1. Chapter 1

1.1. Introduction:

Humanity has been aware of composites materials since several hundred years before *Christ* and has been applied innovations to improve the quality of life. Contemporary composites resulting from research and innovation from the past few decades have progressed from glass fiber for automobiles bodies to particulate composites for aerospace and a range of other applications. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche (hollow in a wall or statues) applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite componentshave resulted in several innovative manufacturing techniques currently beingused in thecomposites industry. Composites that form heterogeneous structures, which meet therequirements of specific design and function with desired properties limit the scope forclassification. Over, this lapse is made up for, by the fact that new types of composites arebring innovated all the time ,each with their own specific purpose likeflakeparticulate andLaminar composites.

Composite materials (or composites for short) are engineering materials made from two or more constituent materials those remain separate and distinct on a macroscopic level while forming a single component.

Composite industries utilize glass fiber-reinforced polyester (GFRP) laminates toproduce water tank, boat hulls, aircraft fuselages, tubing, and a multitude of other products.GFRP laminates are used due to their increased tensile strength, insulating properties, and the cost effectiveness of each component compared to wood or steel. However, glass fibers have several shortcomings in typical applications due to their high hardness, low fatigue, and high density compared to other types of fibers1. There are five main forms of fiberglass: continuous strand roving, woven roving, chopped strands, chopped strand mat, and woven roving mat(Figure1.1).

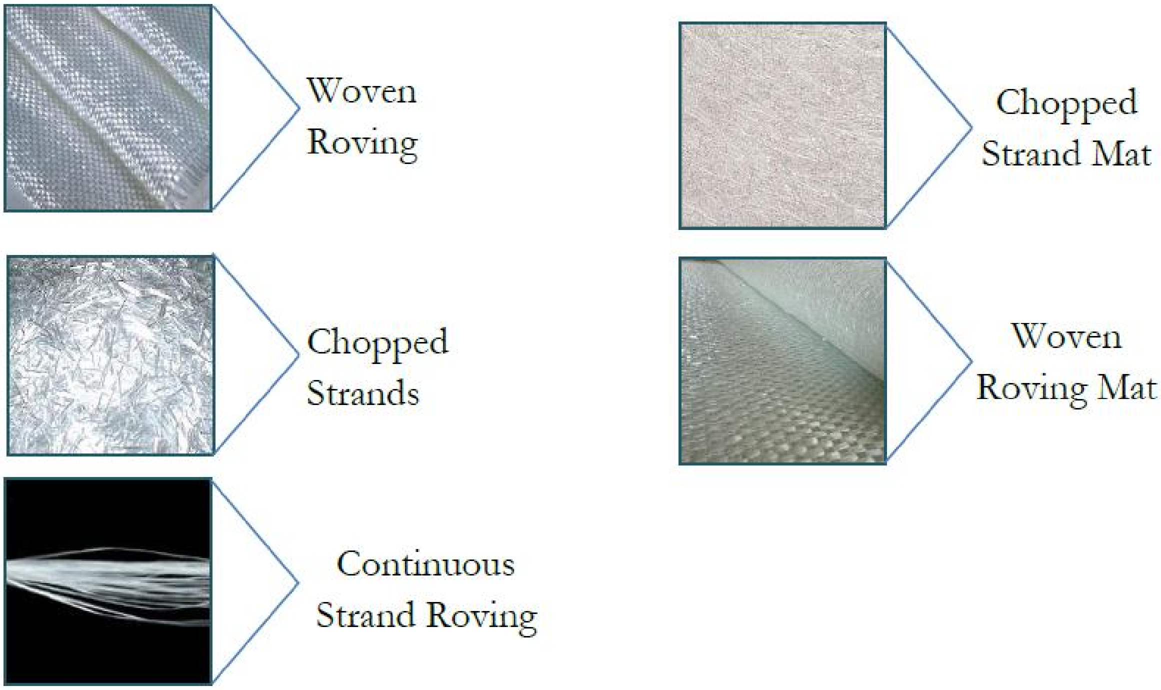


Figure 1.1: Five common forms of glass fibers for use in composite materials.

All of these forms, combined with a particular resin system, are commonly used in many manufacturing industries. Polyester resin is the cheapest and most widely used matrix in conjunction with fiberglass. The curing of polyester is typically initiated with small quantities of catalyst; the catalyst most often used is a type of peroxide, such as methyl-ethylketoneperoxide (MEKP). In most manufacturing processes, several layers of fiberglass and polyester are applied to a part with a curing period in between applications. Determination of when to apply a secondary layer of fiberglass to acquire the strongest bond between laminates is key in reducing manufacturing time, cost, and the amount of material used.

This bond strength can be measured by shortbeam shear testing, which targets the adhesion strength between layers rather than the strength between the fiberglass and the polyester within a layer.

In order to determine the quickest and strongest method of adhesion between Composite laminates, a relation between adhesion and hardness needs to be generated, tested, and verified. In addition to creating a relationship between hardness and adhesive strength, both economic and manufacturing efficiencies must be considered. Currently, no method of relating the degree of cure to hardness has been established in developing lamination standards for maximum adhesive properties. While mechanical abrasion between lamination of excessive layers is used to maximize contact surface area, the chemical adhesion between laminates can be damaged and weakened. If a relationship is determined between the strength of adhesion and the hardness while laminating, abrading could be eliminated. Elimination of abrading could decrease time and resources required in manufacturing setting.

1.2. Realistic Constraints:

Composites are replacing other materials, like woods and metals, every day. Composites are finding their place within an increasing number of industries; for Example the military, marine, aviation, and automotive industries. Not only are the Mechanical properties of composites similar or better than older materials, but Composite applications are much more numerous. The identification of an accurate

Relationship between hardness and adhesion could reduce the manufacturing time ofGFRP and minimize the cost of producing parts. Likewise, finding the optimal Hardness for adhesion could be used in any industry that utilizes secondary layers of fiberglass reinforced polyester laminates.

A reduction in manufacturing time lessens the environmental impact of open Molding techniques by reducing the curing time of parts. With a reduction in the curing process time, emissions of styrene would be minimized and manufacturingassociatedEPA requirements could be met more easily. Additionally, there is a 10%contribution to styrene emissions in the spray lay-up process due to the rate ofapplication4. As such, styrene emissions could be reduced by determination of anoptimal time for adhesion. Another advantage of decreasing the manufacturing time isa reduction in the labor necessary to produce each part.

Successful implementation of this laminating system could result in a reduction in material failures. For example, weak bonding in composite laminates can cause fiber pullout and delamination5. Delamination is a failure that occurs on a plane between adjacent layers with a laminate and is typically determined by the strength ofthe matrix (Figure 3). Delamination is the most common form of defect or cause ofdamage within a composite structure6. Delamination increases manufacturing time aswell as the quantity of materials used. By increasing the strength of adhesion, theprobability of delamination is reduced. The adhesion at the interface of two laminates can be improved by addingspecial coatings and coupling agents5. The interfacial strength can also be increasedby mechanically abrading the surface with grinders, sand paper, and hours of labor. By determining when the maximum strength of adhesion is accomplished, thesecondary lay-up can be applied without the need for abrasion, coatings, or couplingagents. The resulting reduction in labor time and materials used decreases theeconomic impact of each part on the producer. Labor can then be directed towardincreasing the efficiency of the manufacturing processes.

1.3. Fiber-Reinforced Composites:

Fiber-reinforced composites are structural materials that consist of twodifferent components: matrix and reinforcements or fibers. The matrix holds the reinforcements in place while protecting them. The matrix is thesurrounding, continuous component within a composite, while the reinforcementprovides strength, stiffness, and the mechanical properties of the composite. Earlyexamples of fiber-reinforced composites are ancient Israelite mud bricks reinforcedwith straw and Mongolian hunting bows made of wood and glue.

Composites can be classified on the basis of the form of their structural components. One simple scheme for the classification of composite materials is shown in figure 1.2which consists of three main divisions: particle-reinforced, fiber-rein-forced, and structural composites (at least two subdivisions exist for each). The dispersed phase for particle-reinforced composites is equiaxed (i.e. particle dimensions are approximately the same in all directions). For fiber-reinforced composites, the dispersed phase has the geometry of a fiber (i.e. a large length-to diameter ratio). Structural composites are combinations of composites and homogenous materials.

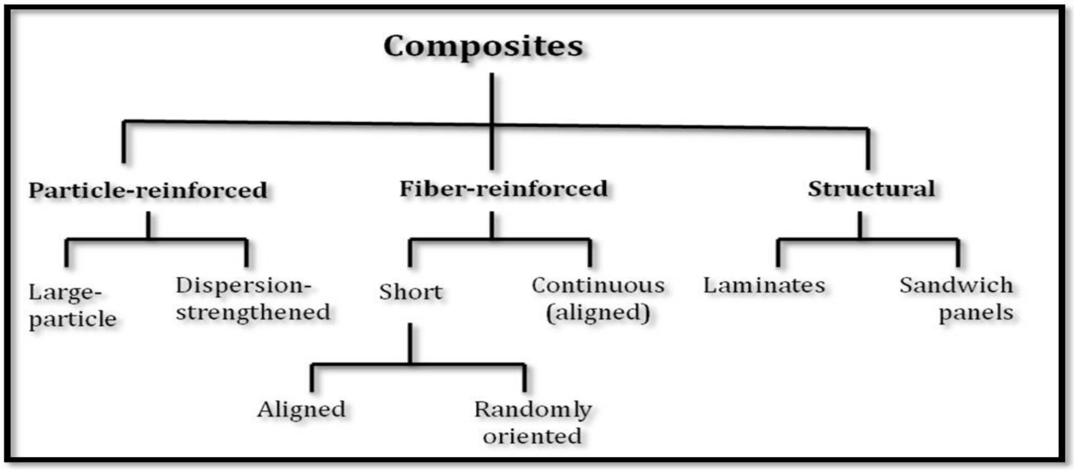
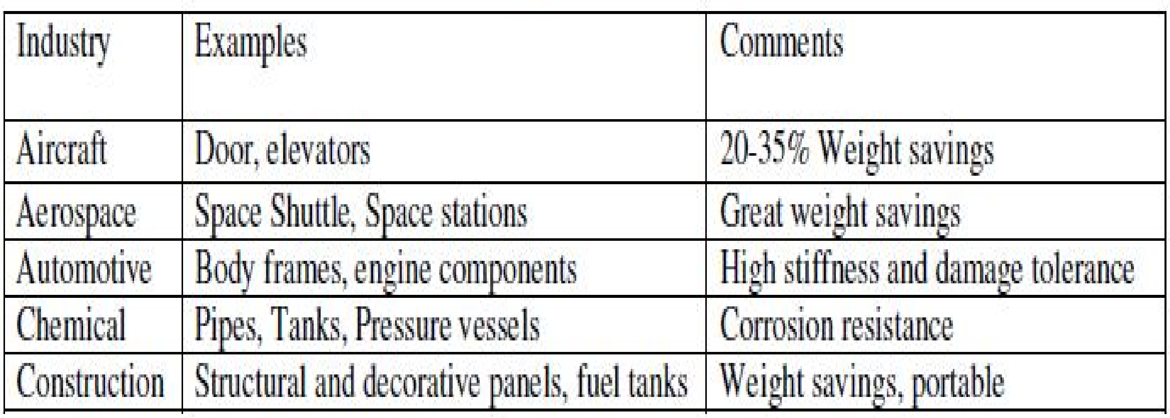


Figure 1.2: Classification of composite materials

1.4. Application of FRP composites in tank constructions:

From table 1.1 we note that, there are many applications of composites, and has been used in many field of industry like aircraft, aerospace,automotive,chemical and construction …etc. But In my study I will be responsible for chemical industry such as tank water.

Table 1.1: Application of composites



Industry	Examples	Comments
Aircraft	Door, elevators	20-35% Weight savings
Aerospace	Space Shuttle, Space stations	Great weight savings
Automotive	Body frames, engine components	High stiffness and damage tolerance
Chemical	Pipes, Tanks, Pressure vessels	Corrosion resistance
Construction	Structural and decorative panels, fuel tanks	Weight savings, portable

Tank water:-

Figure 1.3.Steps of manufacture of tank water

Filament-Wound laminate construction of standard vertical FRP tanks is done with automated equipment on a rotating mold called a mandrel. A resin-rich layer of chemically resistant polyester or vinyl ester is applied uniformly to a specified thickness on an inner surface mat. The mat is usually of a chemically resistant fiberglass reinforcement composition or an organic veil. After the initial layer is applied (approximately 20 millimeter thickness), a second layer of resin-rich, chemically resistant polyester or vinyl ester is applied uniformly, to roughly a four times greater thickness. The reinforcement usually consists of randomly oriented, chopped strand fiberglass.

