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DEVELOPMENT OF COMPOSITE OF SAWDUST, BAMBOO AND COCONUT HUSK FIBRES IN EPOXY RESIN

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ABSTRACT: *The high rate of deforestation, environmental and air pollution has been a challenge in Nigeria. This led to the development and characterisation of epoxy resins composite that consist of sawdust, bamboo fibre and coconut husk fibre where physical and mechanical properties are determined. One hundred and sixty-two different samples were produced by varying the length of the fibres between 10 mm, 30 mm and 50 mm at 7.5% weight for each fibre loading using the hand lay-up moulding technique. The density, percentage water absorption, flexural strength, tensile strength, compressive strength, and impact energy of the composite were obtained and their mean were statistically analysed. The results showed that the highest density ranges between 1.65 g/cm3 and 1.66 g/cm3 and these were not significantly different (p>0.05). Similarly, the percentage water absorption ranged from 10.41 % to 10.44 % for the 162 samples and these were not significantly different (p>0.05). The flexural strength ranges between 5.83 MPa and 15.35 MPa with corresponding fibre lengths combination of 10:10 and 50:50 mm respectively, while the tensile strength ranges between 1.45 MPa and 4.03 MPa with corresponding fibre lengths combination of 10:10 mm and 50:50 mm respectively. The compressive strength has values ranges between 4.53 MPa and 40.7 MPa, while the impact strength has its range between 14.51 J and 22.58 with corresponding fibre lengths combination of 10:10 and 50:50 mm respectively.*

KEYWORDS: *Bamboo fibre, Coconut husk fibre, Composites, Sawdust*

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I. Introduction

The high demands for wooden materials and rise in the use of fibres have increased the importance of composite particleboard. The growing popularity of wooden panels renders market segment increasingly competitive. Wood-based products offer an interesting alternative to expand the range of materials for use in civil construction, cabinet making and other industries [1]. The advantage of wood-based products is that the wood's properties can be improved through the application of science and technology. Wood-based panels are classified as wood-based layers, fibre and particleboard.

It was documented [2] that the composite produced by solidifying sawdust has been developed for effective utilization of wood waste. The composite does not damage the environment because of its composition. The waste sawdust generated by lumbering of the wood can be utilized effectively. The product with complicated shapes can be formed by compression moulding of the sawdust at appropriate temperature. However, the composite will not have high strength, very brittle and it has no water resistance. To improve these defects, epoxy resin was used as an adhesive while natural fibre was used as reinforcement to obtain high strength.

The effect of crosslink on the properties of polyethylene/wood flour composites was studied [3]. In this study, the possibility of using silane technology in crosslinking composites of wood flour and polyethylene has been investigated. Mechanical analysis of the cross-linked composites showed increased tensile strength with increasing amount of wood flour, which might be an indication of improved adhesion between the matrix and the wood flour. The stiffness increased with increasing amount of wood flour with accompanied decrease in strain at break. Stark and [4], also reported the effects of wood fibre characteristics on mechanical properties of wood/polypropylene composites saying that 27% increase in tensile strength of composite prepared with 40% wood–fibre and 3% maleated polypropylene (MAPP).

In addition, [2] developed green composite consists of woodchips, bamboo fibres and biodegradable adhesive'. The experiment focus on the effects of the biodegradable adhesive and bamboo fibres on the bending strength and Impact strength. In addition, using the specimens absorbed water, the effect of its water resistance on the Impact strength was examined. From the experimental results, it was deduced that; (i) the bending strength increases by adding the biodegradable adhesive to woodchips, and it increases remarkably by adding long bamboo fibres in addition. (ii) The Impact strength increases slightly when only the biodegradable adhesive is added to the woodchips, and the Impact strength increases remarkably and the water resistance is also improved when long bamboo fibres are added in addition. (iii) The bending strength is high when the woodchips with the small particle size and long bamboo fibres are used. On the other hand, the Impact strength is high when the woodchips with the large particle size and long bamboo fibres are used. (iv). The proposed composite composed of woodchips, long bamboo fibres and the biodegradable adhesive has the high strength, and the practical application for the composite can be expected.

II. Materials and Method

2.1 Materials

Sawdust was used as base material for the composite formulation with Bamboo fibre and husk coconut fibre as the reinforcement. Epoxy LY 556 resin, which chemically belongs to the 'epoxide' family with common name 'Bisphenol Diglycidyl Ether was used as matrix. The low temperature curing epoxy resin (Araldite LY 556) and corresponding Hardener (HY951) with IUPAC name: NN′-bis (2-aminoethylethane-1, 2-diamin) and Accelerator DY 070 are mixed in a ratio of 10:1:1 by wt% [5] served as the binder.

2.2 Experimental Design

The studied composite material was the mixture of sawdust, bamboo fibre, coconut fibre and Epoxy resins. Randomly oriented configuration was used according to [6]. Four mechanical properties (Flexural, Tensile Compression and Impact) are thought to be influenced by two factors which include:

1. Length of bamboo fibres.
2. Length of coconut fibres.

The design comprises length of the bamboo fibre, length of the coconut to be used in the composite which serve as the factor/independent variable. Applying the principle of full factorial experimental design approach, design for this experiment is X^k
Where:
X = no of levels = 3
k = no of factors = 2

The total number of experimental conditions (Experimental Runs) for this research
$= X^k = 3^2 = 9$
Thus, experimental conditions = 9 as shown in table 1.

Table 1. Layout of Runs

Composite type	Length of Bamboo Fibre (mm)	Length of Coconut Fibre (mm)
1	10	10
2	10	30
3	10	50
4	30	10
5	30	30
6	30	50
7	50	10
8	50	30
9	50	50

2.3 Methodology

2.3.1 Sample Preparation

Sawdust of Mahogany was collected from local wood miller, grinded and sieved to have homogeneous particle size of 1 mm [2]. The green bamboo of 1 mm in diameter was obtained with its fibre removed and dried as documented by [7], [8]. The fibre was later cut into various lengths of 10 mm, 30 mm and 50 mm as shown in plate

I. The fibrous layer of the fruit which made up of smaller threads, each about 1 mm in diameter was removed from the hard shell manually and cut to the lengths of 10 mm, 30 mm and 50 mm [2].

