the major environmental problems, which affects the overall performance of the structure. Rapid chloride permeability test (RCPT) was suggested by ASTM C 1202-1997, which is the most accepted durability test on concrete. Development of High Performance Concrete is the solution to overcome this environmental problem.

This study deals with the durability of M60 Grade High Performance Concrete with and without Nano Silica using RCPT, test results are validated using Scanning Electron Microscopy (SEM) and Energy Dispersion Spectroscopy(EDS). Results of RCPT show that charges passed in the HPC with Nano Silica is less compared to HPC without Nano Silica for all dosages of superplasticizer (0.5% to 2%). At 1% superplasticizer, passing of charges is lowest for both HPC's. Hence, 1% superplasticizer is the optimum dosage to achieve durability. Results of EDS and SEM show that, better packing of HPC can be achieved using Nano Silica.

Keywords: Rapid Chloride Permeability Test (RCPT), Durability, High Performance Concrete, Nano Silica.

1. Introduction

Ingress of chloride ion in the marine structures, bridges, water retaining structures is one of the durability problems. This is due to presence of chloride ion in water. Diffusion of chloride ion is predominate mode of chloride transport in concrete. The rate of chloride ion diffusion mainly depends on the pore structure of concrete. Resistance to chloride ion penetration is one of the simplest measure to determine durability of concrete [1]. This is one of the major durability problem in recent years. One of the main reasons for deterioration of concrete is that too much emphasis is placed on concrete compressive strength rather than on the performance criteria [1]. Use of nano particles in concrete mix can enhance resistance to chloride permeability. Recent study reveals that there is a reduction in the chloride permeability for nano coated concrete hence, nano silica can be applied as an external coating, leading towards durable concrete constructions[2].

Development of high performance concrete is the solution to durability problems.High performance concrete can be produced by low water-cement ratio with the help of superplasticizer and carefully selecting supplementary cementitious materials such as Fly ash, GGBS, Metakaoline and silica fume [3]. Resistance to permeation of chloride ion is the most critical parameter in the determination of concrete durability in aggressive environment [4].

Development of High Performance Concrete is the solution to this environmental problem. Since the beginning of this century, engineers and scientists are being employed to enhance properties of concrete and thereby, development of High Performance Concrete. Nano materials are very reactive because of their small size and large surface yield and have a great potential in improving concrete properties. Incorporation of nano particles can fill the voids more effectively to enhance strength and durability[10]. This study deals with durability study of High Performance Concrete with and without nano silica using RCPT.

Research Significance: Diffusion of chloride ions is one of the environmental problems which affect the durability of conventional concrete. Hence, it is necessary to develop High Performance Concrete to overcome this problem. Durability is the characteristic of High Performance Concrete. Rapid Chloride Permeability Test is the simplest measure of durability of concrete. Nano Silica is used to improve the durability characteristics of concrete. RCPT results indicate the resistance to diffusion of chloride ion. From this it is possible to assess the durability of concrete. EDS and SEM is carried out on High Performance Concrete to validate results of RCPT.

2. Materials And Properties

Cement: Ordinary Portland cement 43 grade confirming to IS: 8112-1989 [11]

Specific gravity: 3.15.

Density: 1.45gm/cc

Sand: Locally available natural sand confirming to zone III of IS: 383.[9]

Density: 1.6 gm /cc

Specific gravity: 2.6

Coarse aggregate: Locally available crushed angular coarse aggregate of size 10mm, 20mm, confirming to IS:383 grade.

10mm:

Density: 1.65 gm/cc

Specific gravity: 2.91

20mm:

Density: 1.7 gm/cc

Specific gravity: 2.7

Water: Potable water confirming to IS: 456-2000.[8]

Nano Silica: Supplied by SMART NANOZ , PUNE , INDIA

TABLE .1 Properties of Nano Silica

Purity	Crystallite size	BET surface area	Density	Specific gravity
99%	1nm	110 m^2/gm	0.236 gm/cc	0.4

Superplasticizer: i) Conplast SP 430 Manufactured by FOSROC, Bengaluru, India

Specific gravity: 1.19

ii) SP111

Specific gravity: 1.19 to 1.24

3. Mix Proportioning Of Hpc

Mix proportioning of high performance concrete M60 grade is done using IS:456-2000 [8], IS:10262-1982[7], IS:10262-2000 [6] and strength efficiency factor (K) of nano silica[5]. For better packing of concrete 20mm[60%] and 10mm[40%] down size coarse aggregates are used. Dosages of superplasticizer is varied from 0.5% to 2.0%.

