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Ductility Behaviour of Nano-Silica Powder and Hybrid Fibre Reinforced Concrete Beams with Cyclic Loading

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***Abstract* – The various properties of concrete are influence by Nano-Silica is obtained by replacing cement with various percentages of nano-silica and with natural hybrid fibres. Nano silica powder is used for partial replacement of cement range of 2%, 2.5%, 3%, 3.5%, 4% and hybrid fibre range of 0.5%, 1%, 1.5%, 2% and 2.5% for M_{25} grade of concrete Mix. Specimens are casted by using Nano-Silica concrete and NHFRC. Laboratory works were conducted to find the ductility strength of concrete at the age of 28 days. Moreover, the density of concrete is reduced when compared to control concrete. Thus, the results of partial replacement of cement with Nano-Silica & NHFRC are higher strength and reduction in the permeability when compared to controlled concrete. The partial replacement of Nano-Silica is more than 3% & 1.5% of NHFRC. Determine the results in the reduction of various physical and mechanical properties of Nano-Silica concrete.**

***Keywords*- Nano silica powder, Natural hybrid fiber reinforced, Coir fiber, Human hair fiber, cyclic load.**

I. INTRODUCTION

Natural hybrid fiber reinforced concrete (NHRFC) is most economical to reducing volume of concrete and the amount of steel required for confined structural member. In addition of hybrid fibers in concrete improve the tensile characteristics by inhibiting crack growth and increase in flexural strength and ductility. Different types of fibers were used in concrete such as artificial fibers, metallic fibers, glass fibers, lathe fibers, polymeric fibers, mineral fibers, and naturally occurring fibers, among these natural fibers (coir and human hair) are economical and easy availability. 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 silica to the concrete matrix to increase the compression strength of the concrete and reduce the porosity between the cement particles. Nano Silica is used to improving the properties of fresh concrete and hardened concrete. The adding of two or more different types of fibers in concrete is called Hybrid Fiber Reinforced Concrete and it is used as secondary reinforcement. In this experimental coir and human hair are used as hybrid fiber reinforcement to the concrete specimen.

Objective

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

Nano Silica Powder

Addition of Nano particles improves the properties of the concrete in micro level. The Nano silica particles are introduced into concrete in the form of powder to improve the compression strength. Its fine size fills voids between aggregates and cement particles are secondly they react pozzolanically with CH to produce CSH gel, increasing the binding quality and decreasing the capillary porosity of concrete.

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Fig 1. Nano silica power

Fibre Reinforced Concrete (FRC)

FRC is the mostly used construction material in practical field. Adding fiber to the concrete is said to be fiber reinforced concrete. By adding fibers of different materials and volume tensile strength will be improved. The most economical fiber is natural fibers. Low volume fractions of fibers (< 1%) are used to reduce minor 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

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length of the fibers also play a role in the effectiveness of fibers in improving the properties of the concrete.

Hybrid Fiber Reinforced Concrete (HFRC)

The addition of two or more different types of fibers in concrete matrix is called Hybrid Fiber Reinforced Concrete. (HFRC) is one in which more than one or two types of fibers are used as secondary reinforcement. In this work coir and human hair are used as hybrid fiber reinforcement to the concrete beam specimen. These hybrid fibers 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.

Types of Fiber

The different types of fibers are commonly used to concrete. Such as 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

Coir Fibre (Coconut Fiber)

Coconut fiber is extracted from the outer shell of a coconut. The 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.

Human Hair Fiber

Human Hair is a natural fibre that can be found abundantly in all parts of the world. It is a proteinaceous fiber with a strong keratin chains. The basic component of hair fiber is known as keratin. Keratin is proteins consisting of long chain (polymers) of amino acids. Hair contains a high amount of sculpture because the amino acid cysteine is a key component of the keratin proteins in hair fiber. The sculpture 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. The properties

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of human hair such as unique chemical composition, slow degradation rate, thermal insulation, tensile strength. Hence we can say that human hairs are found in relative abundance in nature and are non-degradable in the field of Fiber Reinforced Composite materials.

In this experimental coir and human hair are used as hybrid fiber reinforcement to the concrete slab specimen. The fibers 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 fiber is used as reinforced material in concrete for the following reasons:

- Tensile strength is high 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 I PROPERTIES OF FIBER USED IN THIS 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

II. MIX DESIGN

The basic tests are conducted on fine, coarse aggregate & cement. As their results obtained for Proportion M_{25} grade is arrived at.

