

ENHANCING DURABILITY AND PERFORMANCE OF HIGH STRENGTH CONCRETE THROUGH HYBRID FIBER REINFORCEMENT

Yogesh Kumar¹, Mr. Sandeep Pannu²

¹M. Tech Scholar, Matu Ram Institute Of Engineering & Management, Rohtak, India.

²Assistant Professor, Matu Ram Institute Of Engineering & Management, Rohtak, India.

ABSTRACT149

One of the greatest significant and often utilised resources in the construction sector is cementitious material. These cement-based materials may be simply handled and early on, before the curing process, produced into the necessary specified shapes and structural arrangements. Nonetheless, the primary flaw in these substances made from cement is their brittleness, which is associated with their rigidity and causes cracks to form and spread when stressed. Their mechanical qualities deteriorate as a result of this weakness, requiring expensive maintenance or maybe reconstruction of such materials within a comparatively short lifespan. Therefore, the building industry needs new materials made from cement that have better endurance qualities, like increased crack resistance.

Presently, a common practice in the field of concrete is the incorporation of several sub-products into materials made from cement. This study explores the viability of using metallic and natural fibers as reinforcement in high-strength concrete. Steel fiber has exceptional strength and significant possibilities for controlling cracking, despite its high volumetric density. Steel conducts in both magnetism and electrical currents, thus the amount of fibers made of steel must be reduced to a particular degree. Utilizing bio fibers such as coir and palm to create composite materials that rival synthetic composites has been more popular in recent decades because to its renewability, biodegradability, and eco-friendliness. The blend of steel and natural fibers enhances concrete characteristics and decreases the total cost of concrete manufacturing. The key benefits include impeding the creation of large fractures, slowing down the spread of small cracks to a visible level, and enhancing the flexibility when small cracks appear. The current research utilizes high-strength concrete of M50 grade with a mix ration of 1:1.38:2.88. An experiment was directed to study the behavior of a concrete beam reinforced by several natural fibers such as coir fiber, palm fiber, and metallic fiber (steel-corrugated) with an aspect ratio of 50. The fiber volume percentage is kept at 1% relative to the weight of cement. All natural fibers in the composite undergo chemical treatment to avoid decomposition. 72 cubes, 72 cylinders, and 48 flexure specimens were cast for mechanical investigations. Fourteen hybrid reinforced high-strength concrete beams were made and evaluated for first crack load, ultimate load, and maximum deflection, then compared with a control beam. The experimental data indicates that fiber reinforced concrete beams have greater ultimate moment resistance compared to conventional RC beams. applying just one fiber or a mix of multiple fibers with varying proportions shows great potential in attractive the impact confrontation of reinforced concrete targets. The mixture of 0.5% steel, 0.25% palm, and 0.25% coir hybrid fibers exhibits the most significant enhancement in residual strength parameters. An considerable improvement in ductility and flexural toughness is reported in the hybrid fiber-reinforced concrete beam. A new approach is suggested for predicting the structural characteristics of concrete using a multilayer feedforward neural network due to limitations in current methods for handling many variables and nonlinear issues. The neural network model is constructed to represent the intricate nonlinear correlation between the inputs and the outputs. The networks in this study were trained and evaluated using different learning rates, which were then held constant after several trials. The artificial neural network's performance is evaluated using statistical error criteria, demonstrating that the ANN predicts test data more accurately.

Key Words: Brittle, cracks, hybrid fiber, mechanical properties, toughness, durability, shrinkage

1. INTRODUCTION

In concrete structure develops durability and strength are frequently deemed to be the most important characteristics. When subjected to normal pressures and shock loads and concrete is regarded as brittle its breaking strength is individually around 10% of its strength when compressed. Concrete flexible components are not able to sustain the usual loads encountered throughout their service life because of these characteristics. Many concrete buildings now in existence fail to fulfill contemporary design criteria due to insufficient design and construction. The insufficient performance of these structures is a significant concern for public safety due to the growing population and purchasing power. The demand for raw materials needed for structural reinforcement to meet global market needs is increasing rapidly. Portland cement concrete has certain attributes. Its extensible strength is modest, but its capacity for compression is great. and it has a tendency to be brittle. To address the weakness in tension, conventional rod reinforcing may be used together with a suitable amount of fibers. In order to improve the concrete's compressive and

tensile properties, threads are added. They also act as a unique adhesive that enables the cement to bond with cemented composites.