The next step involves the construction of a filament-wound layer impregnated with isophthalmic polyester resin or other suitable resin. The layer thickness depends on the size requirements and the specific gravity design criteria. Generally, the layer composition is comprised of filament winding interspersed with chopped strand fiberglass. The purpose of this third layer is to provide the primary strength characteristics of the vessel.

This layer serves to minimize the strain placed on the corrosion barrier to avoid cracking of this layer. The corrosion barrier can undergo cracking to loads considerably below the ultimate strength of the corrosive layer material, resulting in tank failure. As a fourth layer, a resin-rich outer surface mat is applied that is usually of the same thickness as the inner layer. This generally consists of a chemically resistant fiberglass reinforcement or an organic veil that is saturated by spraying with isophthalic polyester resin. The responsibility of the first and second layers is to provide the tank with non-corroding and non-contaminating features. A cross-sectional view of the standard vertical tank wall laminate is illustrated in Figure

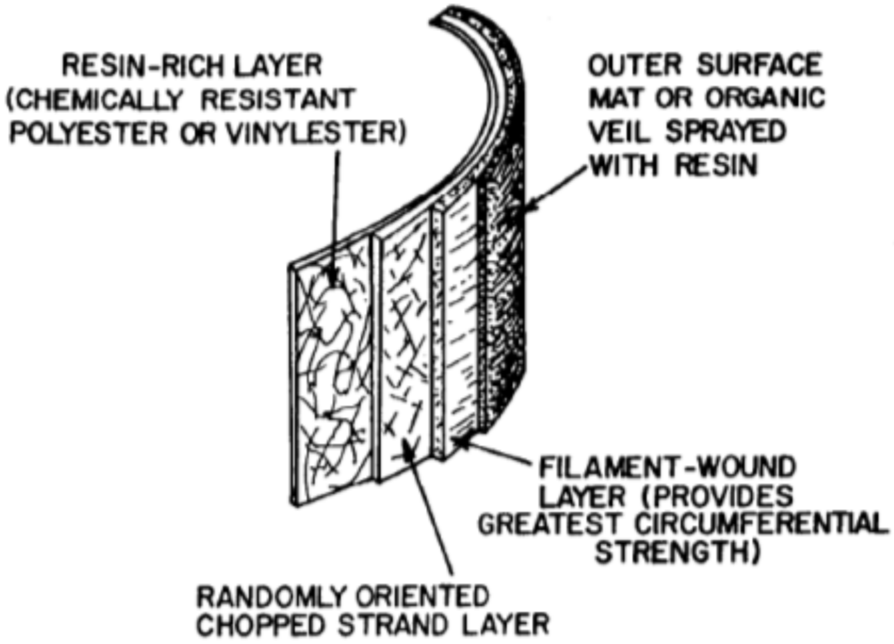


Figure 1.4: Cross-sectional view of standard vertical tank wall laminate.

1.5. Objective:

As a consequence of the concerns discussed above, the objectives of this research are:

- To introduce the fabrication process of composite laminate with layers by compression molding process.
- To fabricate the Fiberglass/polyester by using hand lay-up molding to make the composite laminate.
- To predict the interlaminar fracture toughness by three-point bending test and for delamination failure in laminated composite.
- To compare Fiberglass/polyester composites with water tank made of high density polyethylene.

1.6. Out line

This thesis is divided into five chapters

- Chapter one, gives relevant information oncomposites materials, application of FBP composites in tank constructions.
- Chapter two Background , Review of literature , composites , Thermoset resins , Thermoplastic resins , Structure of composites , advantages of composites , Glass fiber reinforcement , Polyester resin matrix , fiber properties , The Mechanical properties polyester/fiberglass composites.

- Chapter three materials and manufacturing of test specimensand methods

Chapter four the experimental details of tensile test , the three-point bending test ,Hardness test , charpy impact test.

- Chapter five the conclusion and recommendations based on this study are summarized in this chapter.

2. CHAPTER 2

LITERTURE REVIEW

2.1. BACKGROUND:

The earliest man-made composite materials were straw and mud combined to form bricks for building construction. Ancient brick-making was documented by Egyptian tomb paintings. Wattle and daub is one of the oldest man-made composite materials, at over 6000 years old. Concrete is also a composite material, and is used more than any other man-made material in the world. As of 2006, about 7.5 billion cubic metres of concrete are made each year—more than one cubic metre for every person on Earth.

Woody plants, both true wood from trees and such plants as palms and bamboo, yield natural composites that were used prehistorically by mankind and are still used widely in construction and scaffolding.

Plywood 3400 BC by the Ancient Mesopotamians; gluing wood at different angles gives better properties than natural wood Car tonnage layers of linen or papyrus soaked in plaster dates to the First Intermediate Period of Egypt c.

2181–2055 BC and was used for death masks Cob_(material) Mud Bricks, or Mud Walls, (using mud (clay) with straw or gravel as a binder) have been used for thousands of years. Concrete was described by Vitruvius, writing around 25 BC in his *Ten Books on Architecture*, distinguished types of aggregate appropriate for the preparation of lime mortars. For structural mortars, he recommended *pozzolana*, which were volcanic sands from the sand like beds of Petiole brownish-yellow-gray in color near Naples and reddish-brown at Rome. Vitruvius specifies a ratio of 1 part lime to 3 parts pozzolana for cements used in buildings and a 1:2 ratio of lime to pulvisPuteolanus for underwater work, essentially the same ratio mixed today for concrete used at sea.

Natural cement-stones, after burning, produced cements used in concretes from post-Roman times into the 20th century, with some properties superior to manufactured Portland cement. Papier-mâché, a composite of paper and glue, has been used for hundreds of years the first artificial fiber reinforced plastic was Bakelite which dates to 1907, although natural polymers such as shellac predate it.

2.2. Review of literature:

Throughout the years, research has been intensively going on which various publications on mechanical properties of fiber glass/ polyester composite such as The relationship of barcol hardness and interlaminar shear strength in glass reinforced polyester composite laminates, (Ann Livingston-P, 2013) They are used Chopped strand mat E-glass layers were impregnated with isophthalic marine laminating resin by hand lay-up techniques. Once the primary laminate reached the desired Barcol hardness value, the secondary laminate was applied and allowed to cure. All samples showed statistically significant differences with a trend of increasing bond strength with decreasing hardness's. Twenty percent of the samples delaminated while the other sample failed under flexure loads. The samples that were bonded at higher hardness's failed under lower loads in tension and compression rather than in shear. Three-point bend testing following ASTM 7264 was conducted to determine the flexural stiffness and strength properties of the samples to determine the validity of preliminary testing. After secondary testing was completed, the preliminary data was confirmed and conclusions were drawn. It was found that hardness does not affect the strength of adhesion in composite laminates. These results suggest that the use of this particular resin-fiber system could eliminate the sanding manufacturing step used during lamination.

Another study, (Irina .p, et, al 2013) studied the value of Young's modulus for three specimens at different span lengths in order to have a more accurate value. The specimens used are laminated composite carbon fiber oriented unidirectional made by the Cytec Engineered Materials and tested on an Instron 3367 using the three point bending method. The tangent modulus of elasticity is calculated by drawing a tangent to the steepest initial straight-line portion of the load-deflection curve.

There have been a number of mechanical properties such as the impact strength, tensile strength, flexural strength, and hardness. (Dr. Abbas A. Al-Jeebory 2010) studied for composite material reinforced with hybrid fibers as a woven roving for carbon and kevlar fibers respectively. They are found Improvement in these mechanical properties after reinforcement by fibers the value of mechanical properties will increase with increasing percentage of reinforcement.

A.V. Babushkin , D.S, et , al (2013) studied the comparative analysis of effectiveness of test methods of determination of stiffness and strength properties of highly filled unidirectional fiberglass (Direct "E" roving 0.7 - orthophthalic polyester resin 0.3) via tensile testing along the reinforcement and three-point bending testing at several bases. The necessity of deviation from standard procedures is substantiated. Deformation and failure features of the material under quasi-static loading, as well as at low and high temperatures.

2.3. Composites:-

Composites can be defined as materials that consist of two or more chemically and physically different phases separated by a distinct interface. The different systems are combined judiciously to achieve a system with more useful structural or functional properties no attainable by any of the constituent alone.

Composites, the wonder materials are becoming an essential part of today's materials due to the advantages such as:-

1. Low weight.
2. Corrosion resistance.
3. High fatigue strength.
4. Faster assembly.

They are extensively used as materials in making aircraft structures, electronic packaging to medical equipment, and space vehicle to home building.

Composites are combinations of materials differing in composition, where the individual constituents retain their separate identities. These separate constituents act together to give the necessary mechanical strength or stiffness to the composite part.

2.3.1. Classification of Composites:-

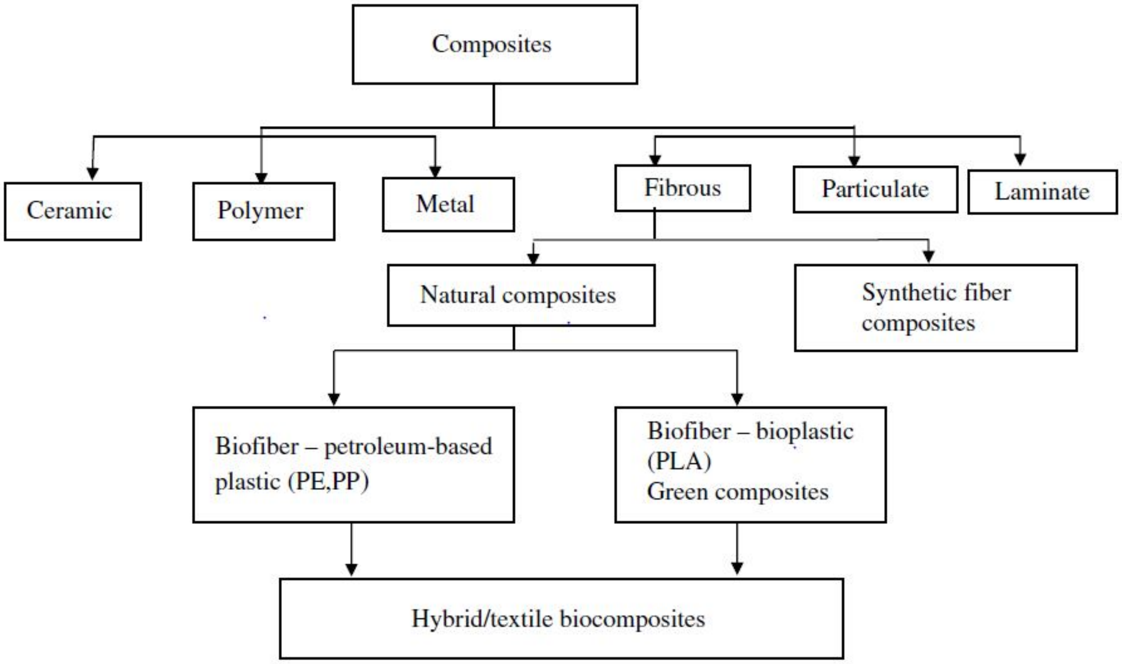


Figure 2.1: Classification of composites

Composite material is a material composed of two or more distinct (phases matrix phase, dispersed phase) and having bulk properties significantly different from those of any of the constituents.

2.3.2. Matrix phase:-

Is the primary phase having a continuous character. Matrix is usually more ductile and less hard phase. It holds the dispersed phase and shares a load with it.

Dispersed (reinforcing) phase :-

is embedded in the matrix in a discontinuous form. This secondary phase is called the dispersed phase. Dispersed phase is usually stronger than the matrix, therefore, it is sometimes called reinforcing phase.

