



Effect of Fabric Design on Physical Properties of Composite

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Abstract: The effect of fabric design on physical property of the composites was experimentally investigated. Two woven fabrics (plain, twill) and chopped strand mat (CSM) are used as reinforcing materials for preparation of three different samples. The composite properties such as tensile strength, flexural strength, impact strength, water absorption value are evaluated. It has been found that the tensile strength of the twill woven fabric reinforced composite (T-C) is higher in comparison to the plain woven fabric composite (P-C) and Chopped strand mat based composite (CSM-C). Incorporation of nonwoven mat in CSM-C as reinforcing material with major fibre orientation in cross direction causes even flow of resin matrix through the structure enhancing the flexural and impact strength property. Water absorption by the composite is higher for P-C and T-C and governed by the fibre-matrix of the composite.

Keywords: Plain; Twill; Chopped strand mat; Polyester Resin; Volume fraction

I. Introduction

Weave is the common architecture of fabric and can be in various shape and configuration [1]. In the woven structure the fibres either in longitudinal or in transverse direction i.e. in warp or weft yarn direction. The most common weave is plain weave. The fibre bundle in warp and weft directions alternate between going over and under each other. The satin weave is more flexible weave because it has fewer interlacement points. The interlacement causes waviness of yarn in the fabric structure known as crimp. The crimp will affect the loading behaviour of the fabric as the yarn is first straighten out before it starts carrying load [2] Crimp is an important factor controlling the property of composite based on woven fabric reinforcement. The objective of this study to investigate the physical property of fibre reinforced plastics (FRP) as a function of weave parameters. This study is planned to start with two different weave (plain, twill) of two different crimps as compared with each other and chopped strand mat (CSM) fabrics.

II. Material And Methods

Glass fibre chopped strand mat system, Plain woven glass fibre fabric, Twill glass fibre fabric were used as reinforcements as mentioned in the Table I. Commercial grade general purpose polyester resin was used as matrix of the composite. For composite Preparation, methyl-ethyl-ketone-peroxide was used as catalyst. Various properties of the resin is also given in Table I.

Table I Shows the Properties of GP Polyester Resin and Reinforcing Fabrics

GP Polyester Resin		Reinforcing Fabrics			
Parameters	Value	Parameters	CSM	Plain	Twill
Appearance	Transparent Yellow	Vertical threads/inch (EPI)		48	36
Specific Gravity at 25°C	1.12	Horizontal threads/inch (PPI)		42	32
Viscosity at 30°C (measured in Brookfield RVDT-1)	485 cPoise	Areal Density (g/m ²)	450±20	400±30	450±30
Acid Value	22	Warp Tenacity		65.02 cN/Tex	47.76 cN/Tex
Volatile Content	36%	Weft Tenacity		55.02 cN/Tex	42.88 cN/Tex
Gel time at 30°C (2% Accelerator, 2% Catalyst)	8.15 min				

The samples were prepared by Hand Lay-up technique. In this process, layers are stacked one above another and are bonded together by unsaturated Polyester Resin mixture. When all the layers are laid one above another, a

definite pressure is applied on the top to consolidate the structure and kept for an hour so that the structure gets solid. Three types of samples were prepared. These are

- Composite with Plain weave Glass fabric: P-C
- Composite with Twill weave Glass fabric: T-C
- Composite with Chopped Strand Mat: CSM-C

The laminate produced was cooled under 5 kg load so that no deformation occurred. The samples (laminates) with surface defects were rejected.

A. Thickness

Thickness of the samples in mm, tabulated in Table II, was measured with the help of slide caliper.

B. Bulk Density

Actual bulk density (ρ_A) of each sample was calculated in Kg/m^3 on the basis of its measured weight and thickness and represented in Table II.

C. Tensile Strength

Tenacity of specified composite samples was measured according to a method prescribed by ASTM-D-638 [3] in Blue Star Universal Testing machine. The results obtained were based on an average of 10 tests for each sample.

D. Flexural Strength

Cross breaking strength was done following a method specified in ASTM-D-790 [4]. The results obtained were based on an average of 10 tests for each sample

E. Impact strength

Izod Impact strength was measured as described in ASTM – D-256[5]. The results obtained were based on an average of 10 tests for each sample.