2.3.2 Treatment of materials

The sawdust, coconut and bamboo fibres were chemically treated with 2% sodium hydroxide (NaOH) concentration as documented by [9] and [10]. The sawdust, coconut and bamboo fibres were soaked separately (100g/litre of 2% NaOH each) in the alkaline for 24hrs at room temperature and thoroughly washed with distilled water to neutral solution and air dried for 7 days.

2.3.3 Preparation of composite

The total weight of the specimen is 100g where percentage biomass of coconut and bamboo fibres is 7.5g each, while the mass of the sawdust 35g and that of matrix is 50g. This is illustrated as shown in table 5. Composites having different fibres content were prepared by varying the fibres length between 10 mm, 30 mm and 50 mm as shown in table 2. Polyetene was laid into the mould prior to mixing of the composite. The sawdust was mixed uniformly with the coconut fibres, bamboo fibre and matrix with the aid of spatula. The mixture was poured carefully into the moulds and flattened appropriately using a roller. Then it was dried for 20 min after which it was separated off from the moulds as shown in figure. 1.

2.3.4 Specimens soaked before test

In accordance with [11], all the specimens tested were soaked in water for 24 hours before the test was conducted. The test was done immediately upon removal from the water. The amounts of water absorbed were reported.

Table 2. Composite studied formulation

Constituent	Composite type								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Length of Bamboo Fibre (mm)	10	10	10	30	30	30	50	50	50
Length of Coconut Fibre (mm)	10	30	50	10	30	50	10	30	50
Mass of Coconut Fibre (g)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Mass of Bamboo Fibre (g)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Mass of sawdust Content (g)	35	35	35	35	35	35	35	35	35
Mass of matrix (g)	50	50	50	50	50	50	50	50	50
Total mass of formulation (g)	100	100	100	100	100	100	100	100	100

Keys:
1 - 10:10 Bamboo and Coconut Fibre length (10:10 BCFL),
2 - 10:30 Bamboo and Coconut Fibre length (10:30 BCFL)
3 - 10:50 Bamboo and Coconut Fibre length (10:50 BCFL)
4 - 30:10 Bamboo and Coconut Fibre length (30:10 BCFL)
5 - 30:30 Bamboo and Coconut Fibre length (30:30 BCFL)
6 - 30:50 Bamboo and Coconut Fibre length (30:50 BCFL)
7 - 50:10 Bamboo and Coconut Fibre length (50:10 BCFL)
8 - 50:30 Bamboo and Coconut Fibre length (50:30 BCFL)
9 - 50:50 Bamboo and Coconut Fibre length (50:50 BCFL)

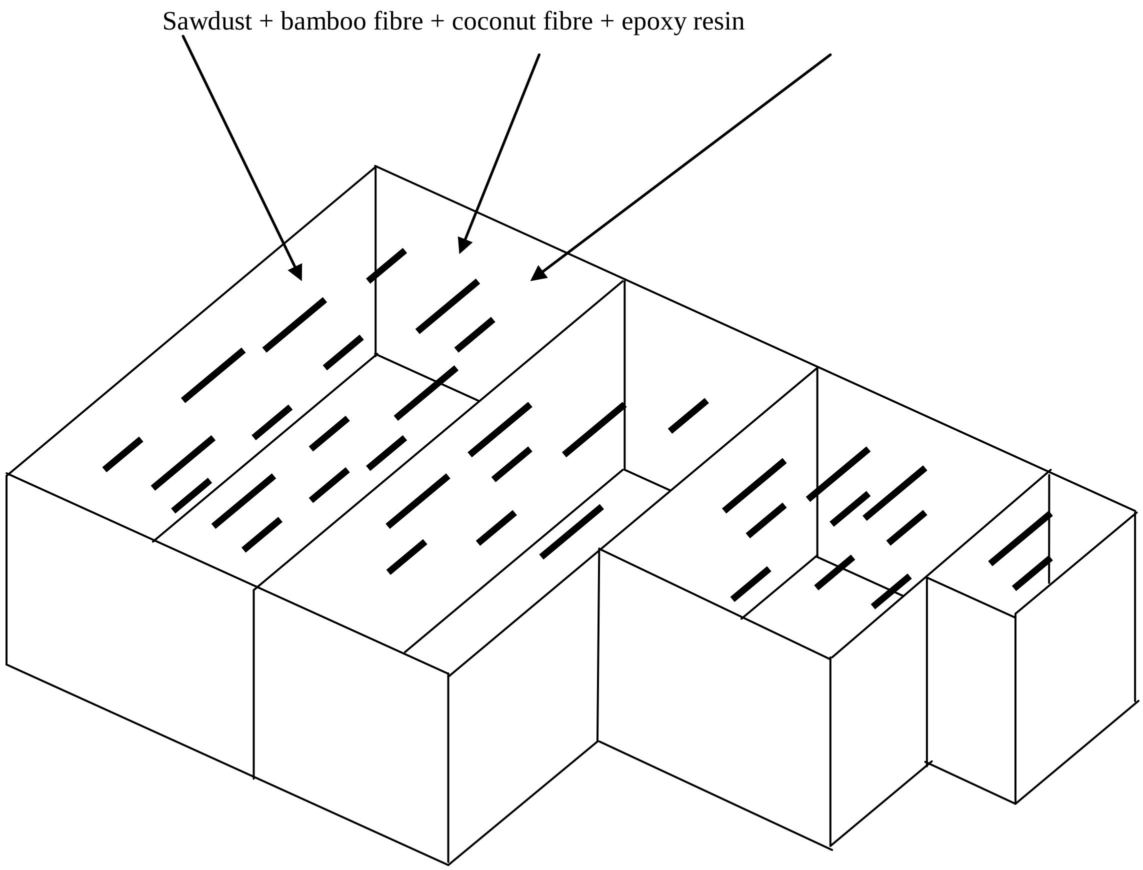


Figure 1. Wooden mould for forming and curing of the specimen [11].

