

Development of *Sansevieria trifasciata* - Carbon Fiber Reinforced Polymer Hybrid nanocomposites

RAGHAVA KRISHNA SAMEER B.¹, M. ASHOK KUMAR²,
V. NIKILL MURTHY³, N. KARTHIKEYAN⁴

¹Department of Mechanical Engineering, Brilliant Grammar School Educational Society's Group of institutions College, Abdullapurmet, Hyderabad.

²Department of Mechanical Engineering, Dr.K.V. Subba Reddy Institute of Technology, Dupadu, Kurnool-518218(AP) India

³Department of Mechanical Engineering, Geethaanjali College of Engineering & Technology, Cheeryaal(V), Keesara(M), R.R.District,Telangana-501301.

⁴Department of Mechanical Engineering, P.V.K.K.Institute of Technology,Anantapur-515004(AP),India

*E-mail address: ashokkumarmala7@gmail.com

Keywords: Carbon Fiber; Reinforced Polymer

ABSTRACT

This paper presents studies on experimental values of tensile strength properties of hybrid nanocomposites were studied and compared with theoretical values. It was observed that, experimental strengths were fallen shorter than the theoretical values. Nanocomposites were fabricated by filling MMT nanoclay by weight ratio and reinforced with short *sansevieria trifasciata* (STF) and short carbon fibre (CF) by randomly orientation. Organically modified montmorillonite clay filled with different proportions viz.0, 1, 3 and 5 wt.% dispersed into the vinyester matrix modified system by hand lay-up technique. Natural fiber was treated by NaOH solution was brought significant performance. Tensile strength was found maximum when clay content was Clay 3wt%. In the fracture surfaces of samples were analysed by SEM analysis, in which it was observed that, increased clay viscosity played vital role in bringing the performance as the viscosity of the mixture made difficult to flow the resin. Thermal stability was significantly improved for the 5wt% sample due to the high content of silicate particles and carbon fibre content.

1. INTRODUCTION

Hybrid composites are those composites which have a combination of two or more reinforcement fibres/filler in a predetermined geometry and scale, optimally serving a specific engineering purpose. The most common type of hybrid composites are carbon-aramid reinforced epoxy (which combines strength and impact resistance) and glass-carbon reinforced epoxy (which gives a strong materials at a reasonable price). Hybrid composites are usually used when a combination of properties of different types of fibres need to be achieved, or when the longitudinal as well as the lateral mechanical performance are required. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers, etc. The composite material however, generally possesses characteristic properties, such as stiffness, strength, weight, high-temperature performance, corrosion resistance, hardness, and conductivity that are not possible with the individual components by themselves. Analysis of these properties shows that they depend on (1) the properties of the individual components; (2) the relative amount of components; (3) the size, shape, and distribution of the discontinuous components; (4) the degree of bonding between components; and (5) the orientation of the various

components. Vinylester, is a resin produced by the esterification of an epoxy resin with an unsaturated monocarboxylic acid. The reaction product is then dissolved in a reactive solvent, such as styrene, to 35 – 45% content by weight. It can be used as an alternative to polyester and epoxy materials in matrix or composite materials, where its characteristics, strengths, and bulk cost intermediate between polyester and epoxy. Vinyl-ester resin, as a structural polymer, was chosen as a polymer matrix in current study due to the fact that the cured resins are thermosetting with a network structure possessing high resistance to the moisture and chemicals, and good mechanical properties. Thus the resultant composites have the potential applications in fabrication and building materials such as electrodeposition tanks, automotive parts and marine vessels which require superior mechanical properties and/or high resistance to harsh environments such as strong acid or base. Furthermore, the functional groups of the polymer surrounding the nanoparticles enable these nanocomposites as good candidates for various applications such as site-specific molecule targeting in biomedical areas.

