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Study of mechanical behaviour of surface mat tissue glass fiber polyester resin composites

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Abstract

Having favourable properties like high specific tensile and compressive strength, controllable electrical conductivity, low coefficient of thermal expansion, good fatigue resistance and suitability for the production of complex shape materials, glass fiber-reinforced composites are very widely used. They have become the alternatives of conventional structural materials in many applications such as car industry, aircraft fabrication, wind power plant, boats, ships, pipelines etc. The objective of present work is to evaluate the mechanical properties of hand lay-up of surface mat tissue GFRP panels. The GFRP specimens have been fabricated at different numbers of layers with different ratio of fiber and matrix of 15, 12 and 8 layers. The rectangular straight sided samples are fabricated as per to ASTM. The optimized format of specimen is prepared for the ASTM using hand layup techniques to achieve the goals towards the applications and uses of composite materials. The fabricated composite are tested by Instron UTM for the purpose of evaluating tensile strength, compressive strength and flexural strength. It has been noticed that the mechanical properties of the composites are also greatly influenced by the fiber orientations.

***Keywords*—**GFRP, Matrix, Fiber, Resin, ASTM

1.Introduction

The concept of composite materials means combination of two or more materials in such a way that the resultant material has quality superiority over the individual constituent materials. The nature also follows composite the structure in most of construction like wood and bones. In wood cellulose serves as fiber and lining as matrix, in bones where collagen as fiber and apatite as matrix.The objective of the research work is to observe better the surface mat tissue GFRP composites by means of characteristics and machinability and to study the effect of loading on mechanical behavior of surface mat tissue glass fiber reinforced polyester based composites for evaluation of mechanical properties for the further development of new class of surface mat tissue glass fiber reinforced polyester matrix composite.Kalyana et. al.[1] have stated fabrication of specimen by hand layup method, it is impossible to remove voids and cracks inside specimen. Raw materials obtained were not of standard quality.Yeo et. al.[2] tensile property of hand lay-up plane-weave woven E-glass/polyester laminate has been investigated. The characteristic tensile deformation from the different lay-up arrangements and curing pressure has shown a relative significant. The elastic tensile stiffness and ductility parameters has been investigated and compared with the variations in the curing pressure and fiber lay-up arrangements. Their characteristic effects are consistent, and the structural arrangements of the fiber lay-ups have shown to adversely affect the ductility behavior of the glass GFRP composite. Therefore, the findings of these tensile characteristic dependence of E-glass woven GFRP composite can contribute to a better understanding in its applications.Shivakumar et al.[3] composite materials have a great potentiality of application in structures subjected primarily to compressive loads. Composite materials have attractive aspects like the relatively high compressive strength, good adaptability in fabricating thick composite shells, low weight and corrosion resistance.Malcom et. al. [4] the material characterization and failure evaluation of thick composite materials in compression is still an item of research. Glass reinforced plastics have wide application to naval & other vessels accompanied by application of conservative design safety factors due to limited durability data and to account for underwater shock loading. Increasingly GRP is being proposed for critical marine components such as masts, submarine control surfaces, transmission shafts propellers, & superstructures, submarine casings etc.Bijesh et. al.[5] with an objective to explore the potential of chopped glass fiber as a reinforcing material in polymer composites and to investigate its effect on the mechanical behavior of the resulting composites.

2.Characteristics of the matrix material and filler material

E glass fiber (surface tissue fiber), polyester resin, hardener and releasing agentswere used as raw materials to form the composite. Surface mat tissue glass fiber was reinforced with polyester resin which chemically in unsaturated form was used as the matrix material. Unsaturated polyester resin is a thermoset, capable of being cured from a liquid or solid state when subject to the right conditions like low temperature curing polyester resin. There is a whole range of polyesters made from different acids, glycols and monomers, all having varying properties. Most polyester resins are viscous, pale colored liquids consisting of a solution of polyester in a monomer which is usually styrene. The addition of styrene (hardener) in amounts of up to 50% helps to make the resin easier to handle by reducing its viscosity. The styrene also performs the vital function of enabling the resin to cure from a liquid to a solid by 'cross-linking' the molecular chains of the polyester, without the generation of by-products. These resins can therefore be molded without the use of pressure and are called 'contact' or 'low pressure' resins. Polyester resins have a limited storage life as they will set or 'gel' on their own over a long period of time. The cast of each composite is cured under a load of about for 48 hours before it removed from the mold. Then this cast is post cured in the air for another 24 hours after removing out of the mold.