2. HIGH STRENGTH CONCRETE

The mixture known as masonry is composed of particles and a paste of cement, which can include pozzolans. Concrete strength is explained by the strength of its workings their distortion qualities, and the bond between the paste and aggregate surface. It is possible to use the simplest materials to produce concretes having compressive strength of 120MPa by strengthening the cement paste. Controlling the strength of cement paste may be achieved by selecting the w/c ratio and the kind and quantity of admixtures used. Current improvements in concrete along with the use of different inorganic and chemical intermixtures and superplasticizers, have made it imaginable to yield commercially available Compression strength concrete of up to 100MPa using regular aggregates while maintaining an acceptable level of consistency. To manufacture high-strength concrete (HSC), it is essential to use quality ingredients, reduce the water-binder ratio, increase the proportion of fine compared to coarse material, use smaller coarse aggregate size, and include acceptable admixtures with their optimal doses. The advancements have resulted in the widespread use of HSC globally.

3. FIBER REINFORCED CONCRETE

FRC is concrete that contains randomly scattered fibers, as described by ACI 116R, Cement and Concrete Terminology. Concrete is naturally fragile when subjected to stretching forces, but its mechanical characteristics may be enhanced by adding small fibers in random orientations. These fibers help to prevent or regulate the formation, spread, or joining of fractures. The performance of the Fiber Reinforced Concrete (FRC) is influenced by the characteristics of both the concrete and the fibers. Fiber concentration, shape, orientation, and dispersion are the key features of interest in fibers. The fiber concentration in a structural concrete component typically ranges from 1-4% in relation to the amount of cement. Fiber reinforcement enhances the mechanical qualities of a construction material that would otherwise be inappropriate for practical use. Fiber modifies the response of concrete when a fracture forms by spanning the cracks, hence enhancing post-cracking toughness. The presence of fibers intersecting the fracture ensures a certain amount of stress transmission between both sides of the crack, contributing to the composite material's residual strength.

Fibers- Utilizing fibers for reinforcement is a longstanding notion. The horses hairs and straws used to be utilized to make clay mortar and bricks, respectively. In the early years of the 1900s, fibers of asbestos were added to concrete. When composite materials became popular in the 1950s, fiber reinforced concrete became the center of attention. A substitute for asbestos in concrete and other building materials was required as soon as the chemical's health risks were discovered. Concrete was mixed with glass, stainless steel, and synthetic fibers like polyethylene in the early 1960s. Research on creating novel forms of fiber-reinforced concrete is still ongoing, concrete. Fibers are often used into concrete to manage cracking caused by plastic shrinkage and drying shrinkage decrease concrete permeability, and minimize water bleeding. Specific types of fibers improve the material's ability to resist effect, scraping, and shattering. The fiber volume percentage usually falls between 0.1% and 3% [3]. Fibers mainly regulate fracture growth and restrict crack widths. High elastic modulus fibers recover the flexural durability of concrete. Fibers contribute significantly to concrete after the matrix has cracked by bridging the spreading fissures. High doses of added fibers may lead to drawbacks such as reduced workability and increased costs.

Carbon fiber- Carbon fibers are used for their exceptional presentation due to their high Young's modulus of elasticity and superior strength. They exhibit brittle failure properties with lower energy absorption and higher failure strength in contrast to both aramid and fibers of glass. Carbon fibers have lower susceptibility to creep-rupture and fatigue, with a little decrease in long-term tensile strength. Carbon fiber reinforced polymer is a very durable, lightweight, but costly composite material. Figure 1 displays the use of carbon fiber in building.

Use of carbon fiber



Glass fiber- Naval and industrial sectors often use glass fibers to create high- performance composites. They are distinguished by their exceptional strength. Glass is mostly composed of silicon arranged in a tetrahedral form. Figure 2 displays the widely accessible glass fiber. Thin sheets of glass fiber are also known as mats. A mat may consist of long continuous and short fibers placed haphazardly and held together by a chemical link Glass fiber



OBJECTIVES

The aim of this study is to investigate the effect of hybridisation (metallic and non-metallic fibres) of fibres on properties of concrete.