TABLE 2. Mix proportions of HPC(M60) without nano silica for 1cum (1:1.12:1.93)

Cement (kg)	Sand (kg)	Coarse aggregate (kg)		Superplasticizer (0.5% of cement)	Water (litres)
		20mm	10mm		
568	640	658	439	2.84	176

TABLE 3 . Mix proportions of HPC(M60) with nano silica for 1cum (1:1.18:2.04)

Cement (kg)	Nano silica (kg) (1.5% of binder)	Sand (kg)	Coarse aggregate (kg)		Superplasticizer(kg) (0.5% of binder)	Water (litres)
			20mm	10mm		
525	8	632	654	436	2.66	176

4. Test Procedure

Specimens of size 92mm dia and 50mm thick are prepared as per mix proportions for HPC without nano silica and HPC with nano silica.Specimenns are kept in between two reservoirs,One reservoir is filled with 3.0 percent concentration NaCl solution, the other is filled with 0.3 M NaOH solution.Then specimen is subjected to 60v DC current for 6 hours. For every half an hour, charges (in Coulombs) passed in concrete specimens is noted.

Total charges passed in specimen is found by the equation

$Q=900*(I_0+2I_{30}+2I_{60}+2I_{90}+\text{--------------------}+2I_{330}+I_{360})$

Where Q= Total charges passed in Coulombs.

I_0= Current in Ampere immediately after voltage is applied.

I_t= Current in Ampere after time 't' in minutes after voltage is applied.

TABLE 4 Chloride ion penetrability based on charges passed as per ASTM C 1202(1997).

Charge passed (Coulombs)	Chloride ion penetrability
>4000	High
2000-4000	Moderate
1000--2000	Low
100-1000	Very Low
<100	Negligible

In this study three specimens for both HPC (without nano silica) and HPC (with nano silica) is tested and average value of total charges passed is taken. Test is carried out for all percentages of Superplasticizer i.e from 0.5% to 2.0%. Average value is considered for analysis.

TABLE 5 Results of current passed for HPC (without nano silica) 0.5% superplasticizer

Time in minutes	Specimen 1		Specimen 2		Specimen 3	
	mA	^{0} C	mA	^{0} C	mA	^{0} C
0	15.4	29.7	18.6	32.2	21.4	31.2
30	19.8	30.2	22.4	32.4	25.6	32.7
60	24.8	30.7	25.8	32.5	32.1	32.9
90	31.5	31.0	32.9	32.6	38.9	33.2
120	36.8	31.6	35.3	32.9	44.2	33.1
150	42.2	31.8	41.1	33.1	56.8	33.6
180	63.4	32.2	56.8	34.5	64.7	35.5
210	88.6	33.4	63.2	34.9	89.7	35.9
240	107.0	33.9	88.1	36.5	108.9	36.6
270	122.1	34.8	110.4	36.8	124.2	38.2
300	135.0	36.4	120.3	37.2	134.3	38.7
330	140.2	37.1	136.2	38.1	142.5	39.2
360	145.8	37.3	142.1	38.4	147.3	39.5
Q=	**1605.6**		**1463.13**		**1703.25**	

$Q_{AVERAGE}$ = 1703.25 Coulombs

TABLE 6 Results of current passed for HPC (with nano silica) 0.5% superplasticizer

