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Investigation Into Impact Of Nano Silica On Concrete's Compressive Strength

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ABSTRACT

Use of nanotechnology in concrete has brought fresh perspective to ongoing endeavours to enhance its characteristics. The four main ingredients of concrete are water, aggregate, sand, and cement. Among most ubiquitous building materials, concrete is indispensable. As their very tiny particle size, nanomaterials have the probability to alter microstructure of concrete assets. Adding 230 nm nano silica to concrete for increasing its compressive strength is the focus of this research. U se of 0.35%, 0.65%, and 1% nano silica in place of cement was subject of an experimental enquiry. Its accompanying experiments demonstrate that concrete's early-age compressive strength and total compressive strength are both significantly increased. A higher proportion of nano silica resulted in a stronger material.

Keywords: Cement Concrete, Nano Silica, Nanotechnology, Sustainability, Durability, Compression Strength.

I. INTRODUCTION

Common Portland cement has been widely used in many building projects throughout recent modern history. The fast growth in the need for concrete in building projects has led to a rise in cement output, which in turn has the potential to impact the environment. In the process of calcining limestone, carbon dioxide is released together with lime, which has a substantial influence on climate change and greenhouse gas emissions. Cement manufacture results in increased emissions of carbon dioxide in this manner. Approximately one tonne of carbon dioxide is released while producing one tonne of cement. Exact amount of CO_2 emitted can vary based on various factors such as the kind of cement, raw materials utilised, and the energy sources utilised in production [1].

The main component that holds the structural parts of concrete together is cement, which comprises tiny particles. Cement manufacturing requires a lot of water, and the runoff from the cement plants may contaminate nearby water sources. Given that cement has health risks to both humans and other animals, we need to find ways to substitute it, or at least utilise less of it, in our projects. There is a lot of research going on in the business world, and nanotechnology is one new technology that is starting to make waves in the building sector.

1.1 NANOTECHNOLOGY

By manipulating materials on a molecular level, nanotechnology in civil engineering provides novel approaches to improving the sustainability, longevity, and structural strength of building materials and methods. A new and exciting possibility for enhancing concrete's mechanical and structural properties is nanotechnology. This introductory piece elaborates on the potential benefits of utilising nanotechnology to civil engineering, such as creation of longer-lasting and greener buildings. Nanotechnology has the potential to transform the building industry and create innovative solutions, as has been abundantly obvious from investigations into its molecular level potential.

1.2 NANO SILICA

Nano silica is one example of nano material utilised in civil engineering; it partly replaces cement in concrete mixes. Silica nanoparticles, or nano silica, are a novel nanomaterial that is attracting focus upon field of civil engineering. Nano silica is an excellent addition to concrete and other building materials due to its distinctive characteristics and very tiny particle size, which falls on nanoscale. This research focus upon of nano silica upon concrete performance enhancement, specifically looking at how it might enhance sustainability, environmental impact, durability, and strength. The more we learn about Nano silica, the more we can see how it might change the face of the construction industry, ushering in a new era of technologically superior and ecologically responsible solutions. Incorporating nano silica into concrete improves its resistance to abrasion, strengthens its microstructure, and decreases its permeability. The overall durability of the construction is enhanced by nano silica. Additionally, it enhances the concrete mix's workability and flowability. On top of that, it makes the concrete-steel link stronger. Nevertheless, studies investigating incorporation of nano silica in concrete are underway. Several factors, like mix design and intended application, determine ideal dosage and specific characteristics of Nano silica. Research on usage of nano silica in reinforced concrete mixtures is ongoing, and so is effort to broaden our understanding of material behaviour.

1.3 APPLICATION OF NANOTECHNOLOGY IN CONSTRUCTION FIELD

There are lot of innovative uses for nanotechnology in the building industry, which is boosting sustainability, performance, and longevity.

1. For improving characteristics of concrete, cement, and coatings utilised in construction sector, new materials are being developed that include nanoparticles.
2. Making concrete with nanoparticles in it makes it self-healing, meaning that fissures in the material will mend themselves over time.
3. Using nano coatings and nanoparticles to make materials more resistant to corrosion and improve their waterproofing qualities, especially in harsh environments.
4. Incorporating nano sensors into building materials allowing real-time analysis of structural health, detecting of any damage, strain, and prompt maintenance and safety.
5. The use of nanotechnology to create building materials that are both strong and lightweight helps to keep building weight to a minimum.
6. Concrete admixtures developed using nanomaterials have improved workability, decreased water content, and increased performance in a range of construction applications.
7. Coating building surfaces with nanoparticles makes them resistant to UV radiation and makes them self-cleaning, allowing for less maintenance and a longer lifespan. Sustainable infrastructure practice might also benefit from this.
8. Reinforced concrete that incorporates nanofibers may have improved structural stability.

