International Journal for Quality Research 8(2) 277–292
ISSN 1800-6450

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Article info:
Received 03.03.2014
Accepted 29.05.2014

UDC – 006.73

EXPERIMENTAL DEVELOPMENT OF BIO-BASED POLYMER MATRIX BUILDING MATERIAL AND FISH BONE DIAGRAM FOR MATERIAL EFFECT ON QUALITY

Abstract: *These days cost of building materials are continuously increasing and the conventional construction materials for this particular purpose become low and low. The weight of conventional construction materials particularly building block is heavy and costly due to particularly cement. Thus, the objective of this paper is to develop an alternative light weight, high strength and relatively cost effective building material that satisfy the quality standard used in the country. A bio-based polymer matrix composite material for residential construction was experimentally developed. Sugar cane bagasse, thermoplastics (polyethylene group) sand and red ash were used as materials alternatively. Mixing of the additives, melting of the thermoplastics, molding and curing (drying) were the common methods used on the forming process of the samples. Mechanical behavior evaluation (testing) of the product was carried out. Totally 45 specimens were produced and three replicate tests were performed per each test type. Quality analysis was carried out for group B material using Ishikawa diagram. The tensile strength of group A specimen was approximately 3 times greater than that of group B specimens. The compression strength of group A specimens were nearly 2 times greater than group B. Comparing to the conventional building materials(concert block and agrostone) produced in the country, which the compression strength is 7Mpa and 16Mpa respectively, the newly produced materials show much better results in which Group A is 25.66Mpa and group B is 16.66 Mpa. energy absorption capacity of group A specimens was approximately 3 times better than that of group B. Water absorption test was carried out for both groups and both showed excellent resistivity. Group A composite material specimens, showed better results in all parameters.*

Keywords: *bio polymer matrix composite, residential building, mechanical test, bagasse, thermoplastics, Ishikawa diagram.*

1. Introduction

Composite is a materials made from two or more constituents with significantly different physical or chemical properties from each other. One of the composite group is bio-composite which is defined as a material that composed of one of its constituent is bio-sources or biodegradable bio-fibers as reinforcement and biodegradable or non-biodegradable polymers as matrix.

According to BMTPC (2009-2010) calendar report bio-composites provide environmental friendly and sustainable alternatives to traditional/conventional composite materials. Bio-composites have applications in Automobiles, Aerospace, Marine, Chemical Industry, Electrical and Electronics and Construction etc. Different bio-composites have different applications in construction BMTPC (2009-2010) such as wood with polymer for making door shutters, doors & window frames; Vegetable fiber/red mud & polyester are also common for flat & corrugated roofing sheets, shutters & tiles; Jute fiber polyester/epoxy with red mud are applied for panels & sheets, wall cladding, partitions & door shutters; Bagasse & UF/PF resin for panels & blocks; Red mud plastic (PVC, polyester) reinforced with sisal fiber are used for producing paneling, roofing, partitions and door panels.

According to (BMTPC 2009-2010, www.compositebuilding.com) nowadays, engineers and researchers are searching and developing new composites for different advantages that include, light weight, high specific stiffness and strength, easy molding property to complex forms ,easy bonding capacity, good dumping properties ,low electrical conductivity and thermal expansion, good fatigue resistivity and low cost.

This time from bio fibers green building www.olympiabuilders.com that economize resources, energy and materials as the same time reducing building impacts on human health and the environment, through better design, construction, operation, maintenance, and removal are in practice in fabrication of construction materials of residential and commercial buildings.

Common practice is fabrication of agri-fiber boards that are made from fibrous residue of the wheat, rice, rye grass, soybean straw, cornstalks, hemp, rice hulls, flax shaves, sunflower stalks, and seed hulls. The most common advanced composites are polymer matrix composites that consist of thermoplastic or thermosettings, which can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion, low cost, high strength and simple manufacturing principles.

Most common thermoplastics, which have been used as matrix for natural fiber reinforced composites include high density polyethylene (HDPE), low density polyethylene (LDPE), chlorinated polyethylene (CPE), polypropylene (PP), normal polystyrene (PS), poly vinyl chloride (PVC), mixtures of polymers, recycled thermoplastics. Bsed on Thermoplastics with processing temperature not exceeding 230 ^{o}c at which fiber is incorporated into polymer matrix are used for bio-fiber reinforced composites. These include polyethylene and polypropylene. For reinforcement of composites particulate, fibers and structural reinforcement are common .Bio fibers are other categories used in composite production. According to S. W .Beckwith (2003) the sources of bio-fibers are classified as Bast, seed and leaf. Williams, G. I.; Wool, R. P. J. Appl. (2000) explained that bast and leaf fibers are the hard type fibers, which are most commonly used in composite applications. Vegetable fibers can withstand processing temperatures up to 250ºC. The strength characteristics of fiber depend on the properties of the individual constituents, the fibrillar structure and the lamellae matrix. Seed fibers include cotton, coir

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(coconut husk materials), and kapok materials in which cotton is easily recognized for its widespread international use in textiles and other fibrous products within the clothing and rope industries.

