Behaviour of Natural Hybrid Fiber Reinforced Slab with Nano Concrete under Static Loading

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Abstract

The performance of conventional concrete is enhanced by the addition of fibers and Nano silica in concrete. In this paper the behavior of RC slab structures by using Natural hybrid natural Fiber (coir and hair) and Nano silica reinforced Concrete (NHFRC) was determined. The mix design was done for M25 grade concrete as per IS: 10262: 2009. The various percentages of fibers ranging from 0.5% to 2.5% by weight of cement were used in the investigations and the various percentages of Nano silica ranging from 0.2% to 4.5% by weight of cement were used in the investigations. The Simply supported one-way slab specimens were casted with NHFR and Nano silica of the various percentages, cured and tested for 28 day strength. The Static loading behavior of the NHFRC with NS specimen were obtained and compared with control specimens. Hybrid fiber dosages of 0.5%, 1%, 1.5%, 2%, and 2.5% and the slabs were subjected to two static line loads at third points of the slab by hydraulic jacks. Totally 6 slabs were casted and tested including control slab specimen. The test results shown that use of NHFRC with Nano silica improves loading performance of slab under static loading.

Keywords: Natural fiber reinforced concrete, Coir fiber, Human hair fiber, Static load, Nano silica

I. Introduction

Natural hybrid fiber reinforced concrete (NHRFC) is most economical alternative by reducing both the total volume of concrete and the amount of steel required for a structural member. Addition of fibers in concrete improve the tensile characteristics by inhibiting crack growth and increase in toughness or energy absorption capacity, flexural strength, fatigue resistance and ductility. Various types of fibers were used in concrete such as metallic fibers, polymeric fibers, mineral fibers, and naturally occurring fibers, among these natural fibers (coir and human hair) are giving better due to their easy availability and tensile strength. It has been shown recently that many researchers investigated the mechanical properties of the concept of hybridization with two different fibers incorporated in a common cement matrix, and the hybrid composite can offer more attractive engineering properties, because the presence of one fiber enables the more efficient utilization of the potential properties of the other fiber. Addition of Nano material (Nano silica) to the concrete matrix to increase the compressive strength of the concrete and reduce the porosity between the cement particles. Nano Silica is used for improving the concrete properties in fresh and hardened states. The use of two or more different types of fibers in concrete matrix is called hybrid fiber reinforced concrete. Hybrid fiber reinforced concrete (HFRC) is the one in which more than one or two types of fibers are used as secondary reinforcement. In this project coir and human hair are used as hybrid fiber reinforcement to the concrete slab specimen.

II. Objective

- The objective of this paper is to determine the behavior of natural hybrid fiber reinforced concrete slab with NS under static loading.
- To conduct static loading test for natural hybrid fiber reinforced concrete slabs with various percentage of fibers, Nano silica powder used.
- To compare results of natural hybrid fiber reinforced concrete slab and NS specimen with control specimen.

III. FIBER REINFORCED CONCRETE (FRC)

Reinforced Concrete is the widely used construction material. When fibers added to the concrete is said to be fiber reinforced concrete. The tensile strength of concrete can be improved by adding fibers of different materials and volume. The most economical fiber is natural fibers. Low volume fractions of fibers (less than 1%) are used to reduce shrinkage cracking. Moderate volume fractions (between1% to 2%) increase flexural strength, fracture toughness and impact resistance. High volume fractions (greater than 2%) lead to strain hardening of the composites. The shape and length of the fibers also play a role in the effectiveness of fibers in improving the properties of the concrete.

A. Hybrid Fiber Reinforced Concrete (HFRC)

The use of two or more different types of fibers in concrete matrix is called hybrid fiber reinforced concrete. Hybrid fiber reinforced concrete (HFRC) is the one in which more than one or two types of fibers are used as secondary reinforcement. In this project coir and human hair are used as hybrid fiber reinforcement to the concrete slab specimen. The hybrid composite can offer more attractive engineering properties, because the presence of one fiber enables the more efficient utilization of the potential properties of the other fiber.

