Eco-Friendly Nature Of Fiber Materials And Its Process During Construction

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Abstract

This paper focuses on the environmentally friendly nature of fiber materials used in buildings. Micro cracks form in traditional concrete before the structure is filled due to the changes in volume and drying. As the structure is filled, the very small cracks spread and open up, are causing inelastic deformation in the concrete. The cementing of a concrete reinforced mixture of more or less uniformly dispersed small fibers is known as FR. During the mixing phase, a large no. of microfibers are distributed and scattered in the concrete and increasing the property of concrete in all ways. A concrete fiber was depending upon the cement composite component that has been produced recently. It has been successfully used in the building because of its good impact and frost resistance, permeability, flexural tensile, and strong resistance to spitting. It's a good way to improve the mortar's durability, shock tolerance, and conflict to reduce plastic cracking. There are several advantages of using these fibers. Steel fibers can increase structural strength while reducing the need for heavy steel reinforcement. The concrete's freeze-thaw tolerance has been strengthened. The concrete's durability is increased, resulting in smaller crack widths. To increase impact resistance, polypropylene and nylon fibers are used.

Key words: FRC, SF, mechanical properties, workability, ductility, SF, flexural tensile, strength

1. **Introduction:**

Portland cement material has strong compression but poor in stress & it is hard. The use of traditional SBR and, to a lesser degree, the blending of an adequate amount of some fibers will resolve the tension weakness.[1]The use of fibers also improves the durability of the FMC, which re-calibrates its action after it has cracked. This study aimed to give data regarding applications and properties of fibers and also their use in concrete manufacturing along with particular properties. A new type of fiber-reinforced concrete made of cellulose fibers has been developed. Fiber is a small distinct reinforcement material made from a variety of materials such as natural, carbon, plastic, glass, and steel components and it comes in a variety of sizes and shapes. [2]
The fiber proportion was referred to as the length of the fiber divided by the equal diameter in fiber. [l/d], and is a numerical parameter that describes it. For length dimensions of 0.3 to 9.01 cm, standard aspect ratios [l/d] range from 50 to 200, with distinctive diameters of 1.01 to 1.0 mm for plastic and 1.34 to 1.5 mm for plastic. When the bend corresponding to the crucial tensile strength was exceeded, ordinary concrete abruptly fails. However, FRC can resist significant loads at deflections well beyond the fracture deflection of plain concrete. [3]

Fibers can fully replace ordinary reinforcement in certain buildings, such as walls, grades, and foundations. It can be used in conjunction along with pre-stressed or ordinary reinforcement in other models, like suspended slabs and beams. The probable benefits in all cases are because of financial concerns, rationalization, and consumption of the working site. Figure 1 shows the effect of the fiber. Crack propagation decreases crack spacing & duration and improved tensile strength that has impacts on load service. [4]

