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Full Length Research Paper

Green Composite Material from Agricultural Waste

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The objective of the work is to produce low cost green composites using indigenously available natural fibers/waste and resins. Utilizing the agro waste banana, baggage and sisal are raw material and polyvinyl alcohol as resin for manufacturing of composite material. Composites are combination of at least two distinctly different materials, which combined together provide an engineering performance that by far exceeds those of any individual component. It is the quality of the interface between the components that determined the mechanical and chemical performance of the composites. The agro waste composite materials are ecofriendly, economically fit as well as disposable material.

Keywords: Absorbency, bending, chemical, physical, mechanical, stress

INTRODUCTION

Standards for composite panel products are voluntary in the United States. However, certification of conformance with a standard is advantageous to a product manufacturer from the standpoint of marketing and product conformance. Standards also permit ready identification of product quality and suitability and protect producers and distributors from cost-cutting competitors (Ortega-Leyva, 2008). Because the construction market in the United States is so important for composite panel producers, building code approval is a significant marketing consideration: reference to a standard in the building code requires the use of products manufactured under that standard. In addition, building codes usually demand conformance of composite panel products to a specific standard. Commodity standards frequently referred to as product standards, can be classified further as manufacturing method standards or laboratory test standards (Steward, 2007). Panel performance is generally evaluated using dimensional tests, physical property tests, and mechanical property tests. Composites are a combination of two different materials which are combined together to form an individual product of excellent properties and performance (Ates et al., 2008). Environment-friendly composites made using the eco materials are decomposed by micro-organisms and hence can act as an alternative for several products such as wood, plastic etc (Adhikiry et al., 2008).,

The portion of the composite microstructure that lies between its constituents composition means matrix and reinforcement. The interface may be a simple row of atomic bonds but may also be included in the matrix/reinforcement reaction products (e.g., aluminium carbide between aluminium and carbon fibers) or reinforcement coatings (La et al., 2005). It is the quality of the interface between the components that determines the mechanical and chemical performance of the composites. The percolating material forming one primary constituent of a Composite in which the other constituents are embedded. The other constituent embedded in this matrix usually serves as reinforcement (Dominique et al., 2011). Reinforcement is a constituent (phase or combination of phases) composite originating from the ingredient material which is combined with the matrix to form a composite. Reinforcement is characterized by its chemical composition, shape and dimensions, properties as ingredient material and volume fraction and Spatial Distribution in the matrix (figure1).

The world is now focusing on biodegradable products. Green composites made of eco friendly and biodegradable fibrous material have replaced the conventional materials like wood, metals etc., the most commonly used boards are ply wood boards and asbestos. Manufacture of ply wood boards, warrant cutting of trees, which are highly undesirable in the context of green effect (Aminullahet al., 2011). Whereas in case of asbestos, research findings have thrown light on the possible harm it could do to human beings due to

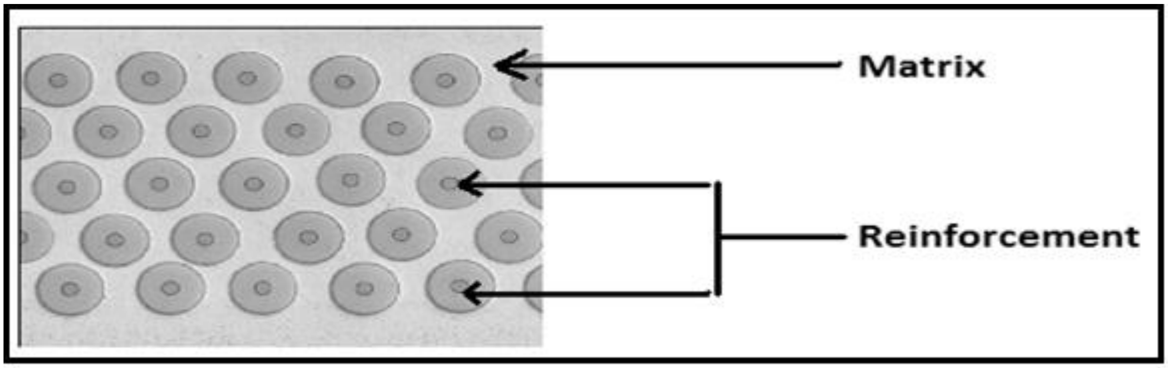

Figure 1. Primary constituents of a Composite material (Albano et al., 2005)