B. Types of Fiber

The various types of fibers are commonly used in concrete. They are asbestos fiber, steel fiber, sisal fiber, glass fiber, carbon fiber, poly propylene fiber, plastic fiber and natural fibers.
Two types of fibers used in this project. They are,

- Coir fiber.
- Human hair fiber.

C. Coir Fiber

Coconut fiber is extracted from the outer shell of a coconut. The common name, scientific name and plant family of coconut fiber is Coir, Cocas nucifera and Arecaceae (Palm), respectively. There are two types of coconut fibers, brown fiber extracted from matured coconuts and white fibers extracted from immature coconuts. Brown fibers are thick, strong and have high abrasion resistance. White fibers are smoother and finer, but also weaker. Coconut fibers are commercial available in three forms, namely bristle (long fibers), mattress (relatively short) and decorticated (mixed fibers). These different types of fibers have different uses depending upon the requirement. In engineering, brown fibers are mostly used. The fibers recovered from various waste streams are suitable to use as secondary reinforcement in concrete. The advantage of using such rural fibers provides generally a low cost construction than using virgin fibers and the elimination of the need for waste disposal in landfills.

D. Human Hair Fiber

Human Hair is a natural fiber that can be found abundantly in all parts of the world. It is a proteinaceous fiber with a strong keratin chains. The Primary component of hair fiber is known as keratin. Keratins are proteins consisting of long chains (polymers) of amino acids. Hair contains a high amount of sulphur because the amino acid cysteine is a key component of the keratin proteins in hair fiber. The sulphur in cysteine molecules in adjacent keratin proteins link together in disulfide chemical bonds. These disulfide bonds are very strong and very difficult to break apart. These disulfide chemical bonds linking the keratins together are the key factor in the durability and resistance of hair fiber to degradation under environmental stress. They are largely resistant to the action of acids. The exceptional properties of human hair such as its unique chemical composition, slow degradation rate, thermal insulation, high tensile strength. It manufactured a hair-based composite material by manipulating a plurality of cut lengths of hair to form a hair mat and combining said mat of hair or web with a structural additive in order to form composite material. Hence we can say that human hairs are found in relative abundance in nature and are non-degradable thereby providing a new era in the field of Fiber Reinforced Composite materials.

In this project coir and human hair are used as hybrid fiber reinforcement to the concrete slab specimen. The hybrid composite can offer more attractive engineering properties, because the presence of one fiber enables the more efficient utilization of the potential properties of the other fiber.
Hair is used as a fiber reinforcing material in concrete for the following reasons:

- It has a high tensile strength which is equal to that of a copper wire with similar diameter.
- Hair, a non-degradable matter is creating an environmental problem so its use as a fiber 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.

Table – 1
The properties of fiber used in this research work

S. No	*Fiber properties*	*Coir fiber*	*Hair fiber*
1	*Appearance*		
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*

IV. MIX DESIGN

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

Mix Proportion for M_{25} Concrete

- Cement = 425.73 Kg/m^3 Fine aggregate = 649.498 Kg/m^3
- Coarse aggregate = 1174.42 Kg/m^3 Water-cement ratio = 0.45
- Water content = 191.58 Kg/m^3 Superplastizicer = 0.8% by weight of cement

The mix proportion for M_{25} concrete is calculated using IS 456:2000, IS 10262:2009. The slump obtained was 165 mm, the degree of workability is high as per IS 456-2000.

V. TEST SPECIMENS

The compressive stress, split tensile strength and flexural strength of concrete was determined by casting cubes of size 150 x 150 x 150 mm, cylinders of size 300 mm height x 150 mm diameter and Prisms of size 500 x 100 x 100 mm respectively. They were allowed for 28 days curing and the test results were obtained for various percentages of fibers (coir and human hair fibers).

