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Experimental Analysis on the Mechanical Properties of Concrete Using Micro Silica and Nano Silica

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ABSTRACT: Cement is the main constituent of concrete. Production of large quantity of cement results in increasing CO₂ emissions and the consequence being Greenhouse Effect. In order to overcome the above problems, an attempt has been made to use micro silica and Nano silica as partial replacement to cement in concrete. Nanotechnology is one of the most promising areas of science. The use of Nano materials in concrete is the new revolution. Nano materials like Nano silica, Nano titanium oxide, carbon Nano tubes, Nano alumina etc. are presently used in concrete in order to modify the strength properties and durability of concrete.

In this experimental investigation, an attempt is made by partially replacing the constituents of concrete with Nano silica and micro silica. Later the workability and strength properties of concrete is determined with the use of micro silica (5,10,15%) and Nano silica (2.5,5,7.5%) as partial replacement by the weight of the cement.

I. INTRODUCTION

Concrete will be stuff composed primarily of cement, combination and water. It is a wide used construction material for varied types of structures ascribable to its structural stability and strength. Increasing the event challenges in combos with the new innovations in materials and production techniques have give new basis for manufacturing high performance concrete structures. Presently concrete is obtaining used for wide styles of functions to make it applicable in varied conditions. In these conditions commonplace concrete could fail to exhibit the desired quality performance or strength. In such cases, pozzolanic or mineral admixtures ar accustomed modify the properties of traditional concrete.

NANO TECHNOLOGY

Nanotechnology is that the employment of really little things of fabric by themselves or their manipulation to make new large scale materials. The particle size may be a big issue. At the Nano scale (anything from 100 or more right all the method all the way down to some of Nano meters, or 10⁻⁹ nm) material properties are altered from that of larger scales. There's a sudden modification in state of affairs and this might be what happens at the dimensions of technology. As particles become Nano-sized, the proportion of atoms on the surface will increase and this ends up in modification among the properties. Knowledge at the Nano scale of the structure and characteristics of materials (otherwise referred to as characterization) will promote the event of latest applications and new merchandise to repair or improve the properties of construction materials. as associate example, the structure of the essential Calcium-silicate-hydrate (C-S-H) gel that is in charge of the mechanical and post-selfing physical properties of cement pastes, like shrinkage, creep, porosity, consistence unit of measurement typically improved to urge higher strength characteristics of concrete.

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NANO TECHNOLOGY IN CONCRETE

One of the foremost and extremely important helpful uses of technology in technology is to use in concrete. It's utilized in regarding of all construction fields like roads, bridges, buildings and varied construction works. Concrete unit of measurement typically changed in varied ways; one in every of that is to feature Nano particles to that. Researchers are aiming for how higher understanding of the delicate structure of cement- based materials at Nano levels. This could ends up in new generation of stronger and additional sturdy concrete with desired behaviors and properties. Association of cement produces a rigid, heterogeneous microstructure. As water is introduced to cement to make a paste that hardens over time the foremost little structural phases within the hydrous cement paste are

- Calcium salt hydrate gel (C-S-H)
- Calcium hydroxide (C-H)
- Ettringite (a Sulfo matter hydrate)
- Monosulphate
- Unhydrated cement particles and
- Air voids

II. LITERATURE REVIEW

Verma ajay et al, (2012) have studied the effect of micro silica and the strength of concrete with ordinary Portland cement. They observed that silica fume increases the strength of concrete and reduces capillary pores. **Dilip Kumar Singha Roy (2012)** has investigated on the strength parameters of concrete made with partial replacement of cement by SF. **T.Shanmugapriya (2013)** studied the influence of silica fume on M₆₀ concrete and found that 7.5% of silica fume replacement increases the maximum compressive strength, split tensile strength and flexural strength.

Ji (2005) studied the water permeability resistant behavior and micro structure of concrete with NS and observed that NS concrete has a better water resistant permeability than ordinary concrete. **Ye Qing et al, (2007)** studied the influence of silica fume and Nano silica individually on fresh concrete and hardened concrete and found that consistency and setting times were different for NS and SF. NS makes cement paste thicker and accelerated the hydration process which improves the bond strength and compressive strength when compared with that of SF in concrete. **Byung-Wan (2007)** studied the properties of cement mortar with NS particles and reported the importance of addition of NS on mechanical properties. **Lin et al. (2008)** have observed the effect of NS addition on permeability and compressive strength of fly ash cement mortar. From the pore analysis study, it was reported that the relative permeability and pore sizes of concrete were decreased, whereas the compressive strength increased by adding more NS. **Yazdi et al (2009)** investigated the effect of NS on high volume fly ash concrete [HFC], and found that due to the low pozzolanic reactions of fly ash, early strength of HFC reduced considerably, but with the addition of NS promoted the pozzolanic activity reaction which enabled the enhancement of strength of HFC, especially in the early ages.