The objectives of this research are:-

- To study the workability of hybrid fibre reinforced concrete.
- To study the mechanical properties of hybrid fibre reinforced concrete.

4. LITERATURE REVIEW

Title: The mechanical and dynamic properties of coconut fiber reinforced concrete.

By Majid Ali, ET. AlNewzealand [1]. the mechanical and dynamic properties of coconut fiber reinforced concrete members were well examined. A comparison between the static and dynamic Moduli was conducted. The influence of 1%, 2%,3% and 5% fiber contents by mass of cement and fiber lengths of 2.5, 5 and 7.5 cm is investigated. Noor Md.sadiqulHasan, et. al from Malaysia, have investigated the physical and mechanical characteristics of concrete after adding coconut fibers on a volume basis.

Title: Study of strength and durability of coconut fiber reinforced concrete in aggressive environmental.

By CF. MahyuddinRamli, et. Al [2]. They conducted a micro structural analysis test using a scanning electron microscope for understanding bonding behavior of studied strength and durability of CFRC in aggressive environment. Their aim was to mitigate the development of cracks in marine structures by introducing CF which would provide a localized reinforcing effect. Yalley, et.al. From UK performed various test to study the enhancement of concrete properties af teraddition of CF. their study focused on the CF obtained from Ghana Africa.

Title: The mechanical and dynamic properties of coconut fiber reinforced concrete.

By (Liu et al., 2011) [3] studied the influence of 1%, 2%, 3% and 5% at fiber lengths of 2.5, 5 and 7.5 cm on properties of concrete. For a proper analysis the properties of plain cement concrete was used as reference. It was seen that damping of CFRC beams increases with the increase in fiber content. It was observed that CFRC with a fiber length of 5 cm and fiber content of 5% produced the best results. In this study the optimum percent of coconut fiber added was 5%.

Title: Introduction to mechanical properties of high-strength steel fiber reinforced concrete.

BySong P.S. and Hwang S[4] thebrittleness with low tensile strength and strain capacities of high strength concrete can be overcome by addition of steel fibers. They investigated an experimental study were steel fibers added at the volume of 0.5%, 1.0%, 1.5% and 2.0%. The observation indicate that compressive strength of fiber concrete reached a maximum at 1.5%volume fraction, being 15.3% improvement over the HSC. The split tensile and Flexural Strength improved 98.3% and 126.6% at 2.0% volume fraction.

Title: Comparative study of steel fiber reinforced concrete over control concrete

By Vikrant S Vairagade, Kavita S. Kene, Tejas R Patil[5] This paper deals with Experimental investigation for M-20 grade of concrete to study the compressive strength, and tensile strength of steel fiber reinforced concrete (SFRC) containing fibers of 0% and 0.5% volume fraction of hook end Steel fibers of 50 and 53.85 aspect ratio were used.

A result data obtained has been analyzed and compared with a control specimen (0% fiber). A relationship between Compressive strength vs. days, and tensile strength vs. days represented graphically. Result data clearly shows percentage increase in7 and 28 days Compressive strength and Tensile strength for M-20 Grade of Concrete. Steel fibers enhance strength of FRC under almost all types of loading but fail to demonstrate deformability [7]. On the

other hand, non-metallic fibers such as Coconut fibers demonstrate superb deformation under different types of loading with moderate strength enhancement. Therefore, the objective of the present study was to evaluate the mechanical properties of FRC having hybrid combinations of a metallic fiber (steel fiber) and a non-metallic fiber (Coconut fiber). As a research work on FRC has established that addition of various types of fibers such as metallic (steel) and non-metallic fibers (glass, synthetic, natural and carbon) in plain concrete improves strength, toughness, ductility, post-cracking resistance, etc. For optimal result therefore different types of fibers may be combined and the resulting composite is known as hybrid-fiber reinforced concrete in this experiment steel fiber (continuously crimped) and natural fiber (coconut) have been tried.

