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An Experimental Study on Effect of NANO Silica, Mechanical and Durability Behavior of Concrete by Using OPC and Blended Cement

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Abstract:
The Construction Industry is a major consumer of material and energy sources of India. Among all the materials used in construction, concrete is one the most consumed material after water on the earth for infrastructure & construction industries. Meanwhile, nanotechnology is one of the most influential technologies in this century and it has significantly attracted the construction sector. The aim of this study is to investigate the effect of Nano-silica and mechanical and durability properties at different ages of concrete. Nano-silica used as partial replacement for Ordinary Portland Cement (OPC) and Blended cement in concrete with different proportion such as 0%, 1.5%, 3.5%, 5.5% and 7.5%.

Nano-silica particles with size of 17 nm have been used. Mechanical properties have been investigated such as Compressive strength through testing the cube specimen size is 150*150*150 mm for concrete at 7,14 and 28day.Durability properties have been investigated such as The Rapid Chloride Permeability Test (RCPT) through testing the standard cylindrical disc specimens of size 100*50mm for concrete at 7,14 and 28days. In RCPT, Sodium chloride (NaCl) solution 2.4M and Sodium Hydroxide (NaOH) solution 0.3M, concentration solutions are used for testing.

The compressive strength of the hardened concrete also decreased with increasing PPC replacement with Nano-silica. It is recommended that further studies be carried out to gather more facts about the suitability of partial replacement of OPC & Blended Cement with Nano-Silica in concrete.

Key Words:
Nano silica, Cement type: OPC and Blended Cement.

1. INTRODUCTION:

Ground water contains high concentrations of sulfate, chloride, and other chemicals which posses serious challenges to infrastructure construction that routinely utilizes Portland cement concrete. concrete is one the most consumed material after water on the earth for infrastructure & construction industries, a commendable contribution cam be made by optimizing the use of cement and natural resources in concrete manufacturing. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of non-conventional and innovative materials, and reusing of waste materials in order to compensate the lack of natural resources and to find alternative ways for conserving the environment.

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In this research, silica fume is initially considered as a waste material which could have a future in construction industry. Recently, there are large numbers of applications of nanotechnology in the construction engineering field. Nano technology is one of the most influential technologies in this century and it has significantly attracted the construction sector. Engineering concrete at the nanometer scale includes the incorporation of nano sized particles into concrete at suitable proportions and methods. The basic concept behind using nano material which are having large surface area is to improve compressive strength at early ages, improved hydration characteristics and reduced porosity and water absorption when compared with conventional cementitious materials. Investigating how nano material improved strength of concrete and durability and found that very little amount of nano materials like nano silica in concrete can improve the compressive strength and durability of concrete.

1.1Pozzolanic Material used in Concrete:

Pozzolans are generally defined as siliceous or siliceous and aluminous materials which are not cementitious by themselves but in finely divided form, when react with lime in the presence of water, produce compounds possessing cementitious properties.

1.2Nano Silica:

Nano silica is a byproduct of producing silicon metal or ferrosilicon alloys. It is typically a highly effective pozzolanic material. Nano silica normally consists of very fine vitreous particles approximately 1000 times smaller than the average cement particles. The most beneficial use of silica fume in concrete is a very reactive pozzolane and it gives high strength and durable. Silica fume is in Nano form has more specific surface, than silica fume. Due to its form and specific surface area, the Nano silica fills the voids and makes the interfacial transition zone in concrete stronger. Due to the improved properties of interfacial transition zone the concrete properties like strength and durability will also be improved.

Nano silica reduces the setting time and increases the compressive strength of resulting cement in relation with other silica components that were tested . Nano-silica is direct synthesis of silica sol or crystallization of nano-sized crystals of quartz. Utilization of waste materials in cement and concrete industry reduces the environmental problems. In this present research work OPC and Blended cement is replaced with Nano silica in different percentages i.e., 0%, 1.5%, 3.5%, 5.5% & 7.5% respectively while increase in replacement of Nano silica in OPC upto 3.5% increases the strength and further increment of Nano silica decreases the strength. High volume of Nano silica concrete gains strength in long duration compared to other. It resists alkali-silica reaction which results in a longer life for concrete. Cement with Nano silica reduces the permeability of concrete and replacement of Nano silica in cement will benefit both the fresh and hardened states of concrete.

1.3Advantages of using Nano Silica:

1. Nano silica reduces the heat of hydration.
2. Nano silica reduces the setting time.
3. Nano-silica is applied in HPC and SCC concrete mainly as an anti-bleeding agent.
4. Nano silica reduces the micro cracking of concrete and improves the soundness of concrete.
5. It improves the strength and durability of concrete.

