

## Glass Fibre as a Reinforcing Material for Composites

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Received: 30.05.2019 | Revised: 27.06.2019 | Accepted: 8.07.2019

### ABSTRACT

*This review paper shows the study about the FRP system and Glass fibre reinforcement material. Glass fibre is a most commonly used for a composites and reinforcement purpose. Because of its tremendous properties, which are allows to use in multiple applications. This reinforced material use to make roof of house, house door, automobile industry, in aerospace, aircraft, industrial pipe, shipping, marine, medical instrument, and electrical insulating component, design PCB. The other material, which are very expensive to make such type of reinforced material and not give, tensile, chemical and physical properties like glass fibre composite. Ultimately the glass fibre reinforced material save the cost of product and give better properties and quality than other material. The glass fibre reinforced material recycled and after recycling it use as new glass fibre reinforce material. The new recycled reinforced material gives same properties like previous reinforced material. The new technology developed to make bio based glass fibre reinforced composite by using natural oil and using ring-opening technology.*

**Keywords:** FRP, Glass Fibre, Automobile industry

### INTRODUCTION

Composites are a combination of two material yielding properties superior to those of the individual ingredients. One material is in the form of a particulate or fibre, called the reinforcement or discrete phase. The other is a formable solid, called the matrix or continuous phase. The region where the reinforcement and the matrix meet called the interface.

Fibre glass reinforced plastic, commonly known as fibreglass. The term “fibreglass” describes a thermoset plastic resin that is reinforced with glass fibres. A plastic

resin comes in two different classes’ thermosets and thermoplastics, it is easy to remember that thermoset maintain their moulded shape at higher temperature and cannot be melted and reshaped. Thermoplastics will melt at a given temperature and can be solidified into new shape by cooling to ambient temperature.

The plastic resin system determines chemical, electrical, and thermal properties. Fibre provides strength, dimensional stability, and heat resistance.

**Cite this article:** Chaudhary, P., & Saraswat, H. (2020). Glass Fibre as a Reinforcing Material for Composites, *Ind. J. Pure App. Biosci.* 8(2), 114-126. doi: <http://dx.doi.org/10.18782/2582-2845.7536>

Additive provide colour and determine surface finish, and affect many other properties such as weathering and flame retardance. Processing of FRP composites involves complex chemical action. Final properties are

determined by many factors including the type, amount and composition of the resin systems and reinforcements. In addition, the use of an additive can greatly affect the FRP composite properties.

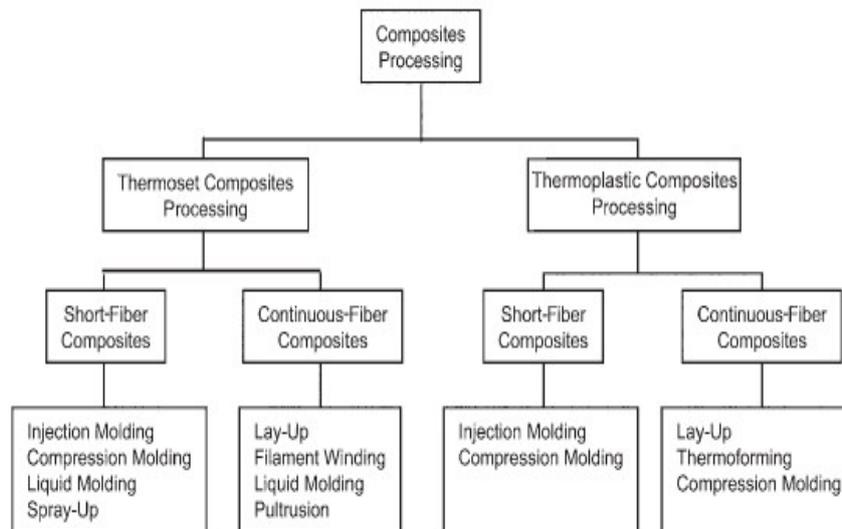


Fig 1.1 Classification of fibre reinforcement processing

## 2. Benefits and features of FRP composites (MFG)

**2.1 Corrosion resistance-** FRP composites do not rust, corrode or rot and they resist attack from industrial and household chemicals. This quality has been responsible for applications in corrosive environments such as those found in the chemical processing and water treatment industries. Resistance to corrosion provides long life and low maintenance in marine applications from sailboats and minesweepers to seawalls and offshore oil platforms.