Specimens of suitable dimension are cut using a diamond and carbide steel saw for mechanical testing.

Fig. 1 Matrix material

Surface mat tissue glass fiber is used as filler substance for its unique property Glass fiber surface tissue is mainly used in the surface layers of FRP products. It is capable of significantly improving the strength of FRP surface layer, strong impaction resistance, excellent uniformity of surface, good covering up the texture of under layers, and good corrosion resistance, construction of various water proofing structures

Fig. 2 Filler material

Table 1: Surface Mat Characteristics

Table For Hand Lay-up Type surface mat tissue glass fiber Characteristics.				
Item	Unit	SCC30H	SCC40H	SCC50H
Area Weight	g/m2	30	40	50
Binder Content	%	7	6	6
Tensile Strength MD	N/5cm	≥20	≥25	≥30
Soaking Time	S	≤10	≤15	≤20

3. Preparation of ASTM specimens

By using fabrication procedure precise and small dimensions cannot be produced but large rectangular plates of GFRP composites can be produced. Now desired specimen size was cut out of as the ASTM standard needs precise geometrical dimensions. The accurate length and width was obtained from cutting the large composite plate which was fabricated but in case of getting proper thickness for specimen it is needed to carry out an optimization work. So before producing any composite plates for the ASTM standard specimen the work on determination of amount of glass fiber layers (laminas) required for specific thickness. So a thickness optimization experiment to get what is the actual thickness of single lamina, first started with a single layer surface mat tissue glass fiber cloth (glass tissue lamina) and fabricated it with polyester resin. The fabricated composite was very thin can be measured by conventional measurement tools. Then we increased the number of surface mat glass tissue lamina to two and again fabricated it but the result was no different so by keep on increasing the glass tissue lamina finally we got something measurable in our measurement tool. The measurement of fabricated composite plate was 1-milimeter and the numbers of laminas are used four. So now the required thickness in terms of millimeters can be obtained by multiplying the four laminas e.g. 3mm required for ASTM d638 for the tensile test then the numbers of laminas required is (3x4=12) twelve numbers of laminas.

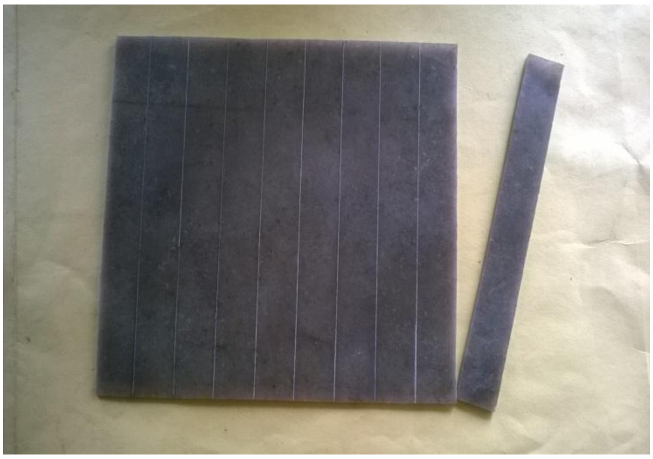


Fig. 3 ASTM-D638 Specimen

For ASTM standard d638 for tensile test large composite sheet was produced having 12 surface mat GFRP lamina having dimensions of length, width, thickness 200x200x3 mm with wt. percentage of GFRP to resin is 10 %. The individual specimen cut from the composite plates using carbide saw.

