Report on:

INVESTIGATION OF MATERIAL PROPERTIES OF WOVEN GLASS FIBER REINFORCED EPOXY COMPOSITE

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Submitted to:

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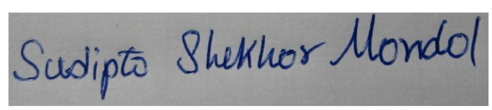
Declaration of Originality and Compliance of Academic Ethics

I hereby declare that this report contains original research work by the undersigned student.

All the information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by these rules and conduct, I have fully cited and referred all material ad results that are not original to this work.



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Certificate of Supervision

We hereby recommend that the thesis presented under our supervision by **Mr. Sudipto Shekhor Mondol** entitled "*Investigation of material properties of woven glass fiber reinforced epoxy composite*" be accepted.

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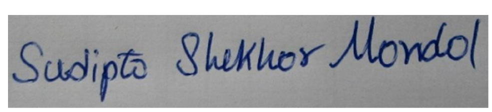

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List of Figures

List of Tables

Nomenclature

$(CH_3)_2CO$	Acetone
WR	Woven Roving
FRP	Fiber-Reinforced Plastics
PVC	Poly Vinylchloride
UTM	Universal Testing Machine
UTS	Ultimate Tensile Strength
TS	Tensile Strength
J	Joule
kN	Kilo Newton
GFRC	Glass Fiber Reinforced Concrete

Abstract

In this experimental study, glass fiber reinforced epoxy composite samples were prepared for tensile and impact strength analysis. Woven roving mats (E-glass fiber orientation $0^0/90^0$, 300g/m^2) were cut in measured dimensions and a mixture of Epoxy Resin (CY-205, Density-1.27gm/cm^3), Hardener (HY 951, Density- 0.94 gm/cm^3) and Acetone [$(CH_3)_2CO$, M= 38.08g/mol] was used to manufacture the glass fiber reinforced epoxy composite by hand lay-up method. The ratio of epoxy: hardener: acetone was varied and the tensile and impact strength of the specimen were compared.

1. Introduction

Fiber-reinforced composites are being increasingly used in manufacturing numerous parts in aerospace and automobile industries. The main leverage that glass fiber reinforced composites gives over other materials is the high strength and modulus might be comparable to or even better than most conventional metallic materials. Owing to their strength- weight ratio, modulus - weight ratios, fatigue strength - weight ratio, fatigue damage tolerance and low specific gravity, these composites are remarkably superior to many metals. In addition, glass fiber composited are easy to manufacture and are cheap.

Fiber-reinforced composites have successfully established itself as a leading class of structural material and are either used or being considered as substitutions for metals in many weight-critical components in aerospace, automotive, and other industries. Glass fiber composites have higher impact strength and excellent surface finish and high modulus to weight ratios compared to other fiber reinforced composite materials, and therefore extensively used in industries. In most of the applications, the properties of polymers are modified by using fibers to suit the high strength/high modulus requirements. The high performance of continuous fiber (e.g. carbon fiber, glass fiber) reinforced polymer matrix composites is well known and documented. Among the thermosetting polymers, epoxy resins are the most widely used for high-performance applications, such as matrices for fiber reinforced composites, coatings, structural adhesives and other engineering applications. Epoxy resins are characterized by excellent mechanical and thermal properties, high chemical and corrosion resistance, low shrinkage on curing and the ability to be processed under a variety of conditions. However, these composites have some disadvantages related to the matrix dominated properties which often limit their wide applications. In the industry, the addition of filler materials to a polymer is a common practice. This improves not only stiffness, toughness, hardness, heat distortion temperature, and mold shrinkage, but also reduces the processing cost significantly. In fact, more than 50% of all produced polymers are in one way or another filled with inorganic fillers to achieve the desired properties. Mechanical properties of fiber- reinforced composites are depending on the properties of the constituent materials (type, quantity, fiber distribution and orientation, void content). Beside those properties, the nature of the interfacial bonds and the mechanisms of load transfer at the interphase also play an important role. Nowadays specific fillers/additives are added to enhance and modify the quality of composites as these are found to play a major role in determining the physical properties and mechanical behaviour of the composites. For many industrial applications of glass fiber reinforced epoxy composite, information about their mechanical behaviour is of great importance. Therefore, in this work, the mechanical behaviour of E-glass fiber reinforced epoxy composites has been studied.

2. Fabrication of Glass Fiber Reinforced Polymer Composites

The following materials are used for the fabrication of GFRP- Epoxy Composites.

1. Epoxy Resin
2. Glass Fibers such as Woven Roving (WR)
3. Hardener
4. Acetone

2.1 Epoxy Resin: Epoxy resins, also known as polyepoxides are a class of reactive prepolymers and polymers which contain epoxide groups. A wide range of epoxy resins are produced industrially. The raw materials for epoxy resin production are today largely petroleum derived. Hardener forms a thermosetting polymer, often with high mechanical properties, temperature and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics / electrical components, high tension electrical insulators, fiber-reinforced plastic materials, and structural adhesives etc.

2.2. Glass fibre (Woven roving mat): The two types of glass fibers commonly used in the fiber-reinforced plastics (FRP) industry are E-Glass and S-Glass. Another type, known as c-glass, is used in chemical applications requiring greater corrosion resistance to acids. S-Glass, originally developed for aircraft components and missile casings, has the highest tensile strength among all fibers in use. However, the compositional difference and higher manufacturing cost make it more expensive than E-glass. A lower cost version of S-Glass, called S2-Glass, is also available. For the cost consideration S2-Glass fibre is used in our present work.

2.2.1 Woven Roving Mat: Woven roving is a coarse fabric in which continuous roving woven in two mutually perpendicular directions as shown in fig.2.2.Woven cloth is weaved using twisted continuous strands, called yarns. Both woven roving and cloth provide bidirectional properties that depend on the style of weaving as well as relative fiber counts in the length (warp) and crosswise (fill) directions. A layer of woven roving is sometimes bonded with a layer of CSM to produce a woven roving mat. All of these forms of glass fibers are suitable for hand lay-up molding and liquid composite molding.

2.3 Hardener: Hardener is high viscous liquid material, mixed with resin in suitable proportion during the process of preparation of composites which helps in the solidification of the wet, smooth composite. It is used to harden the smooth composite hence it is called as hardener. In this project a suitable grade of hardener is used to mix with epoxy resin in 1:2 proportions in the process of manufacturing of composite.

