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Development and Property Exploration of Composite Structural Insulated Panel as Alternative House Construction Material

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Abstract

Composite materials mainly integrate two or more materials to get a combined property of individual materials. One of the considerable types of composites is structurally insulated panels (SIP).

This research paper intended to investigate and analyze structural panel composite using Bagasse reinforced PET and polyester resin with bagasse composite as a facing material. It extruded polystyrene as an insulation foam core. After the juice is extracted from sugarcane, the sugarcane bagasse is prepared with 1.2 and 1.5 cm length and 1 mm width, and then washed using pressurized water for 1 hour and made dried at normal temperature for one day. It was then treated with 0.3 and 5% wt of NaOH solution for 2, 4, and 12 hours with a 15:1 solution to bagasse ratio at 60°C. After its alkaline treatment, it was washed until the NaOH is completely removed. It is then dried in the oven for 6 hours and after 24 hours of room temperature drying. An optical microscope finally observes the samples before blending.

The matrices used are polyester resin and recycled PET. The recycling is done mechanically. Different types of PET bottles were collected and cut into pieces. A hot wash-down with 2% NaOH solution and using a detergent at 80°C then finally washed only by cold water. Dried and 60-gram melt at 246°c, 250°c, 300°c, and 380°caccording to the DSC result. A furnace and hot Stirrer is used to melt the samples. The sample at the temperature of 380°c is melted into some form in hot and Stirrer plates. The samples in the furnace melted at the temperature of 265°c. The fiber could not withstand the melting temperature of the PET. This is due to a lack of physical property for facing. Its hardness is measured and found to be 100Hv. The other sample is the polystyrene resin matrix. This is found to be highly compatible with the sugarcane bagasse. 100 grams of Bagasse is added to 50-gram polyester raised with 1ml of catalyst and compressed. Waited until it cures about 12 hours and characterized. Its hardness was found to be 180 HV. The structural insulated panel is prepared using three facing materials, recycled PET matrix, and a composite of polyester risen and sugarcane bagasse. In both cases, the insulated foam core is extruded polystyrene. Wood fix glue is used as an additive and compressed with pressure.

Keywords: *Composite, SIP, Sugarcane Bagasse, Alkaline Treatment, PET Recycling, Polyester Resin-Paper*

I. INTRODUCTION

In our country, Ethiopia, there is a basic housing material problem, which is officially known by the government and the country's citizens. One of the reasons behind it is that housing making is a very expensive process in Ethiopia, especially in Addis Ababa due to limited house construction materials scarcity. Governments have often given less priority to the housing sector due to their shortage of investible construction material resources.

Most African cities, including Addis Ababa, have the world's biggest share of urban residents living in slums. About 80% in the capital Addis Ababa, housing and neighborhoods out of the city are slums houses. The majority of the slum houses, which are about 70%, are concentrated in the inner-city and owned by the government called Kebele-bet (the lowest administration level), which are dominantly owned by low-income citizens [1]. "Chika" (mud and wood construction type) constructs almost all slum houses.

There are many problems and a lack of beauty with these "chika" houses. Design rigidity, relatively high cost, is very difficult to find straws used to enforce mud "chika" mainly of teff straw near the urban area and the house not comfortable for urban living. This type of traditional house-making uses the oldest and most un-updated house construction materials, such as composites of muds and teff straws.

Since houses constructed using this method do not meet the urban living standard and not that environmentally friendly, there is a current demand for high-performance, economical, and environmentally friendly building construction materials.

This paper aims to develop and introduce recent and high-performance composite material called structural insulated panels (SIP). Many developed nations are using these types of materials for their houses Construction, especially in Europe.

A. Composite Materials

Composite materials are types of engineering materials obtained by the combination of two or more of them to acquire improved and best possible thermal and mechanical properties. Composites are multiphase materials with a significant proportion of the properties comprising both constituent phases such that a better Combination of properties is realized [2].

