PROPERTIES OF CHEMICALLY MODIFIED BAOBAB POD/SISAL FIBRE REINFORCED LOW DENSITY POLYETHYLENE HYBRID COMPOSITE

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ABSTRACT

The present study determined the effect of sodium hydroxide (NaOH) treatment on the properties of baobab pod/sisal fibres reinforced low-density polyethylene (LDPE) hybrid composites. Used to treatment the fibres, were different concentrations of NaOH 2 -10 wt% at 2 wt% interval. The hybrid composites were compounded using two roll mills machine and compressed in a mold using hydraulic press at a pressure of 10 kN and temperature of 120 °C. The fibre content of the hybrid composites was 10 wt% with baobab and sisal fibre ratio of 1:1. Tensile, impact, hardness, water absorption and morphological analysis were conducted on the produced hybrid composites. The mechanical properties of the hybrid composite increased with increase NaOH concentration up to 6 wt%, while the water absorption decreased with increase in concentration of NaOH solution. The morphology revealed that surface cracks and voids were more in hybrid composites produced with untreated and fibres treated at higher concentrations of NaOH.

Key words: *Mechanical Properties, Baobab, Sisal, Polyethylene, Hybrid Composite, Sodium hydroxide.*

1. INTRODUCTION

Currently, attention is shifting to natural fibres as Substitute for man-made fibres such as glass, carbon, Kevlar, because of their nonbiodegradability and lack of sustainability (Mishra *et al*., 2004; Jawaid *et al.,* 2011 and Abdulkhalil *et al*., 2012). However, natural fibres have setbacks of being hydrophilic and of low mechanical properties. Treatment of natural fibres using different methods has been demonstrated to solve the problem associated with hydrophilic nature of the fibres (Li *et al*., 2007; Paul *et al*., 2010 and Liu *et al*., 2011). Treatment of fibres improves interlocking at the interface thereby providing improved adhesion with matrix (Kumar *et al*., 2011), and subsequently improved properties. Also, to improve on the properties of the composite, a single fibre may not be able to provide, thus combing two or more different fibres in matrix is also a way by which improved properties of natural fibre reinforced composites can be accomplished.

Combining two or more fibres in matrix or a fibre incorporated in combined matrices result to hybrid composite. Tailoring the properties of these types of composite materials, could achieve balance of properties, weight and cost savings (Saha *et al*., 1996).

Natural fibre reinforced hybrid composites have found use in sliding panels, bearings, bushings, because of the improved properties achieved by chemical treatment and hybridization (Singh *et al*., 2014).

Singh *et al*., (2014) studied the flexural behavior of hybrid sisal/hemp reinforced recycled high density polyethylene (rHDPE) hybrid composite. In the work, sample with 20 % sisal combined with 5 % hemp fibres had the highest specific flexural strength. The tribological properties of hybrid of sisal, jute and hemp in epoxy resin for orthopedic implant has been reported. A noticeable improvement in property at 36 % of the natural fibre compared with the lower fibre content was observed (Gouda *et al*., 2014). Thombre *et al*. (2014) reported the mechanical properties of jute/bagasse-Epoxy hybrid composite and jute/lantana camara-Epoxy hybrid composite to have good tensile strength, good elasticity and excellent resilience. Using different fibre loading in their work, Siddika *et al.* (2014) reported that 20 % fibre loading of coir/Epoxy fibre had the best mechanical properties. Interest in sisal fibre reinforced composite is higher than other fibres. This is because it has high impact strength, moderate tensile and flexural properties when compared with other lingo cellulosic fibres (Kuruvilla *et al*., 1999).

Despite various reported works on the use of natural fibres as reinforcement in composites, the report on the use of baobab (*Adansonia digitata*) fibre or its combination with other fibres as reinforcement in composite is scanty. But, reports are available on its use in rope making, basket nets, fishing line (Sidibe *et al*., 2002). Investigation showed it has potential as reinforcement when treated (Shehu, 2016). This work is thus aimed at studying the effect of alkali (NaOH) treatment on the properties of baobab pod fibre hybridized with sisal fibre in low density polyethylene composites.