Time in minutes	Specimen 1		Specimen 2		Specimen 3	
	mA	^{0} C	mA	^{0} C	mA	^{0} C
0	34.2	30.9	29.2	32.1	32.3	31.2
30	46.3	31.1	34.8	32.4	33.4	31.3
60	56.2	31.6	37.7	32.6	36.2	31.5
90	64.2	32.1	40.2	32.6	37.3	31.9
120	65.1	32.3	42.2	32.7	39.2	32.3
150	65.7	31.4	43.9	32.8	42.4	32.5
180	66.8	31.0	47.5	32.9	51.2	32.7
210	67.2	31.7	48.2	33.1	51.8	33.9
240	67.9	33.2	49.4	33.4	52.9	34.3
270	68.2	34.5	50.3	33.9	53.8	34.5
300	68.7	35.5	51.9	34.2	54.2	34.9
330	69.3	35.6	53.7	34.8	54.7	35.5
360	69.9	35.4	55.9	35.9	56.1	35.8
Q=	**1363.77 Coulombs**		**976.23 Coulombs**		**992.34 Coulombs**	

$Q_{AVERAGE}$ = 1110.78 Coulombs.

TABLE.7 Average charges passed in Coulombs for different percentages of Superplasticizer

0.5% Superplasticizer		1.0% Superplasticizer		1.5% Superplasticizer		2.0% Superplasticizer	
HPC without nano silica	HPC with nano silica	HPC without nano silica	HPC with nano silica	HPC without n ano silica	HPC with nano silica	HPC without nano silica	HPC with nano silica
1590.66.	1110.78	1498.60	1009.54	1623.50	1230.45	1594.75	1124.65

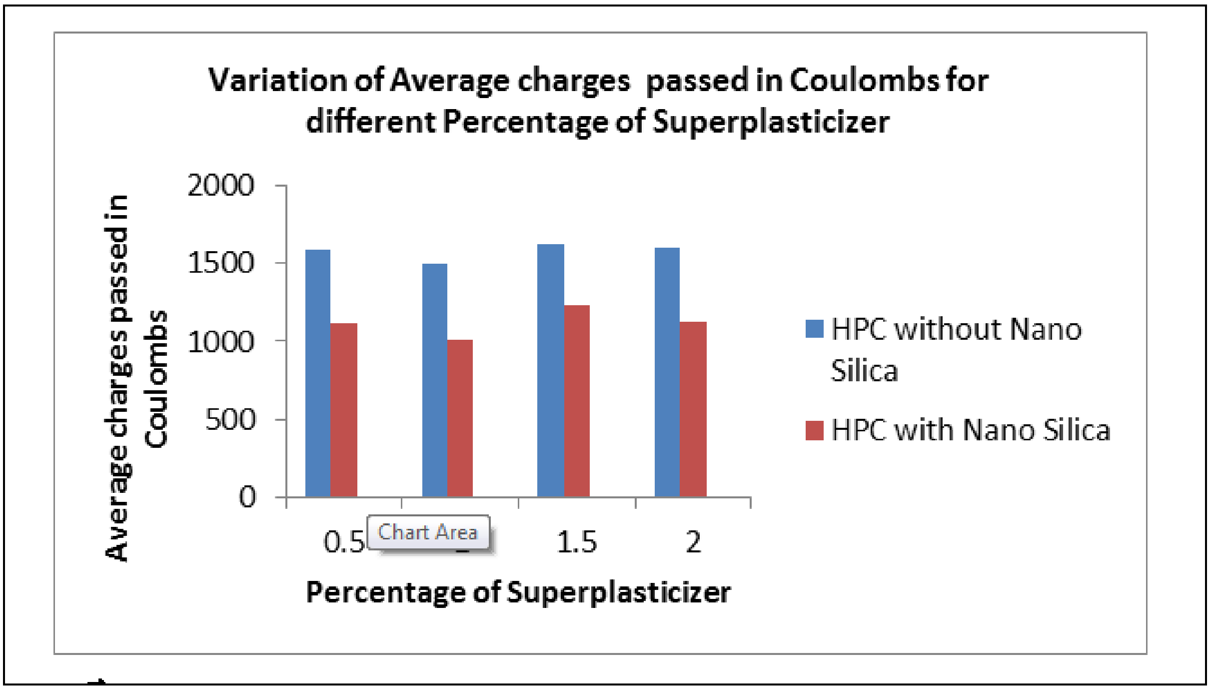


Fig 1. Variation of average charges passed in Coulombs with percentage superplasticizer