The properties of carbon fibers, such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion, make them very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. It is commonly called the snake plant (not to be confused with the very similarly named "Snake plant", *Nassauvia serpens*), because of the shape of its leaves, or mother-in-law's tongue because of their sharpness. Like some other members of its genus, *S. trifasciata* yields bowstring hemp, a strong plant fiber once used to make bow strings. It is now used predominantly as an ornamental plant, outdoors in warmer climates, and indoors as a house plant in cooler climates. It is popular as a houseplant as it is tolerant of low light levels and irregular watering; during winter it needs only one watering every couple of months. It will rot easily if overwatered. A study by NASA found that it is one of the best plants for improving indoor air quality by passively absorbing toxins such as nitrogen oxides and formaldehyde. Natural fibers such as banana, cotton, coir, sisal and jute have attracted the attention of scientists and technologists for application in consumer goods, low cost housing and other civil structures. It has been found that these natural fiber composites possess better electrical resistance, good thermal and acoustic insulating properties and higher resistance to fracture. Natural fibers have many advantages compared to synthetic fibers, for example low weight, low density; low cost, acceptable specific properties and they are recyclable and biodegradable. They are also renewable and have relatively high strength and stiffness. [1-31]. The main aim of this research is to check suitability of STF/CF hybrid nanocomposites for specific applications in aerospace and automotive applications.

In the present research paper hybrid nanocomposites were prepared which are reinforced with STF and CF using rule of hybrid mixture. Nanoclay was dispersed into the vinylester matrix with different weight proportions to see where strength was optimised. Experimental values of tensile strengths were correlated with theoretical values with experimental values. SEM was also evaluated by comparing the different samples of their cross sections.

2. MATERIALS AND METHODS

2.1. Materials

In the present work, a commercially available vinylester, and methyl ethyl ketone peroxide (catalyst), Cobalt napthenate (accelerator) were purchased from the V.G.R. Enterprises, Madhurai, 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/cm³ and a viscosity of 350 centipoises (cps) at room temperature. A JEOL JSM-6400 JAPAN scanning electron microscope at 15 kV accelerating voltage was equipped with energy dispersive spectroscopy (EDS) to ascertain the fiber/filler interfaces with the main modified matrix. Fractured specimen surfaces were gold-coated and the fractures surface was observed using a scanning electron microscope. The fractured surfaces were gold-coated with a thin film to increase the conductance. The thermal characteristics TGA, DSC measured on laminated polymer nanocomposites using SDT Q600 TGA/DSC (TA Instruments) at a rate of 10°C/min under nitrogen flow measurements were carried out at 20°C

temperature, 40 % relative humidity. Montmorillonite clay(Product No: 682659;Brand: Aldrich, Product name:Nanoclay, hydrophilic bentonite; Formula:H₂Al₂O₆Si;Molecularweight: 180.1g/mol; Appearance (Color):Conforms to Requirements Light Tan to Brown; Appearance (Form): Powder; Loss on drying:=18.0%; Density:600-1100kg/m³ ;Bulk density: Avg. particle size:=25micron) supplied by Sigma- Aldrich Chemicals Pvt. Limited, Bangalore, India Commercially available polyester/catalyst/accelerator supplied by HUNTSMAN Ciba-Geigy India Ltd Company. Sansevieria trifasciata was obtained from the near Enumuladoddi forest, Kalyanadur, Anantapur, India. Tensile strength was carried out on par with ASTM D 53455. Tensile test was performed on Instron universal testing machine (3369). This test was carried at ambient conditions. In each case, five identical specimens were tested and their average load at first deformation was noted and the average value tabulated. All the tests were accomplished at a room temperature of 20 °C. At least, 5 samples were tested for each composition and results were averaged.