Figure 2. Specimen samples

2.4 Physical Characterisation of the Composite

2.4.1 Density test

To determine the density, the samples were weighed using an electronic balance (Metlar balance, Model MT-2000 with a precision of ±0.001g), while the dimensions of the samples were measured using a vernier calliper from which the volumes were calculated. The density was mathematically calculated using (1).

$$Density\ (g/cm^3) = m/v \qquad (1)$$

Where m = mass of the composite (g) and v = volume of the composite (cm^3)

2.4.2 Water absorption test

The water content of the composite samples was determined using the method of saturated moisture content based on thermo gravimetric principle. The samples were first air dried for 7days and weighed (M_1). Then soaked in water at room temperature of 25 ^{0}C for 24hrs after which they were removed and droplets of water on their surfaces were mopped with cloth and their weights (M_0) measured. The percentage moisture absorption was determined using (2) [12].

$$Water\ content = \frac{M_0 - M_1}{M_1} \text{ X } 100\% \qquad (2)$$

Where: M_1= initial mass (g) and M_0 = final mass (g)

$M_0 > M_1$

2.5 Mechanical Characterisation of the Composite

2.5.1 Flexural test

Flexural test was performed using 3-point bending method according to [11] procedure. The test specimens were prepared with the long dimension parallel and the other with the long dimension perpendicular to the long dimension of the board in order to evaluate directional properties.

2.5.2 Tensile test (Parallel to Surface*)*

Tensile test was performed according to [11] procedure. The tests for tensile strength parallel to the surface were made on specimens using universal mechanical testing machine to determine whether or not the material has directional properties.

2.5.3 Compressive test.

The test for compression strength parallel to the surface according to [11] was done on specimens. Tests was carried out on specimens both with the load applied parallel and perpendicular to the long dimension of the board to determine whether or not the material has directional properties

2.6 Morphological characterisation

The fractographs of the nine different samples were obtained using scanning electron microscopy to determine the structural arrangement of the composite.

2.7 Statistical Analysis

Means data generated were tested for significant differences p>0.05 with ANOVA SAS, window 2010 being used. Means of data were also represented graphically for clear explanation.

III Results and Discussion

3.1 Physical Characterisation of the Matrix Composite

3.1.1 Combine Effect of Fibre Lengths on Density Property

The results of density test are shown in figure. 3. The density of the composite ranged between 1.65 g/mm^{3}and 1.66 g/mm^3. The results of the combine effect of fibre lengths on density of the composite were not significantly different (p>0.05). This could have been as a result of equal weight of the fibre content which implies that fibre length does not affect the density of a composite. This did not agree with the assertion of [13] because they introduced variations in the weight of the fibre used. It was documented that [14] the density of composites increases with increase in fibre content, while a decrease in density was observed with increase in fibre length. Their findings corroborate with the results from this study although the variations in fibre lengths resulted insignificant effect which could have been from the composite used in the current study.

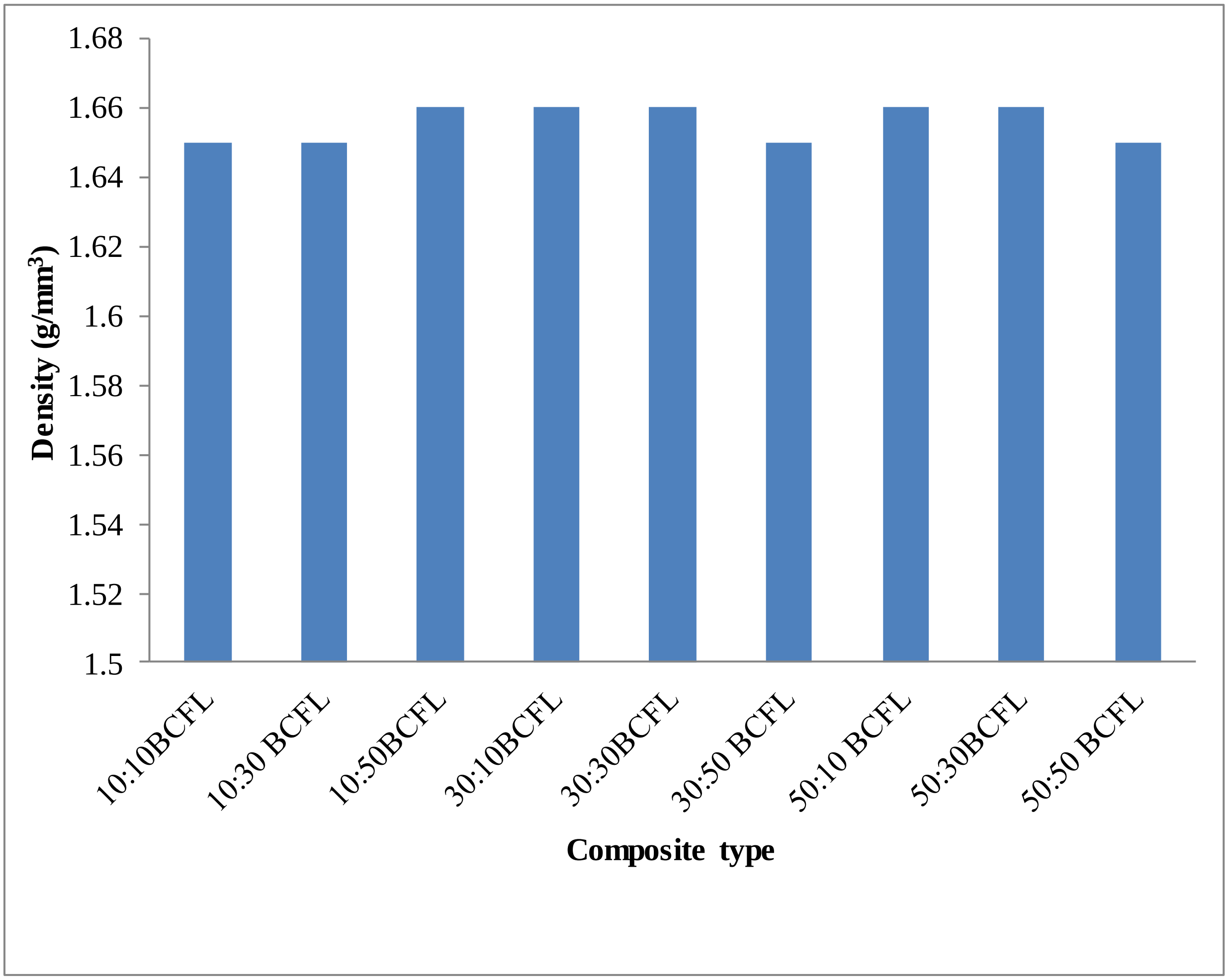


Figure. 3. Density of the composite

3.1.2 Combine Effect of Fibre Lengths on Water Absorption

The result for water absorption of the composite specimens immersed in water for 24 hours at 25 0C is as shown in the graph figure. 4. It can be seen that the water absorption exhibited by the composite is closer in range despite variations in the fibre length of different natural fibres used. The value of water absorption ranges between 10.41 % and 10.45 %. This insignificant difference is as a result of equal weight of the fibre content in the matrix composite. The statistical analysis of variance (ANOVA) showed that there is no significant difference in the samples specimens as ($p>0.05$).

