A Review on Durability Methods for Natural Fibers in Polymer Matrices from Sustainability Aspects

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Abstract

The researchers around the globe are working hard to develop new material which would improve the quality of product environmentally, as this world needs eco-friendly materials. This article gives a critical review of the treatment methods/techniques that can improve durability for natural fibers in polymers. The natural fibers are very low cost as compared to other fibers and having specific high properties. These natural fibers are not abrasive and can biodegradable. The natural fiber polymer proffers certain properties which are similar to traditional fiber polymers. However, while preparation of these polymers, the critical issue is frequently the reduction of the strength of natural fibers in polymer matrices which is caused by unsuited fibers and less resistive against. The durability can be achieved by increasing strength, better workability, good mixing and by enhancing the bond strength of fibers with the surrounding. These require very low energy which is consumed during the production and hold mechanical properties of superior quality. By using such materials with properly treated natural fibers in construction works, it is quite possible to produce more sustainable material by minimum construction waste.

Keywords: *Durability Methods, fiber reinforced composites, natural fiber reinforced polymers.*

I. INTRODUCTION

The use of fibrous material in the construction industry is growing day by day. In the construction industry, fiber reinforced concrete and fiber reinforced polymers are the most common composites composed of fibers. Many researchers investigated the effect of fibers on the properties of the composite [1-3]. The dynamic and mechanical properties of the composite improved by the addition of the fiber [4, 5]. The addition of fibers has enhanced the resistance against the cracking of the composite [6, 7]. In comparison with construction materials like concrete and steel, fiber reinforced polymers (FRP) have several benefits. In the construction industry, the use of FRP is limited in building and construction [8–10]. Natural fiber reinforced polymer (NFRP) is a composite of natural fiber reinforcement and with a polymer matrix [11]. In general, FRP is used in the automotive, aerospace and marine industry. FRP materials are lightweight high strength materials compared to other composites. The FRP composites with reinforcement of fibers have comprehensive use in the civil engineering construction industry in complementary applications, such as bathrooms and vanities, kitchen, ornamentation and finishing, for many years. The ballistic performance of bulletproof vests and helmets was enhanced by the distribution of natural fibers in the composites [12]. In the last year of the 20th century, the second-largest consumer of FRP materials industry in this world was the construction industry by consuming 35% of the around the globe [13]. From the beginning of the 21st century until now, there have been a lot of efforts and research work done to shift fiber reinforced polymers (FRPs) into the construction sector to be used as basic material for load-bearing members of civil structures and condemnatory applications. The use of FRP composites is being increased in the construction works as time passes and has significant importance for larger use in civil works and buildings, as well as it also includes large primary structures [14]. Now construction industry is the most consuming industry of polymers and their composites. These days, the increment has been seen in the preparation of load-bearing structural implementations in construction works. As a substitution of steel in concrete, FRP has been initiated as a feasible, aggressive choice for retrofit and convalescence of medieval civil structures [15]. In a research study, it was observed that jute fiber reinforced polymer composite is better than the polypropylene fiber reinforced polymer composite for external strengthening of concrete [16]. Nowadays, the use of NFRP is going to be traditional material like concrete and masonry due to the incremental use of these composites in civil and structural engineering sectors [17].

FRP composites are composed of fibers and a polymer matrix in which fiber act as reinforcement. There are two types of fibers either artificial fibers, such as aramid, glass and carbon fibers, or natural fibers, such as plant and animal fibers. Artificial FRP composites are more likely used in the aerospace and automobile industry in high-performance applications because of the fact of their better mechanical qualities and lightweight. Anyhow, these fibers are expensive, then the natural fibers, need large energy in production. Synthetic or artificial fibers are not eco-friendly. If not recycled properly, hence, their immense usage can lead to environmental pollution [18]. Due to ensure competitive cost, energy consumption while production, reduce dependency on nonrenewable resources

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and non-eco-friendly, hence, have changed the focus to use natural fibers as reinforcement instead of synthetic fibers [19–21]. In both the academic and construction industry, NFRPs are gaining increased attention. Due to their preferable properties and ease of availability, natural fibers like jute, sisal, flax and hemp are commonly used as reinforcement in FRPs [22]. A FRP composite part made of natural fibers will be light in weight than others produced with synthetic fibers such as glass fibers. This is because of the variance between the densities. The density of natural fibers is lies between 1.2 to 1.6 g/cm3 and synthetic such as glass fibers lie between 2.16 to 2.68 g/cm3 [23, 24]. On the other way around, NFRP composites have a lot of disadvantages, such as high moisture content, poor fire aversion, poor linking adhesion, low aversion to microbiological attack and a need to use at low refining temperatures [22]. The flexural strength, as well as thermal and physical properties of the composite, are highly dependent upon the interfacial adhesion conditions [25]. The use of different lengths of natural fibers has shown different effects on flexural strength physical properties of NFRP [26]. However, many of these issues can be tackled with suitable surface treatment methods. The use of NFRP composites can be different according to interest from section to section, for example, the NFRP is used for structural applications like railing, decking and fencing in the United States region, while in the Europe region NFRPs are primarily used in the automotive industry [27].

