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Study on Strength and Durability Properties of High Performance Concrete Incorporating Nano-Silica

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ABSTRACT: Concrete is the commonly used building material everywhere but it's maintenance in severe exposure areas are really challenging for engineers. In order to attain better performance throughout its lifetime without detrimental to its quality, it is recommended to use high performance concrete (HPC). High Performance Concrete is mostly preferable for its durability and strength which is suitable for long term structures and heavily loaded bridges. In this project, a mix ratio is arrived for high graded concrete and an optimum percentage of silica fume (SF) is added as pozzolanic reactor. Nano silica (nS) is a suitable cementitious material for packing the voids in concrete and added in various proportions to improve the density and impermeability. Addition of nS and SF may reduce the workability in order to fulfil the needs of fresh concrete super plasticizer (Conplast SP430 G8) is used. The mechanical and durability properties of HPC with varying parameters were studied. The optimum level of nS in HPC was found by considering the relevant tests.

KEYWORDS: High performance concrete, nano silica, silica fume.

I. INTRODUCTION

Concrete is the material standing in front of our mind when we think of construction unconsciously. In India the annual consumption of concrete exceeds hundred million cubic meters. Being in the usage for many decades still concrete rules the construction world. It starts as a composite material consists of various size of aggregates, the binder cement and water. The basic sense makes to convince that the characteristic strength of a concrete is inversely proportional to water binder ratio. To attain the state of high strength the water cement is reduced from the normal level to a low water content that sufficient for hydration. So in order to have a high graded concrete the water cement ratio is limited as 0.20 to 0.40.

There are lots of improvements and innovations have emerged in concrete industry, the one that satisfies the engineer with their needs during casting and gives long lifetime is High Performance Concrete (HPC). Generally the high performance concrete is the special type of concrete that has been designed to be durable and stronger than convectional concrete. It is far superior to normal concrete as the ingredients of HPC contribute most optimally and efficiently to the various properties. High performance concrete is same as high strength concrete but only the difference is HPC is workable and durable.

II LITERATURE SURVEY

Nano technology has its separate path in every industry. Concrete is not a stipulated material to be develop without nano technology. Nano usage makes a remarkable benchmark in concrete applications. Nano concrete becomes a special type concrete with most advantageous compared to other types. Nano concrete is the concrete that contains nano material as a cementitious material. Lot of materials were used in concrete, each had separate features like,nano $CaCO_3$, nano silica, nano alumina, nano titanium, etc., on comparing all the materials with concrete, a number of laboratory tests revealed that nano silica gives more useful results.

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Vivek, et, al., had explained about the flexural behaviour of the nano silica concrete beams. He used nano silica in three proportions namely, 5, 10 and 15%. He analysed the load carrying capacity, flexural rigidity and the relation between load and deflection and got better results in the higher order replacement.

Bernal, et, al., studied on the behaviour of fresh and hardened self-compacting concrete with addition of nano silica and silica fume. They used nano silica and micro silica in standard incremental proportions of volume of cement. The assessed the following parameters: flow test, box test and funnel test for fresh concrete and compressive strength, tensile strength and modulus of elasticity for hardened concrete. They had concluded that the optimum results attained at 2.5% of nano silica and 2.5% of micro silica to the volume of cementitious material. Additionally they also reported that the compressive strength depends on the particle size, amount of admixture and particle size distribution.

S.Chithra, et al., investigated about the compressive strength of high performance concrete with nano silica. They used nano silica as a partial replacement for cement and copper slag as partial replacement for fine aggregate. They had dealed with various ratios using multiple regression analysis and artificial neural network.

Li, et al., examined the microstructure and impermeability of concrete with nano silica. They worked with two test procedures: water permeability and water absorption by capillary action. He also investigated some microstructural features and finally resulted as 2-6% of nano silica gives expected improvement in the concrete than higher proportions.

Omar, et al., concentrated on the durability properties of the concrete that contains nano and micro silica. The nano and silica particle combination directly protect the steel in the beam from corrosion as they increase the impermeability. This combination also increase the mortar sulphate resistance upto 16%. The durability properties are improved to a higher level with the nano and micro silica added at 2 and 8 percent of the cement.

Pedro, et al., reported on the durability of high performance concrete made with different pozzolanic materials. He experimentally investigated on 12types of concrete and evaluated water absorption by both immersion and capillary action, resistance to carbonation and chloride penetration and the permeability of oxygen tests. Finally he proved that densified silica fume is suitable to use as an additional ingredient in the production of high performance concrete.

