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Development of waste polystyrene (Styrofoam) adhesive as matrix in composite applications

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Abstract
This research paper is about the development of waste polystyrene (styrofoam) adhesive to be use as matrix in composite application. The research is aim to convert non-biodegradable waste polystyrene material, to wealth. The waste polystyrene adhesive produced increases in pH (6.0, 6.1 and 6.2) demonstrated reduction in curing rate and the gel time of the waste polystyrene adhesive. The viscosity at speed of 30, 40, 50 and 60 RPM, the viscosity decreases to an equilibrium of 998 cPs, this indicates the quality of the formulated adhesive produced fall within the range of viscosity used as a matrix in composites production. Analysis of variance for responses indicated that the coefficients of determination (R^2 = 97.49, and 92.84%) is adequate for the model to be considered. Furthermore, the optimal conditions for the produced composite results show a minimal error difference between the predicted results and the experimental results. The composite materials absorbed water readily on daily bases ranged from 0.24% to 1.67%, the rates of absorption remain constants on reaching a saturated stage. Generally organic materials absorb water readily, increasing the quantity of the fibre particles in a composition increases the percentage of water absorption. Interfacial bonding occurred between the particles and matrix, which resulted in improving the tensile strength of the composite produced.

Keywords: waste polystyrene, styrofoam, matrix and composite

Introduction

Composite are combination of two materials in which one of the materials, called reinforcing phase, is in the form of fibers, sheets or particles, and is embedded in the other material called the matrix phase [13].

The volume and number of applications of composite materials have grown steadily which constitute a significant proportion of the engineered materials. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques manufacturing techniques currently being used in the composite industries. It is essential that there will be an integrated effort in designing, material processing, tooling, quality assurance, manufacturing, and programme management for composites to become competitive with metals [7].

Composites based upon thermosetting or thermoplastic polymeric matrices are being increasingly used in many diverse applications. The composites based polyester resins possess a relatively polar surface with relatively high values of surface free energy and this makes them intrinsically receptive to adhesive bonding, unless they are contaminated by residual release agents or by absorbed water. On the other hand, composites based upon thermoplastic polymers tend to have low values of surface free energy and hence more intrinsically difficult to bond using conventional engineering adhesives.

1. Matrix in Composite

Many materials when they are in a fibrous form exhibit very good strength property but to achieve these properties the fibres should be bonded by a suitable matrix. A good matrix possesses ability to deform easily under applied load, transfer the load onto the fibres and evenly distributive stress concentration. The fibre matrix includes thermosets, thermoplastics and rubber. Thermoplastic resins constitute an important class of materials with a wide variety of applications. Thermoplastic natural fibre composites are gaining acceptance due to renewed interest in the environment, the trend towards recycling, protection of natural resources and biodegradability is the driving force behind the increased use of natural fibre thermoplastic composites [7].

2. Waste Polystyrene

Polystyrene is a synthetic aromatic polymer made from simple chemical units called monomer, the repeating units are called styrene, which can either be foamed or solid. It is normally produced by alkylation of benzene reacting with ethylene to produce ethyl benzene. Its dehydration changes into formation of styrene monomer. [2]. Adhesive is the general term used for substance capable of holding material together by surface attachment to provide some form of geometric continuity. Adhesives may come from either natural or synthetic sources and it is cure (harden) by either evaporating a solvent or by chemical reactions that occur between two or more constituents, depending on the composite application.

The effect of pH, solid and catalyst on the gel time and viscosity of adhesive are some of the factors to be considered in ascertaining the quality of adhesive strength in a composites [5]

This research is desired to developed waste polystyrene (styrofoam) adhesive for use as matrix in composite application.

Materials and methods

1. Materials

The major raw materials for this work are the wood dust fibres which were collected from Timber market (kasuwan katako) Muda lawal market, Bauchi metropolitan of Bauchi State Nigeria. Other materials include waste polystyrene unsaturated polyester resin, sodium hydroxide (NaOH), gasoline and distilled water.