**2.2 High strength, light weight-** FRP composite provides high strength to weight ratios exceeding those of aluminium or steel. High strength, light weight FRP composite are a rational choice whenever weight saving is desired, such as components for the transportation industry.

**2.3 Dimension stability-** FRP composites have very high dimension stability under varying physical, environmental and thermal stress. This is one of the most useful properties of FRP composites.

**2.4 Parts consolidation and tooling minimizations-** A single FRP composite

molding often replaces an assembly of several metal parts and associated fasteners, reducing assembly and handling time, simplifying inventory and reducing manufacturing cost. A single FRP composite tool can replace several progressive tools required in metal stamping.

**2.5 High dielectric strength and low moisture absorption-** the excellent electric insulating properties and low moisture absorption of FRP composite quality them for use in primary support application such as circuit breaker housing and where moisture absorption is low required.

**2.6 Minimum finishing required-** FRP composites can be pigmented as part of the mixing operation or coated as part of the molding process, often eliminating the need for painting. This is particularly cost effective for large components such as tub/shower units. Also, on critical appearance components, a class 'A' surface is achieved.

**2.7 Low moderate tooling cost-** Regardless of the molding method selected, tooling for FRP composites usually represent a small part of the large-volume mass production or limited runs, tooling cost is normally substantially

lower than that of the multiple forming tools required to produce a similar finish part in metal.

**2.8 Design flexibility-** No other major material system offers the design flexibility of FRP composited. Present applications vary widely. They range from commercial finishing boat hulls and decks to truck fenders, from parabolic TV antennas to transit seating and from outdoor lamp housing to see hoppers.

### 3. Glass fibre

Glass fibres are among the most versatile industrial materials known today. They are available in virtually unlimited supply (Loewenstein, 1993). All glass derived from compositions containing silica. They exhibit useful bulk properties such as hardness, transparency, resistance to chemical attack, stability and inertness, as well as desirable fibre properties such as strength, flexibility and stiffness (Wallenberge 1999). Glass fibres are used in the manufacture of structural composites, printed circuit boards and a wide range of special purpose product (Wallenberger, 1994). Fibre forming process, glass melts are made by fusing (co-melting) silica with mineral, which contain the oxides needed to form a given composition. The molten mass is rapidly cooled to prevent crystallization and formed into glass fibres by a process also known as fiberization.

Nearly all continuous glass fibres are made by a direct drawn process and formed by extruding molten glass through a platinum alloy bushing that may contain up to several thousand individual orifices, each being 0.793 to 3.175 mm (0.0312 to 0.125 in.) in diameter (Loewenstein, 1993). While still highly

viscous, the resulting fibres are rapidly drawn to a fine diameter and solidify. Typical fibre diameters range from 3 to 20  $\mu\text{m}$  (118 to 787 in.). Individual filaments are combined into multifilament strands, which are pulled by mechanical winder at velocities of up to 61 m/s (200 ft/s) and wound onto tubes or forming packages.

The marble melt process can be used to form special purpose, for example, high strength fibres. In this process, the raw materials are melted, and solid glass marbles, usually 2 to 3 cm (0.8 to 1.2 in.) in diameter, are formed from melt. The marbles are remelted (at the same or at a different location) and formed into glass fibres. Glass fibres can also be down drawn from the surface of solid performers. This is the only process used for manufacturing optical fibres and structural fibres, such as silica or quartz glass fibres.

#### 3.1 Sizes and Binders

Glass fibre are highly abrasive to each other<sup>6</sup> “Size” coating or binder are therefore applied before the strand is gathered to minimize degradation of filament strength that would otherwise be caused by filament to filament abrasion. Binders provide lubrication, protection, and/or coupling. The size may be temporary, as in the form of a starch-oil emulsion that is subsequently removed by heating and replaced with a glass-to-resin coupling agent known as a finish. On the other hand, the size may be a compatible treatment that performs several necessary functions during the subsequently forming operation and which, during impregnation, acts as a coupling agent to the resin being reinforced.