2.4 Acetone: Acetone (systematically named propanone) is the organic compound with the formula $(CH_3)_2CO$. It is a colourless, volatile, flammable liquid, and is the simplest ketone. Acetone is miscible with water and serves as an important solvent in its own right, typically for cleaning purposes in the laboratory. About 6.7 million tonnes were produced worldwide in 2010, mainly for use as a solvent and production of methyl methacrylate and bisphenol A. Acetone is a good solvent for many plastics and some synthetic fibers. It is used for thinning polyester resin, cleaning tools used with it, and dissolving two-part epoxies and superglue before they harden.

3. Literature Review

A survey of the past research already available involving the issues of interest has been presented here. The research works on the hybrid composites and the effect of various parameters on the performance of composites studied by various investigators has been described in detail below:

3.1 Study on Natural Fiber Based Polymer Composites: In the recent years there is a vast growth in natural fiber based polymer composites due to its various attractive features likes biodegradability, no abrasiveness, flexibility, availability, low cost, light weight etc. Different researchers have performed various experiments to enhance the mechanical properties of natural fiber based polymer composites. The effect of length on mechanical behaviour of coir fiber reinforced epoxy composites had been studied and it was observed that the hardness decreases with the increase in fiber length up to 20 mm. A study on pulp fiber reinforced thermoplastic composite shows that while the stiffness is increased by a factor of 5.2, the strength of the composite is increased by a factor of 2.3 relative to the virgin polymer.

3.2 Study on Synthetic Fiber Based Polymer Composites: A great deal of work has been done by many researchers on synthetic fiber based polymer composites. Effect of water absorption on the mechanical properties of glass/polyester composites had been studied. It was concluded that the breaking strength and tensile stress of the composites decreased gradually with increased water immersion time because the weakening of bonding between fiber and matrix. studies on the combined effect of injection temperature and fiber content on the properties of polypropylene-glass fiber composites had been done from which it was observed that the melting flow index of the composites depend upon fiber content, fiber length distributions. The tensile strength and elastic modulus was increased with increasing in fiber contents.

3.3 Study on Hybrid Fiber Based Polymer Composites: The composites obtained by incorporation of two or more fibers within a single matrix are called as hybrid or hybrid composites. Hybrid fiber composites may be the combination of two or more different natural fibers or it may be the combination of natural or synthetic fibers. The conventional material such as glass, carbon and boron fibers are quite expensive and the use of fiber like carbon or boron is justified only in aerospace application. Therefore it is meaningful to explore the possibility of using cheaper materials such as natural fiber as reinforcement. Various aspects of hybrid fiber based polymer composites has studied by various investigators. Studies had been made on the mechanical behaviour of hybrid composites based on jute and oil palm fiber. It was found that the use of hybrid system was effective in increasing the tensile and dynamic mechanical properties of the oil palm-epoxy composite because of enhanced fiber/matrix interface bonding. The mechanical properties of glass/jute hybrid composites were examined. The jute fabrics were modified by treatment with different chemicals. It has been observed that titanate treatment of jute fabric results in enhanced performance characteristics and mechanical properties of hybrid composites. Investigations were made on the elastic properties and notch sensitivity of untreated woven jute and jute-glass fabric reinforced polyester hybrid composites, analytically and experimentally. The jute composites exhibited higher notch sensitivity than jute–glass hybrid composites. A remarkable improvement in the tensile and flexural properties of hybrid composites compared to the un-hybrid composites was reported. It was also found that the hybrid composite offers better water absorption resistance. Experimental investigation of the effect of stacking sequence on mechanical properties of woven jute and glass fabric reinforced polyester hybrid composites were made. The layering sequence has larger effect on the flexural and inter-laminar shear properties than tensile properties. On comparing the overall properties of the laminates it was concluded that the hybrid laminates with two extreme glass plies on both side has the optimum combination with a good balance between the properties and the cost. In order to improve the tensile strength of glass fiber composites, a method is proposed for mixing coal ash particles size ranging from 52 to 75 μm in to epoxy resin. Coal ash reinforced epoxy glass fiber composites are fabricated in different weight proportions of coal ash mixed in epoxy resin and glass fiber composites are usually fabricated by using hand layup.

3.4 Polymer Degradation: There are elements of degradation behaviour that are common to all polymers and elements that are peculiar to a particular polymer. Much research has been conducted on the important commodity polymers PVC, polyethylene, and polypropylene, and these materials are used by way of example in this review.

3.4.1 Chemical mechanisms of degradation: In an aggressive chemical environment polymer molecules- break (chain scission), cross-link, or suffer substitution reactions. Substitution is the least common and causes the smallest property changes. Scission and cross-linking both occur under natural weathering conditions, and molecular degradation can also take place during processing. There is general agreement that molecular degradation occurs almost exclusively at defects in the molecule.

3.4.2 Photo-Oxidation: Of major importance is the process of photo-oxidation is proceeds by a radical chain process initiated either by dissociation caused by the collision of a photon with sufficient energy with a polymer molecule, or as the result of some impurity present, for example trace metals from the polymerization catalyst. Once initiation has occurred, converting the long- chain polymer molecule, PH, into a radical, P, the reactions are as listed by Davis and Sims[1] : Termination is then normally through the reaction of pairs of radicals. The reaction schemes are affected by trace metal impurities such as polymerization catalyst residues or contaminants from processing machinery, for these may catalyse some of the degradation reactions. Degradation can still occur slowly in the dark through the formation of hydroperoxides through intermolecular back-biting hydrogen abstraction by peroxy radicals. Degradation occurs because the radicals are unstable and may undergo scission reactions.

3.4.3 Thermal decomposition and oxidation: Thermal degradation is of relevance here because damage suffered by the polymer during processing at elevated temperature can lead subsequently to further deterioration under the conditions of photo oxidation. Thermal degradation is a serious problem with PVC and has been the subject of much research. The initial step in the process of degradation is dehydrochlorination, with hydrogen and chlorine atoms on adjacent chain carbon atoms stripping off to form HCI and leaving behind a double bond in the polymer backbone, adjacent sites become less stable, more HCI may be stripped off, and a conjugated polyene structure develops. This causes yellowing of the material. HCI catalyses the reaction which is therefore auto- accelerating unless steps are taken to remove the HCI. The process is accelerated in oxygen but can occur in the absence of oxygen at temperatures above 1200 C [IS]. Mechanico-chemical degradation may occur during processing, producing free radicals that may then initiate dehydrochlorination in PVC.