A. *Compressive Test (Cube Specimen)*

During testing, the cube bulged outwards, the crack originated from the bottom and propagated. Then spalling and crushing of concrete occurred. The cube didn't show splitting due to the presence of fiber bonding. The results are shown in Figure 1. It was found that the compressive strength has been increasing with the increase in volume of fibers up to 1.5% with 3% of NS and again decrease in strength was observed after 1.5% of natural hybrid fibers with 3% of NS added. The specimen with 1.5% natural hybrid fibers with 3% of NS showed maximum compressive strength of 33.23 N/mm^2. It was understood that typically adding any fiber to concrete does not increase compressive strength but some fibers at higher volume loadings can reduce compressive strength.

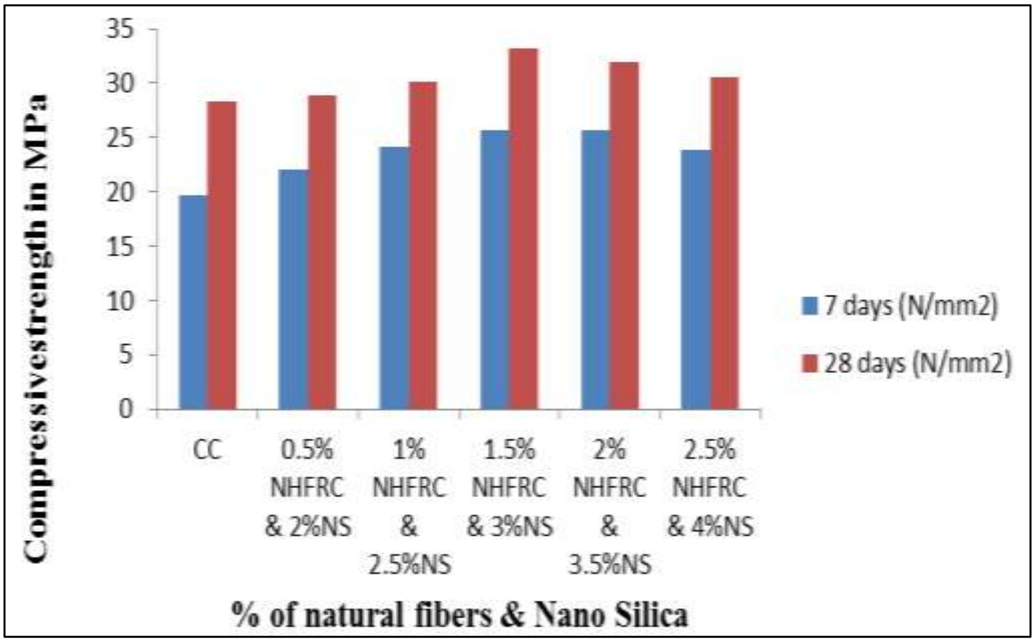

Fig. 1: Graphical Representation of cube compression test results

B. Split Tension Test (Cylinder Specimen)

During testing, the cylinder bulged and formed into elliptical cross- section during failure. No spalling of concrete occurred due to the presence of fiber. The concrete was held together by the fibers. In this test, an increase in strength was observed up to 1.5% natural hybrid fibers with 3% of Nano silica and the specimen with 1.5% natural hybrid fibers with 3% Nano silica showed maximum split tensile strength of 4.1 N/mm^2. The results are shown in Figure 2.