1.4 Necessity for Using Supplementary Materials:

- To find an alternative for the ordinary Portland cement.
- To reduce CO2 emissions.
- To produce eco-friendly concrete.
- To develop a cost-efficient concrete.
- To provide high strength and durability to the OPC and Blended cement concrete.

1.5Objectives:

- To study the use of Nano Silica in the production of normal strength concrete.
- To study XRD results to know and ensure the Nano form of silica.

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- To study the different strength properties of Nano silica concretes.
- To study the variations of Compressive strength, and RCPT of Nano silica at early age and late ages of concrete compared to OPC and PPC concrete.

2. LITERATURE REVIEW:

This chapter presents the literature on a short review of the terminology and also the past studies on silica fume. A comprehensive review of the work of earlier investigators on using ordinary Portland cements; studies on the activation of low-calcium and high-calcium fly ashes and natural pozzolans; studies on the Nano Silica addition of properties of concrete, namely workability, mechanical durability properties; and some of the literature used to study the partially replaced by Nano silica combination to find out the properties of concrete have also been presented. The literature review mainly focusseson the studies of mix proportioning methods; effect of elevated temperature; mechanical and durability properties and influence of Nano silica in concrete. The available published literatures on Nano silica is reviewed and presented.

S. Maheswaran Themain aim of this paper is an overview of the influence of nanosilica in concrete. Nanotechnology finds application in various fields of science and technology and this article presents a critical review of the literature on the influence of nano silica in concrete and its application for the pore filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects.

AlirezaNajiGivi (2010)[(1)]et al explained the effects of SiO_2nano particles on both physical properties (water permeability, workability and setting time) and mechanical properties (compressive, split tensile and flexural strength) of binary blended concrete have been investigated. It was concluded that the SiO_2nano particles can improve the filler effect and its ultra high pozzolanic activity causes more C–S–H gel formation when cured in lime solution, and the lime solution can reduce the strength of control concrete.

3. MATERIALS AND EXPERIMENTATON

3.1 Materials:

The cement used in this study is Ordinary Portland Cement and Blended Cement is used for cocrete. And for the concrete cubes and cylinders used the OPC and PPC cement. The two types of fine aggregate should used for this study. For the concrete specimen used the local available fine aggregate . The nano silica is used as the pozzolanic material in this study to improve the mechanical and durability properties of the material.

3.2 Nanosilica:

The nano silica is purchased from Astraa chemicals at Chennai. The used nano silica having the pH value is 4.12. The particle size of the nano silica is 17 Nanometers. In the present experimental investigation, 1.5%,3.5%,5.5%, and 7.5% of nano silica has been replaced with the cement.

Fig. 1: NANO SILICA

Table 1: properties of nano silica

Test item	Standard requirements	Test results
Specific surface area (M^2/G)	200±20	202
pH value	3.7-4.5	4.12
Loss on drying @105^0 C	≤1.5	0.47
Loss on ignition @1000^0 C (%)	≤2.0	0.66
Sieve residue	≤0.04	0.02
Tampered density g/L	40-60	44
SiO^2 content	≥99.8	99.88

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(%)		
Carbon content (%)	≤0.15	0.66
Chloride content (%)	≤0.0202	0.009
Al_2O_3	≤0.03	0.005
TiO_2	≤0.02	0.004
Fe_2O_3	≤0.003	0.001
Specific gravity	2.2-2.4	
Particle size	17 nm	

3.3 Mix Proportions:

In the present investigation M_{25} grade concrete is used with a constant W/C ratio of 0.45. Concrete mixes were prepared by varying the percentage of replacement of cement with Nano Silica (1.5%, 3.5%, 5.5% and 7.5%) replacement in cement.

3.4 Casting of Specimens:

A total of 135 specimens have been casted out of which 45 were cubes, 90 were cylinders (RCPT). For each test 3 specimens were tested and average value is considered for the investigation. 150mm × 150mm × 150mm size cubes, standard cylinders of 50mm height × 100mm dia were casted. The compressive strength and RCPT tests were done for the specimens at 7 days, 14 days, and 28 days.

4. Experimental Investigation:

The concrete mix proportions were determined for M_{25} grade concrete as per the guide lines given in IS 10626 – 2009. In the present investigation cement, has been replaced with different percentages of Nano silica i.e., by 1.5%, 3.5%, 5.5%, and 7.5%. For study of various properties, concrete specimens were casted and tested. Constant water-cement ratio of 0.40 has been adopted. The experimental investigation started with selection of materials and followed by their testing, casting of specimens and curing, and finally by testing the specimens.