its toxic characteristics. A green composite examine fiber reinforced polymer composite production and explains how environmental footprints can be determined at every stage of the life cycle. Green composites is an essential guide for agricultural crop producers, government agricultural companies, composite producers and material scientists all dedicated to the promotion and practice of eco-friendly materials and production methods (Sain and Panthapulakkal, 2003). Ecological awareness in these days brings reuse and recycle of products, environmental protection and saving of energy. In universities and companies, therefore, there is an increase in the number of studies and practical applications on materials recyclability, as seen in the uses of green materials and recycle of petroleum-based materials. Domestic waste, Biodegradable wastes and natural fibers can be used to produce Green Composites (Sain et al., 2000).

So many materials are suggested in literature to make the composite material like wheat straw (Wang and Sun, 2002) banana, bamboo, coir, coconut husk, sisal, rice husk (Rahman et al., 2011) and baggage's. In that most of the research worked in sugarcane baggages. Sugarcane baggages are easily available in almost all part of the world In that regard an attempted has been made to produce the composite particle board from sugar cane baggage.

MATERIAL AND METHODS

Material

Agro-waste: Sugarcane baggage, banana and sisal were arranged from rural area of Ethiopia. Banana Fiber is extracted from Banana tree bark. The trunk is peeled. Brown-green skin is thrown away retaining the cleaner or white portion which will be processed into knotted fibers. The fibers are extracted through hand extraction machine composed of either serrated or non serrated knives. The peel is clamped between the wood plank and knife and hand-pulled through, removing the resinous material. The extracted fibers are sun-dried which whitens the fiber. Once dried, the fibers are ready for knotting. A bunch of fibers are mounted or clamped on a stick to facilitate segregation. The residue obtained after crushing cane in a mill is known as bagasse. Depending on the number of the mill it is referred to as first mill bagasse, second mill bagasse, etc. After a diffuser the residue is called diffuser bagasse. The final residue from a milling train or from the dewatering mills of a diffusion plant is called final bagasse or simply, bagasse. Bagasse (sometimes spelled *bagass*) is the biomass remaining after sugarcane stalks are crushed to extract their juice. Sisal is a plant of the agave family *Agave sisalina.* The stalk grows to about one metre in height. The fibre is contained in the lance-shaped leaves that grow out from the stalk in a dense rosette (Tsai et al., 1998). The sisal plant produces approximately three hundred leaves throughout its productive period. To extract the fibre the leaves are crushed and the pulp scraped from the fibre. This is then washed and dried. The sisal fibre strands are usually creamy white in colour.

Chemical: By choosing among the many polyvinyl alcohol grades available, it is possible to obtain the performance properties required for your specific applications-properties such as water solubility, abrasion resistance, tensile strength, adhesive and bonding properties, grease or oil resistance and film forming qualities. Polyvinyl alcohol (PVOH, PVA, or PVAL) is a water-soluble synthetic polymer (Salemane et al., 2006). Polyvinyl alcohol has excellent film forming, emulsifying and adhesive properties. It is also resistant to oil, grease and solvent. It is odorless and nontoxic. It has high tensile strength, flexibility, as well as high oxygen and aroma barrier (Yang et al., 2006)

Methods: In general there are various methods existing by which the green composite particle board can be produced. But in this work composite material was made from mixture of resin. The steps mention in Figure 2 below:

The amount of banana fiber used in this project is about 2.5 kgs. Immersing of the banana and sisal fibre is done