Bio fibers have selected for many composite reinforcing fibers due to the physical, mechanical and chemical properties they attained.

The properties of bio-fibers can vary depending on the source, age and separating techniques of the fibers. Quality and other properties of fibers depend on factors such as size, maturity and processing methods adopted for the extraction of fiber (Mohanty *et al.*, 2001). Desirable properties for fibers include excellent tensile strength and modulus, high durability, low bulk density, good mold ability and recyclability. Bio-fibers are complex mixture of organic materials and as a result, thermal treatment leads to a variety of physical and chemical changes. Chemical modification (Ray and S. Bandyopadhyay, 1965) was found to improve the thermal stability of the composites. Fibers with higher cellulose content, higher degree of polymerization of cellulose and lower microfibrillar angle give better mechanical properties. The mechanical properties of bio-fibers are influenced by the composition, structure and number of defects in a fiber. Moisture content in fibers influences the degree of crystallinity, crystallite orientation, tensile strength, swelling behavior and porosity of vegetable fibers (Sukumaran, *et al.* (2013); Mohanty *et al.*, 2000).

According to M. Roger, Rowell (1998), bio-composite is classified with respect to their application in construction in to two main groups structural and non-structural bio-composite. In structural and infrastructural applications (Ticoalu and Aravinthan, 2010) bio-fiber composite have been used to develop load bearing materials like beam, roof and multipurpose panels. Thermoplastics possess several advantages such as they do not need storing under refrigeration, possess improved damage tolerance, environmental resistance, fire resistance, recyclability and potential for fast processing. Primary reason for the use of thermoplastics is their cost effective processing. Process conditions for high performance thermoplastics are temperature in the range of 300 to 400°C and pressure between atmospheric pressure for thermofolding process to 20 times the atmospheric pressure for high performance press forming. Thermo-loading is the most straight forward thermoplastic forming technique where a straight line is heated and folded. Thermoplastics are recyclable. Low-density polyethylene (LDPE), high-density polyethylene (HDPE) and linear low density polyethylene (LLDPE) are major matrix materials. Bagasse the residue fiber remaining of pressed sugarcane is one of the bio-fiber. The fiber is thick walled and relatively long (1-4mm) (Mekuria *et al.*, 2007). Analysis of show that there exist 46.5% of fibers in bagasse.

Bagasses used as reinforced filler in production of bio-composite construction materials, in different part of the world like North America, Venezuela, Middle East (Egypt, Saudi Arabia) (Golbabaie Res, 2012). In Ethiopia also bagasses has used as filler in manufacturing of Agrostone (panels and board). Other components used to make composites for construction purpose are sand, which contains silicate(silicon dioxide, or SiO_2) and lime (www.wikipedia.com), and scoria (red ash) (Dinku, 2005) a volcanic cinder which generally has a rough surface and high porous nature, with its pores chiefly in the form of vesicles instead of the more tube like, interconnected pores.

Studies have been carried out in the areas of various flame retardant fillers / compounds in fiber reinforced plastic composites for various applications. Researcher (Rowell, 1998) indicates, one of the biggest new areas of research in the value added area is in combining bio-fibers with thermoplastics. Blending of the plastics with the bio-based fibers may require compatibilization to improve dispersion, flow and mechanical properties of the composite. Typical blending involves the plastic-filler/reinforcement to be shear mixed at temperatures above the softening point of the plastics. The heated mixture is then typically extruded into “small rods” that are then cut into short lengths to produce a conventional pellet. The pellets can then be used in typical injection or compression molding techniques (Fainleib and Grigoryeva, 2011). Generally, however, the composite properties are derived from the intrinsic properties of the components. The case study (van Wyk, 2007) stated that the determination of the required mechanical properties for a fiber-based composite could be suitable for application in the construction sector.

Given the list of products identified four applications can be extracted as generic to construction products namely; load bearing element, non-load bearing element; solid section; and hollow tube.

In the work of (www.xco2.com, http://www.nnfcc.co.uk/library/publications/index.cfm),it has said that mechanical testing of Hemp/Cellulose Acetate and Hemp/Polyhydroxy buterate composites were performed and demonstrated that these bio-composites have strength properties comparable to structural lumber and higher than plywood. In Ethiopia bio-based composite production for residential construction materials is in practice.