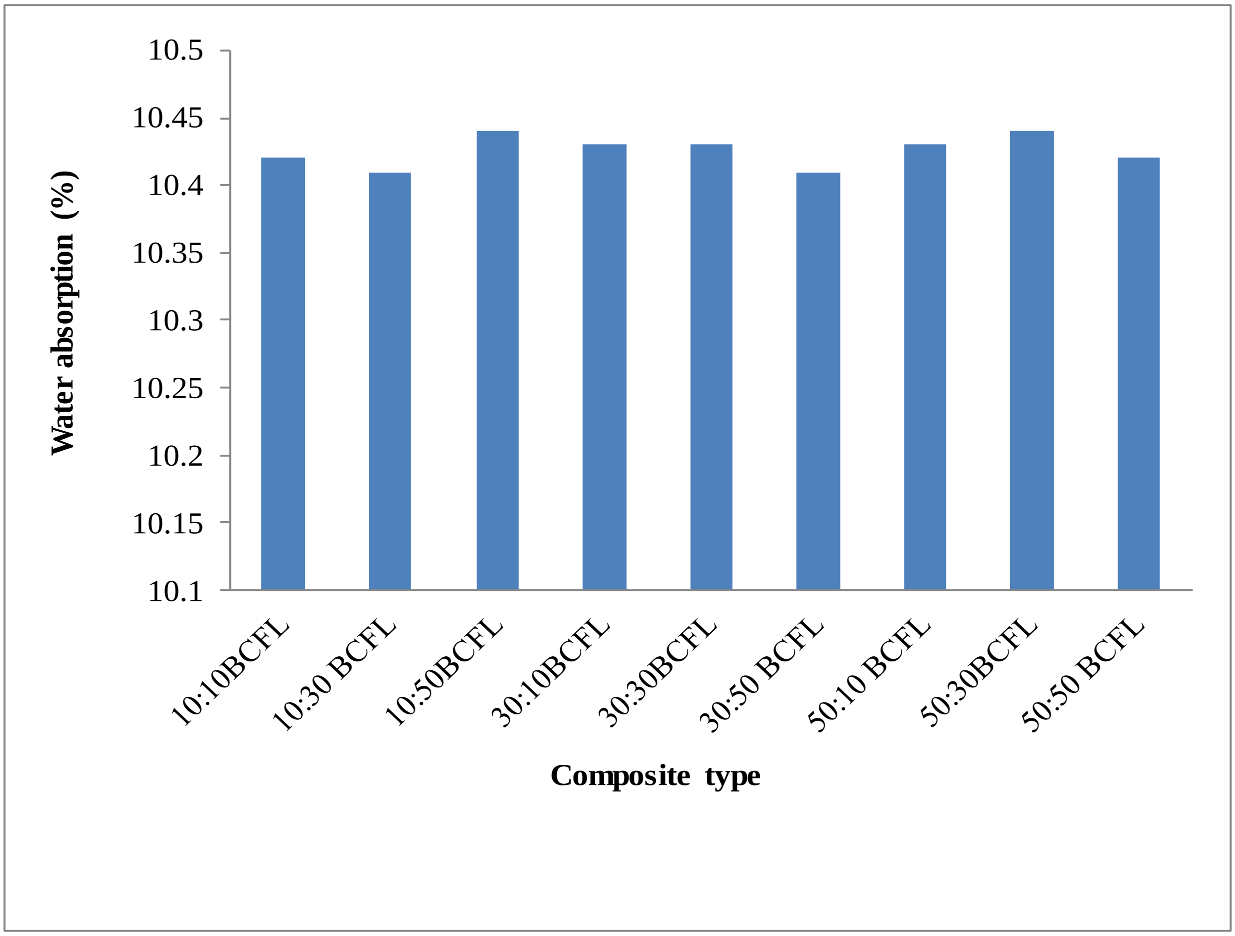


Figure. 4. Water absorption of the composite

3.2 Mechanical Characterisation of Composite

3.2.1 Combine Effect of Fibre Lengths on Flexural Strength.

The flexural strength is the one of the influence properties in composite material. In this study, figure 5 depicts the result of the flexural strength of the composite matrix. The graph indicates that at 15 wt. % of each bamboo and coconut fibre length present in the composite, the flexural strength has its minimum value of 5.83 MPa with corresponding value of 10 mm length each of bamboo and coconut fibre. At fibre length of 30mm each of bamboo and coconut fibre, the value of flexural strength equals 11.68 MPa. The composite has its maximum flexural strength of 15.35 MPa with length of 50mm each of the fibres. Overall, from figure 4, it was deduced that the tensile strength increased remarkable with the introduction of long bamboo and coconut fibres length into the composite. [15] also affirms this in their research where 30 wt. % of jute fibre in the various lengths of 5, 10, 15 and 20 mm into epoxy matrix were examined. It was observed that there is enhancement in flexural properties of epoxy resin by reinforcement with long jute fibre. The flexural properties of the jute fibre of 15mm composite were found maximum compare to epoxy and other all the composites. The flexural strength of Jute fibre of 15mm length in the composite was improved by 63.84%, 91.07%, 80.39%, and 50.76% as compared to E, J5, J10 and J20 composite respectively.