F. Fibre content and Volume Fraction

The glass content of the specimen was determined by burn test following the ASTM standard (D 2584-68) [6], on a Muffle Furnace using the sample dimension of 50mm×50mm. The sample was burnt for 30 minutes at 575°C. The mass fraction or glass content and volume fraction is calculated from the following relationship:

$$\text{Glass content or the mass fraction of glass } W_f(\%) = \frac{\text{weight of glass}}{\text{Total wt. of specimen}}$$

$$\text{Volume fraction of glass, } (v_f, \%) = \frac{W_f \rho_c}{\rho_{cf}}$$

$$\text{Volume fraction of resin, } (v_r, \%) = \frac{(1 - W_f) \rho_c}{\rho_r}$$

$$\text{Volume fraction of void, } v_v (\%) = 1 - (v_f + v_r)$$

Where, ρ_c is the density of composite sample; ρ_f , the density of glass fibre; ρ_r the density of resin.

G. Water absorption

Water absorption test of the Composite samples were carried out following ASTM – D-570 [7].

III. Results and Discussion

The Mechanical properties for composites are derived starting from properties of fibre and matrix, using the rule of mixtures, and the fiber volume fraction plays a significant role in the determination of the mechanical properties. The fibre content of the three different sample in ascending order of fibre content is CSM-C<T-C<P-C and shown by Fig 1a. There is very small variation in value of fibre content of the sample T-C and P-C.

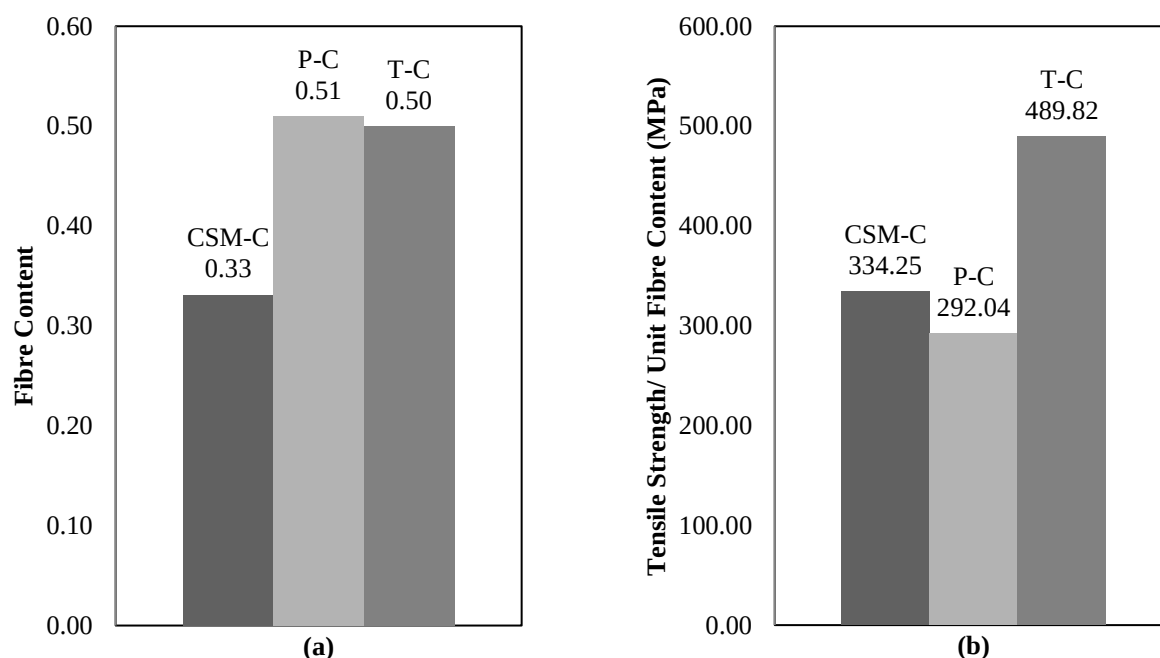
Table II. The Dimensional and Mechanical Properties Glass- polyester composites

Sample	Thickness (mm)	Density (kg/m^3)	Tensile Strength (mPa)	Tensile Strength (mPa)/unit fibre content	Flexural Strength (mPa)	Flexural Strength /unit fibre content (mPa)	Impact Strength (J/m)	Impact Strength/unit fibre content (J/m)	Water Absorption (%)	Fibre content
CSM-C	4.49	1463.49	110.77	334.25	153.58	463.43	982.87	2965.81	0.8	0.33
P-C	2.76	1625.20	148.94	292.04	96.76	189.73	992.89	1946.84	1.6	0.51
T-C	2.74	1576.54	244.91	489.82	94.70	189.40	763.27	1526.54	1.5	0.50