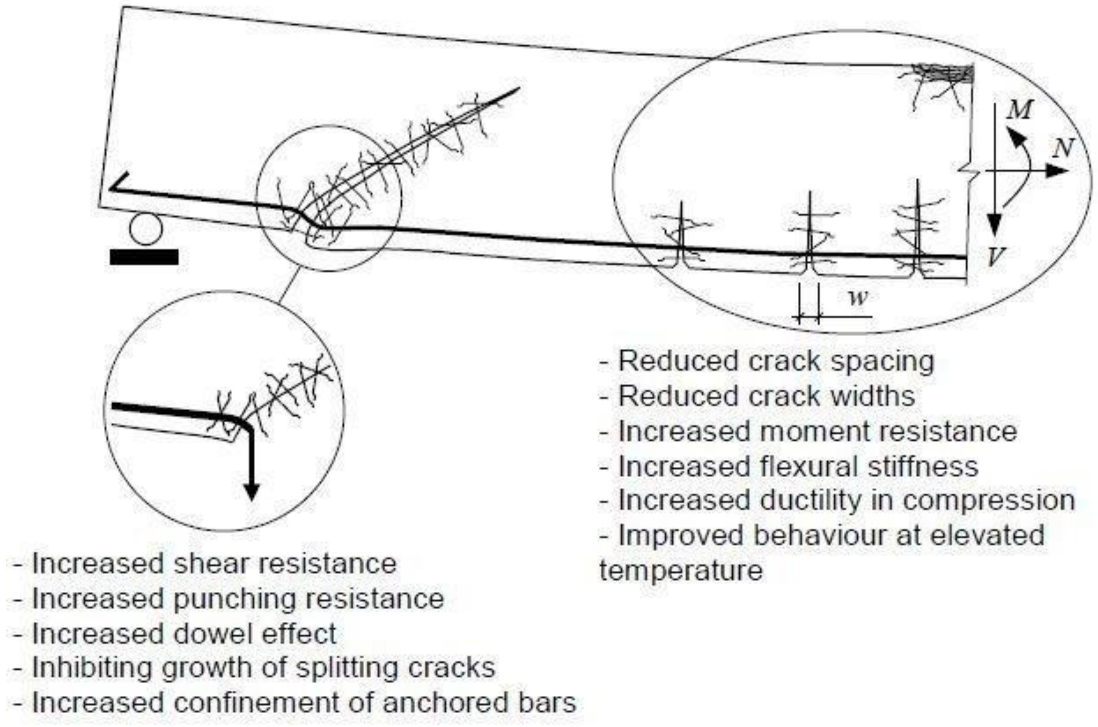

Fig.1. Structural behavior of fibers.

FRC was a construction component made of discrete and cement, randomly discrete fibers. The aim of incorporating fibers into a concrete mix was to bond distinct cracks, allowing for the better regulator of the crack process and increased crack energy. Combining concrete with scattered "fibers" made up of steel scraps is an innovation unproved by A. Berard in 1874, resulting in a modern, more ductile material. Synthetic and steel fibers were now used for both non-structural and purposes. It is used to monitor early slab cracking Löfgren (2005). It has been discovered that including fibers in concrete improves cracking things such as ductility and crack width reduction. It demonstrates the increased mechanical things which can be projected with acceptable precision and integrated into the model. [5,6]

2. **Literature survey**

The current understanding of the fiber-matrix process was focused on a series of pullout experiments with single or multiple fibers, as well as the creation of theoretical models. Leung and Li (1991), Grünewald (2004), Kullaa (1994),, Bentur and Mindess (1990), Stang and Shah (1990),, Wang et al. (1990b), Li et al. (1993),, Li and Stang (1997), Gopalaratnam and Shah (1987), Namur and Naaman (1989), Chanvillard and Atcin (1996), Bentur et al (1990a).
According to Löfgren (2002), in-situ concrete construction may be considered industrial if the following conditions are met: The entire operation, including design, manufacturing,

transportation, erection, and on-site construction, is designed, coordinated, and regulated. The product's design and manufacturing/construction processes are intertwined, and all functional disciplines must be involved. As far as possible, the production is systematized, mechanized, and automated. The design was structured and assisted by CIC instruments, such as FE/CAE, ICT, CAM/CAD, and so on. The method and development are handled in such a way that risks and disruptions, such as the effects of climate and weather, are minimized. Temporary workers are not needed for production. Measures are taken to ensure that the whole process is continually improved, including the consideration of emerging technologies, new/improved products, and so on.

Pelissier et.al studied the physical and mechanical properties of reprocessed polyethylene terephthalate (PET) fibers in concrete. PET is a form of fiber that can be made from the waste of recycled bottles. After 28 days and 150 days, tests were conducted. The PET-FRC, except the lowest fiber content study, showed an improvement in flexural strength, impact resistance, and durability after 28 days. The findings were modified after 150 days, as the PET fibers slowly deteriorated in the alkaline atmosphere of the concrete. The modulus of compressive power and elasticity was not affected in any way.

Several theoretical approaches to FRC flexural behavior have been suggested, including Zhang and Stang (1998) for a semi-analytical model, Shiah, and Ezeldin(1995), Xiao and Lok(1999), Pei and Lok (1998), for purely analytical design. Barros and Figueiras define an analysis model designed for finite element calculations (2001). Rossi (1999) and Stang et al. (1999) describe the strength of fiber concrete regarding cracking.