Sadrmontazi Barzegar (2010) concluded that the properties of self compacting concrete with and without Rice Husk Ash [RHA], an agro-industry waste, and exhibited improvement in the physical and mechanical properties of concrete with addition of NS. **A. Siva Sai, B.L.P. Swami, B.SaiKiran (2013)** have observed the mechanical properties of M₆₀ and M₇₀ grade concrete with micro silica and in combination with colloidal Nano-silica. They found that concrete composites with superior properties can be produced with the combination of micro-silica and Nano-silica. **Mohammad Reza Zamani Abyaneh, et al (2013)** have found that the concrete produced with Micro-SiO₂ and Nano-SiO₂ show higher degrees of quality in their compressive strength than the concrete which only have Micro-SiO₂ in their mixtures. Specimens with 2% Nano-SiO₂ and 10% Micro-SiO₂ had less water absorption and more electrical resistance.

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III. DESIGN MIX

A. Materials Used

The materials used in preparing the required proportion of concrete mix are as follows.

Cement

The cement (C) used in this investigation is 53 grade as per IS: 12269 - 2013. The overall quantity of cement required for the investigation was procured in a single lot and stored in the appropriate manner.

Fine Aggregates

Fine aggregates (FA) used was Manufactured Sand (M Sand) retained on 20 mm and 12.5 mm IS sieves as per the specifications in IS: 383 - 1970 were used.

Coarse Aggregates

Coarse aggregates (CA) retained on 20mm and 12.5mm IS sieves as per the specifications in IS: 383 - 1970 were used.

Micro silica

Micro silica is a mineral admixture composes of very fine solid glassy spheres of silicon dioxide (SiO_2). Micro silica is a byproduct of the industrial manufacture of ferrosilicon and metallic silicon in high-temperature electric arc furnaces. It changes the rheology and reacts with the cement hydration products to dramatically improve concrete strengths, durability and impermeability, allowing concrete to be used in ways never before possible.

TABLE I. PHYSICAL PROPERTIES OF MICRO SILICA

Tests	Results
Specific Gravity	2.55
$\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	96.27%
Form	Ultra-fine amorphous powder
Colour	White
Particle size	<90microns

Nano silica

Nano silica is a new pozzolanic material in the form white amorphous material which has nowadays proven to be better than other pozzolanic materials. It is generally available in the form of colloidal silica. It is believed that by using Nano silica it prevents in the early cracking of concrete in the pavement structure.

TABLE 2. PHYSICAL PROPERTIES OF NANO SILICA

Tests	Results
SiO_2	> 99.8
Specific gravity	1.32
Crystalline size	20 nm
Purity percentage	99%
Specific surface	160 m^2/gm
Density	2.12 g/cm^3

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IV. EXPERIMENTAL TESTS AND RESULTS

1. Slump Test

Slump test was carried out according to the Indian standards. For the M20 grade concrete, MS concrete and NS concrete.

TABLE 3. SLUMP VALUES FOR DIFFERENT PROPORTIONS

Micro Silica (%)	Slump(mm)	Nano Silica (%)	Slump(mm)
0	120	0	120
5	92	2.5	25
10	65	5	0
15	23	7.5	0

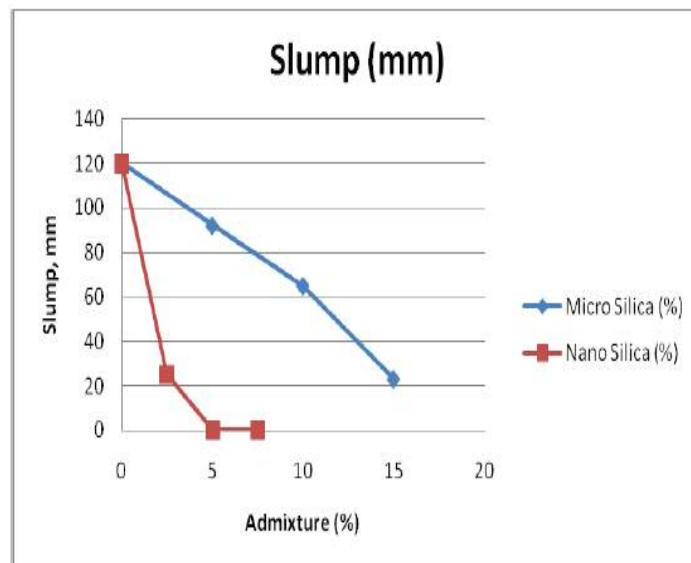


Fig.1. Slump Test Values

The results shows there is flow reduction with increasing MS and NS percentages in concrete up to 15% and 7.5%. The mixing water was getting exhausted due to the large specific surface area of MS and NS particles.

2. Tests on Hardened Concrete Specimens

All the cast specimens were de-moulded after 24 hours and were placed in a curing tank for a period of 28 days. The specimens were then taken for Strength tests such as Compression and Split Tensile Tests. All the test results were compared and analysed with that of control mix.

A. Compressive strength test

The Compressive Strength tests was conducted as per **IS: 516 - 1959**. The compressive strength of the cube specimen is calculated using the following formula:
Compressive Strength, $f_c = P/A$ N/mm²

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where P = load at failure in N
A = Area subjected to compression in mm²
The test results are shown below.

