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EXPERIMENTAL INVESTIGATION OF NATURAL HYBRID FIBRE REINFORCED WITH NANO CONCRETE BEAMS UNDER CYCLIC LOADING

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Abstract:
The influence of Nano-Silica on various properties of concrete is obtained by replacing the cement with various percentages of Nano-Silica and natural hybrid fibres. Nano-Silica is used as a partial replacement for cement in the range of 2%, 2.5%, 3%, 3.5%, 4% and hybrid fibre of percentage 0.5%, 1%, 1.5%, 2% and 2.5% for M_{25} mix. Specimens are casted using Nano-Silica concrete. Laboratory tests were conducted to determine the strength of Nano-Silica concrete at the age of 28 days. Results behaviour. However, the density is reduced compared to standard mix of concrete. The replacement of cement with Nano-Silica results in higher strength and reduction in the permeability than the controlled concrete. The replacement of cement with Nano-Silica more than 3% results in the reduction of various properties of Nano-Silica concrete.

Key Words: Nano Silica, Human Hair Fibre, Coir Fibre, Nano Concrete & Natural Fibre Reinforced Concrete

1. Introduction:

Fibre Reinforced Concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres – each of which lends varying properties to the concrete. In addition, the character of fibre-reinforced concrete changes with varying concretes, fibre materials, geometries, distribution, orientation, and densities. The main reasons for adding steel fibres to concrete mix is to improve the post-cracking response of the concrete i.e., to improve its energy absorption capacity and apparent ductile and to provide crack resistance and crack control. Also, it helps to maintain structural integrity and cohesiveness in the material.

Hybrid Fibre Reinforced Concrete: Hybrid fibre reinforced concrete is the one in which more than two types of fibres are used as secondary reinforcement. In Fibre Reinforced Concrete (FRC), fibres can be effective in arresting cracks at both macro and micro levels. For an optimal response, different type of fibres may be suitably combined to produce Hybrid Fibre Reinforced Concrete (HFRC) .The use of optimized combinations of two or more types of fibres in the same concrete mixture can produce a composite with better engineering properties than that of individual fibres.

Coconut Fibre: The coconut fibre is mainly used for the purpose of controlling the crack and also for its excellent insulation against temperature. The coconut fibres are found in abundance and the coconut fibres obtained from coconut husk, belonging to the family of palm fibres, are agricultural waste products obtained in the processing of coconut oil, and are available in large quantities in the tropical regions of the world, most especially in Africa, Asia and southern America. The coconut fibres are tough and durable, resilient, spring back to shape even after constant use.

Human Hair Fibre: The human hair is strong in tension and it has strength equal to the copper wire of similar diameter. Hair, a non-degradable matter is creating an environmental problem so its use as a fibre reinforcing material can minimize the problem. It is also available in abundance and at a very low cost. It reinforces the mortar and prevents it from spalling. As hair is a non-degradable matter they can only really be disposed of by consigning them to landfill, and as such they are relatively environmentally unfriendly, thus the usage of hair as fibre reinforcement will reduce the landfill and it is eco-friendly.

Nano Silica Powder: Is the first Nano product that replaced the micro silica. Advancement made by the study of concrete at Nano scale has proved Nano silica much better than silica used in conventional concrete.

Properties of Nano Silica Powder:

- ✓ High compressive
- ✓ Strength concretes.
- ✓ High workability with reduced water/content ratio.
- ✓ Use of super plasticizing additives is unnecessary.
- ✓ Fills up all the micro pores and micro spaces.
- ✓ Cement saving up to 35-40%.

Table 1: Properties of Natural Hybrid Fibre

S.No	Fiber Properties	Coir Fiber	Hair Fiber
1	Appearance		

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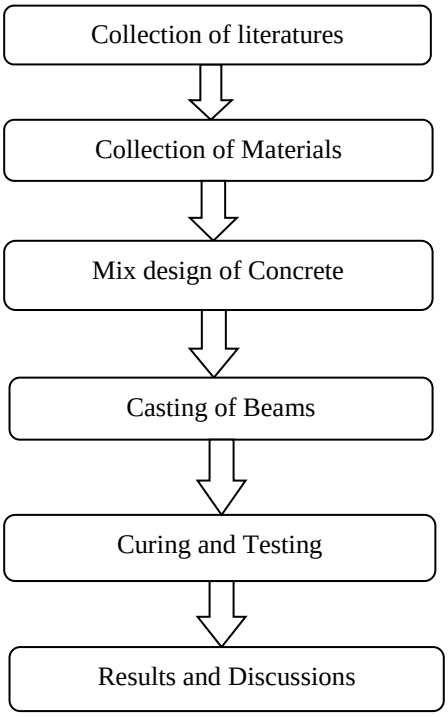
2	Length (mm)	60 to 250mm	60mm
3	Shape	Straight	Straight
4	Diameter (mm)	0.005 to 0.45 mm	100 to 120 µm
5	Aspect ratio	133	75
6	Density (kgm^{-3})	1150	7850
7	Young's modulus	3.7 to 6 GPa	2.74 Gpa
8	Tensile strength	15 to 500 MPa	16 Mpa

