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Experimental Study On Concrete With Partial Replacement Of Cement By Nano Materials And Fibers

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ABSTRACT

Building sector is always on the lookout for new ways to improve concrete's qualities while cutting down on waste. Impact on mechanical characteristics and durability of concrete by partially replacing cement by nano materials and fibres are investigated in this experimental investigation. The cement was substituted with nano silica and other nano materials in different percentages; fibres similar to polypropylene were utilised to increase the ductility and tensile strength. Results for the changed concrete mixes were measured for water absorption, compressive, splitting tensile, and flexural strengths. Nanomaterials, via impact of filler and better particle packing, considerably increased concrete's compressive and flexural strengths, according to results. Fibres enhanced concrete's efficiency by increasing its ductility and tensile strength while decreasing creation of micro-cracks. Evidence from this study points to possibility of creating long-lasting, high-performance concrete by partially substituting nano materials and fibres for cement.

Keywords: Nano-Silica, Polypropylene Fiber, Nano materials.

I.INTRODUCTION

1.1 GENERAL

Most popular building materials, concrete, has recently been subject of a lot of research and development aimed at improving its performance and characteristics. The tensile strength and longevity of traditional concrete are two areas where it falls short, despite its strength and adaptability. In response to these concerns, scientists are investigating new ways to enhance concrete's properties. Adding polypropylene fibres and partially replacing cement with nano-silica is one such potential technique. Examining how these changes impact concrete's strength characteristics is primary objective of this research.

The particles in nano-silica are far smaller than those in regular silica fume, making it a very reactive kind of silicon dioxide. Microstructure in concrete may be greatly improved with use of nano-silica because of its large surface area. The addition of nano-silica particles to the concrete mixture causes the material to become denser and better cohesive by filling small spaces between the cement grains. Concrete's compressive strength, resilience, and resistance to chemicals and moisture are all enhanced by this.

Synthetic fibres known as polypropylene are renowned for its long lifespan and great tensile strength. Reinforcing and reducing the likelihood of cracking, these fibres disperse evenly throughout concrete mixture when added. Incorporating fibres into concrete may enhance its energy absorption and dissipation properties, fortifying it against impacts and fluctuating stresses.

Concrete reinforced with nano-silica & polypropylene fibres may outperform regular concrete in terms of strength and durability thanks to a synergistic effect. The amended concrete's mechanical characteristics, such as its compressive, tensile, and flexural strengths, will be thoroughly assessed in this experimental investigation. Furthermore, research will evaluate concrete's resistance to different types of environmental stresses.

Goal of this study is to help create better, more sustainable building materials by figuring out what works and what doesn't when nano-silica and polypropylene fibres are mixed with concrete. Buildings that are stronger, more robust, and survive longer might become possible as a result of new building applications made possible by this study's results.

1.2 OBJECTIVES

1. The experimental considerations here are based on the M30 concrete grade.
2. Fibres (1% variation), nanoparticles (1% variation), and nanoparticles (2% variance) relative to cement (3% variation).
3. Determining the ideal dose for maximum potency.
4. To investigate how concrete acts in relation to its mechanical characteristics.

1.3 AIM OF THE STUDY

In light of these difficulties, the current research is looking at the feasibility of using nano materials and fibres in lieu of some of the cement in concrete. In doing so, it hopes to increase strength and longevity of concrete while decreasing its impact upon environment and, maybe, the price tag. Making a building material which is better for the environment and lasts longer than concrete is the main objective.

1. Think about using nanofibers and materials in lieu of some of the cement.
2. Decrease concrete's impact upon environment.
3. Make concrete stronger and more long-lasting.
4. Reduced expenses linked to superior concrete.

II. LITERATURE SURVEY

2.1 LITERATURE REVIEW

2.1.1 Enhanced freeze-thaw resilience of cement mortars through Nano-SiO2 and single/hybrid basalt fiber incorporation: Assessing workability, strength, durability.

Author: Soner Guler, Zehra Funda Akbulut, Hocine Siad, Mohamed Lachemi. Year: 9 April 2024
Incorporating nano-silica and basalt fibers into cement mortars significantly enhances freeze- thaw resilience. Nano-SiO_2 improves microstructure and bonding, while basalt fibers add strength and durability. Together, they enhance workability, strength, and overall durability, making the mortars suitable for challenging environments.