TABLE 4. 28 DAYS COMPRESSIVE STRENGTH, N/MM²

Micro Silica (%)	Compressive Strength, N/mm ²	Nano Silica (%)	Compressive Strength, N/mm ²
0	29.59	0	29.59
5	33.92	2.5	29.81
10	34.06	5	28.85
15	34.16	7.5	24.24

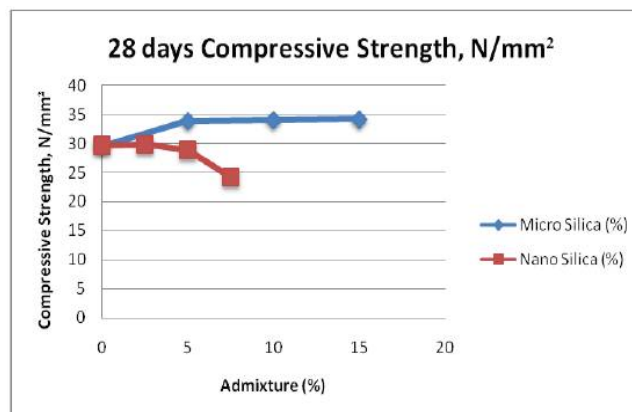


Fig. 2. Compressive Strength of Concrete with varied percentages of Micro Silica and Nano Silica

From the above test results, the compressive strength of M20 grade concrete with partial replacement of cement by 15% MS shows 15.44% increase in strength and that with partial replacement of cement by 2.5% NS shows 11.25% decrease in the strength.

B. Split –Cylinder Test

It is the standard test, to determine the tensile strength of concrete in an indirect way. This test was performed in accordance with **IS: 5816-1970**.

The formula used to calculate this split tensile strength is as follows:

$$\text{Split Tensile Strength} = \frac{2P}{\pi DL} \text{ (N/mm}^2\text{)}$$

Where P = load at failure in N

D = diameter of the specimen in mm

L = length of the specimen in mm

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The test results and the strength variations of MS and NS replacements are illustrated below.

TABLE 5. 28 DAYS SPLIT TENSILE STRENGTH, N/MM2

Micro Silica (%)	Split Tensile Strength, N/mm ²	Nano Silica (%)	Split Tensile Strength, N/mm ²
0	2	0	2
5	2.2	2.5	2.81
10	2.85	5	2.62
15	3.12	7.5	2.58

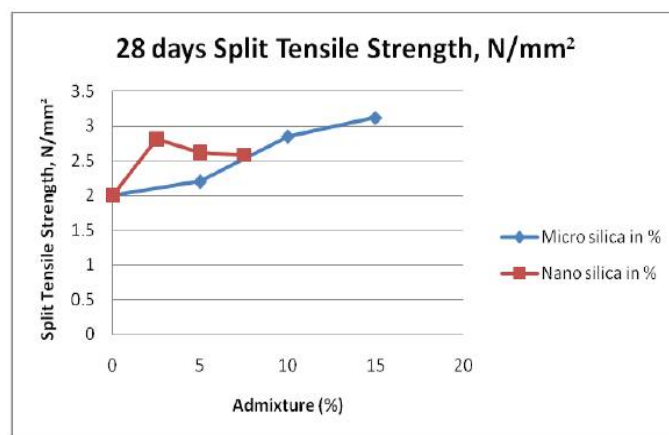


Fig. 3. Split Tensile Strength of Concrete with varying percentages of Micro Silica and Nano Silica

From the above test results, the split tensile strength of M20 grade of concrete with partial replacement of cement by 15% MS shows 0.56% increase in strength and that with the partial replacement of cement by 2.5% NS shows 0.40% increase in strength and gradually decreased with increase in replacement percentages.

V. CONCLUSION

1. The study shows that as the content of silicon powder increased after certain limit, its effect on compressive strength decreases. Thus, adding the appropriate content of Micro silica and Nano silica should be given due consideration.
2. The workability of concrete with partial replacement of Micro silica and Nano silica which decreased by increasing the amount of micro silica and Nano silica. Micro silica and Nano silica absorbs the quantity of mixing water, reducing the workability.
3. Addition of silica powder makes concrete sticky hence suitable super plasticizer should be used to achieve required workability.
4. Cement replacement up to 15% with MS and 2.5% with NS leads to increasing compressive strength and split tensile strength for M20 grade. Beyond 2.5% of NS, there is decrease in compressive strength and split tensile strength.

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5. The maximum replacement level of micro silica is 15% and Nano silica is 2.5% for M20 grade.
6. Until achieving the optimum percentages, NS at 2.5% and MS at 15%, then decreases due to the decreasing of Ca (OH)₂ that exhausted in the activation process.

5.2 RECOMMENDATIONS FOR FEATURE WORK

1. Further studies can be carried out with the high grade concretes.
2. In this present study colloidal Nano silica was used, the further study can be carried out by using Nano silica powder.
3. Further studies can be carried out with suitable combinations of different Nano materials like Nano metakolin, Nano iron, and Nano titanium and carbon Nano tubes.

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