2.3.3. Reinforcement:

Reinforcements are supplied in several basic forms to provide flexibility in cost, strength, compatibility with the resin system, and process requirements. Regardless of the final form, all fiber reinforcements originate as single filaments. A large number of filaments are formed simultaneously and gathered into a strand. A surface treatment is then applied to facilitate subsequent processing, maintain fiber integrity, and provide compatibility with specific resin systems. After this treatment, the strands are further processed into various forms of reinforcements for use in molding FRP/Composites:

a) Continuous strand roving:

This basic form of reinforcement is supplied as untwisted strands wound into a cylindrical package for further processing. Continuous roving is typically chopped for spray-up, sheet 14 moulding compounds. In the continuous form, it is used in pultrusion and filament-winding processes.

b) Woven roving:

Woven from continuous roving, this is a heavy, droppable fabric available in various widths, thicknesses and weights. Woven roving costs less than conventional woven fabric and is used to provide high strength in large structural components such as tanks and boat hulls. Woven roving is used primarily in hand lay-up processing.

c) Woven fabrics:

Made from fiber yarns, woven fabrics are of a finer texture than woven roving. They are available in a broad range of sizes and in weights. Various strength orientations are also available.

d) Reinforcing mat:

Made either from continuous strands laid down in a swirl pattern or from chopped strands, reinforcing mat is held together with a resinous binder or mechanically stitched. These mats are used for medium strength FRP/Composites. Combination mat, consisting of woven roving and chopped strand mat bonded together, is used to save time in hand lay-up operations.

e) Surfacing mat:

Surfacing mat or veil is a thin fiber mat made of monofilament and is not considered areenforcing material. Rather, its purpose is to provide a good surface finish because of itseffectiveness in blocking out the fiber pattern of the underlying mat or fabric. Surfacing matis also used on the inside layer of corrosion-resistant FRP/Composite products to produce a smooth, resin-rich surface.

f) Chopped fibers:

Chopped strands or fibers are available in lengths from 1/8” to 2”for blending with resins andadditives to prepare moulding compounds for compression or injection moulding and otherprocesses. Various surface treatments are applied to ensure optimum compatibility withdifferent resin systems.

The matrix or resin is the other major component of an FRP/Composite. Resin systems areselected for their chemical, electrical and thermal properties. The two major classes of resinsare thermoset and thermoplastics.

2.4. Thermoset resins:

Thermosetting polymers are usually liquid or low melting point solids that can easily combine with fibers or fillers prior to curing. Thermoset feature cross-linked polymer chainsthat become solid during a chemical reaction or “cure” with the application of a catalyst andheat. The high level of cross-linking provides for reduced creep compared to thermoplastics.

The thermoset reaction is essentially irreversible. Among the thermoset resins for FRP/Composites, the family of unsaturated polyesters is by far the most widely used. Theseresins are suitable for practically every moulding process available for thermoset. Polyesters offer ease of handling, low cost, dimensional stability, and a balance of good mechanical, chemical, and electrical properties.

They can be formulated for high resistance to acids, weak alkalies and organic solvents. Theyare not recommended for use with strong alkalis. Other formulations are designed for low orhigh temperature processing, for room temperature or high-temperature cure, or for flexibleor rigid end products.

Polyurethanes are easily foamed in a controlled process to produce a wide range of densities. Additives are easily incorporated into resin systems to provide pigmentation, flame retardance, weather resistance, superior surface finish, low shrinkage and other desirable properties. Gel coats consisting of a special resin formulation provide an extremely smooth next-to-mould surface finish on FRP/Composites.

They are commonly applied in hand lay-up and spray-up processes to produce a tough, resilient, weather-resistant surface. Gel coats, which may be pigmented, are sprayed onto the mould before the reinforcement and resin are introduced. Other thermosetting resin systems, generally formulated with chopped strand or milled fiber reinforcement for compression or transfer moulding are:

1. *Phenolics:* Good acid resistance, good fire/smoke, and thermal properties.
2. *Silicones:* Highest heat resistance, low water absorption, excellent dielectric properties.
3. *Melamines:* Good heat resistance, high impact strength.
4. *Diallyl phthalates:* Good electrical insulation, low water absorption.

2.5. Thermoplastic resins:

Thermoplastic polymers can soften and become viscous liquids when heated for processingand then become solid when cooled. The process is reversible allowing a reasonable level ofprocess waste and recycled material to be reused without significant effect on the endproduct. Thermoplastic resins allow for faster moulding cycle times because there is nochemical reaction in the curing process. Parts may be formed as fast as heat can be transferred into and out of the moulding compound. Polypropylene and polyethylene are the most common thermoplastic resins used in FRP/Composites. They have excellent resistance to acids and alkalies and have good resistance to organic solvents. Their relatively low melting points allow for rapid processing at lower cost. Nylon and Acetal are highly resistant to organic solvents and may also be used where increased mechanical properties are required.

2.6. Structure of Composites:

Structure of composite material determines its properties to a significant extent.

Properties:

1) Nature of the constituent material (bonding strength)
2) The geometry of the reinforcement (shape, size)
3) The concentration distribution (vol. fraction of reinforcement)
4) The orientation of the reinforcement (random or preferred)

Good adhesion (bonding) between matrix phase and displaced phase provides transfer of loadapplied to the material to the displaced phase via the interface. Good adhesion is required forachieving high level of mechanical properties of composites. Very small particles less than0.25 micrometer finely distributed in the matrix impede movement of dislocations anddeformation of the material. They have strengthening effect. Large dispersed phase particleshave low share load applied to the material resulting in increase of stiffness and decrease ofductility. Orientation of reinforcement:

1) Planar: In the form of 2-D woven fabric. When the fibers are laid parallel, the composite exhibitsaxis trope.

2) Random or Three Dimensional: The composite material tends to posses isotropic properties.

3) One Dimensional: Maximum strength and stiffness are obtained in the direction of fiber.

2.7. Advantages of Composites:

Different materials are suitable for different applications. Advantages of composites overtheir conventional counterparts are the ability to meet diverse design requirements withsignificant weight savings as well as strength-to-weight ratio. Processing of FRP/Compositeinvolves complex chemical reactions. Final properties are determined by many factors including the type, amount, and composition of the resin systems and reinforcements. Inaddition, the use of additives can greatly affect the FRP/Composite properties. When composites are selected over traditional materials such as metal alloys or woods, it is usually because of one or more of the following advantages:

Advantages of Composites

Cost

- Maturity of technology
- Part consolidation
- Production time

Weight

- Light weight
- Strength and Stiffness
- High strength-to-weight ratio

Dimension

- Large parts
- Special geometry

Surface properties

- Corrosion resistance
- Weather resistance
- Tailored surface finish

Thermal properties

- Low thermal conductivity
- Low coefficient of thermal expansion

Electric property

- High dielectric strength
- Non-magnetic
- Radar transparency

It is to be noted that there is no one-material-fits-all solution in the engineering world. Also, the above factors may not always be positive in all applications. An engineer has to weigh all the factors and make the best decision in selecting the most suitable material for the project at hand.

2.8. Glass Fiber Reinforcement:

Glass fibers have been used for centuries to strengthen various applications, such as Renaissance era vases and pitchers. Fiberglass, in more recent years, has been commonly used as an insulating material. In WWII, when supplies of steel and other strategic materials were in high demand, fiberglass was combined with resin to create composite structures. For many years after WWII, glass fibers were the only commercial reinforcements used in composites. Recently, within the last fifty years, the corrosion resistance of fiber-reinforced plastics has led to the replacement metals. Metals in many different applications such as car hoods, fenders, and other body components. The low cost and advantageous properties of fiberglass continue to drive high demand for the material. For example, the manufacturing process of glass fibers is one reason the cost of fiberglass is lower than that of other reinforcing agents.

There are several types of glass fibers used for particular applications:

1. Eglass was originally used when high electrical resistivity and strength were needed in electrical devices. Due to their low cost, E-glass is still the most widely used fiber in the composite applications, and less so for electrical ones.
2. S-glass has the ability to retain its mechanical properties at higher temperatures while being 35% stronger than E-glass. S-glass is primarily used in advanced composites where carbon and Kevlar fibers are not used.

3. C-glass is especially suited for chemically corrosive environments.

4. Quartz fibers have less strength than the other three types, and are only used when electrical signal transparency or a higher glass transition temperature is desired.

All of these types of fibers vary in their composition, and thus, mechanical properties fiberglass is an easy and inexpensive method to improve the strength and stiffness of any part, which is why glass is used in many different industries.

2.9. Polyester Resin Matrix:

There are three different types of matrix materials: polymeric materials, ceramic materials, and metallic matrix materials. Each type of matrix is chosen based upon its specific properties and how the matrix reacts with the reinforcement. The most common type of matrix material is a polymer.

In a polymer matrix, single molecular units called monomers are linked together into short chains called oligomers that are then bonded together to create a polymer molecule.

Polyester is a polymer that is created through a condensation polymerization reaction in which two monomers with active end groups react with each other multiple times when mixed. This reaction results in the condensation orelimination of a byproduct molecule. Unsaturated polyester is the most commonly used thermosetting resin due to its low cost, ease of cure, and ease of molding.

Despitehaving disadvantages like poor durability, brittleness, and air quality pollutants, polyester continues to dominate the resin market. In the production of unsaturated polyester resin, glycols and diacids are combined to start the condensation reaction. The reactive groups on the glycol monomers are the alcohol

(OH) groups located on the ends of the molecule. The reactive groups on the diacid molecule are the carboxylic acids (COOH).

When the alcohol and the carboxylic acid react with one another, they form an ester. This ester is repeated in the polymer chain, thus forming the polyester resin with a byproduct of water (Figure 2.2).

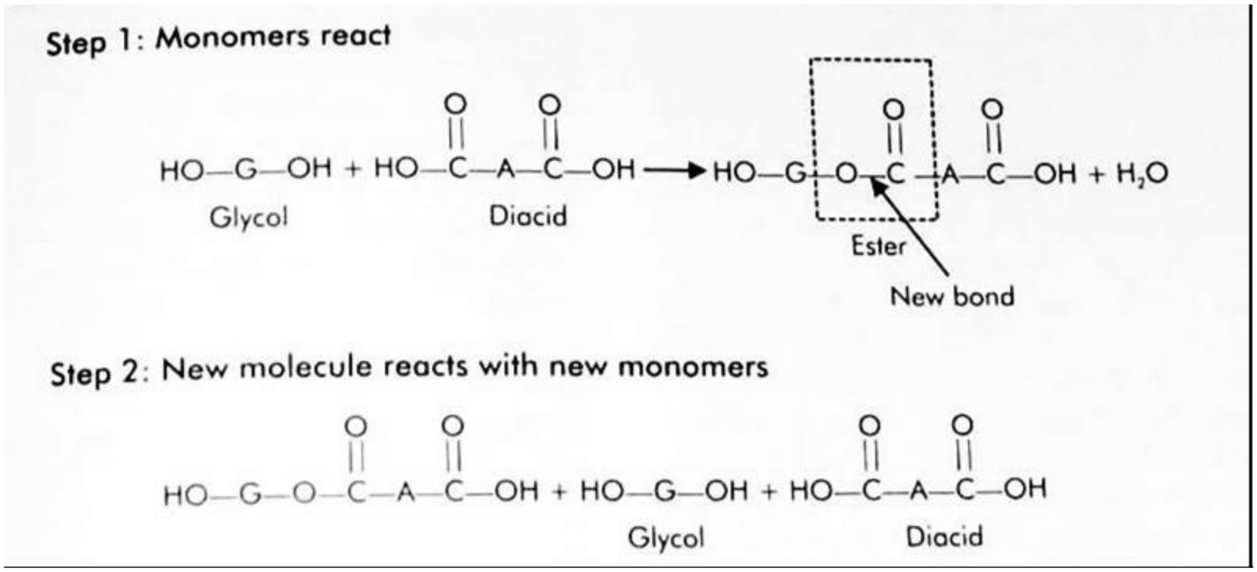


Figure 2.2.Condensation polymerization of a typical polyester

The properties of polyesters are dependent on several factors. Introduction of different additives to polyester slows or quickens the crosslinking reaction that occurs during curing. This crosslinking process is an exothermic reaction that produces significant heat while curing .

In addition to altering reaction speeds, additives can change the color, viscosity, resulting hardness, and brittleness of the polymer. These properties can be ordered specifically from manufacturers or altered during the lamination process.

2.10. Fiber Properties:

The mechanical properties of most reinforcing fibers are considerably higher than those of un-reinforced resin systems. The mechanical properties of the fiber/resin composite are therefore dominated by the contribution of the fiber to the composite. The four main factors that govern the fiber’s contribution are:

1. The basic mechanical properties of the fiber itself.
2. The surface interaction of fiber and resin (the 'interface').
3. The amount of fiber in the composite ('Fiber Volume Fraction').
4. The orientation of the fibers in the composite.

The basic mechanical properties of the most commonly used fibers are later. The surface interaction of fiber and resin is controlled by the degree of bonding that exists between the two. This is heavily influenced by the treatment given to the fiber surface, and a description of the different surface treatments and 'finishes' is also given here.