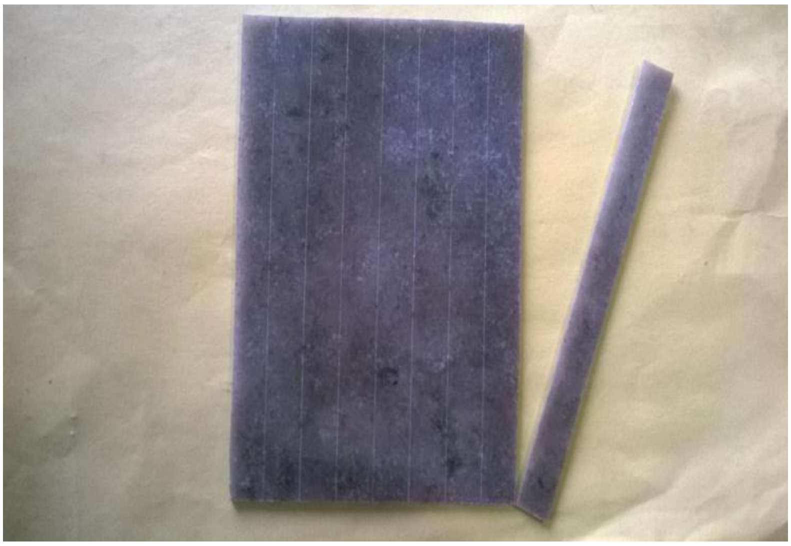


Fig. 4 ASTM-D3410 Specimen

For ASTM standard d3410 for compression test large composite sheet was produced having 8 surface mat GFRP lamina having dimensions of length, width, thickness200x150x2 mm with wt. percentage of GFRP to resin is 16 %.The individual specimen cut from the composite plates using carbide saw by a skilled technician.

Fig. 5ASTM-D7264 Specimen

For ASTM standard d7264 for flexural test large composite sheet was produced having 15 surface mat GFRP lamina having dimensions of length, width, thickness200x250x4 mm with wt. percentage of GFRP to resin is 22 %.The individual specimen cut from the composite plates using carbide saw.

4. Mechanical Characteristics

The characterization of the composites reveals that the loading is having significant effect on the mechanical properties of composites. The properties of the composites with different loading under this investigation were presented under three types of loading conditions tensile, compressive and flexural. When the force being exerted on the sample is known, we then that numberis divided by the cross-sectional area of our sample. The answer is the stress that our sample is experiencing,

$$\text{STRESS} = \frac{FORCE}{AREA}\ \text{N/mm}^2$$

4.1 Tensile Test

Deformation is simply a change in shape that anything undergoes under stress. Percent elongation is just the length the polymer sample is after it is stretched (L), divided by the original length of the sample (L_0), and then multiplied by 100.

$$\frac{L_0}{L} \times 100 = \%\ OF\ ELONGATION\ OF\ SPECIMEN$$

Ultimate elongation and elastic elongation are measured here. But for some other types of materials, like plastics, it usually better that they not stretch or deform so easily. To measure tensile modulus, the stress exerted on thematerial is measured, just like tensile strength. The amount of stress is increased slowly and then the elongation the sample undergoes at each stress level is measured. This is done until the sample breaks. The height of the curve when the sample breaks is the tensile strength, of course, and the tensile modulus is the slope of this plot. If the slope is steep, the sample has a high tensile modulus, which means it resists deformation. If the slope is gentle, then the sample has a low tensile modulus, which means it is easily deformed.For some polymers, especially flexible plastic composites, curves look like this

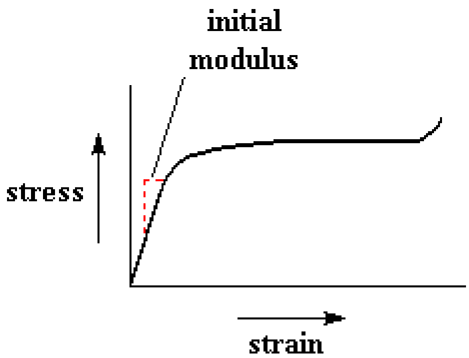


Fig. 6 Stress Strain Curve

Modulus is measured by calculating stress and dividing by elongation, and would be measured in units of stress divided by units of elongation. But since elongation is dimensionless, it has no units by which we can divide. So modulus is expressed in the same units as strength, such as N/mm^2.

4.2Compressive Test

The compressive strength is usually obtained experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen is shortened as well as spread laterally. This is known as the engineering stress and is defined by,

$$\sigma_e = \frac{F}{A_o}$$

Correspondingly, the engineering strain would be defined by,

$$\epsilon_e = \frac{l - l_0}{l_0}$$

4.3 Flexural Test

In flexural test flexural strength, also known as modulus of rupture, or bend strength is a material property, defined as the stress in a material just before it yields in a flexure test. The flexural strength represents the highest stress experienced within the material at its moment of failure. It is measured in terms of stress, here given the symbol (Ϭ). It is clear that the material will fail under a bending force which is smaller than the corresponding tensile force. Both of these forces will induce the same failure stress, whose value depends on the strength of the material.The resulting stress for a rectangular sample under a load in a three-point bending setup is given by the formula below the equation of these two stresses (failure) yields:

