

# Mechanical, Structural, and Morphological Assessment of Vinylester Hybrid Composites Stuffed with Sansevieria *Cylindrica* Fiber and Carbon Fiber

B. Amarababu, V. Pandu Rangadu

<sup>1</sup>Department of Mechanical Engineering, PBR Visvodaya Institute of Technology & Sciences, Kavali, Nellore-Dist, Andhra Pradesh, India

<sup>2</sup>Department of Mechanical Engineering, Jawaharlal Nehru Technological University Anantapur College of Engineering (Autonomous), Anantapur, Andhra Pradesh, India

## ABSTRACT

This paper presents preparation and characterization of vinylester polymer composites reinforced with sansevieria *Cylindrica* fiber (SCF) and carbon fiber (CF). Flexural strength, compression strength, FT-IR properties were studied for both untreated and treated composites. Rule of hybrid mixture were used for designing different SCF/ CF variations. In FT-IR spectroscopy different functional groups in a molecule was identified. Fractured cross-sectional areas were studied by the scanning electron microscope analysis.

**Keywords :** Hybrid Composites, Flexural Strength, Compressive Strength, SEM, FT-IR

## I. INTRODUCTION

Composite materials are formed by reinforcing two or more materials of varying properties. Our paper deals with the analysis of hybrid composite materials. Hybridization is a process of incorporating synthetic fibers with that of natural and metallic fibers in order to yield better strength, stiffness, high strength to weight ratio and other mechanical properties. Hybrid materials are composites consisting of two constituents at the micro-level. Generally hybrid reinforcing materials are retrieved from synthetic and natural fibers with specific properties. Thus, they differ from traditional composites where the constituents are at the microscopic. Stacking at the microscopic scale leads to a more interface of that material which either shows characteristics in between the two original phases or even new properties. The incorporation of several different types of fibres into a single matrix has led to the development of hybrid biocomposites. The behavior of hybrid composites is a weighed sum of the individual components in which there is a more favorable balance between the inherent advantages and disadvantages.

Also, using a hybrid composite that contains two or more types of fibre, the advantages of one type of fibre could complement with what are lacking in the other. As a consequence, a balance in cost and performance can be achieved through proper material design. The properties of a hybrid composite mainly depend upon the fibre content, length of individual fibres, orientation, extent of intermingling of fibres, fibre to matrix bonding and arrangement of both the fibres. The strength of the hybrid composite is also dependent on the failure strain of individual fibres. Maximum hybrid results are obtained when the fibres are highly strain compatible. The properties of the hybrid system consisting of two components can be predicted by the rule of mixtures.

$P_H = P_1 V_1 + P_2 V_2$  where  $P_H$  is the property to be investigated,

$P_1$  the corresponding property of the first system and

$P_2$  the corresponding property of the second system.

$V_1$  and  $V_2$  are the relative hybrid volume fractions of the first and second system and

$V_1 + V_2 = 1,$

A positive or negative hybrid effect is defined as a positive or negative deviation of a certain mechanical property from the rule of hybrid mixture. The term hybrid effect has been used to describe the phenomenon of an apparent synergistic improvement in the properties of a composite containing two or more types of fibre. The selection of the components that make up the hybrid composite is determined by the purpose of hybridization, requirements imposed on the material or the construction being designed. The problem of selecting the type of compatible fibres and the level of their properties is of prime importance when designing and producing hybrid composites. The successful use of hybrid composites is determined by the chemical, mechanical and physical stability of the fibre / matrix system. There are several types of hybrid composites characterized as: (1) interply or towby-tow, in which tows of the two or more constituent types of fiber are mixed in a regular or random manner; (2) sandwich hybrids, also known as core-shell, in which one material is sandwiched between two layers of another; (3) interply or laminated, where alternate layers of the two (or more) materials are stacked in a regular manner; (4) intimately mixed hybrids, where the constituent fibers are made to mix as randomly as possible so that no over-concentration of any one type is present in the material; (5) other kinds, such as those reinforced with ribs, pultruded wires, thin veils of fiber or combinations of the above. The concept of hybrid systems for improved material or structural performance is well-known in engineering design. However, it is the inspiration from nature's own materials that is recently motivating the path towards innovative material and structural designs. Studies on natural materials show how high structural performance can be achieved with non-exotic materials through hybrid combinations assembled in optimized hybrid hierarchical configurations. Although hybrid fiber reinforced polymer composites are gaining interest, the challenge is to replace conventional glass reinforced plastics with biocomposites that exhibit structural and functional stability during storage and use and yet are susceptible to environmental degradation upon disposal. An interesting approach in fabricating biocomposites of superior and desired properties include efficient and cost effective chemical modification of fibre, judicious selection of fibres, matrix modification by functionalizing and blending and efficient processing techniques. Another interesting concept is that of