3.4.4 Hydrolysis: Hydrolytic attack can cause chain scission in some polymers, leading inevitably to deterioration in properties. A general hydrolysis scheme can be summarized as follows: Polymers susceptible to this kind of attack include polycarbonate. The reaction can be unacceptably fast at elevated temperature and can be a problem with articles that need to be sterilized; Some polymers absorb water, leading to other problems. Nylons become plasticized and their Young’s modulus can fall by as much as an order of magnitude. When water is absorbed in polycarbonate in sufficient quantity it can form disc-shaped defects that act as stress-concentrating flaws and cause a serious fall in toughness.

3.4.5 Attack by pollutants: Some of the pollutants themselves are photolytic, leading to further products that may cause degradation.

3.4.6 Mechanical degradation: If a chemical bond is placed under sufficient stress it will break. It may not always be easy to apply such a stress because deformation mechanisms intervene. For a polymer chain bond to be broken, the segment in which it is contained must not be able to uncoil (i.e. it roust be extended between entanglements or cross- links already) nor slip. Such constraints may be present in a cross-linked polymer, where the short chain segments become fully extended at fairly low extension in a highly oriented polymer, or possibly at the tip of a growing crack. Molecular fracture has been shown to occur in this way using electron spin resonance to detect the free radicals that are produced when chain scission occurs.

3.4.7 Stress-aided chemical degradation: The phenomenon of mechanicochemical degradation (or sometimes more specifically "mechanicooxidative" degradation) has been known to occur in rubbers for many years. Unlike the case of mechanical degradation dealt with in the previous section in which very high stresses are needed to break a chain bond, a more modest stress may accelerate scission caused by chemical reaction. The most highly stressed bonds will still be the most likely to react 50 that bonds contained within short segments or highly strained bonds near entanglements will be most vulnerable. Highly oriented polymers are generally m-'- resistant to this type of attack than when in more randomly oriented form because the molecules tend to share the load evenly, so that the chance of overstressing is much less. Nevertheless, the rate of oxidation of oriented polypropylene at 130°C was found to increase with load at high loads.

3.5 Effects of Processing: Much of the discussion of thermal degradation is related to the problem of molecular degradation during processing, when the temperature required to produce the desired flow properties for a moulding operation is often high enough to promote significant degradation, especially if oxygen is present. There will often be circumstances during processing operations in which stress-aided chemical degradation will occurs this problem in the formed product, but some degradation of this kind may have already occurred during processing. There is a further aspect of processing that has not yet been dealt with and that is the morphology of the moulded or formed polymer. The rate of cooling is often quite high in molding operations and varies considerably from one position within the moulding to another. As a consequence the morphology of a semi-crystalline polymer varies substantially within an injection moulding, which normally contains equiaxed spherulites in the core and an oriented structure near to the surface. The degradation reactions occur almost exclusively in the amorphous phase because it takes up oxygen much more readily than the crystal phase and that there can be a strong influence exercised by the morphology. It is further suggested that oxidation may occur preferentially at the crystal-amorphous boundary where the effects will be most damaging.

The crystal structure of their polypropylene samples varies with the quenching conditions and that there was a marked variation in property deterioration even though the (γ) radiation-induced oxidation did not differ. The diffusion rates of the various reactants are very different in the crystal and non-crystal regions of most polymers. Another morphological feature is molecular orientation, which can occur in either crystalline or amorphous regions.

3.7 Creep Fracture: The mechanism of polymer-matrix composite is complicated than the other materials, since it can fail under a constant load that is significantly lower than its static strength even at room temperature and its degradation mechanism has not been fully discussed yet. If it is assumed that a fiber was elastic and a matrix was viscoelastic then the matrix stress transfers to the fiber stress with time and makes the fiber strain increase equal to the composite strain. Curtin[3] predicted the rupture strain and the maximum fiber stress of unidirectional composites in view of estimating the probability of fiber breakages in its own cross section. Du and McMeeking[4] , Sofronis and McMeeking[5] and Ohno et al.[6] also predicted the creep rupture time of unidirectional composites under tensile loads. They discussed about the relaxation of the interfacial shear stress that could decrease the unidirectional composite’s strength. Among the above studies, although only the fiber breakages were considered as the fatal damage, the interfacial debondings that were likely to progress even for the normal PMC were not examined. This time-dependent failure would promote fiber breakages and degrade the mechanical properties of composites[4–8]. From this point of view, Beyerlein and co-workers[9,10] investigated the interfacial debonding propagation and verified that the interface failed with time in a single fiber composite under a constant strain.

3.8 Predictions of Fatigue Life: FRP laminates have been subjected to the variable amplitude loading. The linear cumulative damage rule and Palmgren-Miner rule were used for the prediction of fatigue life under the variable amplitude loads. However, the linear cumulative damage rule for the materials is not useful for describing the complicated fracture mechanism[11–13] . Therefore, the cumulative damage was evaluated using residual strength or residual stiffness as the parameter of damage[11, 13, 14] . Recently, Yao and Himmel [15] assumed that the cumulative damage was proportional to the decrease of strength, and they modified the analysis by considering the residual strength caused fatigue damage in FRP.

3.9 Interfacial Shear Strength: The interfacial shear strength was reported to decrease against the water absorption rate[16]. The maximum interfacial shear strength was influenced by matrix Young's modulus. Therefore, the interfacial shear strength decreased as a function of the water absorption rate, and it depended on the mechanical degradation of the matrix.

3.10 Effect of Fiber Orientation on Mechanical Properties: There is no significant effect on hardness of the materials having different orientations of fiber and it is maximum in discontinuous fiber specimen. However, the difference in the orientation had significant effect on the impact strength of the composite material and it was concluded that the impact strength is minimum in orientation 90°and above of that in parallel orientation and still constant in specimen of angle 45°. The tensile test showed that the load increased to the maximum value and then dropped suddenly as a brittle fracture at angle of 0° and 90°, while the shear response quite nonlinear for angle of 45°. It has been observed that the crack propagates in a direction perpendicular to the direction of the external load action glass fibers/epoxy composite specimens of 90° fiber orientation angle, while for 0° fiber orientation angle of glass fibers/ epoxy specimens, failure was irregular and cracks propagate in different directions. Experimentally determined material properties were compared to analytical predictions based on micromechanics.

Also tensile test for every specimen for the three showed that the load in the tensile test for the matrix and for the glass/epoxy composites increases linearly for $\theta = 90°$ and non-linearly for $\theta = 0°$ to its maximum value then drops suddenly at final fracture load. The maximum tensile loads for glass/epoxy composites in case of $\theta = 0°$ are higher than that for $\theta = 90°$. The tensile test for $\theta = 45°$ for composite materials showed nonlinear behavior up to fracture [2] .

