Experimental Study on Performance of Fibre Reinforced Nanosilica Concrete

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Abstract - Nanotechnology offers promising enhancements to concrete, with nanoparticles augmenting its strength, workability, and durability. This study focuses on employing nano-sized cement as a replacement for conventional cement, particularly utilizing nano-silica due to its beneficial pozzolanic interaction with cement hydration products. Nano-silica effectively modifies concrete's durability by refining pore size and distribution. Experimental investigations reveal an optimal nano-silica replacement dosage of 1.5% to 3% b.w.c , beyond which efficacy diminishes. Further improvements are achieved by combining 0.5% nano-silica with 5% silica fume and varying percentages of aramid, steel, and polypropylene fibres. Notably, the inclusion of 0.1% steel, 0.2% polypropylene, and 0.03% aramid fibres by weight of volume, along with 5% silica fume and 0.5% nano-silica b.w.c , results in substantial compressive strength enhancements, as demonstrated by experimental findings.

Key Words*: *Concrete, Nanosilica, Mixing Technique, Aramid, Compressive Strength.

1. INTRODUCTION

Concrete, a ubiquitous construction material, owes its strength and durability to the hydration process of cementitious compounds. However, to further enhance its properties, additives like nanosilica have garnered attention. Nanosilica, a form of silica with high SiO2 concentration exceeding 99%, offers unique benefits to concrete. By filling the voids between cement particles, nanosilica contributes to denser and more compact concrete, improving its mechanical properties such as compressive strength and durability. Despite its advantageous properties, the use of nanosilica presents challenges, including high cost and potential health hazards associated with its fine particle size. Nevertheless, the pursuit of optimizing concrete performance drives the exploration of nanosilica's incorporation, aiming for structures that are not only stronger but also more sustainable and resilient in the face of various environmental factors.

1.1 Need of fibres

Incorporating fibers alongside nanosilica in concrete is essential for enhancing its mechanical properties and overall performance. While nanosilica contributes to densification and strength improvement by filling voids, fibers reinforce the concrete matrix, offering increased tensile strength, crack resistance, and durability. Aramid, steel, and polypropylene fibers each bring unique characteristics to the mix, such as exceptional strength, ductility, and corrosion resistance, respectively. By combining these fibers with nanosilica, concrete can achieve synergistic effects, optimizing its mechanical properties while ensuring long-term durability and structural integrity.

2. METHODOLOGY

1. Identification of the materials and fibers to be utilized.
2. Gathering the necessary materials and fibers.
3. Assessment of the properties of the chosen materials.
4. Determination of the appropriate concrete grade.
5. Development of the mix design in accordance with IS 10262:2019 for M30 grade concrete.
6. Establishment of the optimal mixing technique.
7. Pouring and forming concrete cubes.
8. Conducting tests on the cubes and analyzing the results.

3. MATERIALS

The materials used for this experimental work are cement, sand, aggregates, water, nanosilica, silica fume, fly ash, steel fibres, aramid fibres, polypropylene fibres, and superplasticizer.

3.1 OPC Cement - Ultratech 43 grade Ordinary Portland cement will be used confirming to IS 12269:1987

3.2 Coarse Aggregate - Crushed granite stones of 10 mm size and 20mm having specific gravity of 2.74, water absorption of 1.74 %, conforming to IS 383-1970

3.3 Fine Aggregate - Sand from the Vaitarna River served as the fine aggregate. . Sand shall be subjected to sieve analysis in accordance with IS 383:1970, and zone-II sand will be confirmed having specific gravity 2.65 and water absorption 4.8%.