2.2. Composite Manufacturing

A glass mould was prepared based on the ASTM standards and mould was coated with PVA solution as it facilitates easy removal off the composite after curing completes. The resin, catalyst and accelerator were taken in the ratio of 100: 2:2 parts by weight, respectively. Then, a pre-calculated amount of catalyst/accelerator was mixed with the vinylester resin and stirred for 10 min before pouring into the mould. The hand lay-up technique was used to impregnate the composite structures [12, 18]. A predetermined amount of clay was mixed with vinylester and stirred with mechanical stirrer and ultra sonicator subsequently. In this technique, the CF and the STF were wetted by a thin layer of vinylester suspension in a mould. A stack of hybrid fibers were carefully arranged in a unidirectional manner after pouring some amount of resin against the mould to avoid the poor impregnation. The remaining mixture was poured over the hybrid fiber. Brush and roller were used to impregnate fibre. The closed mould was kept under pressure for 12hours at room temperature. Then the post cured sheets were cut on par with ASTM standards.

2.3.Fiber Treatment

Sansevieria trifasciata was taken in a glass tray and a 5 % NaOH solution was added in to the tray and the fibers were allowed to soak in the solution for 1 hr separately. The fibers were then washed thoroughly with water to remove the excess of NaOH sticking to the fibers. Final washing was carried out with distilled water and the fibers were then dried in hot air oven at 70 °C for 4 hrs. The fibers were chopped into short fiber length of 3 cm for molding the composites.

3. TENSILE STRENGTH

A tensile test is a fundamental mechanical test where a carefully prepared sample is loaded in a very controlled manner while measuring the applied load and the elongation of the sample over some distance. Tensile strength or ultimate strength is defined as the maximum load that results during the tensile test, divided by the cross-sectional area of the test sample. Therefore, tensile strength, like yield strength, is expressed in MPa. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, reduction in area, tensile strength, yield point, yield strength and other tensile properties. Tensile strength can be obtain from the following formula:

$$\sigma = \frac{P}{A}; \text{ where}$$

$$\sigma = \text{tensile strength (N/m}^2\text{); } P = \text{test load (N) ; } A = \text{Area of cross section(m}^2\text{)}.$$

4. RESULTS AND DISCUSSIONS

The primary goal of the hybrid composites as a product is to withstand the applied mechanical forces. This is achieved by load transfer between the matrix and the nanoparticle induced by the shear deformation of the matrix around the filler. This shear deformation is produced because of the high young's modulus of the nanoparticles and the larger differences between the mechanical of the

composite constituents. Tab.1 and Fig.1 shows the experimental and theoretical values of the tensile strength of the hybrid composites. It was observed that tensile strength of the pure vinylester matrix is 15.1 MPa for experimental values. It was also noticed that experimental values are unable to meet the theoretical strengths due to constraints. The tensile strength of composites increased up to 3wt% clay loaded into vinylester matrix. The increase in strength was due to good filler matrix interactions, which was largely due to the needle shaped structure might have enhanced ability of the filler. Needle type fillers have higher aspect ratio and this increases the wet ability of the fillers by the matrix, thus creating fewer micro voids between the filler and matrix. The filler has higher surface area due to its small particle size, tends to agglomerate and these results in the reduction of surface interactions between the matrix and the filler. This may be the substantial reason for reduction of tensile strength after 3wt% clay. Similar observations were observed from the literature [10, 14, 15].

Table 1. Tensile strength of hybrid nanocomposites of Experimental and theoretical results as a function of clay.

Material	Tensile strength(MPa)	
	experimental	theoretical
V-CF-STF+0wt.% clay	15.25	25.45
V-CF-STF+1wt.% clay	26.37	30.96
V-CF-STF+3wt.% clay	45.52	50.34
V-CF-STF+5wt.% clay	40.32	55.24

5. MORPHOLOGY STUDIES

Fig. 2 (a &b) shows the morphological analyses of various samples of 3 and 5 wt.% clay loaded reinforced with STF and CF fiber hybrid composites. From the fig.2 (a) the fracture sample cross sections were clearly indicates that filler distribution was homogeneous and there was only no voids, and pullouts and also it is slightly looks like ductile nature of cross section. This is the genuine reason for improved performance at 3wt%. It indicates the bright whitish matrix indicates feature from nanoclay of microstructure indicates well cross linking between the fiber and matrix, on other hand in fig.2 (b) cross section was slightly somewhat different as it looks like more ductile nature but due to increased viscosity of the modified composites it was unable to flow all over the mold in a given time as result of that it led to poor strength as stuff can left unfilled and consequently suffered with voids. When viscosity increases generally there will be a tendency of formation of voids and also from the same image we can also observe the random orientation of the fiber [23, 24]. After comparing the two images we come to conclusion that adding more clay leads to agglomeration as a result which causes microvoids which at as a stress concentration factors which facilitates shear yielding in the system and therefore ultimately strength would be going down[16,17].

