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Construction and Property Test of a Sugarcane and Molted plastic Sheet Composite

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ABSTRACT

In this experiment, a hybrid composite made of melted plastic and crushed sugarcane bagasse was created. Changing the ratio of plastic to sugarcane resulted in the creation of seven distinct samples. The samples that were produced were A1 (100% plastic, 0% sugarcane), A2 (95% plastic, 5% sugarcane), A3 (90% plastic, 10% sugarcane), A4 (85% plastic, 15% sugarcane), A5 (80% plastic, 20% sugarcane), A6 (75% plastic, 25% sugarcane), and A7 (70% plastic, 30% sugarcane). Then There were several tests performed, including flexural, impact, compressive, and thermal conductivity testing. After comparing all specimens, sample A1 has maximum strength in the flexural test as well as the impact test. The A7 combination of composite materials provides the best strength in compressive strength tests. The composite A1 combination provided the best heat conductivity. Out of the seven samples tested, the A7 composite combination had the lowest heat conductivity, indicating the best insulating property.The composite material combination in A1 provides the greatest flexural strength. The best impact strength is also provided by it. The compressive strength of A7 is the best among other specimens. It can be summed up by saying that the flexural, compressive, impact, and thermal conductivity vary with changes in the weight ratio of plastic and sugarcane. The desired composites can be utilized to replace window grills, insulation, and plastic.

Keywords: Wasted plastic, Recycling, Compression molding, Weight ratio, Thermal conductivity

1. Introduction

Environmental regulations and public pressure have raised interest in composite materials reinforced with natural fibers, leading industry to explore alternatives to sugarcane fibers. This research evaluated how chemical treatment affected bagasse/PP composites with 1% sodium hydroxide-delignified fibers after 10% sulfuric acid. These fibers were combined with polypropylene to create fiber compositions ranging from 5-20%. Compression, three-point bending, and impact evaluated mechanical quality. SEM fracture analysis also helps to evaluate the quality. Composites outperform polymers in compression, flexure, and impact. Composite materials are created by coordinating reinforcement and network. Composite materials are rising out of the domain of cutting-edge materials, enabling them to attack additional sectors such as automotive, wind energy, aviation, general applications, etc. These materials replace normal ones due to their improved mechanical, thermal, and electrical properties, greatsolidity, high consumption resistance, low density. and low cost. Lack of fundamental properties induced by assembly process, form, and interphase connection. Modern design uses composites extensively. Regular strand-reinforced composites are stronger (tensile, flexural, impact). Consumer demands and expectations, along with technology improvements, continue to impose further stresses on world resources, resulting in substantial material shortages and worries about environmental sustainability. N.S.M. Tayeb explored sugarcane/polyester tribology[1]. Y. R. Loh et al. evaluates the practical applications and potentials of SCB for composite materials[2]. E.F. Cerqueria et al. evaluated bagasse-reinforced polypropylene composites [3]. S.M. Luz et al. researched sugarcane bagasse-reinforced polypropylene composites[4]. Lu et al. analyze fiber type, shape, size, and polymer melt flow index affected sugarcane fiber/HDPE composite mechanical performance (MFI)[5]. RM Leao et al. explained mechanical recycling reuses rubbish and makes plastic items. Natural fiber composites have become popular, although their mechanical performance after recycling is unknown. Melt mixing and compression molding created polyethylene/sugarcane bagasse composites[6]. A. A. El-Fattah et al. examined sugarcane bagasse fibers and malleated polyethylene[7]. Sugarcane-reinforced PP composites were created and pure PP, stearic acid-treated, and untreated were compared mechanically, rheologically, and morphologically by Kiattipanich et al[8]. Injection-molded LA/sugarcane bagasse fiber composites with varied fiber characteristics were created by Bartos et al.[9]. H. Hajiha et al. made composites employing RHDPE and natural fibers[10]. H.A Youssef et al. evaluated the impact of thermoplastic/bagasse fiber ratio and electron beam irradiation on LDPE and HDPE composites[11]. Zhiliang Huang et al. reported SRF/PBS composites lost more weight and mechanical properties than pure PBS after 100 days of soil burial[12]. A polymeric composite features a thermoplastic matrix and organic or inorganic fibers fabricated by R. Y. Miyahara et al.[13]. E Elsayed et al. said HIPS included sugarcane bagasse. HIPS was melted and combined with sugarcane bagasse using a screw extruder[14]. R.S.Chan et al. created green composites by melt-blending HDPE from plastic bags with SCB fiber[15]. M. Zainal et al. fabricated and