$$\sigma = \frac{3FL}{2bd^2} \text{N/mm}^2$$

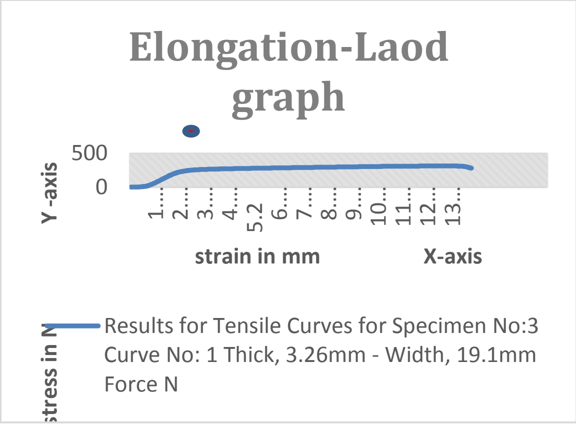
5. Results and discussion

This chapter presents the mechanical properties of the surface mat tissue GFRP composites prepared for this present investigation. Results of various characterization tests are reported here. This includes evaluation of tensile strength and flexural strength has been studied and discussed. The interpretation of the results and the other narration composite samples are also presented.

Fig. 7 Instron UTM

5.1 Tensile strength

Red dot represents the maximum elastic strength & Yellow dot represents the maximum ultimate strength.



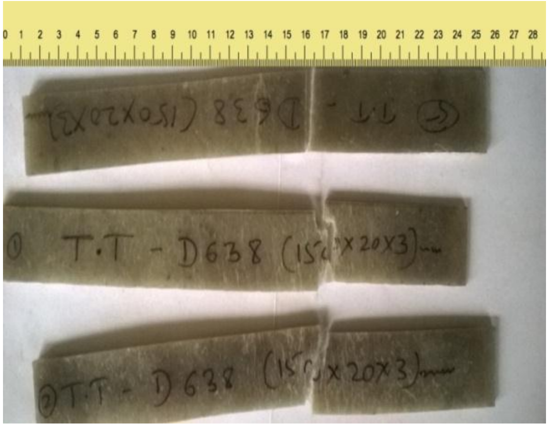


Fig.8 Tensile Test **Fig. 9 Specimen after Tensile Test**

By testing the composite specimen in ASTM standard d639 by the help of instron universal testing machine at a speed of 2mm/min the data obtained in a excel sheet when the data plotted in graph it appeared like this. From the graph we can notice that initially the specimen behave like an elastic material but when the stress is very high it behave like a ductile material so one of the advantage like this material is it never undergoes sudden failure.

Table 2: Elastic strength and ultimate strength

Dimensions	(i) Elastic strength	(ii) Ultimate strength
$L_0 = 150mm$	Elastic Load (F) = 248.4 N	Ultimate load = 314 N
	Elastic elongation ΔL= 2.84 mm	Ultimate elongation = 13.34 mm
b =19.1mm	Final length L=102.84 mm	Final length = 113.34 mm
	Percentage of elastic elongation=98.14%	Percentage of ultimate elongation = 91.83%
d = 3.26 mm	Elastic strain = 0.0189	Ultimate strain = 0.0889
	Elastic stress = 3.989 N/ mm^2	Ultimate stress = 5.042 N/ mm^2

5.2Compressive strength

This test method is designed to produce compressive property data for material specifications, research and development, quality assurance, and structural design and analysis. Factors that influence the compressive response and should therefore be reported include the following: material, methods of material preparation and layup, specimen stacking sequence, specimen preparation, specimen conditioning, environment of testing, specimen alignment and gripping, speed of testing, time at temperature, void content, and volume percent reinforcement. Properties, in the test direction, that may be obtained from this test method and in accordance to ASTM D3410 standard specimen size.By testing the fabricated specimen in instron universal testing machine at a speed of 2mm/min the data obtained in excel sheet when the data plotted in graph it appeared like this