In this study, different methods were elaborated for the durability of natural fiber in polymers. The use of NFRP in the construction sector has been scrutinized by many researchers, who have investigated the properties and characteristics of different types of NFRPs, for example, modification of fiber, fiber biodegradability, crystallinity and thermal stability. However, the majority of work has based on plastic materials reinforced with natural fibers. And few studies have been conducted considering polymers reinforced by natural fibers and their functionality in the building and construction industry. Furthermore, the main focus of the review has been on moisture content, fiber matrix and adhesion property to the surrounding of fiber with polymers. The purpose and focus of this article are to examine the durability for the engineering purposes of polymers reinforced with natural fiber as filler material and their functionality in the construction industry. It has been claimed that even after some treatment of durability for natural fiber, NFRPs properties are superior to those without some treatment of fibers for durability, and thus, more sustainable material can be obtained with the help one these durability methods. In this study, different methods were elaborated for the durability of natural fiber in polymers. The use of NFRP in the construction sector has been scrutinized by many researchers, who have investigated the properties and characteristics of different types of NFRPs, for example, modification of fiber, fiber biodegradability, crystallinity and thermal stability. However, the majority of work has based on plastic materials reinforced with natural fibers. And few studies have been conducted considering polymers reinforced by natural fibers and their functionality in the building and construction industry. Furthermore, the main focus of the review has been on moisture content, fiber matrix and adhesion property to the surrounding of fiber with polymers. The purpose and focus of this article are to examine the durability for the engineering purposes of polymers reinforced with natural fiber as filler material and their functionality in the construction industry. It has been claimed that even after some treatment of durability for natural fiber, NFRPs properties are superior to those of without some treatment of fibers for durability, and thus, more sustainable material can be obtained with the help one these durability methods.

II. FACTS ABOUT REDUCED DURABILITY OF FIBERS IN FRP

During the serviceable life, FRP materials aspect a diversity of climate circumstances developing from artificial or/and natural factors. These factors consist of fluctuating temperature and humidity, vital ultraviolet rays caused by the sun or any other human activities, and chemical reactions such as chemical liquids in storing tanks and pipes connected with it, and atmospheric ozone and oxygen. The durability reduction factors like the fiber's degradation, cracking of matrix, and de-bonding were presented from applicable records to control for the climate effects on behavior on composites of FRP [28]. FRP materials react to environmental factors which cause a reduction in durability. These factors cause the change in the structure of material chemical and physical and its formation. Effects of these kinds of changes are permanent decay of the mechanical properties and characteristics of a commodity. Aesthetic looks/conditions, like color and shine, go through permanent change. The material may also develop into brittle and cracks can occur. In practice, degradation is defined as any change that affects the material properties related to advisable properties. As shown in Figure 1, this can also be caused by the FRP helix rupture at failure [29].

Mostly, the degradation caused by the environment is a slow process

Figure 1. FRP spiral broke at failure.

that can last up to many years before effects are probable [30]. Degradation caused by environmental can result from environmental effects like temperature, humidity, climate type, overburden resulting in debonding, impacts and rusting of the actual reinforced steel [31]. The alkaline polymer's environment can also result in the degradation of fiber. The most of study work has been done on the fiber, nonetheless, the resin has turn into the study focus. This is the major review in FRP composite is the durability in the field and service life. The concrete structures are which are exposed to the environment, there still need to understand the long-term durability of FRP [32]. In research work, it was concluded that meaningful reflection has been managed to the durability of fiber reinforced polymers commodity in infrastructure functions [33]. The researchers spotted a long-term data deficiency related to the service life of more than 75 years of civil structures [34]. A study conducted by the Civil Engineering Research Fund to bridge cracks in long-term durability data associated with construction industry functionalities spotted the points that are needed like effects of moisture, alkaline solution, creep, fatigue and deterioration [35]. Degradation of natural fibers, i.e., bamboo fibers, accelerates in an alkaline environment than the glass fibers [36]. The effect of

ultraviolet rays (UV) also affects the durability of fibers in FRP. Table 1 shows the comparison between the strengths of unseasoned and seasoned fibers and FRPs affected by the UV rays.

Table 1. UV's effects on natural fibers and FRP [37]**.**

Composite	Unseasoned		Seasoned	
	Tensile Strength (MPa)	Young's Modulus (GPa)	Tensile Strength (MPa)	Young's Modulus (GPa)
Jute	45.55	3.89	25.45	2.77
Epoxy	20.62	1.98	19.18	1.02
EFB	22.61	2.23	21.20	2.17

III. DURABILITY METHODS IN FRP

A. Proper Good Mixing of Fibers in Polymers

1. Specifications

Arbitrarily blended palmyra reinforced composites were set up with various fiber lengths and distinctive fiber content (49%–54%). At 30 mm and 40 mm fiber length, the impact, flexural and tensile properties were achieved with 54% fiber content. At 50 mm fiber length, every one of the static mechanical properties was higher with 55% fiber content. Further expanding the fiber substance will diminish the mechanical properties [38]. After the manufacturing, the FRP was placed in resin for 24 hours. A research study was performed on test beams of size 152 mm 254 mm 2743 mm reinforced by NFRP fabrics and plates to assess durability exposing 10,000 h in severe environmental conditions [20]. Glass transformation temperatures were the same for the two resins. Across the whole 152 mm width of beam NFRP plate and two fabrics were applied to meet the strength of 1.2 mm thick NFRP plate. No information regarding epoxy thickness was provided.