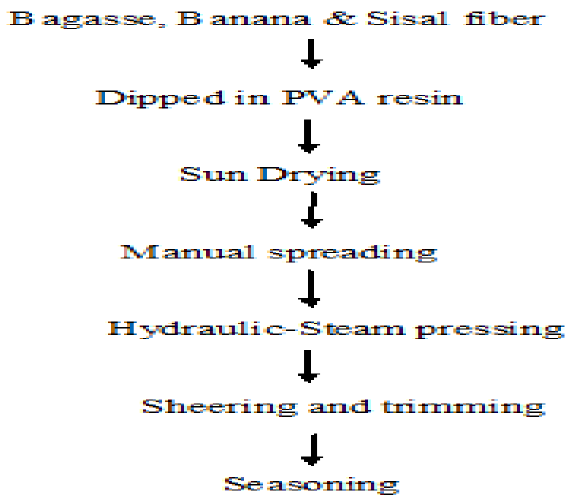

Figure 2. Steps for making composite material

for few minutes until the poly vinyl alcohol resin is absorbed by the fibre.(b) The same procedure mentioned above is done for bagasse. Totally about 15 kgs of PVA (polyvinyl alcohol) is used in the dipping process. The moisture content of particles is critical during hot pressing operations. Thus, it is essential to carefully carryout the drying process. The moisture content of the material depends on whether resin is to be added dry or in the form of a solution or emulsion. After the spreading process is completed the layers are assembled in between aluminium caul plates on either sides and then processed onto the press. After pre-pressing, the mats are hot-pressed into panels. Hot press temperatures are usually in the range of 100–140°C. PVA resins are usually cured between 75 and 85°C. Pressure depends on a number of factors, but is usually in the range of 40 to100 kg/cm ^{2}. After pressing, the board is trimmed to bring the board to the desired length and widths, and to square the edges. Trim losses usually amount to 0.5–8%. After trimming, the boards are on the size of the board. Trimmers sanded or planned prior to packaging and shipping. The particleboards may also be veneered or overlaid with other materials to provide better surface and improve strength properties. Generally seasoning is done to improve the strength of the board. The board is immersed into water which is about 13 to 15% of the weight of the board; this process is carried for a period of one week.

Fitness test

Physical property tests

The physical property tests discussed in this section refer to American Society for Testing and Materials (ASTM) standard D1037 (ASTM, 1994a) unless otherwise noted (Bavan and Kumar, 2010).

(a)Dimensional Test

Methods of measuring panel dimensional properties and the required accuracy of these measurements for composite panel products are defined in ASTM D1037.

(b) Moisture Content

The average moisture content of a panel at the time of shipment from the manufacturer cannot exceed 10% (based on the oven dry weight) for all grades of particleboard. In the United States, the average moisture content of hardboard should not be less than 2% or more than 9%. Three specimens should be cut from different locations in the panel and the test results averaged. Generally, a 76 mm wide by 152 mm long specimen of full thickness is used to obtain the dimensions to accuracy not less than ±0.3% and the weight to an accuracy of not less than ±0.21%. The oven dry weight of the sample is then obtained after drying the sample at 103 ±2°C until constant weight is reached. Moisture content is calculated as follows:

$M = 100 \{(w – f)/ f\}$

m = moisture content (%)

w = initial weight

f = final weight when oven dry

(c) Water Soak Test

The 24 h water soak test determines the water absorption behaviour of the composite and the effects of the absorbed water on composite dimensions. The test specimen is 304 by 304 mm or 152 by 152 mm, with edges smoothly and squarely trimmed. The specimen is conditioned to a constant weight and moisture content in a conditioning chamber maintained at a relative humidity (RH) of 65 ± 1% and a temperature of 20 ± 3°C. The specimen is weighed to an accuracy of not less than ±0.2% and the width, length, and thickness are measured to an accuracy of not less than ±0.3%. The thickness is measured at four points midway along each side 25 mm. After 24 h of submersion in distilled water at 20 ± 1°C, the specimen is weighed after the excess water drains off. The thickness is measured at the same four points and the average is obtained. The following calculations can then be made:

1) Thickness swelling (%) = $\{(T_w - T_i) / T_i\} \times 100$

T_w = wet thickness

T_I = initial thickness

2) water absorption (%) = $\{(W_w - W_i) / W_i\} \times 100$

W_w = wet weight

W_I = initial weight

Thickness swelling is critical where the composite board is exposed to water or moisture for extended periods.