engineered natural fibres to obtain superior strength biocomposites. This concept explores the suitable blending of bast (stem) and leaf fibres. The judicious selection of blends of biofibres is based on the fact that the correct blend achieves optimum balance in mechanical properties for e.g., the combination of bast and leaf fibre is expected to provide a stiffness toughness balance in the resulting biocomposites. The influence of chemical modifications on the tensile properties of intimately mixed short sisal/glass hybrid fibre reinforced low density polyethylene composites was investigated by Ashok Kumar et al [1-16]. Chemical surface modifications such as alkali, acetic anhydride, stearic acid, permanganate, maleic anhydride, silane and peroxides were given to the fibres and matrix and were found to be successful in improving the interfacial adhesion and compatibility between the fibre and matrix. It was found that the extent of improvement in tensile properties of Fiber reinforced hybrid composites varied with respect to the nature of chemical modifications between fibre and matrix. Improved mechanical anchoring and physical and chemical bonding between fibre and polyethylene matrix are the reasons for superior tensile strength and Young's modulus in treated composites. Among the various chemical modifications, the best tensile strength and modulus was exhibited by composite containing benzoyl peroxide treated fibres. This is attributed to the peroxide-initiated grafting of polyethylene on to the fibres.

In the present research focus on the development of the polymer hybrid composites reinforced with SCF/CF on mechanical, structural, and scanning electron microscope analysis.

## II. METHODS AND MATERIAL

### Materials

In the present work, a commercially available vinyl ester, methyl ethyl ketone peroxide (catalyst), Cobalt naphthenate (accelerator) were purchased from the V.G.R. Enterprises, Madurai, Tamilnadu, India. Vinyl ester monomers with two reactive vinyl end groups enable the cross-linking for network formation. The liquid resin has a density of 1.045 g/cm<sup>3</sup> and a viscosity of 350 centipoises (cps) at room temperature. SCF fibers were

obtained from the Radhaswamy Hill Area, Enumuladoddi forest, Kalyanadurgam, Anantapur, Andhra Pradesh, India, SCF were extracted through natural soaking process. That process is explained as mentioned below [5].

### SCF Preparation (untreated)

First sansevieria leaves from the plant was cut with the help of sickle and then the bunch of cut leaves thrown into the water and these leaves will be subjected to under compression for a month. After removing from the soaking, then the leaves will be smashed with the help of stick for half an hour to remove all the organic material out of fibers. Then the fibers will be washed with the help of distilled water for several times until to get clean fibers. The clean fiber will be dried for another 2days [10]. This fiber is also called treated SCF. In order to obtain treated SCF the following chemical process has to be done.

### SCF Preparation (treated)

Then the fibers are cleaned normally in clean running water and dried. A glass beaker is taken and 6% NaOH is added and 80% of distilled water is added and a solution is made. After adequate drying of the fibers in normal shading for 2 to 3 hours the fibers are taken and soaked in the prepared NaOH solution.

Soaking is carried out for different time intervals depending upon the strength of fiber required. For this project the fibers are soaked in the solution for three hours.

After the soaking process is completed, then the fibers are taken out and washed in running water and dried for another 2 hours. A mould of 150mm length and 120 mm width and 3mm thickness and is created using glass mould. This mould is coated with mould releasing agent for easy removal of casting. A glass beaker and a glass rod or a stirrer is taken and cleaned well with running water and then with warm water. Then calculated quantity of vinylester resin is added and measured quantity of promoter/accelerator/catalyst is added and the mixture is stirred for nearly 15 minutes. The reason behind this stirring is to create a homogeneous mixture of resin and accelerator. Then after the mixing is over, calculated quantity of fibers are added and stirring process is continued for the next 45 minutes. After the