2.1.2 Investigation of the flexural strength of ultra-high-performance concrete using recycled aggregate treated with nano-silica and steel fibre in an experimental setting.

Author: Liang Luo et.al, Year: 6 December 2023
Modifying UHPC with recycled aggregate with nano-silica and steel fibres may greatly improve its flexural efficiency, according to research. This mix overcomes the difficulties of using recycled material in HPC by increasing bond strength & tensile characteristics.

2.1.3 Incorporating nano-iron oxide and sisal fibre reinforcement into plastic aggregate concrete improves its mechanical and durability resistance.

Author: Hassan et.al. Year: 17 August 2023
This research explores how using plastic waste, nano-iron oxide, and sisal fiber can improve concrete. Plastic makes concrete more sustainable but weaker, while nano-iron oxide and sisal fiber strengthen it and make it more durable. Together, they create eco-friendly concrete with better strength and durability.

2.1.4 Investigating the properties of composite fibre reinforced high-performance concrete with nano silica and ultra fine fly ash in terms of its durability using experimental means.

Author: Sujay H.M, et.al.

Year: 6 October 2020
It gives an analysis on use of composite fibre reinforcing to increase the longevity of efficient concrete. In lieu of 15% cement, they utilised ultra-fine fly ash and added nano silica in varying concentrations. It was found that the most efficient combination was 15% fly ash & 3% nano silica, which resulted in less porosity and better

durability. Addition of steel polypropylene fibres to concrete significantly enhanced its properties.

2.1.5 Concrete reinforced with nano silica and steel fibres exhibits enhanced compressive strength and magnetisation thanks to a new magnetic technique

Author: Omid Rezaifar, et.al

Year: 25 April 2024
Compressive strength of 7- and 28-day specimens was found to increase by 88.19% and 59.59%, respectively, when up to 10% nano silica was used in place of cement and 1% steel fibre, respectively. Enhancing magnetic flux density had a positive correlation with compressive strength of samples, meaning that enhancing this parameter up to 1% increased compressive strength.

2.1.6 An investigation into the microstructures and characteristics of recycled aggregate concrete reinforced with polypropylene fibres using nano calcium carbonate is underway.

Author: Xuyong Chen, et.al.

Year: 10 August 2023

Recycled concrete is strengthened, shrinkage is reduced, and durability is increased by adding NC & PPF. Since NC increases hydration, the resulting concrete is denser, stronger, and more resistant to environmental deterioration; as a result, it is better suited for building projects with a longer lifespan.

III.EXPERIMENTAL METHODOLOGY

3.1 GENERAL

The materials and their procedures are covered in this chapter. Concrete, sand, gravel, nanoparticles, and fibres are all part of the test, which follows Indian norms.

The 53 Grade OPC is an excellent cement that sets very quickly and has great strength. After 28 days of curing, it reaches compressive strength of 53 MPa, making it perfect for building projects that need strong and long-lasting structures. The higher fineness level of this cement makes it easier to work with and produces smoother finishes. Because of its strength and durability, OPC 53 Grade Cement is frequently utilised in construction of bridges, flyovers, reservoirs, manufacturing facilities, and skyscrapers.. It is also a preferred choice for making prestressed concrete structures, which require high tensile strength. Made from a blend of limestone, clay, gypsum, and other additives, OPC 53 Grade Cement complies with the Indian Standard IS 12269, ensuring that it meets stringent quality and performance requirements. Its durability and load-bearing capacity make it an essential material for modern construction projects.

3.2 METHODOLOGY

Flow chart of methodology

Selection of Admixture

Study of Journals

Test on Cement

Test on Aggregate -Coarse and fine

Mix Design

Concrete Moulding

Curing for 7 Days and 28 Days

Test on Concrete (Cube, Cylinder, Beam)

Results

TEST ON CEMENT, FINE AND COARSE AGGREGATE

3.3 Test on aggregate and sand

1. Sieve Analysis (Fineness Modulus)
2. Specific Gravity

Sieve Analysis: Process of separating an aggregate sample into smaller portions made up of uniformly sized particles is known as particle sizing. The gradation, or distribution of particle sizes, of a sand or aggregate sample may be found by doing the sieve analysis.

