ISSN: 0974-5823 Vol. 6 No. 3 December, 2021

International Journal of Mechanical Engineering

Optimizatation of Partially Replacement of Nano – SiO_2 with Cement

A Jayaraman[1], N Sathyakumar[2] , S Dhivyabharathi[3]and J Jeba Jenkin[3]

[1,2,3] Assistant professor, Department of Civil Engineering, Bannari Amman Institute of Technology, Sathyamangalam, Tamilnadu

[4]Assistant professor, Department of Civil Engineering, DMI Engineering College, Aralvaimozhy, Tamilnadu

Abstract

Nowadays, the high strength concrete is develop using nano-materials incorporated by cement. The nano - materials fill the voids or porous in concrete so that strength and durability are easily has been achieved. In this paper, the nano-SiO_2 materials are partially incorporated into cement and enhance the strength. The various percentages of nano - SiO_2 materials partially incorporated such as 1%, 2%, 3%, 4% and 5% . In this paper, briefly introduced the influence of nano-SiO_2 on mechanical and durability performance of concrete. In addition, this review also includes the micro structure measured by scanning electron microscope (SEM). The results show that the enhanced compressive strength and durability of concrete has been achieved, when nano - SiO_2 incorporated up to 2% by cement. The nano - material increased above 2 %, the strength and durability of concrete also reduced. Whan up to 2 % nano - SiO_2 incorporate with cement, the 28 days compressive and tensile strength has been increased, and also durability performance also good.

Key words: Cement, Sand, compressive strength and flexural strength, nano materials, tensile strength, water absorption

I INTRODUCTION

Nowadays, nano - materials are processed in all the fields, such as electrical, solar energy, medicals, aeronautic industry, food technology, fuel cell and construction field. In this paper, the high strength concrete has been developed by nano - SiO_2. The nano - SiO_2 materials, partially replaced or incorporated with cement materials. Nowadays a lot of nano materials are used in the construction field such as nano - $CaCO_3$, nano - SiO_2 , nano silica, nano - $TiO_2$and nano - $Ca(OH)_2$. The mechanical properties, durability of concrete and workability of concrete have been achieved by various percentages of nano - materials incorporated with cement. The high dosage of nano materials incorporated with cement, the strength has been gradually decreased by**Peng Zhang (2021).Yanqun Sun et al (2020)** he reported that, the 1% nano - $CaCO_3$ and 2 % of fly ash concrete has given best mechanical properties of concrete by water cement ratio 0.4. The durability of concrete has been achieved under the synergistic effect of nano-$CaCO_3$ and fly ash. The nano - materials fill the voids in concrete and also during the hydration has been developed the pozzolanic effect of the concrete, the results also has been observed by SEM analysis. The addition of nano - materials and fly ash concrete has developed the resistance of carbonation of concrete.

The assorted proportion of nano - materials increase in cement such as nano - Ni ferrite, Cu-Zn ferrite, nano ferrite and nano - silica. The compressive and tensile strength of concrete has been acquire by 3 % Ni ferrite and 2%Cu-Zn ferrite concrete. And as well recovered nano ferrite and nano silica has been given best compressive, tensile and flexural strength of concrete about 21% and 17%& 44% and 60% & 23% and 25% respectively, with respect to the control mixes**by Mohamed Amin Sherif et al (2015).**

Chithra *et al.* (2016) generally nano material has high Pozzolanic activity, so that curing ages time has been attained early. the compressive and tensile strength has been reduced by early age strength. whereas bledding and segreation has been reduced in concrete after the curing period.The nano composite materials fully or partially replace by cement , the strength and durability also increased. upto 2% of nano composite material replace with cement has given good mechanical properties and durability of concrete. (Quercia *et al.* 2011).

nano TiO_2 and calcium hydra-oxide material has high surface area, so that curing ages time has been attained early due to produce high temperature when during the hydration period. so for compressive and tensile strength has been reduced. whereas durability and corrosion of concrete has been reduced due to produce high meta silica during hydration period.The TiO_2 and calcium hydra-oxide materials fully or partially replace by cement , the strength and durability also increased. Upto 2.5 % of nano composite material replace with cement has given good mechanical properties and durability of concretereported by (Hongjian *et al.* 2014, Singh *et al.* 2012,Chithra *et al.* 2016)