Löfgren (2002) suggested that in-situ concrete production be considered commercial if some of the conditions are met but not all. Furthermore, on-site concrete construction is considered mechanized if it is first and foremost modified to the usage of robotics, equipment, and machinery to reduce the work of human beings.
(Sarja 1998) investigated the design of industrial buildings. It is seen as a necessary advancement to address some of the issues that plague the existing construction process. For eg., competition is based on low cost rather than efficiency, CP factor, and sustainability. The process is disjointed, and the connection between the manufacturer and user, as well as the link between designers and contractors, is weak. However, since various types and techniques exist, composing a perfect break description of the industrialized building couldn’t be as simple as one would think. According to ICR and IBC “Industrialised Building is the term given to building technology where new systematized methods of design, production planning, and control, as well as mechanized and automated manufacturing, are applied,”

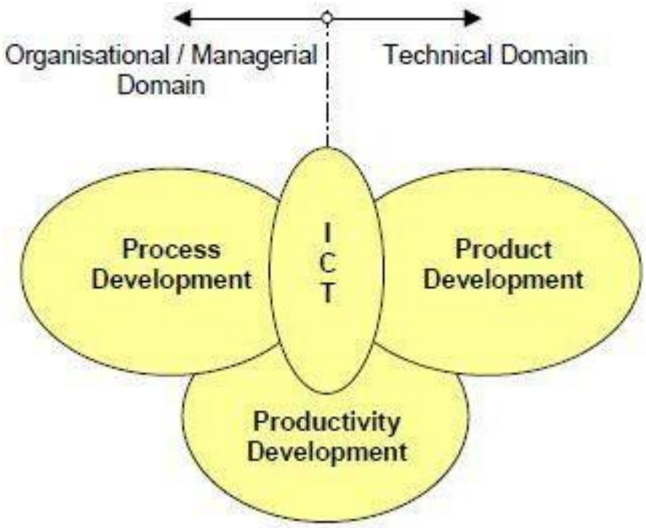

Figure 2. Three cornerstones of industrial construction

According to Girmscheid and Hofmann (2000), industrial construction fails due to a focus on development while ignoring product and management processes. Similar findings are reached by Koskela (2000) and Warszawski (1999). Three cornerstones were described in an investigation of bridge construction which was organized by Harryson (2002). He also examines the growth of productivity, product, and process. Harryson recognizes the value of the managerial and organizational and aspects for emphasizing the technological domain, and ends which were seen in fig.2. Effective implementation cannot be based solely on one of the domains. As a result, for industrial in-situ construction to be effectively implemented, all stages of the process must be included, and all stakeholders (clients, designers/engineers, contractors, and suppliers) must be involved and work as a project team.

3. ENVIRONMENTAL PROPERTIES OF FRC :

Fibers are mixed with concrete, they have the following effects:

i. Increases the concrete's tensile strength.
ii. Air and water voids are reduced.
iii. Increases the concrete's longevity
iv. Minimizing bleeding in new concrete
v. Providing greater flexural strength than rebar.
v. Limiting the spread of cracks under load.
vii. Certain fibers have a higher impact and abrasion rate in concrete.

4. BIODEGRADABLE FIBERS:

Biodegradable fibers are NFRC, SNERC, SFRC and SNFRC.

4.1 SF:

SFRC was a form of rebar reinforced concrete that is less expensive and easier to use. Steel bars are laid inside the liquid cement in rebar reinforced concrete, which takes a lot of prep work but results in much tougher concrete. SFRC (Fig. 3) is made of thin steel wires blended with cement. In most cases, circular fibers are used. The diameter can range between 0.30mm and 0.76mm. Concrete's flexural, impact, and fatigue strength all increase significantly when steel fiber is used. [7] Steel fibers are prone to rusting and losing some of their power. However, research has shown that fiber rusting occurs only on the surface. It has a tensile strength of 1800 N/m2 which is extremely high. Steel fibers are mixed into the shot concrete to consume its resistance impact, toughness, ductility, and crack resistance. This increases the structural strength of the concrete, prevents cracking, and protects it from extreme cold. SF was sometimes used in combination with rebar or another form of fiber. Overlays for sidewalks, plates, pavements, bridge decks, and thin shells are all made with these. [8] The mix proportions for SFRC, like any other form of concrete, are determined by the specifications for a specific job in terms of workability, intensity, and other factors. There are many methods for proportioning steel fiber mixes, all of that emphasize the mix's process. There are, however, certain considerations that are unique to the SFRC. The mixtures of steel fiber have more cement and contain high aggregate proportions than normal concretes. This method was applied to conventional concrete which cannot be applied fully to steel fiber. [9] Typically, up to 45 percent of the cement is substituted with fly ash to minimize the amount of cement used. In addition, water-reducing admixtures, especially super plasticizers, are frequently used in combining with air to increase the workability of fiber blends. Fig 3 illustrates the steel fibers.