Specific Gravity: Material used to determine the concrete mix's specific gravity during the design process. It is theoretically possible to determine yield of concrete/unit volume by knowing specific of every component and then converting its weight into solid volume. In addition to workability test, specific gravity of the aggregate is needed to calculate compacting factor. From 2.6 to 2.8 is average specific gravity of the rocks.

3.4 Test on Cement

A characteristic called standard consistency must be utilised to determine the beginning setting time, total setting time, soundness, and strength of cement.

3.5 Test on Concrete

One empirical method for determining whether newly mixed concrete is workable is the slump cone test. It is a more precise indicator of the batch-specific concrete's uniformity. The consistency of newly mixed concrete is checked by doing this test. There is a tight relationship between the terms workability and consistency.

3.6 Tests on Concrete Specimen

Experimental experiments were conducted on M30 grade concrete to assess its fresh state qualities, and the results are detailed in this chapter. The presentation of concrete's hardened state qualities occurs when nano silica and fibre are used in lieu of natural sand. To evaluate the different attributes, the following experiments were carried out.

Evaluation of compressive, split-tensile, and flexural strengths.

PHYSICAL PROPERTIES OF FINE AGGREGATE

SPECIFIC GRAVITY OF FINE AGGREGATE BY USING PYCONOMETER METHOD

SL.NO	OBSERVATIONS	TRAIL
1.	weight of pycnometer (W1 in grams)	625
2.	weight of pycnometer + dry soil (W2 in grams)	1025
3.	weight of pycnometer + soil + water (W3 in grams)	1775
4.	weight of pycnometer + water (W4 in grams)	1530

Specific Gravity of fine aggregate

$$= (W2 - W1) / (W2 - W1) - (W3 - W4)$$

RESULT: Specific Gravity of the fine aggregate is = 2.580

WATER ABSORPTION OF FINE AGGREGATE

Procedure:

1. Gather a random sample of fine aggregate, making sure it is devoid of any dust or smaller particles, to serve as a representative sample.
2. Get the Dry Sample's Weight: Using a weighing scale, measure the weight of the dried sample (Weight B).
3. Soak in Water: With the sample in a wire basket, soak it in water between 22 and 32 degrees Celsius.
4. Grab the air bubbles by lowering the basket 25 times at a rate of one drop per second at a height of 25 mm above the base of the tank.
5. Let the Sample Soak: Submerge basket and sample in water for at least 24 hours and no more than 0.5 hours.
6. Carefully take the basket from the water, let it drain for a few minutes, and then use dry absorbent towels to surface-dry the sample.
7. Check the Sample's Saturation Level: While the surface-dry sample is still floating in water, weigh it (Weight A).
8. Oven Sample Drying: In a shallow pan, place the sample and dry it in an oven preheated to 100–110°C for at least one day.
9. Return the oven-dried sample to its original weight by weighing it once again after it has cooled in a sealed container (Weight B).
10. Determine How Much Water Is Absorbed: Apply the equation:

Water Absorption=(C−D) / D ×100%

Important for many building uses, this test finds out how much water fine aggregates can absorb.

Fig 1: Water Absorption of Fine Aggregate

CALCULATION:

Weight of saturated surface dry aggregate (C) = 495 grams

Oven dry sample after 24 hours (D) = 490 grams

Water Absorption=(C−D) / D ×100% = 1.02%

RESULTS: water absorption for fine grained soil = 1.0%

FINENESS MODULUS:

Aim: In order to find the fineness modulus, effective size, and uniformity coefficient, as well as the particle size distribution, one must do sieve analysis, also known as grain size analysis.

To find out where the coarse, bigger particles are distributed, mechanical or sieve analysis is carried out. A soil's engineering qualities are impacted by the distribution of grain sizes. As a prerequisite for soil classification, grain size analysis gives the distribution of grain sizes.