2. EXPERIMENTAL

2.1 Materials

The baobab pod and sisal fibres were obtained from National Research Institute for Chemical Technology

(NARICT), Zaria, Nigeria. The fibres, modified with sodium hydroxide (97 % purity, BDH Chemical, Poole, England) before use. The matrix was low density polyethylene obtained from Chemical store, Zaria.

2.2 Methods

2.2.1 Treatment of baobab and sisal fibres

Some quantities of baobab fibre (1 mm size) were soaked in the prepared 2 wt% of sodium hydroxide solution to remove some of the lignin, wax, pectin and other impurities. The soaked fibres were kept on a regulated hot plate at 40 °C for 20 min., followed by occasional stirring with a glass rod to ensure an even treatment. After 20 min., the fibres were removed and rinsed severally with distilled water until a neutral pH was reached. Drying was done in oven at 50 °C for 20 min. The procedure was repeated using the 4, 6, 8 and 10 wt% of sodium hydroxide solutions respectively. The procedure was adopted to treat the sisal fibre.

2.2.2 Hybrid composite production

The baobab pod/sisal fibres content of the hybrid composite was 10 wt% (5 wt% baobab pod fibre and 5 wt% sisal fibre). Preliminary work by Shehu, (2016) showed that at 10 wt% loading, most of the mechanical properties were highest for baobab fibre reinforced low density polyethylene. The fibres were mixed with low density polyethylene using two-roll mill model number 5183, made by Reliable Rubber Company New Jersey USA . The two-roll mill machine was preheated at the melting temperature of polyethylene of 120 °C for 30 min. At the end of the preheating period, 90 wt% of LDPE was gradually poured into the preheated two-roll mill to melt the LDPE for about 5 min. Introduced to the melting LDPE to mix was 10 wt% untreated baobab pod/sisal fibres. Mixing continued until the matrix and the fibre were uniformly mixed. The compounded baobab-sisal fibres and LDPE in form of a sheet was removed from the roll mill. The same procedure was followed to compound the treated fibres and low density polyethylene.

After that, composite samples were fabricated using hydraulic press model number 1200, made by Carver Incorporation New Jersey USA. The mold was prepared and the compounded composite was cut to the size of the mold, placed in the hydraulic press after preheating and compressed at 120 °C at pressure of 10 kN for period of 6 min. After that, the mold was removed from the press, allowed to cool and the composite sample removed from the mold.

2.3 Characterization of Samples

2.3.1 Mechanical test: tensile strength, impact test and hardness test

ASTM D638 (1987) was adopted for the tensile test using an Instron Machine Model 3369, System Number 3369K1781. From the tensile test, tensile strength, modulus of elasticity and percentage elongation at break were obtained. The impact test was conducted according to ASTM D256 (1987) using the Charpy impact testing machine, Capacity 15 J and 25 J serial number 412-07-15269C.The hardness test was performed according to ASTM D2240 using Shore Duro-meter test.

2.3.2 Water absorption test

Water absorption test was conducted using ASTM D570-98 (2005). Using Equation 1 the percent water absorbed was calculated. Where W_i is initial weight of dry sample and W_f is final weight of wet sample.

$$\%\text{water absorbed} = \frac{W_f - W_i}{W_i} x100 \qquad 1$$

Three test samples were used in each of the tests and the average taken.

2.3.3 Morphological analysis using scanning electron microscope (SEM)

The morphological analysis of the samples was conducted using Phenom tm Prox scanning electron microscope. The samples size were 2 mm x 2 mm thinly coated with gold, transferred to the SEM machine where they were observed and images captured.

3. RESULTS AND DISCUSSION

3.1Effect of Treatment on Tensile Strength

Figure 1 presents the effect of varying NaOH treatment concentration on the tensile strength of baobab/sisal fibre reinforced low density polyethylene hybrid composite.