Mechanical testing alone cannot be an instrument to determine the failure or devotion of production from the standard quality .Various quality analysis methods that include Ishikawa diagram, Pareto diagram, control chart, etc. methods are essential in different condition. Causes in the diagram are often categorized, such as to the 6 M's. Cause-and-effect diagrams can reveal key relationships among various variables, and the possible causes provide additional insight into process behavior.The 6 Ms (used in manufacturing industry: Machine (technology), Method (process),Material (Includes Raw Material, Consumables and Information.),Man Power (physical work)/Mind Power (brain work), Measurement (Inspection) Milieu/Mother Nature (Environment). Fish bone diagram (Yesharg, 2012) is commonly used to analyze human, machine, material and method factors of production. The quality of the present experiment was analyzed by using Ishikawa diagram. The Fishbone diagram (also called the Ishikawa diagram) is a tool for identifying the root causes of quality problems. Fishbone diagram find to use in the following cases (Asmamaw and Ajit, 2013): When there are many possible causes of problems, when the traditional method of quality assurance is difficult, when necessary to analyze root causes of the problem etc. Underlining these concepts the quality problem of group B composite product was analyzed using e fish bone diagram.

Thus from literatures, experience in the country and existing conditions there is a need to focus on alternative building materials development from raw materials like agro-industrial wastes, and mineral products with relatively low price and much higher strength than the ordinary hollow concrete blocks. At the same time analyzing the major causes of quality problems using appropriate quality instrument will help to determine the application of the product.

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2. Materials and Methodology

2.1. Materials

10Kg of bagasse (bio-fiber) was collected from Agrostone factory. 10Kg waste recyclable commodity thermoplastics namely polyethylene (PE) was collected from the surrounding area were used as matrix. These types of materials were selected because of their property and are widely used in commodity areas as packages, containers and other applications. More over the waste of plastics affect the environment and protecting the environment is essential. PE includes low-density PE (LDPE), high-density PE (HDPE), and linear low-density PE (LLDPE) were used as a material for this research. As PE are widely used as commodity packages, after use they are thrown and affect the environment. Thus recycling them and applying for some useful application may help to reduce the environmental pollution and save economy. Other minerals (white silica sand, red ash) were purchased and used as matrixes. About 45 specimens were prepared for triplicate tests.

Table 1. Materials used for making the samples based on the weight proportion

Group of materials	Materials	Weight, g(proportion)	
A		50:30:20	50:40:10
	Thermoplastics	187.5	187.5
	Bagasses	112.5	75
	Sand	75	37.5
B	Thermoplastics	187.5	187.5
	Bagasses	112.5	75
	Red ash	75	37.5

2.2. Tools and equipment

To prepare samples some equipment like, melting and mixing equipment were used. The melting and mixing device were assembled from waste fruit and onion crashing materials. It is because of the interest to reuse wastes for extruder or mixer of the polyethylene that insisted to construct newly melting device using wasted parts of old fruit crusher machines. Steel cans were used as hopper to put the chopped thermoplastics. The molding equipment was constructed from steel sheet and aluminum foils. Wood charcoal was used as a source of heat energy at first and latter electric power was replaced.

Tools and equipment used were: Digital photo camera for analysis, molding equipment for samples preparation, Vernier caliper , beam balance ,cutter(scissors, knife) , oven , heater , marker , melting equipment , dryer equipment ,boards.

2.3. Methods

2.3.1. Sample preparation

Two groups of samples group A that contains, sand, bagasse and thermoplastics, group B that contains red ash, bagasse and thermoplastics were used in the composition (table 1). Bagasse was chopped and ground and dried by heating to 40^{o}C in the oven ;As the thermoplastics were wastes collected from different areas after use for different purposes it was required to wash, drying and then cut as well as chopped into small sizes suitable for melting. After the sand and red ash were prepared weighing each materials using beam balance according to the ratio illustrated in table1 was carried out and then by heating the thermoplastic materials up to a temperature below 175^{o}C mixing of sand/red ash, bagasse and molten thermoplastic was carried out. Pouring the blends in to the mold to obtain the desired shape, and then allowing to cure in air for 40minutes and finishing the surface was performed. The samples were exposed to mechanical testing including tensile test, compression test and impact tests. The tests were carried out to assure the products quality. Water absorption test carried out by immersing both groups of samples in bath of water for 10 days and washing of the surface by using tap water to test the erosion capacity due to rain was also carried out. A fire clay slurry was painted and tested for fire resistance.