Objectives:

- ✓ The main objective of this project is to determine the behaviour of natural hybrid fibre reinforced beam with Nano concrete under cyclic loading (NHFRC).
- ✓ To compare the behaviour of various specimens between control concrete specimen and Natural Hybrid Fibre Reinforced with Nano Concrete.
- ✓ The Nano materials such as Nano silica powder (SiO_2) of varying percentage are used in this project like 2%, 2.5%, 3%, 3.5% and 4%in the concrete.
- ✓ And the Natural Fibres like Coir and Human hair are used at 0.5%, 1%, 1.5%, 2 %and 2.5 %in concrete.
- ✓ To compare the strength of control specimen and Nano concrete with various percentages of NHFR with NS specimen.

2. Methodology:

The main aim of this project is to determine the behaviour of Natural Hybrid Fibre Reinforced beam with Nano Concrete under cyclic loading. The following flow chart shows methodology of this project



3. Test on Materials:

The preliminary tests were conducted on cement, fine aggregate, coarse aggregate, and the test results were obtained. Based on the results obtained the mix proportion for M_{25} concrete were done.

Property	Cement	Fine Aggregate	Coarse Aggregate
Fineness	1%	4.72	8.212
Consistency	30%	-	-
Initial setting time	80 min	-	-
Specific gravity	3.18	2.62	2.78

Mix proportion for M_{25} concrete

Cement	=	425.73 Kg/m³
Fine aggregate	=	649.498 Kg/m³
Coarse aggregate	=	1174.42 Kg/m³
Water cement ratio	=	0.45
Water content	=	191.58 Kg/m³
C: F.A: C.A	=	1: 1.52: 2.75

The mix proportion for M_{25} concrete is calculated using 456:2000, IS 10262:2009. Super plasticizer CONPLAST SP430 is added to increase the workability of concrete.

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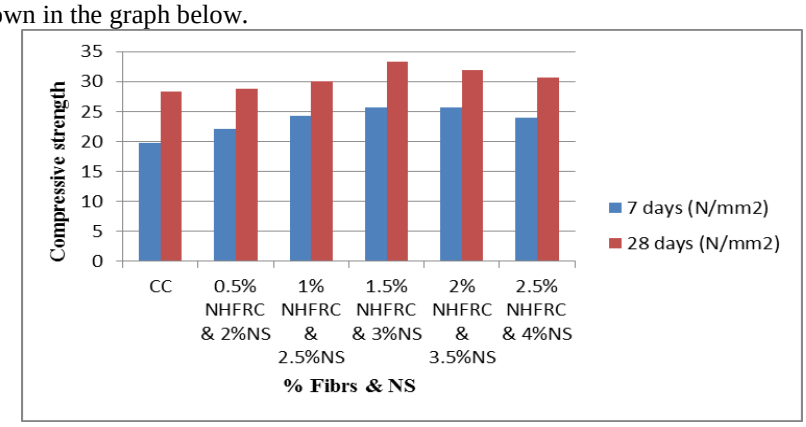
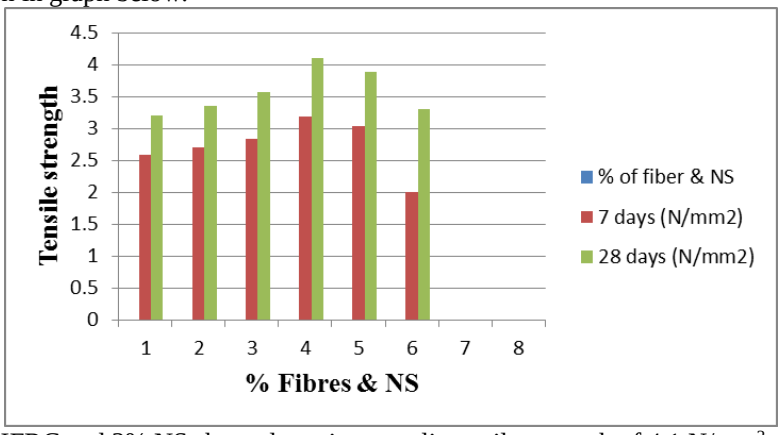
4. Results for Various Specimens:

Compressive Strength Test: The comparative results for compressive strength of concrete cubes between control specimen and NHFRC specimens are shown in the graph below.