x

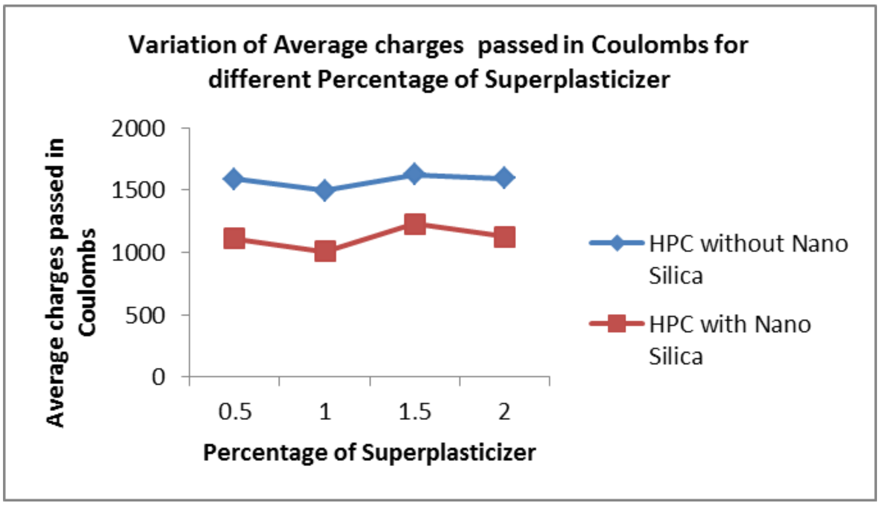


Fig 2. Variation of average charges passed in Coulombs with percentage superplasticizer

5. Results And Discussion

RCPT results shows that, the average charges passed in both HPC's is between 1000 and 2000.Hence the chloride ion penetrability is low in both HPC's s (as per ASTM C 1202-1997), however there is substantial decrease in average charges passing in HPC with nano silica (i.e up to 32.6%), indicating HPC with nano silica is better resistance to chloride ion penetreblity. By this it can be concluded that HPC with nano silica is more durable than HPC without nano silica.

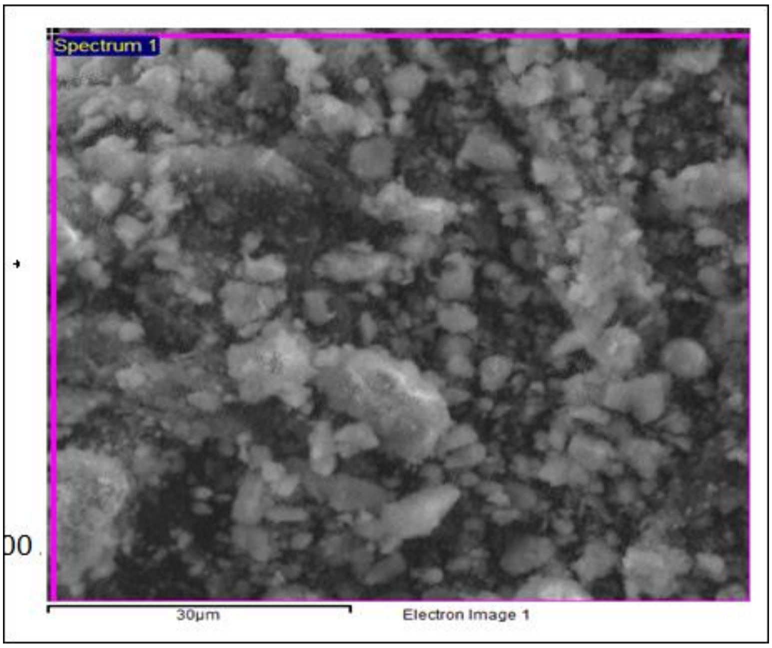
6. Characterization of HPC

Characterization of HPC is carried out to validate test results. This is done through EDS(Energy dispersive spectroscopy) and SEM (Scanning electron microscopy).HPC's containing 1% superplastcizer is considered for the analysis.As test result shows, it is optimum to achieve durability.

7. Energy Dispersive Spectroscopy (EDS)

EDS gives composites and elemental analysis present in the material, also it gives electronic image. It is possible to analyze the results easily. XRD gives only crystalline components present in composites. But won't gives elemental composition. Hence, it is advantageous to study the EDS results.