Composite materials usually contain two separate phases, an uninterrupted matrix often a resin, surrounded by the fibrous reinforcing assembly. The reinforced one has high strength and toughness while the intermixed binds of the fibers compose, having stress to be relocated from one fiber to another, creating a combined structure [3]. Many composites occur in nature—for instance, Natural composites found in both animals and plants' bodies. Wood is internally a composite structure- made from long cellulose fibers (a polymer), which are held together by a much weaker substance named lignin. The bone-in animal body is also a composite material. It is made of hard but brittle material called Hydroxyapatite (mainly calcium phosphate) and a soft and flexible material named collagen, a protein. Collagen is another natural composite also found in hairs and claws nail. On its own, it would not be of much use in the skeleton, but it can association with Hydroxyapatite to provide bone the character that is required to skeleton our body.

There are three major types of composites. Generally, we can observe, namely are Particle reinforced, fiber-reinforced, and structural composites.

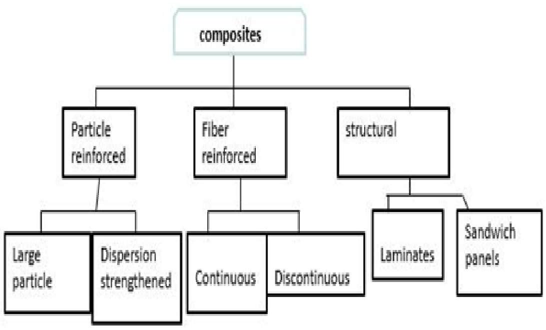

Fig 1: General classifications of various composites

B. Structural Insulated Panels (SIP)

Structural Insulated Panels (SIPs) are panels simply with sandwich composites. According to international, simple sandwich panels (ASTM), they are the three-layered interaction created by bonding a thin layer (facing) to the sides of a thick layer or core. Having their high effectiveness, are used for roofs of residential houses and light commercial buildings constructions. These panels are manufactured in industry and transported to a house construction area, where they can be easily assembled to form tight, energy-efficient building covers [4]. Usually, SIP is manufactured by sandwiching a core of inflexible foam plastic insulation between two structural skins. However, many differences based on coverings and inner core sandwiches are included in the blanket definition. SIP in this time is brought together with various structural skin materials, beside oriented strand board (OSB), treated plywood, fiber-cement board or cementations', and metal. However, any bondable materials can be used as a facing material in making a SIP. The typical inner core materials are expanded Polystyrenes (EPS), extruded polystyrene (XPS), (polyurethane); however, other rigid insulation can be used as well. Covering and inner core materials are bonded by structural adhesives [5].

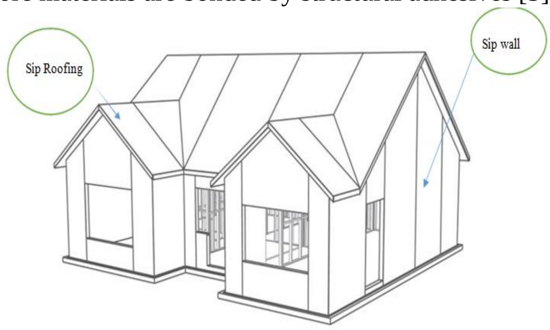

Fig 2: Simple house designed Using SIP

C. Bio-composites

A bio-composites are materials made by a matrix and a reinforcement of natural fibers. Using Natural fibers like Banana and Bagasse as reinforcement material is very usual in developed countries because of their low-cost with high specifically require properties with low density and eco-friendliness. Now a day, the developments of innovative bio-composite materials made are increasing worldwide. It could be an alternative model to develop the bio-composites that could be specifically used in common people's daily demands, whether houses hold furniture, houses, fencing, and flooring. Many tons of Bagasse is produced, but most of their waste is not usefully managed [6]. These bagasse wastes can be used to prepare the fiber-reinforced polymer composites for commercial use.

D. Recycled PET Matrix

Recycling of polyethylene terephthalate (PET) is also one of the most intentional and important polymers recycling shows. The main driving force behind increased recycling of post-consumer poly or ethylene terephthalate (PET) is its wider use, specifically in the beverage factories; those have made PET the main goal to recycle plastics. [7].

In our country, Ethiopia, the major materials for the beverage industry is PET. Even though PET has good optical properties for the beverage industry, it negatively impacts the environment due to its non-biodegradability. Therefore, careful disposal and recycling are very necessary. However, in our country, almost no attention is given to its disposal and recycling. We can see many Pet bottles on the streets, and nobody concerns about it.

