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Cite as: AIP Conference Proceedings **2404**, 080034 (2021); https://doi.org/10.1063/5.0068874
Published Online: 11 October 2021

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Mechanical Properties of Concrete Using Natural Fibres -An Overview

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Abstract. Currently, due to global warming, a lot of investigation and advance has been growing in the possible use of natural fibres composite universally. Scholars highly initiated the significance due to its advantage of human-made fibres, such as little ecological impact and low cost. Many studies were established to enhance the mechanical execution and uses of natural fibre in the manufacturing trade. Investigation revealed on natural fibre composites can be set into a load-bearing structural and infrastructure use. As an engineered usual material, related to human-made fibre composites, the attributes of natural fibre compounds can be oriented to attain a positive request. The common problems in operational with natural fibre compounds were excessive discrepancy and appearances. Natural fibre composites' attributes, which have a significant level, are mostly subjective by the category of fibres, ecological circumstances also the source of cellulose fibres, and the kind of fiber treatments. As the addition of natural fibre increases in fiber-reinforced concrete production, its slump test value decreases, but it improves the mechanical property of concrete up to a certain value. Then, it starts to decline compared to the control mix design and also, the mode of failure changes from brittle to ductile with the inclusion of natural fiber. Though, cellulose fibre composites might appear as a novel substitute for a rock-solid material with their uniqueness and unevenness and substitute expensive human-made fiber composites. This assessment will deliver an overview of natural fibre mechanical performance and toughness in the concrete, one of the importance of natural fibre compared to a human-made one, and the detailed achievements on its uses supported by the literature.

Keywords. Construction material**,** Compressive strength, Flexural strength, Fiber-reinforced concrete, Mechanical property of concrete, Natural fiber.

INTRODUCTION

Due to the increase in population worldwide, the construction industry's rising demand increases rapidly from day to day [1]. This vast construction industry relies more on concrete, which proceeds to furthermost extensively applied in a building material an exclusive characteristic in belongings such as an outstanding compressive strength, better toughness, fire-resistant, & little absorbency [2]. However, besides these favorable characteristics, there are low tensile strength, breakability, less in resistance to cracking, and lower effects on hostility. This property needs to be improved by incorporating other materials [3]. These shortcomings made it a crucial to discover a technique to

2nd International Conference on Engineering & Science
AIP Conf. Proc. 2404, 080034-1–080034-8; https://doi.org/10.1063/5.0068874
Published by AIP Publishing. 978-0-7354-4136-1/$30.00

enhance concrete properties by standard reinforcing bars and, to a rational level, by including the optimal quantity of individual fibers in concrete, such as fiber-reinforced concrete (FRC) [4].

Fibre is inconsequential separate reinforcing material formed by numerous resources similar to steel, plastic, glass, carbon, and cellulose-natural materials in different forms plus dimensions [5]. As per the source of origin, fibres were categorized as into animal, mineral, and plant. Plant cellulose fibre are the ultimate regularly recognized fibre by the industrial for different purpose of applications. Plant fibres are currently a fundamental investigation area for researchers widespread to replace synthetic materials and non-renewable properties. It is mainly because plant fibres have a short growing period and low-cost. Also, they are renewable, eco-friendly, and widely available [6].

Plant fibres are mostly lignocellulose, comprising a helically shaped twisted cellulose microfibril in a shapeless structure in the lignin matrix and at hemicellulose of a numerous fibrils surrounds lengthwise the entire dimension of the fibre. The natural cellulose extent and microfibril angle govern the mechanical properties of fibre. Their composites structure, which is built on cellulosic fibres, gives several advantages for both technically and ecologically for its use in reinforcing composites as compared to synthetic ones such as small density, cheap, biodegradability, incredible precise stiffness and strength value, appropriate aspect ratio cellulose fibre, and flexibility throughout a production has nontoxic to equipment [7]. However, natural fibre exhibits compatibility problems among the natural hydrophilic fibres and the hydrophobic matrix, needful a suitable treatment to boost the fiber and matrix [8].

