American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-6, pp-165-173
www.ajer.org
Research Paper Open Access

Development of Roofing Sheet Material Using Groundnut Shell Particles and Epoxy Resin as Composite Material

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ABSTRACT: *The present work is on the development of roofing sheet material using groundnut shell particles and epoxy resin as composite material. Three different samples of roofing sheets "A", "B" and "C" were prepared and produced from three different weight particle length sizes of 0.5mm, 1mm and 1.5mm at a weight ratio of 70:30 between epoxy and groundnut shell. The sample roofing sheets were cast manually and the rate of water absorption, tensile strength, impact and flexural strength due to bending and deflection were all experimentally evaluated. The sample specimen A with a particle length of 0.5mm have the lowest rate of water absorptivity value of 8.3% ,with the highest impact value of 29.65KJ/m^2. Likewise sample B with a particle length of 1mm have the highest ductility and tensile strength of 2.356mm and 8.25N/mm^2 respectively. The results revealed that Groundnut shell particles can be used as reinforcement for polymer matrix for the production of roofing sheets. Sample "A" was adopted in this work because of its excellence performance properties.*

Keywords: *Composites, reinforcements, fibres, matrix, groundnut, roofing sheets.*

I. INTRODUCTION

Emphasis on the development of new materials and technology for the building industry has been there for the past few decades, especially in developing countries or third world, so that the overall cost of construction becomes affordable by the people. If overall economy in the construction of shelter is to be achieved, then, economy in each major component of shelter to the extent possible has to be realized. Roof is one of the main building elements which constitute about 8% of the total cost of construction [1]. Asbestos cement based roofing and other light roofing materials such as long span Aluminum, Aluminium-Zinc, are very commonly used in the construction of houses and industrial buildings in all developing countries of the world or third world. In spite of the fact that asbestos based roofing elements and products pose health hazards, ban on their use has not been effectively enforced [2].

Composite materials are made by combining two or more materials to give a unique combination of properties, one of which is made up of stiff long fibres and the other a binder or matrix which holds the fibres in place [3].

Kelly [3] clearly stated that the composite should not be regarded as a mere combination of two materials. In the broader significance, the combination has its own distinctive properties in terms of strength or resistance to heat or some other desirable quality. It is better than either of the component along or radically different from either of them.

Beghezan [4] defined composite as compound materials which differ from alloys by the fact that the individual components retain their characteristic but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings in order to obtain improved materials.

De S.K. *et* [5] defined composite materials as heterogeneous materials consisting of two or more solid phase, which are in intimate contact with each other on a microscopic scale. They can also be considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

In the present study, Epoxy Resin is being considered as matrix material. Epoxy resin is a polymer containing two or more epoxy groups and has high mechanical properties due to its low shrinkage and relatively unstressed structures. Epoxy resin system exhibits extremely high resistance to alkali, good acids and solvent. It has good electrical properties over a range of frequencies and temperature. The cured epoxy systems generally exhibit good dimensional stability, thermal stability and exhibit resistance to most fungi.

They are self- excellent moisture barriers exhibiting low water absorption and moisture transmission [6].

Natural organic fibres have a very important role in the alleviation of the housing problem. They not only occur in luxurious abundance in many parts of the world, but can also lead directly to energy savings, conservation of the world's most scare resources and protect human and environment [7]. Natural and vegetable plants and fibres have thus a unique irreplaceable role in the ecological circle. Despite the fact that natural fibres generally have poor mechanical properties compared with synthetic fibres their use as reinforcement material has been adopted by mankind to make straw reinforced huts and other articles [8]. Their natural abundance, plentiful supply, relative cheapness and swift replenish ability are the strongest arguments to utilize them in the construction industry [9].

Groundnut botanically belongs to arches hypogea Linn of leguminous family. It is a self-pollinated, annual and herbaceous legume crop. A complete seed of groundnut is called pod and contain up to five Kermis, which develop underground in a needle like structure called peg, which grow into the soil and then converts into a pod. Groundnut has taproot system which has many nodules contain Rhizobium bacteria which are symbiotic in nature and focus atmospheric nitrogen. [41]

The outer layer of groundnut is called groundnut shell. The shell constitute about (25-35%) of the pod. Nigeria is one of the foremost producers of groundnut in the world, producing up to about 2.699 million matrix tones in 2008. Groundnut shell is found in large quantities as agricultural farm wastes in Northern part of Nigeria such as Sokoto, Kebbi, Kaduna, Borno and Yobe States [2].