Procedures:

- Dry a little amount of dirt that you collected from the field using an oven.
- Incorporate a well-separated quantity of dry soil that is known to be free of grains.
- No more than one thousand grammes of soil may be collected for analysis.
- Get a stack of strainers ready.
- Arrange the sieves in descending order of opening size, with the bigger apertures (lower numbers) positioned above the smaller apertures (higher numbers). This 75 u sieve, #200, is the final one. The parts that pass through the #200 sieve are collected in a pan that is fastened to the bottom 75 u sieve; then, the nest is set up on a motorised shaker.
- Clean the sieves thoroughly. If there are a lot of dirt particles jammed within the holes, you may use a brush to loosen them.
- To ensure that the dirt retained on each sieve achieves a consistent value, the whole nest is shaken

horizontally in a sieve shaker for 10 minutes.

- Find the total amount of dirt extracted from each sieve, including that which settled to the bottom of the pan.

Fig 2: Fineness Modulus

Sieve Analysis of Fine Aggregates:

Sieve size(mm)	Weight of sieve with soil	weight of sieve	Weight of soil retained	% retained	Cumulative weight % retained on each sieve	Percent passing
4.75	405	405	0	0	0	100%
2.36	305	285	20	2%	2	98%
1.18	-	-	-	-	-	-
600	945	370	575	57.5	59.5	40.5
300	655	345	310	31.0	90.5	9.5
150	310	235	75	7.5	98	2.0
Pan	440	420	20	2.0	100	0

Total weight of soil sample = 1000-gram

Fineness modulus of sand = 2.5

RESULT: (weight of cumulative retained / weight of sample) x 100 = 2.5

SPECIFIC GRAVITY & WATER ABSORPTION OF COARSE AGGREGATE

2386 (Part 3) of 1963

- Aggregate size >10mm

Sample of aggregate not less than 2 Kg

- A1 = Weight of aggregate + basket in water = 4 Kg
- A2 = Weight of basket in water = 2.75 Kg
- A = A1-A2

  = 40 - 2.75

  = 1.25

- A = weight in gram saturated aggregate (A1-A2) = 1250 gram
- B = weight in gram of saturated surface dry aggregate = 2.010 kg = 2010 gram
- C = weight in gram of oven dried aggregate = 2.005 kg = 2005 gram

Specific gravity of coarse aggregate = C/ B-A

= 2005/(2010-1250)

= 2005/760

= 2.638

Specific gravity of coarse aggregate = 2.64

Water absorption = B-C/C*100

= 2010-2005/2005*100 = 0.249 %

Water absorption of coarse aggregate = 0.25 %

AGGREGATE (CRUSHING VALUE TEST)

OBSERVATION AND CALCULATION:

Trail no	Weight of aggregate (W1)	Weight of aggregate passing through 2.36 mm sieve (W2)	Impact value W1/W2*100
1	0.335	0.04	11.940%
2	0.325	0.05	15.38%
3	0.315	0.025	7.93%
4	0.275	0.025	9.09%

Aggregate impact value = (W2 / W1) x 100

RESULTS: Aggregate Crushing value = 11.08%

AGGREGATE (IMPACT VALUE)

Trail no	Empty weight of mould (W1)	Weight of mould + aggregate (W2)	Weight of aggregate (W=W2-W1)	Weight of aggregate passing through 2.36 mm (W3)	Crushing value =W3/W*100
1	3.88 kg	6.730	6.730-3.88 =2.580	0.235	9.10 %
2	3.980 kg	6.800	6.800-3.980 =2.820	0.30	10.63%

FORMULA: Impact value = (W3 x100) / (W2-W1)

Calculation: 9.10+10.63/2

RESULT: Aggregate impact value = 9.865%

FLAKINESS INDEX

OBSERVATION:

SLNO	Size of aggregate passing through IS sieve in mm	Retained in IS sieve in mm	Passing through thickness gauge (flakiness) (W2)
1	63	50	0
2	50	40	0
3	40	31.5	60
4	31.5	25	45
5	25	20	75
6	20	16	15
7	16	12.5	15
8	12.5	10	10
9	10	6.3	5
10	6.3	Pan	5
			W2 = 230

Weight of 200 piece of aggregate, W1 = 3070 gram Flakiness index = W2/W1*100 = 230/3070*100=7049%