The test results also show that different fracture modes were observed like brittle fracture of the matrix and breaking of the fibers gradually depending on the fiber orientation angle. For $\theta = 90°$ the failure occurs by breaking of the matrix and the crack propagates in direction perpendicular to the load direction while for θ = 0° the failure was irregular and the crack propagates in different directions because of the high strength of the fiber in the longitudinal direction. While for θ = 45° the failure starts by shear and splitting of the matrix parallel to the direction of reinforcement.

4. Experimentation

4.1 Requisition of material and setup with specifications:

1. Epoxy Resin: CY-205, Density-1.27gm/cm^3.Glass transition temperature (Tg)- 1080C.

2. Hardener: HY 951, Density- 0.94 gm/cm^3. Mixed in ratio of 10:1:4 (epoxy: hardener: acetone).

3. Glass Fiber: Woven fabric E-glass fiber orientation $0^0/90^0$, 300g/m^2.

4. Acetone: $(CH_3)_2CO$, M= 38.08g/mol.

5. Die: For samples of 100mm x100mm x 12mm

6. Beaker: 3pc, ½ ltr

7. Gloves: Ordinary 12pcs

8. Brush: 4pcs

9. Scissors

10. Steel ruler

11. Hacksaw

4.2 Fabrication: Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Capital and infrastructural requirement is less as compared to other methods. Production rate is less and high volume fraction of reinforcement is difficult to achieve in the processed composites. Hand lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, dais board, deck etc. The fibers are first put in place in the mould. The fibers can be in the form of woven, knitted, stitched or bonded fabrics. Then the resin is impregnated. The impregnation of resin is done by using rollers, brushes or a nip-roller type impregnator. The impregnation helps in forcing the resin inside the fabric. The laminates fabricated by this process are then cured under standard atmospheric conditions. The wet/hand lay-up process is depicted in the figure. The materials that can be used have, in general, no restrictions. One can use combination of resins like epoxy, polyester, vinylester, phenolic and any fiber material.

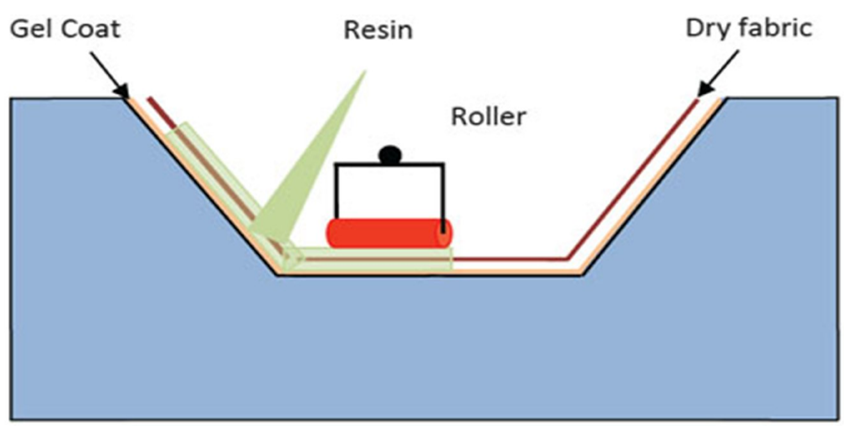

Figure 1: Hand Lay-up Technique

(Dr. Inderdeep Singh, Department of Mechanical Engineering, IIT Roorkee)

Advantages:

- The process results in low cost tooling with the use of room-temperature cure resins.
- The process is simple to use.
- Any combination of fibres and matrix materials are used.
- Higher fibre contents and longer fibres as compared to other processes.

Disadvantages:

- Since the process is worked by hands, there are safety and hazard considerations.
- The resin needs to be less viscous so that it can be easily worked by hands.
- The quality of the final product is highly skill dependent of the labours.
- Uniform distribution of resin inside the fabric is not possible. It leads to voids in the laminates.
- Possibility of diluting the contents.

Applications:

The process is suitable for the fabrication of wind-turbine blades, boats and architectural mouldings.

4.3 Specimen Preparation: After the fabrication of glass fiber samples were prepared as per requirements for performing tests. The glass fiber composited were cut by a hacksaw and then smoothened by filing. The specimen used for tensile test were made square at the ends to facilitate better grip by the UTM jaws and the region around the gage length was kept cylindrical.

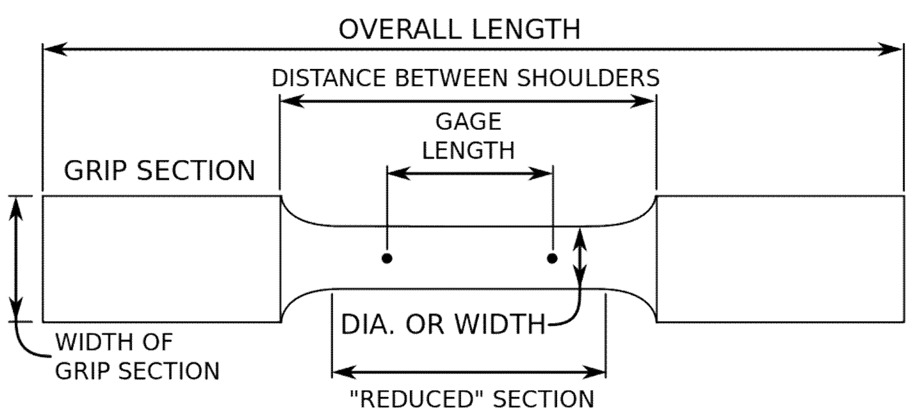

Figure 2: UTM Test Specimen Nomenclature

(Tensile testing by Joseph R. Davis, p. 50.)

According to ASTM A370, the standard specimen size for Charpy impact testing is 10 mm × 10mm × 55mm. Subsize specimen sizes are: 10 mm × 7.5 mm × 55mm, 10 mm × 6.7 mm × 55 mm, 10 mm × 5 mm × 55 mm, 10 mm × 3.3 mm × 55 mm, 10 mm × 2.5 mm × 55 mm.

According to EN 10045-1, standard specimen sizes are 10 mm × 10 mm × 55 mm. Subsize specimens are: 10 mm × 7.5 mm × 55 mm and 10 mm × 5 mm × 55 mm.

According to ISO 148, standard specimen sizes are 10 mm × 10 mm × 55 mm. Subsize specimens are: 10 mm × 7.5 mm × 55 mm, 10 mm × 5 mm × 55 mm and 10 mm × 2.5 mm × 55mm. In the present study, samples of 10 mm × 10mm × 55mm were used for Charpy test.