Over the years, groundnut shell constitutes common solid waste especially in the developing part of the world. It's potentiality as a useful engineering material has not been investigated. The utilization of groundnut shell will promote cleanliness and increase the economic base of the farmer when such wastes are sold. This work therefore investigates the possibility of using groundnut shell matrix composites for the production of roofing sheets.

Previous research works by Khalid et al, Ngala and Nwankwo, Raju, Gaitondi and Kumarappa, Naidu et al, Iducula et al, Agrawal et al,Alsina, et al, Sada, Amartey and Bako, Chanakan A., Bensely A., Sanjay K., Sangita M., Dixit S., Brian George et al., [5 – 19] have been reviewed in this work.

II. MATERIALS, EQUIPMENT AND EXPERIMENTAL PROCEDURES

2.1 Materials

The materials used for this research work were all sourced locally. These include:

i. Groundnut shell
ii. Epoxy resin (Bisphenol-A-Co-Epicholorohydrine)
iii. Tetraethylenepentamine (Hardener)
iv. Sodium hydroxide solution (NaOH)
v. Distilled water
vi. Wax

2.2 Equipment

The major items of equipment used for this work are as follows:

i. Impact Testing Machine 100kg (Norwood)
ii. Monsanto Tensometer serials No. 9875, UK (200KN)
iii. Universal Material Testing Machine (100KN)
iv. Thermal conductivity testing machine (Norwood)
v. Metallic sieve of size 0.5mm, 1mm and 1.5mm.
vi. Mixing Sterilizer
vii. Metal Mould

2.3 Experimental Procedures

2.3.1 Specimen Preparation

The strength of the composite largely depends on the preparation of the shell. The groundnut shells were collected and sun dried. The dried groundnut shells were washed with water to take away the sand and other impurities. The washed shells were later treated with 10% sodium-hydroxide (NaOH) solution for two (2) hours and then washed with distilled water until the sodium hydroxide (NaOH) in the groundnut was eliminated. Subsequently, the shells were solar dried and hammer milled to reduce its size to smaller ones and then grinded in a machine and particles were sieved through 0.5mm, 1mm and 1.5mm BS sieves to obtain fine uniform shapes and get different sizes of groundnut shell particles. The three (3) different fine sieved particles were used as reinforcement material in the polymer matrix.

The low temperature curing epoxy resin (Bisphenol-A-Co-Epichlorohydrine) was dissolved in acetone and then mixed with tetraethylenepentamine in ratio of 10:1 by weight as recommended [20]. A prototype of a gerrad roofing sheet was used to design a metallic mould for the production process.
The mould made of Aluminum was constructed for producing the sample roofing sheets. Aluminum material was chosen due to its availability, relatively low cost and resistance to corrosion.

2.3.2 Production Technique

Each composite consist of 30% groundnut particles and 70% epoxy resin (weight ratio 30:70). The designations of these composites are given in Table 1 below. A layer of wax was applied to the mould so that the specimen can be easily taken out of the mold. Measured quantities of groundnut shell particles and resin were taken in a plastic container and stirred thoroughly to get homogenous mixture. After adding a suitable quantity of hardener, the mixture was again stirred for ten minutes. The prepared composite was placed in the mould and compressed uniformly. Compression is done carefully to avoid buildup of air gap within the sample, the set up was allowed to cure for 8 hours at room temperature and then the sample roofing sheet was taken out from the mould, it was taken to an electric oven for 48 hours at 38^{0}C for further curing. This procedure was repeated for each of the three specimens.

Table 1: Specimen Composition

Specimen	Composition
A	70%wt Epoxy + 30%wt shell particles (particles length 0.5mm)
B	70%wt Epoxy + 30%wt shell particles (particles length 1mm)
C	70%wt Epoxy + 30%wt shell particles (particles length 1.5mm)

2.4 Mechanical Tests

In the present study, tests were conducted to determine the following characteristics of the sample groundnut reinforced roofing sheets:

i. Water absorptivity test
ii. Flexural strength
iii. Tensile Strength
iv. Impact strength.