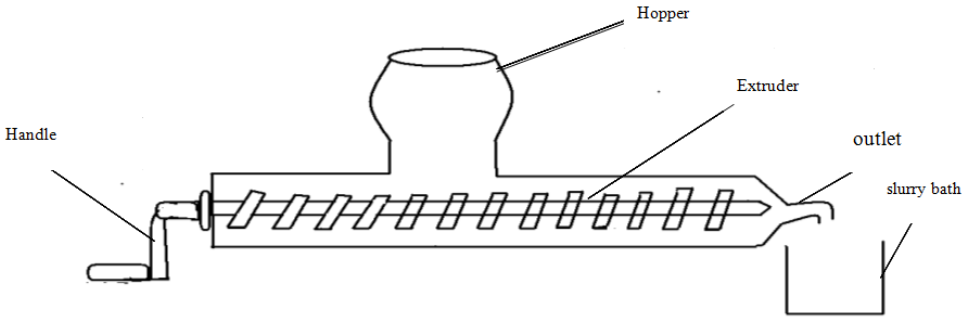

Figure 1. Plastic extruding device (newly constructed)

2.3.2 Mechanical property testing

To determine the soundness of the product and to apply for the designed purpose three mechanical testing, namely tensile testing, compressive testing and impact testing were carried out. The tensile testing was carried out to determine the yield point of the material that is an important property for any construction material. With regard to compression test, the developed product is assigned to carry compression load as the product is designed to make walls and partitions of the building. The wall and partitions are exposed to external impact loads from different sources like wind, storm and other related potential dynamic loads. Based on the mentioned reasons the tests were carried out using samples prepared that are suitable for each test. The wall of an ordinary house usually has to support the roof, keep the interior warm and dry, and provide protection from fire (for a specified period) and noise. Where the wall is load bearing, its strength must be sufficient to carry the loads placed on it. These loads are calculated from the live and dead loads on the structure supported by the wall. Any building must be able to safely support the weight of its own components with an appropriate reserve of strength and stability. Wind pressure and impact forces must also be taken into account in the design of external walls, and indeed for panel walls in a framed structure the principal strength requirement is the power to withstand wind load (van Wyk. (2007), www.xco2.com,http://www.nnfcc.co.uk/library/publications/index.cfm).Weather xclusion may even be regarded as their most elementary and basic purpose, and, with very rare exceptions, it must be total. In addition, any building must be capable of resisting likely additional gravity loads and other forces that are likely to impinge on the walls and roof of the building – such as impact loads – with sufficient reserve of strength and stability.

Tensile and compression testing

The tensile testing and compression testing were carried out at 20°C using WP 310 Universal strength tester capacity 50KN. The specimen dimensions for tensile testing were 10mm diameter, and gauge length of 50 mm.

Total of 10 specimens were tested for each group. The dimension of specimens for compression test was 35mm x 35mm x 10mm.A total of five specimens were tested for each group.

Impact test

Impact resistance of a composite material is one of the most important properties for the particular designed work since it works under external and internal impact forces. Energy absorption capacity of materials determines the toughness of the material and hence the specimens prepared from bio-based polymer matrix materials have to pass through this test. The impact tests were conducted at 20°C using impact testing machine, model T50, serial no. 010106.The Charpy test was carried out using a specimen size of, 55mm x 10mm x 10mm and 2mm depth with 3mm width notch. Ten specimens were tested for each group. As mentioned above water absorption capacity of the samples after mechanical testing was carried out by immersing the samples in the water bath for 10 consecutive days. After this kind of test fire clay slurry was painted for both groups of samples, allowed first to dry in air and then exposed to fire.

3. Experimental analysis

3.1. Compression and tensile tests analysis

As mentioned earlier tensile test, compression test and impact tests for group A and group B specimens particularly with silica sand and red ash particles respectively have carried out. The results obtained from the tests are illustrated in tables 2-4 and are illustrated graphically.

Table 2. Test results of tensile strength for type A and type B experiments

No. of sample	Tensile strength(N/mm^2)			
	Group A	Average	Group B	Average
1	1.4	1.15±0.32	0.38	0.44±0.14
2	1.15		0.31	
3	0.89		0.64	
4	1.11		0.41	
5	1.50		0.36	

As seen in table 2 the tensile test results of samples in group A attained better performance. The average value of tensile strength of group A (Sand, bagasse and thermoplastics) is 1.15±0.32 N/mm^2 and group B (Red ash, bagasse and thermoplastics) is0.44±0.14 N/mm^2. If comparing between the two groups the samples with silicate sand matrix (group A) can be directly applied for construction purpose.

Figure 2 compares group A and group B samples for strength testing. As seen in the figure the maximum strength for group A samples is 1.5N/mm^2 and the minimum is 0.89 N/mm and the maximum strength for group B is 0.64 N/mm^2 and minimum is 0.31N/mm^2.Accordingly strength of group A samples is approximately 2.6-3 times higher than group B samples.

