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EXPERIMENTAL INVESTIGATION ON STRENGTHENING OF CONCRETE BY PARTIAL REPLACEMENT OF NANO AND MICRO SILICA

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ABSTRACT

The most flexible and resourceful material is Concrete. It is mainly because of the high and tenacious demands of concrete. By using advanced chemical admixtures and additional cement oriented resources like fly ash, silica fume, granulated blast furnace slag and more, Engineers have been incessantly pushing the limits to increase the performance of Concrete. Large amount of the usage of cement yields increasing emissions of Carbon dioxide (CO_2) resulting in the greenhouse effect. Using silica fume, a non-crystalline polymorph of silicon dioxide in concrete mixtures is a method that helps in reducing the content of cement. One of the most favorable and hopeful zones of science is Nano technology. The usage of Nano materials such as Nano silica, Nano alumina, Nano titanium oxide and Carbon Nano tubes in concrete is a new revolution. These materials greatly amend the strength properties of concrete. The present study aims at such strengths like Compressive, Flexural and Split Tensile of M_{40} grades of concrete along with usage of micro silica (5%, 7.5%, 10%, and 15%) and Nano silica (1.5%, 2%, and 2.5%) as partial replacement of cement.

Key words: Nano Silica (NS), Micro Silica (MS), Compressive Strength (CS), Split Tensile Strength (ST), Flexural Strength (FS).

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1. INTRODUCTION

Concrete is the most widely used construction material in the world [1]. A reaction between the cement and water yields calcium silicate hydrate, which gives concrete strength and other mechanical properties of concrete, as well as some by-products including Calcium Hydroxide (CH), gel pores etc. Despite the hydrated cement and their byproduct materials available everywhere in the concrete, the reactions within it are hard to control. This is a lasting problem in the industry of concrete. The fissure and its consequent problems in concrete is a major issue. These cracks in the structure of concrete and impulsive erosion are mainly due to a chemical reaction such as alkali silica reaction. Further corrosion in the strengthening of concrete is caused by the penetrability of gases through pores and micro-cracks. Moreover, the expansion and contraction in concrete, is also a reason for cracks at the later stages. This is due to the sulphate spasm, which in turn leads to the fragmentation in concrete. Chemical discharge is another cause for the same. These two actions are mainly because of the excess of calcium hydroxide, which is the byproduct during cement hydration. This byproduct is produced as per the equation (1) and equation (2).

$$2C_3S + 6H \longrightarrow C_3S_2H_3 + 3CH \qquad (1)$$

$$2C_2S + 4H \longrightarrow C_3S_2H_3 + CH \qquad (2)$$

1.1. NANO TECHNOLOGY

Nano science and Nano technology are new fields of emergence in Materials Science and Engineering, which makes the basis for evolution of new technological materials. The *Nano science* refers to the study, manipulation and engineering of matter, particles and structures on the nanometer scale. Nanotechnology is manipulation of matter on an atomic, molecular, and supramolecular scale. Nano science and Nano technology finds out application in different fields of science and technology. The usage of Nano materials in concrete is a welcoming factor. Its application helps in the progress of long-standing materials in construction industry. The pore filling effect and its pozzolanic activity with cement helps in improving mechanical properties and durability aspects. This leads to a scope for the development of crack-free concrete with regard to sustainable construction.

1.2. SUPPLEMENTARY CEMENT-BASED MATERIALS

Engineers are persistently trying to improve its performance with the help of innovative chemical admixtures and additional cement oriented materials such as silica fume, fly ash, granulated blast furnace slag and steel slag. Using a large quantity of cement produces increasing CO_2 emissions and result in the greenhouse effect, which is a method towards reducing the cement content in concrete mixtures with the help of cement-based materials.

2. PROPERTIES OF THE MATERIALS

The materials used in this investigation are Cement, Fine Aggregate (F.A), Coarse Aggregate (C.A), Silica Fume (SF), Nano Silica (NS) and Super plasticizer [2-5].

2.1. CEMENT

Ultra tech cement of OPC of 53 grade has been used in the properties of cement. The properties are shown in Table 1.