Jayaraman et al (2021) he reported that, the mechanical properties and durability of concrete has been increased, when incorporated 2% of Nano - composite materials by cement. The binary combination mix has given best mechanical and durability performance compare than the other mixes such as conventional mix and ternary combination mix. The corrosion performance of concrete also found in concrete elements, the 5% of ternary combination mix has given best corrosion resistance compare then the other mixes. Finally observed from the results, the optimum dosage of 2% binary combination mix, has given the best mechanical and durability performance, may be the Nano - materials has fill the voids in concrete and produced the more Di - Calcium silicate, when during the hydration period. The Nano - composite materials increased above 2%, the mechanical and durability of concrete also decreased due to the Nano - materials has more surface area so that, produce the more

heat of hydration and early age strength. The ternary combination mixes has given the best corrosion resistance due to the Nano ternary composite materials produce the more metasilicate when during the hydration time. The meta silicate generally good corrosion barrier. The main aim of the project is the development of high strength concrete using nano-SiO_2 materials. Finally observed from the results, the Nano - materials increased up to 2%, the strength and durability of concrete has increased. The Nano - materials increased above 2 % the strength and durability of concrete also decreased. Generally the Nano materials has occupied more surface area, so that produce the high temperature in the inside the concrete.

II AIM OF THE PROJECT

To development of high strength concrete using Nano - SiO_2 materials

III MATERIALS USED

3.1 Cement: OPC cement 50 grade conforming to IS 8112 – 1989, density and specific gravity of cement is found to be 1440kg /m^3 and 3.16. The physical and chemical properties of cement are given in Table.1

Table 1 Physical and chemical properties of cement

Compound	OPC
Silicon-DI-oxide (SiO_2)%	20–21
Aluminium oxide (Al_2O_3)%	5.2–5.6
Ferric oxide (Fe_2O_3)%	4.4–4.8
Calcium oxide (CaO)%	62–63
Magnesium oxide (MgO)%	0.5–0.7
Sulphur-ti-oxide (SO_3)%	2.4–2.8
Loss on ignition (LOI)%	1.5–2.5
Sodium oxide (Na_2O)%	----
Potassium oxide (K_2O)	---

3. 2 Fine aggregate: River sand is collected from the local area and specific gravity and density of sand is found at 2.65 and 1760 kg / m^3. The physical and chemical properties of cement are given in Table.2

Table 2 Physical and chemical properties of river sand

Compound	OPC
Silica	79.98
Aluminium	13.86
Ferric	1.89
Calcium	0.87
Magnesium	1.44
Titanium	0.15
Loss on ignition (LOI)%	0.31
Sodium	1.67
Potassium	1.67

3.3 Coarse Aggregate

The coarse aggregate of 20 mm is used and it has bulk density of 1710 kg/$m^3$and the specific gravity 2.81and fineness modulus of 2.72 is used. The physical and chemical properties of cement are given in Table.3

Table 3 Physical and chemical properties of coarse aggregate

Compound	OPC
Maximum size (mm)	20
Fineness modulus	7.10
Specific gravity	2.64
Bulk density	1.42 - 1.61
Water absorption	0.15
Average crushing value	17.50
Average impact value	14.40
Maximum dry density	13.70
Aggregate absorption value	28.10

3.4 Nano - SiO_2

Nano-SiO2, used for partially replacing the cement and are procured from Elkem Metallurgy (P) Ltd. The physical and chemical properties of Nano - composite materials are given in Table 4 and as shown in Figure 1.

Table 4 Physical and chemical properties of Nano - SiO_2

S NO	**Component**	**Nano - SiO_2**
1	Specific gravity	-
2	Fineness, m^2/ kg	257
3	Silicon dioxide	95.3
4	Calcium oxide	0.27
5	Alumina	0.65
6	Ferric oxide	0.28
7	Manganese oxide	0.41
8	Loss of ignition	1.03

Figure1Nano - SiO_2

3.6 Specimen Details

A - 0 – Conventional Concrete

S - 1 - OPC + 1 % Nano - SiO_2

S- 2 -OPC+ 2 % Nano - SiO_2

S - 3- OPC + 3 % Nano - SiO_2

S - 4 - OPC+ 4 % Nano - SiO_2

S - 5- OPC+ 5% Nano - SiO_2

IV CASTING AND TESTING OF SPECIMEN

M20 grade of concrete has been used for all the type mixes. Various types of mixes have been used such as S1, S2, S3, S4, S5 and S6. Water cement ratio is 0.4 used for entire project work and all experimental work. Totally 54 cubes 54 cylinders have been cast for compressive strength and tensile strength of concrete. The Size of the cube is 150 mm x 150 mm x 150 mm and the size of the cylinder is 150mm diameter and 300 mm height. The mortar cube has been cast for water absorption, acid penetration and permeability of concrete. Totally 108 mortar cubes have been cast for durability test and size of mortar cube is 70mm x 70 mm x 70mm. A prism of size 500 × 100 × 100 mm has been cast for determining the flexural strength of concrete.