Figure 1: a) Nano Silica Powder b) Nano Silica Concrete

II. LITERATURE REVIEW

Vikram Singh Kashyap et al. [2023] [1]

This includes studies that looked at impact of addition of varying concentrations of nano silica to concrete, ranging from 1% to 3%, in an effort to increase its strength. The concrete containing nano silica was tested for compressive, split tensile, flexural strength respectively, water absorption, carbonation, and acid attack utilising 43-grade OPC with W/C proportion of 0.4. Findings demonstrated that by substituting nano silica for cement, compressive strength of concrete was increased. In part, to counteract the effects of increased focus. Adding 3% nano silica to concrete increases its flexural strength in the first curing stages but reduces it as the material ages; adding nano silica also reduces gaps and holes without changing the concrete's volume. When nano-silica is employed in mixes at concentrations greater than 2% instead of cement, the split tensile strength test shows a drop. This is because the nano-silica particles primarily function as fillers and do not contribute to hydration process. After 30 days of carbonation testing, there was no discernible difference amongst concrete mixes including and those lacking Nano silica. Adding 2% nano silica causes a densification and alteration to the pore structure. The acid resistance, weight change, and compressive concrete strength are all improved when the concentration of nano silica is increased compared to the control mix. Outcomes of research show improved and concrete's qualities.

Fadi Althoey et al. [2023] [2]

The manufacturing of concrete, an essential building material, releases a great deal of CO_2 in atmosphere due to use of Portland cement, as this study explains. To lessen this effect, researchers have been looking at ways to make concrete better at nano level by adding NS, which increases its strength and endurance. This gel enhances microstructure and increases matrix density of the concrete. Better mechanical and durability qualities are the end consequence of a stronger link between the aggregate and binder, which is achieved by densification. According to studies, mechanical & physical qualities of concrete are much enhanced when 2-4% Nano-silica is added. This is because the pores are filled, the pore structure is refined, and the hydration process is accelerated. Nevertheless, NS's benefits may decrease with increasing doses as a result of intricate interactions inside the cement. The characteristics of concrete may be further improved by combining nano-silica with waste pozzolanic components. Nevertheless, there are still obstacles to its commercial implementation, such as the need to optimise its usage in building via research, and issues like preserving workability with high-surface-area Nano-materials.

Rajput Babalu et al. [2023] [3]

Research was conducted for examining thermal characteristics of concrete mixture that included nano silica and other ingredients. This study compares the thermal characteristics of concrete grades M30 and M40 made with and without Nano silica. W/C ratios for such mixtures are 0.34 and 0.29, respectively. An upsurge in nano silica concentration of concrete mixes results in intensification in compressive strength of M30 and M40 grade concrete. Comparing control samples, concrete with 3% NS had 13.95 percent and 16.82 percent improvement in compressive strength, correspondingly, for M30 and M40 grade concrete. The density of a concrete mix will decrease as the proportion of nano silica in mix upsurges. Also discussed in this work is the topic of thermal conductivity, which drops as concentration of nano silica in material drops and as size of nano silica particles becomes smaller. According to findings, addition of nano silica to concrete not only increases its strength but also enhances its thermal qualities.

Changjiang Liu et al. [2021] [4]

This study demonstrates how addition of nano silica to concrete expands its characteristics. With a twenty percent reduction in cement concentration, researchers investigated concrete-reducing additives and cementitious materials to reach carbon peaking and neutralisation targets. Improving concrete's mechanical properties is as simple as adding more nano silica. At 3,7, and 28 days, correspondingly, with NS dosages of 2.0%, 2.5%, and 2.5%, compressive strength of the concrete reached 22.58 MPa, 31.82 MPa, and 40.87 MPa. A 15.6% increase, an 11.9% increase, and a 6.6% increase were seen when compared to the control groups. At 3,7, and 28 days, highest concrete flexural strength was measured at 3.2 MPa, 4.4 MPa, and 6 MPa for NS dosages of1.5%, 2.5%, and 2.0%, respectively. There was an increase of 10.3%, 18.9%, and 11.1% in these figures when comparing with control group. Concrete's splitting tensile strength was 1.5 MPa after 3 days, 2.6 MPa after 7 days, and 3.8 MPa after 28 days when NS dosages were set at 1.5%, 2.5%, and 2.5%, respectively. This experiment concludes that upsurging dosage of NS from 0.25% to 3% considerably reduces concrete slump. To reduce this impact and make the material more workable, you need to change the amount of Portland cement (PC).