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analyzed polymeric composites have a thermoplastic matrix with organic or inorganic fibers[16]. B Ramaraj created SCB-reinforced PP composites to test sugarcane bagasse waste in thermoplastic polymer matrix. PP resin was extruded with 5, 10, 15, and 20% SCB in a corotating twin screw extruder. Extruded strands were chopped into pellets and injection molded. Tensile, flexural, Izod, and Charpy impact strengths, density, water absorption, and thermal characteristics were tested[17]. G.l. Ribeiro et al. created LDPE/sugarcane composites[18]. Zizumbo Turo et al. attached sugarcane bagasse to polystyrene[19]. This experiment's primary goal was to build a composite sheet in order to evaluate the composite's heat transfer properties, and to evaluate the composite's mechanical properties, flexural, compression, and impact test were performed.

2. Materials & Methodology

2.1 Materials of composite

The main components of the composite were compression moldede wasted plastic and sugarcane bagasse fiber.

Wasted plastic: Recycling reprocesses discarded plastic into new items. his reduced landfill usage, plastic pollution, and greenhouse gas emissions, while also conserving resources. Two components are recycled by manufacturing plastic composite sheets. The primary purpose was to enhance plastic's mechanical and thermal qualities.

Wasted sugarcane bagasse: Bast fibers include sugarcane, jute, kenaf, flax, and ramie. Sugarcane bagasse is biodegradable and cheap. Its filaments are quite resilient compared to bast in length, durability, quality, retentiveness, and antibacterial properties. Various sorts of beautiful material items are created. Biodegradable, recyclable, natural sugarcane fiber. Unbending stem bast is the cheapest vegetable fiber. Sugarcane fiber is a very strong fiber and isn’t dyeable. Elastic recovery of sugarcane fiber is very poor compared to the linen fiber. The average moisture regain is 12% which is more than cotton and linen fiber.

2.2 Sugarcane preparation

After fiber extraction, sugarcane fiber was screened, sun-dried for 6 hours, and then chopped. After 2 hours of alkaline treatment in 1.5% NaOH, the samples were washed in distillation water to neutral pH. Fiber was dried for 24 hours after washing. Alkali-treated fiber was then treated with 5% $HClO_4$ or 5% $KMnO_4$ for 45 minutes. Again, dry the fiber for 48 hours after washing. Once again, fiber was soaked in 20% NaOH for 2 hours and boiled for 10 minutes. The fiber was dissolved in alkali for 24 hours. submerged and maintained the fiber in distillation water for the next 16 hours. Then I rinsed with oxalic acid and dried up well. The fiber then reacted with a 1% phosphoric acid solution. After 3 hours, the fiber was cleaned and air-dried (approximately 24 hours). Pulverized dry fibers and 60-micron BSS mesh sieved the powder fraction.

2.3 Preparation of Composites

Used plastics were cleaned in a special compartment. The amount of plastic in the container was weighed. The sealed container was then placed in front of a powerful heater. It was 160 degrees Celsius in the plastic container. Following this step, sugarcane fiber that has been processed is mixed with liquid plastic in a range of percentages by weight. The steel mold was then filled with the plastic composite.

(a) (b)

Fig.1: (a)Composite sheet (b)Microscopic Structure

The molten Composite was compressed by the load plate. Space between plates was 1.5cm. The mold hardens after 30 minutes. The composite sheet formed after the load released. which measures 15 cm on each side and 1.5 cm in thickness.

Table 1 Different weight proportion of the composites

Specimen	Plastic	Sugarcane
A1	100 %	0%
A2	95%	5%
A3	90 %	10%
A4	85 %	15%
A5	80%	20%
A6	75%	25%
A7	70%	30%

3. Testing of composite materials

The ASTM D790 standards guide the flexural examples. The 3-point flexure test is widely used for composites. The test specimen is forced until it fractures and breaks in the universal testing machine. The tests are carried out at 23 °C and 50% relative humidity.Flexural stress was determined using Eq. (1).

$$\sigma = \frac{3FL}{2b * h^2} \qquad (1)$$

Here,

$\sigma =$ Flexural Stress in (N/mm^2)