The amount of fiber in the composite is largely governed by the manufacturing process used. However, reinforcing fabrics with closely packed fibers will give higher Fiber Volume Fractions (FVF) in a laminate than will those fabrics which are made with coarser fibers, or which have large gaps between the fiber bundles. Fiber diameter is an important factor here with the more expensive smaller diameter fibers providing higher fiber surface areas, spreading the fiber/matrix interfacial loads. As a general rule, the stiffness and strength of a laminate will increase in proportion to the amount of fiber present. However, above about 60-70% FVF (depending on the way in which the fibers pack together) although tensile stiffness may continue to increase, the laminate's strength will reach a peak and then begin to decrease due to the lack of sufficient resin to hold the fibres together properly.

Finally, since reinforcing fibers are designed to be loaded along their length, and not across their width, the orientation of the fibers creates highly 'direction-specific' properties in the composite. This 'anisotropic' feature of composites can be used to good advantage in designs, with the majority of fibers being placed along the orientation of the main load paths. This minimizes the amount of parasitic material that is put in orientations where there is little or no load.

2.11. The Mechanical Properties polyester/fiberglass composites:-

The mechanical properties are often the most important properties related for technology. This is because virtually all service conditions involve some degree of mechanical loadings.

The selection of polyester/fiberglass composites for a specific application is usually based on the mechanical tests that applied on that particular resin such as tensile, impact, compressive, bending, flexural and hardness tests. From a very general point of view, mechanical behavior is the response of a solid to mechanical stress. The atoms of solid under load are displaced from their equilibrium position, which induces restoring forces that are opposed to the deformation and tend to restore the initial shape as the load is removed. In the elastic region, usually for small deformations, the behavior remains wholly reversible.

Increasing load leads to formation and propagation of defects that allows mechanical stress to be relaxed.

2.11.1. The Impact Test:

The resistance to impact is one of the key properties of materials. A tough polymer is one which has a high energy to break in an impact test. Impact strength depends on a range of variables including temperature, geometry of article, fabrication conditions and environment.

The simplest method which has been developed in both the Izod and Charpy tests is to break the specimen with a pendulum and measure the energy absorbed. The Charpy test is essentially a high-speed three-point bending test. In a brittle material, the force exerted by pendulum increases linearly with deflection, and the crack begins to propagate. Once the crack has initiated, no further energy is required from the pendulum, crack propagation is maintained by energy already stored in the specimen, therefore it is clear that the impact strength is basically a measure of the energy absorbed in bending the Charpy bar to the point of crack initiation, in addition, a small proportion of energy abstracted from the pendulum is converted into kinetic energy of the two halves of the specimen

The energy required to break the specimen is determined from the pendulum weight, the height from which it dropped and the height which it reached after impact. The impact strength is defined as the energy to break, with units such as (k J .m^{-2}) or (ft .Ib/in^{2}); from the definition of the impact strength the following relation was proposed:

Impact Strength = Energy of fracture /Cross section area …………………(2.1)

2.11.2. The Tensile Test:

The ability of a material to withstand forces tending to pull it apart is called tensile strength, also may be defined as the maximum tensile stress sustained by the material being tested to its breaking point.

In the tensile test, the specimen was subjected to a continually increasing uniaxial tensile force while simultaneous observations were made on the elongation of the specimen. The tensile strength is the maximum tensile stress of the material and can be found by applying equation (2.2).

Stress = AF ……………………………………...……………………….. (2.2)

Where:

F = applied Force (N)

A= cross section Area (mm^2)

2.11.3. The Hardness Test:

Hardness is a mechanical property which represents the resistance of the material to penetration and scratching, it is measured by the distance of indentation and recovery that occurs when the indenter is pressed into the surface under constant load.

Hardness can be expressed in several ways. There are four methods used to express the resistance of materials to indentation based on different concepts of measurements, shore hardness, diamond pyramid hardness, Brinell hardness and Rockwell hardness.

2.11.4. The Flexural Test:

The flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material’s stiffness when flexed. Since the physical properties of many materials can vary depending on ambient temperature, it is sometimes appropriate to test materials at temperatures that simulate the intended end use environment.

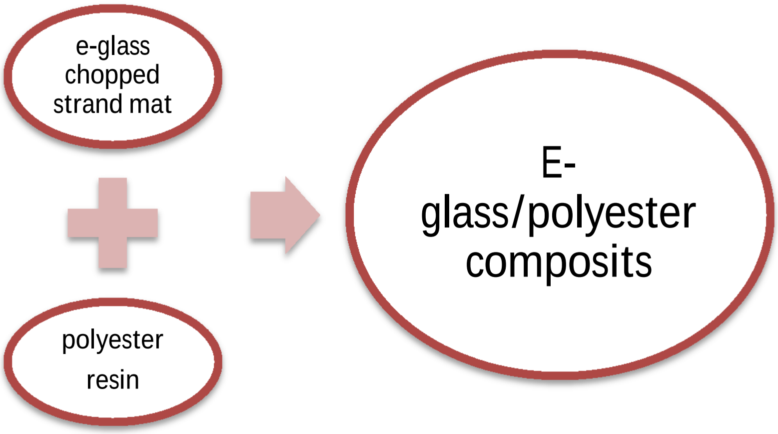
Most commonly the specimen lies on a support span and the load is applied to the center by the loading nose producing three points bending at a specified rate. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and are defined differently by ASTM and ISO. For ASTM D790, the test is stopped when the specimen reaches 5% deflection or the specimen breaks before 5%. For ISO 178, the test is stopped when the specimen breaks. Of the specimen does not break, the test is continued as far as possible and the stress at 3.5% (conventional deflection) is reported.

3. Chapter 3

Materials and Methods:-

3.1. Materials:-

In this study the composite used containing:-



3.1.1. E-glass chopped strand mat:-

Chopped strand mat (ECM1-450E/127) is manufactured by glass fiber technology co.ltd (GFT) mad from e-glass chopped strand bonded with emulsion binder designed for use in orthophthalic and isophthalic polyester resin systems. The E glass fiber supplier from (Alain company).

Table 3.1:

ECM1	GFT Code
540	Density(g/m^2)
E	Emulsion bonded
127	Mat width in cm

Chopped strand mat is primarily use for lay-up (HLU) process , filament winding (FW) process and press molding of fiber reinforced polymer products that includes water tanks, boats, pipes, shelter building materials ,automobiles and other fiber reinforced polymer products.

Typical data:-

E-glass chopped strand mat properties (standard) show in this table 3.2 blow:-

Properties	Value
Weight (density)	450 g/m^2
Tensile strength (MPa)	196 Mpa
Loss on lgnition (%)	3.75 $\%mass$
Residual Moisture	0.02 $\%mass$
Width standard	127 cm

Source: chopped strand mat, glass fiber technology co.ltd (GFT), Technical Data sheet.

3.1.2. Polyester resin:-

Polyester resin and hardener code and pack size (13552-1kg)) is manufactured by Global paint company Polyester resin and hardener is many use include repairs to fiber glass products , sealing cracks and other products.

Table 3.3: The basic Technical data of the Polyester resin

Viscosity	2.5-2.7 p
Specific gravity	1.12
Gel time	15-20 mints
Mixing ratio	2 %hardener by weigh
Storage	Store in cool dry place

Source: from chem. Spec, Global paint company,F40 Reinforcing resin.

3.2. Method:-

In this research, we used four testing to study some properties for fiberglass/polyester composite. The samples describe below was tested in national research center and mechanical engineering department at SUSTCH.

Tensile test:-

Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. If a material is to be used as part of an engineering structure that will be subjected to a load, it is important to know that the material is strong enough and rigid enough to withstand the loads that it will experience in service.

As a result engineers have developed a number of experimental techniques for mechanical testing of engineering materials subjected to tension, compression, bending or torsion loading.

The most common type of test used to measure the mechanical properties of a material is the Tension Test. Tension test is widely used to provide a basic design information on the strength of materials and is an acceptance test for the specification of materials. The major parameters that describe the stress-strain curve obtained during the tension test are the tensile strength (UTS), yield strength Or yield point (σy), elastic modulus (E), percent elongation (ΔL%) and the reduction in area (RA%). Toughness, Resilience, Poisson's ratio(ν) can also be found by the use of this testing technique**.**

Equipment

A universal testing machine (Hegewald&Peschke) The most common testing machine used in tensile testing is the *universal testing machine*. This type of machine has two *crossheads*; one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. The universal testing machine showing in figure (3.1).

Figure (3.1) a universal testing machine

Sample Preparation:

Composites laminated were fabricated at room temperature in shape of rectangle plates by hand layup technique proper care was taken during fabrication of laminates to ensure uniform thickness minimum voids in the material and maintain homogeneity.

The laminates were fabricated by placing the glass fiber one over the other with a matrix in between the layers. Tools were used to distribute resin uniformly, compact plies and to remove entrapped air.

The surfaces of the laminates were covered with 25 micron Mila film to prevent the layup form external disturbances. The laminates were cured in room temperature and at constant pressure for two days.

The laminates were cut to suit ASTM dimension by a band saw cutter and edges were ground.

Table (3.4): tensile specimen geometry Recommendations

Fiber orientation	**With mm(in)**	**Overall length, mm(in)**	**Thickness ,mm(in)**	**Tab Length, mm(in)**	**Tab thickness, mm (in)**	**Tab Bevel $Angle^{\circ}$**
Random discontinuous		**250(10.0)**		**Emery cloth**	**–**	**–**

Figure (3.2) Test configuration

Testing procedure:-

A thin flat strip of material having a constant rectangular cross section is mounted in the grips of a mechanical testing machine and monotonically loaded in tension while recording load.

The ultimate strength of the material can be determined from the maximum load carried before failure. If the coupon strain is monitored with strain or displacement transducers then the stress-strain response of the material can be determined,

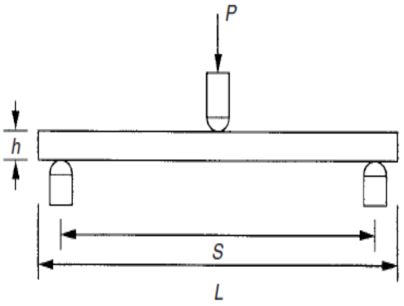
from which the ultimate tensile strain, tensile modulus of elasticity, Poisson’s ratio, and transition strain can be derived.

3.2.1. Flexural tests (Three-Point Bend Testing):-

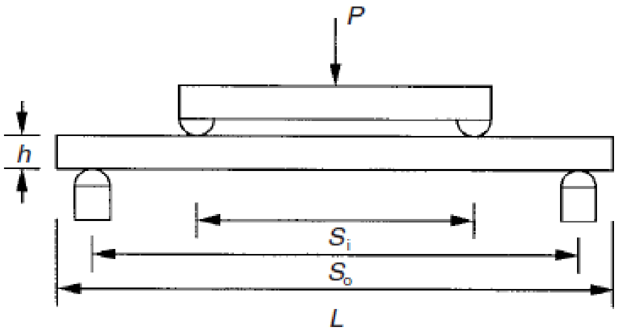
The use of flexural tests to determine the mechanical properties of resins and laminated fiber composite materials is widespread throughout industry owing to the relative simplicity of the test method, instrumentation and equipment required. It is also possible to use flexure tests to determine the interlaminar shear strength of a laminate (using a short beam), Flexure may also be used to evaluate the interlaminar fracture toughness of laminates, as described in, and to assess the stiffness, strength behavior of more complex structures.

The two methods most usually used for the determination of flexural properties of laminates are:

1. Three-point bend tests.



2. Four-point bend tests :



The three point bend test was chosen to carry out all the testing. This choice was made for the following reasons:

(1) The testing apparatus has a simple setup, and does not require any complicated hardware or equipment and.

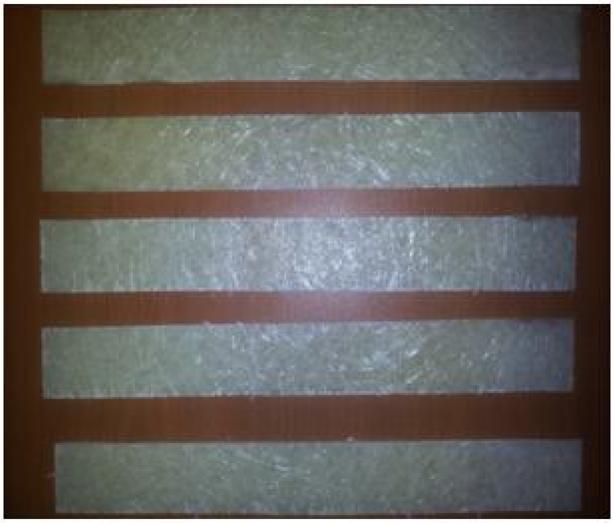
(2) The results are relatively easy to interpret.

The three point bend test usually yields good results for material characterization of composites (such as lamination module of elasticity, laminate stresses, etc.).