Saber compared with the pozzolans and fibres separately. He used the nano silica and silica fume as the cementitious materials additionally to the cement and the fibres, macro polymeric and the polypropylene fibres. He used 28 different test groups and related the test results of mechanical and durable parameters. The optimum percentage of the fibres were 0.25% macro polymeric fibre and 0.1% polypropylene fibre whereas for the nano silica and silica fume were 3% and 10%. He also proved experimentally that the silica group gives much better improvement in both mechanical and durability properties than that of fibre group. And the concrete with both silica group and the fibres does not give any special advantages.

III. EXPERIMENTAL INVESTIGATION

A. MATERIALS USED

In this study, ordinary portland cement of grade 53 was used as per IS 12269-2013[] and its quality is verified based on IS 4031[].The basic properties of cement of were checked based on the guidelines in the codal provisions and listed below in table 1.

Table 1: properties of cement

Specific gravity	3.13
Fineness (m^2/kg)	225
Initial setting time	29min
Final setting time	420min

Nearby local river sand was used as fine aggregate and 20mm sized aggregate was used as coarse aggregate. Their properties were verified as per and listed below in table 2.

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Table 2: properties of aggregates

Properties	FA	CA
Specific gravity	2.62	2.67
Fineness modulus	3.25	6.89
Loose Bulk Density	1420	1560
Rodded Bulk Density	1580	1670

i. Silica fume

Micro levels of silicondioxide are named as silica fume. The silica fume is purchased from Bhaskara Building Solutions, a company in nearby region. Its properties composition was certified in table3 as follows:

Table 3: Details of Silica Fume

SiO2	93.5
Al_2O_3	0.27
Fe_2O_3	0.23
CaO	0.41
MgO	1.01
SO_2	0.40
K_2O	1.51
Na_2O	0.79
Specific gravity	2.19
Density (g/cm^3)	2.0
Specific surface area (m^2/g)	160

ii. Nano silica

Nano scale particles of silicon dioxide is called as nano silica. A package of 5kgs was bought from Astra Chemicals, a well-known chemical supplier in Chennai. It is powdery in form and white in colour. The company itself have ensured the standards of the material and provides a certificate with it. The following table4 includes the basic details.

Table 4: Properties of Nano Silica

Test item	Standard requirement	Test result
Specific surface area(M2/G)	200-210	204
pH value	3.7-4.5	4.09
SiO_2 content	>99.8	99.92
Carbon content	<0.15	0.07
Loss on drying @ 105^0C	<1.5	0.53
Loss on ignition @ 1000^0C	<2.0	0.77
Sieve residue (5)	<0.04	0.02

iii. Super plasticiser

As we reduced the water content in the concrete inorder to obtain high strength, we are in need of some plasticisers to balance the workability since the name high performance uniquely means the ease of work. To fulfil this, Conplast SP430 was used. It is a Forsoc product and is commonly used in the field where water reduction and workability are needed. It is a chloride free liquid and so is recommended for RC members as it does not lead to corrosion.

B. MIX DESIGN

High performance concrete had higher characteristic strength and is need to be designed specifically. The usual procedure could not match this demand that make us to design based on ACI211.4R-93[]. The mix proportions for different ratios has been set out in table 6.

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Table 6: Mix proportions

	W	FA	CA	C	SF	NS	SP	w/b
0%	138	304	1002	354	39.4	0	96	0.35
1%	138	304	1002	350	39.4	3.94	96	0.35
2%	138	304	1002	346	39.4	7.88	96	0.35
3%	138	304	1002	342	39.4	11.8	96	0.35

C. CASTING OF SPECIMEN

All the ingredients needed for the concrete mentioned above were batched as per the arrived design and kept ready. Initially the required amount of silica fume is mixed well with the weighed ordinary portland cement and then the measured quantity of nano silica is mixed with the cement slowly until the nano material gets blended so that its white colour could not be seen. This dry mixing process is carried out till the silica materials invisible to the naked eyes and the whole mixture look like as cement. After this as usually fine and coarse aggregates were added and mixed dryly for 2minutes. Half of the water quantity is added to the dry mix and blended evenly for 2 more minutes, the remaining water mixed with super plasticiser was poured and the blended thoroughly to obtain the perfect concrete.

Quantity of silica fume was kept constant as 10% of cement for all the mixes. So specimens are casted for three different ratios for 1, 2 & 3% of nano silica. Followed by the norms three specimens were castedfor each ratios. Therefore altogether 12specimens were casted for each test including the control specimens. The planned chart is arranged in below table 7.