Fig.3 shows the TGA analysis of the two different clay loaded samples such as 3wt.% and 5wt.%, and also it was noticed that for 5wt.% clay loading thermal stability was increase from 352°C-356°C. it was found that 5wt.% clay loaded sample is more thermal stability than the 3wt.%, clay contains the more silicate particulates, that makes when addition of clay and fiber makes the composite highly viscous and also same contains the more unburnt stuff which led to high thermal stability[14,18].

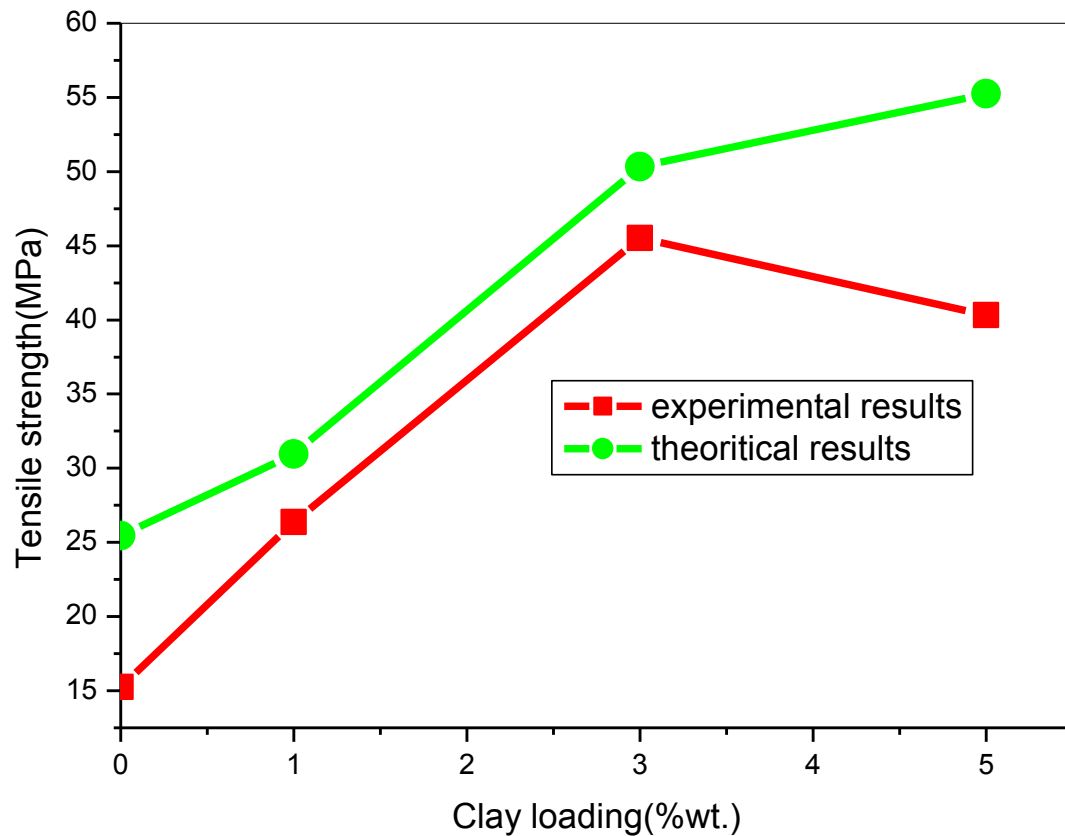
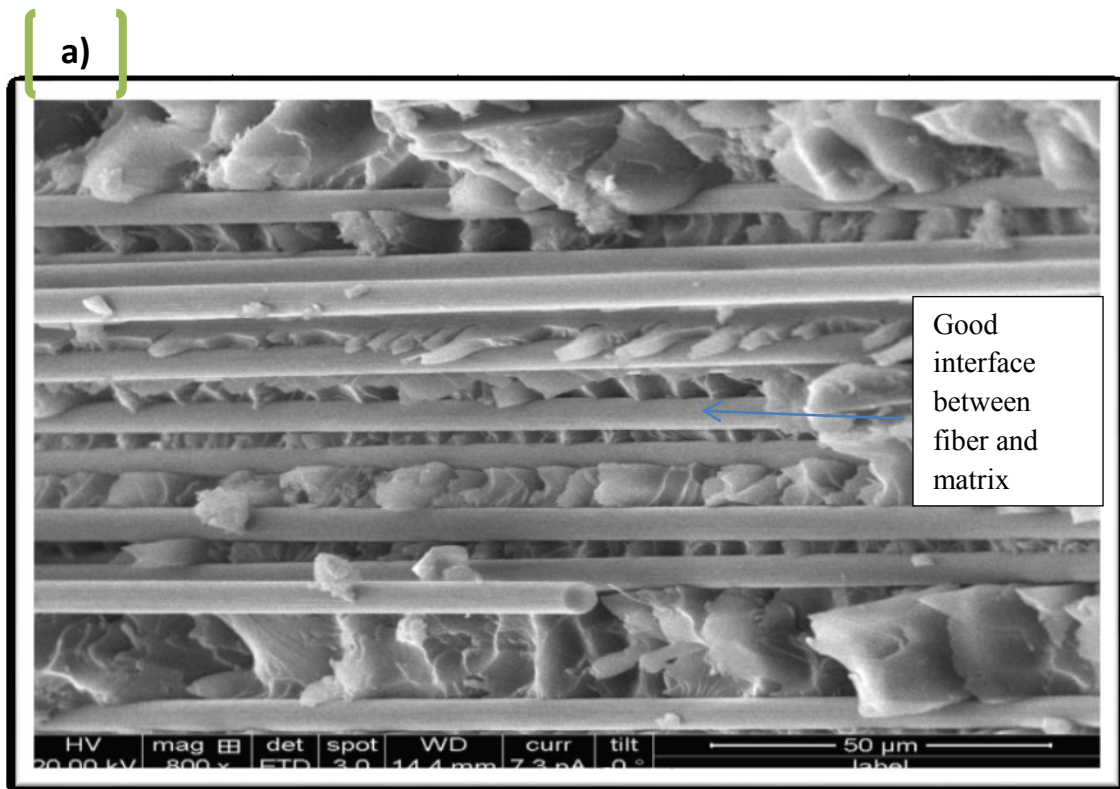


Fig.1: Hybrid Nanocomposites of tensile strength Experimental and theoretical analysis.