2.4.1 Water Absorptivity Test

The test quantifies the water absorptivity of the sample roofing sheets, this test is pertinent to measure its response to water leakage from the roof after or during down pour (rainfall). This test was carried out in accordance with international method for determination of water absorptivity test ASTMD 570 for all composite [21]. Three samples were cut from each mass fraction, weighted and socked in water, cleaned, dried and re-weighted. The obtained data were recorded against each mass fraction and the mean value obtained. The percentage water absorptivity was calculated and recorded against each mass fraction. The percentage increase in weight during immersion was calculated using the following equation.

$$m = \frac{w - w_0}{w_0} \times 100\%$$

Where m, w, w_0 are the moisture absorption content, weight of dried and wet composite material respectively [21].

3.4.2 Flexural Test

This test was carried out in accordance with international method for determination of flexural test ASTM DS 654 [22], the sample sheets were subjected to a central line load over a sample supported span of 115mm. The sample roofing sheets were all tested in natural dry conditions and the load was measured using a 100KN proving ring load which was gradually applied till failure of specimen occurs.

2.4.3 Tensile Test

This test was carried out in accordance with international method for determination of tensile test ASTM D638 [22], on sample roofing sheets due to direct loads (gradually applied). A point load was applied along the center of the span of the corrugation. The maximum load at the point was noted, which gives the splitting load for the corrugated specimen.

2.4.4 Impact Test.

This test was carried out in accordance with international method for determination of impact test ASTM D256 [21]. Corrugation portion of a size 220mmx250mm was cut from the sample roofing sheet and used for the impact test.

The projectile was so arranged such that the impact took place exactly on the crown of the specimen. For each sample sheet, the number of blows required for the appearance or initiation of first crack at the Crown Point and the number of blows required for complete propagation of the crack along the line of the specimen were noted. The height of fall was fixed at 60mm which was based on a few initial trials conducted. The weights of the ball used were maintained constant throughout the test for all specimens.

III. RESULTS, ANALYSIS AND DISCUSSION

3.1 Test Results

3.1.1 Result of Water Absorptivity Rate Test

The results obtained from the Water Absorptivity Rate Test are indicated in table1 below:

Table 1: Rate of Water Absorptivity

Specimen	Dry Pieces Weight (gm)	Weight of the Water Content (gm)	Average % of Water Absorption (%)
Specimen A	3.0	3.25	8.3
Specimen B	5.6	6.8	21.43
Specimen C	5.6	6.9	23.21

3.2 Flexural Test: Bending & Deflection

The result of the flexural test obtained for sample A, B, C are indicated in table2 below:

Table 2: Results of Flexural Tests

Specimen A	**width(mm)**	**Thickness (mm)**	**Load (KN)**	**Deflection (mm)**
A1	52.0	5.5	130	1.941
A2	50.6	4.2	140	2.019
A3	53.6	4.7	160	2.192
Average A	52.06	4.8	143	2.051
Specimen B				
B1	54.8	4.0	90	2.128
B2	53.4	4.4	130	2.637
B3	53.0	4.7	130	2.304
Average B	53.7	4.4	117	2.356
Specimen C				
C1	52.0	3.7	80	1.748
C2	52.0	4.5	130	1.591
C3	53.4	3.6	130	2.387
Average C	52.5	3.9	113	1.907

3.3 Tensile Test

The results obtained for the tensile test is shown in table 3 below:

Table 3: Result of Tensile Tests

Specimen A	Width (mm)	Thickness (mm)	Cross Area (mm^2)	Load (N)	Tensile Strength (N/mm^2)
A1	11.4	4.1	46.74	400	8.56
A2	10.6	10.6	112.36	350	3.11
A3	10.6	10.6	112.36	300	2.67
Average A	10.9	9.8	30.9	350	4.78
Specimen B					
B1	10.3	2.5	25.76	160	6.21
B2	10.5	6.0	63	684	10.86
B3	10.2	5.2	53.04	408	7.96
Average B	12.3	4.6	47.3	584	8.25
Specimen C					
C1	10.0	2.7	27	276	10.22
C2	10.3	3.8	39.14	360	9.20
C3	10.0	5.5	55	228	4.15
Average C	10.1	4	40.4	228	7.86

