

## Mechanical Properties Of Glass Fibers Reinforced Composites: A Concise Review

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**Abstract:** The utility of composites in today's modern world is not hidden from anyone. From tiny objects like football to aerospace, everything involves the use of composites. Composites nearly form the backbone of our society. Composites are basically made from matrices and reinforcement. Out of the majority of reinforcement being used, Glass fibers usage cannot be neglected. These are made of fine fibers of glass (made of  $\text{SiO}_2$ ). They are used to reinforce various materials like arrows, bows and crossbows, translucent roofing panels, tent poles, boat hulls and paper honeycomb. This review paper is a study of various research papers related to mechanical properties of glass fibers when used with different type of matrices namely, tensile strength, impact strength and flexural strength.

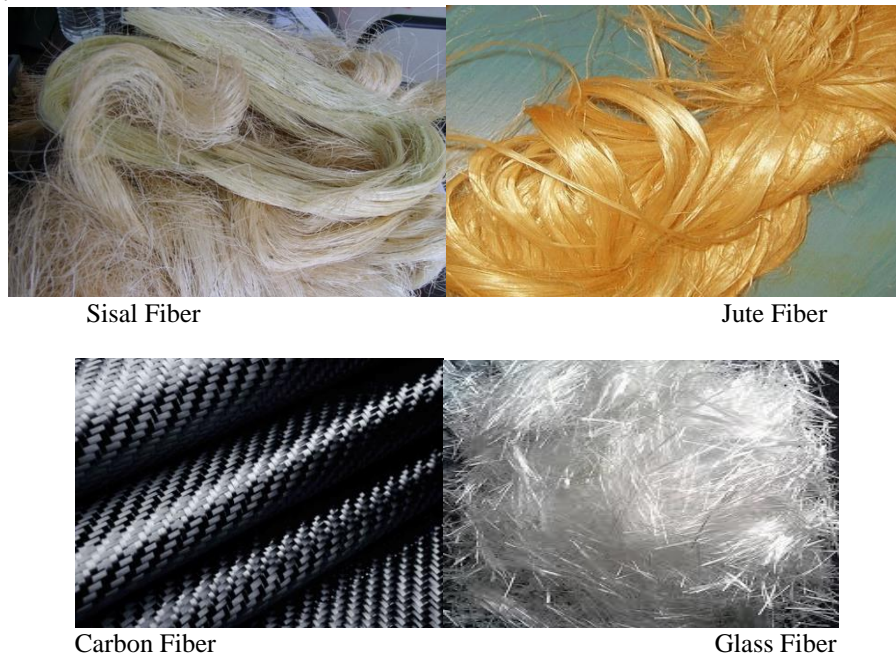
**Keywords:** Composites; Glass fiber; Reinforcement; Mechanical properties; strength.

### 1. INTRODUCTION:

Composites also called Fiber reinforced plastic are simply combination of various components in particular composition. These components have different properties on individual level but end up building a much stronger material. They do not lose their individual identity totally; they combine and contribute their most useful trait to improve the outcome or final product. The two materials work together to give the composite unique properties.

Composite consist of matrix and reinforcement. Matrix is basically a medium in which the reinforcement is embedded. The matrix is of three types: ceramic, polymeric and metallic. Reinforcement used in building the composite can be either fibrous or non fibrous in nature. Fibers are either derived from sources like plant or any other living species [1] or they can be made artificially. Artificial fibers offer many advantages over natural ones. They show more durability than natural fibers also they show properties like stain resistance, waterproofing and also water resistance. Natural fibers in addition, show high moisture absorption because of the presence of groups like hydroxy or any other polar group which further deteriorates the mechanical properties of the composite. Such effects of environment have been reported on the natural fibers like sisal, wood flour etc. [2-8]