Test specimens:-

Four specimens of composite were prepared and tested. The specimens were cut according to ASTM-D790. Rectangular specimens with thicknesses of 3 mm, Table (3.5)Error! Reference source not found.The details o f the specimen

Test	Total Length mm	Span Length mm	Width mm	Thickness mm
3-point penetration	250mm	150mm	3mm	3.63mm



Testing procedure:-

A flat rectangular specimen is simply supported close beam between two supports with the load applied at the midpoint. **Error! Reference source not found.** shows a load configuration for a beam in three point bending test during the test. The data collected during testing is fed into a PC connected to the electronic universal tester machine.

Figure 3.3: Three-Point Bend Testing

Confirming the maximum flexural stress was calculated and recorded using Equation 2, shown below.

$$\sigma = \frac{3PL}{2bh^2} \qquad (3.1)$$

Where

σ- Stress at the outer surface at mid-span of the specimen
P- Applied force
L- Specimen length
b- Specimen width
h- Specimen thickness

.

The distribution of shear stress is parabolic, with a maximum at the neutral axis and zero at the outer surfaces of the beam; the maximum value is given by Equation [7.2]:

$$\tau = \frac{3F_z}{2bh} \qquad (3.2)$$

Where;

F_z Is the shear force on the specimen cross-section.

The flexural response of the beam is obtained by recording the load applied and the resulting strain. The strain can be measured by bonding a strain gauge to the tensile surface of the beam, or by measuring the displacement at the center of the beam and assuming that beam theory applies, so that strains can be calculated. The bending moment, M, is a function of the measured load and specimen geometry.

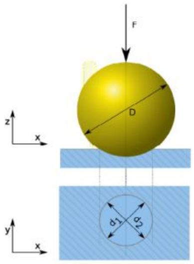
3.2.2. Hardness tests:

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting.

Hardness of materials has probably long been assessed by resistance to scratching or cutting. The usual method to achieve a hardness value is to measure the depth or area of an indentation left by an indenter of a specific shape, with a specific force applied for a specific time. There are three principal standard test methods for expressing the relationship between hardness and the size of the impression, these being Brinell, Vickers, and Rockwell. For practical and calibration reasons, each of these methods is divided into a range of scales, defined by a combination of applied load and indenter geometry.

Brinell Test Method

Testing procedure:-



Force diagram

All Brinell tests use a carbide ball indenter. The test procedure is as follows:

- The indenter is pressed into the sample by an accurately controlled test force.
- The force is maintained for a specific dwell time, normally 10 - 15 seconds.

- After the dwell time is complete, the indenter is removed leaving a round indent in the sample.
- The size of the indent is determined optically by measuring two diagonals of the round indent using either a portable microscope or one that is integrated with the load application device.
- The Brinell hardness number is a function of the test force divided by the curved surface area of the indent. The indentation is considered to be spherical with a radius equal to half the diameter of the ball. The average of the two diagonals is used in the following formula to calculate the Brinell hardness.

In former standards HB or HBS were used to refer to measurements made with steel indenters.

HBW is calculated in both standards using the SI units as

$$HBW = 0.102\frac{2F}{\pi D(D-\sqrt{D^2})} \quad \ldots\ldots\ldots\ldots (3.3)$$

Where:

F = applied force (N)
D = diameter of indenter (mm)
d = diameter of indentation (mm)

3.2.3. Impact testing:-

Charpy impact testing has been used for many years to test the impact toughness of various metals. The advent of modern composites brought about materials with properties that depend on their orientation. Consequently, new test methods had to be found to accurately test the directionally dependent impact resistance of composite materials. Since Charpy impact testing is both cheap and fast, its use was extended to composites. A Charpy impact test machine is shown in the following picture.

Figure 3.1 Charpy impact

Specimen Preparation:

The specimen that fits into the Charpy impact tester is rectangular with a notch cut in one side. The notch allows for a predetermined crack initiation location. Many composite Charpy impact tests are performed without the notch cut into the specimen. In these cases it should be noted in the experimental procedure if the notch is not present. A typical Charpy impact specimen is shown in the following figure.

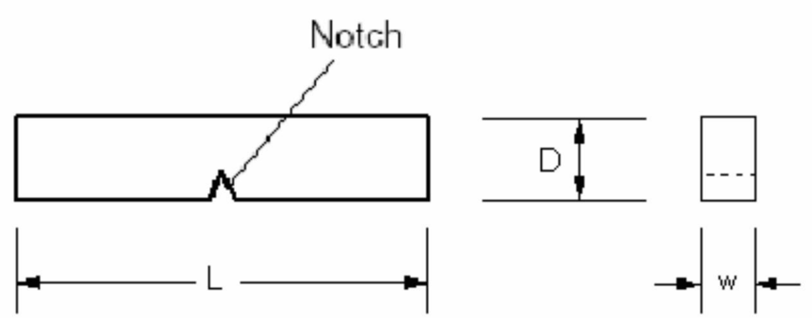
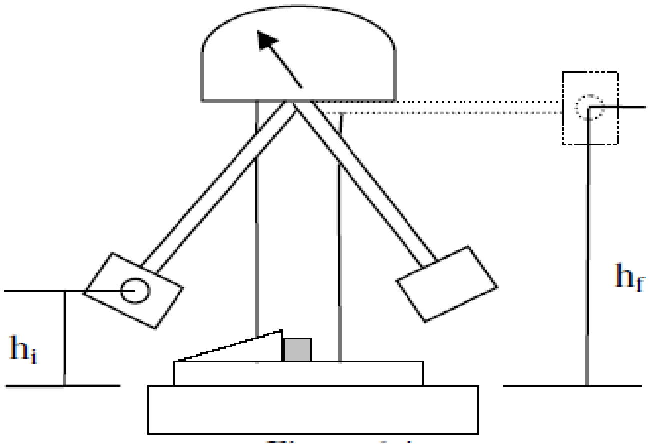


Fig Charpy impact specimen

Testing procedure:

The Charpy impact test method works by placing a notched specimen (with the notch facing away from the point of contact) into a large machine with a pendulum of a known weight. The pendulum is raised to a known height and allowed to fall. As the pendulum swings, it impacts and breaks the specimen, rising to a measured height. A figure displaying the process is shown below.



Charpy impact procedure

The difference in the initial and final heights is directly proportional to the amount of energy lost due to fracturing the specimen. The total energy of fracture is determined by

$\Gamma_{total} = mg(h_o - h_{f)}$……………………………………………………………… (3.4)

Where:

Γ_{total}= total energy.

m = mass.

g = gravitational acceleration.

ho = original height.

hf= final height.

3.3. Manufacturing of Glass-Reinforced Polyester Composites:

Several manufacturing techniques are used to creating GFRP laminates. Two major categories of manufacturing composites are open molding and closed molding processes. Open molding consists of laying fibers into an open mold and then applying resin. There are two methods of applying resin: lay-up molding and spray-up molding. Lay-up molding is used when complex shapes need to be produced and for the ease of adding inserts and stiffening (Figure 8).

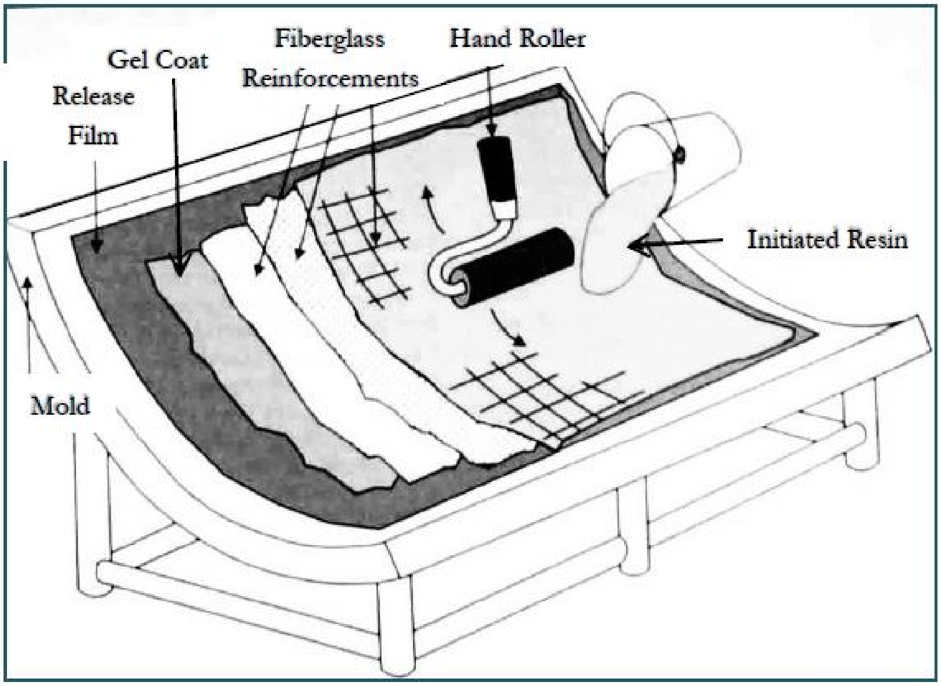
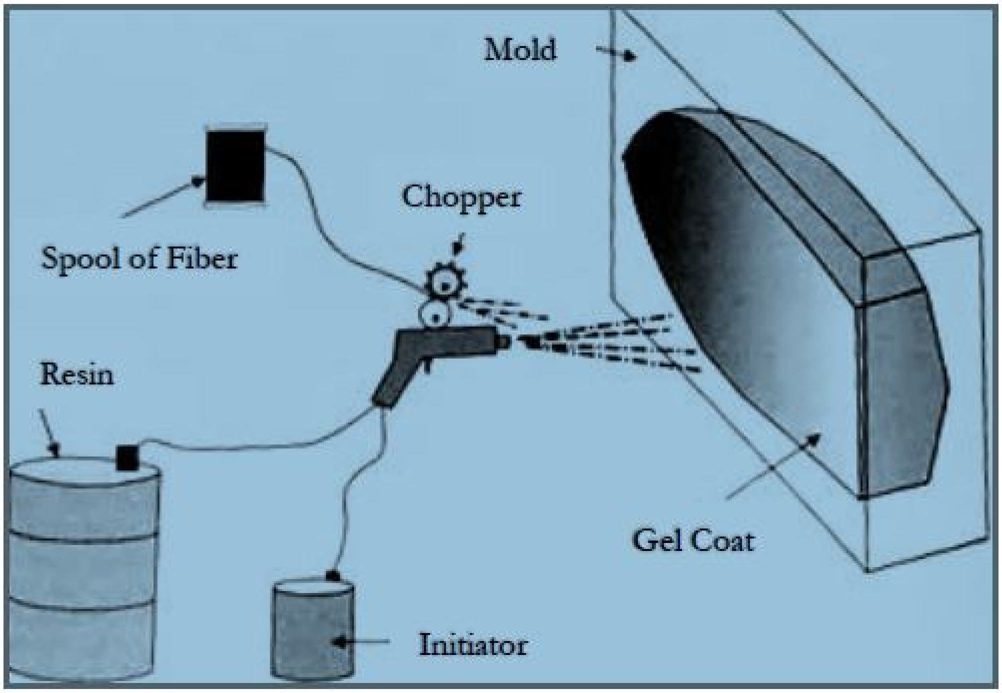


Figure 8: Hand lay-up process diagram.[3]

In the lay-up process, dry fibers are placed within a waxed mold cavity. Once all the dry materials are in place, the resin is applied with a hand roller. The hand roller is used to spread the resin and to remove any excess air within the fibers. Removing the air from the lay-up is critical for maintaining strength and decreasing the chance of crack propagation. Resin can also be applied to the fibers prior to being placed within the mold by using rollers or squeegees. Throughout the lay-up process, proper partthickness must be maintained to minimize shrinkage and to minimize the peak

Exothermic temperatures. If the desired thickness cannot be achieved in one lay-up, additional layers may be applied in a secondary bond. To maximize the strength between layers, the resins used in the secondary layer must be similar to those used in the first layer. Additionally, the secondary layer must be added before the primary layer is completely cured. The dual-layer associated increase in strength is due to the chemical bonding and adhering of the styrene between the two layers. If the first layer is allowed to cure for an excessive amount of time, contaminates can deteriorate the adhesion strength.

The second type of open mold processing is called spray-up molding. In sprayupmolding, glass strands are cut and catalyzed resin is sprayed from a chopper gun into a mold surface. Spray-up processing is typically used when parts are larger and less complex than those that use the hand lay-up process. The greatest advantage of the spray-up method is the decreased manufacturing time. Spraying both the fiberglass and the resin at the same time reduces the overall application time. The spray-up method has several disadvantages, including the need for special spraying equipment, a lack of control over fiber direction, and higher air pollution due to the atomizing of resin. Additional considerations for spray-up molding are that the spray equipment can only be operated by a trained operator, and that spray-up molding requires low viscosity resin to achieve proper wetting.