3.4 Impact Test Result

The results obtained from the impact test is indicated in table 4

Table 4: Result of Impact Tests

Specimen A	Load KJ	Cross Section Area m^2	Impact Value KJ/m^2
A1	220	0.4674	10.28
A2	350	`0.11236	39.33
A3	350	0.11236	39.33
Average	306.7	0.2307	**29.65**
Specimen B			
B1	300	0.02576	7.73
B2	350	0.063	22.05
B3	450	0.05304	23.87
Average	367	0.0473	**17.88**
Specimen C			
C1	200	0.027	5.4
C2	220	0.03914	8.61
C3	250	0.055	17.75
Average	223	0.0404	**10.58**

IV. DISCUSSION OF THE RESULTS

4.1 Water Absorptivity Test

The purpose of water absorptivity test is to determine the amount of water that the roofing sheet can absorb during raining season or down fall in relation to its weight.

The percentage of water absorbed was computed to be 8.3% for specimen A with 0.5mm particle length, while specimen B and C with 1mm and 1.5mm particle length had 21.43% and 23.21% respectively, when soaked for 17hours.

Figure 1 below depicts the results graphically, from the result obtained, specimen A with 0.5mm particle length had the lowest percentage mean water absorptivity with a value of 8.3% followed by sample B with 1mm particle length had a value of 21.43%. Then sample C with 1.5mm particles length had a value of 23.27% respectively. The smaller the grain size, the better the bond, the lower is the water absorptivity ratio.

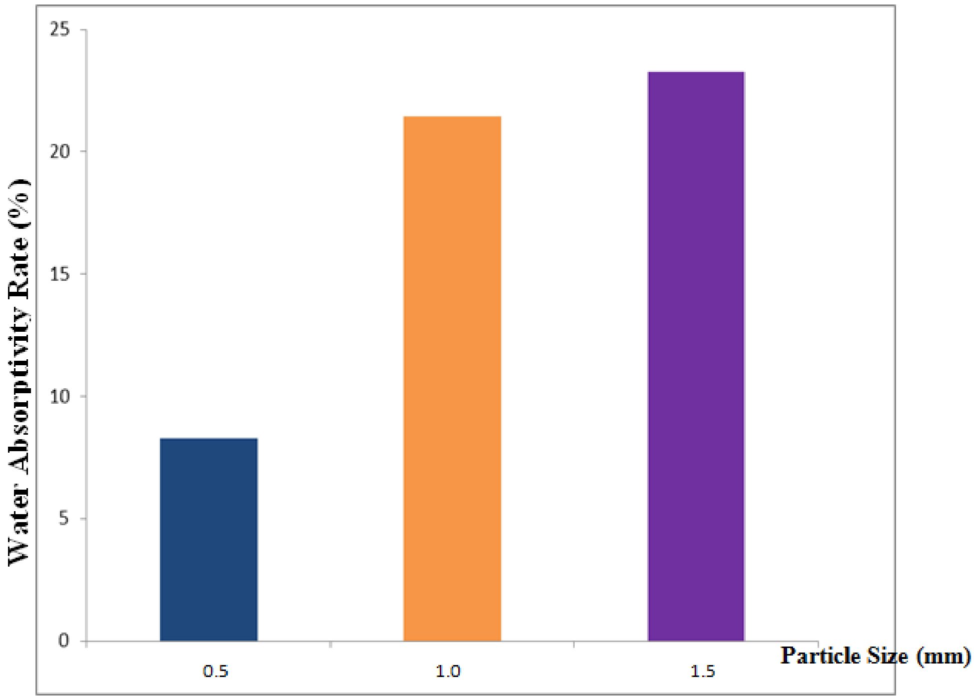

Fig1: Water Absorptivity Rate of Groundnut Shell Composite

4.2 Flexural Test

4.2.1 Flexural Test (Bending)

The flexural load is the minimum load the composite can bear before fracture during flexure or bending test. Figure 2 depicts the results graphically. Specimen B with 1mm particle length showed excellent ability to withstand the load before fracture with value of 140N.While specimen A and C with particle length of 0.5mm and 1.5mm had strength ability values of 117N and 113N respectively. Therefore the bending strength initially increase for grain size 0.5mm to 1.0mm before it latter dropped to 113N for 1.5mm where the bond turned out to be weak and brittle decreases as the grain size increases.