L= Span Length, in or mm

b= Width, in or mm

h= Thickness, in or mm

F=Load Applied, in or mm

Impact strength is defined as how much essentialness a material can bear before breaking under rapid deformation.Charpy impact test, often called the Charpy V-indent test, measures a material's essentiality during break. ASTM D256 cut the materials.Impact energy per unit area can be determined by following Eq. (2).

$$\frac{E}{A} = \frac{m(h_1 - h_2)}{b \times h} \qquad (2)$$

Where,
l= Length of the specimen in mm
b= Width from V-notch in mm
h= Thickness in mm
A= Area from V-notch cross section = b*h in mm^2
E= Impact energy = $m(h_1\text{-}h_2)$ in Joule

Compression machines are produced in Class 1 starting at 50 kN. The upper platen adjusts to load the sample uniformly. Internationally-specified upper and lower plates 55 HRC surface hardness and 0.02 mm flatness. The compressive stress was determined using Eq. (3).

$$\sigma = \frac{3FL}{2b * h^2} \qquad (3)$$

Where,
σ= Compressive Stress in (N/mm^2)
L= Span Length, in or mm
b= Width, in or mm
h= Thickness, in or mm
F=Load Applied, in or mm

The rate at which heat goes through a material, represented as the quantity of heat flowing per unit time via a unit area with a one degree per unit distance temperature gradient, This test involves placing the composite in an isolated chamber. A heat source (a 100 watt bulb) is located on one side. On each side of the composite plate, two thermocouples have been set. These two thermocouples will measure the temperature difference between the two sides of the plate. By putting the values of temperature difference and heat generated in the conductivity equation, the thermal conductivity of the plates can be evaluated.

Thermal conductivity of a plate can be calculated using Eq. (4).

$$K = \frac{QL}{A\Delta T} \qquad (4)$$

Here,
ΔT = Temperature difference
L = Plate thickness
Q =Heat generated
A = Area
K = thermal conductivity

For each sample total seven observations has been taken. Each one of them took around 35 minutes.

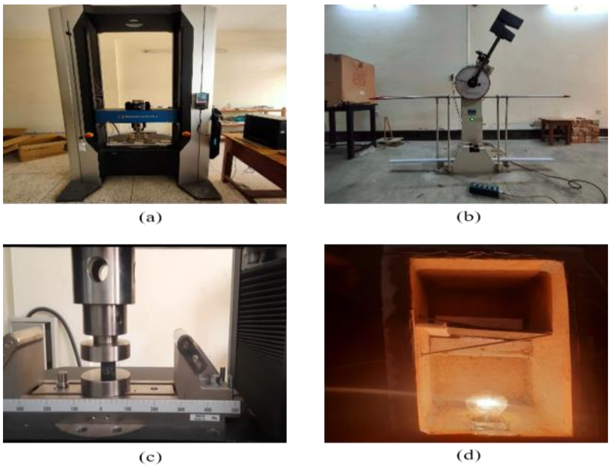

Fig.2 (a)Universal testing machine (b)Izod Charpy impact machine (c)Compression testing machine (d)Isolated chamber for thermal conductivty measurement[20]

4. Result & Discussion

4.1 Flexural strength test

The flexural strength test was completed by three-point bending method.

Table 2 Ultimate Flexural strength of Different Compositions of composites

Specimen	Thick-ness mm	Width mm	Lower support mm	Ultimate Flexural Strength N/mm^2
A1	11.45	23.93	100	1.90426
A2	7.76	21.92	100	8.23957
A3	10.94	22.72	100	5.71232
A4	10.32	26.32	100	4.92216
A5	11.03	27.7	100	4.76354
A6	15.18	21.92	100	4.39655
A7	13.95	27.12	100	1.90426

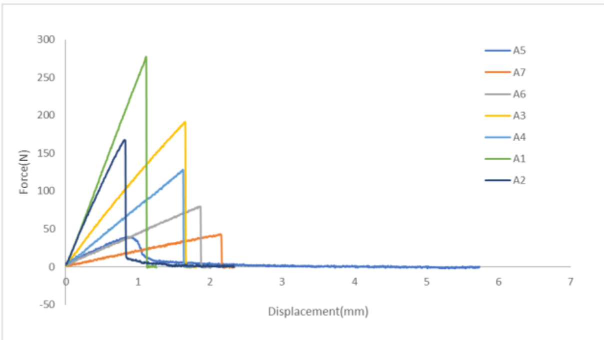

Fig.3 Force-Displacement curve for flexural test

Fig.3 indicates that there is no one specimen that exemplifies all desirable characteristics. The 7 samples (labeled A1, A2, A3, A4, A5, and A7) each provided a value for the flexural force. As for flexural stress, the A1 composite combination provided the greatest value. The A7 composite combination had the lowest flexural force value.