4.1Compressive Strength Test:

Concrete specimens, cubes of sizes 150mm×150mm×150mm were tested for crushing strength. Compressive strength depends on many factors such as w/c ratio, cement strength, quality of concrete material and quality control during production of concrete. Compression test on cube was conducted with 2000KN capacity compression testing machine. The specimens were placed centrally on the base plate of the machine and the load was applied gradually at the constant rate of 140 kg/cm^2/min till the specimen failed. The maximum load applied was noted for each test. The specimen results were calculated at 7days, 14days, and 28days and noted. The cube compressive strengths of various concrete mixtures are presented in graphical form. The crushing strength is the ratio of failure load to the area of cross section of specimen. The cube compressive strength can be calculated as follows.If f_c is the cube compressive strength,

Then $F_C=P/A$ N/mm^2

Where, P is an ultimate load in Newtons, A is a cross sectional area of cube in mm^2

Fig. 2: Compressive strength testing mechine

4.32Rapid Chloride Permeability Test [RCPT]:

RCPT has been performed as per ASTM-C-1202 to determine the electrical conductance and chloride permeability of concrete. RCPT is performed by monitoring the amount of electrical current that passes through a sample of 50 mm × 100 mm diameter for 6 hours and maintained 60 V DC voltage current constant across the ends of the sample throughout the test. One lead is immersed in a Sodium Cholride (NaCl) solution 2.4% and the other in a Sodium Hydroxide (NaOH) solution 0.3 N.

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The RCPT test set-up is shown in Fig. 6. From the current readings, total charge passed is calculated using the Eqn(1).

$Q = 900(I_0 + I_{360} + 2(I_{30} + I_{60} + : : : : : : : : : + I_{300} + I_{330}))$

where, Q – Charge passes (Coulomb),

I_0 – current (ampere) immediately after voltage is adapted, and

I_{360} – current (ampere) at 360min after voltage is applied.

Fig. 2: RCPT

Table 2: Rating of chloride permeability

S.NO.	Charge passing in coulombs	Chloride permeability rating
1.	Greater than 4000	High
2	2001 to 4000	Moderate
3.	1001 to 2000	Low
4.	100 to 1000	Very low
5.	Less than 100	Negligible

Table 3: Mix Designations of Concrete used in the Study

S.No	Mix designations	Binding materials
1	A1,	Conventional OPC concrete.
2	A2	1.5% replacement of OPC with Nano Silica.
3	A3	3.5% replacement of OPC with Nano Silica
4	A4	5.5% replacement of OPC with Nano Silica
5	A5	7.5 replacement of OPC with Nano Silica.
6	B1	Conventional PPC concrete
7	B2	1.5% replacement of PPC with Nano Silica.
8	B3	3.5% replacement of PPC with Nano Silica.
9	B4	5.5% replacement of PPC with Nano Silica.
10	B5	7.5% replacement of PPC with Nano Silica.

5. RESULTS AND DISCUSSIONS

5.1 Compressive Strength:

Compressive strength of concrete is considered as the important property of concrete since it gives the overall picture of the concrete quality.

5.1.1Effect of Nano Silica on Compressive Strength of Concrete by using OPC:

Table 4: Compressive strength test results for Nano Silica by using OPC

Mix designations	Proportions of Binding Materials	Compressive strength N/mm²		
		7-Days	14-Days	28-Days
A1	100% cement	15.28	21.13	29.72
A2	98.5% cement +1.5% Nano Silica	17.36	22.45	31.19
A3	**96.5% cement + 3.5% Nano Silica.**	**18.37**	**23.36**	**32.26**
A4	94.5% cement + 5.5% Nano Silica.	16.89	21.26	30.36
A5	92.5% cement + 7.5% Nano Silica	16.10	20.13	29.48

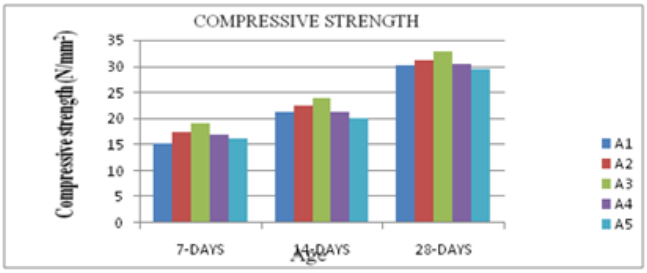

Fig. 3: Effect of Nano Silica on concrete by using OPC.