Result: The flakiness index if the given sample of aggregate is 7.49%

ELONGATION INDEX

SLNO	Size of aggregate passing through IS sieve in mm	Retained in IS sieve in mm	Passing through thickness gauge (flakiness) (W2)
1	63	50	0
2	50	40	0
3	40	31.5	28
4	31.5	25	0
5	25	20	65
6	20	16	46
7	16	12.5	215
8	12.5	10	110
9	10	6.3	15
10	6.3	Pan	0
			W2 = 479

Calculation: elongation index = W2/W1*100 = 479/3070*100 = 15.60%

Result: The elongation index of the given sample of aggregate = 15.60%

SIEVE ANALYSIS OF COARSE AGGREGATE

Sieve size (mm)	Mass retained in kg	Percentage retained	Cumulative % Retained	Percentage passing (%)
22.5	0.065	2.16	2.16	97.84
20	0.110	3.666	5.826	94.174
16	1.360	45.33	51.156	48.844
12.5	1.125	37.5	88.656	11.344
10	0.295	9.833	98.489	1.511
4.75	0.045	1.5	99.989	0.011
2.36	0	0	99.989	0.011
0.6	0	0	99.989	0.011
0.3	0	0	99.989	0.011
0.15	0	0	99.989	0.011
		Total =	746.232	

Total weight of sample taken = 3kg

Fineness modulus = cumulative % retained /100 = 746.232/100 = 7.46

% retained = 0.065/3*100 = 2.16%

% retained = mass retained in kg / Total weight of aggregate * 100 = 0.110/3*100=3.66

TEST CONDUCTED ON CEMENT

SPECIFIC GRAVITY OF CEMENT

OBSERVATIONS:

Description of item	Trail 1
Weight of empty bottle (W1 kg)	0.045
Weight of bottle + Cement (W2 kg)	0.095
Weight of bottle + Cement + Kerosene (W3 kg)	0.160
Weight of bottle + full Kerosene (W4 kg)	0.130
Weight of bottle + full water (W5 kg)	0.145

Specific gravity of Cement:

(W2-W1) x (W4-W1) / [(W4 – W1) – (W3 -W2) x (W5 – W1)]

RESULTS: specific gravity of given Cement = 3.125

NORMAL CONSISTENCY

OBSERVATION AND CALCULATION:

1. Type of cement: - OPC 53 GRADE
2. Brand of cement: - ULTRATECH

SLNO	PARTICULAR	TRAIL 1	TRAIL 2	TRAIL 3	TRAIL 4
1.	Percentage of water	25	30	35	40
2.	Initial reading	40	40	40	40
3.	Final reading	24	9	18	30
4.	Depth penetration	16	31	22	10

RESULTS: The percentage of water corresponding 33 to 35mm depth of penetration gives the standard consistency = 30%

INITIAL SETTING TIME
Observation:

Sl.No	Weight of Cement Sample In (Grams)	Quantity of Water In (ML)	Time In (Mins)	Penetration In (Mm)
1	300 grams	0.85*300*30/100	0	0
			5	0
			10	0
			15	0
			20	0
			25	1
			30	2
			35	4
			40	7

Result: The initial setting time of given cement sample is 40mins

FINENESS TEST OF CEMENT BY SIEVE ANALYSIS

OBSERVATIONS:

1. Weight of cement taken = 100 grams

2. Weight of cement retained after sieving = 3.5 grams

Percentage weight of residue = weight of sample left on the sieve / total weight of sample*100

RESULT: Fineness of the given sample is = 3.5 %

MIX PROPORTIONING

Table 1: Mix Proportioning For (7 days)