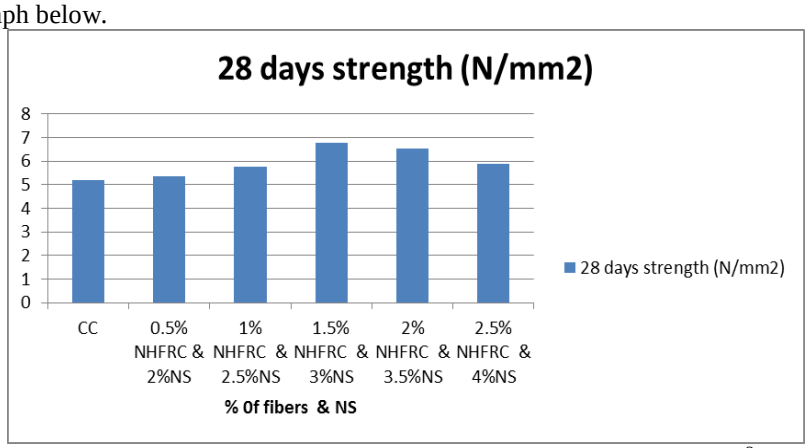
The specimen with 1.5 % NHFRC and 3% NS showed maximum compressive strength of 33.23 N/mm^2

Split Tensile Strength Test: The comparative results for split tensile strength of concrete cylinders between control specimen and NHFRC specimens are shown in graph below.



The specimen with 1.5 % NHFRC and 3% NS showed maximum split tensile strength of 4.1 N/mm^2

Flexural Strength Test: The comparative results for flexural strength of prism specimen between control specimen and NHFRC specimens are shown in graph below.



The specimen with 1.5 % NHFRC and 3% NS showed maximum flexural strength of 6.79 N/mm^2

5. Experimental Programme:

Dimensions of the Beam Specimen: Six numbers of beam specimens were casted totally including control beam specimen. The size of the beams is 700mm x 150mm x 150mm.The dimensions of the beams casted are shown in figure 1 below.

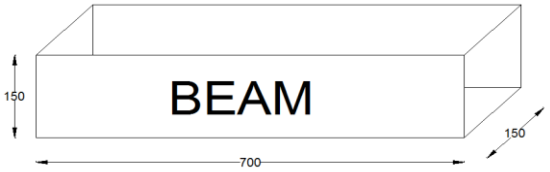


Figure 1: Dimensions of the beam

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Reinforcement Details of the Beam Specimen: The details of reinforcement adopted for the beam specimens are given below

- ✓ Main reinforcement - 4nos. of bars at 12mm diameter
- ✓ Shear reinforcement - Stirrups of 8mm ϕ at 100mm c/c spacing
- ✓ Cover - 20mm

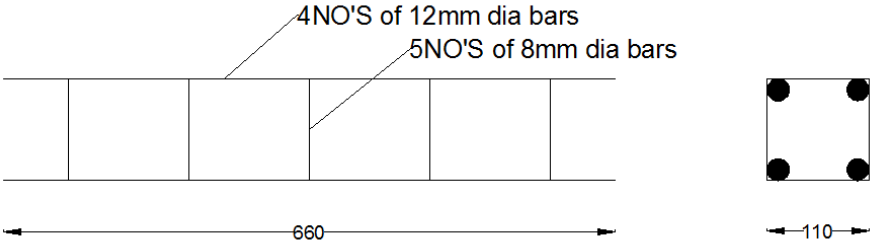

Figure 2: Reinforcement details of the beam specimen

The control beam specimen without fibres of grade M_{25} was casted, cured and tested for 28 days strength. Also Nano silica and NHFRC beams were casted for varying percentage of Nano silica powder 2%, 2.5%, 3%, 3.5% and 4% , natural hybrid fibre such as 0.5%, 1%, 1.5%, 2% and 2.5% based on the test results obtained from compressive strength test, split tensile strength test and flexural strength test. There is an increase in strength for 1.5% NHFRC and 3% Nano silica. The beams were cured for 28 days and then tested.