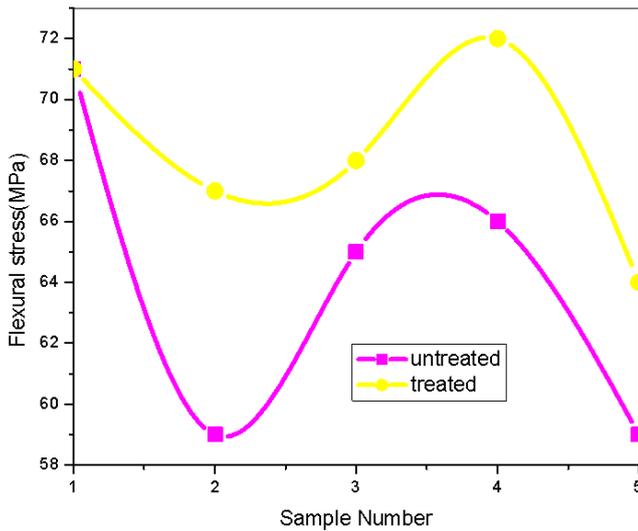
complete mixing of fiber and resin materials is over measured quantity of catalyst is added and stirred for a short while. Then the mixture is poured into the mould and rammed mildly for uniform settlement. Then the mould is allowed to solidify for 24 hours. Rule of hybrid mixtures were used to prepare the composites of untreated and treated hybrid composites as shown in the Table 1. The SCF and CF fibers are cut to the required size of 1 cm [3]. Specimens for mechanical testing such as flexural and compression testing are prepared on par with the ASTM standards. Scanning electron microscopy (SEM) studies of the fractured surface of the flexural specimen were carried out on a Jeol (6380LA, Japan). The specimen was sputter-coated with gold to increase surface conductivity. Flexural (bending) specimens were cut on par with ASTM D 53455. Flexural tests were performed on Instron universal testing machine (3369).

**Table 1** Tabulation of specimens with variation of untreated and treated hybrid composites

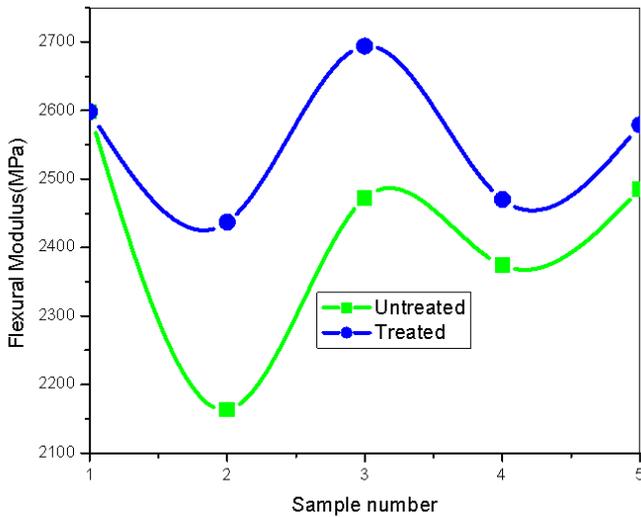
Specimen. No.	Cond.	SCF	CF
1	UT	0	100
2	UT	100	0
3	UT	25	75
4	UT	50	50
5	UT	75	25
6	T	0	100
7	T	100	0
8	T	25	75
9	T	50	50
10	T	75	25

### III. RESULT AND DISCUSSION

**Fig.1** shows the variation of flexural strength as a function of SCF/CF variations for untreated and treated hybrid composites. For 100% CF hybrid composite got 71MPa flexural strength which is shown maximum performance than other composites. And also the second highest strength was noticed for (75 % SCF +25 %CF) 66MPa strength. Increase in SCF content shown the significant improvement in the flexural strength. And also for another system (i.e. 25%SCF + 75 %CF) composite also gained somewhat lesser performance which is approximately 65MPa.