To apply the GFRP laminate, the operator sprays the resin and the chopped fibers onto the mold surface with an even coverage (Figure 9). If the coverage is not even, curing will occur at varying rates, which creates defects in the mold surface.

The length of the chopped fibers can vary between projects, but is typically is 1-3inches. The smaller fibers provide easier coverage around corners, but can weaken the part. Once the materials are sprayed on the surface, the surface is then rolled out as in the hand lay-up process. The rolling insures proper wet out and removes entrapped air which can cause voids in the finished composite.

As in the hand lay-up process, additional layers can be added to the primary layer to increase the overall thickness. The additional layers may contain dye to distinguish them from the others, and must be added after the surface is mechanically abraded. This abrasion increases the mechanical bonding of the layers, but disrupts the chemical bonding that should take place between layers.

4. Chapter 4

Results and Discussion

The results show that the flexural behavior of the composites depends on several factors, such as fiber orientation, laminate stacking, surface waviness and moulding temperature. ISO 527.5-1997 Plastics-Determination of tensile properties

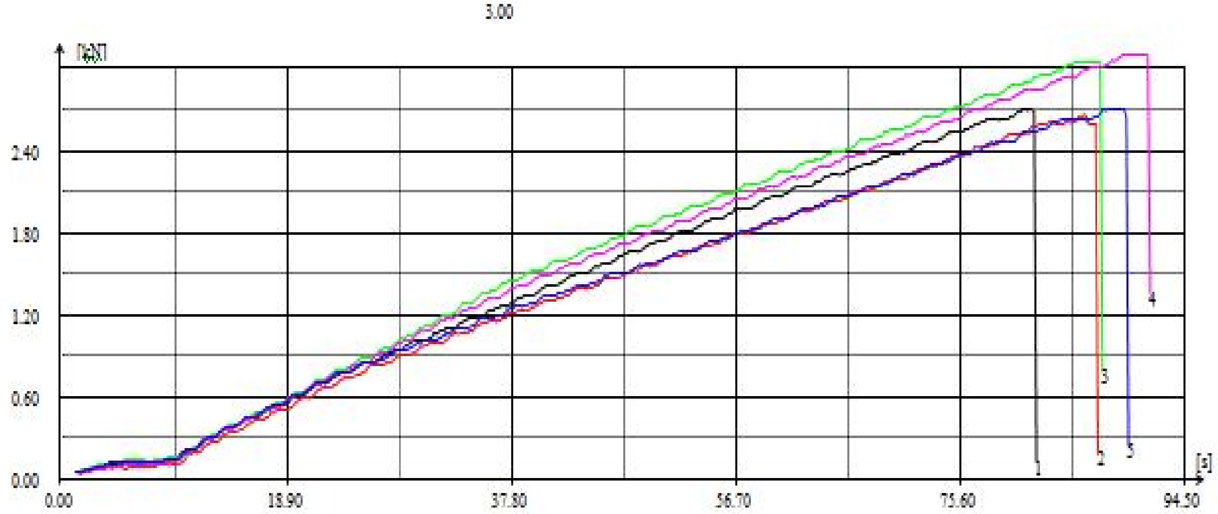
4.1. Tensile test:-

The tests were conducted in the same order as the specimens were prepared so that the time between preparation and testing was the same for all bars. A universal testing machine was used for the tests. The top end of the specimen was fixed by the grips on the top cross-head of the machine while the bottom end was not fixed before applying the load. A slotted steel plate was placed between the top of the bottom anchor and the bottom of the middle cross-head. When the specimen was loaded, this plate engaged the bottom anchor. The load was applied at a constant speed until the failure of the specimen

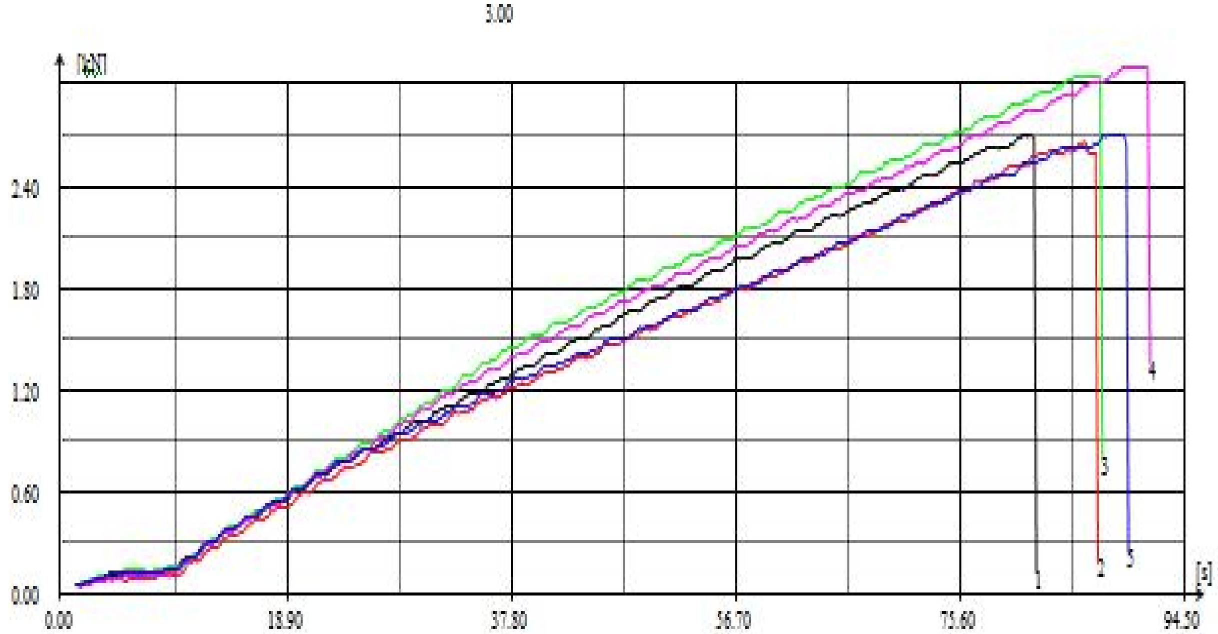
All specimens failed suddenly as expected, the result show for the random the type of the failure was crack. All the failures start with splitting and end with rupture of the every split into different numbers and sizes of pieces. This might also be related to the type of manufacture. Mean values were determined as given in Table [4-1] the results of the individual tests are reported in Table [4-1].

No.	Fm(kN)	ΣM(MPa)	ΣB(MPa)	EM(%)	EB(%)	Et(MPa)
tensile test 1	2.700	40.439	40.140	1.50	1.51	2841.844
tensile test 2	2.660	38.965	2.783	1.56	1.59	2383.731
tensile test 3	3.050	50.010	13.117	1.58	1.61	3828.266
tensile test 4	3.090	41.264	18.161	1.64	1.69	2916.244
tensile test 5	2.700	36.062	35.260	1.62	1.65	2184.648
Average	2.840	41.348	21.892	1.580	1.610	2830.947

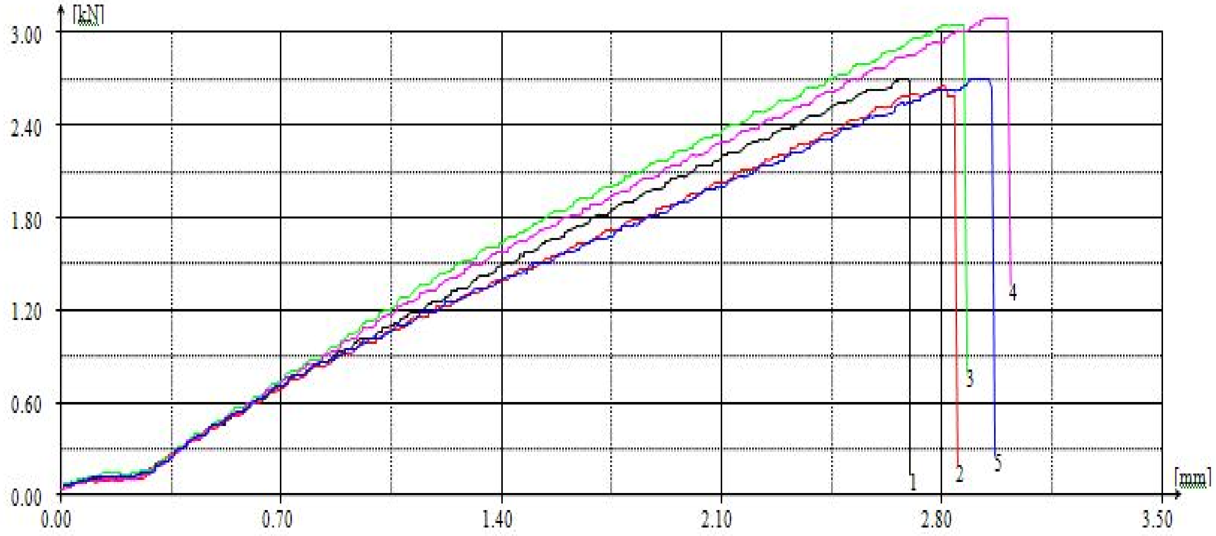
Load vs time:-



4.1.1. Load vs. Deformation:-



4.1.2. Load-displacement :-



4.2. Three point pending test:-

Results and discussions

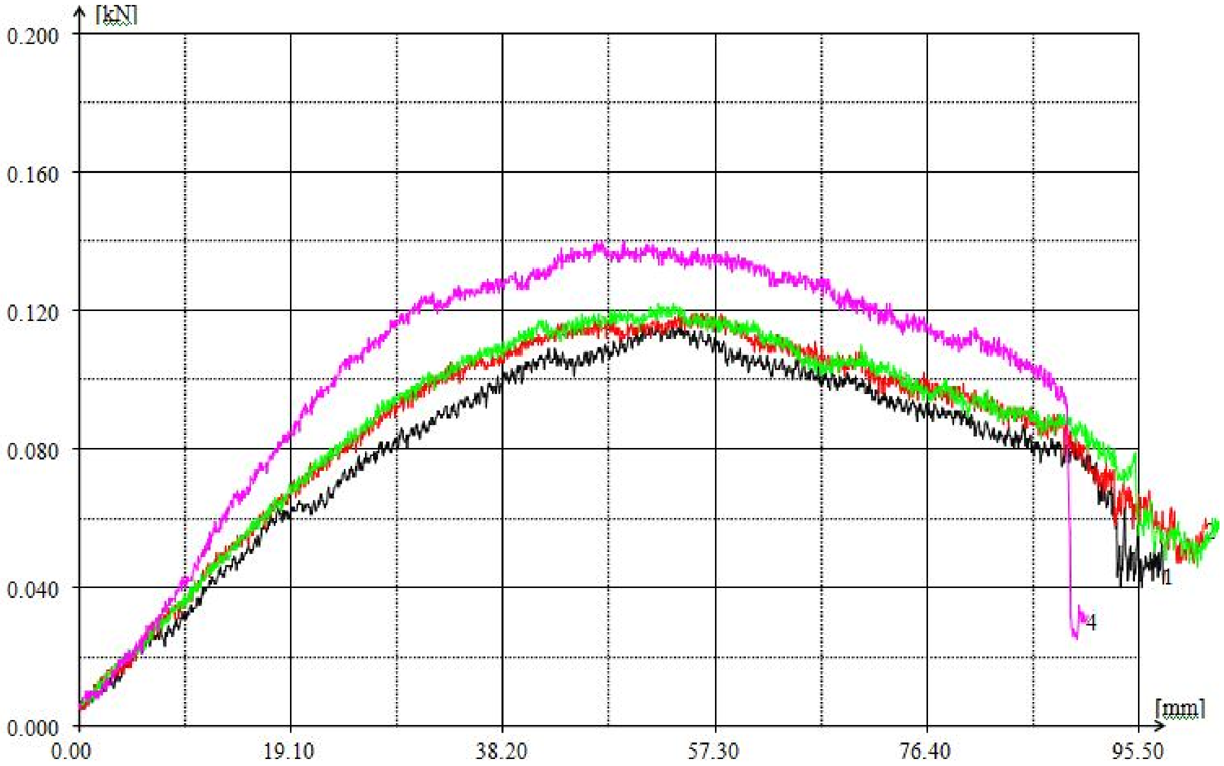
Section: rectangle
Area of section= 11.351mm^2
b= 3.290mm
L: 250mm
h= 3.450mm

No.	Pmax(kN)	Rb(MPa)	E(MPa)
fiberglass polyester 1	0.116	98.053	7461.220
fiberglass polyester 2	0.119	110.661	7393.360
fiberglass polyester 3	0.122	120.096	8447.935
fiberglass polyester 4	0.140	1340.680	131426.872
Average	0.124	417.373	38682.347

The experimental result of the three point pending test of the matrix composite structures is discussed in the following subsections. The load-displacement behavior and the failure mode of the glass fiber composite are discussed in detail.