Test Setup: The beams were placed in the loading frame of capacity of 50 tons under two point loading. The end condition of the beam was kept as simply supported. The beam was divided into number of grids before placing in the loading frame for the observation of crack pattern. The load cell was placed in the hydraulic jack at the center of the beam from which load imparted to the beam can be observed. For finding the deflections under the mid-point, the (LVDT) Linear Variable Displacement Transformer was in the centre of the beam to measure the mid deflection. The load cell was connected to a 20 channel data logger, where the results can be viewed. The control beam, 0.5%, 1%, 1.5%, 2% and 2.5% of NHFRC beams were tested until failure load.

6. Result and Discussion:

The beams of varying percentage of fibers were tested under cyclic loading. During testing the cracks appeared at the bottom centre and propagated further on loading. The cracks appeared are flexural cracks and most of the cracks appeared at the both support edges & mid span. The ultimate load and ultimate deflection of the control beam and various Nano silica and NHFRC beams against cyclic loading were determined experimentally.

Ultimate Load and Deflection of beams

Type of Beam	At mid-span		% increase in ultimate load
	Ultimate load (KN)	Ultimate deflection (mm)	
Control beam	60.70	5.2	-
0.5% NHFRC	70.65	7.4	16.39
1% NHFRC	80.50	8.6	32.61
1.5% NHFRC	90.40	9.8	48.92
2% NHFRC	70	12.9	15.32
2.5%NHFRC	60.20	12.1	0.823

It was seen that the load carrying capacity of nano silica and NHFRC beams increased with an increase in hybrid fibre dosage when compared to control beam specimen. The load carrying capacity of the beams also increased in each cycle.

Result for 1.5% Nano silica and 3% NHFRC beams:

The mid-deflection is measured for loading and unloading conditions and the results are tabulated. Discussions for 1.5% NHFRC & 3%NS Beam Result. The midspan-deflection is measured for loading and unloading conditions for 1.5%.

- ✓ The first crack occurred at the load of 45.85 kN in mid-span.
- ✓ The ultimate load was recorded as 90.40 kN with a deflection of 8.6 mm.

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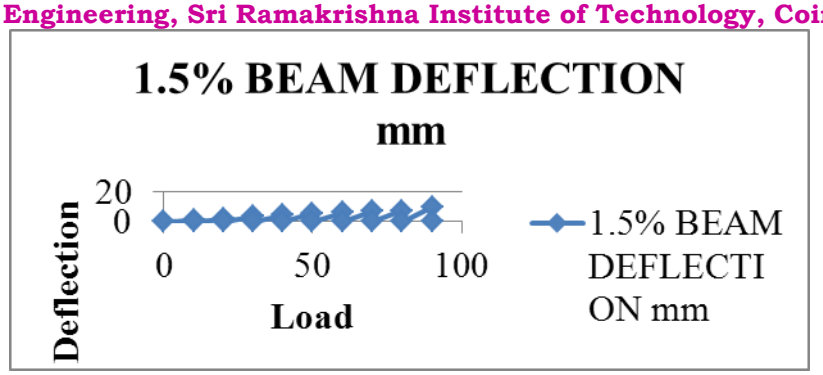

Graph 1: Cycle VS Load at mid-span for 1.5% NS and 3% NHFRC

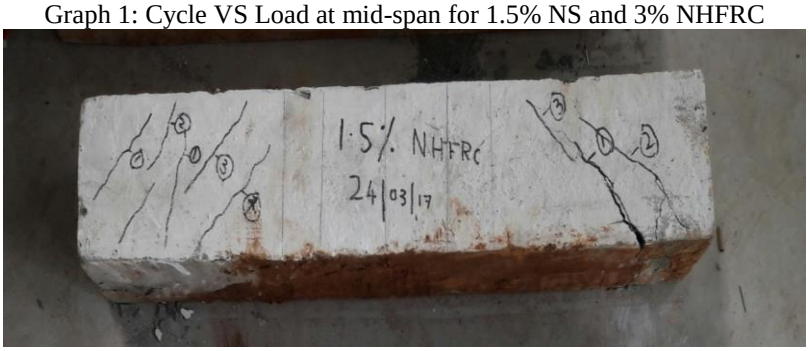

Figure 4: Crack pattern for 1.5% NHFRC & 3% NS beam

7. Conclusion:

Based on the experimental results, the following conclusions were drawn for NHFRC & Nano silica beams subjected to cyclic loading.

- ✓ Tension cracks were formed in the NHFRC beams with NS under the loaded area.
- ✓ The cracks originated from the both support edges and propagated towards the top & bottom when the load is increased.
- ✓ The ultimate deflection for the NHFRC beams with NS was found to be increasing when compared to the control specimen.
- ✓ It was found that beam with 1.5% NHFRC and 3% Nano silica beam specimen shows an increase of 48.92% in ultimate load and 88.46% in deflection when compared to that of control beam.

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