HYBRID NATURAL COMPOSITE AS A POTENTIAL WOOD SUBSTITUTE MATERIAL

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Abstract— This Paper deals with material characterization and utilization of abundantly available and renewable resources such as jute fiber and Banana fiber. These plant fibers along with industrial wastes such as Fly ash and Groundnut shell powder have been used for synthesizing composite materials. Our main aim is to introduce an alternative in wood usage which will promote forest conservation and also to reduce industrial waste deposits which will enhance environmental protection. Further to make use of natural fibers and resin which will lead to economical benefit by providing low cost and eco-friendly product equivalent to plywood. The versatile material system so developed has potential for plywood substitute applications such as Furniture like table, Door shutters, Roof and Floor tiles. The study strongly suggests that the newly developed plant fiber and industrial waste reinforced natural composite material is capable to serve as a potential cost, energy effective to the conventionally used plywood.
Index Terms— Banana Fiber,Castor Oil ,Fly ash, Groundnut Shell Powder, Jute Fiber.

I. INTRODUCTION

Environment is the key factor which decides the quality of human life. It is important to keep our environment safe and clean. Since technology has evolved in human life, it created a path for depletion of environment. No remedial measures were taken yet to stop this depletion. Fly ash has a major contribution in eroding the environmental health. Though the generation of electricity created a great evolution in human life, it creates a harmful effect to environment while it is produced by burning of coal which leads to the disposal of fly ash in large quantities. So we do not have enough space in land to accumulate it. This in turn leads to dumping of fly ash in land which ways for land pollution. Spread of fly ash in land fills the voids of soil pores, maintains as block to soil by restraining the water from entering into ground, thus reducing the ground water recharge. Also it settles in the root of the tree that stops the primary process of root system which is absorption of water, thereby reducing the growth and lifespan of trees. Lots of efforts are taken to use fly ash in a efficient way [1]. Groundnut has been used as a source for oil industry while its shell is of no use, it remain as waste material. The use of fibers in every season does not meet the higher demand hence to reduce its wastage it can be used to produce the potential product. We know that castor oil has been used as domestic product, but it also serves as good natural resin.

Over the last few decades efforts have been made to utilize fly ash in huge quantities for road construction, land filling and building materials like bricks, blocks, cement, paints etc [2-3]. Groundnut Shell Powder has been used as an alternative of cement in concrete now a days [4-5]. Fibers are used mostly for the cordage, sacks, fishnets, mats, ropes, wall coverings and as filler for mattresses and cushions [7-14]. Natural oils have been used as a resin in composites [15-18]. In view of the above, hybrid natural composite have been synthesized with different trials [19-20]. Relevant engineering properties of the composites have also been characterized with the view to use them as wood substitute products in building construction such as furniture like table, door shutters, roofing sheets, and floor tiles to reduce environmental pollution and deforestation [21]. Relevant characteristics of conventionally used plywood products have also been compared in order to access the application potential of the developed composites as plywood substitutes.

II. MATERIAL CHARACTERIZATION

A. Fly ash

Fly ash was characterized using X-ray diffraction analysis to determine their chemical composition. Addition of Silicon dioxide, Aluminium oxide and Iron oxide content is greater than 70% which gives good strength and durability. It contains less than 7% lime. It provides increased pore refinement and decreased permeability.

Figure 1: Fly ash (Class F)

Chemical Composition:

Table 1 Chemical Composition of Fly ash

Oxide composition	Percentage
CaO	5
SiO2	54.8
Al2O3	31.7
Fe2O3	3.8
Na2O	0.8
K2O	0.8
MgO	1.1
SO3	0.3
LoI	0.8

B. Groundnut shell powder

Groundnut shell is a lignocellulosic waste and its chemical composition was characterized using X-ray diffraction analysis. A potential valorization of groundnut shell is its possible use as reinforcing filler in polymer matrix. Groundnut shell powder will be effective, if the size ranges from 300 to 600 micron. Addition of Silicon dioxide, Aluminium oxide and Iron oxide content is greater than 70% which gives good strength and durability. It contains less than 7% lime. Upto 15% replacement as supportive material, gives good strength.

Figure 2: Groundnut Shell Powder

Chemical Composition:

Table 2 Chemical Composition of Groundnut Shell Powder

Oxide composition	Percentage
SiO2	54.03
Al2O3	39.81
Fe2O3	4.34
CaO	1.7
MgO	0.004
Na2O	0.85

C. Jute fiber

Jute fibers are first extracted by retting process. The retting process consists of bundling jute stems together and immersing them in slow running water. Jute fiber is then dipped in NaOH solution for one week and then dried in sunlight for one month to remove alkalinity nature, and to make it as a fire retardant material. Jute fibers possess high tensile strength, low extensibility and ensures better breathability of fabrics. It has good insulating , acoustic and antistatic properties. It has low thermal conductivity and moderate moisture regain. It can be easily blended with other fibers.