A. Tensile Strength per unit fibre content

The strength of the composite depends on the length of the fibres and the orientation as well as the volume fraction [8]. The effect of fibre content was eliminated by dividing the average tensile strength of each type of sample with fibre content. It was found that T-C sample exhibits higher strength in comparison to CSM-C and P-C (Fig. 1.b). Theoretically, the plain weave will have high crimp due to maximum interlacement compared to twill weave. The twill weave results in greater strength on the fabric as its free inter yarn and fibres contribute towards force [9]. The tensile strength of the twill woven reinforcement fabric is higher in comparison to the plain woven fabric of same areal density (GSM) as the number (Table II) may responsible for higher strength of T-C composite. The CSM-C samples are subjected to tensile force with major fibres orientation in the direction of loading may cause higher strength realisation in comparison to P-C.

Figure 1.a. Fibre Content, b. Tensile Strength/ Unit Fibre Content (MPa)



B. Flexural strength per unit fibre content

As the geometrical shape of the cross section of the specimen during flexural strength testing is same for all type of samples flexural strength behaviour can be explained by the intrinsic property of the composite itself [10]. The effect of fibre content was eliminated as mentioned earlier in case of tensile strength. The flexural strength per unit fibre content is higher for CSM-C sample in comparison to P-C and T-C samples as shown in Fig.2a. The reason may be associated with disadvantage of woven structure where the fibres get crimped as they pass over each other at the time of weaving while the orientation of fibre in CSM causes even flow of resin matrix through the structure [11]. The flexural strength per unit fibre content of P-C and T-C samples are found same.

C. Impact Strength per unit fibre content

The Fig. 2b shows that impact resistance property of CSM based composite (CSM-C) is found to be higher than P-C and T-C composite. The impact resistance of a material is determined by the amount of absorbed energy inside the material. This energy is dissipated between the interface of reinforcement and matrix. Plastic deformation during impact causes various failure interfaces in the material. Surface cracks, through-the thickness cracks and delamination may happen together. The damage induced by low energy impact is often a complex combination of failure that consists of inter-laminar fracture (de-lamination), intra-laminar fracture (debonding between reinforcement and matrix) and fiber fracture. These failures apart from fiber fracture generally depend on the laminar toughening mechanisms and shear strength of the fiber-matrix interface [12].

It is perhaps one of the great advantages of CSM that it is the nonwoven mat where the fibres are more or less randomly distributed with major fibre orientation in cross direction. The fibre volume fraction for CSM is 0.35 as shown in Table II. At low volume fractions of fibres, the matrix constitutes the major load bearing section and the addition of fibres gradually increases the strength as the applied load is partitioned between the fibres and the matrix. When the strain in the composite reaches the fracture strain of the matrix, the matrix fails and all of the load then transfer instantly to the fibres, which occupying such a small fraction of the sample area. This is called matrix controlled fracture. The dissipation of the impact force is more uniform as it strikes the more randomly oriented

structure of CSM reinforced composite. Impact energy dissipated through the point of contact in CSM/cross-over i.e. intersection point for woven structure. The number of lesser intersection for twill may responsible for lowering of impact strength for T-C samples.

D. Water absorption percentage

Moisture diffusion in composites may degrade mechanical properties by three different mechanisms [13]. The first mechanism involves the diffusion of water molecules inside the micro gaps between polymer chains. The second mechanism involves capillary transport into gaps and flaws at interfaces between fibre and matrix. The third mechanism involves swelling effects which propagate micro cracks in the matrix. In general, moisture diffusion in a composite depends on factors such as volume of fibre, voids, viscosity of matrix, humidity and temperature. Water absorption value in percentage is higher for twill woven glass fibre reinforced composite (T-C) is 1.6%. The value is lowest for CSM-C (0.8%) as shown in Fig. 3. The increase in water absorption of T-C and P-C in comparison to CSM-C may due to the greater interfacial area available between the fibre and the matrix at higher fibre content.