Mizanur Rahman M et al (2007) concluded that because of their benefits to the ecology and economy, regenerated fibres including coir might be utilised as strengthening elements for inexpensive composites. Strength of the fiber improved significantly after UV treatment. Alkali treatment increased surface roughness resulting in better mechanical interlocking and the amount of cellulose exposed on the fiber surface.

Li et al (2007) used multilayer coir meshes mats to perform a controlled study of the fraction of the fiber volume and fiber surface treatments with a moisturizing agent for coir meshes reinforcement masonry. Slab samples underwent bending at four points tests as part of the investigation. It was determined that the greatest bending strain was improved by 40% in the composite supplemented with a total of three layers of 1.8 percent content of fiber coir mesh.

Wu Yao et al (2002) have observed the machine-driven assets of cement with a minimal volume percentage. The compression strength, breaking tensile force, and bending characteristics of concretes with several kinds of blended fibers at a comparable volume percentage (0.5%) were evaluated. The test results indicated that the fibers used in a hybrid form could result in superior composite performance compared to their individual fiber-reinforced concretes. The ductility properties of carbon-steel fibres were enhanced. The investigation revealed that it was feasible to produce material with greater power and enhanced durability at little fiber capacity percentage.

Wu Yao et al (2003) conducted untried examination on concretes covering dissimilar kinds of fibers at the similar capacity segment 0.5%. In the experimental study it was found that increase of 31.4% of compressive strength, 36.5% split tensile strength and 32.9% modulus of rupture were obtained using carbon –steel hybrid compound. It was also concluded that the hybrid combination would increase the flexural toughness.

Sabu Thomas et al (2004) examined natural rubber reinforced with sisal and palm fibers. The tensile strength and tear resistance increased with the inclusion of sisal and palms fiber, according to the research. After treating the cellulose fibers with alkali, it was discovered that the degree of adhesion between the fiber and rubber matrix increased. Compared to untreated composite materials, the mechanical characteristics of the alkali-treated fibers demonstrated superior flexibility.

Maries Idicula et al (2005) have studied the mechanical properties of randomly oriented hybrid fiber reinforced concrete composites. From the experimental investigation it was concluded that by hybridizing banana and sisal fiber, the fiber reinforced became user friendly and cost effective composite material and it possess appropriate stiffness and damping behavior.

5. METHODOLOGY

flow chart



Collections Of Raw Materials- The materials used in this study are Portland cement (OPC); ultratech cement

Sand: Aggregates passing through 4.75mm IS sieve

Coarse aggregate: Aggregates passing through 20mm IS sieve

Coconut fiber: locally available in kalaburgi

Steel fiber: Collected from local fresh water sources

TESTS ON MATERIAL

Tests on Cement- Cement is an important constituent in concrete. The process of manufacture of cement consist of grinding the raw materials mixing them intimately in certain proportions and burning them in kiln at a temperature 13000C to 15000C. To determine the various properties of cement different tests are done.

The tests done are

1. Standard Consistency
2. Initial Setting Time
3. Final Setting Time
4. Fineness of Cement
5. Density of Cement

Tests on Coarse Aggregate- Aggregates are important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. The aggregates occupy 70-80 percent of the volume of concrete; their impact on various characteristics and properties of concrete is considerable. To determine the various properties of aggregates different tests are done.

1. Bulk density of coarse aggregates
2. Specific gravity of coarse aggregates
3. Sieve analysis of coarse aggregates

Tests on Fine Aggregate

1. Bulk density of fine aggregates
2. Specific gravity of fine aggregates
3. Sieve analysis of fine aggregates

Mix Design- Mix design is defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. A Mix design was conducted as per IS 10262-2009 to arrive at M 25 mix concrete.

Mixing Of Concrete- The coarse aggregate and fine aggregate were weighed and the concrete mixture was prepared by hand mixing on a water tight platform. On the water tight platform cement and fine aggregates are mixed thoroughly until a uniform colour is obtained, to this mixture coarse aggregate was added and mixed thoroughly. Then water is added carefully making sure no water is lost during mixing. While adding water care should be taken to add it in stages so as to prevent bleeding which may affect the strength formation of concrete rising of water required for hydration to the surface. Clean and oiled mould for each category and filled in three layers. Each layer is tamped by 25 blows using standard tamping rod. The finishing was stopped as soon as the cement slurry appeared on the top surface of the mould.