Table 1 Properties of Cement

S.No	Properties	Results
1	Specific Gravity	3.11
2	Initial Setting Time	30 Minutes
3	Final Setting Time	10 Hours
4	Consistency	30%

2.2. AGGREGATE

Fine Aggregate: The properties of Fine Aggregate (F.A) are shown in Table 2.

Table 2 Properties of F.A

S.No	Properties	Results
1	Bulk density kg/m^3	1650
2	Specific gravity	2.67
3	Fineness modulus	2.81

Coarse Aggregate: The properties of Coarse Aggregate (C.A) are given in Table 3.

Table 3 Properties of C.A

S.No	Properties	Results
1	Fineness modulus	4.6
2	Bulk density kg/m^3	1673.13
3	Specific gravity	2.74
4	Max.nominal size	20mm

2.3. MICRO SILICA

The Silica fume that has been used here is obtained from Astrra Chemicals, Chennai. The properties of Silica Fume are given in Table 4.

Table 4 Properties of Micro Silica

S.No	Properties	Result
1	Form	Ultra-fine amorphous powder
2	Particle size	15 micron m
3	SiO_2	99.89%
4	Pack density	0.76 gm/cc
5	Specific surface	20 m^2/g
6	Specific gravity	2.63

2.4. NANO SILICA

Cem Syn-XFX is a series of silica based binders/fillers obtained from Astraa Chemicals Ltd., Chennai and its properties are depicted in Table 5.

Table 5 Properties of Nano Silica

S.No	Properties	Result
1	Active Nano content	40 - 41.5
2	Ph	9 - 10
3	Specific gravity	1.3 - 1.32

2.5. SUPER PLASTICIZIER

Fosroc Aura mix 400 was used for M_{40} Grade of concrete. The properties of super plasticizer are shown in Table 6.

Table 6 Properties of Super Plasticizer

S.No	Properties	Result
1	Appearance	Light yellow colored liquid
2	Alkali content	Less than 1.5 g Na2O
3	Ph	Min 6
4	Volumetric mass	1.09 kg/liter

3. EXPERIMENTAL INVESTIGATION

The experimental study is mainly designed to compare the mechanical properties such as compressive strength, split tensile strength and flexural strength of high strength concrete with M_{40} grade of concrete with different replacement levels of OPC with silica fume (5%, 7.5%, 10% and 15%) and (1%, 1.5%, 2%).

3.1. MIX PROPORTIONS

Concrete mixes were designed to M_{40} with water cement ratio of 0.4 as per IS code 10262-2009. The cement was replaced with Silica Fume by (5%, 7.5%, 10% and 15%) and NS by (1%, 1.5%, 2% and 2.5%). The proportions of the constituent materials for M_{40} Mix are presented in the Table 7.

Table 7 Mix Proportion

S.No	Materials	Quantities in Kg/m^3
1	Cement	350
2	Water	140
3	Fine aggregate	896
4	Coarse aggregate	1140
5	Water cement ratio	0.4

4. RESULTS AND DISCUSSION

The Compressive, Split Tensile and Flexural strength of M_{40} grades of concrete are tested [6, 7].

4.1. COMPRESSIVE STRENGTH

The compressive strength of M_{40} grade concrete, replacement of both MS and NS in different replacement by the weight of cement. The compressive strength for different replacement of cement at 28 days curing is shown in Table 8 and Figure 1.

Table 8 Compressive Strength after 28 Days Curing

S.No	Micro Silica	Nano Silica	Compressive Strength in N/mm^2
1	5%	1.5%	56.22
		2%	56.57
		2.5%	56.84
2	7.5%	1.5%	58.26
		2%	58.57
		2.5%	57.86
3	10%	1.5%	44.84
		2%	43.95
		2.5%	41.32
4	15%	1.5%	41.77
		2%	41.22
		2.5%	40.20