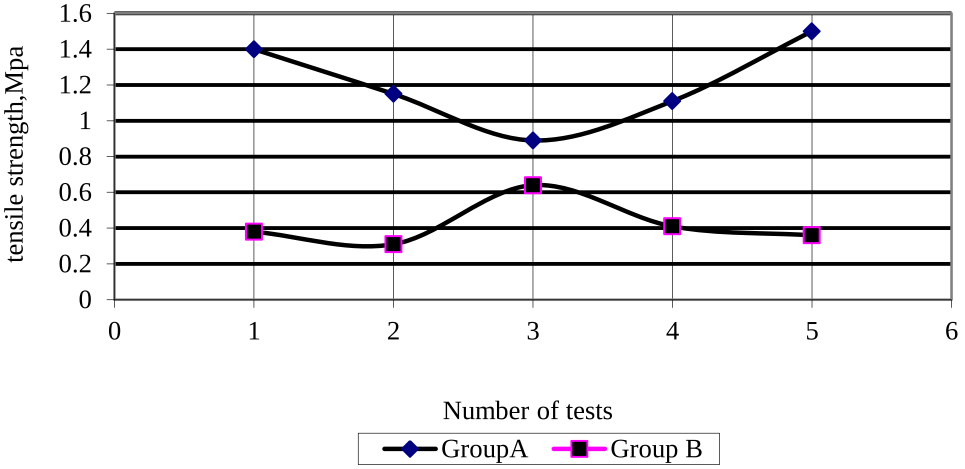

Figure 2. Graphic representation of tensile samples of group A and group B

Only the ultimate strength was taken for comparing tenacity.

It is also clear that the mechanical properties of composites are analyzed based on mixtures rule ,however the fibers used are considered to be discontinuous almost similar to particles and the matrixes are particles, thus the assumption of equality of strength for matrix and filler was considered.

The main static load required for construction materials is compression load. Bearing this in mind the compression test was also carried out for the same materials. Table 3 illustrates the value of compression test results. As seen in table 3 the average value of compression strength of group A (sand, bagasse and thermoplastics) is 25.66±5.99 N/mm^2 and for group B (Red ash, bagasse and thermoplastics) is16.66±9.34N/mm^2. Accordingly the samples with silicate sand matrix (group A) show better compression strength than samples of group B. Figure 4 below compares group A and group B samples for compression testing.

Table 3. Compression of strength test results for group A and group B samples

No of samples	Compression strength (Mpa)			
	type A	Average	type B	Average
1	34.98	25.66±5.99	31.04	16.66±9.34
2	24.43		17.53	
3	18.25		5.6	
4	25.78		16.92	
5	24.86		12.22	

As seen in figure 2 the maximum compression strength for group A samples is 34.98 Mpa and the minimum is 18.34Mpa and the maximum compression strength for group B is 31Mpa and minimum is 5.6Mpa. Accordingly compression strength of group A samples is approximately 1.5 times by average higher than group B samples.

Graphic representation of test results on compression strength is illustrated in figure 3. From the graph it is clear that the materials produced from silicate sand, polyethylene and sugar cane bagasse showed better performance than group B.

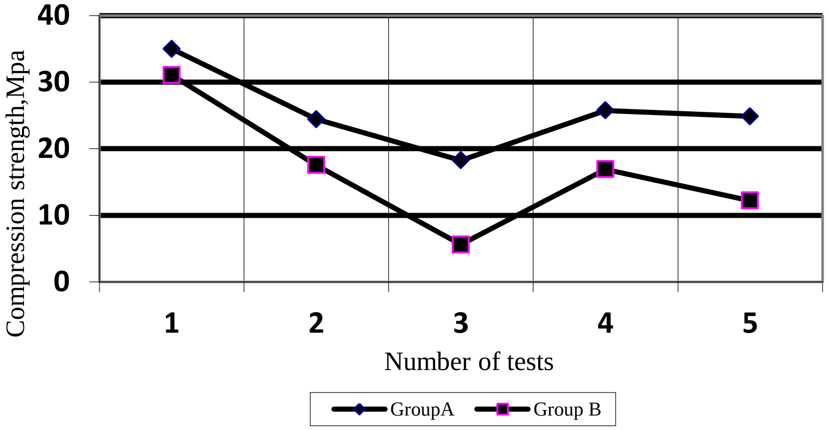

Figure 3. Comparison of Group A to Group B samples for compression strength

As compared to the existing construction composite products particularly concrete block and agro stone products, the new product shows better advantage both in compression strength and cost as well as production time. This comparison is seen in table 4 below.