Fig. 3 - Steel Fibers

4.2 Glass Fiber:

Glass fiber is a relatively new addition to the world of fiber concrete. To strengthen the concrete, Fig.4 demonstrates glass fiber reinforced concrete (GFRC), which is similar to fiberglass insulation. The glass fiber insulates the concrete while also strengthening it. Glass fiber also helps to resist the cracking of concrete caused by mechanical or thermal stress over time. Furthermore, unlike steel fiber insulation, GFs do not affect the signal from the radio. Glass fiber concretes are primarily used as decorative precast concrete and as exterior building façade panels. Alkali-resistant GF, water, cement, and sand glass fibers are used in GFRC. Glass fiber reinforced cementitious composites with a paste or mortar matrix and fiber material were designed for the manufacture of thin sheet elements.

Fig. 4 – Glass Fibers

4.3 SF:

Many researchers investigated that SFs were used to build on plant and animal fibers. SFs are used

to enhance concrete's process. These fibers are long-lasting and used to increase the strength of tough concrete and to prevent cracks in semi-hardened concrete. [11] Synthetic fibers aid in the permeability of concrete and prevent it from spalling during impacts. SFs do not contract in cold and expand in the hot climate. It helps to prevent cracking. The synthetic fiber is depicted in Figure 5.

SF are used in concrete are polyethylene, polypropylene, polyester, carbon and nylon.

4.4 Naturally occurring fibers:

Natural fibers such as straw and horsehair were used in the first examples of fiber-reinforced composites. Fibers can now be extracted thanks to modern technology. To use in cement composites, various plants such as jute and bamboo can be economically harvested.

The low energy used to remove these fibers is one of the fiber's distinguishing features. (12) The main issue with using these fibers in concrete is that may collapse in alkaline ether. The results of using the mixture to have the low alkaline and subjecting the fibers to increase the durability of this fiber in concrete. [13] The mechanical properties of some of the natural fibers used in PC composites, such as wood, sisal, flax, bamboo, akwara, sugarcane bagasse, coconut, and jute are presented in the following. [14]

Fig. 7 – Natural Fibers

5.Mechanical Properties of FRC

The mechanical elements of concrete are influenced by the addition of fibers, which are highly dependent on the form and percentage of fiber[2-4J. Fibers with a high aspect ratio and end anchorage were found to be more efficient. Crimped-end fibers can achieve the same properties as straight fibers by using 50% fewer fibers for the same length and diameter[S]. The same equipment and technique that are used to determine the mechanical properties of traditional fiber concrete may be used to analyze the mechanical procedure of fiber reinforced concrete. The following are some of the properties of FRC that have been determined by various researchers. [15] The existence of fibers can change the failure mode of cylinders, but the effect of fibers on compressive strength values will be minimal (2 to 16 percent). The elasticity modulus of fiber concrete increases slightly as the content of fibers increases. It was discovered that every 2% increase in fiber content by volume results in a 3% increase in elasticity. Flexural strength was stated to be 2.5 times higher when 5 percent of fibers were used. FRC has a hardness of 14 to 50 times that of ordinary concrete. The addition of 4% fiber by volume increased the splitting tensile strength of mortar by around 3.6 times that of unreinforced mortar. At 1 x 106 cycles, the addition of fibers improves exhaustion strength by around 80% and 60% of fixed strength for reverse and non-reversal loading. Fibrous concrete has an impact strength of 10 to 15 times that of plain concrete, depending on the amount of fiber. Steel Fiber Erosion is a term that refers to the corrosion of steel fibers. The strength properties of an l0yrs exposure of steel fiber revealed no opposing effects in an industrial area.