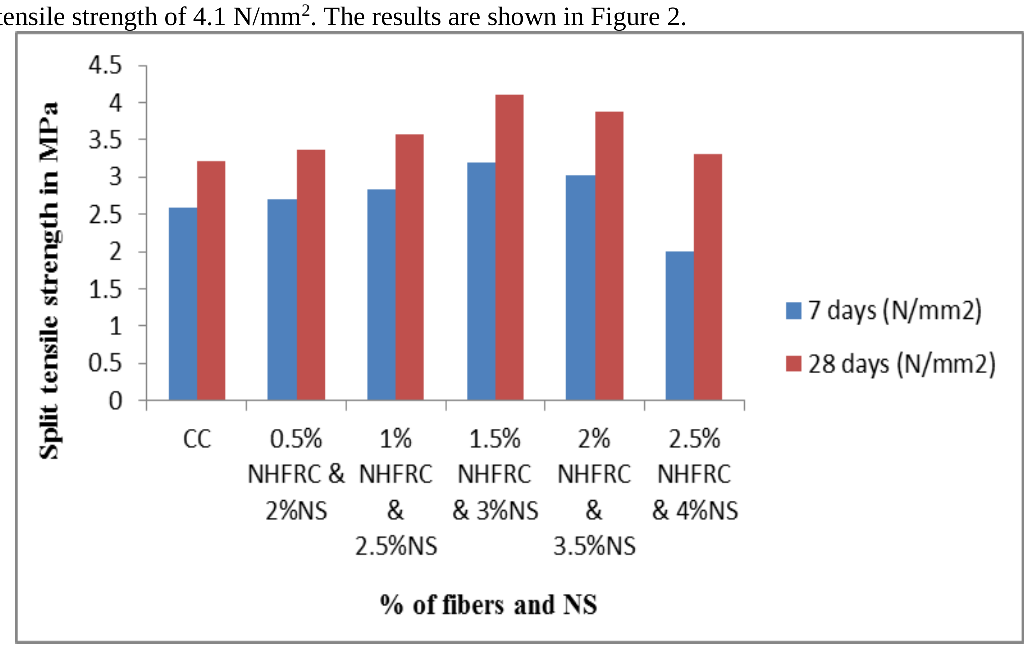

Fig. 2: Graphical Representation of Split tension test

C. Flexural Strength Test (Prism Specimen)

During testing, the prism specimens developed flexural cracks and no spalling of concrete occurred due to the presence of fibers. The fiber bonding was clearly seen. It was observed that the flexural strength of the concrete increases from 0.5% to 1.5% of fiber with 3% of Nano silica and it decreased gradually from 2%. The specimen with 1.5% natural hybrid fibers with 3% Nano silica showed maximum flexural strength of 6.79 N/mm^2. The test results are shown in Figure 3.