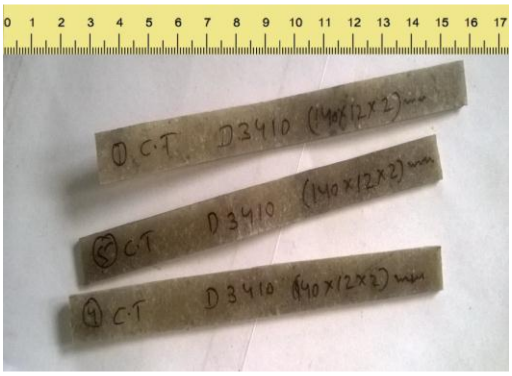


Fig. 10 Specimen after compressive test

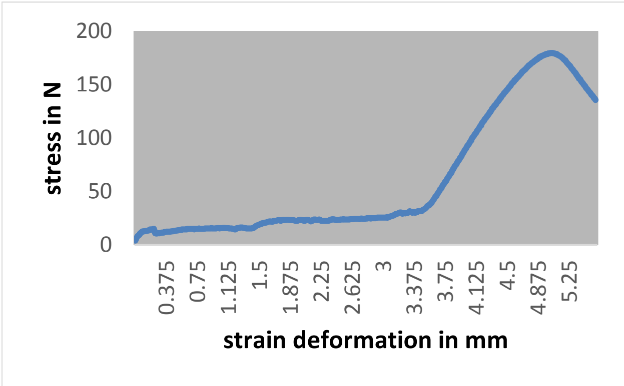


Fig. 11 Compressive Test

The graph shows that initially when the load is applied to it elastically deforming but after sometime it taking the load exponentially& finally buckling occurs to thecomposite fiber it leads to failure of the composites.

Table 3: Calculated data

Dimensions	Maximum load	Maximum deformation	Strain	Stress
L_0 = 140mm	179 N	5.062 mm	0.0631	15.1177 N/mm^2
b = 4.14 mm				
d =2.86 mm				

5.3 Flexural strength

Flexural strengths of the composites obtained experimentally from the three point bend tests. Composite materials used in structures are prone to fail in bending and therefore the development of new composites with improved flexural characteristics is essential.

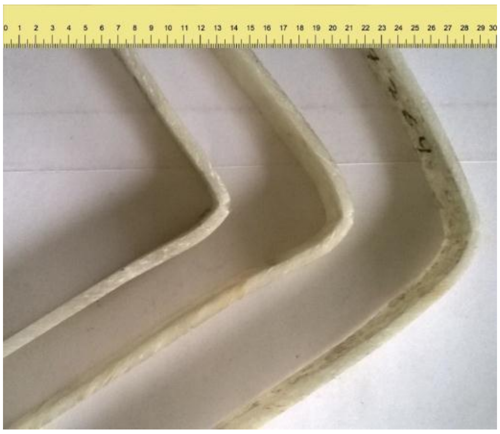


Fig.12Specimen after flexural test

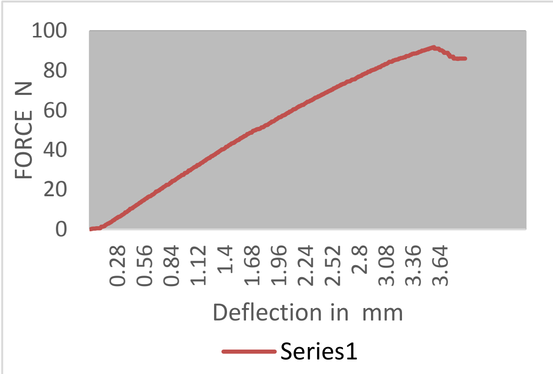


Fig. 13 Flexural test

Table 4: Results of load, bending and stress

Dimensions	**Results**
L = 100 mm	Maximum load = 91.75
b = 13.2 mm	Maximum bending = 3.585 mm
d = 3.16 mm	Bending Stress σ= 103.62 N/mm^2

6.Conclusions

This experimental investigation of mechanical behavior of surface mat tissue glass fiber reinforced polyester composites leads to the conclusions that the simple hand lay-up technique can be used for the successful fabrication of surface mat tissue glass fiber reinforced polyester composites with different loading. It has been noticed that the mechanical properties of the composites such as tensile strength, flexural strength and compressive strength of the composites are also greatly influenced by the fiber orientations. The mechanical properties can be enhanced by more sophisticated fabrication technique in an isolated environment like dust free environment.

7. References

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