2. Preparation of waste polystyrene adhesive

The waste polystyrene was cleaned and made free of dirt. Forty grams (60g) of waste polystyrene was dissolved in 120ml of gasoline and stirred to enhance the dissolution at room temperature and stirred twice daily for a period of a week. Then 30 % unsaturated polyester resin was added into dissolved waste polystyrene and continuously stirred until the adhesive reaches its homogeneity and stabilization. Adhesive pH is critical in handling processes and its longevity is difficult to ascertain. The adhesive curing depends of pH value [5]. The pH meter JENWAY model was used to determining the pH of the produced adhesive. The pH meter was immersed in the sample and The reading of pH values start immediately until it attains stability. The test was run every two (2) days for a period of 14 days.

Rotary viscometer model TT-5 was used in determining the viscosity of the resin. the viscometer was set to rotates at speed increases of (20 rpm, 30 rpm, 40 rpm 60 rpm, 80 rpm) while data for the viscosity at each RPM displayed were recorded after every rotation according to the standard procedure [11].

3. Wood Dust Particles

The wood dusts particle was mercerized using 5%w/v sodium hydroxide (NaOH) solution at room temperature for 24 hours, then thoroughly washed in a fresh tap water and air dried.

4. Sample Preparation

The required quantity of wood dust particles was mixed with prepared waste polystyrene produced adhesive and compounded into the mould, a number of parameters were varied in order to understand their influence on the properties of the composites. Heat and pressure were applied for crosslinking and hardening the composite. Prior to the test, all the samples were conditioned at a temperature of 23±2°C.

5. Percentage water absorption

It is essential to evaluate the effects of moisture absorption on the properties of the composite, the main concerns of using natural fiber is their high hydrophilic behavior which ultimately affects the overall properties of the composite [9].

The dry weight of the composite before immersion (W_1) and the weight of composite after immersion (W_2) in water at ambient temperature for 24 hours until equilibrium were measured. The water absorption was expressed by applying equation (1)

The percentage water absorption rate is given by

$$W_A = \frac{w_2 - w_1}{w_1} \text{ x } 100\ \% \qquad (1)$$

Where: w_1 is the weight of the sample before immersion in water and w_2 the weight of the sample after immersion in water.

6. Tensile strength of Composite

The sample specimens were cut for test using Monsanto tensometer machine, and extension produces within the specimen. The evaluation of tensile strength (TS) of composite produced.

can be determined using equation (2)

$$TS = \frac{Average\ force}{cross\ section\ area} = \frac{P}{A} \qquad (2)$$

7. Compositions and Variables of Matrix / Fibre ratio

Each composite produced is dried at room temperature for 7 days for effective curing. The Design Expert was used for modeling the effects of Composite matrix and fibre ratio and experimental variables shown respectively in Tables 1 and 2.

Table 1: Composite Particles and Matrix Ratio

S/N	Particles /Matrix (Constraints)	Wood Particles	Matrix
1	C_1	50	100
2	C_2	100	50
3	C_3	50	50

Table 2: Experimental levels of the variables

Dependent Variable	Coded and Actual level		
	Low	Medium	High
	(−1)	(0)	(+1)
Constraints	C_2	C_3	C_1
Pressure (kg/m^2)	50	150	250
Temperature (°C)	25	50	80

Results

Optimum results Parameters was used in reproducing the composite experimental sample and the best result solution obtained which satisfied the criteria. The results show a minimal error difference between the predicted results and the experimental results.