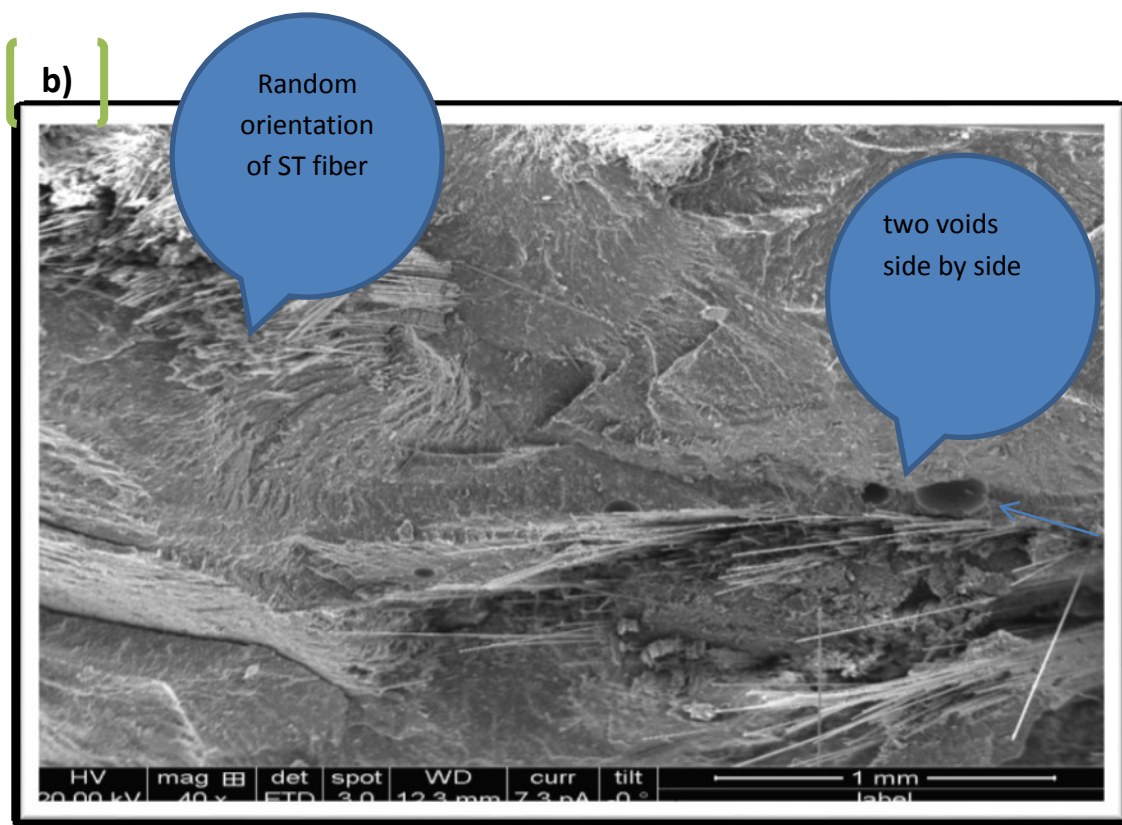


Fig.2: Images of SEM's that shows the cross sections of the sample of 3wt.% and 5wt.% clay hybrid nanocomposites.

