PINEAPPLE LEAF FIBRE (PALF) BASED TEXTILE COMPOSITES FOR CLADDING BOARDS

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INTRODUCTION

Pineapple leaf fibre (PALF) is rich in cellulose, relatively inexpensive, and abundantly available. Mother plant slowly dies once fruiting is completed, but any large suckers or ratoons will continue to grow and eventually produce new fruit. Pineapple leaf contains only 2-3% fibre, covered by a hydrophobic waxy layer (Asim, *et al.*, 2015). Pineapple Leaf Fibres (PALF) contains about 81% of cellulose which means it has higher amount of cellulose than other natural fibres (Asim, *et al.*, 2015). Higher cellulosic content in PALF and its lower microfibrillar angle enhance the physical and mechanical strength of matrix reinforced bio-composites (Asim, *et al.*, 2015). "Mauritius" pineapple is the common variety grown in Sri Lanka which is a "Queen" variety . Commercially Pineapple is served as a fruit as well as a vegetable. After the fruit is harvested the leaves are thrown as waste and burnt. Recently, the biodegradable Pineapple leaves are used to extract fibres from its waste and used in many industries like fabric and yarn manufacturing, aerospace, automobile, furniture, sports etc. (Asim, *et al.*, 2015). Use of this type of waste is important to minimize global problems in dealing with the carbon footprint, global warming as well as waste management. The aim of this project is to produce an eco-friendly composite using PALF waste, which can be used as cladding boards in the construction industry.

METHODOLOGY

Fibre extraction

Pineapple Leaves, which are approximately one year older, were collected from Gampaha area for this experimental work. Fibres were extracted from its leaves using manual method. For this purpose, a ceramic Plate was used to peel-off the upper layer of Pineapple leaf. After peeling off the upper waxy layer, white colour fibres appear on the leaf. Then, fibres are pulled out carefully without damaging them.

Retting of PALF

After fibres are extracted they need to undergo retting process. According to the literature survey, small bundles of scratched pineapple leaves are immersed in water at room temperature in a tank having the liquor ratio of 1:20. Thus, Urea 0.5% was used for fast retting reactions under room temperature.

Treat with NaOH

After retting, PALF are dried under sunlight and treated with 5% NaOH, which is an alkaline treatment, to remove impurities and lignin as well as to provide better adhesion between fibre and matrix, later in the composite. Because, most thermosetting polymers used as a matrix material in making composites are non-polar substances, which are not compatible with polar plant fibres (natural plant fibres consist of cellulose, hemicellulose, pectin and lignin with hydrophilic OH^- groups) and therefore, it causes poor adhesion between the fibres and matrix interaction surfaces. This treatment was done at room temperature without boiling as the reaction is exothermic (Panyasart, *et.al*, 2014).

Fibre preparation

Extracted and treated dried PALF are dyed with three selected colours. Direct dyes are used, because they are easy to apply as well cheaper in price. Even though direct dyes have wash and light poor fastness properties, there will be no issues for dyeing PALF in making composites. Because, fibre web sealed with polyester resin in the PALF composite.

Testing of fibre physical properties

It was tested fibre bundle tenacity at dry and wet state, single fibre strength, moisture content and moisture regain of NaOH treated and untreated PALF fibres. These physical properties were selected as they are important for the applications of cladding boards. Testing was carried out using ASTM standards and standard equipment.

Fibre web formation

Prepared fibres was laid at room temperature in three alternative layers with 0 and 30 degrees directions using hand lay-up method. These directions were determined based on the literature survey and feasibility testing. Layered fibres are then cut to the required size of the mould box in the dimensions of 20x15x0.5 (cm). Prior to placing the fibre layers in the mould box, they are bonded with a commercially available adhesive for easy handling of the fibre layers in making composite. After placing the bonded fibre layers in the mould box, pour unsaturated, thermoset hydrophobic Polyester matrix to make the composite with PALF to enhance the mechanical properties of the end product. Then, the formed fibre web is compressed to obtain a fibre bat. PALF composite is made with two fibre compositions such as 40% fibres (wt%) and 50% (wt%), because, most of the past research work has been carried out with the fibre composition from 10-30%(wt%)s and resins like Epoxy or Low Density Polyethylene (LDPE) or Polyester (Asim,*et.al.*,2015;Pickering,*et.al*,2016;Kumar *et al* 2015). However, it was understood that Polyester matrix is economically available and gives good mechanical and physical properties. Figure 1 (a), (b), and (c) represent treated and dried PALF, dyed PALF, and produced PALF reinforced composite, respectively.