R. Rashmi et al. [2021] [5]

Experimental and analytical studies are carried out in the aforementioned work to enhance the structural behaviour of RC beams using diverse proportions of Nano silica and different ratios of M sand. Mix design calls for Ordinary Portland cement of 43 grade, with concrete grades M40 and M50 also used. To back up the findings, ABAQUS was employed for non-linear finite element analysis. To partly replace cement and natural sand, M-sand was utilised in quantities ranging from 25-100% and nano silica from 1-5%. Therefore, a tiny amount of Nano silica, when utilised as cement substitute, accelerates early stages of pozzolanic reactions and hydration, which in turn improves the mechanical strength & durability of concrete. Test revealed that every single beam failed in flexure, with the first fracture appearing in the beam's mid-span stress zone. Nano concrete beams are superior in flexural strength to their more traditional counterparts. The most common cause of flexure failure is when the steel gives way, which crushes the concrete. Improving fracture performance with fewer and smaller cracks, the failure load in Nano concrete beams is determined by the amount of nano silica. By increasing the flexural ultimate load, M-sand and nano silica enhance concrete's flexural properties generally. Experimental results corroborate the model's ability to foretell bending, fracture patterns, and concrete damage in analytical simulations. An rise of 52% in ultimate load for M40 grade and a decrease of 48% for M50 grade demonstrate that, on the whole, Nano concrete outperforms regular concrete.

Anwar M. Mohamed [2016] [8]

In this research, several combinations involving nano-silica and nano-clay are examined. Using the experimental programme, 24 distinct concrete mixes containing erratic proportions of nanomaterials (0-10%) were cast to substitute cement. It was also possible to create hybrid blends in which the percentage of each Nano material varied from zero to one hundred percent. This research looked at how adding nano clay and nano silica to concrete changed its characteristics. After 28 days, flexure strength improved to 8.6% with 0.5% and 0.75% Nano silica, while compressive strength increased by 8.7% and 24.4%, respectively, according to the data. There was a decline in performance with increasing Nano silica percentage. We found patterns that were similar to Nano clay. Hybrids consisting of 25% Nano Silica and 75% Nano Clay offered the best results. Nano silica concentration increases compressive and flexural strengths up to 0.75% NS. Nevertheless, performance declines beyond this point, which may be associated with particle agglomeration due to the challenges in achieving a uniform dispersion due to its huge surface area. The use of hybrid nanoparticles and wet mixing produced noticeable outcomes. nonetheless, a high Nano concentration has a negative effect on the properties. Further investigation is required since hybrid nanoparticles demonstrated enhanced flexural and compressive capabilities.

III. OBJECTIVE OF THIS PAPER

Bringing attention to the detrimental effects of conventional cement manufacturing on the environment and stressing the need of embracing sustainable construction practices are the aims of this article. The study's main aim is learning more about how civil engineers may use nanotechnology to improve building sustainability, longevity, and structural strength. It also aspires to draw attention to the crucial function that nano silica plays in concrete by serving as partial cement alternative.

The following are the primary aims of the current investigation:

- So that we may learn how nano-silica affects concrete's compressive strength.
- For the purpose of verifying nano silica content in concrete.
- To lessen effect of cement upon environment by reducing its use in concrete

IV. MATERIALS AND METHODS

M25 grade concrete mixes include the following ingredients: cement, sand, coarse aggregate, water, and Nano SiO2. Here are the characteristics of these:

4.1 Properties of Cement :- Concrete specimens are made with 43-grade Portland slag cement as per IS: 455-1989. The table provides information on the cement's qualities.

Specific Gravity	Fineness by sieve analysis	Normal consistency
3.014	2.01%	33%

4.2 Properties of fine and coarse aggregate

For the purpose of sieve analysis, sand is extracted as a fine aggregate from a river that is readily accessible in the area. Results show that the gathered sand meets the requirements of IS: 383-1970. Crushed parent concrete using a small jaw crusher is used as coarse aggregate. The crushing process aims to generate aggregate having maximal size ranging from 20 mm to 4.75 mm. According to IS: 2386 (Part III)-1963, the following table details the physical parameters of recycled coarse & fine aggregate:

Property	Coarse Aggregate	Fine Aggregate
Sp. Gr	2.72	2.65
Bulk Density (kg/L)	1.408	-
Water Absorption (%)	4.469	0.0651
Impact Value	26.910	-
Crushing Value	26.514	-
Fineness Modulus	3.38	2.84

4.3 Properties of Water: - For this experiment, we utilised water from the tap. It is presumed as characteristics are equal to those of ordinary water. We assume a specific gravity of 1.00.

4.4 Properties of Nano SiO2:- Appendix contains report of the Particle Size Analyser, which determined that average size of nano silica was 236 nm. Material's characteristics are illustrated in Figure 1 and Table 1. Demonstrates the experimental nano silica.