4.2.1. Load-displacement behavior:-

The load-displacement curves were recorded for the specimens in the three point pending test. These curves were used to know the behavior of the failure modes of the composite structure. The curves obtained in the three point pending tests are shown in **Error! Reference source not found.**. All of the curves were similar in nature for the four samples. The curves show that linear in appearance can be explain the elastic deformation of the composites. In this region liner behavior with small deformation, this due to when the displacement of the load was affected in the composites, or this could be due to the wrinkling of the composites. When the load has reached a peak value, significant drop of the peak load (0.124KN) in the load–displacement curve was observed for all composites samples. This sudden drop suggested the matrix cracking. After the crack was initiated in tensile side, it propagated to the compressive side within the matrix in all specimens before the final failure occurred are shown in fig( ). After the matrix cracking, this was caused by decrease in stiffness resulting from the total failure of the matrix material which suggests that the matrix did not contribute to the overall stiffness of the composite structure. After the load drop, the specimen continued to sustain the load but never exceeded the previous peak load as only the fiber composite were carrying the load. The final failure occurs when the fiber crushes due to compressive failure or in some case the fiber and the matrix debonding due to matrix shear failure.



Displacement(mm)

Figure 0.1 Load–displacement curves for three-point-pending tests of matrix composites .

4.2.2. Failure modes :-

Major damage modes in the composite panels in bending loads include matrix cracking, fiber-matrix deboning, matrix shear failure, fiber delamination, and fiber fracture. Such tailoring could alter the characteristics of the load transfer between the composite fiber and the matrix material by this means damage mechanisms.

Comparing the failure modes of matrix; it was observed that all composites structures have similar behavior of failure shows the pictures on the failure modes of unidirectional structure. Almost similar behavior like cross-ply was observed in other structures shows the *multiple* crack generation in the matrix . The *multiple* cracks were generated along the tensile side of the specimen. All cracks propagate toward the compressive side of the specimen. However, the final failure occurs when the upper fiber crashed and the fiber-matrix undergoes debonding.

shows the single crack generation in the matrix composites with. The crack initiated close on the tensile side and had propagated to the compressive side. During this process of crack propagation, debondingbetween the matrix and fiber was also observed before fiber failure. However, the final failure occurs when the fiber crashed and the fiber-matrix suffers debonding.

Crack propagations of matrix structures during three point pending penetration are shown in figure (**)**. From figure ( ), it can be observed that the crack initiates close to the point of support along the tensile side and propagates toward point of contact on the compressive side that means in this structure the cracking width found to be bigger than other structures This behavior was quite evident from the load-displacement curves as shown in figure( ).

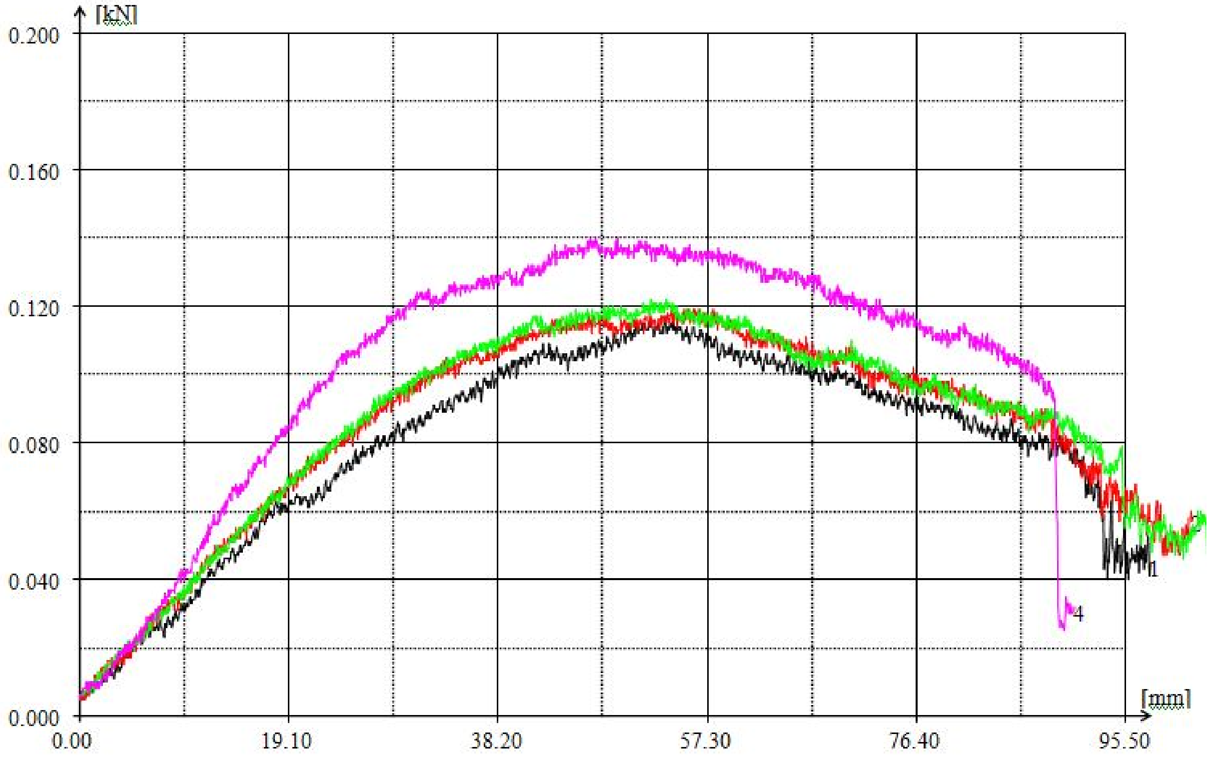
The failure mode of the composites structure materials tested under bending conditions can be summarized as tensile/compressive failure followed by the splitting of the matrix material. The sudden failure of the specimen during three point pending as mentioned earlier occurs because the load transferred to the matrix is more than its strength at the instant of fiber failure. Since matrix materials generally have lower mechanical properties than fiber due primarily to their lower density, they substantially affected the damage initiation characteristics and the local indentation behavior of the composite panels. This led to the matrix failed before the fiber.

4.2.3. Summary

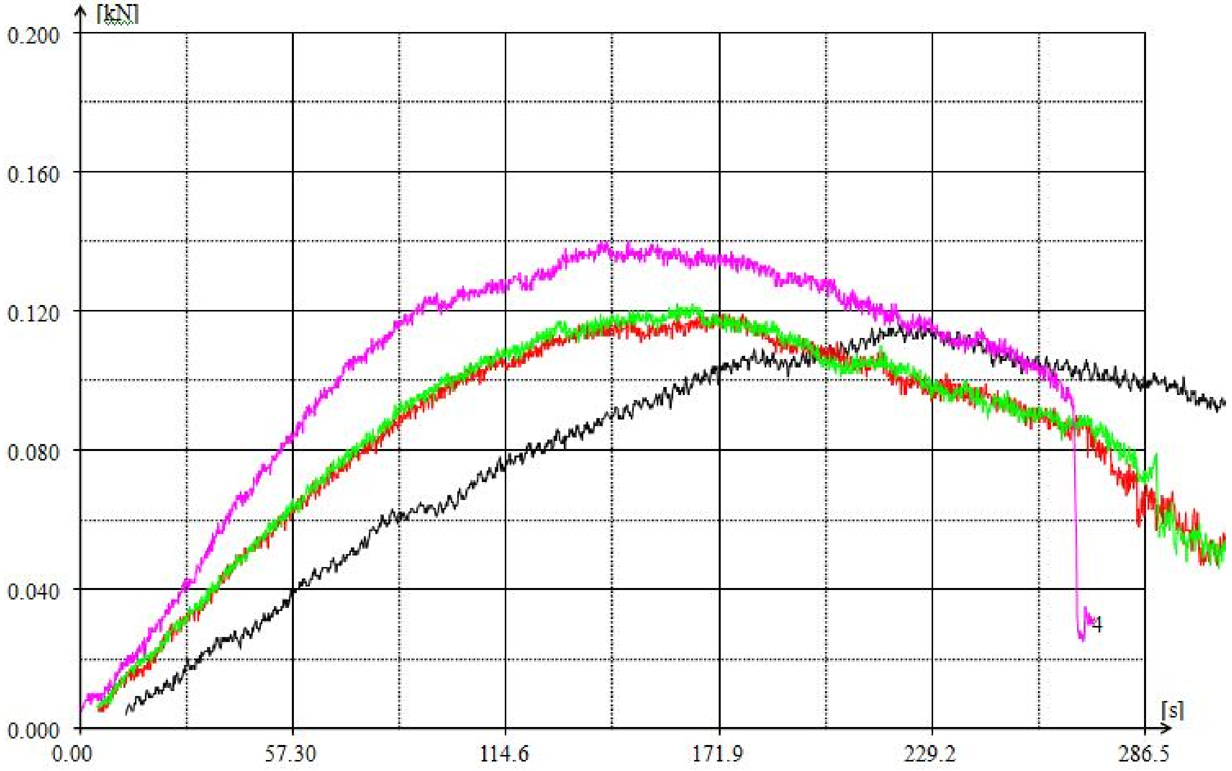
The (pending) behavior and failure mechanisms of for fiberglass/polyester composite have been studied, experimentally. The load carried by the composites structure initially increases linearly while the matrix and fiber are being stressed.

The experimental investigation showed that under pending loading, the composite failed with sudden brittle type failure due to shear failure of the matrix and compressive failure of the fiber followed by debonding between the fiber and the matrix.