**Figure 1 :** Variation of flexural strength as a function of fiber wt. % for untreated and treated hybrid composites

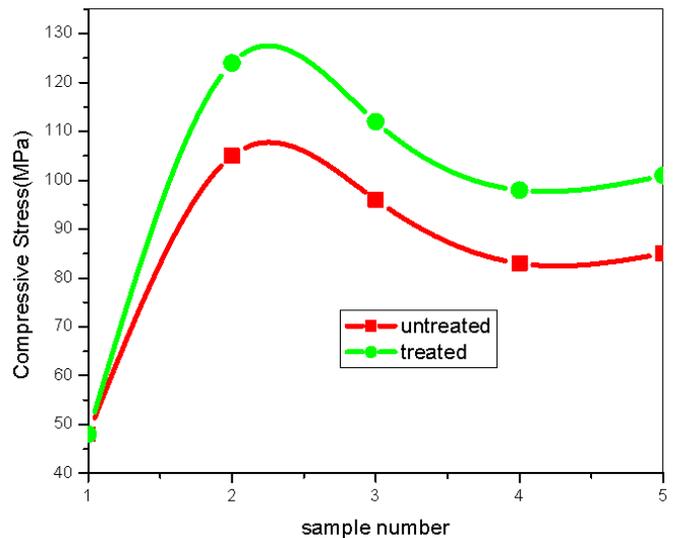


**Figure 2 :** Measurements of flexural modulus as a function of fibers of untreated and treated hybrid composites.

Specimen-5 (i.e. 75 % SCF + 25 % CF) attained 7.57% of flexural strength was increased when compared with Specimen-1 (VE + 0 % SCF + 100% CF). Similarly for Specimen-3 (i.e. 25 % SCF + 75 % CF) composite 6.15% higher flexural strength was recorded when compared with specimen-1. When it's come to treated hybrid composites system-5 has got 72 MPa of flexural strength is significantly improved, whereas for system-3 was recorded as 68MPa of flexural strength was recorded. Strength was improved further when compared with untreated composites. System-5 has got almost equal magnitude when compared with 100%CF composite. The reasons for increased performance was attributes mainly good interface between the matrix and fibers is

the prime reason and the second reason is fewer no of voids in the cross sectional area.

It may be due to the less amount of roughness was normal for the improved performance. **Fig.2** shows the variation of flexural modulus as a function of SCF/CF variations for untreated and treated hybrid composites. For 100% CF hybrid composite got 2598MPa of flexural modulus which is shown maximum performance than other composites. And also for the (50 % SCF + 50 % CF) is 2495MPa. And also when (25%SCF + 75 %CF) composite also gained somewhat lesser performance which is approximately 2472MPa. Specimen-4 (i.e. 50 % SCF + 50 % CF) attained 4.54% lesser flexural modulus when compared with Specimen-1. Similarly, flexural modulus for specimen-3 (i.e. 25 % SCF + 75 % CF) composite is 5.09% decreased when compared with specimen-1. In case of treated composites specimen-3 bagged higher performance which is 2694MPa than the system-1 and also sytem-4 has got some what lesser modulus which is 2579MPa than the system-3.

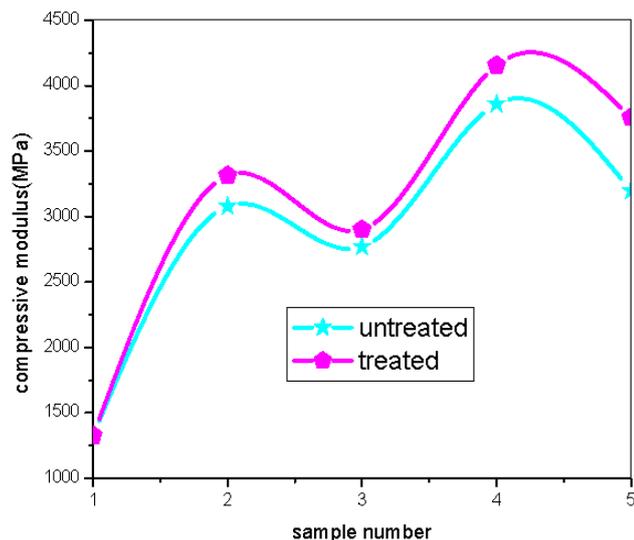


**Figure 3 :** Measurements of compression strength as a function of fibers of untreated and treated hybrid composites

**Fig.3** shows the variation of compressive strength as a function of fibers wt. % for untreated and treated hybrid composites. In case of untreated composites, for system-1 have registered 48MPa, for sytem-2 have got 83MPa, for system-2 have obtained 105MPa, and for system-3

have got 96MPa. System-2 bagged 118.75% higher performance when compared with system-1.

In case of treated composites, system-7 has got 124MPa, system-8 has got 112MPa, and system-9 has got 101 MPa. Overall treated system-7 has got 18.09% higher compression strength when compared with untreated composites.