Therefore, the fibre surface modifications have been applied by chemicals to upsurge fibre and matrix relationships before utilization or application for different industrial raw materials [9]. Due to an increase of attentiveness to the harm produced by artificial provisions to the environment and society, the adoption of new green regulations and the reduction of unsustainable consumption of non-renewable resources have made many researchers look for ecologically friendly materials for different applications.

Awareness of using natural fibre composite increases due to several benefits that offer the society, such as replacing synthetic fibre, lower cost with sustainability potential, environmentally friendly, and it has a good mechanical property compared to human-made fibre [10].

TABLE 1. Advantages and disadvantages of natural fibre composites [11, 12]

Advantages	Disadvantages
• Narrower density, excellent basic strength and resistance • Naturally available; it requires a small amount of energy during d evelopment • Mass-produced at a miner's price compared to human fiber • Harmless methods of development • Important release of poisonous exhausts when subjected to heat a nd scorching during • Less extreme disability compared to manmade fiber composites d uring a manufacturing kit	• Less resilience than composites of human material, on the other han d, it has been extensively improve d by the treatment process • A greater absorption of wetness a s a result of swelling. • Less durability and impact strengt h relative to composites of human fibre. • More land contradictions

The most preferable natural fibre in the polymer composites application extended noticeably day to day, especially in automotive companies in the last few years. Its applications also are increasing in several aspects of engineering. Furthermore, the practices of natural fibre composites are observed now in auto and civil manufacturing, sports, aerospace, and others such as panels, window frames, decking, and bike frames [13]. According to statistics, natural fibre reinforced composites in manufacturing fabrication applications predictable about U$2.1 billion in 2010. This numerical value shows the consecutive 5-year evaluation from 2011-2016 that shows this industry expands, and based on this value, the natural fibre polymer composites industry is estimated to grow up to 10% worldwide [14].

Various categories of natural cellulose fibres are available worldwide, and their performance depends mainly on the mechanical, physical and chemical properties of natural fiber-reinforced composites, affected by various features such as fiber composition, age, preparation and extraction methods, chemical and structural composition, the category of fibre, modification of fibers, textile technical process [15]. The various kinds of primarily available natural fibre plants are shown in Figure 1.

FIGURE 1. Natural fibre plants [16]

Plant cellulose fibres differ in their chemical composition from one another. It was greatly affects a composite material during formation; this was due to the amount of cellulose, hemicellulose, lignin and waxes content in the fibers [10]. The chemical composition of varied plant fibre is illustrated in Table 2.

TABLE 2. Commonly available Chemical composition of some natural fibres [10].

Plant type	Cellulose (wt. %)	Hemicellulose (wt. %)	Ligning (wt. %)	Waxes (wt. %)
Abaca-fiber	56-63	20-25	7-9	3
Bamboo-fiber	26-43	30	21-31	
Coir-fiber	32-43	0.15-0.25	40-45	
Flax-fiber	71	18.6-20.6	2.2	1.5
Hemp-fiber	68	15	10	0.8
Jute-fiber	61-71	14-20	12-13	0.5
Kenaf-fiber	72	20.3	9	
Ramie-fiber	68.6-76.2	13-16	0.6-0.7	0.3
Sisal-fiber	65	12	9.9	2
Wheat-straw	38-45	15-31	12-20	

The properties of cellulose natural fibre must be understood since these properties govern the mechanical properties of natural fibre composites. The mechanical properties of natural fibres are smaller than those of synthetic fibres, but their basic properties is compared with each other’s. The mechanical properties of natural fibre are mainly dependent on microfibril angle, amount of cellulose, and percentage of hemicellulose in cellulose fiber. The widely available mechanical and physical properties of natural fibre are shown in Table 3.