**Table 3.1: first column gives compositions and column second gives physical mechanical properties of commercial glass fibre**

Letter designation	Property or characteristics
E , electrical S , strength C , chemical M , modulus A , alkali D , dielectric	Low electrical conductivity High strength High chemical durability High stiffness High alkali or soda lime glass Low dielectric constant

### 3.2 Glass melting and fibre forming (ASM International, 2001)

A glass is an amorphous solid is obtained by cooling a melt (i.e. liquid phaitse) sufficiently fast that crystallization can occur at the liquidus temperature, TL, where crystal and melt are in equilibrium, or below. Glass fibers are therefore obtained at high cooling rates. Chemically, a glass consists of a silica network. Other oxides facilitate melting,

homogenizing, removal of gaseous inclusions, and fibre formation at optimum temperatures. This section addresses the generic glass-melting and fibre forming process, including the viscosity versus temperature profile that is required for general-purpose E-glass glass fibres and, more specifically, for E-glass fibres containing 5% to 6% boron oxide (Loewenstein,1993).

**Table 3.2: Chemical composition of various glass fibres (Scott, (2009))**

Chemical Component	E-glass (%) Electrical	A - glass (%) High –Alkali	C-glass/ECR-glass(%) Chemical	S2-glass (%) High –Strength
SiO <sub>2</sub>	54.3	72.0	64.6	64.2
Al <sub>2</sub> O <sub>3</sub>	15.3	0.6	4.1	24.8
B <sub>2</sub> O <sub>3</sub>	8.0	-	13.2	Trace
CaO	17.2	10.0	3.3	Trace
MgO	4.7	2.5	7.7	0.3
Na <sub>2</sub> O	0.6	14.2	1.7	-
K <sub>2</sub> O	-	-	-	0.2
Fe <sub>2</sub> O <sub>3</sub>	-	-	-	-
ZnO	-	-	-	-
TiO <sub>2</sub>	-	-	-	-

Depending on the fibre diameter, optimum fibre formation is achieved with melts having a viscosity ranging from 2.5 to log 3 P. The generic melting and forming process that is required for boron free E-glass is the same as that required for boron-containing E-glass, but the viscosity or temperature profile differs. The relative forming temperature can be deduced from the Flusher curves shown in fig

1. They will be proportionately higher for boron free E-glass at equal melt viscosities between log 2.5 to log 3.0 P.

This section does not address the glass melting and fibre forming processes required for the special purpose glass fibres, that is, ECR-glass, S-glass, ultrapure silica fibres, and D-glass (MFG).

**Table 3.22: Glass composition by weight (Hex Force®)**

Composition	E-glass	S-2 glass
Silicon Dioxide	52-56%	64-66%
Calcium Oxide	16-25%	
Aluminium oxide	12-16%	24-26%
Boron Oxide	8-13%	
Sodium &Potassium Oxide	0-1%	
Magnesium Oxide	0-6%	9-11%

### 3.3. Batch mixing and melting (ASM International, 2001)

The glass melting process begins with the weighing and blending of selected raw materials. In modern fibre glass plants, this process is highly automated, with

computerized weighing units and enclosed material transports systems. The individual components are weighted and delivered to a blending station where the batch ingredients are thoroughly mixed before being transported to the furnace.

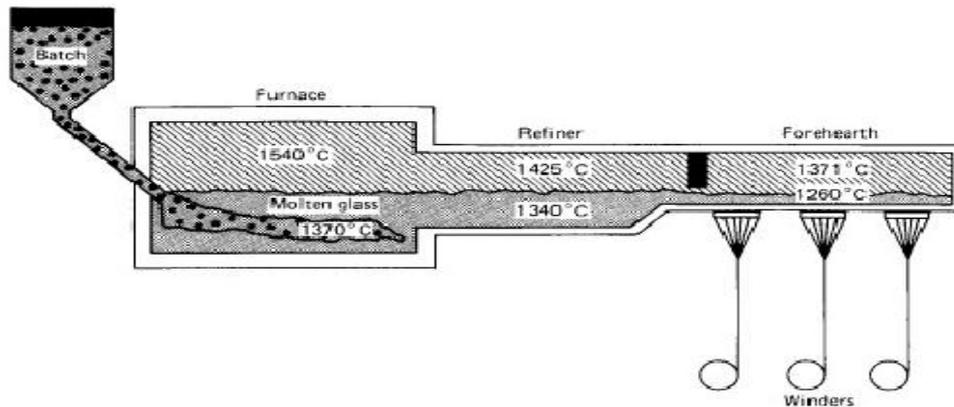


Fig. 3.3: Furnace for glass melting (ASM International, 2001)