3.4 Water - The Reverse Osmosis filtered water will be used which satisfies water standards as per IS 456–2000.

3.5 Nanosilica - Powdered form nanosilica having specific gravity 1.21 will be used.

3.6 Silica Fume - Belgium microsilica having specific gravity 2.88 will be used.

3.7 Fly Ash -. A fine powdered form fly ash having specific gravity 2.8 will be used.

3.8 Steel Fibre - 60 mm steel fibres having specific gravity 7.8 will be used

3.9 Aramid Fibre - Para-aramid fibre in rope form will be used.

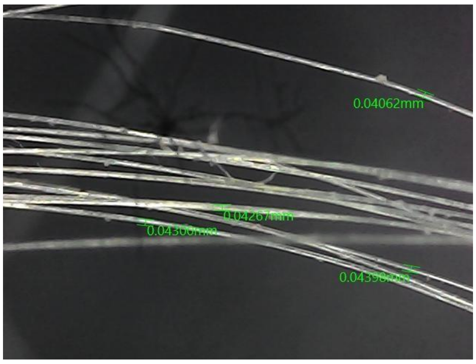

Fig -1:Microscopic Image of Aramid Fibre

3.10 Polypropylene Fibre - 6 mm polypropylene fibre having specific gravity 0.92 will be used.

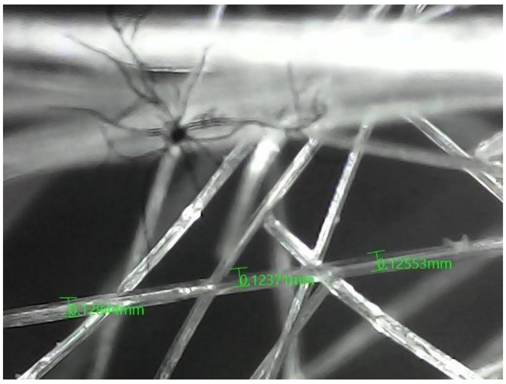

Fig -2:Microscopic Image of Polypropylene Fibre

3.11 Superplasticizer - Liquid form of Polycarboxylate Ether (PCE) having specific gravity 1.622 will be used as a superplasticizer.

4.MIXING TECHNIQUES

To determine the most effective method of incorporating nanosilica into concrete for optimal mixing, we selected from the following techniques:

4.1 Homogenizer:

The scattered components are broken up or divided into smaller particles by a homogenizer, which then distributes the smaller particles equally throughout the mixture. Due to immiscibility and precipitation, the homogenizer's activity continuously prevents the production of big particles.The same mechanical homogenizing apparatus is frequently known by a variety of names, such as Cell Lysor, Disperser, High Shear Mixer, Homogenizer, Polytron, Rotor Stator Homogenizer, Sonicator, or Tissue Tearor. The homogenization of a variety of materials, including tissue, plants, food, soil, and many others, is accomplished with a homogenizer. For mixing the nano silica in concrete, we shall use alternative machines or methods because the homogenizer's price of about Rs. 1 lakh is unaffordable.

4.2 Drum Mixer:

Drum mixer was used in order to mix concrete constituents and NS mechanically (mechanical method). Coarse aggregate, sand, cement and NS were mixed during 2 min in dry form. Then 50% of mixing water enclosing the total quantity of SP was combined and mixed till 3 min. After that, about 1 min rest was allowed and finally the remaining water was added inside the mixture and mixed for 1 min.

4.3 Hand Mixing:

The concrete batch shall be mixed on a sample tray with a square-mouth shovel or similar suitable implement, using the following procedure: The cement and fine aggregate shall be mixed dry until the mixture is uniform. The coarse aggregate shall be added and mixed dry with the cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch. The water shall then be added and the whole mixed for at least three minutes and until the concrete appears to be homogeneous.

4.4 Hand Mixer:

For the optimal mixing of nano and micro silica with cement, separate dry patching methods were employed before blending with other constituents. A hand-held mixer was utilized at a speed of 480 rpm, with various mixing durations tested. It was determined that 10 minutes of mixing produced an acceptable mixture for nano silica, while 2 minutes sufficed for micro silica. When mixing both nano and micro silica with cement, the process involved initially blending cement and micro silica for 2 minutes, followed by the addition of nano silica and an additional 10 minutes of mixing for the entire mixture. Thus, a total mixing time of 12 minutes was required for the combined mixture. These optimized mixing durations ensured thorough integration of the silica additives with cement before subsequent concrete ingredient blending.