As seen in the table both Group A and group B newly developed materials have better compressive strength than the existing construction products. The cost of new products is also comparatively low. More over the production time is too small that the cost can be very minimum when mass production is produced.

Table 4. Comparison of construction composite products in compression strength, cost and production time

Product	Price/M^2,ET,Birr	Production time	Compressive strength, Mpa.
Traditional concrete block	250	28days	7
Agro- stone	210	8hrs	16
New polymer matrix Bio-composite(A)	200	40hrs	25.66(average)
New polymer matrix bio-composite (B)	167	40hrs	16.66(average)

One of the mechanical loads that may affect residential buildings could be impact load from various dynamic sources including weather. To determine this condition a Charpy impact test was conducted.

3.2. Impact test analysis

Impact testing may be performed using either the *Izod* or *Charpy* method. For this particular experiment the Charpy test method was used because of its availability. Both group A and Group B samples were tested using the Charpy test method having the following initial parameters: The mass of striking is 6.6Kg, angle through which the pendulum falls (α) is 70°, angle through which the pendulum rise (β) varies; the pendulum arm length (R) is 0.3m. Angle through which the pendulum rise (β) are recorded from the experiment and energy absorbed are also actual experimental reading. Since the direct reading of Charpy test is relative calculating the energy absorbed was carried out using equation 1.

$$E_{Abs} = WR(\cos\beta - \cos\alpha) \qquad (1)$$

Where:
E_{Abs}- Energy absorbed, J;
W- Weight of the pendulum, Kg;
β - Angle through which the pendulum rise, deg;
α- Angle through which the pendulum falls, deg;
R- The pendulum arm length, m;

The impact strength of the prepared samples was calculated using equation 2:

$$\text{Impact strength} = \frac{\mathbf{E\ Abs}}{V} \qquad (2)$$

Where:
E_{Abs}- Energy absorbed, J
V- The volume of sample, m^3

The result obtained is displayed in tables 4 and 5 below. The calculated results are higher than the readings .This may help predict that the actual impact strength of the specimens are higher than the readings and can be accepted as useful product for building application.

Group A and Group B samples are compared and as seen in tables in appendix (B) and appendix (C) the samples of group A have better impact strength and energy absorbing capacity. However the impact strength of group B are also better than the conventional concert block that it can also be accepted as a building materials, where low severity application is required ,such as partition panels, roofing boards and columns in partition of internal walls.

The average value of Charpy impact test for specimens of group A is that the energy absorbed is 7.1±0.82 J and its toughness or impact strength about 1.89±027 Mpa. On contrast the average value of energy absorbed and impact strength of specimens of group B are 2.5±1.21J and 0.92±0.41 Mpa respectively. This confirms that material with silicate sand, polyethylene and sugar cane bagasse painted with refractory clays is best choice for residential and commercial buildings.

As has been discussed, the Charpy impact test is relative and hence validating the results confirmed the appropriateness of the test as well as the standard of the material. Thus the experimental and calculated results for both group A and group B specimens are presented in figure 4.As seen in the graph the experimental and calculated results are approaching each other that approves the validity of the tests.

Figure 4 represents the toughness or impact strength for group A and B specimens. As seen in the figure Group A specimens have higher impact strength than group B specimens. This shows that group A specimens have more resistance to sudden impact loads than group B specimens in which the red ash with coarse grain structure has less importance for the designed products. By considering the average values of energy absorbed and impact strengths of group A and group B components it is possible to conclude that the material composition in A has the required property for building materials since the average energy absorption capacity is approximately 3 times higher than that of group B and the impact strength is approximately twice higher than group B.

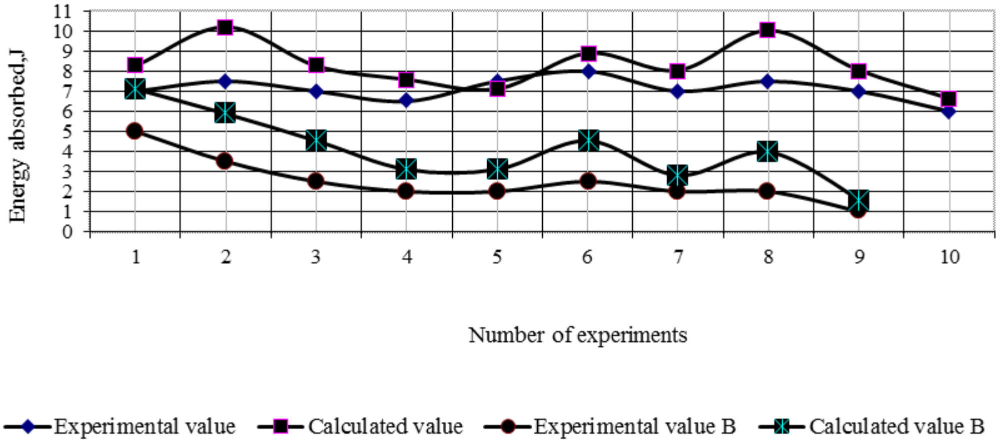

Figure 4. Experimentally obtained absorbed and calculated energy results for group A and B specimens

This may be due to the waxy characteristics of the bagasse together with the binding capacity of silicate sand that expands when heated as well as the fine grain size of the sand since finesse increases the surface area and improves the binding effect by occupying the spaces between interfaces of materials.