V RESULTS AND DISCUSSION

Scanning Electron Microscope (Sem)

The SEM is used to determine the particle size of nano - material and internal defects such as porous structure, air voids and density of concrete. Figure 1.(A) shows the micro-structure of A-0 conventional concrete. Figure 1. (B), 1 (C), 1(D) and 1 (E) show the dosages of 1% , 2%, 3%, 4% and 5% with the single combination mix S-1, S-2. S-3, S - 4 and S - 5 show the optimum dosage used in mixtures where the structure is very tight and void is less. Finally these micro-structure views are used for easy identification of the strength and durability of concrete and mortar specimens .

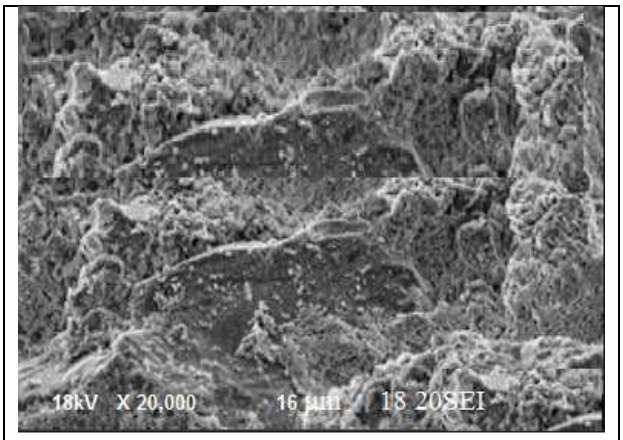

Figure 1 (A) A - 0 Convectional Mix

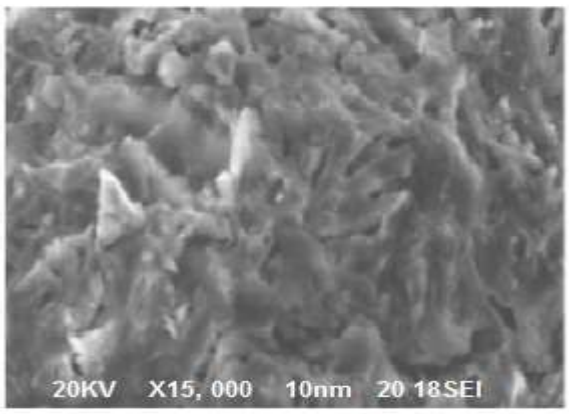

Figure 1 (B) S - 1 - OPC + 1 % Nano - SiO_2

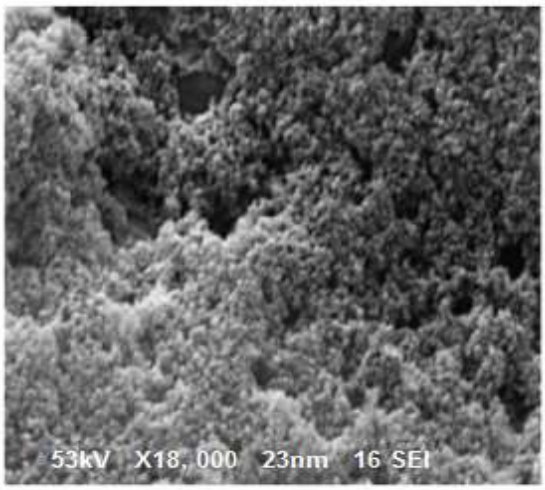

Figure 1 (C) S - 2 - OPC + 2 % Nano - SiO_2

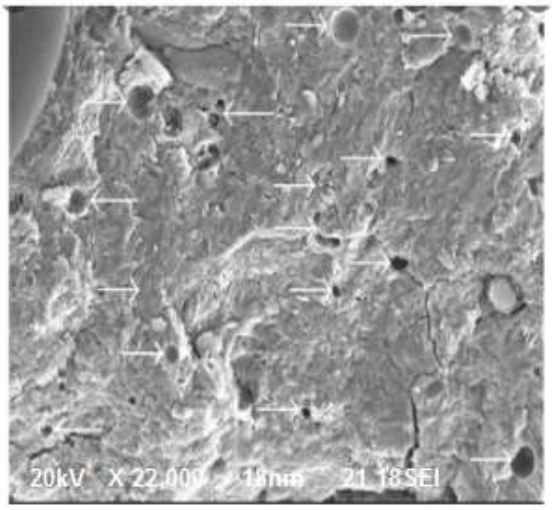

Figure 1 (D) S - 3 - OPC + 3 % Nano - SiO_2

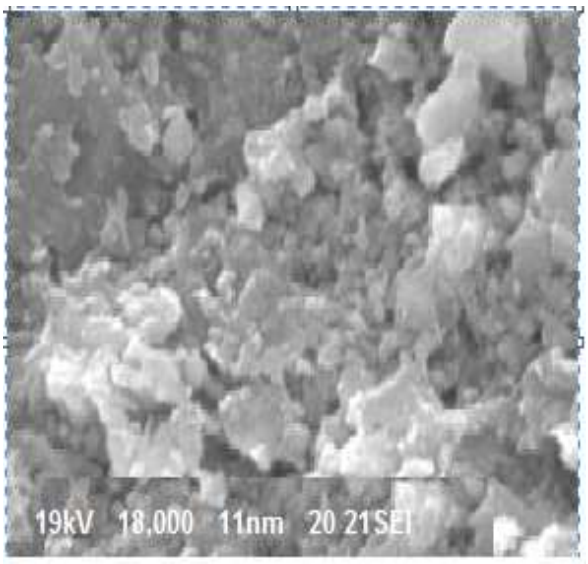

Figure 1 (E) S - 4 - OPC + 4 % Nano - SiO_2

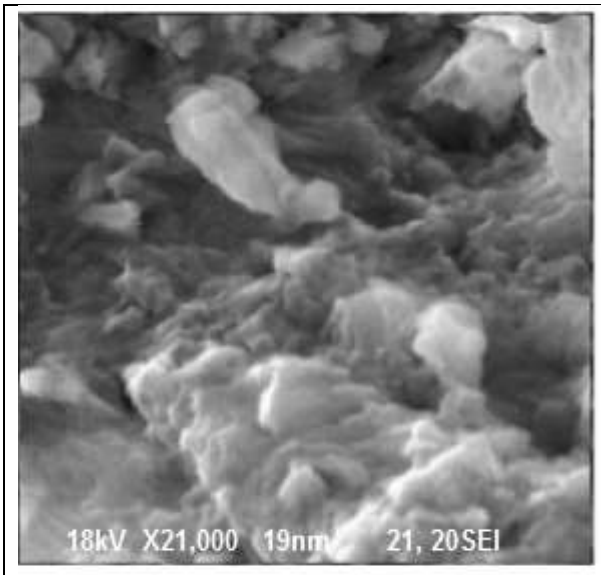

Figure 1 (5) S - 5 - OPC + 5 % Nano - SiO_2