5.1.2. Effect of Nano Silica on Compressive Strength of Concrete by using PPC:

Table 5: Compressive strength test results for Nano Silica by using PPC

Mix designations	Proportions of Binding Materials	Compressive strength N/mm²		
		7-Days	14-Days	28-Days
B1	100% cement	17.12	23.41	30.14
B2	98.5% cement +1.5% Nano Silica	17.55	23.98	32.61
B3	96.5% cement + 3.5% Nano Silica.	**18.47**	**24.93**	**34.73**
B4	94.5% cement + 5.5% Nano Silica.	16.68	22.84	31.16
B5	92.5% cement + 7.5% Nano Silica	15.39	21.02	29..99

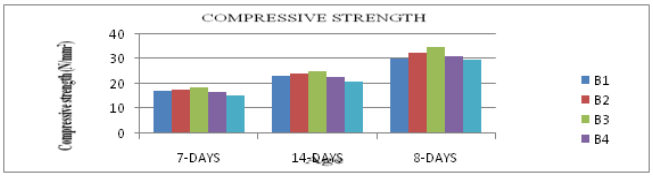

Fig.4: Effect of Nano Silica on concrete by using PPC.

5.2Rapid Chloride Permeability Test:

5.2.1 Effect of Nano Silica on Rapid Chloride Permeability Test of Concrete by using OPC:

Table 6: Rapid Chloride Permeability Test test results for Nano Silica by using OPC

Mix designations	*Proportions of Binding Materials*	*Average value in coloumbs*		
		7-Days	14-Days	28-Days
A1	100% cement	6543 H	5183 H	4283 H
A2	98.5% cement +1.5% Nano Silica	5992 H	4955 H	3973 M
A3	96.5% cement + 3.5% Nano Silica.	5278 H	4250 H	3228 M
A4	94.5% cement + 5.5% Nano Silica.	4681 H	3274 M	2682 M
A5	92.5% cement + 7.5% Nano Silica	3003 M	2101 L	1870 L

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*H=High *M=Modarate * L=Low

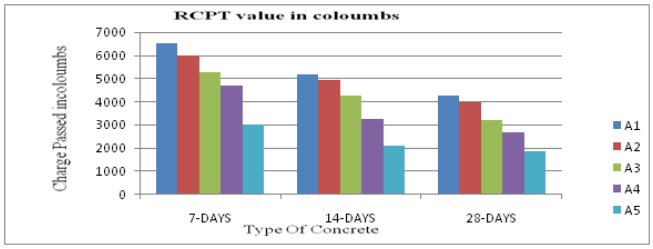


Fig.5: Average values of rapid chloride penetration

5.2.2 Effect of Nano Silica on Rapid Chloride Permeability Test of Concrete by using PPC:

Table 7: Rapid Chloride Permeability Test test results for Nano Silica by using PPC

Mix designations	*Proportions of Binding Materials*	*Average value in coloumbs*		
		7-Days	14-Days	28-Days
B1	100% cement	5820 H	4699 H	3701 M
B2	98.5% cement +1.5% Nano Silica	4732 H	3731 M	2689 M
B3	96.5% cement + 3.5% Nano Silica.	4024 H	2645 M	2062 L
B4	94.5% cement + 5.5% Nano Silica.	3672 M	2095 L	1979 L
B5	92.5% cement + 7.5% Nano Silica	2113 L	1521 L	1122 L

*H=High *M=Modarate * L=Low

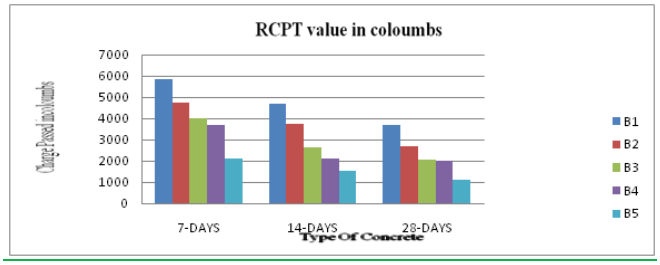
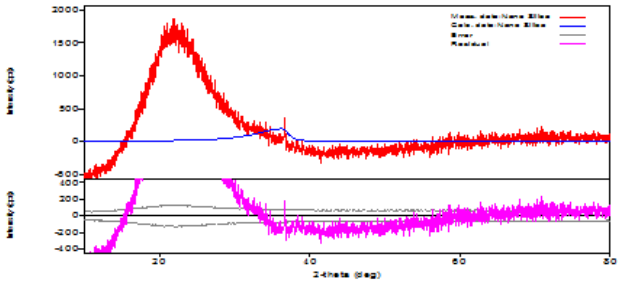