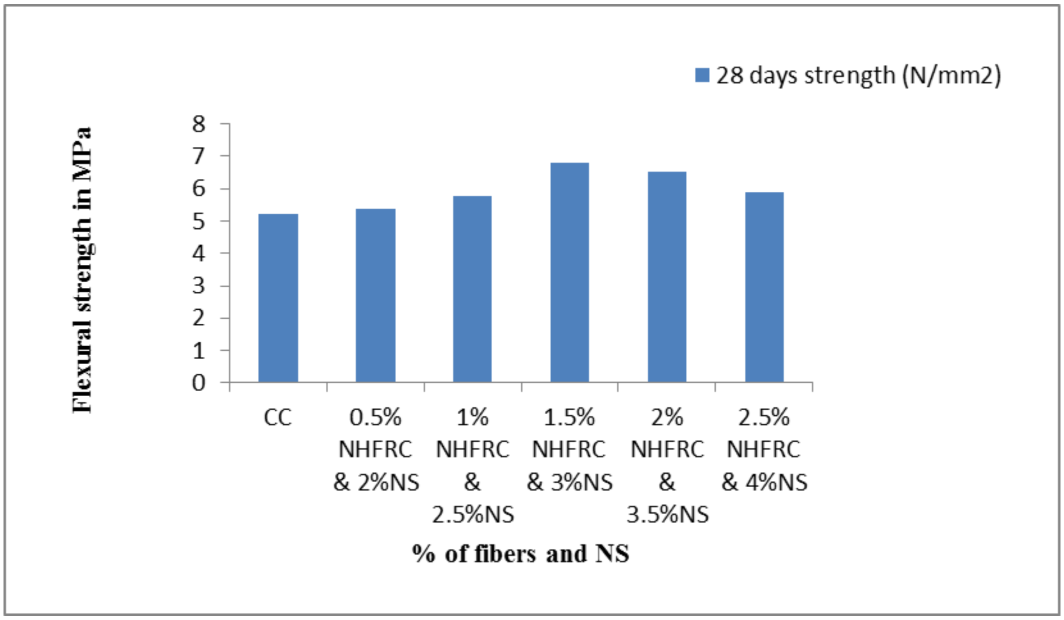

Fig. 3: Graphical representation of Flexural strength

VI. EXPERIMENTAL SET-UP FOR SLAB

Specimen Casting of Specimens One- way slabs of size 1000 x 300 x 70 mm with varying percentages (0.5%, 1%, 1.5%, 2% and 2.5%) of hybrid fibers with varying percentages (2%, 2.5%, 3%, 3.5% and 4%) of nano silica respectively and conventional slab without fibers were casted and kept for curing. After 28 days, the slabs were simply supported at their ends and tested by applying static loading subjected to two line loads by means of a hydraulic jack at one-third distances.

A. Size of the Specimen and Reinforcement Details

The dimension of the model slab is shown in Figure 4. For the slab specimen of size 1000 x 300 x 70 mm, 2 nos. of 10 mm diameter bars of Fe 500 as main reinforcement, 7 nos. of 8 mm diameter bars of Fe 500 as distributive rods with 135 mm spacing, and a clear cover of 20mm was provided. The reinforcement details are shown in Figure 4.

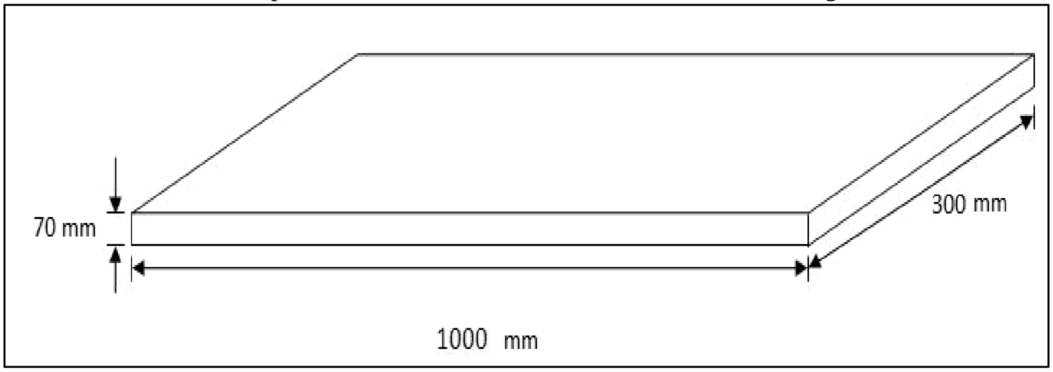

Fig. 4: Dimensions of the slab specimen

B. Loading Setup

The slabs to be tested were placed in the loading frame of capacity 50 tons under two point loading and the test set up is shown in Figure 5. The end condition of the slab was kept as simply supported. The slab 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 loading jack at the Centre of the slab from which load imparted to the slab can be observed. For finding the deflections under the two point loading, the LVDT (linear variable differential transformers) were placed at the Centre of the slab to measure the middle deflection and result can be viewed.

C. Test Result and Discussions

All the slab specimens were tested till collapse. It was observed that the shear cracks appeared from the edge of the specimens and extended towards the top of the specimen with increase in load and vertical cracks at regular spacing were observed with further increase in load. The deflection of the NHFRC slab with NS specimens increased when compared to the control slab.

For the control slab specimen, the first crack appeared directly under roller at a load of 100kN. At the load of 120kN second crack appeared at the mid span and the ultimate load was found to be 150kN.

Fig. 5: Loading setup of slab specimen.

For slab with 0.5% of natural hybrid fiber and 2% of nano silica, the first crack is appeared at both right edge and left edge support of slab at a load of 100kN. At the load of 120kN second crack appeared at directly under roller and the ultimate load was found to be 180kN.