TABLE 3. Mechanical and physical properties of natural fibre [17]

Fiber	Density (g/cm3)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break (%)	Length (mm)	Diameter (μm)
Abaca	1.50	400.0-980.0	6.20-20.0	1.0-10.0	-	-
Bamboo	0.60–1.10	140.0-800.0	11.0–32.0	2.50-3.70	1.50-4.0	25.0-40.0
Baggase	1.250	222.0-290.0	17.0-27.10	1.10	10.0-300.0	10.0-34.0
Coir	1.150-1.460	95.0-230.0	2.80–6.0	15.0-51.40	20.0-150.0	10.0-460.0
Cotton	1.50-1.60	287.0-800.0	5.50 – 12.60	3.00 – 10.00	10.0-60.0	10.0-45.0
Flax	1.40-1.50	345.0-2000.0	27.60-103.0	1.20–3.30	5.0-900.0	12.0-600.0
Hemp	1.40-1.50	270.0-900.0	23.50-90.0	1.00-3.50	5.0-55.0	25.0-500.0
Jute	1.30-1.49	320.0-800.0	8.0-78.0	1.50–1.80	1.50-200.0	20.0-200.0
Kenaf	1.40	223.0-930.0	14.50-53.0	1.50-2.70	-	-
Ramie	1.00-1.550	400.0-1000.0	24.50-128.0	1.20-4.00	900.0-1200.0	20.0-80.0
Sisal	1.330-1.50	363.0-700.0	9.0–38.0	2.00–7.00	900.0	8.0-200.0

Nowadays, in many countries, natural fibres are nearby accessible and have a low price. This usage as a building material to increase the composites' possessions costs nearly negligible related to the composites' entire rate. Their application can promote to supportable progress [18]. Additionally, the advantage was a comfortable usage of the fibres due to their flexibility. The difficulty happened when there was a significant fraction of fibre is to be utilized in steel fibers. Volume of fraction and amount of fibre are the two expressions used for stating the extents of fibres in given composites material [19-21], which can be used in civil engineering construction, comprising roofing tiles, corrugated slabs, simple slab panels, boards, formwork and mortar.

A variety of reasons describe the motivation for using natural fibre composite materials such as a relatively low cost, low density, good ratio of modulus-weight, sustainability, strong mechanical properties, biodegradable nature, environmentally friendly, and lower carbon footprint [22] to be used for fiber-reinforced composite materials.

CRITICAL LITERATURE REVIEW ON THE MECHANICAL PROPERTY OF CONCRETE

The subsequent are the research papers reviewed on the concrete used in the construction projects. This overview emphasizes the mechanical performance of different cellulose fibres in concrete production and detailed achievements. The addition of fibre in concrete explained in related literature was focusing on the substantial property's performance. According to the experiment results of Kavitha & Felix [23], samples were collected at different steam bamboo stages. It was split and rolled by the roller to extract fibres mechanically then prepared in different a proportion by weight (0.5%, 0.75%, 1% & 1.25%) with a constant aspect ratio (l/d=40) of 4.9 mm distance to the mass of cement. The Mix design of concrete based on the Nan-Su method carried with recognized water to cement ratio. Result of a slump test decreases as fiber content increases. The fibres amount of 1.0% by weight caused significant improvement at the initial and final stage of a compression and split tensile strength of concrete. Still, the peak flexural strength was obtained from 1.25% fibre contents. As a result, the strength performance in compression, split tensile and flexural strength shows a significant change observed compared to control concrete mix design.

Raw bamboo fibre has been extracted from the steam of 3-5 years by using a heavy-duty splitter into a strip of approximately 13mm*15mm*1500mm. The strips were treated with an alkaline solution with concentrations of zero and ten weight percent at 24.0 hours and then by roller milling techniques to obtain fibres also to remove impurities. The treated and untreated fibre surface was characterized, and also the mechanical properties of single fibre were also investigated using ASTM C1557-14 standard procedures. The result reveals that the tensile strength and modulus of the alkali-treated fibre was improved by 45.60% and 72.00%, respectively, compared with untreated fibre. The surface morphology of the treated fibre was enhanced, in which the surface roughness was reduced significantly, as proven in Scanning Electron Microscopy (SEM). The Fourier Transform Infrared (FTIR) and Thermal stability analysis (TGA) data recommended that alkaline treatment slowly detached the lignin and hemicellulose impurities on the fibre surface [24].