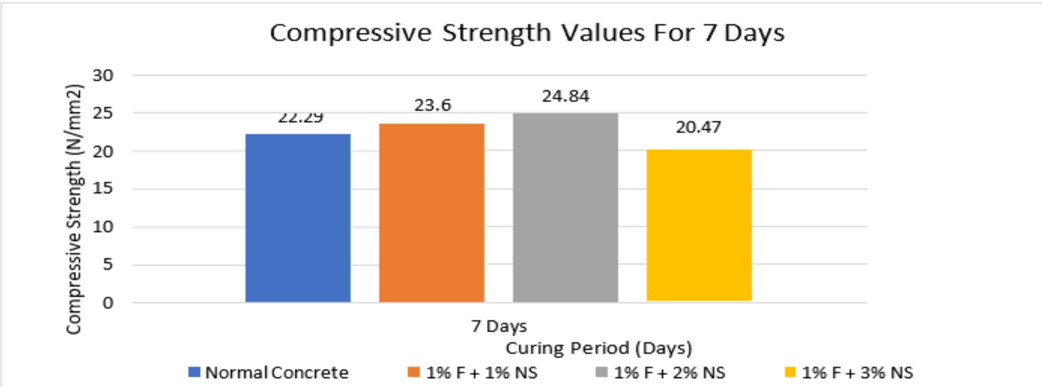
7 days	Normal Concrete	1% F + 1% NS	1% F + 2% NS	1% F + 3% NS
Cement	11.52 kg	11.52 kg	11.52 kg	11.52 kg
Sand	23.374 kg	23.374 kg	23.374 kg	23.374 kg
Aggregate	37.19 kg	37.19 kg	37.19 kg	37.19 kg
Water	6.679	6.679	6.679	6.679
Fiber	NIL	0.115 kg	0.115 kg	0.115 kg
Nano silica	NIL	0.115 kg	0.230 kg	0.345 kg

Table 2: Mix Proportioning For (28 days)

28 days	Normal Concrete	1% F + 1% NS	1% F + 2% NS	1% F + 3% NS
Cement	13.072 kg	12.812 kg	12.681 kg	12.55 kg
Sand	26.506 kg	26.506 kg	26.506 kg	26.506 kg
Aggregate	42.218 kg	42.218 kg	42.218 kg	42.218 kg
Water	7.578	7.578	7.578	7.578
Fiber	NIL	0.130 kg	0.130 kg	0.130 kg
Nano silica	NIL	0.130 kg	0.261 kg	0.392 kg