II. PROBLEM STATEMENT

Most house construction in Ethiopia, including towns and cities, is usually are mud houses that are made by using wood and mud to cover and enforce it. There is no attention given from the government and research institutes for the development of the new house construction material development and introduction. High building construction use cement and concrete blocked, which is enforced with a steel bar, usually of high income little people for rarely living houses and usually for hotels, pensions, and supermarkets. Most Ethiopia people make their living housed using wood and mud enforced with teff straw, which leads to deformation for the area and limits the wood resource for other purposes. Deforestation also leads to ecological imbalance and also contributes to the global warming effect. Teff straw used for mud preparation that should remain on the farmland to increase the fertility of the agriculture land also negatively affects. High-level construction materials like cement and concrete block materials are very costly and cannot preferable for Ethiopia's majority of low-income people.

Fortunately, this project research is changing peoples' sight in our country, Ethiopia, looking for alternative cheap house construction material development and application with high strength and reliability using locally available waste materials. It will solve all the problems mentioned above and the future trend of house construction.

III. OBJECTIVES OF THE STUDY

The study's main objective is to develop and introduce composite alternative house construction material using a waste of locally available materials.

The specific objectives of this research project are listed as:

- ✓To explore alternative materials used in insulated structural materials and their performances;
- ✓To preparing natural fiber from sugarcane bagasse and conduct different kinds of fiber treatments;
- ✓To Recycle PET bottles by heat treatment procedure at various temperature ranges for composition;
- ✓To form sugarcane baggage-polyester composite;
- ✓To develop the Summarized different composite processing techniques to investigate its thermal and mechanical properties to conduct the sample's characterization using different characterization techniques, including optical microscope, Vickers hardness tester, and DSC.

IV. LITERATURE REVIEW

Structural insulated panels (SIP) are slowly holding popularity as an alternative optional construction material for residential houses and light commercial constructions. Structural Insulated Panels (SIPs) are a prefabricated structure that combines the structural support of a building and the insulation into a single factory produced item [8]. The relative effectiveness of the Structure insulated panels (SIPs) are tabulated in Table 1 below.

A. Processing structural insulated panels (SIP)

Structural insulated panels (SIPs) are classified as sandwiched panels, fabricated by laminating two strong, rigid materials on either side of a layer and lower density material in the inner core. This splits the high strength materials and greatly adds the composite Structure's flexible rigidity while reducing material mass.

They bind to the idea of the stressed skin principle when properly fused ; The stress created on either outside cover account as tension on the panel as a single item. When the panel faces deflection stress, one end cover needs to compress, and the other end stretches. The stress load applied to each end skin cover is related to the gap between the two skins. This means that the greater gap between the skins ends to make it stronger [8].

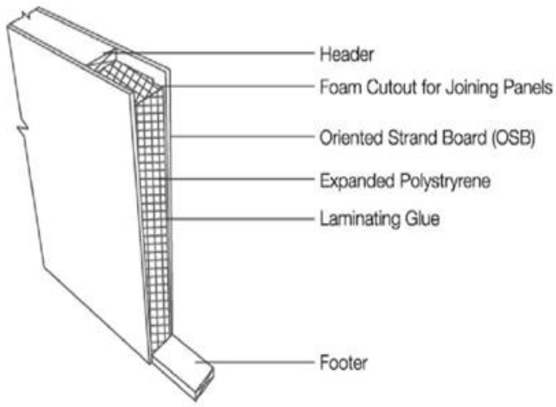

Fig 3: Composite of SIP

TABLE I
The relative performance of structural insulated panels (SIP) [26]-[30]

Technical specifications	Materials					
	SIP	Mud and Straw	Concrete	Agro-stone	Timber	Bricks
Tensile strength	22-25Mpa	16-18Mpa	1.4 Mpa	2.6 Mpa	0.02-0.03 Mpa	2.1 Mpa
Bend resistance	3Mpa	1.6-1.9Mpa	3.5 Mpa	25.6 Mpa	30 Mpa	35 Mpa
Fire resistance	60 minutes	Class A1 non-combustible	Class A1 non-combustible	Class A1 non-combustible	Class B-S1 ,D -0	Class A1 non-combustible
Sound insulation	5-10db	11 db	1-3db	18db	22db	32db
Heat insulation	0.13 W/mk	0.37-0.47 W/mk	0.35 W/mk	0.38 W/mk	0.21 W/mk	0.32 W/mk
Water Absorption	4.3 %	8-10%	5-7%	0.05 - 0.25 %	6-7%	5-6.5 %

B. Structural composites fabricating

Structural composites are generally composed of both homogeneous and heterogeneous or composite materials. The properties rely not only on the properties of the materials of the composition but also on the design of the configuration of the various structural elements.