(a) (b) (c)

Figure 1: (a) Treated and dried PALF (b) Dyed PALF (c) PALF reinforced composite

Testing of physical properties and characteristics of composites

Prepared composites were tested for tensile properties using ASTM-D 3039, Rock well hardness using ASTM- D0785-03, compressive strength using ASTM-D5024-01, flexural strength using ASTM D5023-01 and moisture absorption using ASTM-D5229 standards.

RESULTS AND DISCUSSION

Physical properties of PALF

Table 1 shows the tested physical properties and characteristics of PALF important for cladding boards.

Table 1 : Physical properties of PALFs

Fibre physical testing		**Result**
Effective fibre length		93cm
Dry fibre bundle tenacity	Untreated	23.30 g/tex
	Treated	37.89g/tex
Wet fibre bundle tenacity	Untreated	20.26 g/tex
	Treated	32.25 g/tex
Single fibre strength	Untreated	10.25 gf/den
	Treated	10.93 gf/den
Moisture content	Untreated	8.93%
	Treated	10.05%
Moisture regain	Untreated	9.82%
	Treated	11.16%

According to the Table 1, it was found that PALF fibres compose high fibre bundle tenacity, high single fibre strength, high moisture content and high moisture regain. Thus, treated fibres have higher values of the physical properties than untreated fibres due to removing of impurities and lignin during mild alkali treatment.

Microscopic views of PALF

To observe on microscopic view of PALF digital microscope with Leica Microsystem framework is used. Both treated and untreated PALF were observed with 10x,20x and 40x magnification, but 40x magnification gave very clear views. Figure 2 shows the longitudinal views and cross-sectional views of PALF.

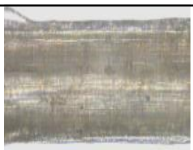
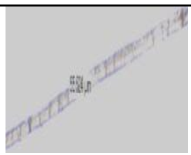
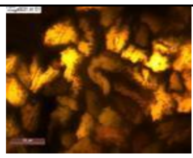
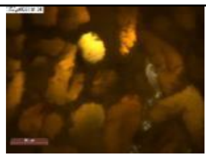
	Longitudinal view		**Cross-sectional view**	
	Untreated fibre	**Treated fibre**	**Untreated fibre**	**Treated fibre**
40X				

Figure 2: Longitudinal views & cross-sectional views of untreated and treated PALF with 40x magnification.

- **Longitudinal view**

Untreated PALF are with impurities, cellulose as well as lignin. Therefore, when observed under microscope, dark image can be observed. When PALF are treated with NaOH, cellulose as well as impurities are removed, therefore a clear image can be seen and, it shows that there are cross-wise striations on treated PALF. With the removal of impurities, these striations become clearly visible. Also, there is less fibrillation with the treated PALF. This is due to the reaction between alkaline solution and lignin deposited on the fibre surface or close to the surface. As a result of this reaction, protruded fibres are bonded on to the fibre strand giving smooth surface with less fibrillation.

- **Cross-sectional view**

Untreated fibres show polygonal shape cross-section. When treated with NaOH polygonal shape transform to circular shape. This is because, when treated with NaOH, native structure of PALF changes from Cellulose I (Polygonal cross section) to Cellulose II (circular cross section). This happens, when NaOH molecules enter to the polymer structure of PALF cell wall through amorphous polymer regions, polymer structure will get swollen by pushing apart crystalline polymer chains with releasing energy. Due to this, polygonal cross-section achieves circular shape and the change is irreversible. This behaviour is common for most vegetable fibres.

Physical properties of PALF composites

Table 2 shows the important physical properties of PALF based composite with 40 %(wt %) and 50 %(wt %) PALF fibre compositions. The results were produced with testing of five specimens for each property.