Fibre glass furnaces generally are divided into three distinct sections (fig). Batch is delivered into the furnace section for melting, removal of gaseous inclusion, and homogenization. Then, the molten glass flow into the refiner section, where the temperature of glass is lowered from 1370<sup>0</sup> C (2500<sup>0</sup> F) to about 1260<sup>0</sup> C (2300<sup>0</sup> F). The molten glass next goes to the fore hearth section located directly above the fibre forming stations. The temperatures throughout this process are prescribed by the viscosity characteristics of the particular glass. In addition, the physical layout of the furnace can vary widely, depending on the constraints of the plants.

**3.4. Fiberizing and sizing (ASM International, 2001)**

The conversion of molten glass in the fore hearth into continuous glass fibres is basically an attenuation process (fig 3.4). The molten glass flows through a platinum-rhodium alloy bushing with a large number of holes or tips (400 to 8000, in typical production) the bushing is heated electrically to maintain a constant glass viscosity. The fibres are drawn down and cooled rapidly as they exit the bushing.

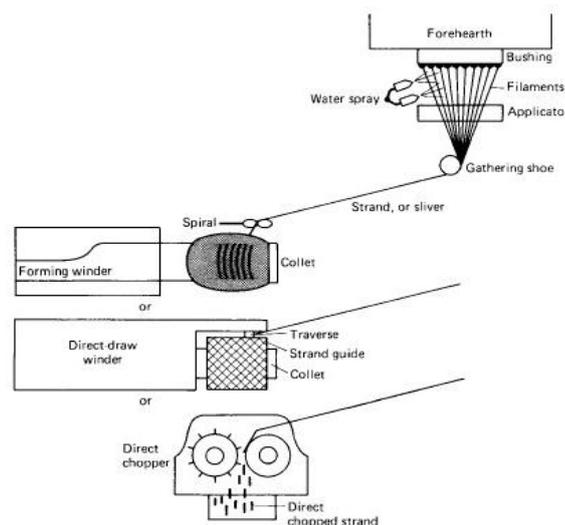


Fig 3.4: Fibre glass forming process (ASM International, 2001)

A sizing then applied to the surface of the fibres by passing them over an applicator that continually rotates through the sizing bath maintain a thin film through which the glass

filament pass. It is this step, in addition to the original glass composition, which primarily differentiates one fiber glass product from other.

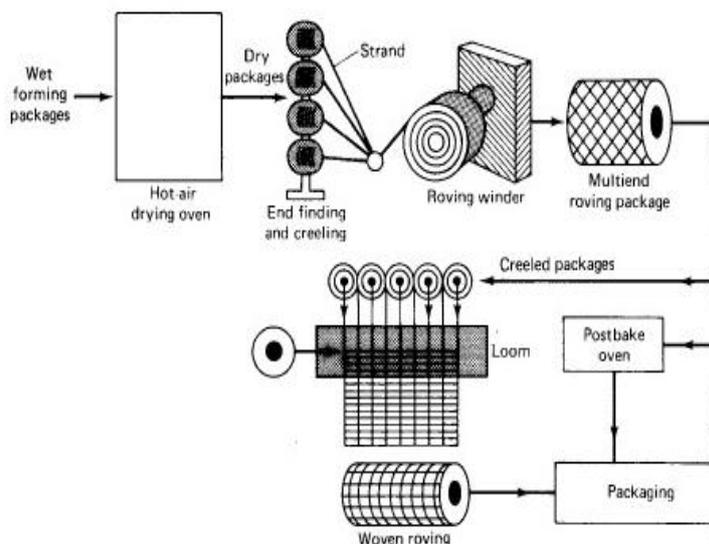


Fig 3.42:– Multi end roving process production (ASM International, 2001)

The components of the sizing impart strand integrity, lubricity, resin compatibility, and adhesion properties to the final product, thus tailoring the fiber properties to the specific end-use requirement. After applying the sizing, the filaments are gathered into a strand before approaching the take-up device. If small bundles of filament (split strands) are needed, multiple gathering devices (often called shoes) are used.