Figure 3: Jute Fiber

Chemical Composition:

Table 3 Chemical Composition of Jute Fiber

Constituents	Percentage
Cellulose	65.2
Hemicellulose	14
Lignin	11.3

Physical Properties:

Table 4 Physical Properties of Jute Fiber

Parameters	Properties
Diameter	0.05 mm
Length	5 mm
Density	1.36 g/cm³
Effect of light and heat	Average
Abrasion resistance	Average
Dimensional stability	Good

D. Banana Fiber

Banana fiber is extracted from *Musa Acuminate* by retting process and then fiber is dipped in NaOH solution for one week and dried in sunlight for one month to remove alkalinity nature, and to make it as a fire retardant material. Fibers are light weight and highly strong. It has smaller elongation. It has strong moisture absorption quality and absorbs as well as releases moisture very fast.

Figure 4: Banana Fiber

Chemical Composition:

Table 5 Chemical Composition of Banana Fiber

Constituents	Percentage
Cellulose	63.4
Hemicellulose	19
Lignin	5

Physical Properties:

Table 6 Physical Properties of Banana Fiber

Parameters	Properties
Diameter	0.07 mm
Length	7 mm
Density	1.3 g/cm³
Effect of light and heat	Average
Abrasion resistance	Average
Dimensional stability	Good

E. Castor Oil

Castor oil is vegetable oil pressed from castor beans, in general acts as a natural resin. It is a triglyceride in which approximately 90% of fatty acid chains are ricinoleates. Oleate and Linoleates are the other significant components. Ricinoleic acid is a monounsaturated 18 carbon fatty acid which is unusual in other oils.

Because of high monounsaturated content, it doesnot require any catalyst to involve in reaction process.

Physical Properties:

Table 7 Physical Properties of Castor Oil

Parameters	Properties
Density	961 kg/m³
Boiling point	313° C
Melting point	-10° C
Viscosity	6 poises
Molecular weight	933.45 g/mol

Chemical Composition:

Table 8 Chemical Composition of Castor Oil

Parameters	Percentage
Ricinoleic acid	89.5
Oleic acid	3
Linoleic acid	4.2
A-linolenic acid	0.3
Stearic acid	1
Palmitic acid	1
Dihydroxystearic acid	0.7
Eicosanoic acid	0.3

III. MANUFACTURING PROCESS

Composite Preparation

Composite Consists of fly ash, groundnut shell powder, fibers and castor oil. Proportions were varied in each trial. Hand mix was prepared and laid in tile mould by sandwich method i.e. between each layer of fly ash and groundnut shell powder, layer of fibres were placed as reinforcement. Pressure of 0.5 MPa was applied for one hour. Specimen was then oven dried at 60°C in furnace. Heating was done for about 3 hours. Specimen was allowed to cure at room temperature.

Table 9 Optimum Composition (wt %) of the developed composite

MATERIALS	PROPORTION
Fly ash	50%
Groundnut shell powder	9%
Jute fiber	0.5%
Banana fiber	0.5%
Castor oil	40%

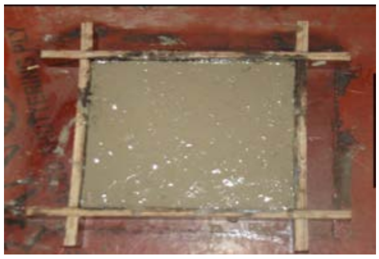

Figure 5: Casting in tile mould

Figure 6: Specimen during heating in furnace

IV. TESTS

A. COMPRESSIVE STRENGTH TEST

a. Test on Plywood

Compressive strength test was conducted using Compression Testing Machine.

Figure 7: Plywood in Compression Testing Machine

b. Test on Composite

Compressive strength test was conducted using Universal Testing Machine

Figure 8: Specimen in Universal Testing Machine

c. Comparison of test results

The Compressive strength test results of plywood and composite are compared below.

Table 10 Result Comparison of Compressive Strength Test

Parameters	Plywood	Composite
Weight	1.33 kg	1.42 kg
Density	813.25 kg/m³	887.5 kg/m³
Strength	1.85 MPa	1.93 MPa

B. FIRE RESISTANCE TEST

Fire resistance rating typically means the duration for which a passive fire protection system can withstand standard fire resistance test. This can be quantified simply as a measure of time, or it may entail a host of other criteria, involving other evidence of functionality or fitness for purpose. Time / temperature curves used for testing the fire resistance rating.