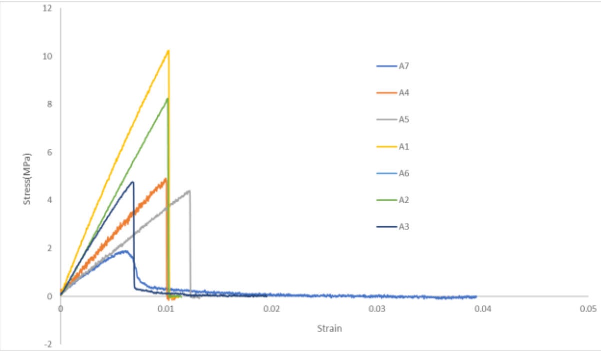

Fig.4 Stress- Strain curve for flexural test

Fig.4 shows that Seven samples, labeled as A1, A2, A3, A4, A5, A6 and A7 each provided an own set of numerical numbers. The A1 composite combination had the highest flexural stress value and least flexural stress in sample A7. When additional sugarcrane was included in the sample, more air was allowed to pass through the composite plate, reducing the flexural stress.

4.2 Impact test

Charpy sway test was used to assess composite impact energy.

Table 3 Impact Strength of Different composites

Sample	Thick ness mm	Width mm	Length mm	Height h_1	Area, (b*d) cm^2
A1	11.45	10	100	123	1.145
A2	7.76	10	100	128.5	.776
A3	10.94	10	100	132	1.094
A4	10.32	10	100	132.7	1.032
A5	11.03	10	100	133	1.103
A6	15.18	10	100	133.3	1.518
A7	13.95	10	100	137	1.395

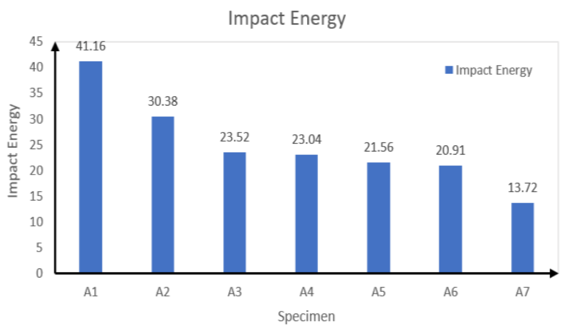

Fig.5 Impact energy bar chart for various specimens

Fig.5 demonstrated that the best example of an attribute is not necessarily the same thing. A1, A2, A3, A4, A5, A6, and A7 all provided figures for the kinetic energy of the impacts. The A1 composite layer stack provides the most impact energy.

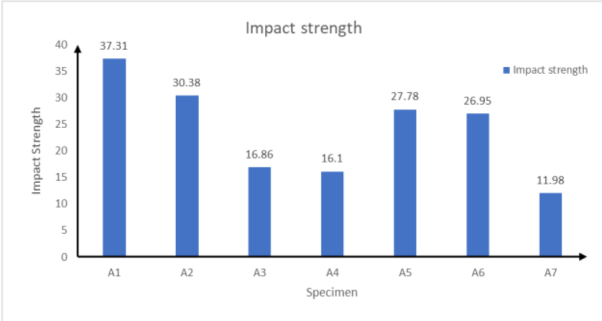

Fig.6 Impact strength bar chart for different specimen

According to the Fig.6 the impact energy values of composites were 37.31 J/cm^2, 30.38 J/cm^2, 23.52 J/cm^2 , 23.04 J/cm^2, 21.56 J/cm^2, 20.91 J/cm^2 , 13.72 J/cm^2 were given by A1, A2, A3, A4, A5, A6, A7 sample respectively. The best impact energy value is given by A1 combination of layers of composite,

4.3 Compressive strength test:

Table 4 Maximum compression load for Different Compositions of composites

Specimen	Thickness mm	Width mm	Height mm	Maximum load for of composites, N
A1	20	25	25	702.75
A2	20	25	25	1248.447
A3	20	25	25	1357.69
A4	20	25	25	1537.128
A5	20	25	25	3063.609
A6	20	25	25	3445.473
A7	20	25	25	5839.156