4.2.2 Flexural Test (Deflection)

Figure 3 below shows the mid-span deflection and toughness of each of the specimen. The specimen (B) with 1mm particles length showed the greatest deflection with value of 2.356mm signifying that it possessed the highest ductility followed by the specimen (A) with 0.5mm particle length with value of 2.05mm, specimen C with 1.5mm particle length had the lowest value of 1.907mm showing that it had a poor ductility and hence, most brittle of all the specimens. Therefore, ductility increases with grain size up to a maximum of 1mm beyond which it reduces.

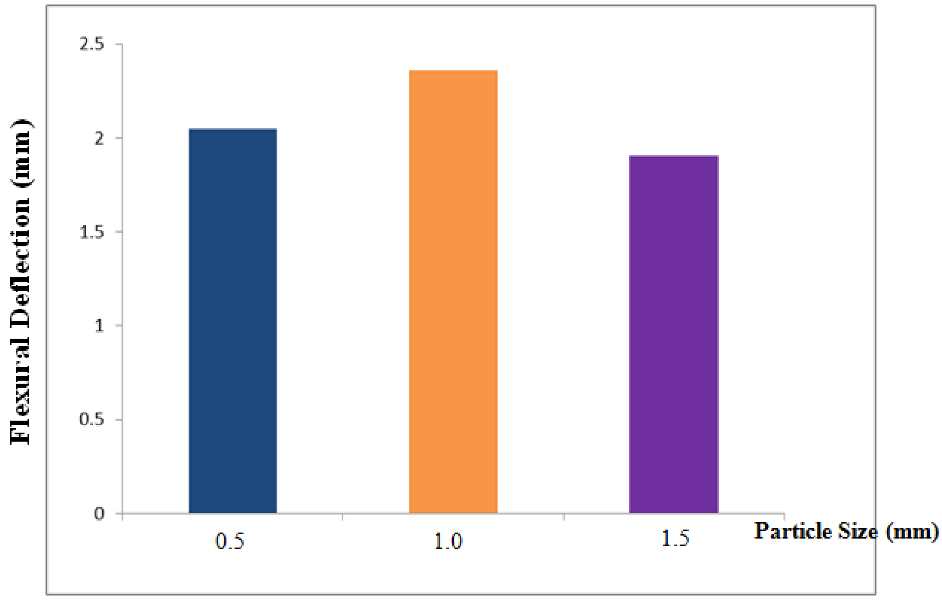

Fig3: Flexural Deflection Strength of Groundnut Shell Composite

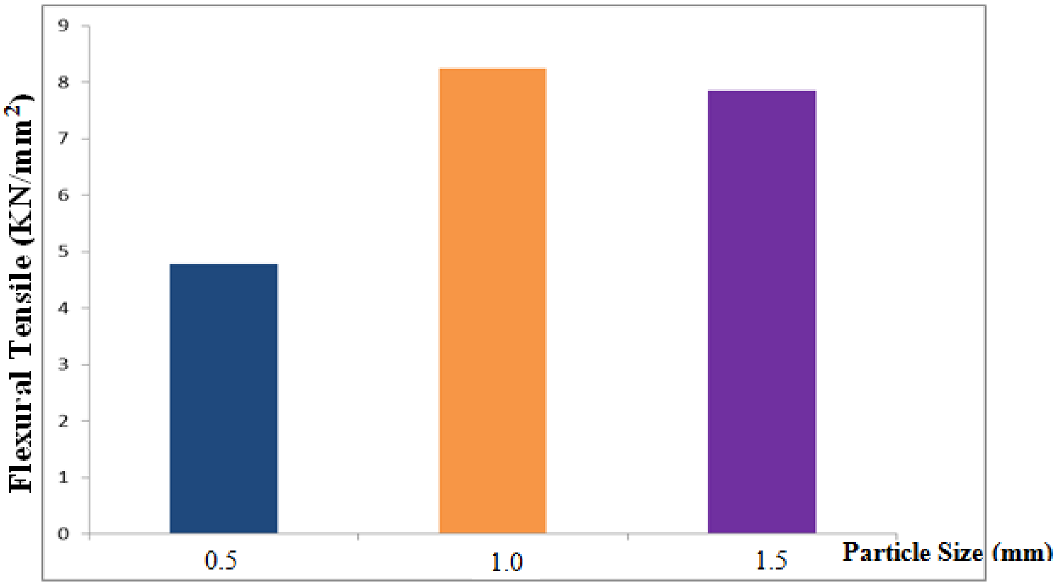

Fig4: Flexural Tensile Strength of Groundnut Shell

4.2.3 Flexural Strength (Tensile)

Figure 4 above depicts the tensile test result graphically. Specimen B with 1mm particle length followed by specimen C with 1.5mm particle length had the highest strength of 8.25 N/mm^2 and 7.86 N/mm^2 respectively. While specimen A with 0.5mm particle length had 4.78 N/mm^2 strength value, therefore the strength increases with grain size up to maximum of 1.00mm beyond which the strength decreases.