Sandwich Panels

A sandwich panel contains two outer shells, or faces, separated and bonded adhesives bond to a thicker inner core. The outer shells are made of a relatively stiff and strong material, typically aluminum alloys, fiber-reinforced plastics, titanium, steel, or plywood; they contribute high stiffness and strength to the Structure and are must be thick enough to handle tensile and compressive stresses that result from external loading.

The inner core material is lightweight and usually has a low modulus of elasticity. In contrast, the inner core materials typically fall within three categories: rigid polymeric foams (i.e., phenolics, epoxy, polyurethanes), wood (i.e., balsa wood), and honeycombs.

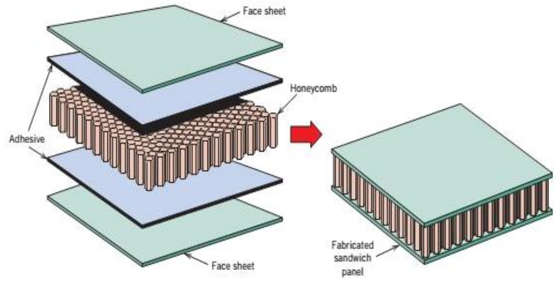

Fig 4: Schematic illustration of honeycomb sandwich panel [9]

SIP Materials Overview

SIPS can be produced from a diverse range of materials and two distinct methods, provided they stick to the main constituent of SIP illustrated above. It is the skins that show inevitable flexibility in material choice. The familiar materials are Cement board (CSIPs), strand board or plywood, orthopedic thermoplastic laminate, glass fiber reinforced plastics, and sheet metals [10].

Preferably, SIP covers must have high stiffness, excellent compressive and tensile strength, shockproof, good coarseness and endure to different environmental impacts like chemicals, Ultraviolet lights, heat and having good life span durability

Sugarcane Bagasse

Over the last few years, natural fibers' usage has been increased as a potential structural material. The pleasing view and its different best properties have been made; it's more demanding also in industrial scopes.

Their usage is also increasing due to their non-hazardous and Biodegradable nature, and they are easily available in particular for construction environments.

Natural fibers are fascinating choices to reinforce in the polymer matrix. The majority of pre-preparation of lingo cellulosic fibers in thermoplastic polymers has focused on wood-based chips or fibers, and many investigations have made tremendous improvement. In addition to reducing the product's cost, it acted as reinforcement so that the ultimate mechanical property changed inevitably. The main positive outcomes of such fibers include improved mechanical property, good surface property, cheap, availability renewability, and low abrasion compared to other construction material.

Bagasse comprised Cellulose, lignin, and hemicellulose in respective of 40%, 15%, and 30% and currently used as a fuel source in sugarcane milling furnaces. Ethiopia currently produces about 300,000 tons of sugar a year from factories like Mathura, Wonji, and Fincha [9].

The sugar cane's inner pitch comprises 45% fiber, which also contains 45% of Cellulose, 35% hemicellulose, and 20% contain lignin. Fine and

relatively long fibers are situated in the covering rind part of the cane. The shorter ones are located in the interior part called the pith. Bagasse is the blend of both parts, and the fibers have an uncontrolled irregular length.
However, due to its massive fiber content and its cellulose rate, Bagasse can be used to produce feasible fibers.

Fiber Properties

It is estimated that natural fibers have about half the density of glass fibers and have identical tensile modulus; however, they have lower tensile strength and, notably, higher moisture absorption [14].

The specific tensile modulus of hemp and flax fibers is better than that of the glass fiber, making them an incredible choice for composite material production.