5.1 Compressive strength of concrete in various mixesμ

The test is carried out conforming to IS 516 -1959 to obtain compressive strength of concrete at the 7, 14 and 28 days. The cubesare tested using a 15400 tonne capacity HELICO compressive testing machine (CTM). The test results are given in Table 5 and figures 2, 3&4

Table 5 Compressive strength of concrete

Days	Conventional concrete A- 0 Mix	S - 1 Mix (OPC + 1 % Nano - SiO_2)	S - 2 Mix (OPC + 2 % Nano - SiO_2)	S - 3 Mix (OPC + 3 % Nano - SiO_2)	S - 4 Mix (OPC+ 4 % Nano - SiO_2)	S - 5 Mix (OPC + 5% Nano - SiO_2)
7 days	27.76	30.22	44.90	43.00	34.88	26.66
14 days	37.32	44.40	54.44	48.76	42.22	34.42
28 days	46.66	28.22	72.88	53.68	53.78	42.66

5.1.1 7- Days compressive strength of concrete

The 7 days compressive strength of S - 5 Mix (OPC+ 5% Nano - SiO_2) concrete is more or less the same compared to conventional concrete. The S - 1 Mix (OPC + 1 % Nano - SiO_2), S - 2 Mix (OPC+ 2 % Nano - SiO_2), S - 3 Mix (OPC + 3 % Nano - SiO_2) and S - 4 Mix(OPC+ 4 % Nano - SiO_2) concrete is 8.89%, 61.17%, 55.25% and 25.645% of compressive strength has increased than the conventional concrete specimen. The results are given in Table.5 and Figure 2