Figure 2. a. Flexural Strength /Unit Fibre Content (MPa), b.Impact Strength /Unit Fibre Content (J/M)

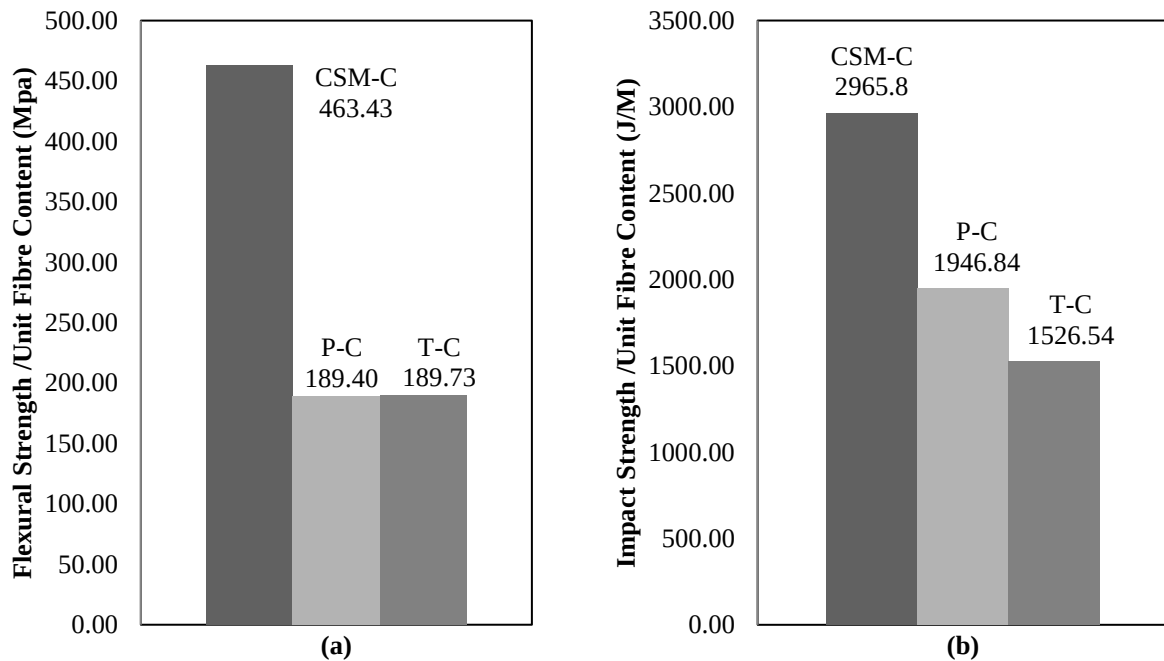
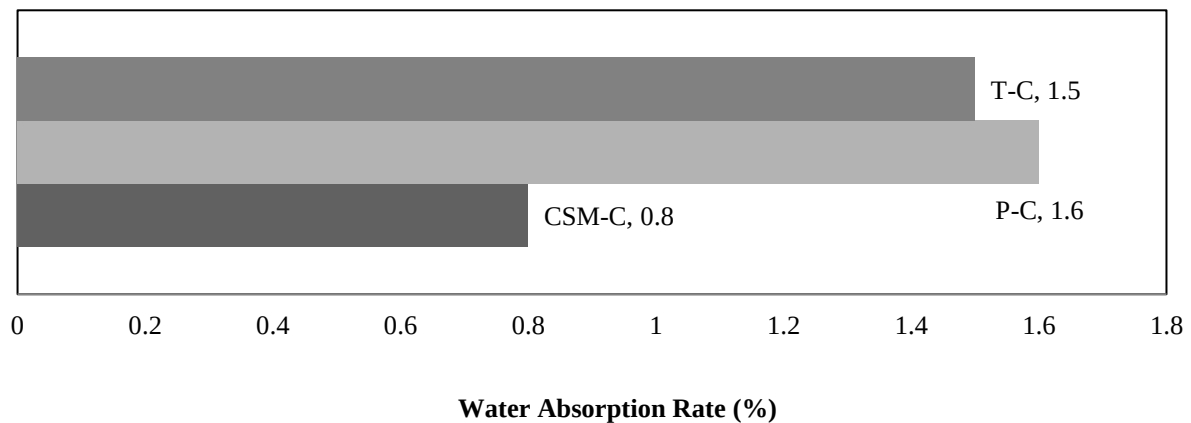


Figure 3. Water Absorption Rate (%)



IV. Conclusion

- The tensile strength of the twill woven fabric reinforced composite (T-C) is higher in comparison to the plain woven fabric composite (P-C) and Chopped strand mat based composite (CSM-C).
- Incorporation of nonwoven mat in CSM-C as reinforcing material enhancing the flexural and impact strength property.
- Water absorption by the laminates is higher for P-C and T-C is governed by the greater interfacial area available between the fibre and the matrix at higher fibre content.

V. References

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