Natural fibers are safe to use and none of any hazardous effects in addition to their inevitable mechanical properties. They are biodegradable and recyclable, depending on their life process path.

The pros associate with natural fibers when used as reinforcement include high moisture intake, which can result in swelling, decomposition, and disintegration, which in turn gets far to lamentable mechanical properties, flexural strength, and impact resistance, and also relatively low temperature and heat endurance which means high burning probability when exposed to bad situations (this occurs approximately about 200 °C.

Natural fibers have a strong affinity for water, which means it can also be the case that they can be incompatible with hydrophilic matrices.

Fiber Treatments

To surpass the above limitations of natural fibers, especially the poor integration with polymers, high moisture intake, and low thermal stability, various chemical and physical treatments used to modify fiber's feature and quality have been investigated.

Physical treatments

Treatments like plasma and corona discharge methods can upgrade the functional features of natural fibers. The plasma treatment in the oxygen can significantly roughen the surface fluxirability of the surface. Moderate and low-temperature treatments can also improve the surface through etching, chemical imposing, polymerization, alpha particles and chaining, and crystallization. Plasma treatment is considered an ecologically safe and inexpensive method though some of the gases emitted from the reactions can be harmful to our environment.

It is difficult to augment plasma treatment for industrial uses. Atmospheric pressure plasma treatments have served in an even operation, but its availability and scope are currently limited [15].

Chemical Treatments

This is the usual technique to clean and refine the natural fibers' surface to improve and acquire significant fiber-polymer compatibility. Mercerization is a common alkali treatment using Sodium hydroxide, which improves dye consumption in textile fabrics. Various research has shown that the alkali treatment can improve natural fibers' features and the integration and compatibility compartment with polymers.

Acetylation is the desired treatment particularly for natural fibers; the substitution of acetic anhydrides, which contains in the cell wall of the hydroxyl group of the fiber by the acetyl groups, makes the surface more water-repelling and less prone to moisture intake, increasing the compatibility of polymer matrices with the fiber. This basic process consists of immersing the fibers in acetic acid, treating with an acid anhydride, and cleaning by washing.

The isocyanides are used as the binding agent to improve the bonding of fibers with the matrices. For instance, the stiffness and strength of wood polypropylene composite are augmented by treating the fiber with polymethylene polyphenyl-isocyanate [18].

Treatment with an additive:

To achieve a better natural fiber-polymer matrix, we have to induce the fibers with the compatible host material. This can be done using an exchange of solvent or introducing monomer into the fiber and polymerizing using certain catalysts and heat [15].

C. Recycling PET Bottles

Polymers are labeled as thermoplastic and thermosets. Thermoplastics are formed from the molecular linear chains, which turn them soft when exposed to heat and become harder in cooled [13].
Thermosets exhibit an irreversible polymerization, and they become infusible or insoluble after being affected by certain heat and chemical reactions.
Thermoset polymers consist of various ranges of plastics. They are categorized into three types, which are crystalline, amorphous, and semi-crystalline thermoset polymers.

- ✓ Crystalline thermoplastics, usually translucent with Crystalline thermoplastics, consist of a periodic arrangement, and mechanically they are resistant to impact shocks. Usually, they are translucent .this types of Polymer include Polypropylene (PP), Low-density polyethylene(LDPE), and high-density polyethylene (HDPE).
- ✓ Amorphous thermoplastics whose molecules are arranged irregularly or randomly, and they are often transparent. For instance, polyvinyl chloride (PVC), Polymethylmethacrylate (PMMA), Polycarbonate (PC), Polysterene (PS), and others,
- ✓ Semi-crystalline polymers exhibit combined

features of amorphous and crystalline polymers. These polymers are mainly polyester polybutylene terephthalate (PBT) and polyamide Imide (PAI).

These are polymers currently unique characters (physical, thermal, and electrical) that make them are suitable for many engineering applications [11,12, 13].

D. PET Synthesis and Properties

PET is a polymer type, polycrystalline polyester made of esterification process of terephthalic acid (TPA), and Ethylene glycol (EG) or by the trans-esterification dimethyl terephthalate with Ethylene Glycol.