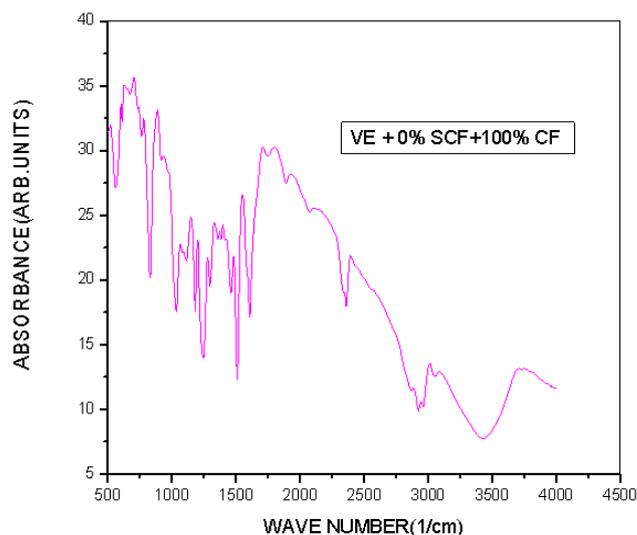


**Figure 4 :** Variation of compression modulus as a function of fiber wt. % for untreated and treated hybrid composites

**Fig.4** shows the compression modulus of untreated and treated hybrid composites as function of wt.% SCF/CF. Untreated composites for system-5 have attained maximum modulus which is 3860MPa whereas for system-2 3078MPa was noticed. Unfortunately for 100% CF composites have registered 1326MPa. For treated composites system-10, 9, 7 have got the following performances 4156MPa, 3756MPa, and 3314MPa respectively. **Fig.5** shows the variation of absorbance as a function of wave number for hybrid composites. FT-IR analysis are used mainly used to find the functional groups in a molecule. From the graph it was observed that the 1680  $\text{cm}^{-1}$  there was sharp medium peak was identified. This indicates the carbon double bond ( $\text{C}=\text{C}$ ) of aromatic groups were observed. Another medium peak was observed at the 2260  $\text{cm}^{-1}$  was carbon, carbon triple bonds were identified at this peak which is belongs to CHO aldehydes.

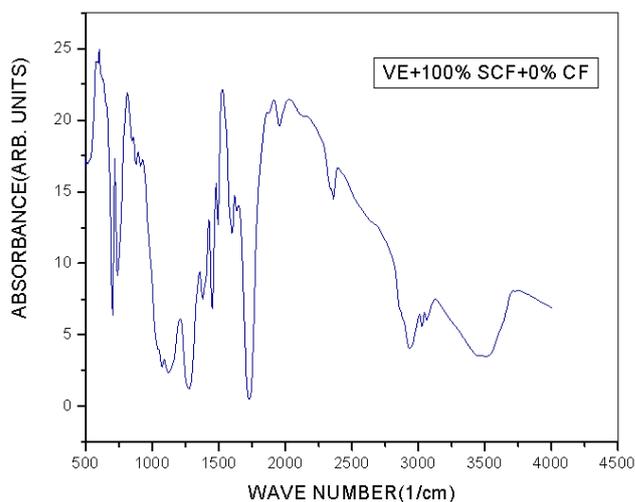
Another peak was observed at 2900  $\text{cm}^{-1}$  these are belongs to C-H groups of COOH. At 3400  $\text{cm}^{-1}$  there

was another broad peak was identified which is O-H alcohol groups are present.



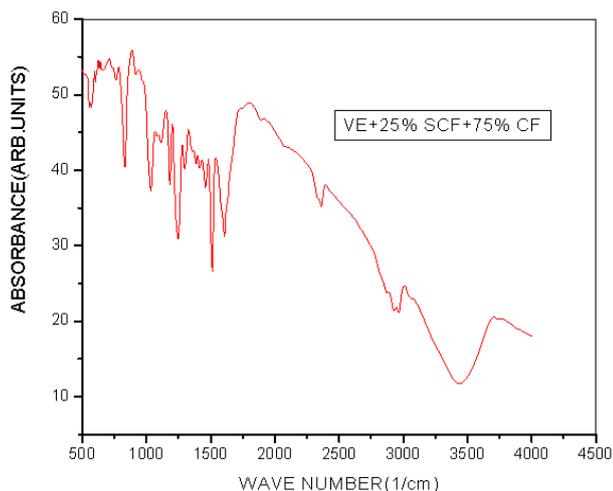
**Figure 5 :** Variation of wave number as a function of absorbance for (VE + 0 % SCF + 100 % CF) untreated hybrid composites.