#### Types of fibers:



**Fig:1 Types of Fibers**

Glass fiber is a type of reinforcement used in polymer composites which are made of extremely fine fibers of glass. The glass fibers can be used in many ways. They can either be woven into simple fabric, flattened or even randomly arranged, all of which further alters the mechanical properties of the composite synthesized. One of the reason that glass fibers are in extreme use in present scenario is its ability to get molded into various complex shapes. Also they offer many advantages like strength, light weightness and less brittle. Whereas the plastic resins are strong in compressive loading and relatively weak in tensile strength the glass fibers are very strong in tension but tend not to resist compression. By combining the two materials, GRP becomes a material that resists both compressive and tensile forces well. [9]The two materials may be used uniformly or the glass may be specifically placed in those portions of the structure that will experience tensile loads. [10,11]

The mechanical properties of Fiberglass vary considerably when different types of matrix materials are used with glass fibers. This paper reviews the mechanical properties of composites made from glass fiber when different matrix are used with it.

**2. Glass Fiber: An Introduction**

Depending on the raw materials used and their proportions to make fiberglass, glass fiber can be classified into 5 major types:

A glass: A glass is made with Soda lime silicate. It is resistant to chemicals and is used predominantly in making containers and window panes.

C Glass: C glass is corrosion resistant glass which is made from Portland cement. Thus it is also called chemical glass.

D Glass: This glass is used in electrical applications. It is made with borosilicates.

E Glass: E glass is by far the most commonly used glass and is also least expensive. It is very good conductor of electricity. It is known for its good strength and electrical resistivity.

R Glass: It is reinforcement glass and is used where acid corrosion resistance and higher strength is needed.

S Glass: Also called as structural Glass and is used where high strength, high stiffness, temperature resistance and corrosion resistance is needed. Table 1 shows the mechanical properties of different types of glass fibers

**TABLE 1. SHOWS THE MECHANICAL PROPERTIES OF DIFFERENT TYPES OF GLASS FIBER**

Type of glass fiber	Tensile Strength	Modulus	Density
A Glass	3300	72	2.44
C Glass	3300	69	2.56
D Glass	2500	55	2.11
E Glass	3400	72	2.54
R Glass	4400	86	2.52
S Glass	4600	89	2.53

### **Fiberglass:**

The composites which are made by using glass fiber as the reinforcing material are called Glass Fiber Reinforced Polymer (GFRPs) or simply Fiberglass. The earliest patent in production of glass fiber was awarded to the Prussian inventor Hermann Hammesfahr (1845-1914) in U.S. in 1880 [12, 13].

Glass fibers offer many advantages over other fibers although strength properties are somewhat lower than carbon fiber. They are highly cost effective, corrosion resistant, show good structural strength are also have ability to be molded to precise tolerances. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. [14] Glass fibers work well with epoxy, polyester, and other thermosetting plastics. Common uses of fiberglass include in boats, automobiles, oil and gas, metal processing, mining and minerals etc. [15] Fiberglass composites are an extremely versatile family of materials that are highly customizable and offer several advantages over traditional materials.

### **3. Glass fiber reinforced polymer (GFRP):**

Jiang Zhu et al. [16], processed vinyl ester composite reinforced with glass fiber in which carbon nanotube was used for enhancement of interlaminar shear strength. Carbon nanotube was coated onto fiberglass fabric using coating system and then it was processed into vinyl ester laminates. The short beam shear test (SBS) was conducted on a three point bending rig over a span of 40 mm (1.75 in.) in accordance with standard ASTM D2344-84 [17]. It was observed that the all specimens with nanotubes exhibited increased shear strength by about 45% compared to the control composite specimen also prepared without any treatment. This new technique called VARTM was introduced due to which the shear strength increases considerably.

Shang-Han Wu et al [18] prepared nanocomposites using polyamide 6 and polyamide 6/clay with glass fibers as reinforcing material. Samples were examined for impact strength (measured by TMI Testing Machine), heat distortion temperature (measured by heat distortion temperature testing machine), flexural strength( measured by Testometric Micro 500) and three point bending test (performed in an Instron test machine; model 4468). It was observed that Tensile and flexural strength and modulus of the both composite systems increased with fiber content, while impacting strength of the composites decreased with fiber content. It was seen that that the tensile strength of polyamide- 6/clay containing 30 wt.% glass fiber was 11% higher than polyamide-6 containing 30 wt.% glass fiber. As with flexural modulus, it was seen that the flexural strength and flexural modulus of neat polyamide-6/clay was nearly close to polyamide-6 containing 20 wt.% glass fiber.