8. EDS OF HPC without nano silica



Spectrum processing :

No peaks omitted

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

O SiO2 1-Jun-1999 12:00 AM Mg MgO 1-Jun-1999 12:00 AM

Al Al2O3 1-Jun-1999 12:00 AM

Si SiO2 1-Jun-1999 12:00 AM

S FeS2 1-Jun-1999 12:00 AM

Ca Wollastonite 1-Jun-1999 12:00 AM

Fe Fe 1-Jun-1999 12:00 AM

TABLE-8 Elements present in HPC (without nano Silica)

Element	Weight %	Atomic %
O K	59.64	76.06
Mg K	0.71	0.59
Al K	4.27	3.23
Si K	10.42	7.57
S K	1.37	0.87
Ca K	21.29	10.84
Fe K	2.30	0.84
Totals	100.00	

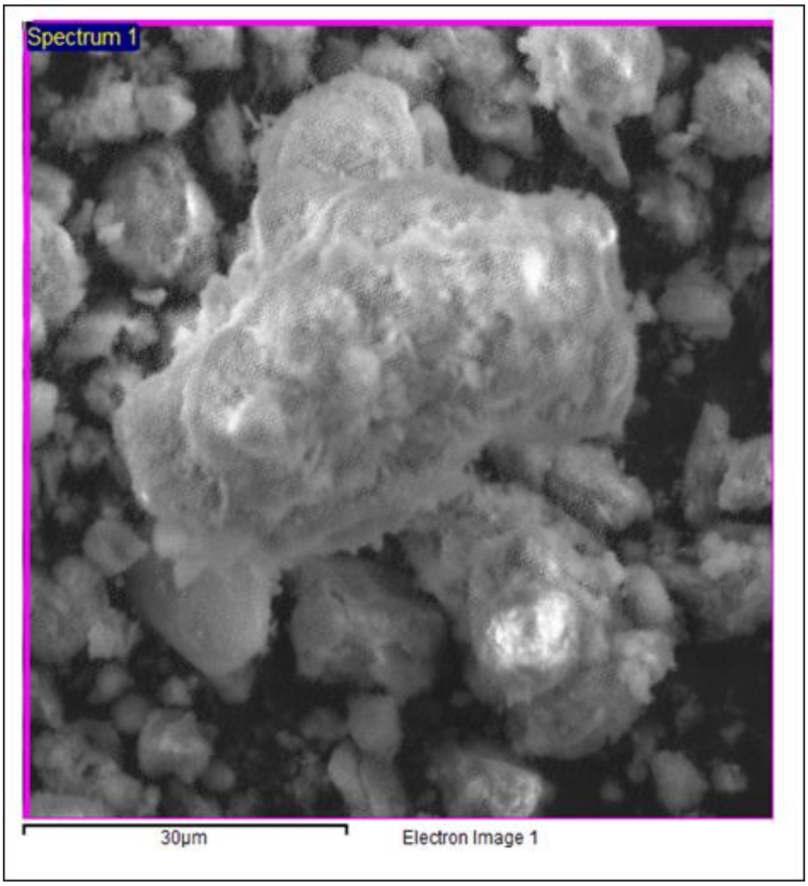


Fig 3 EDS of HPC without nano silica

EDS of HPC with nano silica

Spectrum processing :

No peaks omitted

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

O SiO2 1-Jun-1999 12:00 AM

Al Al2O3 1-Jun-1999 12:00 AM

Si SiO2 1-Jun-1999 12:00 AM

S FeS2 1-Jun-1999 12:00 AM

Ca Wollastonite 1-Jun-1999 12:00 AM

Fe Fe 1-Jun-1999 12:00 AM

TABLE-9 Elements present in HPC (with nano Silica)

Element	Weight %	Atomic %
O K	57.46	75.10
Al K	3.26	2.53
Si K	9.40	7.00
S K	1.09	0.71
Ca K	26.40	13.77
Fe K	2.38	0.89
Totals	100.00	