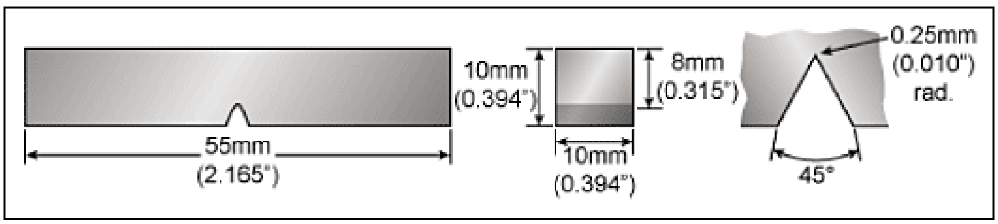

Figure 3: Charpy Test Specimen Nomenclature

The ratio of epoxy: hardener: acetone used is 10:1:4 for specimens 1, 2, 3, 4, 6, 7, 8 and 9. In specimen 5 ratio 10:2:4 was taken.

Sample Number	Weight of epoxy used (in gm)	Number of glass fibre layer	Sample Dimensions	Weight of epoxy (in gm)	Weight of hardener (in gm)	Weight of acetone (in gm)
1	30.6	6	10 x 10	20.2	2.1	8.3
2	29.9	6	10 x 10	19.3	2.4	8.2
3	31.1	12	10 x 10	21	2.1	7.9
4	241.28	22	300 x 200	164.91	17.4	65.58
5	60.56	20	10 x 10	37.96	7.55	15.05
6	212.76	18	320 x 220	160.69	16.06	64
7	121.8	18	300 x 120	81.71	8.12	31.97
8	15.8	54	55 x 10 x 10	15.06	1.33	5.78
9	15.38	54	55 x 10 x 10	13.6	1.58	5.2

Table 1: Resin Composition

4.4 Density: The density, or more precisely, the volumetric mass density, of a substance is its mass per unit volume. The symbol most often used for density is ρ (the lower case Greek letter rho). One sample was considered for evaluating density:

Length = 30cm

Width = 28cm

Thickness = 0.4cm

Weight = 368.7gm

Volume = 336cc

Density = 368.7/336= 1.097gm/cc

5. Mechanical Property Testing

Mechanical properties of composites were evaluated by tensile and impact measurements. Tensile and impact tests were carried out using Universal testing machine and impact machine. Four identical samples were tested for tensile strength and five samples were tested for impact strength.

5.1 Ultimate Tensile Strength: Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the capacity of a material or structure to withstand loads tending to elongate, as opposed to compressive strength, which withstands loads tending to reduce size. In other words, tensile strength resists tension (being pulled apart), whereas compressive strength resists compression (being pushed together). Ultimate tensile strength is measured by the maximum stress that a material can withstand while being stretched or pulled before breaking. Some materials break very sharply, without plastic deformation, in what is called a brittle failure. Others, which are more ductile, including most metals, experience some plastic deformation and possibly necking before fracture. Tensile tests were examined according to ASTM D3039 using a universal testing machine at room temperature. The universal testing machine consists of three main units: control and recording unit, straining unit and hydraulic unit. The UTS is usually found by performing a tensile test and recording the engineering stress versus strain. The highest point of the stress–strain curve is the UTS. It is an intensive property; therefore its value does not depend on the size of the test specimen. However, it is dependent on other factors, such as the preparation of the specimen, the presence or otherwise of surface defects, and the temperature of the test environment and material. Tensile strengths are rarely used in the design of ductile members, but they are important in brittle members. In the International System of Units (SI), the unit is the pascal (Pa) (or a multiple thereof, often mega pascals (MPa), using the SI prefix mega); or, equivalently to pascals, newtons per square metre (N/m^2).

Figure 4: Tensile Test Sample

The set-up and usage of UTM are detailed in a test method, often published by a standards organization. This specifies the sample preparation, fixturing, gauge length (the length which is under study or observation), analysis, etc. The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips. The UTM had a maximum capacity of 400KN. The specimen was loaded between two manually adjustable grips of a 60 KN computerized universal testing machine (UTM). Test was repeated four times for different fiber resin composition and the tensile strength was calculated.

5.2 Impact Strength: In Charpy Impact test differs the test piece is tested as a beam supported at each end. A notch is cut across the middle of one face, and the striker hits the opposite face directly behind the notch. Charpy impact testing involves striking a standard notched specimen with a controlled weight pendulum swung from a set height. The standard Charpy-V notch specimen is 55mm long, 10mm square and has a 2 mm deep notch with a tip radius of 0.25mm machined on one face. The specimen is supported at its two ends on an anvil and struck on the opposite face to the notch by the pendulum. The amount of energy absorbed in fracturing the test-piece is measured and this gives an indication of the notch toughness of the test material. The pendulum swings through during the test, the height of the swing being a measure of the amount of energy absorbed in fracturing the specimen. This test is practical for the assessment of brittle fracture of metals, and is also used as an indicator to determine suitable service temperatures. A brittle metal will absorb a small amount of energy when impact tested, a tough ductile metal absorbs a large amount of energy. The appearance of a fracture surface also gives information about the type of fracture that has occurred; a brittle fracture is bright and crystalline, a ductile fracture is dull and fibrous. The percentage crystallinity is determined by making a judgement of the amount of crystalline or brittle fracture on the surface of the broken specimen, and is a measure of the amount of brittle fracture.