#### 4. Fiber Diameter (ASM International, 2001)

The attenuation rate, and therefore the final filament diameter, is controlled by the take-up device. Fiber diameter is also affected by bushing temperature, glass viscosity, and the pressure head over the bushing. The most widely used take-up device is the forming winder, which employs a rotating collets and a traverse mechanism to distribute the strand in a random manner as the forming package grows in diameter. This facilitates strand removal from the package in subsequent processing steps, such as roving or chopping. The forming packages are dried and transferred to the specific fabrication area for conversion into the finished fiberglass roving, mat, chopped strand, or other product.

#### 5. Glass Fiber Type

Glass fiber falls into two types of category, low- cost general-purpose fibers and premium

special- purpose fibers. Over 90% of all glass fiber general-purpose products. These fibers are known by designation E-glass and, are subjected to ASTM specification. The remaining glass fibers are premium special-purpose products. Many, like E-glass, have letter designation implying special properties. Some have trade names, but not all are subjected to ASTM specification.

Special-purpose glass fibers, S-glass, D-glass, A-glass, ECR-glass, ultrapure silica fibers, hollow fibers, and trilocal fibers are come in the special purpose glass category.

#### 6. Ultra high performance glass product (Hex Force®)

The HT fabrics are fashioned after the standard, high volume E-glass aerospace 7781 and 120 styles. Complimenting these styles in fabric areal weight and weave patterns, 6781HT and 6220HT have similar characteristics in fabric hand, flexibility, weight, and thickness, but with the added benefit of superior impact resistance, tensile strength, and bond integrity using S-2 glass® fiber.

The dry fabric tensile strength for HT fabric is dramatically higher than typical S-2 glass® fabrics made with standard starch oil sizing. Starch oil size fabrics require heat cleaning prior to finishing, significantly reducing fiber tensile strength. The HT fabrics

have a simple yet effective organic sizing compatible with high temperature Epoxy, BMI, Phenolics, Cynate Esters, Thermoplastics, Polyamide, Polyimide, PIE, PEEK, PAI, LCP and other.

### 7. Yarn Nomenclature (Hex Force®)

It is standard practice in the fiber glass industry to refer to specific filament diameter by specific alphabet designation, called yarn nomenclature. This nomenclature consist of two parts- one alphabetical and one numerical. In addition, although the final result is the same, there are difference between the customary U.S. system and the TEX/Metric system.

#### 7.1 TEX/MATRIC System

##### Example: EC9 33 1X2

A- First letter, 'E' characterizes the glass composition

B- Second letter, "C" indicates continuous filament. "T" indicates textured continuous filament. "D" indicates staple filament.

C- First number, denotes the individual filament diameter expressed in micrometers (microns)

D- Second number; represent the nonlinear weight of the bare glass strand expressed in TEX. TEX is the mass in grams per 1,000 meters of yarn.

E- Third number indicates yarn construction or the basic number of strands in the yarn. The first digit represents the original number of

twisted strands and the second digit after the "X" indicates the number of these strands twisted or plied together.

#### 7.2 U.S. System

##### Example: ECG 150-1/2

A – First letter "E" characterizes the glass composition.

B – Second letter "C", indicates the yarn is composed of continuous filaments. "S" indicates staple filaments. "T" indicates texturized continuous filament.

C – Third letter denotes the individual filament diameter: BC, D, DE. E, G, H, K.

D – First number, represent 1/100 the normal bare glass yardage in one pound of the basic yarn strands. In the above example, multiply 150 by 100 which result in 15,000 yards in one pound.

E – Second number; represent the number of basic strands in the yarn. The first digit represents the original number of twisted strands. The second digit separated by the diagonal represents the number of strands plied (or twisted) together. To find the total number of strands used in a yarn, multiply the first digit by the second digit (a zero is always multiplies as 1).