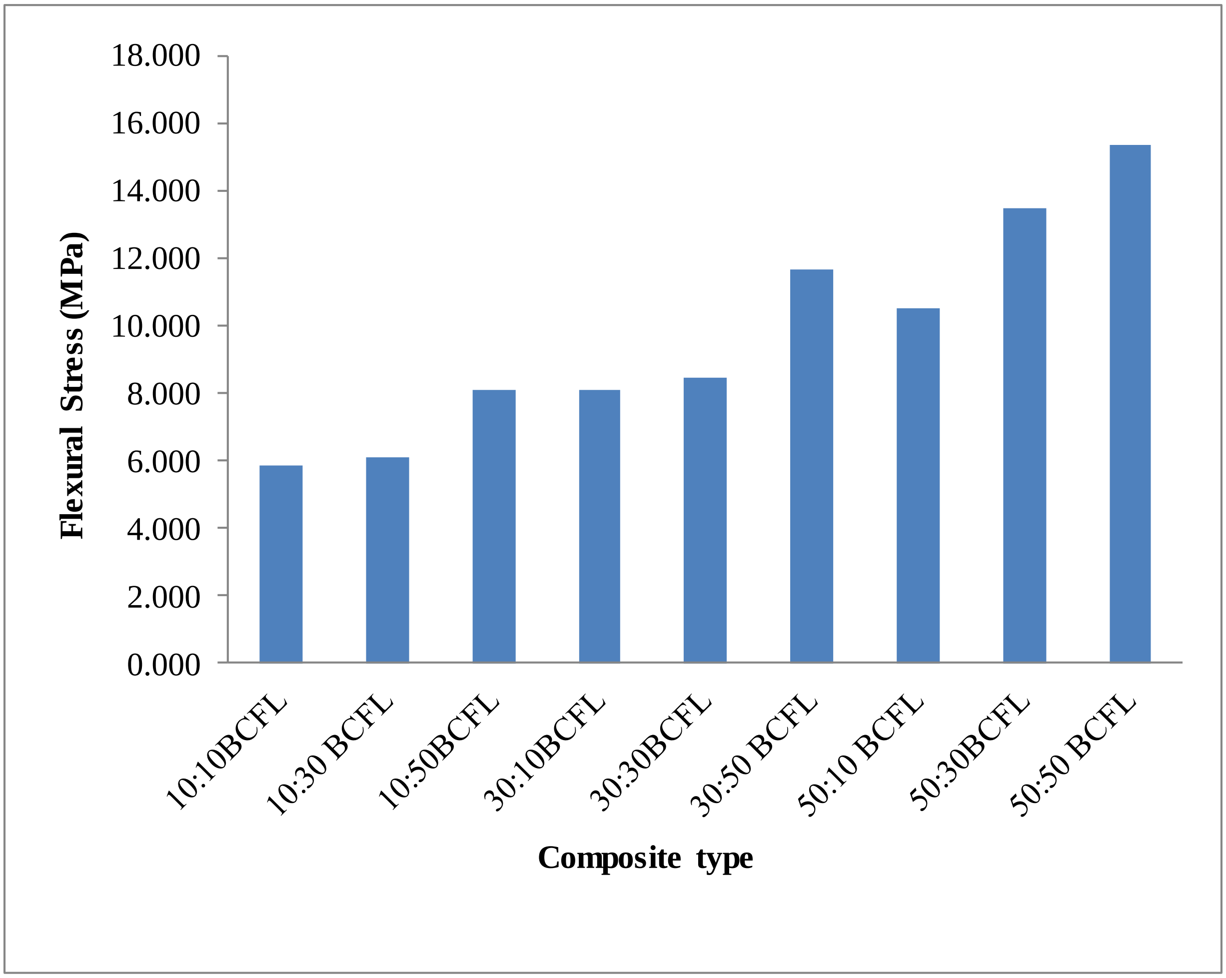


Figure. 5 Flexural strength of the composite

3.2.2 Combine Effect of Fibre Lengths on Tensile Strength.

The results of the tensile test are shown in figure 6. The maximum tensile strength is the main properties evaluated during the test. The values of tensile test for the composite samples range between 1.45 MPa and 4.02 MPa with corresponding fibre length of 10 mm and 50 mm respectively. The results figure 6 shows a comparison of the tensile strengths of the composites made of 15 wt. % volume of both fibres and various combination lengths of fibres. At the combination length of 10 mm each of bamboo and coconut fibre, the composite matrix has a tensile strength of 1.45 MPa. While at 30 mm each of bamboo and coconut fibre, the composite matrix has a tensile strength of 3.48 MPa. The composite matrix has its highest value of its tensile strength of 4.03 MPa corresponding to combination fibre length of 50 mm of each fibre. Thus, increase in both fibre lengths can be seen to have caused a substantial increase in the tensile strength of the composite matrix. The reason for this is that, when load is being applied to the composites, fibres being the reinforcement material acts as a load carrier while matrix transfers the stress to the fibres uniformly and effectively. This in return gives good mechanical properties of composites. [16] asserted this in their study where four different sizes of fibre length were examined in a composite. Their results showed that, sample of fibres without size reduction showed higher tensile strength of 12.26 MPa when compared with different fibre length of 10mm, 20mm and 30mm which have tensile strength of 10.75 MPa, 10.55 MPa and 9.11 MPa respectively. It was also asserted by [15] in their research where 30 wt. % of jute fibre in the various lengths of 5, 10, 15 and 20 mm into epoxy matrix were examined. The results showed that the tensile properties were found maximum for the composite with 15 mm length of fibre with corresponding value of 42.14 MPa. This however affirms the tensile result obtained in this study.

Table 3 Experimental result

Properties		**Composite type**									**SEM**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Flexural	Maximum Flexural stress (MPa)	5.831	6.080	8.072	8.122	8.461	11.675	10.498	13.460	15.352	1.090
	Modulus (E-modulus) (MPa)	209.082	261.101	278.611	294.083	322.148	395.578	365.769	273.141	513.360	30.150
Tensile	Maximum Tensile stress (MPa)	1.452	1.556	1.585	2.393	2.545	3.477	3.720	3.834	4.028	0.350
	Modulus (E-modulus) (MPa)	976.300	13620.900	1384.500	1426.330	1555.710	2682.780	3200.070	4104.290	4396.630	1306.530
Compressive	Maximum Compressive stress (MPa)	4.529	6.521	8.404	10.613	15.563	17.875	19.461	29.859	40.704	3.941
	Modulus (E-modulus) (MPa)	132.355	151.483	164.692	176.254	187.797	257.136	302.452	595.362	648.337	65.189