As already discussed the quality of group B specimen is inferior to group A specimens. The causes for this problem has analyzed based on fish bone diagram (figure 5).

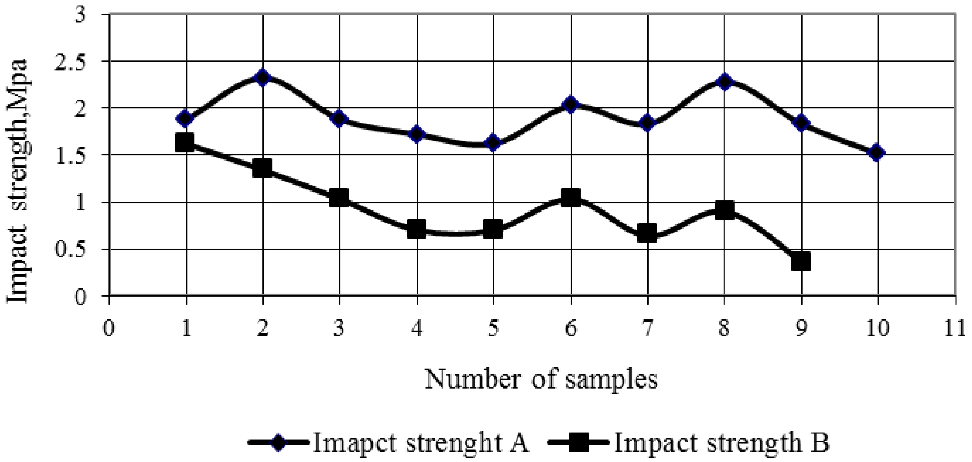

Figure 5. Comparing the impact strengths of group A and group B specimens

AS has been discussed the quality of group B material is inferior to Group A material ,thus analyzing the causes and effects briefly using the fish bone diagram (figure 5) is necessary part for quality improvements. Accordingly, the particular material composition for group B specimens are red ash, bagasse and polyethylene type polymers. Red ash which has a rough surface finish and coarse grain size has an effect on the bonding capacity of polymer matrix, thus affecting the bonding strength.

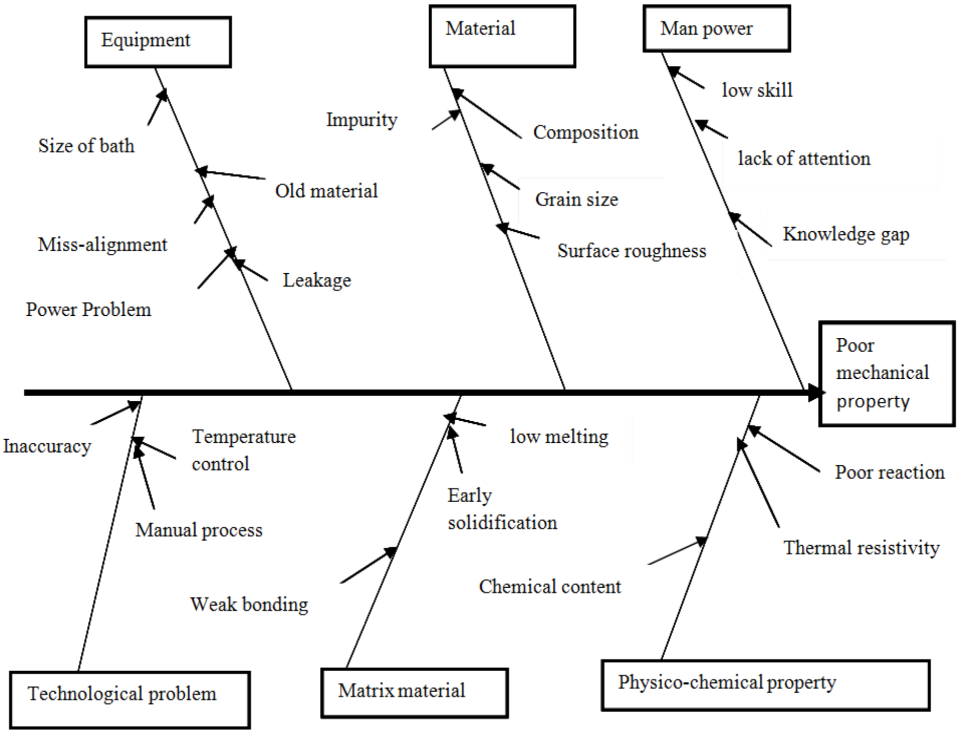

Figure 6. Cause and effect diagram for quality analysis of group B composite product