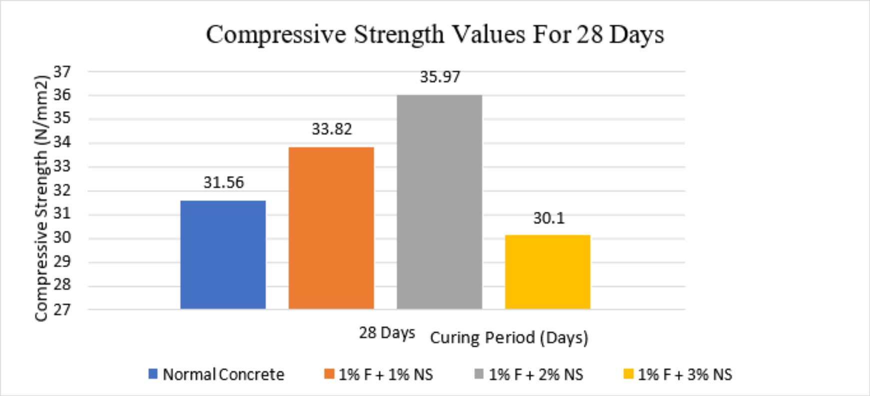
IV. RESULT AND DISCUSSION

7 DAYS COMPRESSIVE STRENGTH FOR NORMAL CONCRETE, FIBERS AND VARING PERCENTAGE OF THE NANO-SILICA



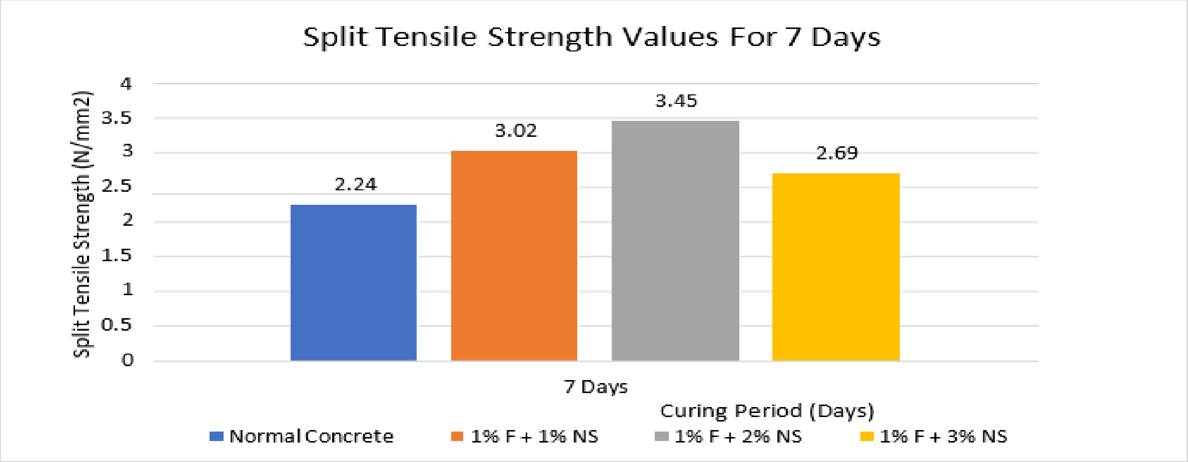
Graph 1 : Graphical Representation of Compressive Strength (7 Days)

28 DAYS COMPRESSIVE STRENGTH FOR NORMAL CONCRETE, FIBERS AND VARING PERCENTAGE OF THE NANO-SILICA



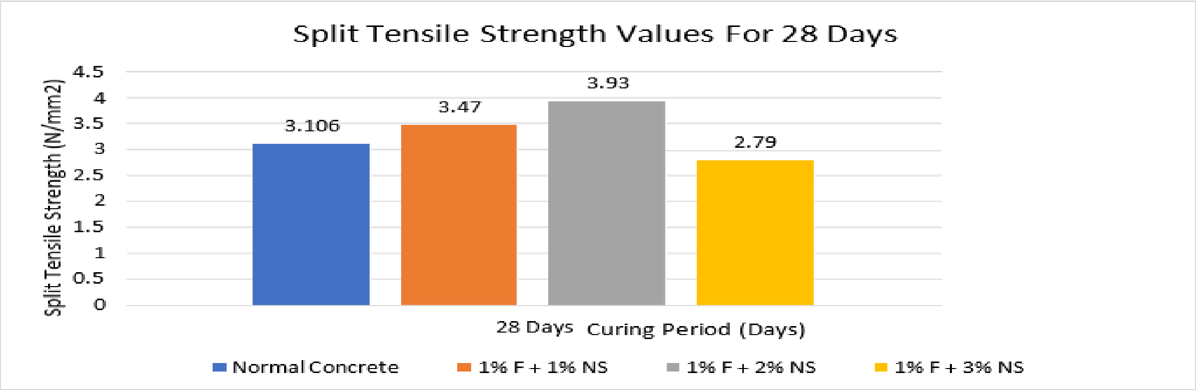
Graph 2: Graphical Representation of Compressive Strength (28 Days)

7 DAYS SPLIT TENSILE STRENGTH FOR NORMAL CONCRETE, FIBERS AND VARING PERCENTAGE OF THE NANO-SILICA



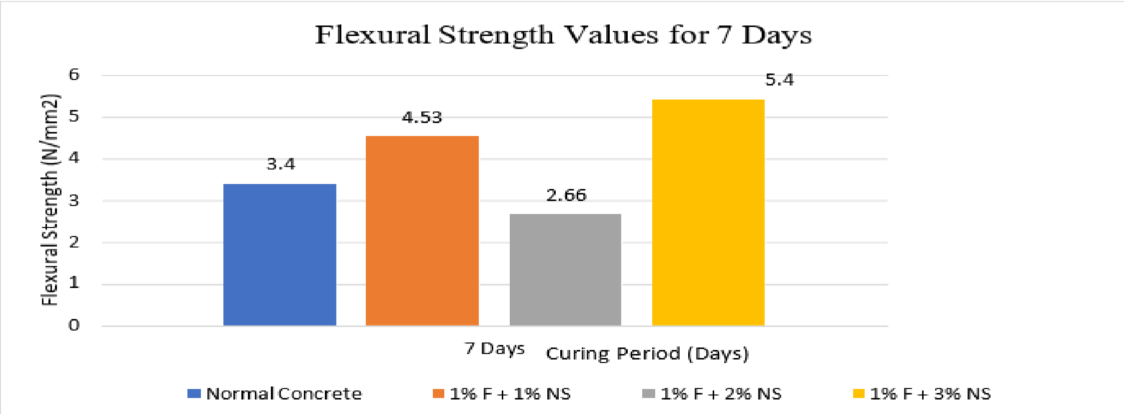
Graph 3: Graphical Representation of Split Tensile Strength (7 Days)