Cement = 425.733 Kg/m^3
Fine aggregate = 649.4889 Kg/m^3
Coarse aggregate = 1174.52 Kg/m^3
Water-cement ratio = 0.45
Water content = 191.58 Kg/m^3
Super plasticizer = 0.8% by weight of cement

The proportion for M_{25} grade concrete is designed using Indian standard. The slump obtained was 165 mm, the degree of workability is high as per IS 456-2000.

Preliminary Tests

The compressive strength, split tensile strength and flexural strength are done for this tests specimens are casting such as cubes of size 150 x 150 x 150 mm, cylinders of size 300 mm height x 150 mm diameter & Prisms of size 500 x 100 x 100 mm respectively. After 28 days curing the test were obtained for different percentages of fibers (coir &Human hair fibers).

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 Fig.1. Among this strength has been increasing in the 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 Nano silica added. The specimen with 1.5% natural hybrid fibers with 3% of Nano silica showed maximum compressive strength of 33.23 N/mm^2.

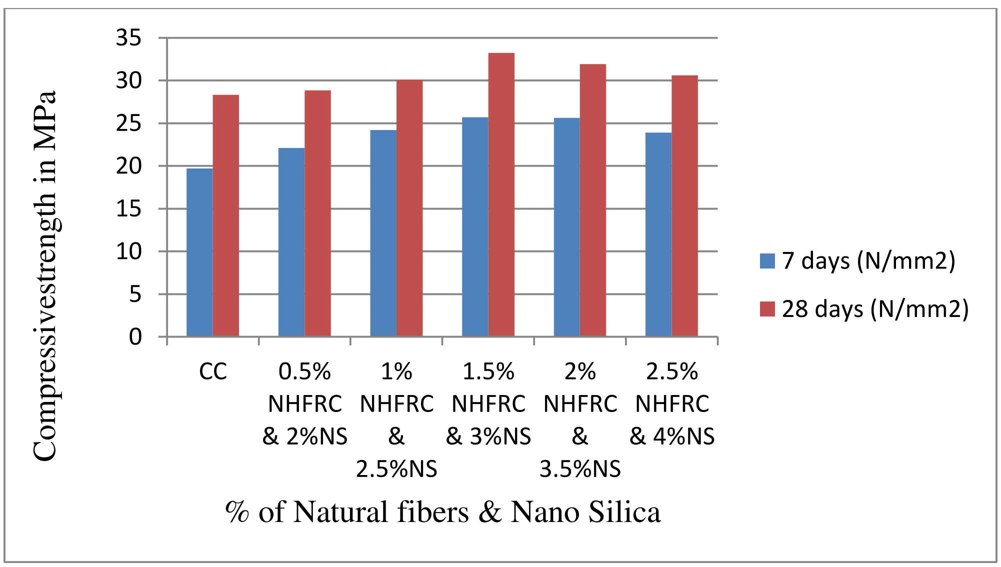

Fig.2. Graphical Representation of cube compression test results

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. 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 Fig. 2.

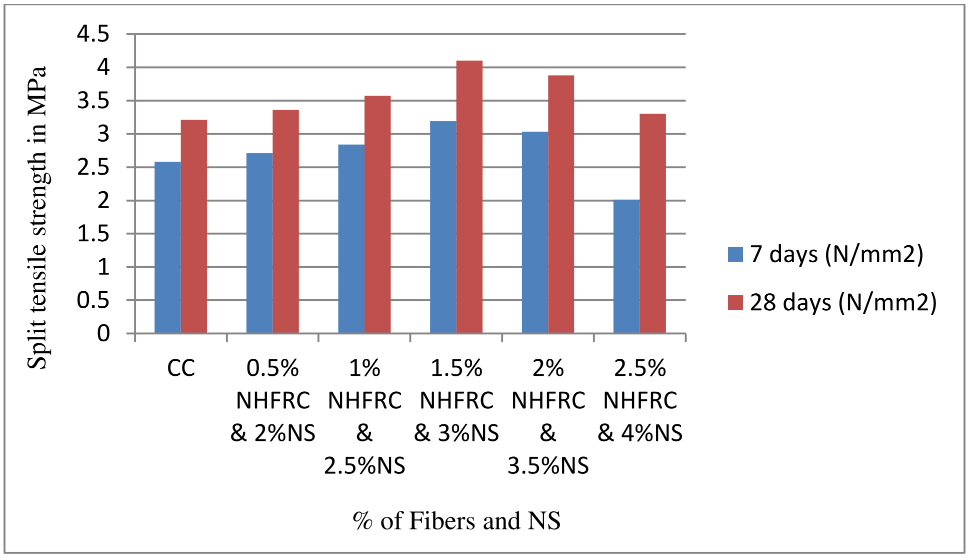

Fig.3. Graphical Representation of Split tension test

Prism Specimen (Flexural Strength Test)