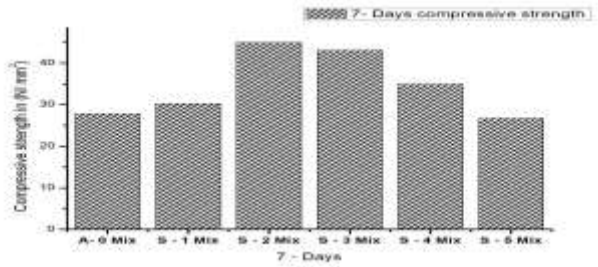

Figure 2,7- Days compressive strength of concrete

5.1.2 14- Days compressive strength of concrete

The 14 days compressive strength of S - 5 Mix (OPC+ 5% Nano - SiO_2) concrete is more or less the same compared to conventional concrete. The S - 1 Mix (OPC + 1 % Nano - SiO_2), S - 2 Mix (OPC+ 2 % Nano - SiO_2), S - 3 Mix (OPC + 3 % Nano - SiO_2) and S - 4 Mix (OPC+ 4 % Nano - SiO_2) concrete has 18.97% , 45.87%, 30.70% and 13.10% of compressive strength has increased than the conventional concrete specimen. The results are given in Table .5 and Figure.3

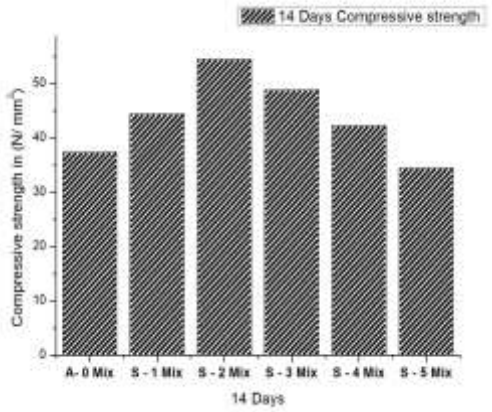

Figure 3, 14- Days compressive strength of concrete

5.1.3 28- Days compressive strength of concrete

The 28 days compressive strength of S - 5 Mix (OPC+ 5% Nano - SiO_2) concrete has 9.37% reduced than the conventional concrete. The S - 1 Mix (OPC + 1 % Nano - SiO_2), S - 2 Mix (OPC+ 2 % Nano - SiO_2), S - 3 Mix (OPC + 3 % Nano - SiO_2) and S - 4 Mix (OPC+ 4 % Nano - SiO_2) concrete has 9.37% , 56.19%, 15.04% and 15.25% of compressive strength has increased than the conventional concrete specimen. The results are given in Table .5 and Figure.4

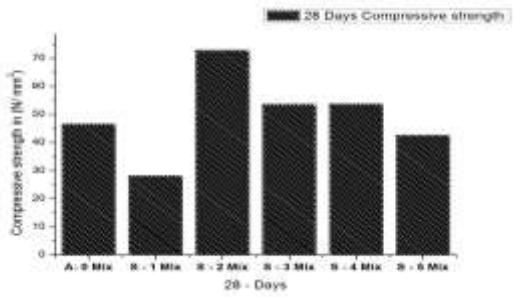

Figure 4, 28- Days compressive strength of concrete

The 7, 14, and 28 day's compressive strength, enhanced by S - 2 Mix (OPC+ 2 % Nano - SiO_2) mixes. Finally observed from the results the quarry dust may be a good bond with cement and coarse aggregate. The quarry dust may fill the voids in the concrete elements. Nano - SiO_2 **ma**y fill the voids in concrete. High dosage of nano - materials occupy more surface area, so that they produce moreheat during the hydration period. It may produce the more Tri -calcium silicate.

5.2 Tensile strength of concrete

The tensile strength is carried to IS 516-1959 to obtain tensile strength of concrete at the 7, 14 and 28 days. The cylinders are tested using 1400 tonne capacity HELICO tensile testing machine (CTM).The results are presented in Table 6 and Figure 5,6 , 7&8

Table.6 Tensile strength of concrete

Days	Conventional concrete A- 0 Mix	S - 1 Mix (OPC + 1 % Nano - SiO_2)	S - 2 Mix (OPC+ 2 % Nano - SiO_2)	S - 3 Mix (OPC + 3 % Nano - SiO_2)	S - 4 Mix (OPC+ 4 % Nano - SiO_2)	Mix (OPC+ 5% Nano - SiO_2)
7 days	2.82	3.022	4.53	4.324	3.512	2.85
14 days	3.82	4.62	5.624	5.124	4.406	4.253
28 days	4.84	5.046	7.424	5.570	5.482	4.73

5.2.1 7- Days tensile strength of concrete

The 7 days tensile strength of S - 5 Mix(OPC + 5 % Nano - SiO2)concrete is more or less the same compared to conventional concrete. The S - 1 Mix (OPC + 1 % Nano - SiO_2), S - 2 Mix (OPC+ 2 % Nano - SiO_2) , S - 3 Mix (OPC + 3 % Nano - SiO_2) and S - 4 Mix (OPC+ 4 % Nano - SiO_2) concrete has 7.16 % , 60.63%, 53.33% and 24.53% of tensile strength has increased compare than the conventional concrete specimen. The results are given in Table.6 and Figure 5.