Table 2: Physical properties of PALF composites with two fibre compositions

	Tensile strength	Flexural strength	Compressive strength	Hardness (HRB)	Moisture content(%)	Moisture regain(%)
40%(wt%)	24.94Mpa	111.3Mpa	19Mpa	53.6	0.7	0.69
50%(wt%)	56.77MPa	70.02Mpa	13.56Mpa	0 reading	1.6	1.7

According to the Table 2, 40%(wt%) fibre composition shows 56% lower tensile strength than that of 50% (wt%) fibre composition. This would be due to the lower % of fibre loading at 40%(wt%) and the applied tensile load is borne by the higher % of matrix component, which has lower strength than fibres, existing in the composite. Further, at 40% (wt%) fibre loading, fibre entanglement is comparatively lower than 50% (wt) fibre composition, which results in easy fibre failures under tensile loads due to the lower inter fibre friction than higher fibre loading in composites. However, tensile strength does not significantly affect the applications of cladding boards compared to the other physical properties given in Table 2. Thus, 40%(wt%) fibre composition shows higher flexural strength (59% higher) and higher compressive strength (40% higher), than that of 50% (wt%) fibre loading. Because, at lower fibre loading, there are comparatively higher voids among reinforced fibres to develop higher fibre-matrix bond, which results higher flexural strength and compressive strength at 40% (wt%) than that of 50% (wt%) fibre loading. With higher fibre loading, comparatively lower voids among fibres and lower matrix volume are available for developing bonds between fibre and matrix, which results good flexural behaviour and lower compressive resistance in composites. Further, lower hardness reported at 50%(wt%) may be another reason for lower flexural strength and compressive strength of composites. In Table 2, zero reading hardness reported with 50 %(wt%), which means poor hardness in composites with that fibre loading. As described previously, lower voids among fibres and lower matrix volume results poor fibre-matrix bond. Therefore, it may affect poor hardness of composites at 50% (wt5%) compared to that of 40% (wt %). Thus, 40%(wt%) fibre loading showed lower moisture content (56% lower) as well as lower moisture regain (59% lower) than 50%(wt%) fibre composition. Because, PALF have naturally very much moisture absorbency in nature. With higher fibre loading in composites obviously show the higher moisture content and regain values. In previous research work, it was found that flexural strength, compressive strength and water absorption is increased with the fibre composition from 10-30%(wt%), but, further sufficient experimental work have not been found with the fibre composition of more than 40% (wt%) (Daramola, *et. al.*, 2017; Shiju, *et. al.*, 2015).

Flexural strength gives the resistance for shear loads, which are applied on the composite. Shear loads are frequently applied on the applications of cladding boards in construction industry, therefore higher flexural strength is more suitable for cladding boards. Thus, compressive strength is also very important for cladding boards as they are subjected to various compressive forces and shear loads. Therefore, higher compressive strength is suitable for cladding boards. Thus, composites with very poor hardness at the fibre composition of 50 % (wt %) may cause to break material during fibre loading, therefore, enough higher hardness is recommended for cladding boards. In addition, lower moisture content and lower moisture regain are important in the applications of cladding boards, because, various micro-organisms can develop on the cladding boards and it may effect on the quality, durability and also may effect on other physical properties such as mechanical properties, physical properties and colour fastness properties of cladding boards. Therefore, lower moisture content and regain is more preferred for cladding boards.

Therefore, according to the physical properties of PALF composites, it can be recommended to use maximum of 40%(wt%) fibre composition. Further, it was understood that, this composite with Polyester resin showed satisfactory mechanical properties in composites considering Epoxy resin, Phenol formaldehyde resin or phenolic resin.

CONCLUSION

PALF have tremendous mechanical and physical properties and can be applied in making of reinforced polymer composites as they compose of high fibre bundle tenacity, high single fibre strength, high moisture content and high moisture regain. Thus, mild alkali treated PALF have higher of these values than untreated fibres. After treating with mild alkali, PALF showed very clear longitudinal and cross sectional microscopic views. Longitudinal view showed cross-wise striations on treated PALF and cross sectional view showed a change of its shape from polygonal to circular contour before and after mild alkali treatment respectively.

Comparison of the two experimented fibre compositions such as 40%(wt%) and 50%(wt%), textile composite with 40%(wt%) fibre composition showed higher flexural strength (59% higher), higher compressive strength (40% higher), higher hardness and lower moisture content (56% lower) as well as lower moisture regain (59% lower) than 50%(wt%) fibre composition. But,40%(wt%) composition showed 56% lower tensile strength than that of 50% (wt%) fibre composition. Based on the above findings, it is recommended to use maximum of 40%(wt%) PALF fibre composition to produce textile composites for cladding boards and Polyester can be used as a matrix material as its ability to give satisfactory mechanical and physical properties, economically available and minimum problems in using it for making textile composites.

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