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Strengthening of RC Beam using Numerous Natural Fibre Laminates - a Review

D. Sowndharya[1*], M. Kathirvel [2], K. Yuvaraj[2]

[1] PG Student, Department of Civil Engineering, K.S. Rangasamy College of Technology, Tiruchengode, Tamil Nadu, India.

[2] Assistant Professor, Department of Civil Engineering, K.S. Rangasamy College of Technology, Tiruchengode, Tamil Nadu, India.

**Corresponding author E-Mail ID: sowndharyadhandapani@gmail.com*

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ABSTRACT

Nowadays natural fibers are getting attention from researchers and scholars to use it for construction of buildings because of their sustainability and eco friendly nature. There are various natural fibers like bamboo, sugarcane fiber, coconut coir, sisal fiber, flax fiber etc., are available for construction. Aim of this paper is to give a detailed study about various experiments conducted on the reinforced concrete structure that are strengthened with fiber laminate. The failure load, ductility, crack pattern, strength properties, flexural behavior of reinforced concrete beam, viscous and mechanical properties and strain characteristics of strengthened beams with different natural fiber composite laminates are reviewed. The result shows that the strength, ductility and durability properties of concrete are increased according to their proportions.

Keywords: natural fibres, laminates, strength and durability of concrete, bamboo fibre, sisal fibre, flax fibre, hemp fibre and kenaf fibre

1. INTRODUCTION

Reinforced concrete structures detoriates with a result of corrosion of internal reinforcement, poor interior design and freezing and thawing action. Thus, repairing and strengthening of reinforced concrete beam becomes a worldwide problem. There are various retrofitting methods available for strengthening of concrete structures. But, nowadays the reinforced concrete flexural member such as slab and beams strengthened with procured fibre reinforced laminates has been extensively studied in recent years. Laminates made with natural fibres provides both technical and environmental advantage due to their renewable nature and low density. Natural laminates shows necessary strength, ductility behaviour and durability characteristics after necessary treatment process. Natural laminates are easily available and also eco-friendly in nature. Natural fibres like coconut fibre, flax fibre, bamboo fibre, hemp fibre, sisal fibre and hemp fibre are extensively used for making laminates. According to the necessity and fibre properties, the fibres are selected for retrofitting of reinforced concrete structures.

LITERATURE REVIEWS

Hallonet et al (2019) presents the characterization of the mechanical and durability performance of wet lay-up flax/ epoxy composites used for the external strengthening of concrete structures. The glass and flax composites present comparable tensile stress at failure. The properties, calculated with the portion of the dry fibers only, remain constant with the number of layers. The tensile property remained constant with the number of fabric layers. As expected, the residual properties of the composites are lower after hydrothermal ageing than after climatic ageing. In contrast, the constraint decreases by 15% for flax composites and by 40% for glass composites. The modulus values decrease by 50% for flax composites and by 20% for glass composites. [1]

Abdul Moudood et al (2019) evaluated the durability and mechanical performance (tensile and flexural behavior) of flax/bio-epoxy composites exposed to different environmental. The tensile strength and modulus is decreased approximately by 9% and 57%, respectively for water saturated (immersed in water until saturation) samples compared to as manufactured samples. On contrary, this reduction rate is only 0.8% and 3%, respectively in case of humidity saturated (exposed to humid environment until saturation) samples. Furthermore, water incurred more severe effects on the flexural properties of the composites, since their flexural strength and modulus is decreased by 64% and 70%, respectively, as compared to as manufactured samples. [2]

Mohammad A. Alhassan et al (2019) The influence of discontinuous structural synthetic fibers (DSSF) on the bond-slip behavior between concrete and carbon fiber reinforced polymer (CFRP) composites was investigated using a double-shear pull-off test. The CFRP composites were bonded to the blocks (with and without a CFRP anchoring strip) in three lengths (Lf): 50, 75, and 100 mm. Addition of DSSF at 0.33% and 0.55% by volume resulted in increase in the bond strength of about 6% and 10%, respectively with respect to plain concrete. The toughness approximately increases by 50% and 100% when the CFRP sheet is increased by 50% or 100% through increasing Lf or bf. The use of 25 mm CFRP anchorage strip attached perpendicular at the end of the main CFRP sheet was very effective and enhanced the bond strength by about 20%. [3]