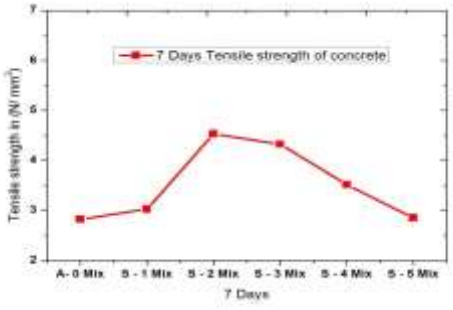

Figure 5, 7- Days tensile strength of concrete

5.2.2 14- Days tensile strength of concrete

The 14 days tensile strength of S - 5 Mix (OPC+ 5% Nano - SiO_2) concrete is more or less the same compared to conventional concrete. The S - 1 Mix (OPC + 1 % Nano - SiO_2), S - 2 Mix (OPC+ 2 % Nano - SiO_2) , S - 3 Mix (OPC + 3 % Nano - SiO_2) and S - 4 Mix (OPC+ 4 % Nano - SiO_2) concrete has 20.94 % , 47.22 %, 34.13 % and 15.34 % of tensile strength has increased compare than the conventional concrete specimen. The results are given in Table.6 and Figure 6.

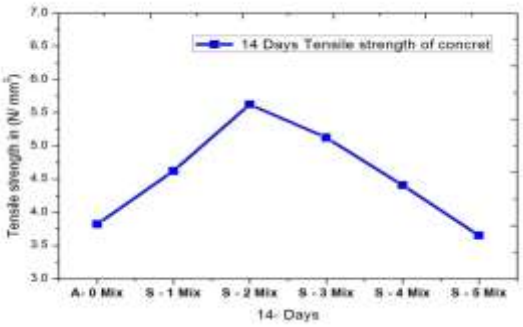

Figure 6, 14- Days tensile strength of concrete

28- Days tensile strength of concrete

The 28 days tensile strength of S - 5 Mix (OPC+ 5% Nano - SiO_2) concrete has 2.232% reduced than the conventional concrete. The S - 1 Mix (OPC + 1 % Nano - SiO_2), S - 2 Mix (OPC+ 2 % Nano - SiO_2), S - 3 Mix (OPC + 3 % Nano - SiO_2) and S - 4 Mix (OPC+ 4 % Nano - SiO_2) concrete has 4.25 % , 53.38 %, 15.08 % and 13.26 % of compressive strength has increased compare than the conventional concrete specimen. The results are given in Table.6 and Figure 7

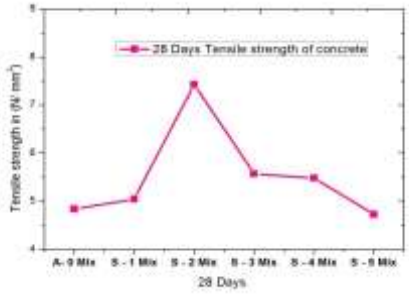

Figure 7 , 28- Days tensile strength of concrete

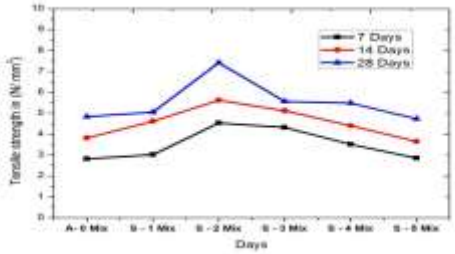

Figure 8 - 7, 14 & 28- Days tensile strength of concrete

The 7, 14, and 28 day's tensile strength, enhanced by S - 2 Mix (OPC + 2 % Nano - SiO_2) mixes. Finally observed from the results the Nano - SiO_2added up to 2 % , the tensile strength increased gradually compared to the other mixes. Nano - SiO_2 **ma**y fill the voids in concrete. High dosage of nano - materials occupy more surface area, so that they produce moreheat during the hydration period. It may produce tri -calcium silicate.

5.3 Flexural strength of concrete

The test is carried out conforming to IS 516 -1959 to obtain flexural strength of concrete at the 28 days are tested using loading frame 750 kN. The results are given in Table.7 and Figure 9.