Table 3: Model Adequacy of the Experiment

S/N	S	R- sq	R- sq(adj)	R- sq(pred)
Water absorption	2.41614	97.49%	92.98%	59.87%
Tensile strength	1.39957	92.84%	74.44%	0.00%

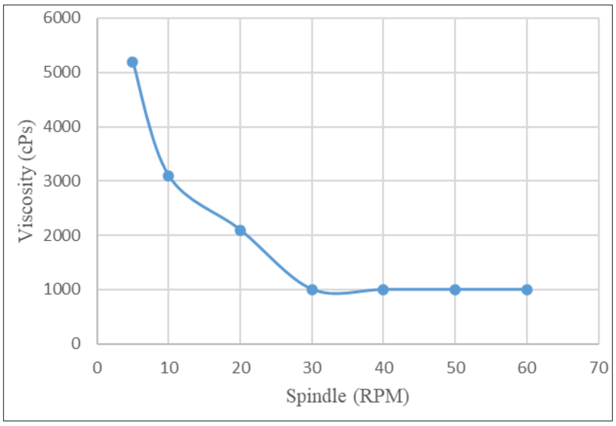

Fig 1

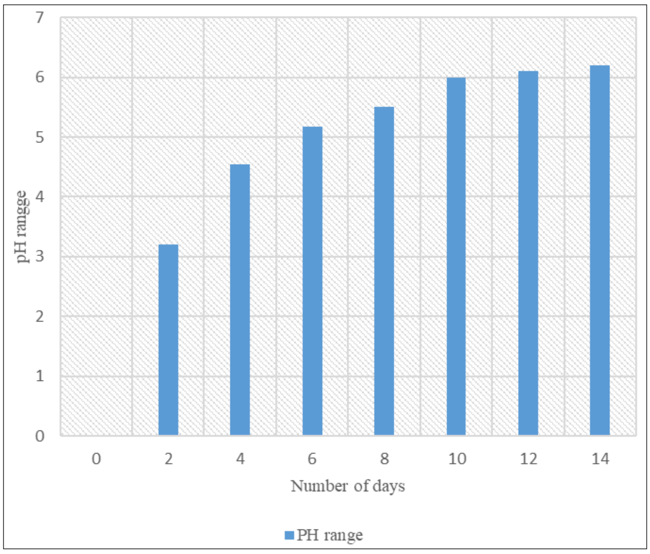

Fig 2

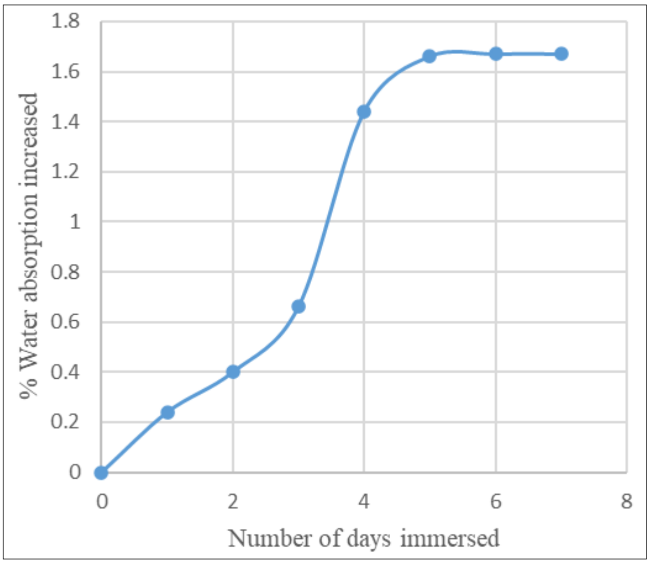

Fig 3

Figure 1 is viscosity blue curve of waste polystyrene adhesive which shows the decreases in viscos by increasing the speed of spindle. At a certain speed of 30, 40, 50 and 60 RPM the viscosity decreases to an equilibrium of 998 cPs, this indicates the quality of the formulated adhesive produced fall within the range of viscosity of urea formaldehyde used as a matrix in composites production.

Figures 2 presents the pH values obtained from experimental results of waste polystyrene adhesive developed. The increase in pH (6.0, 6.1 and 6.2) demonstrated reduction in curing rate. However, the gel time decreases as the acid conditions of the adhesive is increases.

The model adequacy of the experiment in Table 3 shows that, the water absorption R-squared value of the model is 97.49%; this implies that R-squared value is enough, which explained adequately for the model to be considered.