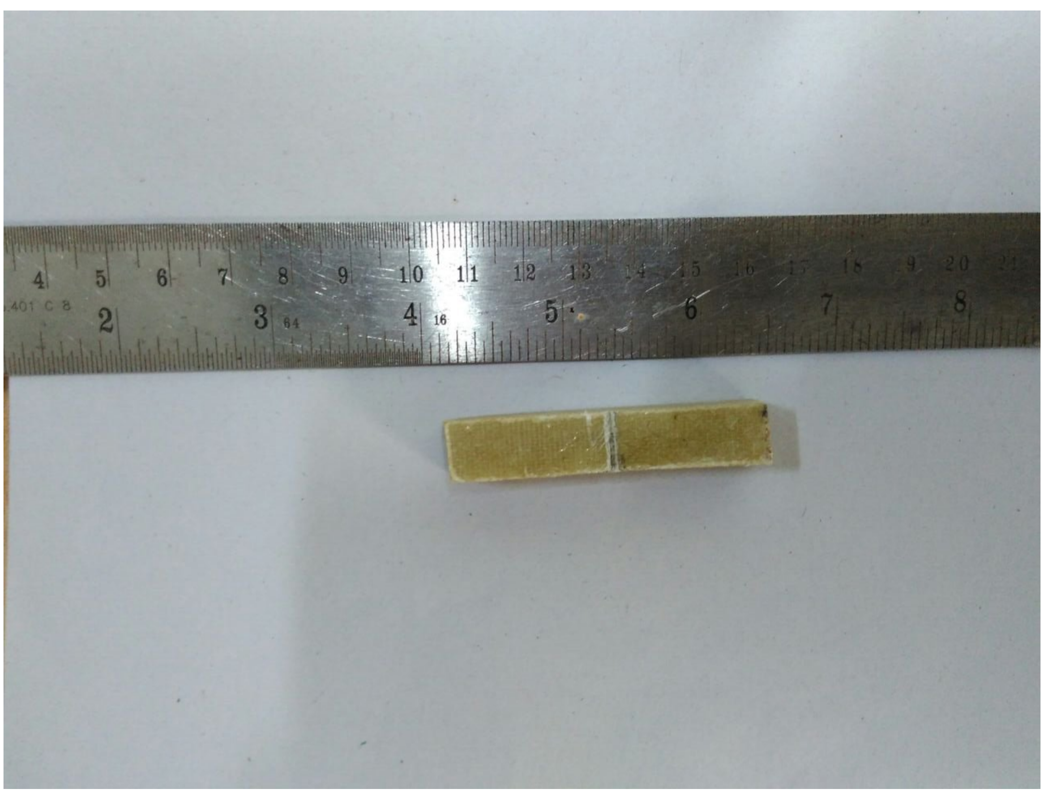

Figure 5: Charpy Test Sample

Lateral expansion is a measure of the ductility of the specimen. When a ductile metal is broken, the test-piece deforms before breaking, and material is squeezed out on the sides of the compression face. The amount by which the specimen deforms in this way is measured and expressed as millimetres of lateral expansion.

When reporting the results of a Charpy test, the absorbed energy (in J) is always reported, while the percentage crystallinity and lateral expansion are optional on the test report. It should be emphasised that Charpy tests are qualitative, the results can only be compared with each other or with a requirement in a specification - they cannot be used to calculate the fracture toughness of a weld or parent metal.

Figure 6: Charpy Test Apparatus

6. Results

6.1 Tensile Strength: The results of tensile strength tested components has been presented and the tensile strength is calculated.

The load vs displacements curves of the samples have been shown in the next page. Reviewing the results it can be established that when fiber content increases the strength of the composite also increases, but at some point it will decline due to lack of bonding element and the 40:60 fiber resin ratio has high tensile strength while compared to other ratios.

Machine : Universal Testing Machine UTE-40

INPUT DATA : Sample Identification :

Sample Type : Round solid C/S Area (mm2) : 58.111 Final Area (mm2) 50.29

Diameter (mm) : 10.13 Original Gauge Length (mm) : 83.0

Final Gauge Length (mm) : 130.0

Results of tension Test

Max. Load kN	14.580
Disp. at Max. Load mm	12.00
Max. Displacement mm	12.50
Ult. Strength kN/mm ²	0.251
Elongation %	56.63
Reduction in Area %	13.467

Graph : Load (kN) Vs Displacement (mm)

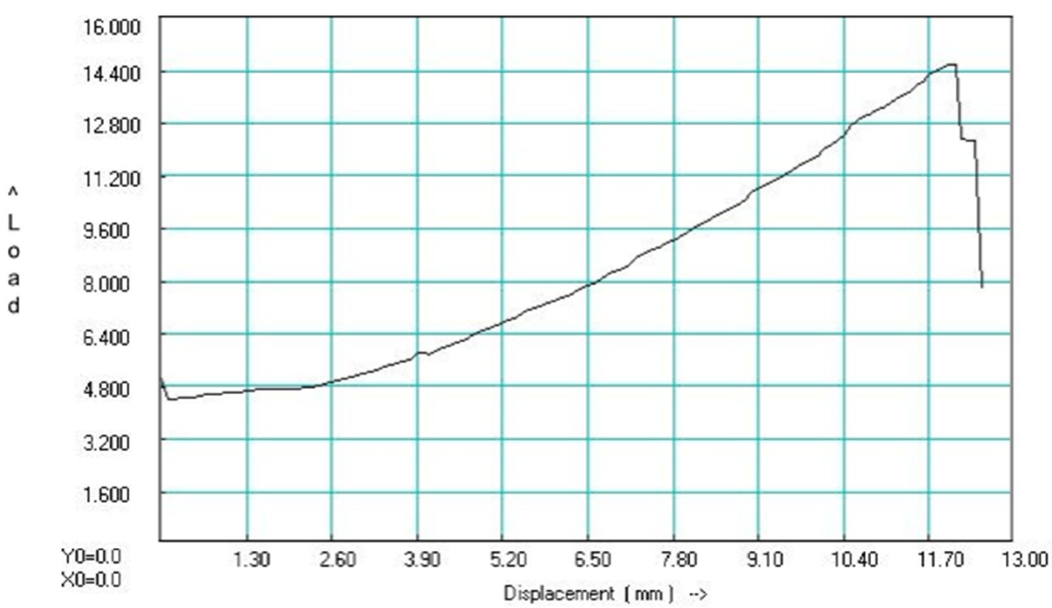

Figure 7.1: Load vs displacement curve for sample 1

Sample Type : Round solid | C/S Area (mm2) : 50.286 | Final Area (mm2) 44.20

Diameter (mm) : 10.13 | Original Gauge Length (mm) : 84.0

Final Gauge Length (mm) : 150.0

Results of tension Test

Max. Load kN	14.040
Disp. at Max. Load mm	12.80
Max. Displacement mm	14.20
Ult. Strength kN/mm ²	0.279
Elongation %	78.57
Reduction in Area %	12.109

Graph : Load (kN) Vs Displacement (mm)