The Effect of the addition of natural short Roselle fibre with a various volume fraction of 1% up 4% on the concrete composite's mechanical behavior was carried out using experimental investigation. The reported compressive strength and bulk density were somewhat improved at the small fibre amount of 0.30% -1.50% by volume compared with the cement paste control. The maximum strength and optimum density are obtained at the 0.3 % fibre content during a mix design and also good homogeneity during fiber-reinforced concrete production as compared to normal concrete, but, as the fibre content approaches the value of 1.50 %, the compressive strength and bulk density

Decrease by about 8.2% for every 0.5% fibre content.However, the tensile strength decreased with the lower fibre volume content of 0.3%, while the bulk density increased to the limit. However, the bulk density steadily diminishes as the fibre content reaches the value of 0.3 %. In comparison, the tensile strength is increased up to 53%, and the compressive strength decreased was observed in the experiment [25].

Treatment effect on the morphology and tensile properties of Roselle fiber studied experimentally was carried out to increase the interfacial connection, discontinue moisture absorption, hygienic the fibre surface, and upsurge surface roughness. In this analysis, Roselle fibres were immersed in a Sodium hydroxide (NaOH) with three different concentrations, such as 3.0%, 6.0%, and 9.0%. The results were compared before and after treatment. Results show that NaOH's higher concentration increased the surface roughness and had a more excellent capability to spotless the fibre surface that removes impurities. The tensile properties at 6% of NaOH give the highest strength as compared to the other ratios, and the outcomes radically descent subsequently a treatment with 9% of NaOH [26].

To detect plain concrete limitation, an experimental comparative study was conducted by T. Sai Vijaya & B. Manoj [27] was conducted to observe the cracks and defects observed in plain concrete. A concrete mix design, 1:1.5:3 ratio with 0.5 water-cement ratio as controlled plain concrete was prepared as well as the various percentage of Jute fibre added to plain concrete, such as 0.5 %, 1 % and 2 %, approximately 25~30 mm length, to the cement weight for reinforced concrete Jute fibre.For various curing times, such as7, 28, 56 and 90 days, this ex perimental analysis on samples was carried out on various mechanical properties, such as compressive, flexural and split tensile strengths. Compared to the control sample and at theearly stages of 7a nd 28 days, the workability of concrete decreased up to 68 % compared to the content of jute fibre.With the increase in the content of Jute fiber to normal concrete, the compressive strength of Jute fiber reinforced concrete decreases. However, the compressive strength increases up to 1 % Jute fibre content on further curing for 56 days, and other curing results with decreasing compressive strengths. In addition, with a 1% jute content, the flexural strength and split tensile strength of concrete reinforced with jute fibres increases and an increase in strength continues to obtain maximum strengths for up to 56

Days of curing. The flexural strength of Jute fibre reinforced concrete decreases compared to plain concrete during further curing.

The relationship between the Jute fibre contents and compressive strength studied by Qiu et al. [28] on a concrete mix design prepared according to IS: 10262- 2009 guidelines to achieve a maximum goal strength of 26.60 MPa with a mix ratio of 1.0:1.41: 2.83 with water to cement ration (by mass) 0.450 to prepare a 10mm length of the different volume content of Jute fibres distributed randomly with (0.2%, 0.4%, 0.6%, 0.8%, 1%, 1.2%, 1.4%, 1.6%

and 1.8 and cured for 3, 7 and 28 days. The mixing process is done manually and cast with a standard cube mold dimension; appropriate shaking was carried for good compaction of concrete to shrink voids' creation. The casted samples remained to stay for 24h for de-molding. Then the concrete samples were cured for the required period as specified in standards. Based on the compressive strength test, the concrete's maximum compressive strength with 0.40 % of Jute fibers, for a curing period of three days is 14.670 N/mm^2, and seven days is 26.88 N/mm^{2}and 28 days was 44.44 N/mm^2 was a significant improvement when compared to conventional concrete. The compressive strength grows until a specific addition of fibers and further decreases with fibre content. Due to the extreme adding of fibres and reduction in the concrete's internal strength, it is due to the establishment of empty space.