Cheng yuvan et al (2019) investigates the interfacial behaviour between hybrid FRP (carbon/basalt) and concrete blocks by using the single-lap shear testing method. The digital image correlation (2D-DIC) technique is used to measure the full fields of displacements and strain of the specimens. FRP stacking order affects the effective bond length because the contacting layer of FRP sheets affects the development of effective bond length. FRP stacking order has significant effects on the bond-slip relationship. The maximum shear stress reduces if the contacting layer is stuck with a stiffer FRP plate. However, the ultimate slip improves when a stiffer FRP sheet is used. [4]

Muhammad H. Hamidon et al (2019) tested the effects of chemical treatment to the surface of kenaf fibre and the mechanical properties of the composites developed based on treated kenaf fibre. The most widely used chemical treatment is the alkaline treatment using a sodium hydroxide (NaOH) solution, followed by a silane treatment. Chemical treatments have been found to increase the interface adhesion between the fibre and the matrix. At the same time, such treatments lead to a reduction of water absorption by the fibres. Overall, all the treatments show great potential in increasing fibre strength, fibre suitability and fibre-matrix adhesion. [5]

Maria Morissa Lu et al (2019) Non-dry flax fibre and polyester resin that has low sensitivity to moisture were used in the production of composites and the effects on flexural and moisture sorption properties of composites under wet-dry cycling were determined. Results showed that composites made of non-dry fibre have lower moisture sorption and degree of swelling and shrinking compared to composites made of dried fibre. The results suggest that composites made of non-dry fibre could be used for enhancing moisture durability of composites and lessen the time, cost and embodied energy to produce the composites, by omitting the step of drying the fibres. [6]

Aladdin M. Sharkawi et al (2018) made experiments on long yarns made of short flax and jute fibers were selected to reinforce polyester bars. Infusion technique was implemented to produce natural yarns reinforced polyester (NYRP) bars having various fiber volume fraction ratios. Microscopic images showed good fibers distribution and resin-fibers impregnation across the of NYRP bars. NYRP bars had specific tensile strength (i.e. tensile strength/density) higher 70% than that of 350/240 grade mild steel. Flexural capacity of plain lightweight concrete slabs was increased up to 5.5-fold by using treated surface NYRP bars as reinforcement. A roofing system of lightweight concrete slabs reinforced with the proposed NYRP bars is one of the examples for providing sustainable solutions for low-cost buildings especially in rural areas where such fibers are cultivated. [7]

I. Papa et al (2018) experiments Basalt, flax and hybrid laminates, obtained by alternatively stacking flax and basalt twill layers, manufactured by vacuum resin infusion and impacted at low velocity to investigate their dynamic behaviour in an attempt to couple the impact resistance of basalt fibres with the environmentally friendly nature of flax fibres. The results of the experimental tests evidenced the advantages of the fibre hybridization. As a matter of fact, hybrid basalt/flax composite showed better impact performances than those of pure basalt and pure flax laminates, being characterized by the maximum impact stress value due to the external layer of basalt fibers, the highest energy absorption correlated to a lower de-lamination respect to the one measured on the basalt laminate and the highest penetration energy. [8]

D. Sivakumar et al (2018) studied the effects of kenaf fabric layers, fibre orientations and chemical treatment on the tensile responses of thermoplastic fibre metal laminates were investigated. The tensile test was performed at a quasi-static rate of loading with reference to ASTM E8. Experimental results revealed that the number of kenaf fabric has a major contribution to the tensile strength and modulus of the laminates. The shear in FMLs with ±45 fibre orientation results in higher stress concentration which reduces the tensile performance. Sodium hydroxide solution improves the fibre aspect ratio and the fibre-matrix interfacial area which allows efficient stress transfer. [9]

Wenjie Wang et al (2017) investigates the impact resistance of a new construction material, being coconut fibre reinforced concrete (CFRC) beams strengthened with flax fiber reinforced polymer (FFRP) laminates. FFRP was very effective in enhancing the flexure strength. The flexural strengths of FFRP-CFRC beams with 2-layer, 4- layer and 6-layer were respectively almost 1.7, 3 and 4 times higher than that of CFRC. The toughness of FFRP-CFRC beams increased approximate linearly with the increment of FFRP thickness. At the fracture stage, the specimen absorbed much more energy than at the other stages Deflection development of FFRP-CFRC specimens depended to a great degree on the damage stages as well as the loading rates. The failure pattern was influenced by the thickness of FFRP. [10]

Luciano Machado Gomes Vieira et al (2017) investigates the novel sisal fibre reinforced aluminium laminates (SiRALs) that have been prepared by cold pressing techniques and tested under tensile, flexural and impact loading. The mean specific tensile strength and modulus of the SIRALs reached increases of 132% and 267%, respectively, when compared to the sisal fibre reinforced composites (SFRCs). Moreover, the mean specific flexural strength and modulus of the SiRALs were significantly higher than SFRCs, revealing increases of 430% and 973%, respectively. A delamination fracture mode was noted for SiRALs under bending testing. The SiRALs can be considered promising and sustainable composite materials for structural and multifunctional applications. [11]