Table 4 Experimental result of Impact energy

Property	**Composite type**								
	1	2	3	4	5	6	7	8	9
Impact Energy (J)	14.5	16.31	16.84	17.27	17.82	18.36	18.9	19.32	22.58

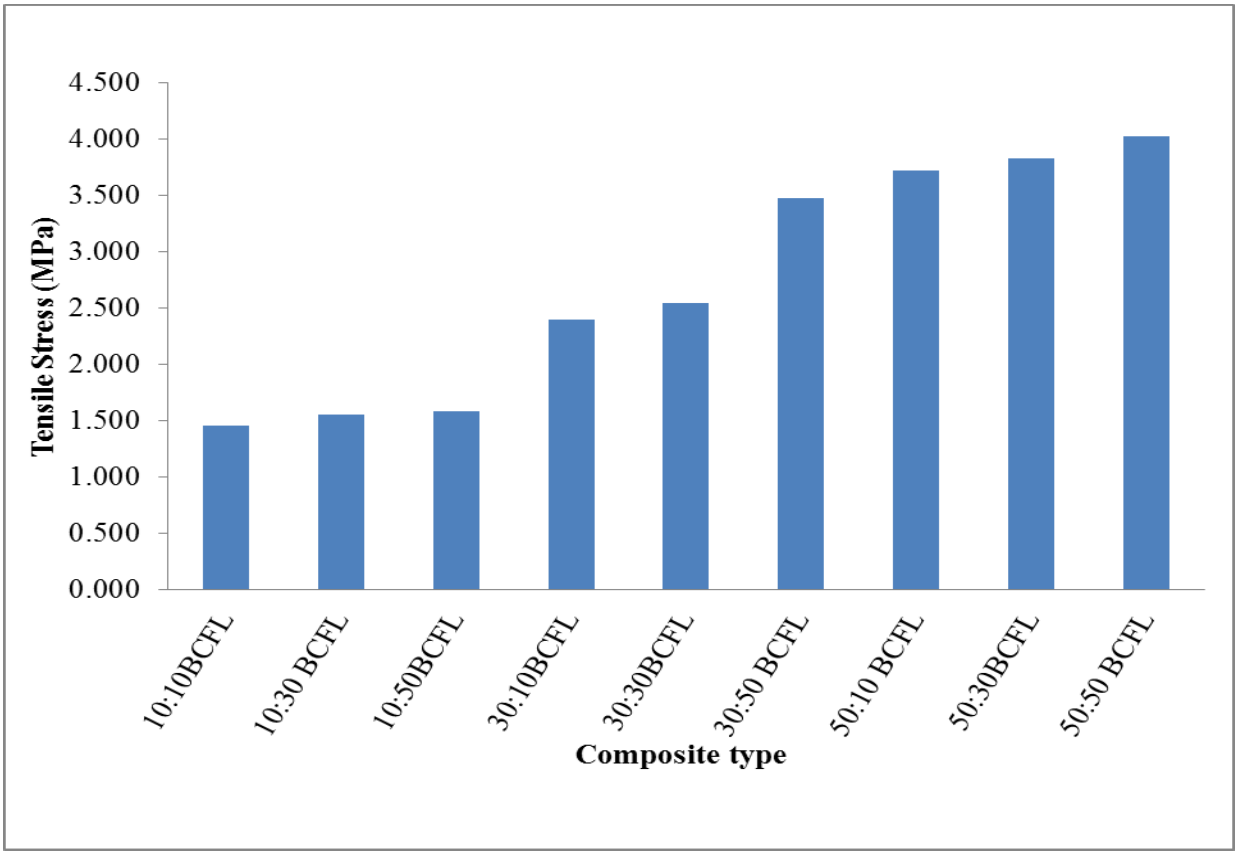


Figure. 6 Tensile strength of the composite

3.2.3 Combine Effect of Fibre Lengths on Compressive Strength

The figure 7 shows the influence of combination fibres lengths on compressive strength of the composite. It shows that the resistance to compressive strength of bamboo and coconut coir fibres reinforced epoxy composites improves with increase in fibre lengths as shown in fig 6. At length of 10 mm each of the fibres, the composite has its minimum value of 4.53 MPa which increases to 17.87MPa as the fibre lengths increased to 30 mm each of bamboo and coconut fibre. The value which further increased to the value of 40.70MPa being the maximum value at the fibre length of 50 mm each of the fibres.