Table. 7 Flexural strength of concrete

Days	Conventional concrete A- 0 Mix	S - 1 Mix (OPC + 1 % Nano - SiO_2)	S - 2 Mix (OPC+ 2 % Nano - SiO_2)	S - 3 Mix (OPC + 3 % Nano - SiO_2)	S - 4 Mix (OPC + 4 % Nano - SiO_2)	S - 5 Mix (OPC+ 5% Nano - SiO_2)
28 Days	5.67	6.61	6.65	7.35	6.02	7.06

The 28 days flexural strength of concrete, the S - 1 Mix (OPC + 1 % Nano - SiO_2), S - 2 Mix (OPC+ 2 % Nano - SiO_2), S - 3 Mix (OPC + 3 % Nano - SiO_2) , S - 4 Mix (OPC+ 4 % Nano - SiO_2) and S - 5 Mix (OPC+ 5% Nano - SiO_2) concrete is 16.57 % , 17.28 %, 29.62 %, 6.17 % and 21.15 % of flexural strength is increased compare than the conventional concrete specimen. Finally observed from the results, the S - 3 Mix (OPC + 3 % Nano - SiO_2) mix has given the better flexural strength than the other mixes. Generally the plastic materials have a good ductile nature. In this regard Nano - SiO_2 may be more ductile, so flexural strength may be increased , when high dosage of nano-materials are added in concrete.

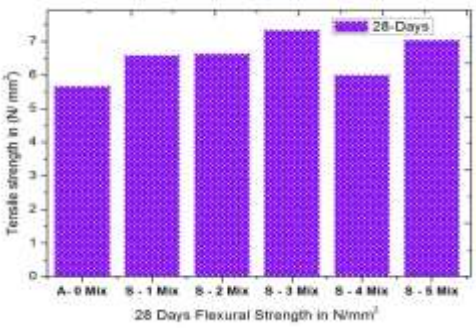

Figure 9 - 28- Days flexural strength of concrete

5.4 Durability test

5.4.1 Percentage of water absorption test

The 28 days water absorption was carried out on ASTM method. The test results are presented in Table 8 and Figure 10.

Table.8 Percentage of water absorption test

s.no	Types of mix	% of water absorption
1	Conventional concrete A- 0 Mix	5.67
2	S - 1 Mix (OPC + 1 % Nano - SiO_2)	4.41
3	S - 2 Mix(OPC + 2 % Nano - SiO2)	6.65
4	S - 3 Mix(OPC + 3 % Nano - SiO2)	8.35
5	S - 4 Mix (OPC+ 4 % Nano - SiO_2)	8.51
6	S - 5 Mix (OPC+ 5% Nano - SiO_2)	8.56

The % of water absorption, the S - 1 Mix (OPC + 1 % Nano - SiO_2) concrete has 6.35% decreased than the conventional concrete specimen. S - 2 Mix(OPC + 2 % Nano - SiO2), S - 3 Mix(OPC + 3 % Nano - SiO2) ,S - 4 Mix (OPC+ 4 % Nano - SiO_2) and S - 5 Mix (OPC+ 5% Nano - SiO_2) concrete has 17.28 % , 47.26 % , 27.73 % and 33.33 % of water absorption has increased compare than the conventional concrete specimen. Finally observed from the results S - 1 Mix (OPC + 1 % Nano - SiO_2) mix has been given better impermeability of concrete. Nano - SiO_2 **ma**y fill the voids in concrete. High dosage of nano - materials occupy more surface area, so that they produce moreheat during the hydration period. During the hydration period required more quantity of water.

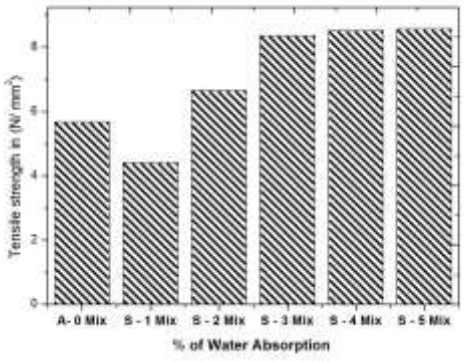

Figure 10 - % of water absorption test

5.4.2 Percentage of Acid Penetration test

The Acid penetration test was carried out on ASTM method. The test results are presented in Table 9 and Figure 11.