J.L. Thomason et.al [19] studied the effect of fiber length and concentration on polypropylene composites which were made by reinforcing glass fibers. The samples were tested for the tensile, flexural and stiffness tests. It was seen that the tensile, flexural strength increased with increase in fiber concentration. The modulus increased linearly with fiber content upto 40% above which increase is not linear. Modulus is also affected by glass fiber length, it becomes independent of fiber length above 0.5 mm.

D.M. Laura et.al. [20] studied the effect of glass fiber surface chemistry on the mechanical properties of glass fiber reinforced nylon-6. Glass fiber was treated with different type of interfacial coupling agents. The glass fiber which was treated with anhydride silane as the coupling agent show the highest value of impact strength and yield strength as compared to amine silane which gave lowest. The epoxy silane gave values intermediate of two. This was due to maximum adhesion of fiber with matrix in case of anhydride silane. On the other hand, increase in thermal properties and modulus was seen in case of octyl silanes.

### **4. Glass fiber reinforced polymer (GFRPs) compared to other fiber reinforced polymers:**

Christopher Wonderly et.al. [21] studied the mechanical properties of carbon fiber and glass fiber reinforced vinyl ester composites and thus compared them. The glass fiber being used was Owens Corning 111A glass fibers. Samples were studied for Tensile strength and compressive strength. Results of tensile strength test clearly showed that the carbon fiber specimens were more strong as compared to glass fiber specimen. [22] Talking about the compression test results, the damage is more localized in carbon specimens and the standard deviation for glass fiber is less.

S Mishra et.al. [23] studied the effect of glass fiber addition on the mechanical properties (Tensile, Flexural and Compressive) of Pineapple leaf fibers and sisal fibers reinforced polyester composites. Also they studied the effect of glass fiber addition on the water absorption capacities of these composites. It was observed that the tensile and

flexural strength of the pineapple-polyester as well as sisal-polyester specimens was increased on addition of glass fiber. A net increase of tensile strength by about 66% was observed on addition of 8.6% glass fiber to PALF-polyester specimen. Between PALF and Sisal, later showed improved mechanical properties on addition of glass fiber. The impact strength was also found to considerably increase on addition of glass fiber but after 12.9% onwards, it showed no considerable effect.

Kasama Jarukumjorn [24] studied the mechanical properties of glass fiber reinforced natural fiber composite. They reported the various works of scientist related to glass fiber enhancement of mechanical properties. They reported that that tensile strength and elastic modulus of bamboo fiber reinforced polypropylene (BFRP) and bamboo-glass fiber reinforced polypropylene hybrid composite (BGRP) fairly decreased after aging at 25°C for 6 months while they reduced significantly after aging at 75°C for 3 months. [25] They studied the mechanical properties of sisal fiber, polypropylene composite by the addition of glass fiber. Malic Anhydride was used as a compatibilizer for polypropylene. The mechanical properties of Hemp-Polypropylene composites was also increased by addition of glass fibers. [26] Samples were then tested for their mechanical properties. The total fiber content was fixed to 30% in order to study its effect on mechanical properties on specimens. By increasing the glass fiber contents, insignificant increase in tensile and flexural properties of the hybrid composites was observed.

M.Ramesh et.al. [27] blended natural fibers with glass fibers. They incorporated sisal and jute with glass fibers using polyester as a matrix. The effect of strain rate on fracture and ductility of the material can be analyzed by using the impact test. The mechanical properties namely tensile, and flexural indeed increased on the addition of glass fibers but the tensile properties showed dramatic increase in case of jute-GFRP whereas impact strength and flexural strength were more for Sisal-GFRP.