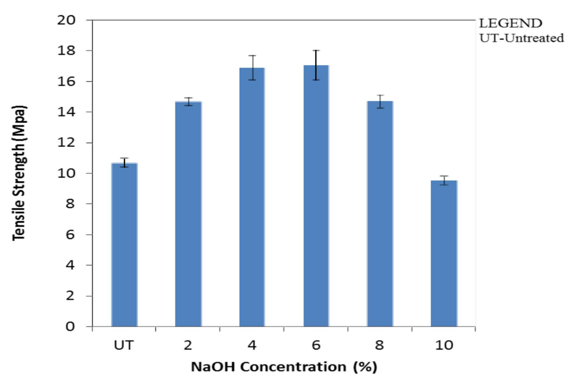

Figure 1: Effect of Fibre Treatment on the Tensile Strength of the Baobab/Sisal Hybrid Composite

A positive treatment effect was observed with fibres treated with 2 wt%, 4 wt%, 6 wt% and 8 wt% NaOH solution respectively. They showed 36 %, 45 %, 55 % and 34 % increase respectively in their tensile strength values over the untreated hybrid composite. The positive treatment effect noted, occurred because of the alkali treatment resulting to in an improvement in the interfacial bonding. This was so because of increase in extra sites for mechanical interlocking, therefore promoting more resin-fibre interpenetration at the interface (Bledzki *et al.,* 1999 and Kabir *et al.,* 2012). Increasing the concentration of NaOH solution to 10 wt% resulted to lower tensile strength than the untreated hybrid composite. This decrease in the tensile strength might be because of excess delignification of the fibres, which results in weakening or damaging of the fibres (Bledzki *et al.,* 1999).

3.2Effect of Treatment on Modulus of Elasticity (MOE)

Figure 2 presents the effect of varying NaOH treatment on the MOE of baobab/sisal fibres reinforced low density polyethylene hybrid composite.

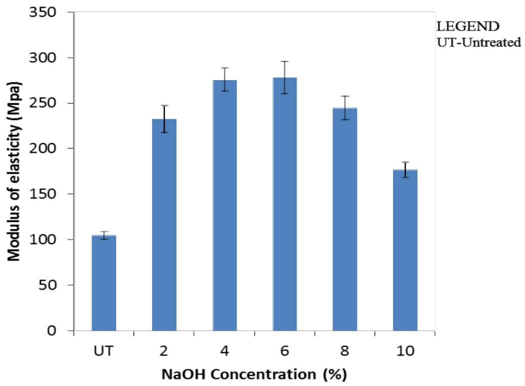

Figure 2: Effect of Baobab/Sisal Fibre Treatment on the Modulus of Elasticity of the Hybrid Composite

The highest MOE was at 6 wt% NaOH treatment and with further increase in NaOH concentration, the MOE decreased to 177.08 MPa at 10 wt% NaOH concentration. The improvement in the MOE of the alkali treated composite could be credited to the treatment improving the adhesive characteristics of fibre surface by removing natural and artificial impurities, thereby producing a rough surface topography. It also leads to fibrillation, creating more available surface area on the fibres to interact with the matrix (Kumar *et al*., 2011). The drop in MOE after 6 wt% could be as result of fibre surface damage because of too much delignification caused by high concentration of NaOH. Moduli of elasticity of composites have been reported to decrease drastically after certain peak NaOH concentration (Wang *et al*., 2007).

3.3 Effect of NaOH Treatment on Elongation at Break

Figure 3 presents the effect of varying NaOH treatment concentration on the percentage elongation at break of baobab/sisal fibres reinforced low density polyethylene hybrid composite.

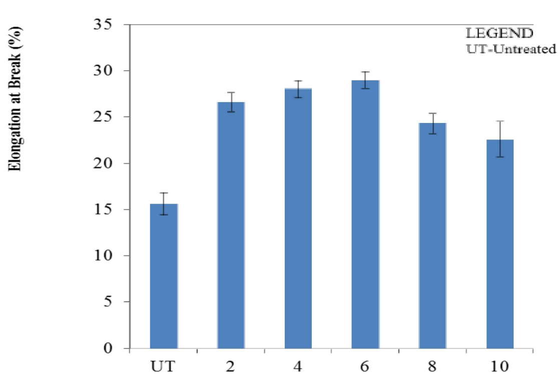

Figure 3: Effect of Baobab/Sisal Fibre Treatment on the Elongation at Break of the Hybrid Composite

On treating with 2 wt%, 4 wt% and 6 wt% concentration of NaOH solution there was increase in elongation, thereafter a noted decrease. The composite resulting from 6 wt% concentration of NaOH solution treated fibre showed the highest percentage elongation at break of 29 % which was 93 % higher than the untreated fibres hybrid composite. The improved percentage elongation on treatment was due to the fact more hemicellulose, lignin and pectin are removed because of treatment to provide more surface roughness, therefore resulting in better compatibility with the matrix (Kabir *et al*., 2012).