As per IS 3808-1979, fire resistance test was conducted as follows:

Initial weight of sample was taken and then Composite was placed in muffle furnace. Temperature was set around 300°C. Heating was done for a period of 3 hours. The specimen was then weighed again. Now, Loss of weight was calculated in percentage. Compressive Strength test was conducted on heated specimen. Finally, Loss of compressive strength was calculated in percentage.

Figure 9: Specimen before exposure

Figure 10: Specimen in furnace

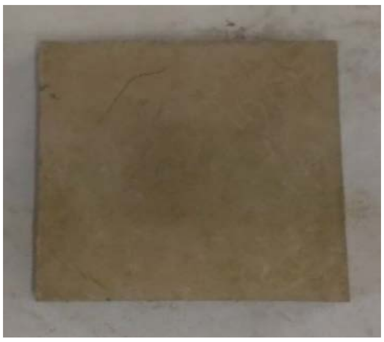

Figure 11: Specimen after exposure

Results

Table 13 Result Comparison of Fire Resistance Test

Parameters	Before Exposure	After Exposure
Colour	Grey in colour	Grey in colour
Weight	1.42 kg	1.31 kg
Strength	1.93 MPa	1.82 MPa

C. ABRASION TEST

Abrasion test was conducted using Abrasion testing machine following procedures given in IS 1237(212).Test was conducted on plywood and composite by giving constant load of 8kN at 250V for about 660 revolutions. Abrasion value for plywood was observed as 0.22mm and for composite as 0.16mm.

D. IMPACT TEST

Impact test was conducted using procedure similar to izod test for plywood and composite. The size of the specimen was 100x10x10 mm. Impact strength for plywood was observed as 0 J/mm^2 and for composite as 1 J/mm^2

E. WEATHERING TEST

The plywood and the developed composite were alternatively exposed to ultraviolet radiation, water spray and humidity. The composite was subjected to weathering for about 168 hours.

V. RESULTS AND DISCUSSION

The chemical composition of fly ash is shown in Table 1. The chemical analysis of fly ash indicated that sum of three major oxides SiO2 (54.8), Al2O3 (31.7), Fe2O3 (3.8) is greater than 70%. While the presence of other oxides such as sodium oxide, Magnesium oxide and Calcium oxide were in smaller proportion. These major oxides are the main reason to promote cementitious properties in composite. The chemical composition of groundnut shell powder is shown in Table 2. The sum of major oxides such as SiO2 (54.8), Al2O3 (31.7), Fe2O3 (3.8) is greater than 70%, and that is the main reason which make it as a supportive material to fly ash. Chemical composition and physical properties of jute fiber and banana fiber are shown in Table 3, Table 4, Table 5 and Table 6 respectively. Resistance of fibers to fire was high as they were treated earlier.

Composition of the developed composite is shown in Table 9. Figure 5 and 6 represents the making of specimen as per mentioned procedure. The nature of the composite material is characterized using conducting compressive strength test and fire resistance test as shown in Figure 8 and 10.

The results of compressive strength have been tabulated in Table 10. Density of the composite was found to be 887.5 kg/m^3, and strength obtained was higher than plywood. The reason beyond increase in strength is due to the cementitious content of fly ash and tensile nature of fiber in composite, leads to hold strength more than conventional plywood. Here, Increase in strength of 4.5% is marked between composite and plywood.

The results of fire resistance test have been tabulated in Table 13. Developed composite can able to withstand the temperature of 300°C. Loss in weight and compressive strength was noted after it was exposed to heat. No visual change was observed after exposure. Since plywood can able to adopt to the temperature of around 40°C, beyond this, it results in emission of smoke. This proves that, Resistance of developed composite to burning is much improved than plywood because of pretreatment of fibers.

The results of abrasion resistance test was shown above. Developed composite show only slight reduction in abrasion rate. It shows that presence of fibers in composite makes it to have less abrasion and good interfacial bonding and the composite shows less abrasion than that of plywood.

The result of impact strength was shown above. Developed composite show greater impact strength than plywood. This is because of the reinforcement of fibers which needs extra energy for fiber pullout and debonding of fibers from the matrix.

The weathering studies in the developed composite showed results same as that of plywood. No visual change was observed during this test. The improved behavior is due to reinforcement of fibers and cementitious content of fly ash.

The above test results were an indication of good adhesion between reinforcement phases. Thus the composites developed attained much better physical and chemical properties than plywood. The developed valuable composite become beneficial by controlling land pollution and bio waste generation.