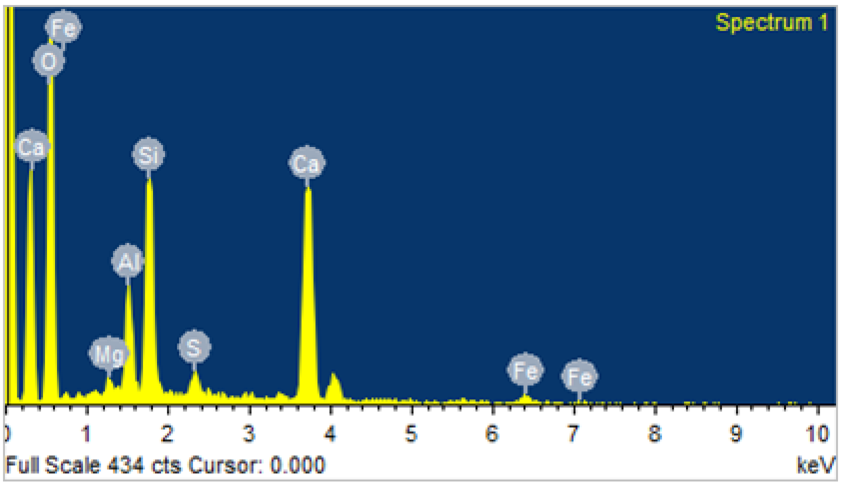


Fig 4 EDS of HPC with nano silica

Energy Dispersive spectroscopy (EDS) report shows that atomic percentage of wollastonite is more in HPC with nano silica i.e 13.77 against 13.84 in HPC without nano silica. Wollastonite is a mixture of Calcium Oxide and silica in the proportion of 48.28% and 51.72%. Wollastonite is responsible in enhancing properties of concrete. Also electron image of HPC with nano silica shows that agglomeration of particles and more dense and compact. On the other hand, electron image of HPC without nano silica shows that scattering of ingredients of concrete and hydrated product indicating more porosity. The atomic percentage of silica is same for both HPC's.

8. Scanning Electron Microscopy (SEM) OF HPC

SEM gives high resolution images of objects, it is possible to study microstructure of the material, variations in chemical compositions present in the material.