Corrosion was discovered to be limited to the fibers that were already exposed on the surface. Steel fibrous mortar that was immersed in seawater for ten years lost 15% of its strength, whereas plain mortar lost 40% of its strength.

6.Structural Behavior of FRC:

Fibers paired with strengthening bars will be commonly used in structural members in the next generation. Here are some examples of mechanical behavior. Fibers improve stiffness, ductility, tensile, and moment strength in RC. The fibers help to manage cracks and maintain the structural integrity of members after they have cracked. The use of fibers prevents the abrupt failure that is common in plain concrete beams. No. of cracks, rotational energy, ductility, torsional power, and stiffness are all improved. Fibers will increase the shear ability of RC rays by up to 90%.
Ultimate power, the strength of 1st crack, and shear friction all improve when randomly dispersed fibers are added. [number 16] Increased fiber content improves the ductility of axially loaded specimens significantly. Fibers aid in the reduction of explosive type failure in columns. The ductility of high-strength concrete is improved by adding fibers. Slender members are created through high-power steel and concrete. The inclusion of fiber would aid in the control of cracks and deflections. Fiber reinforcement has been shown in tests to effectively manage cracking and deflection while also improving strength. Fiber addition improves stability and resiliency in conventionally reinforced concrete beams.

7.Applications:

Isotropic properties are not typical in conventionally reinforced concrete because of the dispersion of the perfect fiber in the concrete blend. The use of fibers in the concrete industry is dependent on the designer and builder's ability to exploit the dynamic and static properties of this latest material. Some of the applications are

7.1 Pavements, runway and aircraft parking:

FRC portions should be half the density of concrete portions for the identical load wheel. A 160mm thick end concrete slab was used to overlay an obtained asphalt way as opposed to a 375mm thick conventionally reinforced concrete slab. Fiber concrete ways are used in mild and harsh climates.

7.2 Slope stabilization and Tunnel Lining:

To line underground openings and stabilize rock slopes, steel fiber reinforced shotcrete (SFRS) is used. Mesh reinforcement and scaffolding are no longer needed.

7.3 Blast Resistant Structures:

Under blast and shock waves, testing revealed no decrease in no. of fragments and their velocities. Plain concrete slabs are reinforced conventionally. Fibrous concrete reinforced slabs, on the other hand, showed a 20% decrease in densities and an 80% reduction in fragmentation.

7.4 Manholes, pipes, thin shell and walls:

Solvent flat and curved structural components can be used for fibrous concrete. The inflated membrane method is used to construct hemispherical domes out of steel fibrous shotcrete. The spray-up process was used to create glass fiber reinforced cement or concrete (GFRC) wallboards. The accumulation of glass and steel fibers is used to decrease handling risk, thickness and increase the strength in concrete pipes.

8.Results and Discussion:

The materials of the hooked and straight fibers are shown in Table 1. The splicing of the 30 fibers results in a synthetic proportion of around 20. The PFs were created manually and cut through stimulated steel wires. All of the blends included Type I portland cement, l0mm graded crushed stone aggregate, quality modulus 4.01 desert sand, and a 4% superplasticizer. The water-cement ratio was 0.55 and the blend proportion was 2.0:3.0:1.7.

Tab.1. Materials of deformed and straight steel fibers

	Hooked fiber	Straight fiber
Material	Carbon	Galvanized steel
F_y(MPa)	240.21	650.12
Proportion	76.15	78.15
Diameter(mm	1.78	1.90
Length (mm)	55.21	40.67

8.1 Workability:

The traditional slump test isn't a good indicator of FRC's workability. The inverted slump cone test (2.4), which was developed specifically for fibrous concrete, is suggested. The inverted cone time was T that takes for the reversed lamp in the shape of a cone with total fiber concrete to be drained. It was drained only after the vibrator was placed into the concrete. It should last anywhere from 10 to 30 seconds. The process of PRC with 2 kinds of fibers was compared using the traditional slump process (ASTM CI54-80). The hooked fibers worked well during mixing because they did not ball up despite being applied to the mixer at the same time as the aggregate. To stop balling, the straight fibers were sprinkled into the blender through the hand. The straight fibers took about 2 minutes of mix and subsequently in an additional 3mis of blending time. The consequence of fiber content on reversed and slump time was shown in Figure 8. The slumps value decreased from 240 to 19mm as the fiber content improved from 0.0 to 2.5%, and the taken time to empty the reversed cone improved from 30 to 90 seconds. (Vf = 1.0%).