The decrease in elongation at break at 8 wt% and 10 wt% NaOH concentration treated hybrid composites might be because of excess delignification of the fibres, which results in weakening or damaging of the fibres (Wang *et al*., 2007).

3.4 Effect of NaOH Treatment on Impact Strength

Figure 4 presents the effect of varying NaOH treatment concentration on the impact strength of baobab/sisal fibres reinforced low density polyethylene hybrid composite.

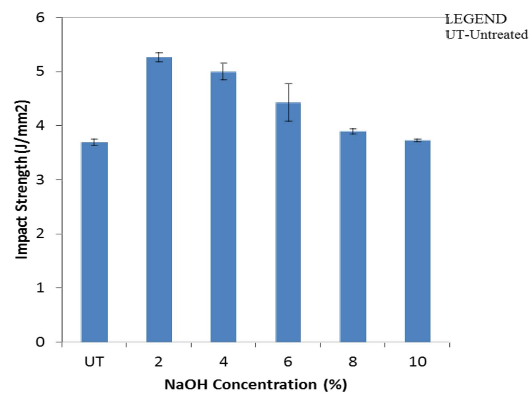

Figure 4: Effect of Baobab/Sisal Fibre Treatment on the Impact Strength of the Hybrid Composite

Increase impact strength was observed with the treated fibre composites compared with the untreated fibre composite. There was about 40.5 % increase in the impact strength of the composite made with fibres treated with 2 wt% concentration of NaOH solution compared with the untreated fibre composite. After the highest at 2 wt% treatment concentration, impact strength was then observed to decrease with increasing concentration of NaOH solution.

However, the entire treated NaOH hybrid composite showed a higher impact strength compare with the untreated hybrid composite. This could result from increase in the fibre surface roughness because of treatment. Therefore, better mechanical interlocking resulting from increase in of cellulose exposed on the fibre surface leading to increasing number of possible reaction sites (Bledzki *et al.,* 1999).

3.5 Effect of NaOH Treatment on Hardness Strength

Figure 5 presents the effect of varying NaOH treatment concentration on the hardness of baobab/sisal fibre reinforced low density polyethylene hybrid composite.

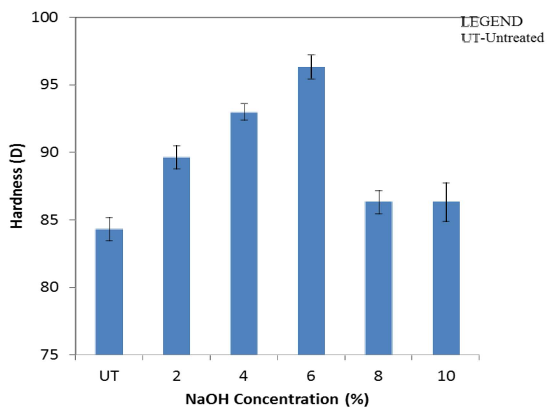

Figure 5: Effect of Baobab/Sisal Fibres Treatment on the Hardness Strength of the Hybrid Composite

The modification of fibre with 2 wt%, 4 wt% and 6 wt% NaOH solutions lead to 6 %, 10.7 % and 14.7 % increase in hardness value of the composite compared with the untreated fibre composite. The noted increase in hardness value could results from strong interface, closed packing arrangement in the composite and increase in stiffness and the dispersing of the fibres properly into the matrix because of the treatment (Kumar *et al*., 2011; Wang *et al*., 2007; Modibbo *et al*., 2009; John *et al*., 2013 and Kaymakci *et al*., 2013).

3.6. Water Absorption

Figure 6 presents the effect of varying NaOH treatment concentration on the water absorption capacity of baobab/sisal fibres reinforced low density polyethylene hybrid composite.