R.S.Rana et.al. [28] worked upon blending of natural fiber composites along with the glass fiber. They used sisal fiber incorporated into epoxy composite which were reinforced by glass fiber. It was seen that upto 4% concentration of sisal and glass fibre, the tensile strength increases. But on further increase of sisal fiber, tensile strength decreases, which is due to decrease in bonding between reinforcement and matrix material due to decrease in concentration of matrix. Same behavior is seen in case of flexural and impact strength as well

Moe MoeThwe et.al. [29] prepared composites consisting of Bamboo fibers and bamboo-glass fiber reinforcing the polypropylene matrix and studied for their degradation due to environmental factors. It was observed that the tensile strength degradation and moisture absorption capacity was improved by the addition of Malic Anhydride as a coupling agent. When both BGRP (Bamboo-glass fiber reinforced polymer) and BFRP (Bamboo fiber reinforced polymer) were exposed to water, due to aging both of them showed reduced tensile and modulus strength. It was also seen that the polymer which were reinforced by glass fibers (BGRP) showed better resistance to environmental aging.

The effect of addition of glass fiber to composite made of polyester and ramie fiber was studied by Daiane Romanzini [30]. Samples prepared by Resin Transfer Molding were characterized for FTIR, TGA analysis. Density measurements were done. Mechanical testing like Impact and flexural were also performed. Overall fiber loading was kept constant at 21% only the composition of glass and ramie fiber was varied. FTIR was used to locate the position of various functional groups; spectra of which revealing hydroxyl, C=O and C-H groups. The flexural strength of 45% composition of ramie fiber was found to be more than other compositions and that of neat polyester. Upon addition of glass fiber, strength further increased. Same trend was observed for impact strength. This happens due to better stress transfer capacity of glass fiber than ramie fiber.

## 5. SOME OTHER RESEARCH:

M.S. Sreekala et.al. fabricated composites using banana fiber and glass fiber. Addition of glass fiber made the phenol formaldehyde composite more brittle. With increase in fiber loading, tensile, flexural as well as impact strength increased. [31]. S.M. Sapuan et.al. researched on the composites made by kenaf/glass epoxy and found it suitable to be used in passenger car bumper beam[32]. K. Sabeel Ahmad found that properties of jute composites can be increased by the addition of glass fiber. [33]R. Velmurugan et. al. found that the addition of glass fibers decreased the moisture capacity of composites. [34]

**CONCLUSION:** Table wise summary of the various research is summarized in following table

Author	Brief summary of work done	Conclusion
Christopher Wonderlya, Joachim Grenestedta, Go'ran Fernlundb, Elvis Cepus	A comparison between the mechanical properties of carbon fiber and glass fibre reinforced vinyl ester composite was studied	<ul style="list-style-type: none"> <li>• Tensile strength results: The glass fiber specimens typically produced XGM failures i.e. explosive failure in the gage area. Carbon fiber composite showed more tensile strength than glass fiber composite.</li> <li>• Compression strength results: The glass fiber showed higher values than the carbon fiber composite.</li> <li>• Open Hole tensile Strength: The OHT strength is lower than the tensile strength for carbon specimen.</li> </ul>
Jiang Zhu, Ashraf Imam, Roger Crane, Karen Lozano, Valery N. Khabashesku, Enrique V. Barrera	They prepared vinyl ester composite reinforced with glass fiber which were enhanced by carbon nanotube addition and interlaminar shear strength was studied.	<ul style="list-style-type: none"> <li>• The interlaminar shear strength was significantly improved by the addition of nanotubes and other properties like flexural strength can also be achieved.</li> </ul>
S. Mishra, A.K. Mohanty, L.T. Drzal, M. Misra, S. Parija, S.K. Nayak, S.S. Tripathy	Sisal and Pineapple fiber composites were prepared in the polyester resin which were further reinforced by glass fibers. Their mechanical properties and water absorption capacity was studied.	<ul style="list-style-type: none"> <li>• The addition of glass fiber resulted in increase of tensile, impact as well as flexural strength of the composites.</li> </ul>
Kasama Jarukumjorn, Nitinat Suppakarn	Synthesized sisal-polypropylene composites which were further reinforced by glass fiber addition.	<ul style="list-style-type: none"> <li>• Mechanical properties like tensile strength and flexural strength were significantly increased.</li> </ul>
Shang-Han Wu, Feng-Yih Wang, Chen-Chi. M. Ma Wen-Chi Chang, Chun-Ting Kuo, Hsu-Chiang Kuan, Wei-Jen Chen	Studied the mechanical properties of polyamide-6/polyamide-6/clay nanocomposites which were reinforced by carbon fiber and glass fibers	<ul style="list-style-type: none"> <li>• It was observed that the polyamide-6/clay nanocomposites were far better than the polyamide-6 nanocomposites, mechanical properties (tensile and flexural) of both which increased on increase of fiber content. Notched izod impact strength decreased on addition of fiber.</li> </ul>
M. Ramesh, K. Palanikumar, K. Hemachandra Reddy	Prepared composites which consisted of glass fiber reinforced sisal, jute fibers separately as well as a blend of all 3 fibers and studied their mechanical properties.	<ul style="list-style-type: none"> <li>• The mechanical properties namely tensile, and flexural indeed increased on the addition of glass fibers but the tensile properties showed dramatic increase in case of jute-GFRP whereas impact strength and flexural strength were more for Sisal-GFRP.</li> </ul>
J. L. Thomason* and M. A. Vluga	Studied the effect of glass fiber length on polypropylene composites also the stiffness of	<ul style="list-style-type: none"> <li>• The laminate stiffness was found to increase also the modulus increased upto the fiber length of 0.5mm.</li> </ul>