Liang Huang et al (2016) studied the effects of number of FFRP layer, steel reinforcement ratio and pre cracking on the flexural response of RC beams were evaluated. FFRP strengthening increases the ultimate load carrying capacity ranging from 15.5% to 112.2%. Beam with more FFRP layer have higher ultimate load. The increase in deflection is more propounded for beams with lower steel reinforcement ratio. Tensile strength and modulus of FFRP composites are significantly lower than those of CFRP, GFRP and steel. In comparison with control beams, both ductility and energy absorption capacity increases significantly due to FFRP sheets. [12]

Romi Sukmavan et al (2016) treats the Steam Exploded Bamboo (SEB) fibers with alkali solution to remove lignin and hemicelluloses and also to increase the compatibility with biodegradable matrix resin. The fibers were processed by simple hand-lay-up method and hot pressed using dispersion-type biodegradable poly lactic acid (PLA) resin to produce a PLA/bamboo fiber cross-ply (0/90)s laminate composites, whose fiber content varied from 17 up to 68 wt.%. The intermolecular interaction among bamboo fiber and PLA matrix was discussed based on Fourier transform infrared (FTIR) analysis. The results showed that the tensile strength of alkali treated bamboo fiber was comparable with those of common strong natural fibers such as hemp and flax fibers. It was also found that the cross-ply (0/90)s SEB/PLA laminate has the same cracking character as the common cross-ply laminates based on carbon or glass fibers. [13]

Claudio Scarponi et al (2016) addresses the damage resistance and post-impact damage tolerance of hemp fabric reinforced bio-based epoxy composites subjected to low-velocity impact at energies ranging from the barely visible impact damage (BVID) threshold up to perforation. The results demonstrate that hemp fabric reinforced bioepoxy composites offer similar if not superior flexural properties, due to an improved fibre/matrix interface, and damage tolerance compared to those based on traditional epoxy resin. [14]

V. Fiore et al (2016) evaluates the influence of external layers of basalt-mat on the durability behaviour of flax reinforced epoxy composites. The fracture surfaces of both laminates were evaluated by using an optical 3D microscope. The resistance of flax reinforced composites can be improved by using basalt layers as outer laminate, indicating that hybridization with basalt fibres could be a practical approach for enhancing mechanical properties and durability of natural fibre composites. The experimental results showed that the hybridization with basalt fibres can be considered as a practical approach for enhancing the durability of natural fibre composites under salt-fog environment conditions. [15]

Igor Maria De Rosa et al (2012) hemp fibre reinforced laminates have been subjected to cyclic flexural tests following falling weight impact at 12, 16 and 20. Laminates with a sufficiently strong fibre–matrix interface have been obtained, as revealed from the impact hysteresis cycles and electron microscopy damage characterization. in the order of 20% in terms of modulus and in the order of 35% in terms of strength at the maximum impact energy applied, which corresponded approximately to 50% of the penetration energy This is confirmed by acoustic emission data and post-impact flexural damage modes, which show that crack propagation quite abruptly involves more complex patterns passing from 30 to 40% of the penetration energy. [16]

S. Rassmann et al (2011) compares the mechanical and water absorption properties of kenaf (Hibiscus cannabinus L.) fibre reinforced laminates made of three different resin systems. The laminates were tested for strength and modulus under tensile and flexural loading. Different resins namely polyester, vinyl ester and epoxy, has been made. Addition of kenaf fibres to these resin systems results in lower tensile strengths but higher tensile moduli than those of the unreinforced resin laminates. Polyester laminates have the highest impact energy and strength, followed by the vinyl ester and then the epoxy laminates. However, specific impact energy and strength of kenaf laminates are an order of magnitude lower than their glass equivalents for all fibre volume fractions. All kenaf laminates absorb substantially more water than those made with glass fibres. [17]

CONCLUSION

From the various literature studies, it concluded that the sisal, hemp, flax and kenaf fibre have the enough strength characteristics for retrofitting of reinforced concrete structures. They also enhance the durability of concrete structures. From the studies, the natural fibres absorb moisture which will make it unworkable and reduces the compressive strength considerably. Hence necessary treatments of natural fibres are needed before using it for making the plate laminates. Using natural fibre is environmental friendly and easily available one instead of artificial fibres.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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