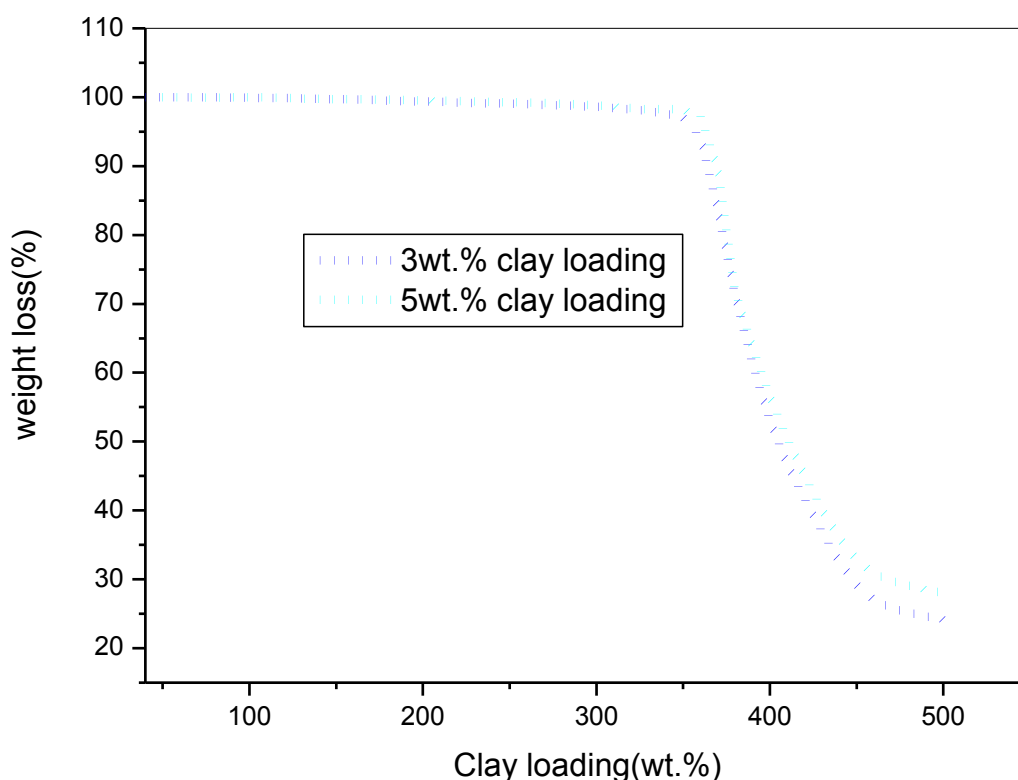


Fig.3: TGA analysis of 3wt.% and 5wt.% clay loaded hybrid nanocomposites.

6. CONCLUSION

Vinyl ester glass fibre reinforced composites filled individually with OC at room temperature has been successfully fabricated using hand layup technique. Improved tensile and impact strengths were factor are observed in OC filled hybrids over vinyl ester *Sansevieria trifasciata* fibre and carbon fibre reinforced composites.

Acknowledgements

We would like to thank the Department of Mechanical Engineering, RV College of Engineering, Bangalore and Department of Polymer Science & Technology, SK University for providing facilities for characterization.

References

- [1] Smita, M.; Sanjay, K.N. Mechanical, thermal and viscoelastic behaviour of nylon 6/clay nanocomposites with cotreated montmorillonites. *Polym. Plast. Tech. Eng.* 2007, 46 (4), 367–376.
- [2] Nayak, P.L.; Sasmal, A.; Nayak, P.; Sahoo, S.; Mishra, J.K.; Kang, S.C.; Lee, J.W.; Chang, Y.W. Nanocomposites from polycaprolactone (PCL)/Soy Protein isolate (SPI) blend with organoclay. *Polym. Plast. Tech. Eng.* 2008, 47 (6), 600–605.
- [3] Viswanath, G.R.; Thangaraj, R.; Guhanathan, S. Thermomechanical and electrical studies on epoxy/hyperbranched polyester blends. *Int. J. Polym. Anal. Chem.* 2009, 14 (6), 493–507.