It is because there is possibly large gap between each read ash particle. At the same time the red ash was not purified and was not washed or screened, thus the dust particles and other volcanic ruminants will burn, melt and evaporate leaving a gap between the fiber, and particles consequently, the molten polyethylene matrix will immediately solidify without sufficient wetting of fibers and particles.

The newly designed equipment was constructed from old and scraped materials as there was no possibility of affording new spares and construction materials. All collected items finished their standard service life, and were worn out and hence the accuracy of alignment, fitting and assembling was inaccurate causing operation process to be below the required standard and as a result the extrusion of polymer was not in good quality. The condition leads to the in homogeneous melting of PE. This is due to the fact that all polyethylene groups (HDPE, LDPE, LLDPE) mixed together were collected from waste area and have different thermal resistance. More over there was no temperature controlling instrument to that could help to fix the true temperature required for particular polyethylene. Solidification process of these polymers was also different. This phenomenon affects the viscosity and flowability of the liquid polyethylene causing early cooling and as a result weak binding effect. Early cooling may also be affected by leakage of cold air through the misaligned joint part of the device in to the extruder. While melting the wood charcoal was a power source, but could not achieve the required temperature and hence there was a time to interrupt the power to electricity. The electric power was also interrupted while melting of PE takes place and thus insufficient melting was the result.

The rough and cold surface of the red ash and the matrix as well as the bagasse fibers could not react easily thus weak bonding was the result. Since the polyethylene groups include HDPE, LDPE and LLDPE the chemical concentration was not clearly known. This is due to in one way lack of characterizing method, in another way lack of sufficient skill and attention of manual processing of polymer matrix bio composite materials. The size of the liquid slurry bath was also small that pouring to the mold was carried out alternatively, hence unequal thermal process and lack of bond strength, which consequently became poor mechanical property of the specimens.

4. Conclusion

From the literature it is clear is that producing bio-polymer matrix composite material for construction purpose is hot issue. The methods used in this research helped to carry out the research as per the designed objective. The produced bio-based composite materials showed better mechanical properties than the conventional building blocks produced from sand, cement, gravels and sand/red ash as well as pumice mixtures. The developed bio-composite using sand, sugar cane bagasses and thermoplastics composite showed good mechanical property that is suitable for the intended application. The recycled thermoplastics reinforced with sugar cane bagasse and sand can be an alternative construction materials. The evaluation of mechanical testing, tensile, compression and impact test, showed that group A (sand, sugar cane bagasses and thermoplastics) have better mechanical properties than group B (red ash, sugar cane bagasses and thermoplastic). Comparing with conventional construction materials like concrete brick, this bio-base composite material has light weight, easily produced without using high technology and is cost effective. The quality problem of group B samples were analyzed using fish bone diagram. Further improvements will be carried out using he analysis results, however the group A materials can be used directly for the designed purpose.

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Appendix A: Specimens for mechanical testing: a. for tensile test, b. for compression testing and c for compression testing.

a. b. c.

Appendix B: Experimental impact test results for samples of group A

No	Energy absorbed(J)	Average (J)	β	E $_{Abs}$ =WR (cos β-cosα) (J)	Impact strength, Mpa.	Average Mpa.
1	7	7.1±0.82	40	8.27	1.88	1.89±027
2	7.5		30	10.21	2.32	
3	7		40	8.27	1.88	
4	6.5		43	7.59	1.72	
5	7.5		45	7.12	1.62	
6	8		37	8.90	2.02	
7	7		41	8.05	1.83	
8	7.5		31	10.04	2.28	
9	7		41	8.05	1.83	
10	6		47	6.64	1.51	

Appendix C: Experimental results of impact test for samples of group **B**

No	Energy absorbed(J)	Average (J)	β	E $_{Abs}$ = WR (cos β-cosα) (J)	Impact strength ,Mpa	Average Mpa
1	5	2.5±1.21	45	7.12	1.62	0.92±0.41
2	3.5		50	5.88	1.34	
3	2.5		55	4.53	1.03	
4	2		60	3.10	0.70	
5	2		60	3.10	0.70	
6	2.5		55	4.53	1.03	
7	2		61	2.81	0.64	
8	2		57	3.97	0.90	
9	1		65	1.60	0.36	