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As the hand mixer yielded the most favorable outcomes, it was ultimately utilized for the mixing process.

Fig -3: Mixing Nanosilica in Water using Hand Mixer

5. QUANTITIES OF MATERIALS

Table - 1 : Proportions of fibers and cementitious materials

Trials	Sample Name	Nanosilica(%)	Silica Fume (%)	Fly ash (%)	Steel Fibre (%)	Polypropylene Fibre (%)	Aramid Fibre (%)
1	CC	-	-	-	-	-	-
2	NSFA1	0.5	-	5	-	-	-
3	NSSF1	0.5	7	-	-	-	-
4	NSSF2	1	7	-	-	-	-
5	NSAM1	0.5	5	-	0.05	0.1	0.015
6	NSAM2	0.5	5	-	0.1	0.2	0.03
7	NSAC1	0.5	5	-	0.05	0.1	0.015
8	NSAC2	0.5	5	-	0.1	0.2	0.03
9	NSAC3	0.5	5	-	-	0.2	0.005

Table - 2 : Quantities of Materials

Trial No.		1	2	3	4	5	6	7	8	9
MATERIALS	**Cement (kg)**	10.2	9.7	9.43	9.43	11.1	11.1	11.1	11.1	11.1
	Water (lit)	5.5	5.5	5	5	6.2	6.2	6.2	6.2	6.2
	Fine Aggregate(kg)	15.6	15.6	15.6	15.6	19.6	19.6	19.6	19.6	19.6
	Coarse Aggregate (kg)	28.0	28.0	28.0	28.0	35.7	35.7	35.7	35.7	35.7
	Silica Fume (kg)	-	-	0.71	0.71	0.59	0.59	0.59	0.59	0.59
	Fly Ash (kg)	-	0.51	-	-	-	-	-	-	-
	Nanosilica (kg)	-	0.05	0.05	0.10	0.05	0.05	0.05	0.05	0.05
	Steel Fibre (kg)	-	-	-	-	0.03	0.07	0.03	0.07	-
	Polypropylene Fibre (kg)	-	-	-	-	0.06	0.14	0.06	0.14	0.14
	Aramid Fibre (kg)	-	-	-	-	0.01	0.02	0.01	0.02	0.003
	Polycarboxylate Ether	-	-	-	-	0.12	0.12	0.12	0.12	0.12
	Sample Name	CC2	NSFA1	NSSF1	NSSF2	NSAM1	NSAM2	NSAC1	NSAC2	NSAC3

6. MIXING AND CASTING

For the mixing process, nanosilica was initially blended with water using a hand mixer before being introduced into the concrete mixture in a drum mixer alongside other materials. Notably, in trials 5 and 6, aramid was employed in mesh form, wherein it was laid in two layers to reinforce the cubes. Conversely, in trials 7 and 8, chopped aramid (10 mm) was utilized. Six cubes were casted for each trial, with dimensions measuring 15mm x 15mm x 15mm. Compressive strength tests were conducted on three cubes at 7 days, while the remaining three were tested at 28 days.

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Fig -4: Casted Cubes

7. TESTING AND RESULTS

7.1 Slump Cone Test

Table - 3 : Slump Cone Test

Sample Name	Slump (mm)
CC1	110
NSFA1	78
NSSF1	75
NSSF2	70
CC2	100
NSAM1	102
NSAM2	102
NSAC1	105
NSAC2	104
NSAC3	91

7.2 Compressive Strength Test

Table - 4 : Compressive Strength Test

Trials	Compressive strength in 7 days (N/mm2)	Compressive strength in 28 days (N/mm2)
CC	15.9	32.38
NSFA1	13.11	30.58
NSSF1	21.08	37.1
NSSF2	13.54	31.92
NSAM1	19.6	30.72
NSAM2	19.83	32.49
NSAC1	19.24	33.34
NSAC2	20.18	35.26
NSAC3	17.13	27.42