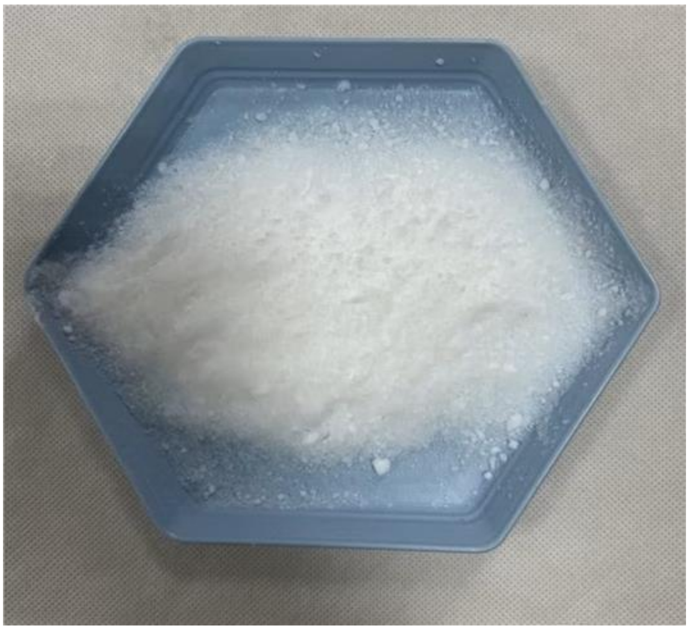

Fig 1:- Image of the Nano SiO2 used

TEST ITEM	STANDARD REQUIREMENTS	TEST RESULTS
SPECIFIC SURFACE AREA (m2 /g)	200 + 20	202
PH VALUE	3.7 – 4.5	4.15
LOSS ON DRYING @ 105 DEG.C (5)	< 1. 5	.48
LOSS ON IGNITION @ 1000 DEG.C (%)	< 2.0	.68
SIEVE RESIDUE (5)	< 0. 04	.02
TAMPED DENSITY (g/L)	40 – 60	46
CARBON CONTENT (%)	< 0. 15	.06
CHLORIDE CONTENT (%)	< 0. 0202	.009

4.5 Preparation of Test Specimen: - Cast concrete cubes of 150×150×150 mm are used to perform compressive strength tests. For efficient mixing and compaction, a rotary mixer and vibrator are used. The concrete examples are submerged in water for 28 days at a temperature of 27 °C after being demolded after 24 hours, after 18 successful castings.

4.6 Compressive Strength Test: - After 7 and 28 days of curing in a surface-dried state, compressive strength of samples is measured as per IS: 516-1959. For each category, 3 specimens are evaluated for compressive strength; given category's value is the mean of these three values.

Fig 2 concrete cubes after de-moulding

V. RESULTS

Compressive Strength of sample having nano-silica 0.35%

7-DAY TEST RESULT			
Specimen No.	Weight (kg)	Load (tons)	Compressive Strength (MPa)
1	8.24	77	29.85
2	8.14	79	29.35
3	8.08	82	34.95
		MEAN	31.38

Compressive Strength of sample having nano-silica 0.65%

7-DAY TEST RESULT			
Specimen No.	Weight (kg)	Load (tons)	Compressive Strength (MPa)
1	8.21	63	27.95
2	8.17	54	31.55
3	8.28	74	23.45
		MEAN	27.65

Compressive Strength of sample having nano-silica 1 %

7-DAY TEST RESULT			
Specimen No.	Weight (kg)	Load (tons)	Compressive Strength (MPa)
1	8.26	66	35.65
2	8.08	72	33.95
3	7.98	76	34.15
		MEAN	34.58

Compressive Strength of sample having nano-silica 0.35%

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.14	79	33.15
2	8.21	84	36.95
3	8.16	87	38.65
		MEAN	36.58

Compressive Strength of sample having nano-silica 0.65%

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.07	81	36.19
2	8.14	80	37.88
3	8.22	76	38.07
		MEAN	37.38

Compressive Strength of sample having nano-silica 1%

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.24	88	39.95
2	8.21	93	39.51
3	8.19	93	39.65
		MEAN	39.70

VI. CONCLUSION

- Addition of nano-silica to concrete makes it much more durable and improves its mechanical properties.
- When compared to control mixtures, a 1% concentration of Nano-silica may increase compressive strength by as much as 11.5%.
- The advantages also apply to flexural and split tensile strengths, albeit the efficacy may be diminished at greater doses.
- By making the concrete matrix denser, nano-silica decreases water absorption and boosts acid attack resistance.
- The binding strength between reinforcement and concrete is also boosted by the improved microstructure.
- Enhanced resistivity against to sulphate assaults and freeze-thaw cycles is one benefit of nano-silica.
- The consequences on workability and higher-grade concrete need more investigation, despite the clear advantages.
- Additional research on reinforced concrete beams utilising nano-silica and high-grade concrete is also necessary.

- Usage of nano-silica in building materials might improve sustainability and structural strength.

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