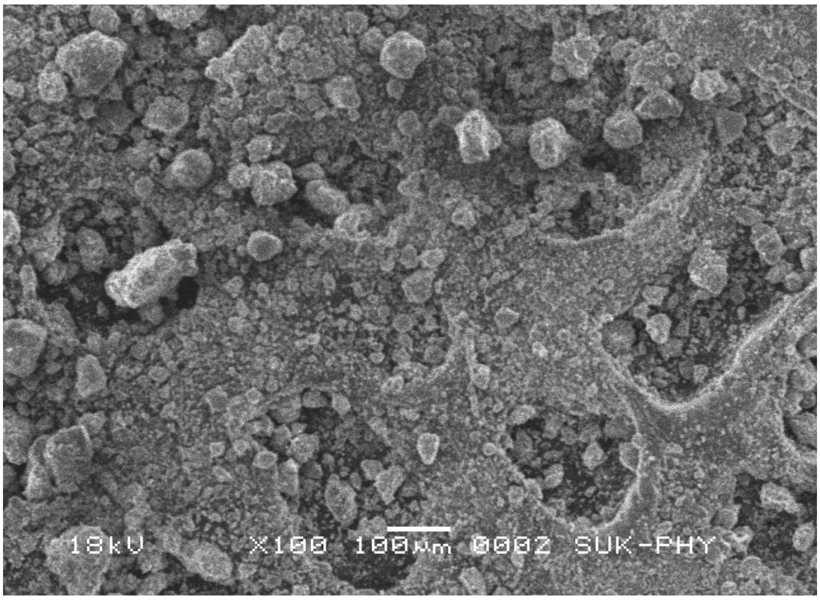


Fig 5 SEM of HPC without nano silica

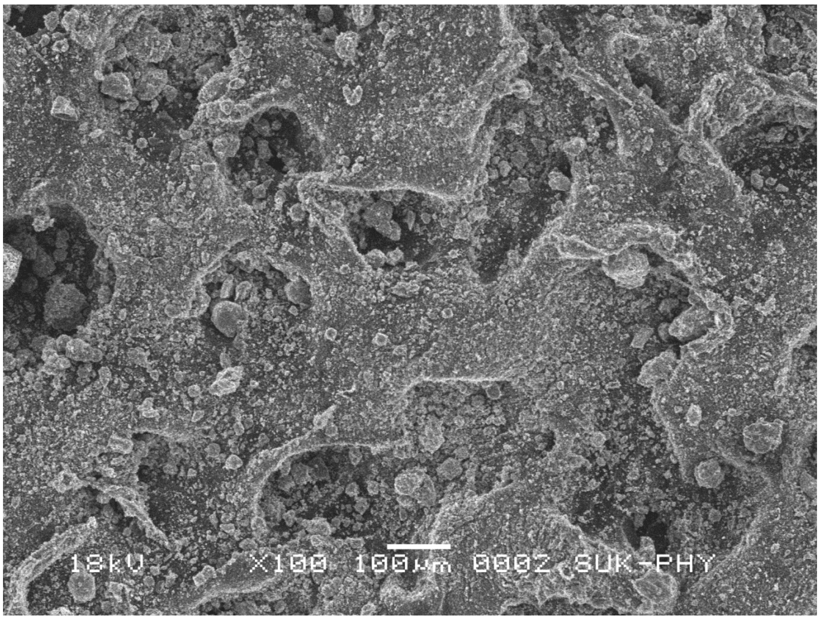


Fig 6 SEM of HPC with nano silica

Fig 5 and Fig 6 shows that there is better particle packing, dense and compactness in HPC with nano silica compared to HPC without nano silica. This is due to reduction in Calcium Hydroxide, resulting in the formation of C-S-H gel. Nano silica improves the microstructure of concrete. The presence of nano silica has increased the packing efficiency of HPC.

9. Conclusions

RCPT result shows that, both HPC's have low penetrability of chloride ion as per ASTM C 1202-1997 , but charges passed through HPC with nano silica is less compared to HPC without nano silica indicating HPC with nano silica have better resistant to chloride ion penetration. At 1% superplasticizer charges passed is lowest for both HPC's, this is due to better packing of particles in both the HPC's. Results of EDS, SEM show that, better packing in HPC can be achieved using nano silica also the microstructure of HPC with nano silica is more denser, homogeneous and uniform compared to HPC without nano silica.

References

[1] Yatin Patel, Dr. B.K. Shah , Prof. P.J. Patel ,"Effect of Alccofine and Fly Ash addition on the Durability of High Performance Concrete ",2013 International Journal for Scientific Research and Development Volume-1, Issue-3. pp 594-598

[2] S.Gopinath , P.CH. Mouli ,"Effect of Nano Silica on Mechanical Properties and Durability of Normal Strength Concrete ",2012, Archives of Civil Engineering 58,4. pp 433--444.

[3] M Vijay Sekar Reddy, I.V Rammana Reddy, et al. "Durability of High Performance Concrete Containing Supplementary Cementing materials using Rapid Chloride Permeability Tests ", Nov 2012, International Journal of structural and Civil Engineering Research Volume-1 pp 96-98.

[4] Yatin. H. Patel, P.J. Patel Prof. Jignesh .M.Patel, Dr. H.S.Patel, "Study on Durability of high Performance Concrete with Alccofine and Fly Ash ", June 2013, International Journal of Advanced Engineering Research and Studies, Issue-3, pp 154-157.

[5] C.K.Sridhar, Dr S.B.Vanakudre , "Strength efficiency factor for Nano silica at different age". Aug 2014 Journal of Civil Engineering and Environmental Technology Volume 1, No 3, pp 32-35.

[6] Concrete Mix Proportioning- Guidelines IS 10262:2009.

[7] Concrete Mix Proportioning- Guidelines IS 10262:1982

[8] Plain and Reinforced concrete- Code of Practice IS 456-2000.

[9] IS:383-1970 "Indian Standard Specification for Coarse and Fine aggregates from natural sources for concrete".

[10] Dr. D.V Prasada Rao, K.Jayalakshmi , "Experimental Investigation on the Properties of Nano Silica Concrete ", June 2014, International Journal of Civil Engineering and Technology , Volume-5,issue-6, pp 116-124.

[11] IS: 1199-1959 "Methods of Sampling and Analysis of Concrete"