CONCLUSION

The jute and banana fiber reinforced composite with fly ash and groundnut shell powder provides good chemical, physical and fire resistance properties than conventional materials like plywood. Its strength and durability make this as exact substitute to plywood. Since the composite was developed using waste materials, it is highly cost efficient to plywood. There is a growing global demand for wood made products since the forest cover is limited. Our composite will provide a solution to this emerging risk. The developed composite is a versatile material and can be used for number of applications like

- Furniture like tables
- Door shutters
- Roofing sheets
- Floorings
- Wall tiles
- Panels
- Partition walls

REFERENCES

1. Morchhale, R.K., Asokan, P., Mohini Saxena and Prasad, B.K.,"Plant Fibre Industrial Waste Reinforced Polymer Composites as a Potential Wood Substitute Material", Journal of Composite Materials, Vol. 42 ; 367,2008
2. Gopinath, P and Suresh, P. ,"Mechanical Behaviour of Flyash filled, Woven Banana Fibre Reinforced Hybrid Composites as Wood Substitute", International Journal Of Mechanical and Production Engineering Research and Development, Vol. 4,111-116,2014.
3. Prabakar , J., Ahirwar R.S., Morchhale, R.K. and Saxena.M.,"Use of Flyash in Development of New Building Materials and Construction", Civil Engineering & Construction Review,12(4):43-46,1999.
4. Nadiminti Venkata Lakshmi and Polinati Satya Sagar.,"Study on Partial Replacement of Groundnut shell ash with cement", Challenge journal of Concrete Research Letters, 84-90,2017.
5. Alabadan, B.A., Njoku, C.F. and Yusuf MO.,"The Potentials of Groundnut shell ash as concrete admixture", Agricultural Engineering International:The CIGR E Journal Manuscript BC 05 012, VIII,2006.
6. Solomon Ikechukwu Anowai and Olorunmeye Fredrick Job.,"Durability Properties Banana Fibre Reinforced Flyash Concrete", International Research Journal of Engineering and Technology, Vol.4-11,2017.
7. Mohanty, A.K., Misra, M. and Drzal, L.T.," Surface Modifications of Natural Fibres and Performance of the Resulting Biocomposites: An Overview, Composite Interfaces", 8(5):313-343,2001.
8. Mohanty, A.K., Misra, M. and Hinrichsen, G.,"Biofibres Biodegradable Polymers and Biocomposites: An Overview, Macromolecular Materials and Engineering", 276-277(1):1-24,2000.
9. Venkatesharan, N. and Elayaperumal, A., "Banana Fibre Reinforced Polymer Composites - A Review", J Reinf Plasts Compos, Vol.29, pp.2387-2396,2010.
10. Pickering KL.,"Properties and Performance of Natural-Fibre Composites", Woodhead Publishing, Ltd.; 2008.
11. Anowai, S.I. and Job, O.F.,"Properties of Banana Fibre Reinforced Flyash Concrete", International Journal of Modern Trends in Engineering and Research, 4(10),227-236,2017.
12. Alavudeen, A. and Thiruchitrambala, M.,"Review of Natural Fibre Reinforced Woven Composites", Rev.Adv.Master.Sci., Vol.27,pp.146-159,2011.

13. McLaughlin EC and Tait RA, Fracture Mechanism of Plant fibres, Journal of Material Science 1980; 15:89-95.
14. Cazan, O.E., Gherman, M.C., Bolder, R.P. and Brata, T.M.,"Hybrid Fibre Reinforced High Performance Concrete at Elevated Temperatures", Acta Technica Napocensis: Civil Engineering and Architecture. 57(2),198-201,2014.
15. Fabricio Moura Dias and Francisco Antonio Rocco Lahr.,"Alternative Castor Oil – based Polyurethane Adhesive used in the Production of Plywood", Materials Research, Vol.7,no.3,413-420,2004.
16. Olorunmeye Fredrick Job, Emmanuel Achuenu, Solomon Soji Maxwell and Sunday Ainoko Itodo.,"Performance of Castor oil as Admixture in Fresh Cementitious Matrix", SSRG International Journal of Civil Engineering, Vol.4,no.6,2017.
17. ASTM D960 (1952). Specification for Quality Castor oil. American Standards Institution, USA.
18. Ogunniyi, D.S.,"Castor oil-A Vital Industrial Raw material. Published by Pubmed", USA,2006.
19. Mohanty, A.K., Misra, M. and Drzal, L.T.,"Sustainable Bio Composites from Renewable Resources: Opportunities and Challenges in the Green materials World", Journal of Polymers and the Environment, 10(1-2), 19-26,2002.
20. Netravali, A.N. and Chabba, S.,"Composites Get Greener", Materials Today, 6(4), 22-9,2003.
21. Harris B.,"Engineering Composite Materials", London: The Institute of Materials; 1999.