Figure 3 shows the percentage water absorption of the produced composite immersed in water increases with increase in number of days immersed. Also the results obtained show that the composite materials absorbed water readily on daily bases ranged from 0.24% to 1.67%. Day 5, 6 and 7 where the rates of absorption remain constants on reaching a saturated stage. Generally organic materials absorb water readily, increasing the quantity of the fibre particles in a composition increases the percentage of water absorption.

Also in Table 3, the tensile strength model adequacy shows that R-squared value for the model reveals that the independent variables account for 92.84% of the variation in tensile strength, this is also enough despite the fact that the lack of fit suggests addition of higher order variables (significant at 1%). This indicate that the interfacial bonding between the particles and the matrix resulted in improving the tensile strength of the composite.

Conclusion

The aim of the study has been successfully achieved. The following conclusions can be drawn from the work:

1. Conversion of non-biodegradable waste polystyrene material, to wealth
2. Formulation of waste polystyrene adhesive, with viscosity at 998 cPs, indicates the quality of the formulated adhesive produced fall within the range of viscosity to be used as a matrix in composites production. Also the adhesive produced from waste polystyrene pH of (6.0, 6.1 and 6.2) demonstrated reduction in curing rate and the gel time of the adhesive.
3. Optimization of particles/matrix ratio, pressure and temperature of the composite; that's yielded responses value water absorption and tensile strength.
4. The experimental investigation revealed that the composite density increases as the ratio of the particles to matrix increases. The composite made from organic materials absorb water readily, increasing the quantity of the particles in a composition increases the percentage of water absorption. The composite also indicates that the interfacial bonding between the particles and the matrix resulted in improving the tensile strength of the composite.

References

1. Abdulkareem SA, Adeniyi AG. Production of Particleboards Using Polystyrene and Bamboo Wastes Nigerian Journal of Technology (NIJOTECH),2017:36:(3):65-71.
2. Ademović Z, Suljagić J, Zulić J. Influence of Physical Properties on Thermal Conductivity of Polystyrene Insulation Materials. Contemporary Materials,2017:8(1):42–47.
3. Anil N. Green Composites: Where we are and where we are Headed, Midwest Bio polymers and Biocomposites Workshop Cornell University. Ames, Iowa, 2010.
4. ASTM. Standard methods for evaluating properties of wood-based fiber and particle Panel materials. American Society for Testing and Material International handbook, 2004.
5. Bomba J, Šedivka P, Böhm M, Devera M. Influence of Moisture Content on the Bond Strength and Water Resistance of Bonded Wood Joints. BioResources, 2014, 9(3).
6. Chitta R. Preparation and characterization of Polymer Matrix composite Using Natural Fiber Lantana-Camara. A Ph.D thesis in Mechanical Engineering. National Institute of Technology, Rourkela, India, 2010.

7. Dagwa IM, Builders PF, Achebo J. Characterization of Palm Kernel Shell Powder for use in Polymer Matrix Composites. International Journal of Mechanical and Mechatronics Engineering,2012:12(4):88-93
8. Deka H, Misra M, Amar M. Renewable resource based “all green composites” from kenaf biofiber and poly (furfuryl alcohol) bio resin. Industrial Crops and Products,2013:41:94-101
9. Dictionary of plastics in use Production Goods Work Station, Industrial Research Center of Japan, Inc, 2018.
10. Ekhlas Aboud Osman Al-Bahadly. The mechanical properties of natural fiber Composites, unpublished Ph D thesis, university of technology. Swinburne, 2013.
11. Kurt R, Cil M. Effects of press pressures on glue line thickness and properties of laminated veneer lumber glued with phenol formaldehyde adhesive. Bio Resources,2012:*7*(4):5346-5354.
12. Montgomery C Douglas. Design and Analysis of Experiments. 6th ed. New York: John Wiley & Sons, Inc, 2005.
13. Shaffer PJ, Ashok S, Stephen DA, Tomas HS, Steven PW. The Science and Design of Engineering Materials. Richard D Irwin, New York, 1995.