Study on the mechanical properties of cement-based composites reinforced concrete with Jute fibres and polypropylene at different content (0.6, 0.8, 1 and 1.2) kg/m^3 in mix amount was added into the cement-based mortar to improve their mechanical properties of the with two different lengths 10 mm and 19 mm fibers to prepare cement-based composite, and jute fibres were treated with alkali treatment techniques. The treated, untreated, and polypropylene cement base composite as compared to the control matrix (pure mortar) for comparison at different proportions separately based on length. Results show that jute fibers can effectively improve the mechanical properties of cement-based composites when jute fibre is 10 mm later in alkali treatment, and also the compressive strength, flexural strength, impact strength of fiber-reinforced cement-based composite materials were better than the pure mortar. Also, the jute fibre of 19mm after alkali treatment showed that the mechanical properties were good at 1.20 Kg/m^3 fiber content [29].

The mechanical properties of lightweight foamed concrete incorporating coir fibre as filler experimentally investigated with a mix proportion of cement, sand, and water is 1:2:0.55 with different percentage of the total weight of mixture incorporated (0.1%, 0.2%, and 0.3%) with a length of 2mm coir fibre. The compressive strength of foamed concrete containing coir fibre of different percentage has a significant improvement of the numerical value of 7day and 28days as compared with control specimens, but the high compressive attained by foamed concrete containing 0.30% coconut fibre has an incremental 67% of 7 days and 80% at 28 days. The split tensile strength and flexural strength were increased by about 60.0%, and 32% increased respectively by 0.3% of coir fiber at 28 days and also modulus of elasticity was also increased by 50% compared with control specimens, as the amount of coir fibre increases, the formation of cracks and their density decreases but less workability [30].An exploration carried by Yan et al. [31] investigated NaOH treatment's influence for coir fibre to enhance its compatibility with concrete composite and epoxy. They considered the mechanical characteristic and microstructure of untreated and different treated coir fibres. It was noticed that after alkali treatment, the coir fibre become coarser and clean. Treatment improved the tensile strength up to 17.8% and compressive strength of concrete up to 16.7% than that of untreated coir fibre reinforced epoxy. It was correspondingly detected that the damping ratio of untreated coir fibre reinforced epoxy even lower by treatment. It was concluded that compressive strength, flexural strength, toughness, deflection, and other properties were improved by adding coir fibre in concrete.

CONCLUSION

Natural fibres, due to their unlimited origins and accessibility worldwide, have a lot of profits for both procedural use and ecological rewards for their help in reinforcing composites as related to human-made fibres, for instance, Low density, cheap, biodegradability, excellent specific stiffness and strength, desirable fibre aspect proportion, and suppleness throughout handling with nontoxic to the environment. But it has some limitations in the compatibility disagreements between the natural hydrophilic fibres and the hydrophobic matrix. It requires suitable treatment to enrich the adhesion between the matrix and the fibre. Natural fibres mechanical and physical properties vary from fiber to fiber-based on the review process.

There was significant variation in mechanical properties of concrete for treated fibres when related to untreated one due to surface enhancement of fibres by chemicals treatment techniques removed the lignin and hemicellulose impurities on the fibres surface. As the addition of natural fibre increases in fiber-reinforced concrete production, its slump test value decreases, but it improves the mechanical property of concrete up to a certain value. Then, it starts to decline compared to the control mix design and also, the mode of failure changes from brittle to ductile with the inclusion of natural fibre. Still, it reduces the workability; to avoid such limitation admixture should be utilized to reduce such influence. Though, cellulose fiber composites might appear as a novel substitute for a rock-solid material with their uniqueness and unevenness and substitute expensive human-made fibre composites.

Advantages of incorporating fiber in fiber-reinforced concrete to control early cracks and shrinkage observed in normal concrete during its intended life and improve the ductility property of the material used for structural & non-structural engineering works and also used in the construction of roof, formworks, and bridges. Hence, the additional inquiry is looked-for to acquire superior strength and modulus properties containing enhancing the fiber and resin's interfacial bond using fiber treatment. Research is more required to apply natural fibre composite in operational and infrastructure, typically about the rate of fibre and the source of fiber for the composites' bulk fabrication.

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