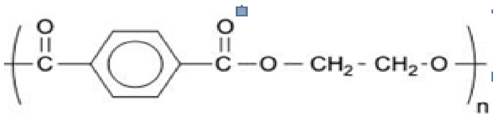

Fig 5: Repeating Unit of PET [16]

Production of PET using either process comprises two reaction steps. Frist is the generation of an intermediate monomer (2-hydroxyethyl terephthalate) in (BHET) with the release of a small molecule, which is water or methanol. The next is the poly-condensation of BHET to form PET in the melt phase with the formation of EG under high pressure [21].

As a thermoplastic polyester resin, PET restricts interesting physical and chemical properties. It is an amorphous structure like glass material in its most pure form. Crystalline Structure in PET can be achieved by adding modifier additives or by heat treatment to melt Polymer. PET is divided as a semi-crystalline polymer when it heat is treated above 72 oC. It can be changed from a rigid glass-like to a rubbery elastic form that the Polymer molecular stretched along with it in either one direction to make fibers or in two directions to make films and bottles. If PET is held in the stretched temperatures above 72 oC, it gradually crystalline and then becomes opaque and inflexible. It is then called a crystalline PET. If the melt is cooled quickly, still in a stretched state while the chains are fuse with their initial orientation. Then the resulting Structure is highly tough plastic, unique of a PET for bottle [21].

Commercially PET melts at temperature 255-265 oC, and crystalline PET melts at a temperature of 265 oC.

.PET Application and Production

PET has been used in various applications because of properties like less cost, good tensile strength, chemical stability, processability, and reasonable thermal resistivity.

It is usually applicable in the textile industry, which consumes more than 60% of the world's total PET product. Huge amounts are also consumed for other applications like video and audiotapes, X-ray films, thermo-formed products (example, material handling equipment, house-wares, automobile factory, lightings, sporting materials, etc.), and food and beverages packaging [19].

In the packaging of food, PET becomes the first choice for beverages mainly because of its glass-like transparency and with adequate gas barriers s for resettlement of carbonation.

From its initial applications, PET is mainly divided into fiber-grade or bottle-grade ones. These grades are usually unique in their molecular weights, viscosity, optical property, and production recipes. Fiber-grade PET has several average molecular weight (MWn) ranges 15,000-20,000 g/mol and has intrinsic viscosity (IV) ranges 0.40 -0.70 dL/g. Bottle-grade PET average molecular weight between 24,000 to 36,000 g/mol while IV between 0.70-0.85 dL/g [19, 20].

E. PET Recycling

PET is deliberated as one of the easiest materials to recycle and is also scrap values for recycled materials only next to aluminum [21, 22]. Thus, PET recycling is one of the most effective and widely applied among polymer recycling processes. PET recycling methods can be classified into four categories named as primary, secondary, tertiary, and quaternary recycling processes. There is also sometimes a 'zero-order 'recycling process, which incorporates the direct recycling of a PET as waste material.

Polystyrene

Polystyrene (PS) is an artificial aromatic polymer created from the monomer styrene. Polystyrene is usually solid or foamed. General application polystyrene is clear, and hard not brittle. It is a high cost. It is a rather poorly exhibit to oxygen and water vapor and has a comparatively low melting point [23]. Polystyrene is one of the utmost widely applicable plastic materials with a scale of several billion kilograms per year. Polystyrene is naturally transparent and can be made colored with colorants. It can be applicable in protective packaging (such as packing peanuts, CD, and DVD), storages like clamshells, lids, bottles, trays, tumblers, and disposable cutlery [24].

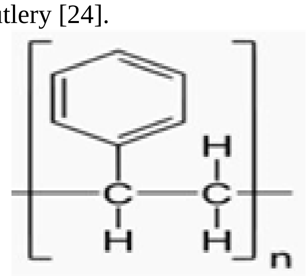

Fig 6: Structural Unit of Polystyrene Chain [25]

Expanded Polystyrene (EPS)

Expanded polystyrene (EPS) is an inflexible and tough, closed-cell foam. It is a mainly white color and produced pre-expanded polystyrene structures. EPS is applications include trays, plates, bowls, and fish boxes, and the like. Other applications include molded sheets of building insulation, packing materials like peanuts for cushioning fragile items inside boxes. Sheets of EPS are commonly packaged as non-flexible panels.