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

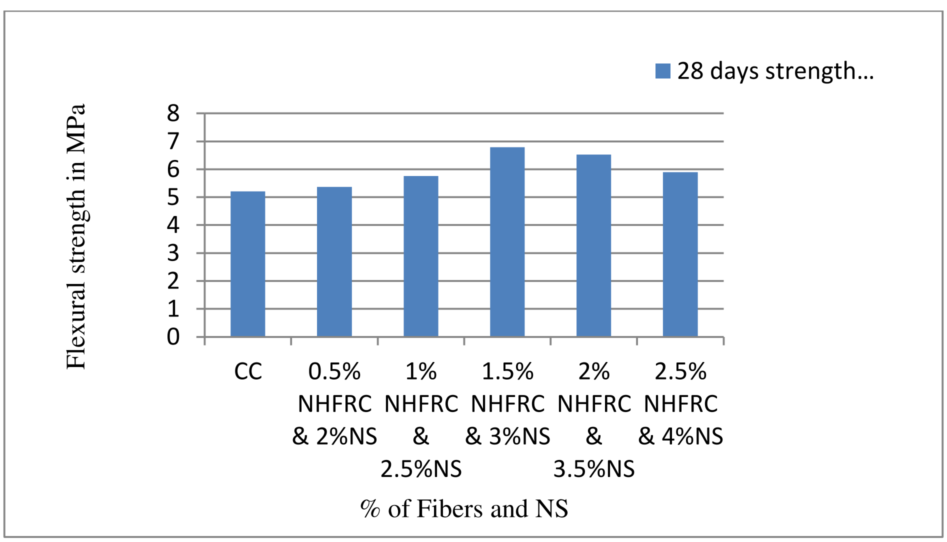

Fig.4. Graphical representation of Flexural strength

III. Experimental Programme

A. 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.

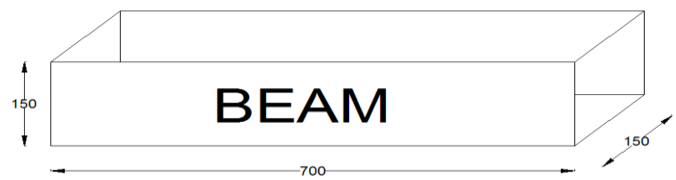

Fig.5. Dimensions of the beam

B. 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

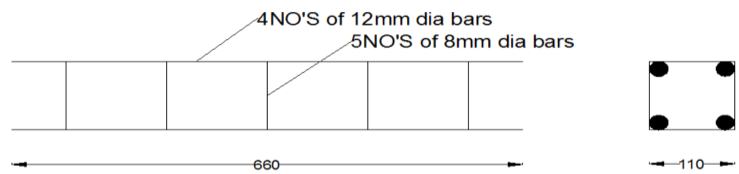

Fig.6. Reinforcement details of the beam specimen

The control beam specimen 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 fiber such as 0.5%, 1%, 1.5%, 2% and 2.5%

Test Setup

The beams are placed with simply supported condition in the loading frame capacity of 50 tons with two points loading. 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 is fixed at 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.

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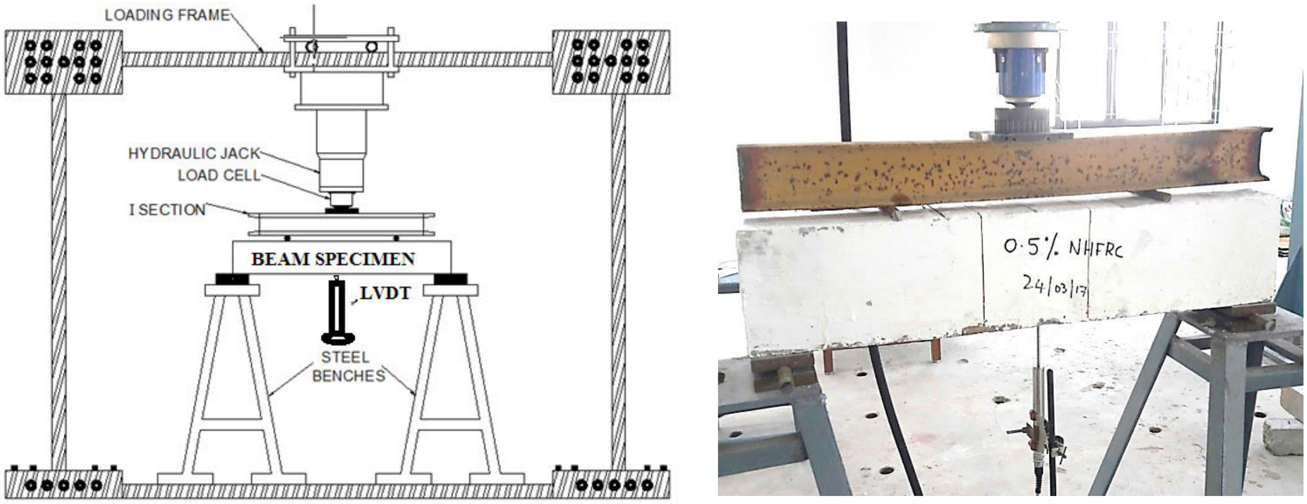