For slab with 1% of natural hybrid fiber and 2.5% of nano silica, the first crack is appeared at both right edge and left edge support of slab when acting 100kN of load. At the load of 120kN second crack appeared at directly under roller. At the load of 140kN third crack is appeared at mid span at bottom of the slab and the ultimate load was found to be 240kN.

For slab with 1.5% of natural hybrid fiber and 3% of nano silica, the first crack is appeared at right and left edge support of the slab when acting 100kN of load and the ultimate load was found to be 260kN.

For slab with 2% of natural hybrid fiber and 3.5% of nano silica, the first crack is appeared at right edge support of slab when acting 120kN of load and the second crack is appeared at both right and left edge support of slab when acting 160kN of load. The ultimate load was found to be 210kN.

For slab with 2.5% of natural hybrid fiber and 4% of nano silica, the first crack is appeared at top surface of slab at near the roller when acting 80kN of load. . The ultimate load was found to be 180kN.

The ultimate load-deflection results for all the slabs are shown in Figure 6.

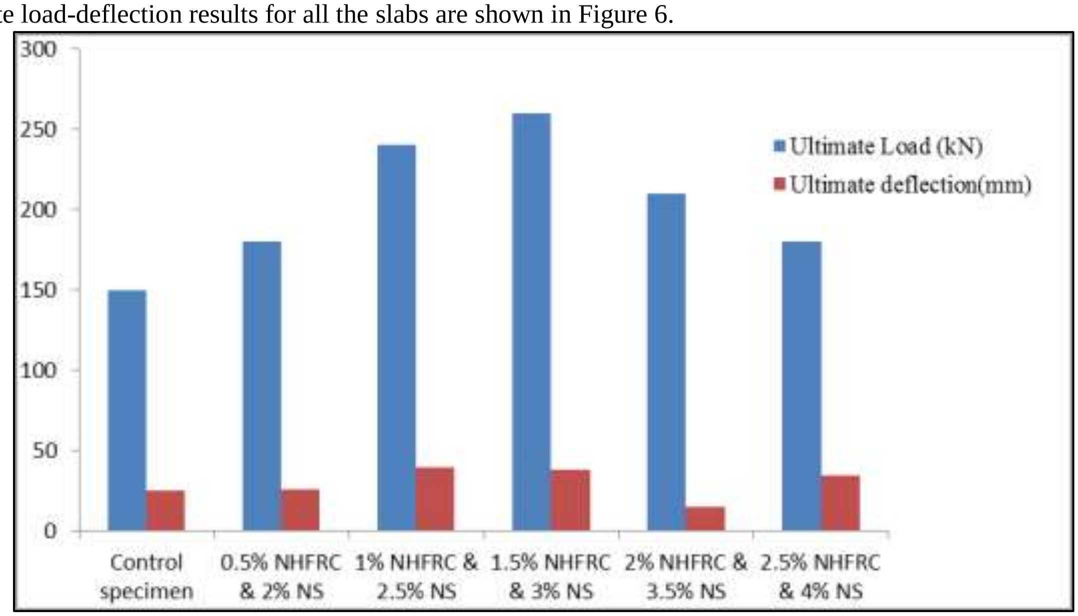

Fig. 6: Graphical Representation of ultimate load and ultimate deflection for various slab specimen

VII. CONCLUSION

Based on the experimental results, the following conclusions were drawn for NHFRC & Nano silica slabs subjected to static loading:

- Tension cracks were formed in NHFRC Slabs with NS under the loaded area.
- The cracks originated from the bottom of the slab and propagated towards the top when the load is increased.
- The ultimate deflection for the NHFRC slabs with NS was found to be increasing when compared to the control specimen.
- It was found that slab with 1.5% NHFRC with 3% Nano silica slab specimen shows an increase of 73.33% in ultimate load and 56.97% in deflection when compared to that of control slab.

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