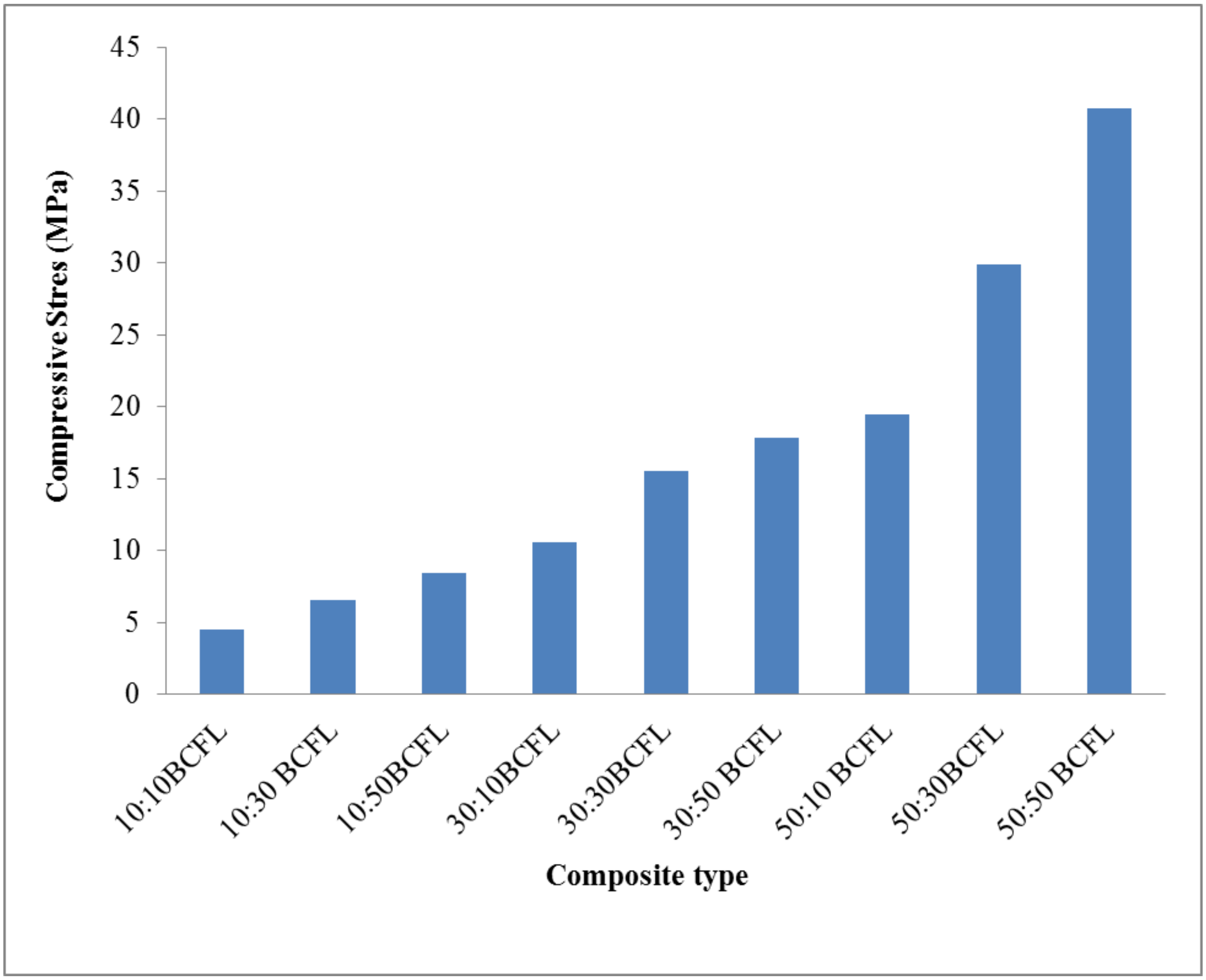


Figure. 7 Compressive strength of the composite

3.2.4 Combine Effect of Fibre Lengths on Impact Strength

The impact energy of epoxy, bamboo and coconut fibre composite is plotted in figure 8. The impact property of composites increased with the increase in length of the reinforcement of bamboo and coconut fibre. The impact property has its minimum value of 14.50 J with corresponding length of 10 mm of each fibre. At fibre length of 30 mm each of the fibres, the impact increased to the value of 18.36 J while it attained its maximum value of 22.58J at the fibre length of 50 mm. [16] affirm in their researched that the particle boards with long unreduced fibres showed higher impact strength of 17.03 KJ/m^3 when compared with the short fibre of lengths 10, 20 and 30 mm. [2] also reported in their research where bamboo lengths of 10 mm, 20 mm and 30 mm with volume content of 10 % and 20 % and woodchips was examined. It was deduced in the impact strength was improved as the bamboo fibre length increases alongside with increase in bamboo fibre content. Specifically, the impact strengths of specimens with fibre length of 20 mm and 30 mm with 20 % volume each were very high. It was made know from those results that bamboo fibres have a good effect on the improvement of the impact strength, and long bamboo fibres increase remarkably the impact strength. These however ascertain the result from this study.

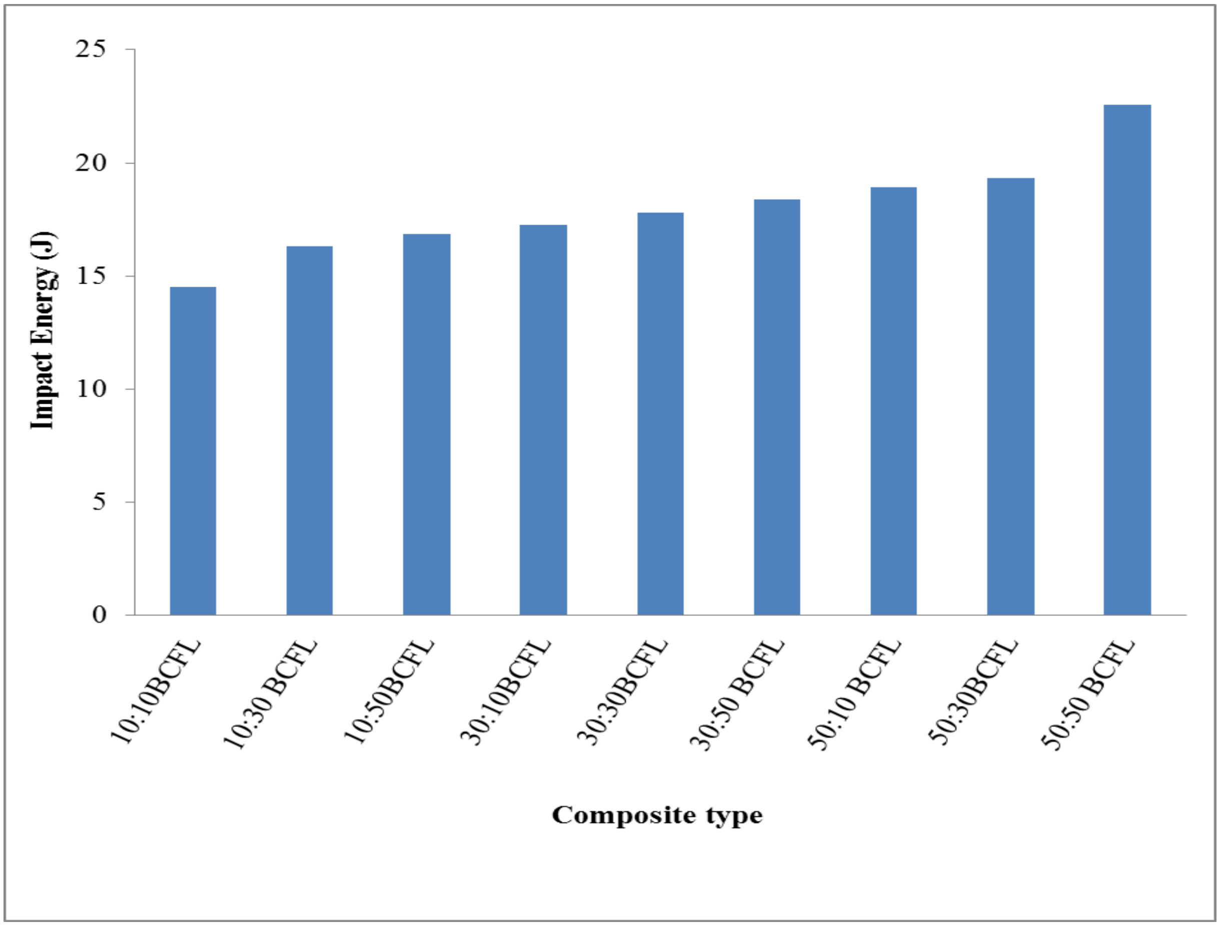
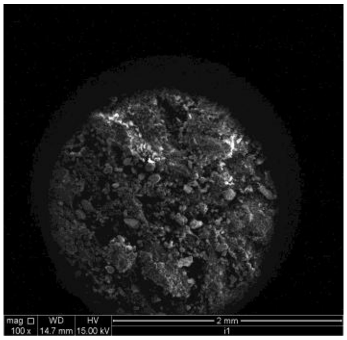