	composite material	
R. S. Rana, Ashish kumre, Saraswati Rana, and Rajesh Purohit	Prepared and studied for the epoxy composites reinforced by glass and sisal fiber.	<ul style="list-style-type: none"> <li>The tensile, impact and flexural behavior followed the same trend i.e. they increased upto fiber concentration of 4% and further decreased.</li> </ul>
D.M. Laura, H.Keskulla, J.W. Barlow, D.R. Pau	Used nylon-6 as matrix and reinforced it with glass fiber. Also glass fiber used was treated with coupling agents so as to improve their performance.	<ul style="list-style-type: none"> <li>Treatment of fiber with octyl silane gave maximum value of tensile strength whereas treatment with anhydride silane showed high value of impact strength.</li> </ul>
Moe MoeThwe, Kin Liao	Polypropylene matrix was used and bamboo fiber and bamboo-glass fiber were used as reinforcement. Environmental effects were studied on these composites.	<ul style="list-style-type: none"> <li>It was observed that composites reinforced by glass fiber showed higher resistance to environmental aging.</li> </ul>
Seena Joseph, M.S. Sreekala, Z. Oommen, P. Koshy, sabu Thomas	Used Glass and banana fiber as well to prepare phenol formaldehyde composite.	<ul style="list-style-type: none"> <li>Mechanical properties increased with increase in fiber loading.</li> </ul>
M.M. Davoodi, S.M. Sapuan, D.Ahmad, Aidy Ali, A. Khalina, Mehdi Jonoobi	Prepared epoxy composites using kenaf/glass fibers as reinforcement.	<ul style="list-style-type: none"> <li>Found it suitable for use in car bumpers.</li> </ul>

#### 6. ADVANTAGES AND DISADVANTAGES OF USING GLASS FIBER:

It was seen that using glass fiber provides many advantages like reduction in moisture absorption capacity as compared to bamboo fibers as seen in work done by Moe Moe et.al (30), S. Mishra et al (21) and Kasama Jarukumjorn et.al. (22). Samples which require more tensile strength, impact strength and flexural strength can use glass fiber as a better reinforcing material as compared to the traditional natural fibers like sisal, jute etc. Composites which are reinforced by glass fibers, show more resistance to environmental aging thus it can be effectively used where long term use is needed. Also they can be used in areas which require moisture tolerance like frequent submerging in water like cooling towers. Since cooling towers are always wet, they have to be protected from rust, corrosion, and other safety issues. Due to the excellent properties of fiberglass, it is used in these towers as screening to keep people and animals away from the danger zones.

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