Load-Deformatio



Load-Time:-


[kN]
0.200
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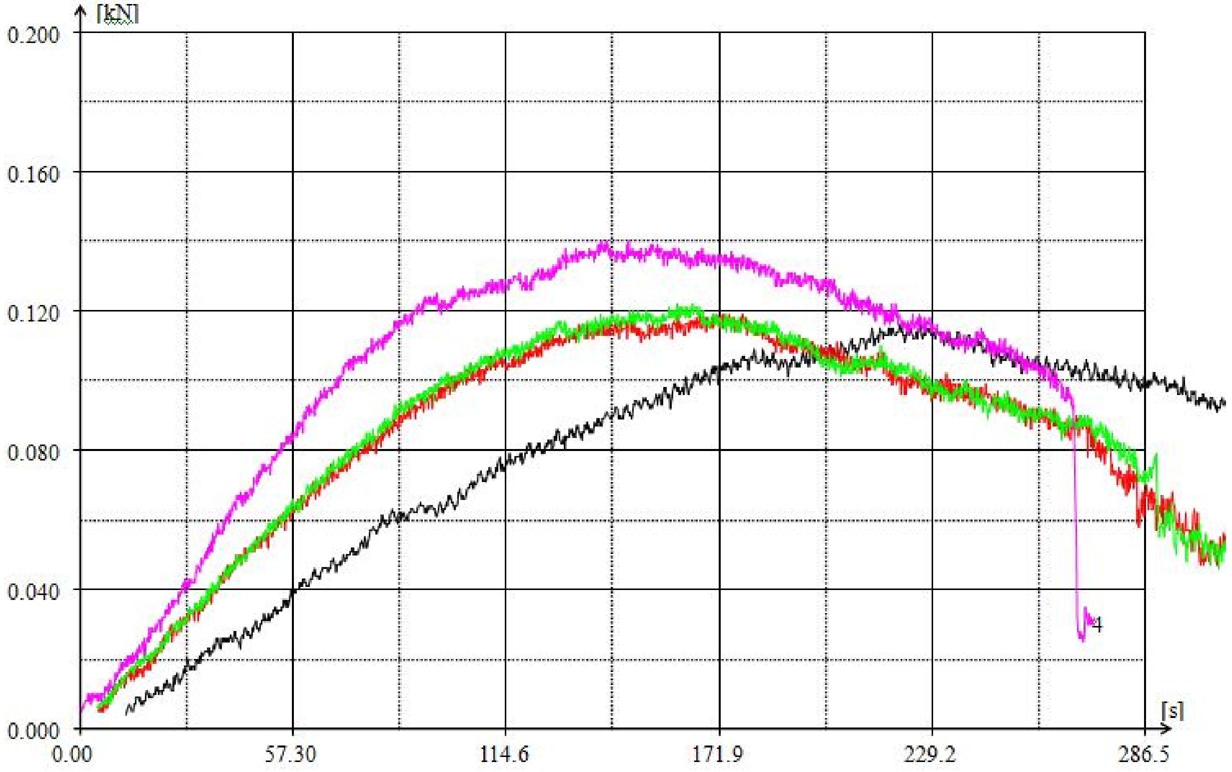
0.00
57.30
114.6
171.9
229.2
286.5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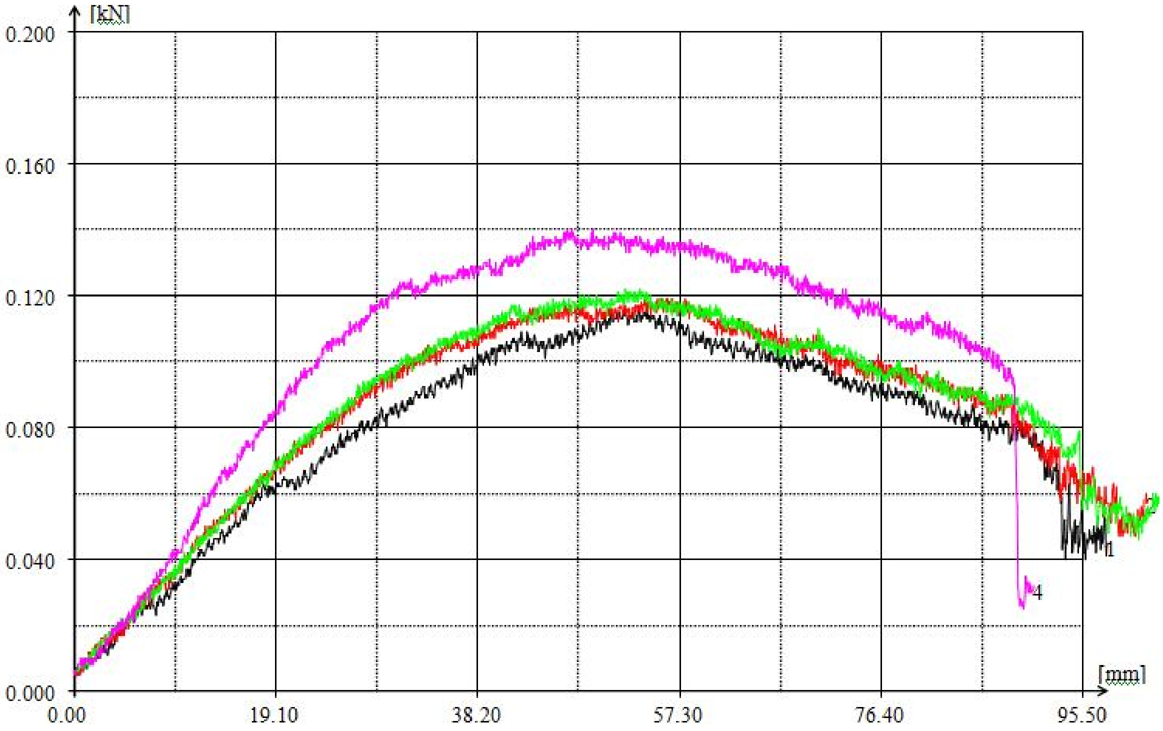
Load-Displacement:-



4.3. Hardness test :-

Load (kg)	BHN
10	0.0579
20	0.0723
25	0.0236
35	0.049
45	3.209

4.3.1.Failure modes

Comparing the failure modes of fiber reinforced compositsit can be observed that all composites structures have similar failure behavior. At low load applaed , the top face sheets failure and for the medium loads levels, the top face sheets completely failed leading to the penetration of the indenter within the matrix and contact with the bottom face sheets. Whereas, in the case of high loads levels the matrix of composites failed due to the indenter penetration. The damage size increased with the increase in the loads levels within all composites loads.

The manufacturing defects in the laminates played an important role in the failure mode of the composites structures. The defects like the non-uniform distribution of the resin in the samples, the bonding between the overall layers (poor adhesion) of the composite, and the void defects, were observed in the cross-section images as shown in figure ( ) to figure( ). These defects can cause delimitation and de bonding under load conditions, and also affected the mechanical behavior of composite such as the stiffness and strength.

4.3.1. Damage parameters

Indicates the damage parameters for matrix of composites samples face sheets at 20, 25, 35, and 45 kg loads levels. Illustrate the pictures the matrix and fiber composites. Table ( ) and figure ( ) results show that the penetration depth becomes deeper with increasing loads applied.

4.3.2.Damage size

The pictures in figure ( ) illustrate the experimental of the top surface for glass fiber reinforced composites. From these figures, it should be concluded that the obtained damage size agrees well with the experimental ones. The damage size increased with an increase in the load levels within all loads. highest loads showed largest damage size in the top face of composites. However, low loads showed smaller damage size.

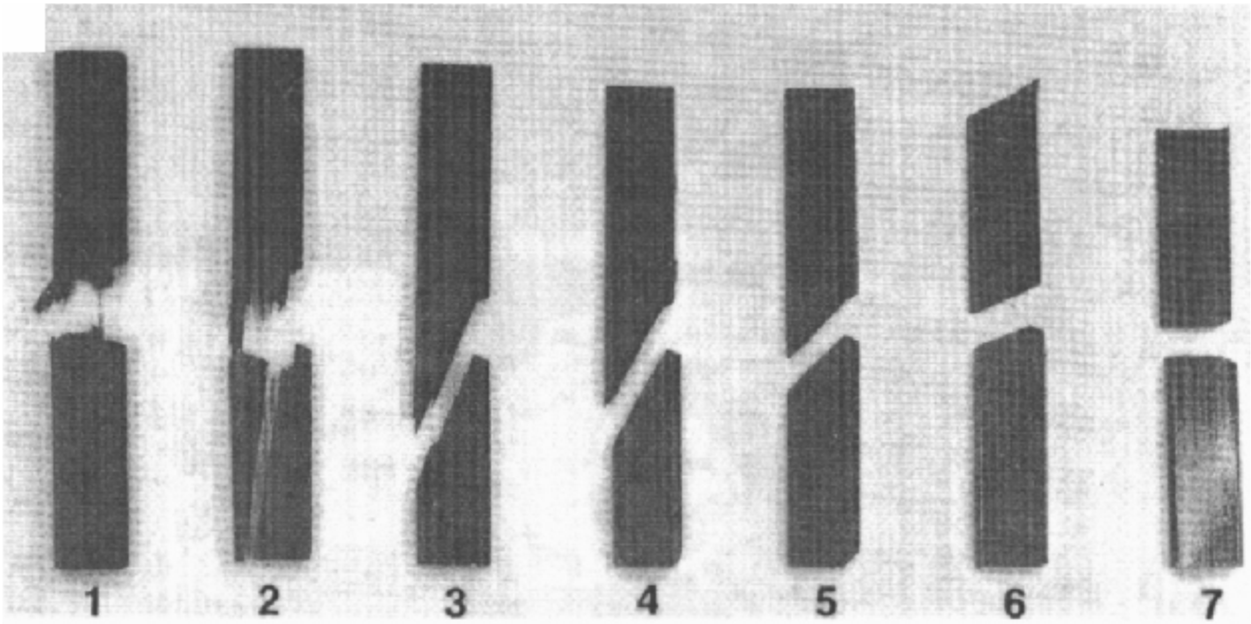
4.4. Charpy Impact test:-

α_1	α_2	Impact energy (J)	Absorbed energy (J) p
162	0	15	15.043
162	43	13	12.988
162	81	8.5	8.588
162	65	10.6	10.625

The failure types for composite Charpy impact tests depend on the specimen orientation. Often, specimens exhibit fiber fracture and fiber pull-out, while other times delamination failure is the primary failure mode. Examples of post fracture Charpy impact specimens with different failure modes are shown below.

Specimens were tested with lay-up angles of 0, 43, 65 ,81 and 90 degrees (from left to right in Figure 6.5).

It is possible to see that specimen 1 failed from fiber breakage and pull-out. Specimen 2 failed from a combination of fiber pull-out and fiber-matrix separation, and specimens 3-7 failed at the fiber-matrix interface. Composites therefore may need to be tested in different fiber directions due to the anisotropy of the material. The failure type is important when characterizing composites.



Picture of failed composite Charpy impact specimens

4.4.1.energy absorbed

The energy absorbed by elastic deformation of the fiber glass reinforce composite was calculated from the charpy formula that present in chapter 3. The absorbed energy increased with the decrease of the angle after the damage ( ). It shows that in the case of low angles (0&43^{o}) the absorbed energy was so high (15J), and in the medium, the absorbed energy was almost high. In the case of high angles (80-90^{o}) shows the minimum energy absorption.

4.5. Factors which effects to damping property:-

4.5.1.Fibers properties:-

The fiber properties which relate to damping are alsoE_1 and E_2.Generally, the amount of E_2 in these fibers is quite small and so their internal energy loss is not usually considered to contribute directly to damping, at least in comparison to the matrix. The damping flexural module different in the fibers and when the storage module high the fiber has high damping but depend on the type of fibers, stacking sequence and their mechanical properties.

4.5.2.Interactions between fibers and matrix

The damping arising from the interactions between fibers and matrix can be very large and are quite complicated because so many different aspects of composites affect the interactions. For instance, the damping arising from the interactions can be affected by fiber length, fiber orientation, and interface effects. Within almost any reasonable fiber length range, the effect of length on damping is small. What little effect there is, seems to suggest that shorter fibers give slightly better damping, probably because there are more ends and, therefore, more interactions with the matrix.

4.5.3.Stacking sequence effects

In this present work we used two types of laminated stacking sequence, quasi-isotropic and unbalance stacking sequence. The results shows that the quasi-isotropic has high tan delta than unbalance sample due to the stacking sequence different and have effect to total amount of the damping on composite laminated and also have high storage module .When a laminate is impacted on its surface, the sequence of stacking can affect the amount of energy that is transmitted from one fiber layer to another. The maximum amount of energy transmission occurs when the layers are aligned, and the minimum energy transmission occurs when the layers are orthogonal (90from each other). When the energy is not transmitted, it is Type equation here.either converted to heat in the region between the fiber layers (thus causing damping) or it is rerouted into a sideways transmission (thus causing delamination). Therefore, the fiber sequences that improve damping are the same as those that make delamination worse. The optimum overall condition might be achieved, therefore, by using a sequence in which the angles between the layers are more than 0but less than 90.

4.5.4.Temperature effects

Through the experiments of the damping property we found that if the temperature that used in the test increase then some of the properties of composite laminated changed such as storage module, loss module, and tan delta. At the different temperatures considered, the damping properties of the composites as function of fiber orientation are fairly well investigated to the evaluation of the different energies dissipated in the materials. explain the effect of degree of the temperature on loss module and storage module, if the temperature increase or decrease , the storage module and loss module will be changed.

5. CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1. The Conclusions of this study are summarized as follows:

FRP composites are composed of two materials or phases joined or connected to each other in such a way to give a combination of properties that cannot be attained otherwise. The properties of the individual components, the relative amount of phases, the orientation of various components, the degree of bonding between the phases, the size, shape and distribution of the discontinuous phase are very important in determining the properties of composite.

Fiber-reinforced polyester composites provide improvements in strength, stiffness and toughness. They also could have corrosion resistance in different hostile environments. By using different glass fibers electrical resistivity is controllable also. Fibers typically have low densities, giving high specific strength and specific modulus, but they often are brittle. Fibers can be continuous or discontinuous. Discontinuous fibers with high aspect ratio produce better reinforcement.

The composite panels were subjected to static and impact loading using Product Computerized Universal Testing Machine. The load-displacement and the load-time curves have been obtained to characterize the failure mechanisms in the glass fiber reinforcement composites.

Tensile test, the type of failure in glass fiber/polyester composites werecrack and the fiber pull out this due to fiber orientation.

Three point bending. The failure mode of GFRC tested under bending conditions can be summarized as tensile failure, compressive failure followed by the cracking of the matrixes material.

It was found that hardness does not affect the strength of adhesion in composite laminates. These results suggest that the use of this particular resin-fiber system could eliminate the sanding manufacturing step used during lamination.

5.2. Recommendations:

From our study we recommend that:

1. Preferably use glass fiber tanks instead of iron and plastic tanks because it has better properties.
2. Use woven fiber glass tanks instead of random fiber glass tanks.
3. The use of vacuum method instead of hand-lay up method.

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