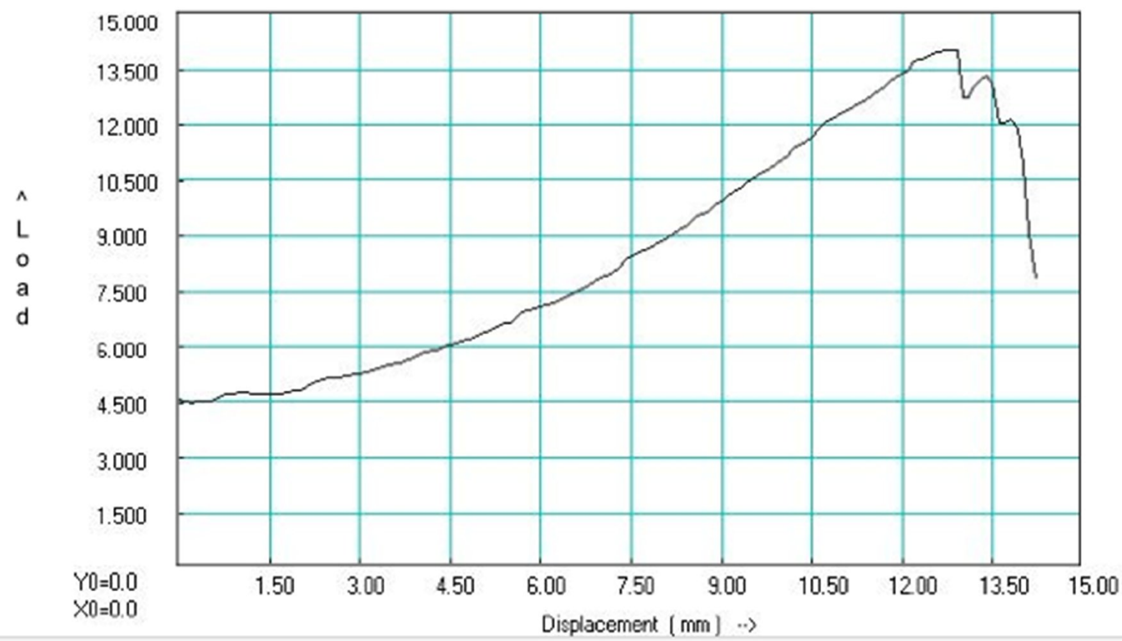

Figure 7.2: Load vs Displacement graph of Sample 2

Machine : Universal Testing Machine UTE-40

INPUT DATA :

Sample Identification :

Sample Type : Round solid C/S Area (mm2) : 47.803 Final Area (mm2) 38.50

Diameter (mm) : 10.13 Original Gauge Length (mm) : 90.0

Final Gauge Length (mm) : 130.0

Results of tension Test

Max. Load kN	14.520
Disp. at Max. Load mm	17.00
Max. Displacement mm	18.10
Ult. Strength kN/mm ²	0.304
Elongation %	44.44
Reduction in Area %	19.461

Graph : Load (kN) Vs Displacement (mm)

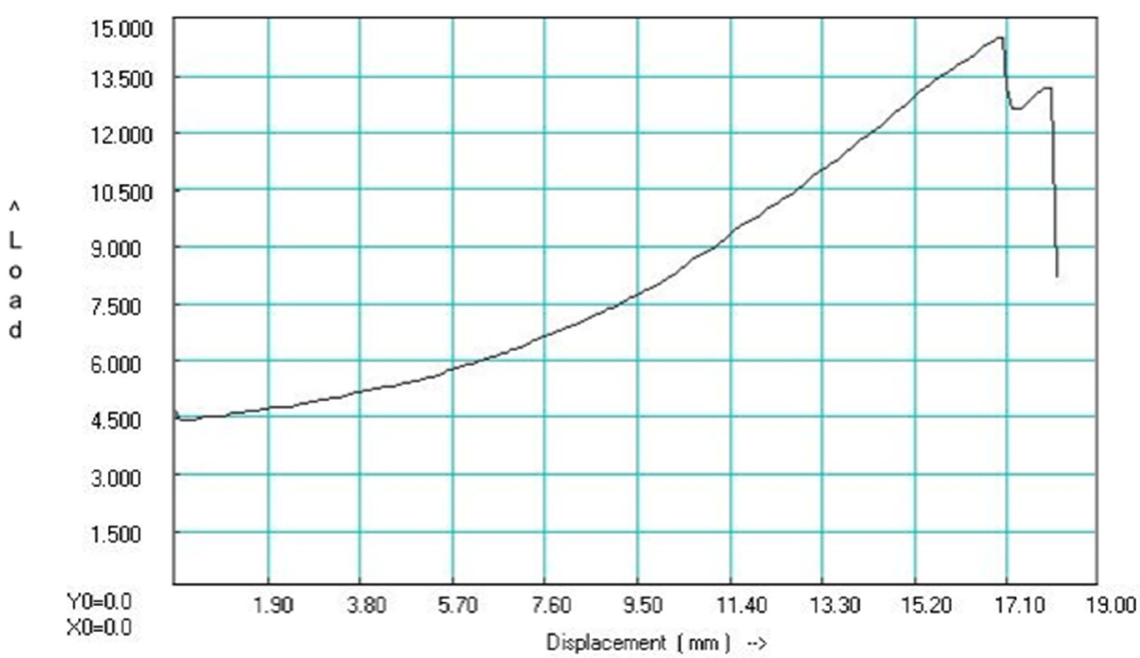

Figure 7.3: Load vs Displacement graph of Sample 3

Machine : Universal Testing Machine UTE-40

INPUT DATA : Sample Identification :

Sample Type : Round solid   C/S Area (mm2) : 54.128   Final Area (mm2) 50.29

Diameter (mm) : 10.13   Original Gauge Length (mm) : 107.0

Final Gauge Length (mm) : 126.0

Results of tension Test

Max. Load kN	14.460
Disp. at Max. Load mm	18.20
Max. Displacement mm	18.80
Ult. Strength kN/mm ²	0.267
Elongation %	17.76
Reduction in Area %	7.098

Graph : Load (kN) Vs Displacement (mm)

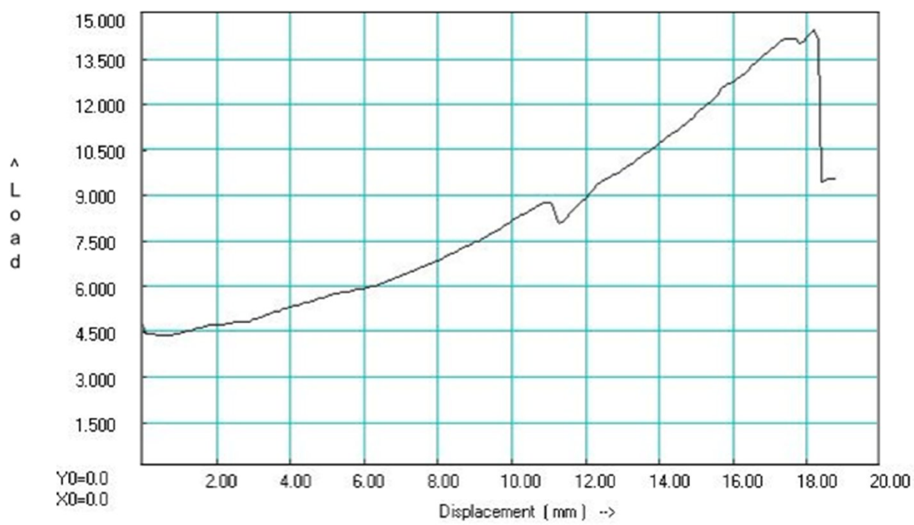

Figure 7.4: Load vs Displacement curve of sample 4

Figure 8: Broken Sample after Tensile Test

6.2 Impact Strength: The results show that there is no major change in the impact strength for different fiber resin ratio. During the impact test the specimen is flexible and it was not broken due to impact load, this shows the elastic property of the material.