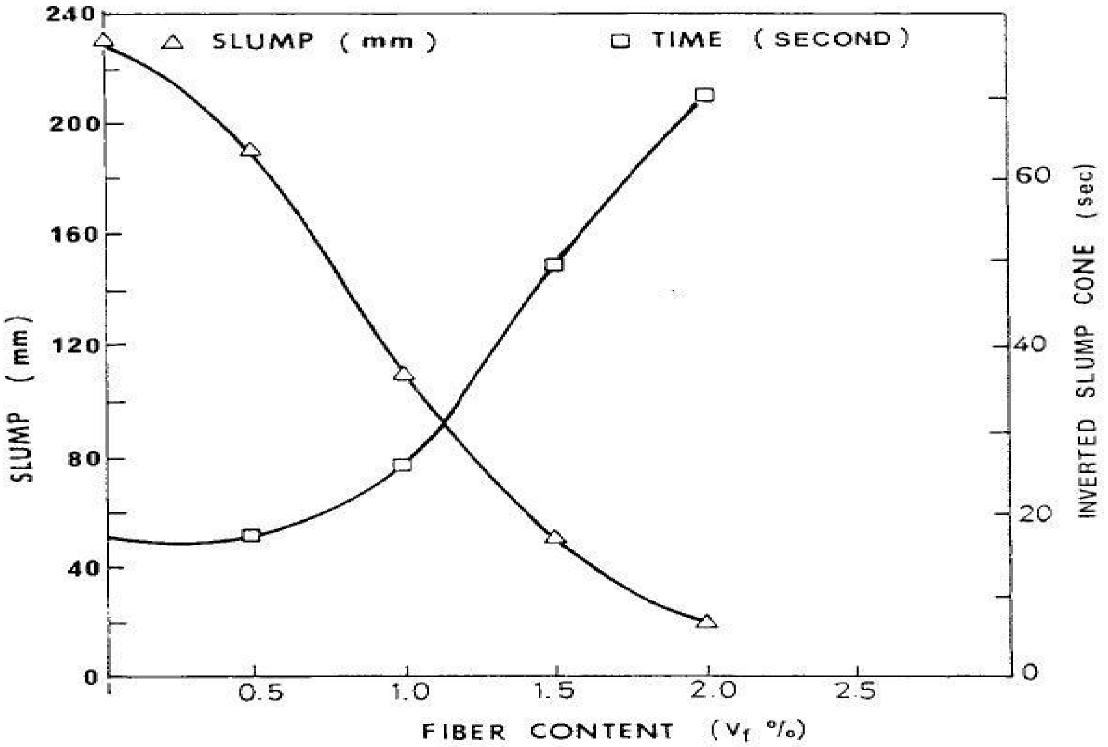

Figure 8 Fiber content on workability.

8.2 Compressive Strength:

At the end of 8, 30, and 95 days, 60 cylinders (1600 x 350mm) were examined in compression (ASTM C40). Figure 9 depicts the stress-strain relationship as well as the influence of hooked fiber content on compressive strength values. The compressive strength values were unaffected by the fiber addition. With the increased addition of fibers, the hard mode connected with plain fiber which was converted into ductility mode.