Because of its properties, such as low weight, rigidity, and formability, EPS can also be applied to many different users [26, 27, 28].

Extruded Polystyrene Foam

Extruded polystyrene (XPS) consists of enclosed structures with well-improved surface roughness, higher stiffness, and lower thermal conductivity. The density is between 28–45 kg/m^3. Extruded polystyrene material is also applicable in crafts and modern buildings, particularly in architectural models. Due to its complicated manufacturing process, XPS does not require outer facers to maintain its thermal and physical property enhance. Therefore, have a more uniform substitute for corrugated cardboard. Thermal conductivity varies 0.029-0.039 W/(m•K) based on its bearing strength to density ratio and has a mean value of approximately 0.035 W/(m•K).

The diffusion of Water vapor resistance (μ) is between 80 250, making it more appropriate to wetter environments than EPS [23].

Polyester

Polyester is also a family of polymers that contain the ester groups. As a definite material, it is most commonly states as a type named polyethylene terephthalate (PET). Polyesters contain natural chemicals like chemicals in the plant cuticles and synthetics through step-growth polymerization like polybutyrate. Natural polyesters and some synthetic Polyester are biodegradable then most synthetic polyesters are non-biodegradable. This is commonly used in clothing.

Depending upon the chemical structural chain, polyester can also be a thermoplastic. There is also polyester resin cured by hardeners, but most corporate polyesters are thermoplastics [26, 29].

V. MATERIALS AND METHODS

Chemicals used Laboratory equipment

NaOH Spatula

Acetic acid Beaker

Polyester Resin Metal Container

Distilled WaterScissors

Hardener HY 951 (Catalyst) Hot and stirrer plate

Detergent Muffle furnace

A. Processing Procedure

Alkaline/Surface Treatment Procedures

Sugarcane Bagasse surface treatment procedures

- ✓ After extraction of juice, the fiber spread was collected on a waterproof sheet to decrease the moisture content.
- ✓ From the available long fibers (rind portion only), small size (12*1*1mm) fibers were cut by pair of scissors.
- ✓ They were then cleaned through pressurized water for about 1 hr. This helped remove fine bagasse particles, sugar resides, and organic materials from the sample using sieves.
- ✓ Then dried in compressed air at a pressure of roughly about 145 kpa at 108 ^oC for about 40 minutes

Fig 7: Sugarcane Bagasse After Washed with Pressurized Water and Dried.

B. Alkali Treatment of Bagasse Fiber

The bagasse fibers were soaked in a 0.3 and 5wt% of NaOH solution at a normal temperature, maintaining a liquor ratio of 15:1 (w/w). The fibers were kept soaked in the alkali solution for 2, 4, and 6 hrs.

- ✓ Then the fibers washed several times with fresh water to remove any NaOH remains on the fiber surface.
- ✓ Neutralization using dilute acetic acid.
- ✓ Finally, I washed again using distilled water.
- ✓ A PH value has been maintained seven finally.
- ✓ The fibers then dried at a normal temperature for bout 48 hrs. Then after, oven drying at 100^{o}C for about 6 hours.

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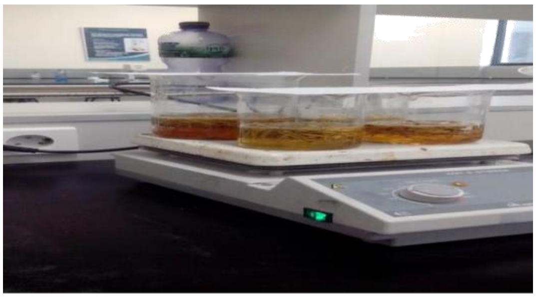

Fig 8: Alkaline treatment of sugarcane bagasse at 60 ^{o}C

Natures of Chemicals Used

NaOH (sodium hydroxide) - is a white crystalline odorless solid that can extract moisture from the air.

It is an artificially manufactured material. When it is dissolved in water or neutralized with an acid, it liberates considerable heat, which may be enough to ignite combustible materials.. it is Corrosive to metals and living cells. It can be used in the chemical industry, petroleum cleaning, cleaning compounds, and drain cleanings.