Fig.7. Test setup

IV. 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. Flexural cracks are mostly 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.

TABLE II ULTIMATE LOAD AND DEFLECTION OF BEAM

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 fiber dosage when compared to control beam specimen. The load carrying capacity of the beams also increased in each cycle.

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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.

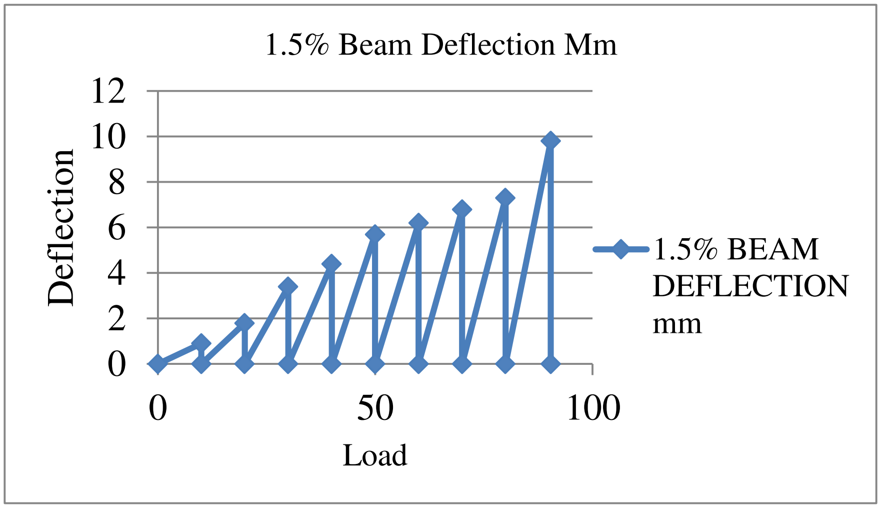

Fig.8. Cycle VS Load at mid-span for 1.5% NS and 3% NHFR

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.
- Failure of load 80.56 kN.
- The ultimate load was recorded as 90.40 kN with a deflection of 8.6 mm.

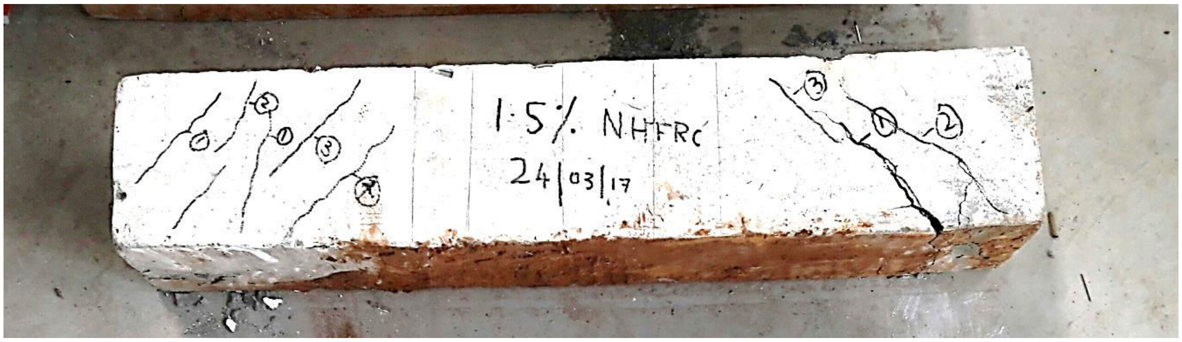

Fig.9. Crack pattern for 1.5% NHFRC & 3% NS beam

Fig.10. Beam specimens after testing with various percentage of NC &NHFRC

V. CONCLUSION

Based on the test results, the following conclusions are suggested for NHFRC & Nano silica beams subjected to static loading.

- Tension cracks were formed in the NHFRC with Nano silica beams 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 load for the NHFRC with Nano silica beams was found to be increasing when compared to the control specimen beam, which is due to the increase in ductility of the beams.
- 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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