In **Fig.6** shows the variation of absorbance as a function of wave number for hybrid composites. At 1750  $\text{cm}^{-1}$  sharp deep peak is belongs to ester groups. At 2000  $\text{cm}^{-1}$  carbon triples bonds were noticed and these are belongs to CHO groups C-H bonds were presented at 2900  $\text{cm}^{-1}$  peak. And last O-H groups are identified at sharp broad peak 3500  $\text{cm}^{-1}$ .

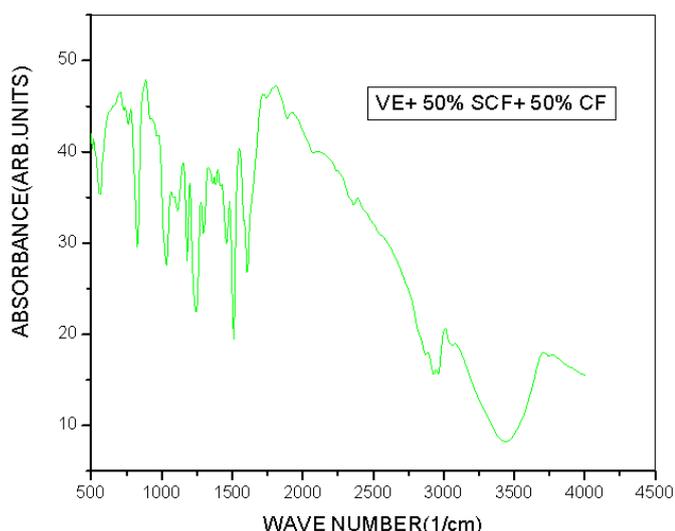


**Figure 6 :** Variation of wave number as a function of absorbance for (VE + 100 % SCF + 0 % CF) untreated hybrid composites.

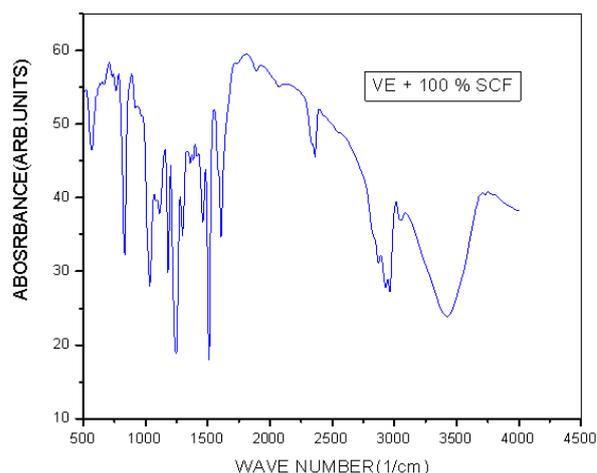
In fig.7 there were only three peaks were observed they are namely  $2300\text{ cm}^{-1}$ ,  $2900\text{ cm}^{-1}$ , and  $3400\text{ cm}^{-1}$  among first peak was observed as C-H bonds were identified and these might belong to COOH groups, and the second, and third peak is related to peak was belongs to O-H groups. In Fig.8 there were only two peaks were observed they are namely  $2900\text{ cm}^{-1}$ , and  $3400\text{ cm}^{-1}$  among first peak was observed as C-H bonds and these might belong to COOH groups, and the second peak is related to O-H groups.



**Figure 7 :** Variation of wave number as a function of absorbance for (VE + 25 % SCF + 75 % CF) untreated hybrid composites