Table.9 Percentage of acid penetration test

s.no	Types of mix	% of Acid penetration
1	Conventional concrete A- 0 Mix	6.61
2	S - 1 Mix (OPC + 1 % Nano - SiO_2)	5.12
3	S - 2 Mix(OPC + 2 % Nano - SiO2)	5.05
4	S - 3 Mix(OPC + 3 % Nano - SiO2)	9.16
5	S - 4 Mix (OPC+ 4 % Nano - SiO_2)	7.15
6	S - 5 Mix (OPC+ 5% Nano - SiO_2)	8.25

The % of acid penetration test results are as shown in Figure 11 and table 9, the S - 1 Mix (OPC + 1 % Nano - SiO_2) andS

- 2 Mix(OPC + 2 % Nano - SiO2) concrete is 29.10 % and 30.89 % decreased than the conventional concrete specimen. S - 3 Mix(OPC + 3 % Nano - SiO2), S - 4 Mix (OPC+ 4 % Nano - SiO_2) and S - 5 Mix (OPC+ 5% Nano - SiO_2) concrete has 38.57 % , 8.16 % and 24.81 % of acid penetration has increased compare than the conventional concrete specimen. Finally observed from the results the S - 1 Mix (OPC + 1 % Nano - SiO_2) mix has been given better acid resistance than the other mix of concrete. **Generally the Nano - SiO2 has more silica content**, In this regard silica has good corrosion and acid resistance. High dosage of nano - materials produce the mostheat during the hydration period.

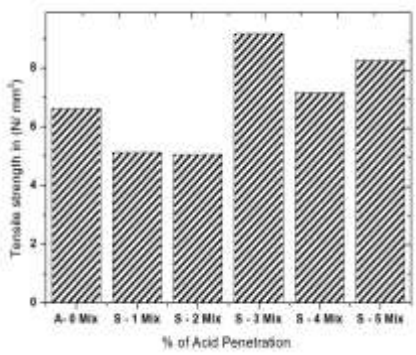

Figure 11 - % of Acid penetration test

5.4.3 Percentage of permeability test

The **Percentage of** permeability test carried out on ASTM method. The test results are presented in Table 9 and Figure 12.

Table.9 Percentage of permeability test

s.no	Types of Mix	% of permeability test
1	Conventional concrete A- 0 Mix	
2	S - 1 Mix (OPC + 1 % Nano - SiO_2)	
3	S - 2 Mix(OPC + 2 % Nano - SiO2)	
4	S - 3 Mix(OPC + 3 % Nano - SiO2)	
5	S - 4 Mix (OPC+ 4 % Nano - SiO_2)	
6	S - 5 Mix (OPC+ 5% Nano - SiO_2)	

The % of permeability test results are as shown in Figure12 and Table 9. The S - 1 Mix (OPC + 1 % Nano - SiO_2) and S - 2 Mix(OPC + 2 % Nano - SiO2) concrete is 35.67 % and 7.87 % decreased than the conventional concrete specimen. S - 3 Mix(OPC + 3 % Nano - SiO2), S - 4 Mix (OPC+ 4 % Nano - SiO_2) and S - 5 Mix (OPC+ 5% Nano - SiO_2) concrete has 45.79 % , 19.67 % and 39.35 % of permeability has increased compare than the conventional concrete specimen. Finally observed from the resultsS - 1 Mix (OPC + 1 % Nano - SiO_2) and S - 2 Mix(OPC + 2 % Nano - SiO2) mix has been given better impermeability of concrete. Nano - SiO_2**may fill the voids in concrete.**

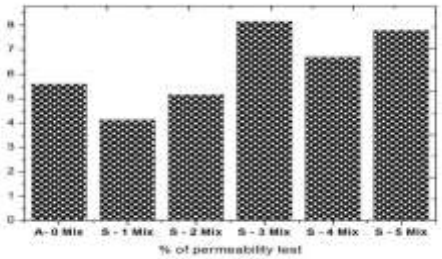

Figure 12 - % of permeability test

VI CONCLUSIONS

1. The conclusion of this project reports the nano - materials have been used in concrete effectively and develop the high strength concrete.
2. Observed from the results, the 7, 14, and 28 day's compressive and tensile strength, enhanced by S - 2 Mix(OPC + 2 % Nano - SiO_2). The nano - materials may be good bonds with cement and coarse aggregate. The nano - SiO_2may fill the voids in the concrete elements.
3. The flexural test results S - 3 Mix(OPC + 3 % Nano - SiO_2) mix have given the better flexural strength than the other mixes. Generally some of the nano - materials have a good ductile nature. In this regard Nano - SiO_2 may be more ductile, so that the flexural strength may be increased.
4. Durability performance, the S - 1 Mix (OPC + 1 % Nano - SiO_2) and S - 4 Mix (OPC+ 4 % Nano - SiO_2) mix have been given better impermeability of concrete. Nano - SiO_2 may fill the voids in concrete.
5. Acid resistance of S - 2 Mix(OPC + 2 % Nano - SiO2) mix has been given better acid resistance than the other mix of concrete. Generally the fly ash has more silica content. In this regard silica has good corrosion and acid resistance.

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