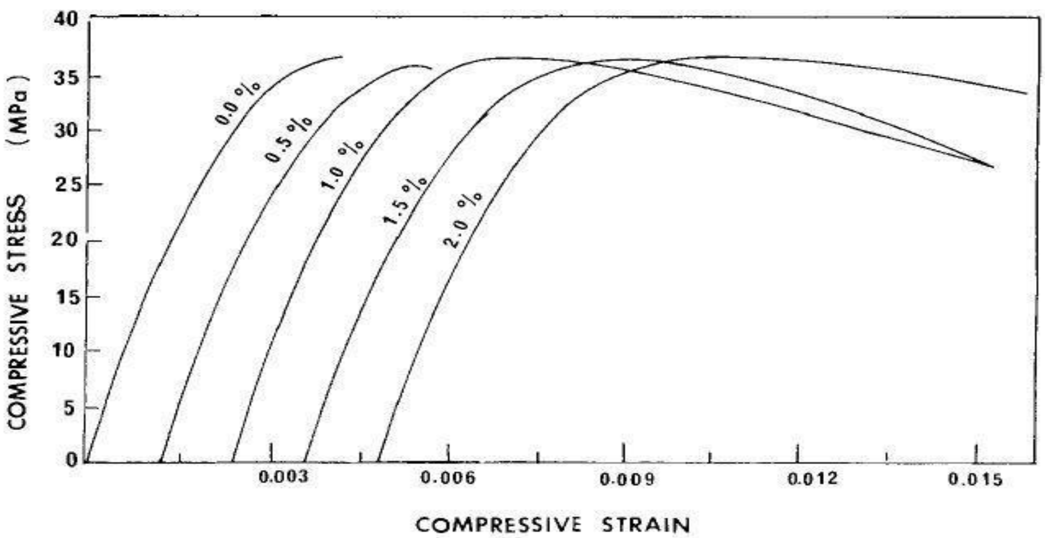

FIG. 9 Hooked fibers effect on compressive strain curves .

A evaluation of the compressive strength of straight and hooked fibers are shown in Table 2 and Fig. 10, indicating that the fiber forms and material have no impact on the compressive strength. The findings are consistent with those of other researchers.

Tab. 2 Evaluation of strength by straight and hooked fibers

V_r (%)	CS		Split tensile strength		Rupture Module	
	Straight (MPa)	Hooked (MPa)	Straight (MPa)	Hooked (MPa)	Straight (MPa)	Hooked (MPa)
1.1	36.9	34.6	6.17	6.17	3.89	3.89
0.6	34.6	38.0	6.78	6.70	4.67	4.98
1.4	38.4	37.8	8.97	6.98	5.12	4.56
1.8	34.6	39.7	12.8	7.98	5.20	5.0
2.0	23.5	42.7	7.89	8.09	5.20	5.16