Fiber glass yarns are available in different formulation. "E" glass (electrical) is the most common all-purpose glass, while "S" glass® (high strength) is used for special applications.

**Table 7.2: Typical mechanical and physical properties of the majority glass fiber (E, S2) (Scott, 2009)**

Fiber property	E-glass	S2-glass
Density (gm/cm <sup>3</sup> )	2.55-2.58	2.46-2.49
Tensile modulus (Msi)	10-10.5	12.5-13.0
Tensile strength (Strands) (Ksi)	500	665
Tensile strength (Nominal design) (ksi)	270-390	530-620
Range of elongation	4.5-5.0	]5.4-5.8
Thermal expansion (10 <sup>6</sup> in/in/° F)	3.0	0.9
Fiber diameter range (micron)	4-25	5-9

### 8. Why the glass fibre is the best than other fibres for FRP system? (Hex Force®)

The versatility of glass as a fibre makes it a unique industrial textile material. Fibre glass in fabric form offers an excellent combination of properties from high strength to fire resistance. Wide ranges of yarn sizes and weave patterns provide unlimited design potential, allowing the end user to choose the best combination of material performance, economics and product flexibility.

**8.1 Dimension Stability-** Fibre glass is a dimensionally stable engineering material. Fibre glass does not stretch or shrink after exposure to extremely high or low temperature. The maximum elongation for “E” glass break is 4.8 % with a 100% elastic recovery when stressed closed to its point of rupture.

**Table 8.1: Mechanical properties of fibres (Scott, 2009)**

Fibre	Density	Tensile Strength Psix10 <sub>3</sub> lb/in <sup>3</sup>	Tensile modulus Psi x 10 <sub>6</sub>	Ultimate Elongation	Cost factor
E-glass	.094	500	10.5	4.8%	1.0
S-glass	.090	665	12.6	5.7%	4.0
Armid-Kevlar49	.052	525	18.0	2.9%	16
Spectra900	.035	375	17.0	3.5%	22
Polyester-COMPET	.049	150	1.4	22.0%	1.75
Carbon-PAN	.06-.065	350-700	33-57	.038-2.0%	17-450

**8.2 Moisture resistance-** Glass fibre do not absorb moisture, and do not change physically or chemically when exposed to water.

**8.3 High strength-** The high strength-to-weight ratio of fibre glass makes it a superior material in applications where high strength and minimum weight are required. In textile form, this strength can be unidirectional or bidirectional, allowing flexibility in design and cost

**8.4 Fire Resistance-** Fibre glass is an inorganic material and will not burn or support combustion. It retains approximately 25 % of its initial strength at 1,000<sup>0</sup>F.

**8.5 Chemical Resistance-** Most chemical have little or no effect on glass fibre. The inorganic glass textile fibres will not mildew, rot or deteriorate. Glass fibers are affected by

hydrofluoric hot phosphoric acids and strong alkaline substance.

**8.6 Electrical Properties-** Fibre glass is an excellent material for electrical insulation. The combination of properties such as low moisture absorption, high strength, heat resistance and low dielectric constant makes fibre glass fabrics ideal as reinforcement for printed circuit boards and insulating varnishes.

**8.7 Thermal conductivity-** A low coefficient of thermal expansion combined with high thermal conductivity properties make glass fabrics a dimensionally stable material that rapidly dissipates heat as compare to asbestos and organic fibres.

**9. Industrial Applications for Fibre Glass Fabric (Hex Force®)**

Fibre glass fabrics are used in a wide range of industrial application. High strength, dimensional stability, design flexibility and excellent electrical properties are some of the characteristics that ensure optimum performance and economy with this highly engineered material.

**9.1 Reinforced Plastics-** Fibre glass fabrics used as reinforcement for plastics have replaced traditional material such as wool, steel, and aluminium in a vast array of products. The inherent strength, light weight, dimensional stability and low tooling costs derived from fibre glass reinforced plastics help make many products more durable, attractive and maintenance free.

**9.2 Electrical-** Fibre glass fabrics offer outstanding performance to the electrical industry. High strength, dimension stability, temperature resistance, and excellent electrical properties provide the basis for use as the prime reinforcement in high pressure laminates for printed circuit boards. Fibre glass fabrics coated with chemistry such as epoxy, silicone, rubber, Teflon® and neoprenes, as well as reinforcing mica product, provide the long term durability and reliability needed in insulating high voltage generators, transformers, switches and cables.