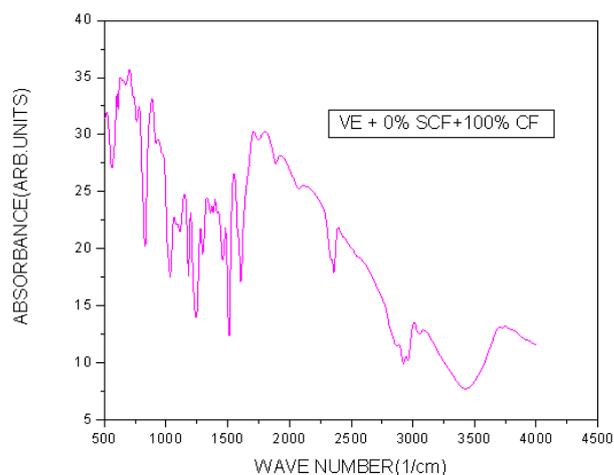


**Figure 8 :** Variation of wave number as a function of absorbance for (VE + 50 % SCF + 50 % CF) untreated hybrid composites

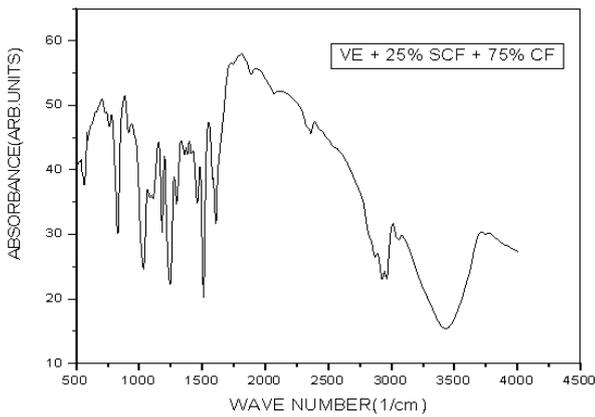


**Figure 9 :** Variation of wave number as a function of absorbance for (VE + 75 % SCF + 25 % CF) untreated hybrid composites.

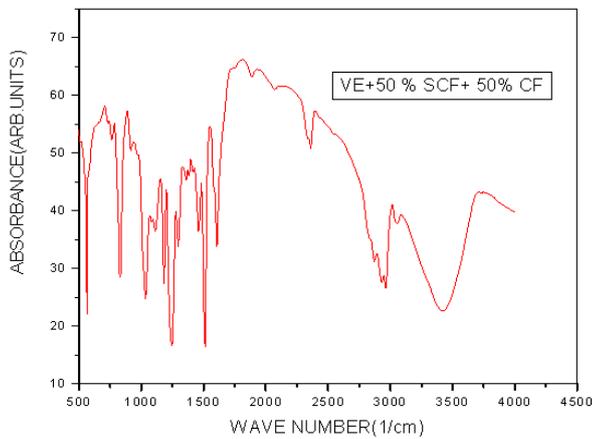
In the fig.9  $1650\text{ cm}^{-1}$  sharp peak was observed and is belong to carbon double bonds (C=C) and these are belongs to amide groups. At  $2250\text{ cm}^{-1}$  there was another peak was observed and these are belong to CN triple bonds. At the  $3450\text{ cm}^{-1}$  there was another medium broad peak was identified which is belong to O-H groups. In fig.10 there were four peaks were identified in the finger print region from the  $1500\text{--}4500\text{ cm}^{-1}$  is quite similar to Fig.5 and only thing is intensities of the peaks are slightly varying. In the fig.11 there were three peaks were observed, they are one peak at  $1650\text{ cm}^{-1}$  is belong to amide groups and followed by another peak at  $2800\text{ cm}^{-1}$  was belongs to C-H groups. In the fig. 12 is quite similar to fig.11 except variation of intensities. Another peak was observed at  $3400\text{ cm}^{-1}$  which is belongs to O-H groups.



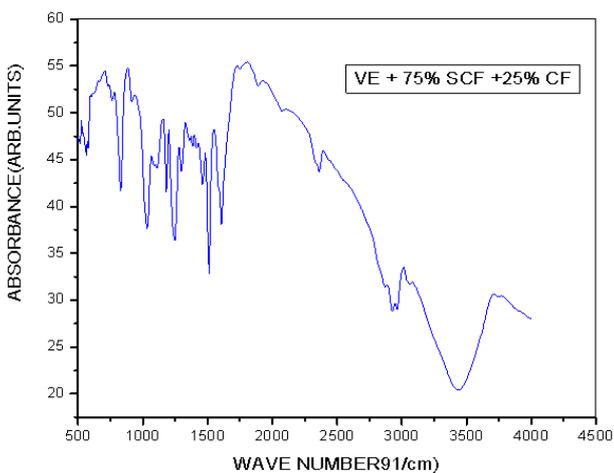
**Figure 10 :** Variation of wave number as a function of absorbance for (VE + 100 % SCF + 0 % CF) treated hybrid composites.