Sample	Energy Absorbed
1	21 J
2	18 J
3	16 J
4	20 J
5	16 J

Table 2: Impact Test Results

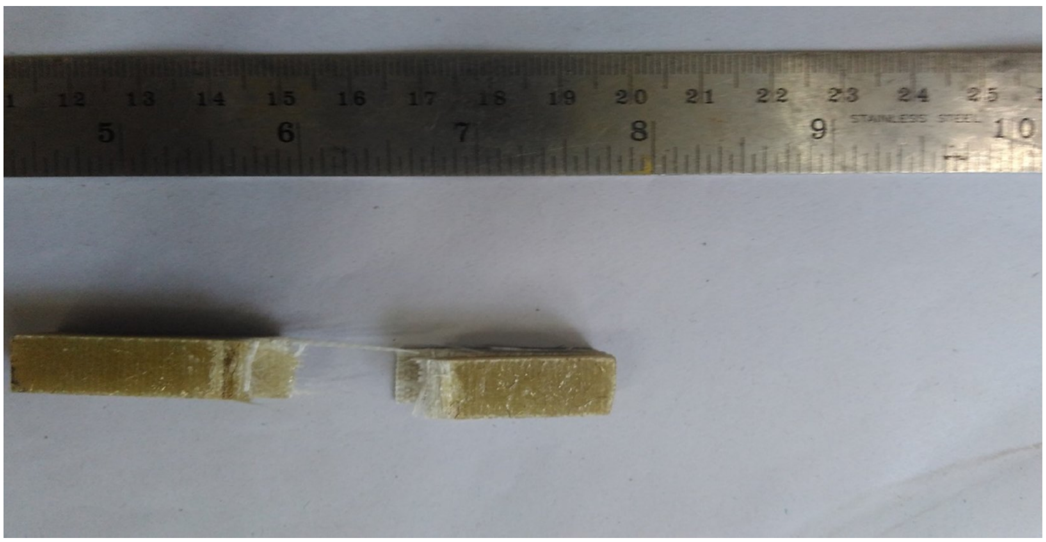

Figure 9: Broken Sample after Charpy Test

7. Conclusion

The Tensile strength and Impact strength of glass fiber reinforced epoxy composite has been analysed. If the fiber content increases the strength of the composite also increases. The impact strength did not show any significant change with different copositions. From this experimental study we can conclude that by increasing the fiber content in the composite material the will be increased, but at some point the strength will start to decrease due to lack of adhesion material (resin).

8. Applications

Glass fibers are suitable for the fabrication of wind-turbine blades, boats and architectural mouldings. Fiber reinforced plastics have been widely used for manufacturing aircraft and spacecraft structural parts, in automotive fields and also in sporting goods because of their particular mechanical and physical properties such as high specific strength and high specific stiffness. Another relevant application for fiber reinforced polymeric composites (especially glass fiber reinforced plastics) is in the electronic industry, in which they are employed for producing printed wiring boards. The main advantage of the glass fiber is its low cost. Its other advantages are its high tensile strength, low chemical resistance and excellent insulating properties Simple enclosures, lightly loaded structural panels, e.g. caravan bodies, truck fairings, bathtubs, shower trays, some small dinghies.

With advanced metals on the one side and carbon fibre on the other, fibreglass has fallen out of popularity in the motoring world. The combination of glass' resilience and plastic's flexibility means fibreglass is very lightweight, fairly strong and resistant to bending. It's not really used in mass production cars anymore and was only popular with the, now-dormant, sports car maker TVR and on early Chevrolet Corvettes for its lightweight. Its relative weakness compared to some metals and the complexity of repairing it means it's now mainly used in maritime and aviation applications.

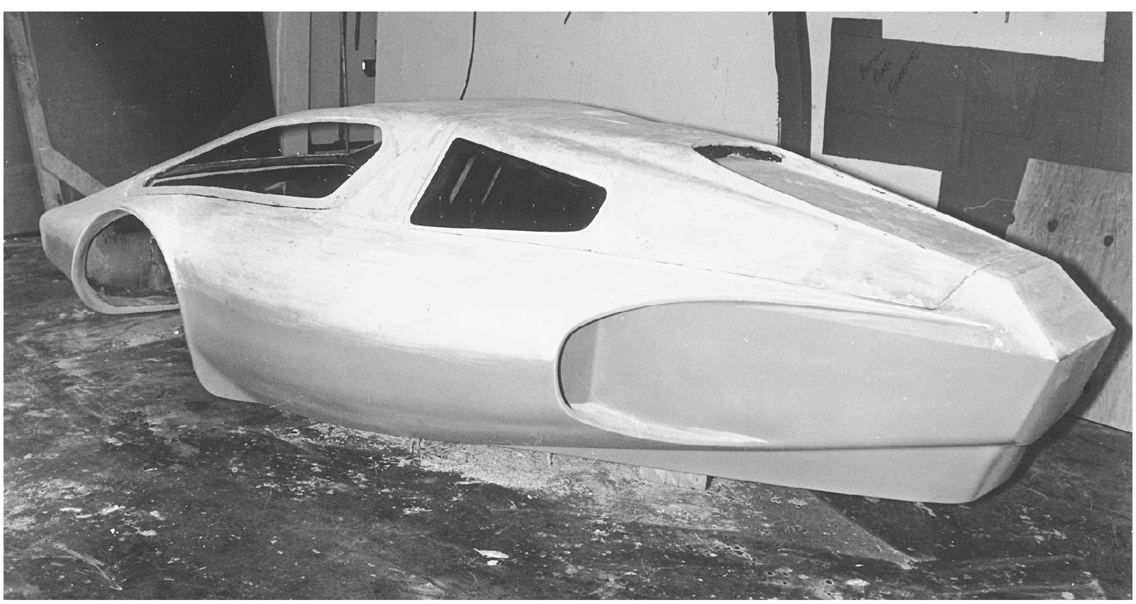

Figure 10: Glass Fiber Car Body

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