Casting And Curing- Concrete was cast in pre-oiled cast iron moulds (Fig.3.1).These specimens were allowed to remain in the steel mould for the first 24 hours at ambient condition. After that these were demoulded with care so that no edges were broken and were placed in the tank at the ambient temperature for curing. After demoulding the specimen by loosening the screws of the steel mould, the cubes were placed in the water for 7 days and 28 days.

cast iron moulds



6. CASTING AND TESTING OF CONCRETE SPECIMEN

TESTS ON FRESH CONCRETE

SLUMP TEST

Slump test is the most commonly used method of measuring consistency of concrete. It is used conveniently as a control test and gives an indication of the uniformity of concrete. Additional information on workability and quality of concrete can be obtained by observing the manner in which concrete slumps. The apparatus for conducting the slump test essentially consists of a metallic mould in the form of frustum of a cone having the internal dimensions of bottom diameter 20 cm, top diameter 10 cm and a height of 30 cm as shown in Figure 4.1.

slump testing apparatus



7. TESTS ON HARDENED CONCRETE

COMPRESSIVE STRENGTH TEST

Compressive strength is the capacity of a material or structure to withstand axial loads tending to reduce the size. It is measured using the Universal Testing machine. Concrete can be made to have high compressive strength, e.g. many concrete structures have compressive strengths in excess of 50 MPa. Here the compressive strength of concrete cubes for the plain concrete and fiber reinforced concrete are found out using Compression testing machine. Three cubes were cast for each percentage of fibers and the average of the three compressive strength values was taken. A Compression testing machine is shown in Figure 4.2.

compression testing machine



8. SPLIT TENSILE STRENGTH TEST

Tensile strength is the capacity of a material or structure to withstand tension. It is measured on concrete cylinders of standard dimensions using a Universal Testing machine. Both conventional and fiber reinforced specimens were tested at varying percentages of fiber and the average value was obtained

FLEXURAL STRENGTH TEST

Flexural strength of concrete is considered as an index of tensile strength of concrete. Tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons. Beam tests are conducted to determine flexural strength of concrete Figure 4.3. In flexural tests on beam theoretical maximum tensile strength is obtained at bottom of beam and is called modulus of rupture, which depends on dimension of beam and position of loading



MIX DESIGN

Mix design is defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. The mix design must consider the environment that the concrete will be in exposure to sea water, trucks, cars, forklifts, foot traffic or extremes of hot and cold. A Mix design was conducted as per IS 10262-2009 to arrive at M 25 mix concrete.

CASTING PROCEDURE

Casting of Concrete Cubes

Concrete is mixed by hand (Fig 4.4) Concrete is a mixture of Cement, Water, Coarse and Fine Aggregates and Admixtures. The proportion of each material in the mixture affects the properties of the final hardened concrete. These proportions are best measured by weight. Measurement by volume is not as accurate, but is suitable for minor projects. The dry ingredients are mixed and water is added slowly until the concrete is workable. This mixture may need to be modified depending on the aggregate used to provide a concrete of the right workability. The mix should not be too stiff or too sloppy. It is difficult to form good test specimens if it is too stiff. If it is too sloppy, water may separate (bleed) from the mixture.



mixing of concrete

For casting, all the moulds were cleaned and oiled properly. There were securely tightened to correct dimension before casting. Care was taken that there is no gaps left, where there is any possibility of leakage of slurry. Careful procedure was adopted in the batching, mixing and casting operation. The coarse aggregate and fine aggregate were weighed first. The concrete mixture was prepared by hand mixing on a water tight platform. On the water tight platform cement and fine aggregates are mixed thoroughly until a uniform color is obtained, to this mixture coarse aggregate was added and mixed thoroughly.

Then water is added carefully making sure no water is lost during mixing. While adding water care should be taken to add it in stages so as to prevent bleeding which may affect the strength formation of concrete rising of water required for hydration to the surface. Clean and oiled mould for each and filled in three layers and finishing is done by using trowel.