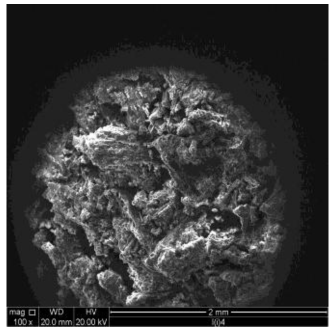
Figure. 8 Impact strength of the composite

3.3 Morphological characterisation of the composite.

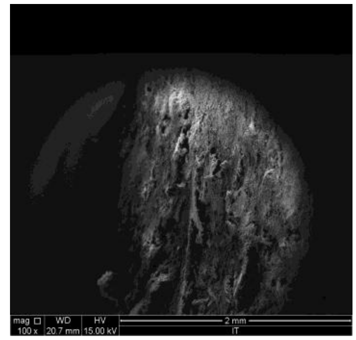
The surface morphology of the matrix composite samples is shown in figure 9. The photograph shows the interfacial bond between the sawdust, bamboo fibre, coconut fibre and epoxy resin. The specimens were viewed at magnification of 500 µm and 2 mm. The fractural surface morphology which includes fibres/matrix interaction condition of the composite samples was examined using scanning electron microscope (SEM). The scanning in composite 1a to 2d indicated that the volume fractions of the volume fibre are low as a result of decrease in length. Composite 4c and 4d showed that there are voids in the composite. This could occur due to manual method applied in producing the composite. In Composite 4c and 4d, it can be seen that the fibres experienced a brittle-like failure, where the fracture occurs all the way through the cross-section of the fibre. This showed that the interfaces of the materials are not fully fixed. This was asserted by [17], [18]. Matrix to fibre ratio may contribute to this, as it ensures cohesion between fibrils and base material.



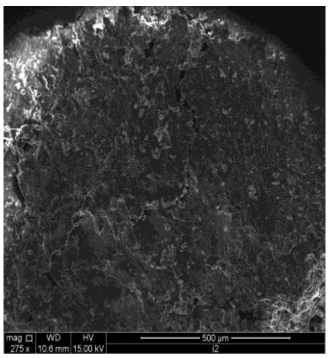
Composite type 1



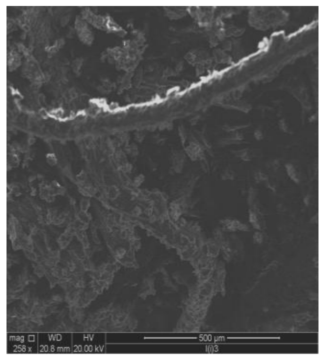
Composite type 4



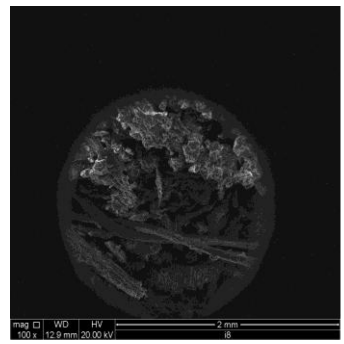
Composite type 7a



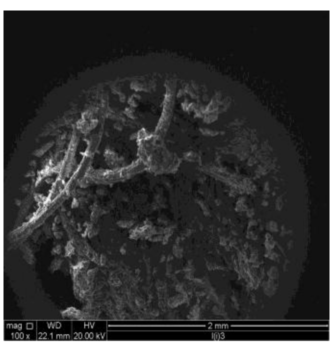
Composite type 2a



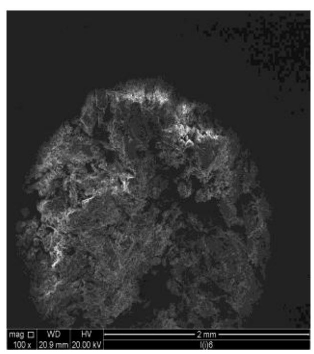
Composite type 5



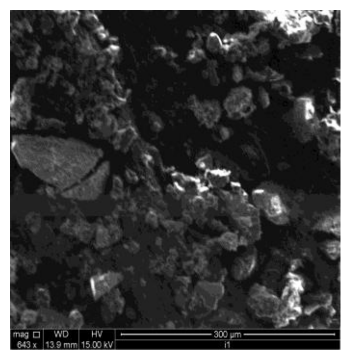
Composite type 8a



Composite type 3



Composite type 6



Composite type 9a

Figure. 9 Surface mophology

IV Conclusion

In this work, acceptable particle board composite was produced with sawdust reinforced with Bamboo and coconut with varying fibres length. While studied the fibre variations, the increase in fibre length from 10 mm to 20 mm and 30 mm combination loading has improved the flexural strength from 5.83 MPa to 15.35 MPa, tensile strength from 1.45 MPa to 4.03MPa, compressive strength from 4.53 MPa to 40.71 MPA and impact strength from 14.05 to 22.58 MPa of the composites. Water absorption of composites has been tested. Percentage water absorption of the composite is virtually the same due to the constant weight of 7.5g of the both fibres in the composite samples. Similarly, the density of the composite samples is also virtually the same due to equal weight of 7.5g of each fibre present in the composite. This phenomena may be explained by the theory of more void over volume found in particleboard with lower density than the high density that provide more space for water storage.

V Acknowledgements

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