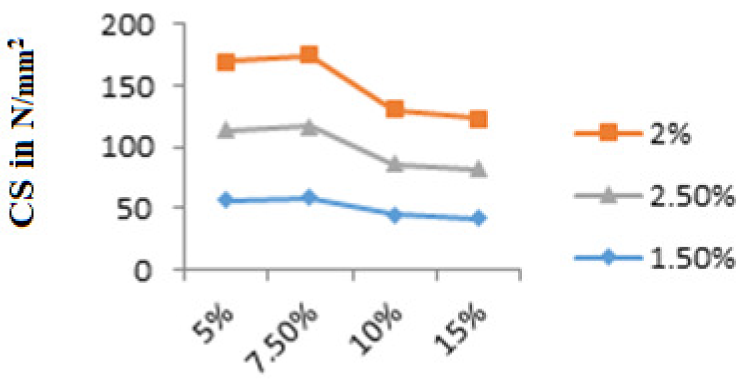

Figure 1 Compressive Strength after 28 Days Curing

4.2. SPLIT TENSILE STRENGTH

The Split Tensile Strength of M_{40} grade concrete as well as the replacement of both MS and NS is done by the weight of the cement. The details are shown in Table 9 and Figure 2.

Table 9 Split Tensile Strength

S.No	Micro Silica	Nano Silica	Split Tensile Strength in N/mm^2
1	5%	1.5%	3.81
		2%	3.85
		2.5%	3.87
2	7.5%	1.5%	3.89
		2%	4.00
		2.5%	3.86
3	10%	1.5%	3.72
		2%	3.50
		2.5%	3.47
4	15%	1.5%	3.42
		2%	3.41
		2.5%	3.36

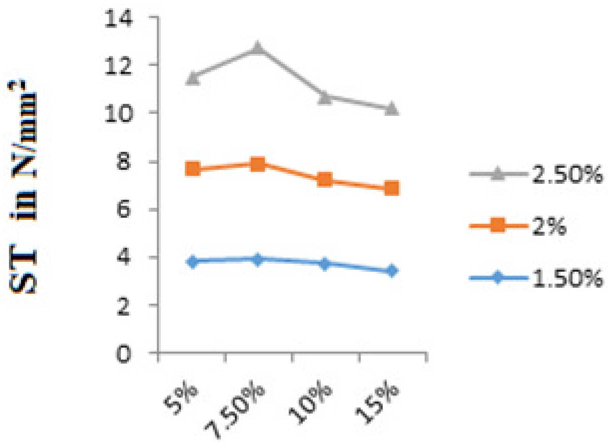

Figure 2 Split Tensile Strength after 28 Days Curing

4.3. FLEXURAL STRENGTH

The Flexural Strength of M_{40} grade concrete as well as the replacement of both MS and NS in different replacement is calculated by the weight of cement. Table 10 and Figure 3 depicts its details.

Table 10 Flexural Strength

S.No	Silica Fume	Nano Silica	Flexural Strength in N/mm^2
1	5%	1.5%	3.78
		2%	3.82
		2.5%	3.91
2	7.5%	1.5%	4.05
		2%	4.20
		2.5%	4.00
3	10%	1.5%	3.98
		2%	3.95
		2.5%	3.91
4	15%	1.5%	3.86
		2%	3.81
		2.5%	3.75

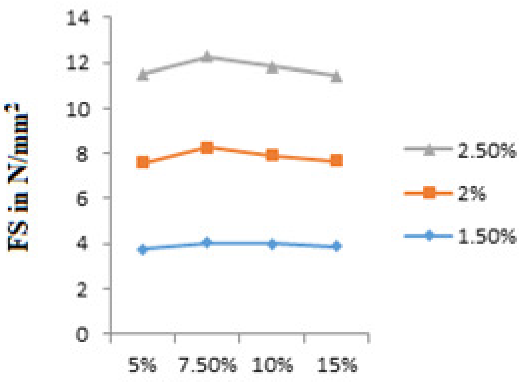

Figure 3 Flexural Strength after 28 Days Curing

5. CONCLUSION

Cement replacement up to 7.5% with Silica Fume and up to 2% with Nano Silica, leads to the increase in the Compressive Strength, Split Tensile Strength and Flexural Strength respectively of M_{40}. Above 7.5% of Silica Fume and 2% of Nano Silica there is a decrease in the compressive strength. The maximum replacement level of SF is 7.5% and NS is 2% for M_{40} concrete. The percentage increase in Compressive Strength, Split Tensile Strength and Flexural Strength of concrete with a combination of Silica Fume at 7.5% and Nano Silica at 2% is 25.807%, 25.766% and 18.9% for M_{40} grade Concrete. This is more when compared to the normal concrete of M_{40} grade.

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