These specimens were allowed to remain in the steel mould for the first 24 hours at ambient condition. After that these were demoulded with care so that no edges were broken and were placed in the tank at the ambient temperature for curing. After demoulding the specimen by loosening the screws of the steel mould, the cubes were placed in the water for 7 days and 28 days finishing of moulds



9. TEST RESULTS

Slump Test- slump test on trial mixes

Trial	w/c ratio	Slump value(mm)	Remarks
Trial 1	0.4	40	Target Slump not achieved
Trial 2	0.45	85	Target Slump achieved Desired Slump value is obtained
Trial 3	0.5	120	(Slump >100mm)

COMPRESSIVE STRENGTH- 30 cubes specimens of size 150mm were used for compression test the test results are summarized in tables below each value is the mean of three test results

INFERENCE- From the table it is observed that the desired slump value is obtained for trial 2 at water cement ratio = 0.45. (For standard m-25mix) Hence we fix it as the design ratio. Trial 1 and 3 yielded very low and very high slump values which may be either due to inadequate paste available for binding the mix or due to improper mixing procedure

Mix No	Steel fiber (SF) (%)	Coconut fiber (SF) (%)	Obtained slump values
M1	0%	0%	80
M2	1%	1%	27
M3	1%	3%	25
M4	1%	5%	23
M5	1%	7%	23

From the table it is observed that the workability drastically decreases when coconut fiber content is increased in concrete. W = Final weight specimen V = Total volume of mould.

average compressive strength

%S F	%C F	Average density (Kg/m3)		Average strength of 7 Days (N/mm2)	Average strength of 28 Days (N/mm2)
		7 Days	28Days		
0%	0%	2601.4 7	2572.1 4	32.59	37.34
1%	1%	2640.9 8	2650.8 7	33.47	42.68
1%	3%	2494.8 0	2552.0 9	27.93	31.67
1%	5%	2531.3 5	2596.0 4	22.67	28.81
1%	7%	2540.2 4	2502.7 1	21.96	27.28

SPLIT TENSILE STRENGTH TEST- A Total 30 standard concrete cylinder of size 150mm dia & 300mm depth were tested for the indirect tensile strength the test results are hown in table below.

average split tensile strength

%SF	%CF	Average density (Kg/m3)		Average strength of 7 Days (N/mm2)	Average strength of 28 Days (N/mm2)
		7 Days	28 Days		
0%	0%	2560.9	2534.2	1.69	2.36
1%	1%	2552.1	2575.7	1.86	2.25
1%	3%	2562.1	2561.2	1.97	2.29
1%	5%	2556.5	2566.2	2.21	2.41
1%	7%	2542.0	2493.3	2.23	2.60

FLEXURAL STRENGTH TEST- A total of 30 beams of size 100x 100 x 500mm were tested for flexural strength in all the tested specimen fracture occurred within the central one third of the beam.

average flexural strength

%SF	%CF	Average density (Kg/m ³)		Average strength of 7 Days (N/mm ²)	Average strength of 28 Days (N/mm ²)
		7 Days	28Days		
0%	0%	2546.6	2641.3	4.33	5
1%	1%	2590	2591.3	5.33	5.67
1%	3%	2458.6	2506	5.67	6.83
1%	5%	2345	2420.3	3.16	6.83
1%	7%	2598.6	2474.6	4.5	5.67

10. CONCLUSION

Based on the experimental investigations on HFRC, the following observations can be drawn. increase of 14.30% compressive strength, 36.6% increase in flexural strength and 10.16% increase in split tensile strength.

1. The improvement in flexural strength reveals that the toughness would be much more than that of non-fibrous concrete which improves ductility and durability of concrete.
2. Addition optimum dosage of 1% of steel fiber and 1% of coconut fiber gives maximum compressive strength up to 42.68%
3. The rate of strength gain for 7 days strength of HFRC is very high as compared to conventional concrete and hence concludes that HFRC has high early Strength and continued strength development.
4. As % of fiber increases the split tensile strength also increases.
5. Workability drastically decreases when coconut fiber content is increased in concrete.

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