-
- [4] Tan, S.G.; Chow, W.S. Thermal properties, fracture toughness and water absorption of epoxy-palm oil blends. *Polym. Plast. Tech. Eng.* 2010, 49 (9), 900–907.
 - [5] Dinakaran, K.; Alagar, M. Development and characterization of vinyl ester oligomer (veo) modified unsaturated polyester intercrosslinked matrices and composites. *Polym. Plast. Tech. Eng.* 2003, 52 (11–12), 957–966.
 - [6] Berthet JF, Ferrier E, Hamelin P. Compressive behaviour of concrete externally confined by composite jackets: Part B: modelling. *Constr Build Mater* 2006; 20(5):338–347.
 - [7] Rubin, I. I., *Handbook of Plastic Materials and Technology*. John Wiley & Sons, (1990).
 - [8] Manson, J. A. and Sperling, L.H., *Polymer Blends and composites*. Plenum Press. New York, (1976).
 - [9] Rochdi EH, Bigaud D, Ferrier E, Hamelin P. Ultimate behaviour of CFRP strengthened RC flat slabs under a centrally applied load. *Compos Struct* 2006; 72(1):69–78.
 - [10] Colomb F, Tobbi H, Ferrier E, Hamelin P. Seismic retrofit of reinforced concrete short columns by CFRP materials. *Compos Struct* 2008; 82(4):475–487.
 - [11] Porter ML., Mehus J, Young K, Barnes B, O’Neil EF. Aging degradation of fibre composite reinforcement for concrete structures. In: *Advanced comp mats in bridges and structures*, 2nd int conference, Canada; 1997. p. 641–648.
 - [12] Abanilla MA, Li Y, Karbhari M. Durability characterization of wet lay-up graphite/epoxy composites used in external strengthening. *Compos Part B: Eng* 2006;37(2–3):200–12.
 - [13] Won JP, Park CG. Effect of environmental exposure on the mechanical and bonding properties of hybrid FRP reinforcing bars for concrete structures. *J Compos Mater* 2006;40(12):1063–76.
 - [14] Hammami A, Al-Ghuiliani N. Durability and environmental degradation of glass-vinylester composites. *Polym Compos* 2004;25(6):609–616.
 - [15] Rahman AH, Kingsley C, Richard J, Crimi J. Experimental investigation of the mechanism of deterioration of FRP reinforcement for concrete. In: *Proc 2nd intl conf on fibre comp in infrastructure ICC’98*, Tuscan, vol. 2; 1998. p. 501–511.
 - [16] Chen Y, Davalos JF, Ray I, Kim HY. Accelerated aging tests for evaluations of durability performance of FRP reinforcing bars for concrete structures. *Compos Struct* 2007;78(1):101–11.
 - [17] Hamelin et al. Réparation et renforcement des structures en béton au moyen des matériaux composites. Document scientifique et technique, Association Française de Génie Civil (AFGC), Décembre; 2003.
 - [18] Gillham JK. The TBA torsion pendulum: a technique for characterizing the cure and properties of thermosetting systems. *Polym Int* 1997;44(3):262–276.
 - [19] Marouani S, Curti L, Hamelin P. Composites realized by hand lay-up process in a civil engineering environment: initial properties and durability. *Mater Struct* 2008;41(5):831–851.
 - [20] Räsänen V, Penttala V. The pH measurement of concrete and smoothing mortar using a concrete powder suspension. *Cem Concr Res* 2004;34(5):813–820.
 - [21] Edwards KL. An overview of the technology of fiber-reinforced plastics for design purposes. *Mater Des* 1998;19(1-2):1–10.
 - [22] Bahadur S, Zheng Y. Mechanical and tribological behaviour of polyester reinforced with short glass fibers. *Wear* 1990;137(2):251–66.

-
- [23] Pihtili H, Tosun N. Effect of load and speed on the wear behaviour of woven glass fabrics and aramid fibre-reinforced composites. *Wear* 2002;252:979–84.
- [24] Pihtili H, Tosun N. Investigation of the wear behaviour of a glassfibre- reinforced composite and polyester resin. *Compos Sci Technol* 2002;62:367–70.
- [25] Bhawani ST, Michael JF. Tribological behaviour of unidirectional graphite–epoxy and carbon–PEEK composite. *J Wear* 1993(162– 164):385–96.
- [26] Myshkin NK, Petrokovets MI, Kovalv AV. Tribology of polymers: friction, wear, and mass-transfer. *J Tribol Int* 2005;38:910–21.
- [27] Sampathkumaran P Kishore, Seetharamu S, Murali A, Kumar RK. *J Reinforce Plast Compos* 1999;18(1):55–62.
- [28] Sampathkumaran P Kishore, Seetharamu S, Vynatheya S, Murali A, Kumar RK. SEM observations of the effects of velocity and load on the sliding wear characteristics of glass fabric–epoxy composites with different fillers. *Wear* 2000;237:20–7.
- [29] Collyer AA. Rubber toughened engineering materials. London: Chapman and Hall; 1994.
- [30] El-Tayep NS, Gadelrap RM. Friction and wear properties of E-glass fiber reinforced epoxy composites under different sliding contact conditions. *Wear* 1996;192:112–7.
- [31] Chand N, Naik A, Neogi S. Three-body abrasive wear of short glass fibre polyester composite. *Wear* 2000;242:38–46.

(Received 01 April 2015; accepted 20 April 2015)