Fig -5: Testing of Cube

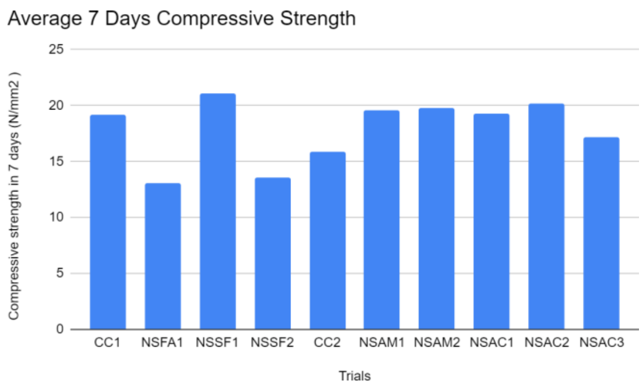

Fig -6: Graph of 7 days Average Compressive Strength

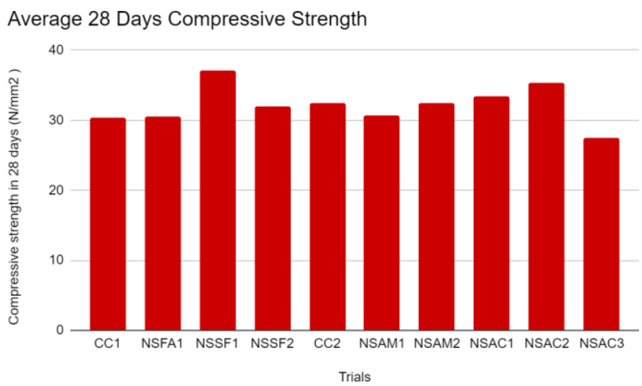

Fig -7: Graph of 28 days Average Compressive Strength

Fig -8: Aramid Fibres Emerging from Cubes

8. CONCLUSIONS

Utilizing 0.5% Nanosilica (NS) alongside a combination of 0.1% steel, 0.2% polypropylene, and 0.03% chopped aramid fibers in concrete yielded the highest compressive strength. The selection of NS at this concentration, coupled with carefully adjusted fiber fractions, optimized both strength and affordability in the concrete mix. This research underscores the importance of meticulous fiber selection and dosage for enhancing concrete performance while balancing cost considerations.

1. Small amounts of NS enhance concrete compressive strength.The finalized methods involve a drum mixer for material combination and a stirrer for NS blending.Optimal NS percentage for maximum strength in 28 days was 0.5%.
2. Previous studies achieved peak strength between 1.5% and 3% NS utilization.
   Our maximum compressive strength reached at 0.5% NS due to affordability and lack of admixtures, unlike industrial processes.
3. Adding aramid, steel, and polypropylene fibers enhances concrete strength.
   Assumed combination was 0.5% NS, 5% Silica Fume, and varied fiber fractions.
4. Initially added 0.1% and 0.5% steel, 0.1% and 0.2% polypropylene, and 5% chopped/mesh aramid fibers along with silica fume and NS, resulting in failure.Adjustments reduced steel fiber to 0.5% and 1% cement volume, and aramid fibers to 0.015 and 0.03% , respectively, yielding positive outcomes.
5. Proper aramid fiber type selection is crucial for reinforcement. Chopped aramid fibers spread uniformly, providing advantages over rope equivalents.
6. In case of fibres, it achieved maximum compressive strength with 0.1% steel fiber, 0.2% polypropylene fiber, and 0.03% chopped aramid fiber.
7. In the last trial, adding only aramid and polypropylene fibers resulted in lower performance compared to the combination of aramid, steel, and polypropylene.
8. Testing revealed that a green foreign material appeared on the cube's surface and spread throughout the curing tank, while aramid fibers were observed growing out of the cube's pores.

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