4.2.4 Impact Test

Figure 5 depicts the result of impact strength graphically. The impact energy absorbed by specimens A with 0.5mm particle length had a value of 29.65 KJ/m^2 followed by sample B with 1.0mm particle length which had a value of 17.88 KJ/m^2 while sample C with 1.5mm particle length had a value of 10.58 KJ/m^2. Thus these indicate that sample A with 0.5mm particle length had the highest impact strength while sample C with 1.5mm particle length had the lowest impact strength.

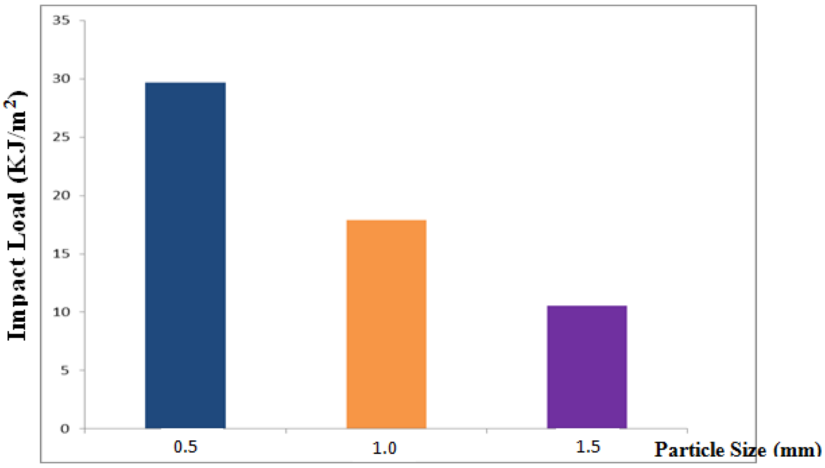

Fig5: Impact Strength of Groundnut Shell Composite

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The aim of this work is to develop roofing sheet material from groundnut shell polymer matrix composite.

Three different grades of sample roofing sheets were produced, the samples differ from one another by varying the composition, epoxy resin proportion and particle sizes during production.

Based on the experimental investigation carried out on the produced sample roofing sheets, the results and analysis of the data obtained shows that:

i. Sample A with 8.3% water absorption rate had the best and lowest rate of water absorption followed by sample B with 21.43% While C had the highest of 23.27% respectively.
ii. Sample A with 140N had the highest strength before bending occurred while sample A and C fracture at the lowest values of 117N and 113N respectively.
iii. Likewise sample B had the highest ductility value of 2.356mm followed by sample A with 2.05mm value, while sample C is the lowest with value of 1.907mm.
iv. Sample B also had the highest tensile strength of 8.25 N/mm2 followed by sample C and A with 7.86 N/mm2 and 4.78 N/mm2 respectively.
v. Sample A had the highest impact value of 29.65 KJ/m2 followed by sample B and C with 17.88 KJ/m2 and 10.58 KJ/m2 respectively.

Sample A and B have the best possible proportion to be taken into consideration for the production of commercial roofing sheets. Sample “A” was adopted in this work because of its excellence performance properties. The results revealed that Groundnut shell particles can be used as reinforcement for polymer matrix for the production of roofing sheets.

5.2 Recommendation

Further research work should be carried out on the design of the produced sample roofing sheets especially on the manufacturing process and finishing process. This could result in improved mechanical properties of the composite and reduce the cost of production. Further work in the following area is hereby recommended;

i. Selection of other manufacturing processes other than hand layer up techniques.
ii. The use of other types of polymer resins such as vinyl ester, polyester or other locally available bonding agent is to be investigated further and compare the result with the existing ones.
iii. There is need for further study on how to control biochemical and environmental pollution in order to safe guard the life span of roofing sheets.
iv. Coating should be carried out on the sample roofing to prevent corrosion.

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