Table 7: Specimen details

TEST	SIZE	QTY
Compressive strength	Cube 150mm	36
Split tensile strength	Cylinder 150mmdiameter 300mm height	36
Acid resistance	Cube 150mm	36
Water absorption	Cube 150mm	12
Sorptivity	Cylinder 100mm diameter 50mm height	12

V. RESULTS AND DISCUSSIONS

A. MECHANICAL PROPERTIES

i. ***Compressive strength:***

For nominal and different mix proportions the standard specimen of size 150*150*150mm has been casted and cured by direct curing method, the specimen is been tested for 7,14 and 28 days. The inclusion of 3% nano silica for cement attains 35% higher strength than to nominal concrete. The strength variation for different mix ratios using nano silica is charted in figure 1.

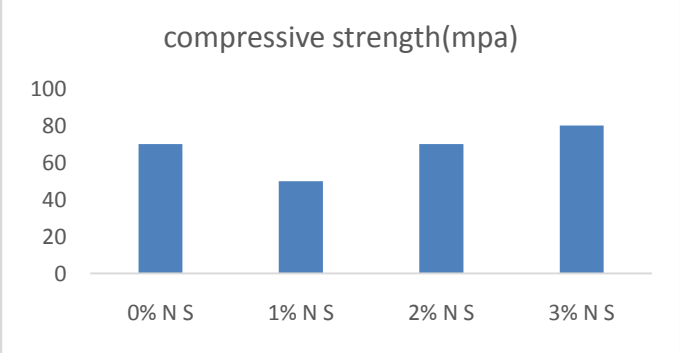

Fig 1: compressive strength

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ii. Split tensile strength

The determination of split tensile strength using the standard specimen of size 150mm diameter and 300mm height has been casted and cured by direct curing method, the specimen is been tested for 7, 14 and 28 days. The inclusion of 3% nano silica for cement attains 28% higher strength than to nominal concrete. The strength variation for different mix ratios using nano silica is charted in figure 2.

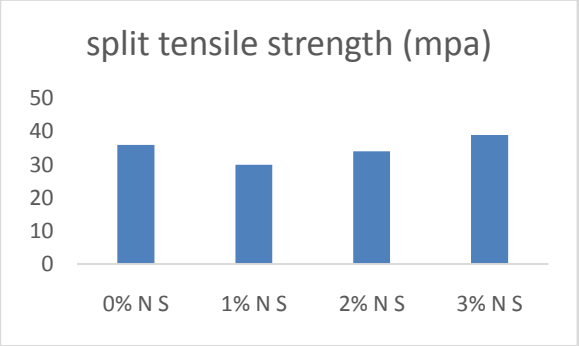

Fig 2: Split tensile strength

B. DURABILITY PROPERTIES

It is also recommended to investigate on durable parameters of concrete to ensure its life time. The following durability tests has been carried over to evaluate the ability of concrete with nano silica to withstand the environmental effects.

i. Acid resistance test:

The cubes are cured in the acid diluted solution concentrated hydrochloric acid. The specimens are weighted and physically inspected before curing. The acid is diluted at 5%as per the previous research works. After 28 days cubes are taken out and the physical changes are observed. Most of the cube's surface were found in brownish in colour and the sharpness of the edges are deteriorated gradually. A minimum loss in mass was found and remarkable loss in compressive strength was identified. The concrete with 3%

ii. Water absorption test:

Water absorption by immersion is tested to decide the durability, after demoulding the cubes are weighed as W1. The sample is immersed in water for 24hours and then taken, dried and weighed as W2. This procedure is repeated until the single value is attained. From the test results it is observed that concrete with higher percentage gives optimum result

iii. Sorptivity:

Water absorption by capillary action is studied. A cylindrical specimen of 100mm diameter and 50mm height is casted. The dry weight of the specimen is taken immediately after demoulding and placed in a tray of water at 5mm height. Weight of the specimen at frequent intervals was waited until a constant value is reached.

V CONCLUSIONS

The review of the above results indicates the following conclusions:

A. The addition of nano silica and silica fume improves the mechanical properties by increasing the bonding between the aggregates.
B. The density of the concrete mass is increased because of the filling effect of the nano and micro silica.
C. The compressive and split tensile strength when nano silica is added at higher order.
D. Water absorption by both immersion and capillary action were improved upto 25% with addition of nano silica.
E. The introduction of nano silica to the concrete makes it durable by enhancing its properties like impermeability, porosity and acid resistance.
F. Its concluded that nano silica added at 3% of cement gives better results than others.

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