2. Technology involved and method implementation

The exposures to the environment considered were fully humidity, salty water, alkaline solution, frost and thaw, expansion due to thermal energy and dry due to heat at 60 °C. ASTM testing standards were adopted for the salty water, alkaline solution and frost and defrost vulnerability. For thermal expansion and frost and defrost testing, two specimens were tested after 1000 h, 3000 h, 10,000 h excepting. To determine fatigue the effect caused by imitated loads, reinforced beams were applied constant magnitude but imitated load repetitions at 3.25 Hz with the load limiting from 15, 25 and 40 percent of ultimate load of reinforced beams.

B. Increase of Bond Strength

1. Specifications

The mechanical properties of hybrid fiber reinforced polymer's properties were investigated with various fiber treatment, ratio and loading. The FRPs were also manufactured with different chemically treated fibers. The bond strength of fibers dispersed longitudinally was higher than transversely dispersed fibers [39]. Bond strength also depends upon the chemical used for the treatment of fibers and the surface texture of the fibers. It was observed that the tensile strength and hardness properties were improved when the chemically treated fibers were used for the manufacturing of the hybrid reinforced composite [40].

2. Technology involved and method implementation

The FRP can be prepared by using different types of methodologies with different weights and directions of dispersion of the fibers. Different researchers used different types of methodologies to improve the bond strength. In a research study, for the manufacturing of the FRP composite, hydraulic press technology was used to improve the bond strength [41]. The hand layup and cold press technique was adopted for the manufacturing of the hybrid fiber reinforced composite [42]. Another research used hot press technology along with the epoxy resin for FRP's manufacturing [43].

IV. LESSONS LEARNT FOR ENHANCING DURABILITY TO ENSURE SUSTAINABILITY

The use of FRP is being increasing day by day in the construction industry. As the 35% total manufactured FRP material is being used in the construction industry only. The construction sector is the second largest industry that uses FRP as a building material. The FRP is a more sustainable and lightweight material than concrete. The bond of fibers with the surrounding matrix of polymer composite directly affects the sustainability of the material. The sustainability of FRP also depends upon the methodology adopted for the mixing and resins type. There is no standardized design code available for FRP. Different researchers used different types of methodology for the manufacturing of the FRP. The different technology of pressing and different types of resins were used. Mechanical properties, brittleness of fiber, characteristics of fiber can be damaged by the execution of loading, variation of temperature and exposure to climate situations. The durability of FRPs is considerable interest durability of FRPs for its extensive functionality, if any, soon exceed the rule of conventional building materials. The durability depends upon the matrix and the fibers used for making them more durable than the fibers themselves. However, the strength is more influenced by making the fiber strong in tension. Collective effect causing by joined action of humidity and temperature is known to be harmful and damaging.

V. CONCLUSIONS

In civil engineering, the use of FRPs allows engineers to gain outstanding achievements in the applicability, economy and safety of construction. The strength to density ratio of FRP is high ratio as these are lightweight and high performance, may be altered to possess specific mechanical properties, have better corrosion resistance behavior, convenient magnetic, electrical and thermal characteristics to be considered as a blessing to the construction industry and its applications. The pursuing conclusions were realized/noticed from recent and past studies on durability of fiber reinforced polymer composites:

- Natural fibers degradation accelerates in an alkaline environment like seawater structures, so the fiber should properly be treated using resins to enhance the durability of natural fibers in the polymers.
- By improving the bond strength between the fiber and polymer, the durability for fibers in polymers enhances. Hence, a more sustainable composite material can be produced.
- To improve the durability of natural fibers in polymers, it is concluded that durability can be improved by increasing the strength of the composite.
- The change in external appearance and look polymer composite material occurred by UV radiation effects.
- While aging of moisture absorption, swelling of the fiber, rusting of fiber, water flow between matrix and fiber surfaces and babble are created in composites.
- Due to ultraviolet radiations, the moisture-absorbing capacity is more of natural fiber as compared to synthetic fibers, FRP material's durability and mechanical characteristics may be lightly enhanced by providing an outside boundary layer as synthetic fibers on exposure of the NFRP composite materials.

- Capillary action of the flow of water is low on synthetic fiber made FRP, hence, provision of the layer of synthetic fiber enhances NFRP materials.
- Proper good mixing of the composite can enhance the durability of the FRP.

It can be observed that FRP is a blessing/gift to the civil and construction works, finding some very alluring functions along with the issues of involvement for their broad acceptance and functionality. These issues, somehow, can be overcome and control by enhancing the durability of natural fibers in the polymer.

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