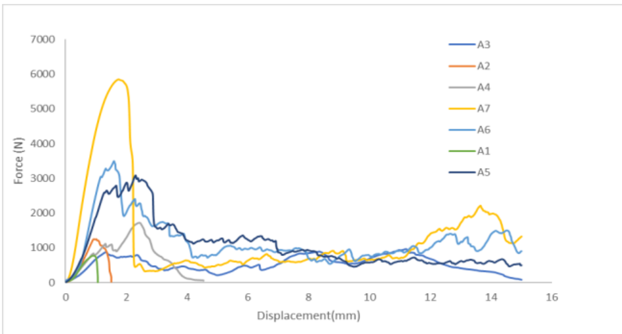

Fig.7 Force-displacement curve for Compression test

In this Fig7, Compressive force values ranged from 702.75 N to 1248.447 N, 1357.69 N to 1537.128 N, 3063.609 N to 3445.473 N, and 5839.156 N to 5839.156 N. A1, A2, A3, A4, A5, A6, and A7 each provided a figure for the compressive force. According to the Fig.7 the A7 composite combination provides the highest compressive load.

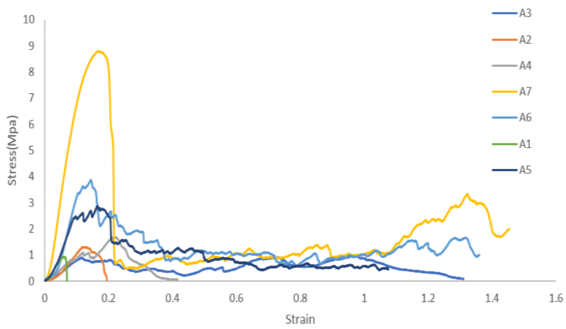

Fig.8 Stress-strain curve for Compression Test

In this Fig 8, based on the data presented, it's clear that there is no one ideal specimen. A1, A2, A3, A4, A5, A6, and A7 each provided a figure for the compressive force. A7 composite combination had the greatest compressive stress value which is shown.

4.4 Thermal Conductivity test

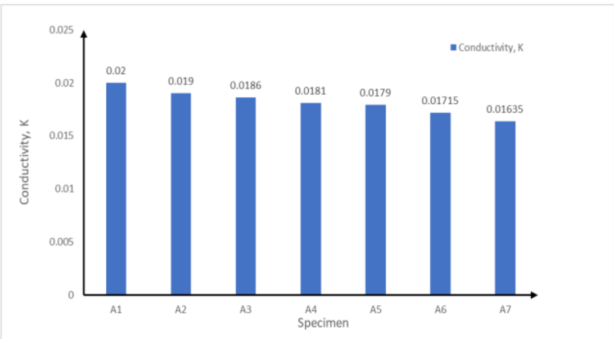

Fig.9 Thermal Conductivity for different specimen

In Fig.9, it seems that including more sugarcane fiber in the composite material reduces its thermal conductivity. The results for thermal conductivity were as follows: 0.02, 0.019, 0.0186, 0.0181, 0.0179, 0.01715, and 0.01635 W/m-K, respectively. A1, A2, A3, A4, A5, A6, A7 each provided a heat conductivity value. The optimum thermal conductivity value was found in sample A1, a composite that included sugarcrane, the material with the lowest thermal conductivity. And A7 has the finest insulating properties of all.

5. Conclusion

This experimental endeavor included the production of a composite sheet made of sugarcane and molten plastic. The composite specimens were tested for both mechanical and physical qualities. The composites were made by combining plastic and sugarcane fiber in varying percentages by weight. A7 combination composite has the best compressive characteristics. There were issues with the flexural stress and impact strength of the composites. There was a clear difference across materials, with A7 composite demonstrating the lowest heat conductivity. As a result, it is more insulating. What this implies is that it can be used as insulation. Insulation materials and window grills may be swapped out for the plastic and sugarcane fiber composite. This composite can access the side entrances. It can be used to form the body of a plastic body since it is lighter than pure plastic. The material's modest weight also makes it suitable for use in furniture construction. Therefore, its applicability spans a wide range.

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NOMENCLATURE

m	: Mass, Kg
g	: Gravitational Acceleration, ms^{-1}
h_1,h_2	: Height, m
σ	: Stress, Nmm^{-2}
F	: Force, N
L	: Length, mm
N	: Width, mm
h	: Thickness, mm