28 DAYS SPLIT TENSILE STRENGTH FOR NORMAL CONCRETE, FIBERS AND VARING PERCENTAGE OF THE NANO-SILICA



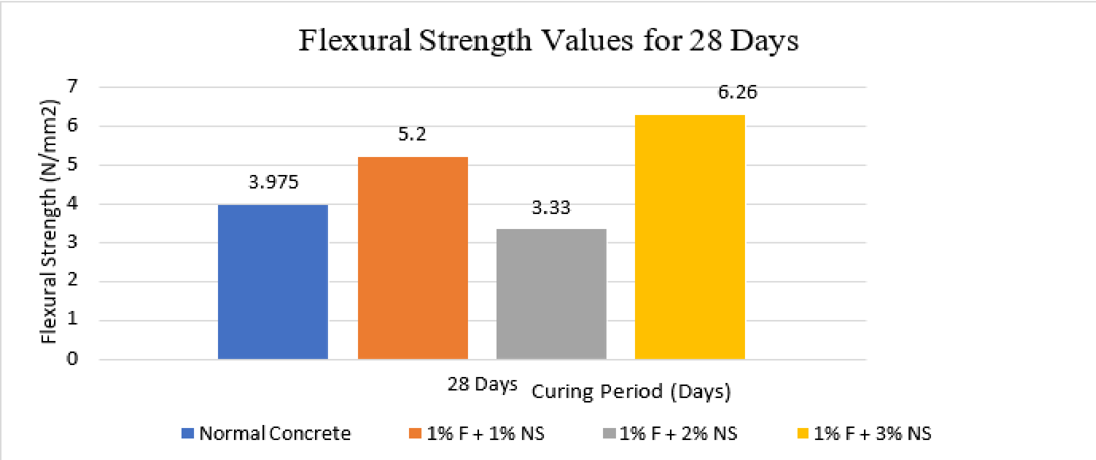
Graph 4: Graphical Representation of Split Tensile Strength (28 Days)

7 DAYS FLEXURAL STRENGTH FOR NORMAL CONCRETE, FIBERS AND VARING PERCENTAGE OF THE NANO-SILICA



Graph 5: Graphical Representation of Flexural Strength (7 Days)

28 DAYS FLEXURAL STRENGTH FOR NORMAL CONCRETE, FIBERS AND VARING PERCENTAGE OF THE NANO-SILICA



Graph 6: Graphical Representation of Flexural Strength (28 Days)

V. CONCULSION

5.1 Conclusions

This research examined the effects of utilising concrete specimens with varying percentages of nano silica and a constant amount of fibre. The findings showed promising outcomes.

1. The compressive strength may be increased by substituting polypropylene fibre and nano silica for cement. Specimens containing up to 1% polypropylene fibre and 2% nano silica showed an improvement at 7 days (24.84 N/mm2) and 28 days (35.97 N/mm2), respectively.
2. Specimens compressed with up to 1% fibre and 2% nano silica at 7 days old had a tensile strength of 3.02 N/mm2 and 3.45 N/mm2 respectively, thanks to the use of fibres and nano silica in lieu of cement.
3. Replacing cement with fibres and nano-silica improves the specimen's flexible strength; at 7 days and 28 days of age, specimens with up to 1% fibres and 3% nano silica had a strength of 5.40 N/mm2 and 6.26 N/mm2, respectively.
4. In addition to clearly demonstrating their impact on building costs, they lessen environmental pollutants.
5. Both the compressive and split tensile strengths are considerably enhanced by the inclusion of nano silica and fibres, according to the results.
6. The research demonstrated that concrete made by substituting 1% fibres and 2% nano-silica for cement may be used in the production of concrete.

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