(1) Mechanical Property Tests

The mechanical property tests discussed in this section refer to ASTM D 1037 standards (ASTM, 1994a) unless otherwise noted. The mechanical properties of composite boards depend on the moisture content at the time of test (Rosa et al., 2009). Material tested dry is conditioned to a constant weight and moisture content in a climate chamber maintained at 20° ± 3°C and an RH of 65 ± 1%. There are also several tests for measuring the properties of a composite product at various moisture contents and humidity levels. Material tested wet is soaked in 20° ± 3°C water for 24 h prior to mechanical property testing. One method of obtaining a measure of the inherent ability of a material to withstand severe exposure conditions is to use an accelerated aging test. Using this method, each sample is subjected to six complete cycles of aging:

- immerse specimen in water at 49 $\pm$ 2^{o}c for 1 hour
- Spray specimen with steam and water vapour at 93 $\pm$ 3^{o}c for 3 hour
- Store at -12 $\pm$ 3^{o}c for 20 hour
- Heat at 99 $\pm$ 2^{o}c in dry air for 3 hour
- Spray again with steam and water vapour at 93 $\pm$ 3^{o}c for 3 hour
- Heat in dry air at 99 $\pm$ 2^{o}c for 18 hour
- After six cycles, further condition the material at 20 $\pm$ 3^{o}c and RH 65 + 1% for at least 48 hour before the test.

(a) Modulus of Rupture

Modulus of rupture (MOR) has become a common measurement of composite board bending strength. The MOR is the ultimate bending stress of a material in flexure or bending, and it is frequently used in comparing one material to another.

(b) Modulus of Elasticity

Modulus of elasticity (MOE) tests the specimen's ability to resist bending. This property is determined from the slope of the straight-line portion of the load deflection curve. (P 1/ Y 1). The MOE is then calculated by the following formula:

$MOE = \{P_1L^3\} / \{4bd^3Y_1\}$

MOE = stiffness (apparent modulus of elasticity), kP

P_1 = load at proportional limit, N

L = length of span, mm, 24 x the depth

b = width of specimen, mm

d = thickness (depth) of specimen, mm

Y_1 = Centre deflection at proportional limit, mm

(c) Tensile Strength

Tensile strength is measured perpendicular (internal bond strength) and parallel to the face of the specimen.

Perpendicular to Face

Tensile strength perpendicular-to-face is a measure of the resistance of a material to be pulled apart in the direction perpendicular to its surface. A 50 mm square specimen is bonded with an adhesive to steel or aluminum alloy loading blocks of the same dimensions. The internal bond strength is an important property of composite boards; it is calculated as follows:

$IB = P / bL$

IB = internal bond, kP_a

P = maximum load, N

b = width of specimen, mm

L = length of specimen, mm

Parallel to Face

Tensile strength in the parallel-to-face orientation (Figure 9.6) is the resistance of a board material to be pulled apart parallel to its surface. The maximum load at the time of fracture is divided by the cross-sectional area (width × thickness) of the specimen to give maximum strength. We have carried out various testing such as tensile strength, bending rigidity and absorbency% for the samples, whereas tensile strength, bending rigidity will be tested in both axis. i.e., parallel to the fiber axis & perpendicular to the fiber axis (Yang et al., 2006).