**9.3 Coated and Laminated Fabrics-** High strength, dimensional stability, fire resistance and low cost are some of the advantages of using fibre glass fabrics to reinforce foils, plastic film and coating. Protective covers, vapour barrier, window shades, movie screen, packaging tapes, awnings, protective clothing, gaskets, wall covering and conveyor belts are just some of product that are improved through the use of fibre glass fabrics.

**9.5 Thermal Insulation-** strength retention at high temperatures, corrosion and fire resistance, and ease of handling make fibre glass fabrics an important material for thermal insulation. Both the U.S. Navy and commercial shipyard use fibre glass fabrics almost exclusive as pipe lagging and thermal pad covers.

**9.6 Constructions-** From pipe wrap to wallboard seaming tape, fibre glass fabrics can be found throughout the construction industry. Fibre glass scrim is used to reinforce paper and, to provide dimensional stability to asphalt used on roofing, roadways and bridge decks. Fabric structures such as tennis courts, sports centres and football stadiums use coated fibre glass fabrics as an economical way to encapsulate space.

**Table 10: Some Special Benefits' of S2-Glass fibre (AGY)**

Features	Benefits
S-2 Glass fibre offers significantly more strength than conventional glass fibre: 85% more tensile strength in resin-impregnated strands.	Consistent high performance for reliable and durable finished parts.
Better fibre toughness, modulus of resilience and impact deformation than conventional glass fibre.	Improved impact capabilities to finished parts and higher composite durability and damage tolerance.
Softening point: 1056 C Annealing point: 816 C Strain point: 766 C	Greater fibre tensile strength and Stability at elevated temperatures in thermoset and thermoplastic applications.

Enhanced stiffness.	Delivers 25% more linear-elastic stiffness than conventional glass fibre.
Excellent tolerance to damage accumulation.	The ability of composite parts to with-stand high levels of tension and flexural fatigue without catastrophic failure.
S-2 Glass fibres deliver 20% reduction in dielectric constant over E-glass fibbers.	Radar transparency.
Long shelf-life, good machinability and excellent durability.	Consistent performance and reliability.
Quick wet-out (penetration of resin into the strand).	Faster, more efficient processing.
Performs well in certain modified epoxy resin systems where high strength and improved hot/wet tensile strength retention are important.	Improved epoxy performance.
S-2 Glass fibres facilitate co-mingling and hybridization with other reinforcement or thermoplastic fibres, including carbon fibres.	Improvements in impact resistance and damage tolerance, as well as material cost reduction.
The 933 sizing is stable at processing temperatures of 670°F and above.	Facilitates molding with high temperature thermoplastic matrices, yielding exceptional laminate mechanical properties.

### 10. Glass fibre as a reinforced bio renewable polymer: -

The entire composite material made from the petroleum product. New ideas are developing a new bio-based composite. The last decade number of modified vegetable oil and original oil is used to produce bio-based composites (Hongyu Cui et al., 1202, Jeong et al., 2009, Li et al., 2003) by using cationic, thermal, free radical, ring-opening metathesis polymerization methods (Mauldin et al., 2018). Fillers are also be using as bio-based polymer to produce bio-based composite.

The ring opening metathesis polymerization has become popular when the Gurbbs Ruthenium catalyst developed in 1990 (Grubba, & Chang, 1998). The ring-opening metathesis copolymerization of Dilulin with Dicyclopentadiene (DCPD) has been studied by Henna et al., (2008). The resulting

polymers range from flexible to hard as DCPD contain increases. Short fibre mat reinforced Dilulin /DCPD resin composites were also prepared and examined. After reinforced with glass fibre, mechanical properties improved significantly. However, mechanical properties were lower than model predictions. Because, it is found that the interface between glass fibre and polymer matrix was poor.