Fig.6: Average values of rapid chloride penetration

5.3 X-Ray Diffraction:



Graph : X – Ray Diffraction for nano silica

5.4 Scanning electron microscope analysis (SEM analysis):

SEM analysis for 0% concrete

SEM analysis for 1.5% Nano SiO2

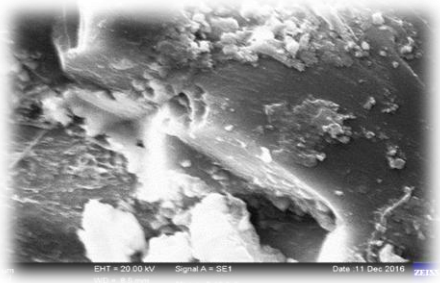


Fig a- SEM analysis for 0% concrete

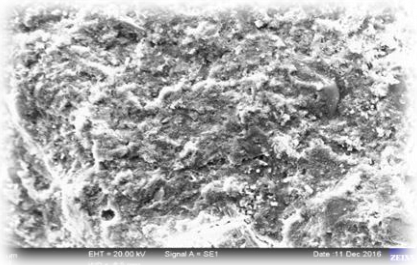


Fig b- SEM analysis for 1.5% Nano SiO2

SEM analysis for 3.5% Nano Silica

SEM analysis for 5.5% Nano Silica

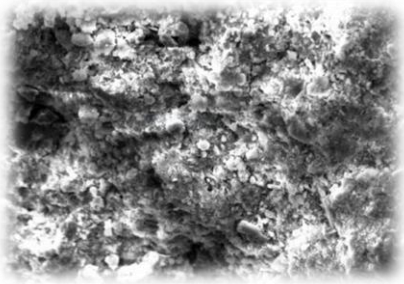


Fig c-SEM analysis for 3.5% Nano SiO2

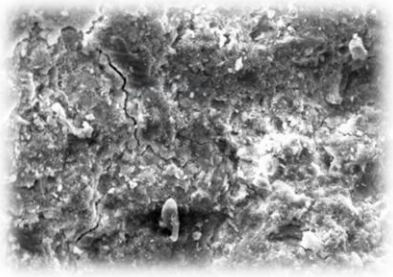


Fig d-SEM analysis for 5.5% Nano SiO2

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SEM analysis for 7.5% Nano Silica

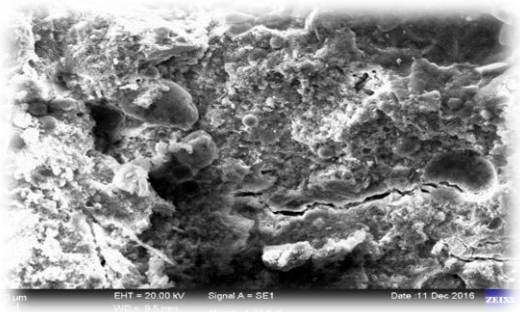

Fig e-SEM analysis for 7.5% Nano SiO2

6. CONCLUSION:

Based on the results obtained from the presented study, the following conclusions are made by

1. The present investigation results show that Nano silica silica exhibit better pozzolanic effect in M_{25} grade OPC and PPC concrete.
2. The compressive strength of M_{25} grade OPC concrete increases at all ages.
3. When OPC is partially replaced by Nano silica f in concrete, the highest compressive strength can be obtained by replacing OPC with 3.5% silica fume.
4. When PPC is partially replaced by Nano silica f in concrete, the highest compressive strength can be obtained by replacing PPC with 3.5% silica fume
5. The workability of M_{25} grade of OPC and PPC concrete can be improved by using Nano silica.
6. By increasing Nano silica content gradually, durability property is improved. Rapid chloride permeability test show that Nano silica gives very less chloride permeability than conventional concrete.
7. Concrete of the Nano Silica upto 3.5% is economical, environmental friendly and sustainable.

6.1 Scope for Future Study:

1. The mechanical and durability properties of concretes with the Nano silica replacements for cement in concrete can be studied by using superplasticizers and other combination of materials.
2. The suitability of these concretes for RCC can be studied.
3. Other durability studies can be carried on these concretes.
4. The workability properties of these concretes can be studied and self-compaction concretes with the combinations of Nano silica can be studied
5. High strength, high performance concretes with the above combination can be tried.

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