**Figure 11** :Variation of wave number as a function of absorbance for (VE + 25 % SCF + 75 % CF) treated and treated hybrid composites

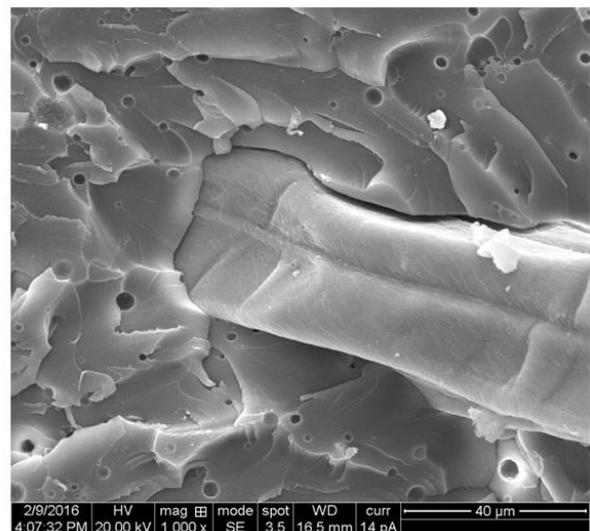


**Figure 12** :Variation of wave number as a function of absorbance for (VE + 50 % SCF + 50 % CF) treated hybrid composites

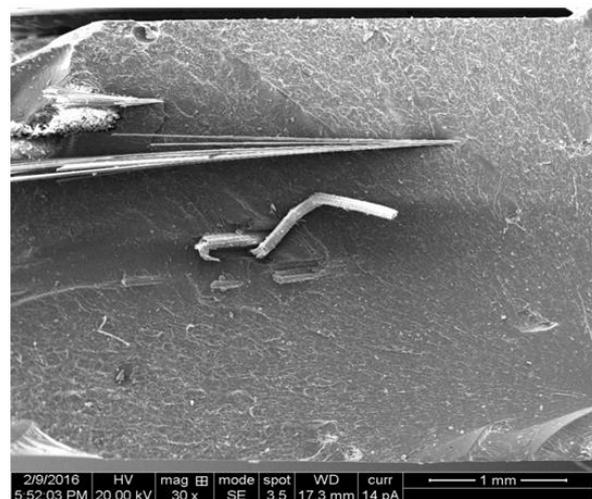


**Figure 13** :Variation of wave number as a function of absorbance for (VE + 75 % SCF + 25 % CF) treated hybrid composites.

Fig.13 four peaks were observed in which first is observed at 1656 cm<sup>-1</sup> is belongs carbon double bonds, C=C, and another peak was identified is belongs to 2250 cm<sup>-1</sup> to C-H groups. Another peak was observed at 2750 cm<sup>-1</sup> is belongs to O-H groups. Another peak was identified at 3400 cm<sup>-1</sup> is belongs to N-H groups. Fig.14 shows the untreated image for the system-2 is clearly indicates that the small gap in between the fiber and the matrix results poor interface and also small voids were found all over the image and these two images are the prime reasons for the decrease in strength. Fig.15 show the cross sectional area of the treated system-10 (i.e. VE + 75%SCF + 25% CF) reveals the bonding between the fiber and the matrix might be the reason for improved strength.



**Figure 14** : Scanning electron image of 100 % SCF (system-2) of untreated polymer hybrid composites.



**Figure 15** : Scanning electron image of the (VE + 75 % SCF+ 25% CF) treated hybrid composites.

#### IV. CONCLUSION

In the present article belongs to development of untreated and treated hybrid polymer composite were successfully achieved by rule of hybrid mixtures. Totally 10 systems were developed. Flexural strength, flexural modulus, compression strength, compression modulus and FT-IR analysis were studied. Flexural strength was significantly improved for system-1 for treated composites than the untreated. Flexural modulus was improved for the system-8(treated) when compared with other systems. Compressive strength was good for system-7 when compared with other systems. Compressive modulus was improved well for the system-10 when compared with the other systems. SEM analysis are hence proved that variation of voids, poor interface, fiber pull outs are the critical reason for improved or decreased strength. In FT-IR analysis we concluded that functional groups in the molecules are identified.

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