Good interfacial adhesion allows more effective stress transfer from the matrix to the reinforcement and increase the ultimate strength of the composite. Surface modification with silane coupling agent is commonly used to improve interfacial strength adhesion in glass fiber reinforced polymer composites. The silane coupling (Drown et al., 1991) agents are difunctional organosilicon compounds with the general structure formula R-Si-X<sub>3</sub>, where X is a hydrolysable group, such

as alkoxy, chlorine, or acyloxy (Plueddemann, 1991). Following hydrolysis, reactive silanol groups are formed, which can undergo condensation with hydroxyl group on the glass fibre surface. The R group is a non-hydrolysable group, which is able to react chemically with the polymer matrix. Silane coupling agents improved the interfacial adhesion by forming covalent band with both fibre and the matrix.

### **11. Reusing recycling fibres in high-value fibre-reinforced polymer composites: improving bending strength by surface cleaning:-**

The fibre reinforced polymer (FRP) composites as high-performance material is increase in the aerospace, military, automobile, and sports industries. It is very difficult to separate-out in fibre, filler polymer, resin etc. If we are used long time glass fibre from the landfill without recycled. Which is very dangerous for the whole world? So recycling of the FRP composite is very necessary. Although researchers developed new technologies to recycle FRP (Peter, 1998, Hernanz et al., 2008, Palmer et al., 2009). fibres obtain from these technologies they are short and fluffy, and they are not treated after recycling by those technologies. Orderly the longer fibre are more valuable. For longer fibre producing, the new technology steam system was developed. Initially superheated stem system used, but they were found in little decline in the tensile strength.

The performance of FRP is depend on fibre and resin characteristics good interfacial adhesion between fibre and resin is necessary to ensure effective load transfer from one fibre to another through the resin.

High value recycled reinforced fibre with high performance can be remanufactured into FRP for reuse. For these purpose the surface modification of the fibre is necessary after recycling of the FRP. Resin which is over the surface of the fibre, is removing by the recycled fibre in solution. Treated glass fibre (TR\_GFs) and recycled carbon fibres (TR\_CFs) were remanufactured by vacuum-assisted resin transfer molding (VARTM).

### **12. Tensile behaviour of glass fibre reinforced plastics subjected to different environmental conditions:-**

Polymer matrix composites (PMCs) are increasingly being used in a wide range of applications. GFRP/Polyester resin have received considerable attention as alternatives to steel and aluminium as structural material in the construction, gas and liquid tanks, pipes offshore platforms, marine, aircraft application, automobile ,recreational equipments and aerospace industries due to their high strength-to-weight ratio, component mechanical properties and ease of handling (Agrawal et al., 2010, Myers et al., 2007). The polymer matrix composites used in building construction, automotive application as well as in sports equipment may be exposed to a variety of environmental conditions such as continuous sun light, high moisture content and exposure to water. Similarly liquid storage tank and pipes may be subjected to acidic attack if they are used for sorting harmful chemicals. It is important to note that composites which are used in aerospace and marine applications may be subjected to freezing conditions. These materials have found application in drilling of offshore platforms of gas exploitation and civil infrastructure for the repair of bridges, where as long term exposure in water and humidity environment is present. Among these properties, the physical durability of composition changes is critical to their long term survival (Ang et al., 2007). The cooperative quality and good mechanical properties of glass fibre has led them to wide spread use in fibre reinforced plastic (FRP) composites application, because of low cost and good mechanical properties (Tounisi et al., 2002, Wei et al., 2009). The lack of resistance of composite structure to degradation agents often becomes apparent within certain period of exposure (Agvendra et al., 2004, Ricky et al., 2008).

The effect of sea water the bearing strength behaviour of the woven glass fibre composite has been investigated. It was concluded that he bearing strength decreases

as immersion period increases (Alattin, & Ibrahim, 2008). For long term stability of FRP composites in corrosive environments (CS<sub>2</sub>), it was found that glass fibres are highly resistance to corrosion (Olmos, et al., 2006). The concentrated storage aging has led to strength reduction of the matrix/fibre interfacial bonds, causing decrease in the mechanical properties of the GFRP composites (Gu, & Hongxia, 2007, Salih, 2009). The moisture present in matrix can cause matrix swelling, inner phase debonding, physical damage of the inter phase and hydrolysis of the material; these are the main reason of the deteriorated tensile strength. So it is found that the exposure time of PMCs increases, the tensile strength of PMCs gradually reduces.

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