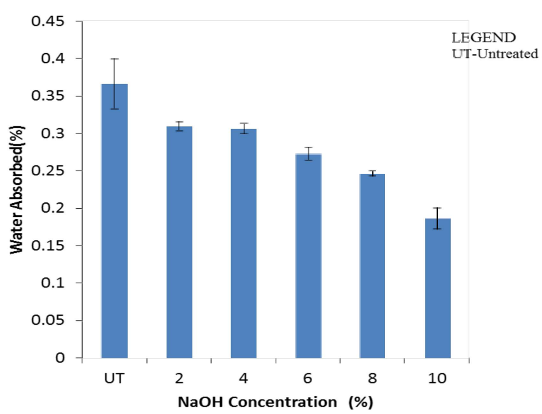

Figure 6: Effect of Baobab/Sisal Fibres Treatment on the Water Absorption Capacity of Hybrid Composite

It seen that water absorption capacity of the untreated fibre composite dropped from 0.36 % to 0.3 %, when the fibres were treated with 2 wt% concentrated NaOH solution. The alkali treatment further decrease the water absorption capacity of the composite compared with the 2 wt% concentrated NaOH solution treated fibre composite. Surface treatment of fibre caused the noticed decrease. Treatment results to the breaking down of alkali sensitive hydroxyl (OH) groups present among other groups which react with water molecules (H-OH) and move out from the fibre structure (Kabir *et al*., 2012 and John *et al*., 2013). The remaining reactive molecules form fibre-cell-O-Na groups between the cellulose molecular chains. Due to this, hydrophilic hydroxyl groups are reduced and increase the fibres moisture resistance property. As the treatment concentration of NaOH increases, the water absorption capacity of the composite decreased. This showed that excessive alkali treatment had taken out a certain portion of hemicelluloses, lignin, pectin, wax and oil covering materials (Modibbo *et al*., 2009 and Kaymakci *et al*., 2013).

3.7 Effect of Treatment of Surface Morphology

Plate 1 a-d show the surface morphology of the untreated and 4 wt%, 6 wt% and 10 wt% treated hybrid composite.

As shown on the micrographs, Plate 1 (a), the untreated revealed more cracks and voids than Plate 1 (b-c), the hybrids composites from fibres of different concentration of NaOH treatment. The cracks visible in the untreated fibre hybrid composites may be due to less interfacial adhesion between fibre and matrix due to presence of surface deposits (Deka *et al*., 2013).

Plate 1 (b and c) showed the surface morphology of the composites reinforced by 4 and 6 wt% of NaOH treated sisal/baobab fibres hybrid composites. It revealed a smooth surface which might be due to better dispersion of the fibres in the matrix. The fibres seemed to be well dispersed in the polyethylene matrix. The good dispersion corroborates good stress transfer from matrix to fibres and the reinforcing effect of the fibres. It is an evidence of better compatibility which yielded better tensile strength (Gupta *et al*., 2008 and Araga *et al*., 2011).

On the other hand, Plate 1(d) shows the surface morphology of 10 wt% NaOH treated sisal/baobab hybrid composite. It was observed there was more cracks and voids in the morphological surface. The surface cracks and voids tends to be associated with high delignification of the fibres at higher concentration of NaOH concentration which lead to surface damage to the fibres and non uniform distribution of the fibre in the matrix. Also, the fibres were strongly damaged and the occurrences of some de-bonding phenomena indicated poor adhesion between fibre and matrix. The non-uniform distribution of fibre gave rise to the formation of stress concentration points (Avella *et al*., 2008). This situation is reflected in the mechanical properties. It is assumed that, increasing the NaOH concentration decreases interfacial adhesion and homogeneity.