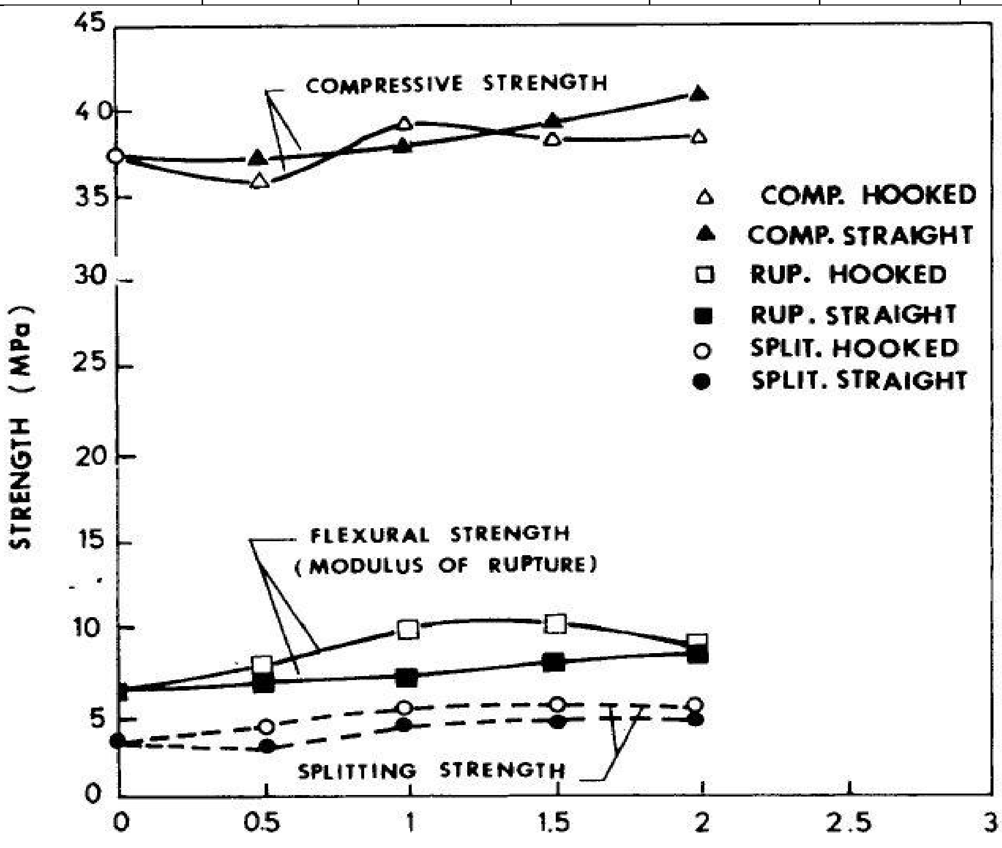

FIG. 10. Splitting, Compressive and Flexural strength for straight and hooked fibers.

8.3 Elasticity:

Figure 9 shows that the stress-strain curve's initial slope is nearly the same for all blends, at 30,700 MPa, as opposed to 43,100 MPa obtained using the ACI formula. This implies that the addition of fibers has no impact on the modulus of elasticity.

8.3.1 Flexural Test· Modulus of Rupture:

After 7, 28, and 90 days, 60 beams (150 x 150 x 300mm) are measured in flexure (ASTM C7875). The LD curves for straight and hooked fibers with numerous density content are shown in Figures 5 and 6. Up to point A (Fig. 5), the LD curve for fibrous and plain concrete was linear, and the power at A was referred to as the 1st strength during cracking. Cracking in simple concrete rays guides to failure instantly. Owing to the presence of fibers, the curve becomes non-linear beyond point A and reaches its maximum intensity at point B. In the situation of hooked fibers, after hitting the peak value, the flexural intensity decreases and stabilizes at 60 to 70% of the peak value. The flexural strength of straight fibers continues to decline until failure, indicating continuous slippage of the straight fiber. The following is an explanation for this conduct. Once cracks appear in fibrous concrete, the fibers begin to act as crack arresters. The use of fiber results in cracks that are more closely spaced and have a smaller diameter. To expand the cracks and debond the fibers from the matrix, more energy is needed.

8.3.2Toughness (Energy Absorption)

The region under the load-deflection curve represents toughness as determined through the absorption of whole energy The inclusion of fibers significantly improves the absorption of energy in concrete. The toughness index is determined by dividing the area up to the 1st crack intensity by the area under the load-deflection curve up to the 1.4mm deflection (proportional limit). Table 3 shows the measured toughness index for each blend. The toughness index of hooked and straight fibers increases to 20.0 and 15.9, respectively, when the fiber is added. The average hardness index of hook-reinforced specimens was 35 to 75 percent higher than that of straight-reinforced specimens.

Tab.3. Fiber content on the EA index

Fiber Content (%)	EA index	
	Straight fibers	Hooked fibers
1.1	2.4	1.9
1.3	12.3	12.6
1.4	19.0	9.7
1.8	18.7	15.8
2.1	18.6	2.3

9.Conclusion:

This paper focuses on the environmentally friendly nature of fiber materials used in buildings. Micro cracks form in traditional concrete before the structure is filled due to the changes in volume and drying. As the structure is filled, the very small cracks spread and open up, are causing inelastic deformation in the concrete. The cementing of a concrete reinforced mixture of more or less uniformly dispersed small fibers is known as FR). During the mixing phase, a large no. of microfibers are distributed and scattered in the concrete and increasing the property of concrete in all ways. A concrete fiber was depending upon the cement composite component that has been produced recently. It has been successfully used in a building because of its good impact and frost resistance, permeability, flexural tensile, and strong resistance to spitting. It's a good way to improve the mortar's durability, shock tolerance, and conflict to reduce plastic cracking. The use of fibers also improves the durability of the FMC, which re-calibrates its action after it has cracked. This study aimed to give data regarding applications and properties of fibers and also their use in concrete manufacturing along with particular properties. A new type of fiber-reinforced concrete made of cellulose fibers has been developed. Fiber is a small distinct reinforcement material made from a variety of materials such as natural, carbon, plastic, glass, and steel components and it comes in a variety of sizes and shapes.

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