RESULTS AND DISCUSSION

Calculation of Bending Strength

Bending Strength of the samples can be assessed by using following formula

Formula: *Bending strength=pl/bd^2*

Example:

Load applied, P = 72 kgf

Bending strength = pl/bd^2

= 74×30×9.81/5×100

= 43.5564 N/mm^2

Calculation of Shear Strength

Formula: *Sheer strength= load/area*
Area = 500mm
Load applied = 588kgf
Sheer = load/area
= 588×9.81/500
= 11.53656 N/mm^2

Calculation of Water absorbency test

Formula: *Water absorbency %* = W_2-W_1/W_1×100
Weight of the dry sample, W_1 = 92.068 grams
Weight of the sample after immersing into water, W_2 = 213.780 grams
Absorbency % = W_2-W_1/W_1×100
= 213.780 – 92.068/92.068×100
= 121.712/92.068×100
= 132.19795

Costing

Raw Material Cost

Banana fiber	- Rs.1.25$/kg
Bagasse	- Rs.0
Sisal	- Rs.1.5$/kg
PVA resin	- Rs.1.5$/kg

Costing is done for the following parameters

Time of Pressing	- 50 minutes
Number of berths in the press	- 8
Dimensions of the board	- 6ft x 4ft
Weight of raw material/board	= 22 kgs
Weight of a single board	≈ 10 kgs
Number of boards/shift	- 64
Weight of raw material used/shift	- 22.5 x 8 x 8 = 1,440 kgs
Total weight of boards/shift	= 64 x 10 = 640 kgs

Labour Wages

No of labours required/shift	- 2
Wage /person/shift	- 10$
Wages for 1kg production	= (10/640) =Rs.0.156$

Proportions of raw material in a board

Quantity of Banana fiber/board	= 2.5 kgs of 22.5 kgs = 11 %
11 % of Banana fiber	= 0.15$
Quantity of Sisal fiber/board	= 2.5 kgs of 22.5 kgs = 11 %
11 % of Sisal fiber	= Rs.0.156$
Quantity of Bagasse/board	= 2.5 kgs of 22.5 kgs =11 %
11 % of Bagasse	= 0$
Quantity of PVA/board	= 15 kgs of 22.5 kgs = 67 %
67 % of PVA resin	= Rs.1$

Final Costing for 1 square feet of the board

(i) Raw material cost/kg of product

11 % of Banana fibre	= 0.156$
11 % of Bagasse	= 0.00$
67 % of PVA resin	= 01$
11% of Sisal fibre	= Rs.0.156

(ii) Labor wages and Inventory charges

Labor wages (2 persons/shift)/kg	= 0.1$
Inventory charges/kg	= 0.25$

(iii) Power and Transport charges

Power charges involved in pressing/kg	= 0.1$
Transport cost/kg	= 0.15
	= 1.25$
Total cost/kg	**≈ 1.35$**

Number of kgs produced/shift= 640

Total cost/shift = 640 x1.35$=864.00$

Total square feet produced/shift = (size of a board x ***number of berths in press*** x ***shift of 8 hours)***

=6 x 4 x 8 x 8

Total square feet produced/shift = 1536 sq.ft

Total cost/square feet = Total cost/shift/ (Total square feet produced/shift)=864/1536

=0.563$

Total cost/square feet of the board = 0.563$

From the above analysis it is clearly indicates that manufacturing cost for producing natural composites is 0.563/ Sq.Ft.

CONCLUSION

Present materials used for manufacturing false ceilings', doors, boxes for agricultural purposes, rims, mobile panels, toys etc are steel, and plastic which are all high expensive materials which create serious impact to the user and ecofriendly. Manufactured composites is undergo for testing of bending rigidity, shear and absorbency. Test results of the green composites produced shows it is suitable for the using in the fit for the entire users field. Bagasse, banana and sisal fibers have high tensile strength which gives high strength without any finishing. Finally it is concluding that it will save the cost involved in manufacturing and processing to a greater extent as well as preserve environment. Since manufacturing / processing / disposing of this composite will not create any negative impact to the user and environment, that's why it know to be **"Natural Green Composite"**

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