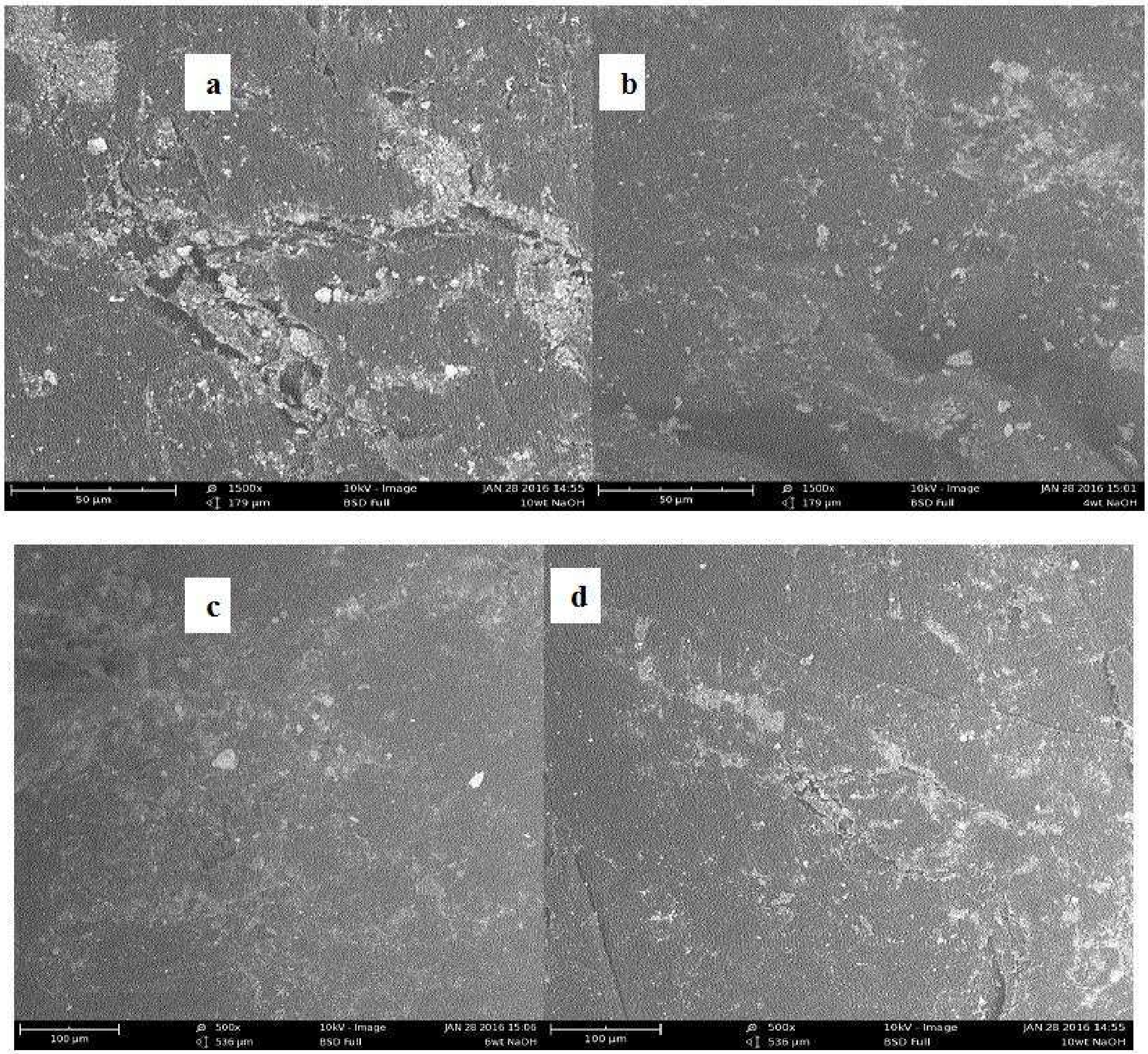

Plate 1: SEM Micrograph of (a) 50:50 untreated,(b) 4 wt% NaOH, (c) 6 wt% NaOH and (d) 10 wt% NaOH treated hybrid sisal : baobab fibre hybrid composite.

Conclusions

Treated Baobab pod fibre was used to reinforce low density polyethylene successfully and the mechanical, physical and morphological analysis conducted. Treatment of the fibres enhanced the properties of the composites. The highest tensile strength, MOE, elongation at break, impact strength and hardness were 55 %, 167 %, 93 %, 41 % and 14.7 % respectively higher than the untreated fibres hybrid composite. The hybrid composites of 6 wt% NaOH treated baobab pod/sisal fibres exhibited higher tensile strength, MOE, elongation at break and hardness of 17 MPa, 278 MPa, 29 % and 96 Shore D respectively. The SEM morphology indicated the surface of the treated baobab pod/sisal fibre hybrid composite had less cracks and voids compared to the untreated baobab pod/sisal fibre hybrid composite. This showed the reason for better properties noted with the treated baobab pod/sisal fibre hybrid composite over the untreated. The values of mechanical properties obtained in this work, compared favorably with values some composites produced in previous works that have been considered to be of good mechanical properties used as building and automotive materials.

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