Diluted acetic acid –it is a colorless liquid compound having a chemical formula CH_3COOH (or some times as CH_3CO_2H or $C_2H_4O_2$). Commonly used as solvent acetic acid is an excellent polar protic solvent; it is repeatedly used as a solvent for recrystallization to purify organic compounds.

Acetic acid is used as a solvent in terephthalic acid (TPA), the raw material for polyethylene terephthalate (PET). In 2006, about 20% of it was used for the production of TPA.

C. Recycling PET Procedures

Mechanical Recycling

The recycling of PET mechanical often is impurities removal consisting of sorting and washing, drying, and melting.

- ✓ Impurities removal: The removal of the PET's impurities is an important step in PET's mechanical recycling.
- ✓ An impurity is removing consists of many processes in which PET bottles are arranged, ground, and washed. The arranging process normally the separation of PET bottles from PVC, polyethylene, and other plastic bottles. The arranging of PET bottles is an important, very vital step.
- ✓ After arranging, PET is ground into flakes that are easy to be reprocessed. PET flakes are washed, and the following is grinding.
- ✓ An aqueous washing consists of two steps; hot water washes with 2% NaOH mixture and a detergent at 80 ºC, followed by a cold wash with water alone.
- ✓ Drying: Drying is also an essential step in mechanical PET recycling. Removing the moisture content of PET flakes to minimize the hydrolytic degradation effect and increase the R-PET melt strength
- ✓ The melting process

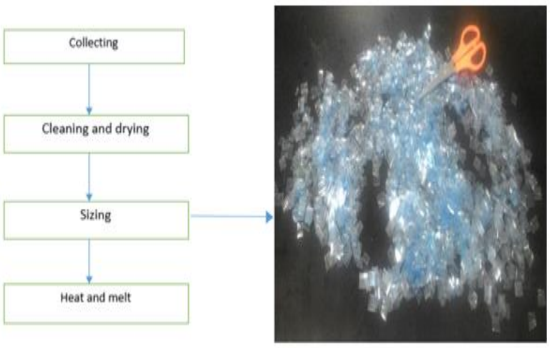

Fig 9: Pet recycling procedure

D. Sugarcane Bagasse Polyester Composite

When we prepare the sugarcane bagasse polyester composite, we have three processing steps. First, the Bagasse is fibrillated and chopped manually with scissors. Second, the resulting fiber is dry blended with polyester resin with manual mixing. Third, the blend is compression-molded by pressing using a traditional way as a stone.

E. Processing of SIP

In a polyester sugarcane bagasse thermoform composite, we used thermoform as a core sandwich structural panel, a soft, lightweight, and heat insulation material. We use polyester sugarcane bagasse composite and PET as facing a material that is strong and stiff. Also, we use wood fix as an adhesive to stick the facing materials with the thick core. The adhesive is uniformly distributed in both the foam core's faces and pressed with 1 Mpa of pressure for about 10 minutes.

F. Characterization Process

Differential Scanning Calorimeter (DSC)

This is to know the glass transition and the melting temperature of the PET bottle.

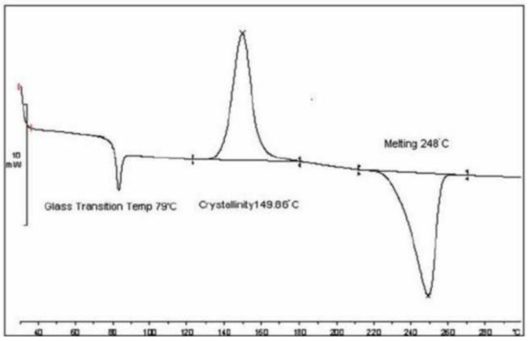

Fig 10: Sample characterization before recycling with DSC.

Hardness test

The Vickers hardness test performs the hardness test. An indenter of 10 kg load is used, and five measurements were carried out. A mean value is calculated from those measurements.

Optical microscope

An optical microscope was used to examine the surface of the alkaline treated sugar cane bagasse, polyester sugar cane bagasse composite, and recycled PET at a magnification of 20X.

VI. RESULT AND DISCUSSIONS

A. Alkaline treatment of sugarcane bagasse

The sugarcane bagasse after alkaline treatment with 0, 3, and 5wt% of NaOH amount is obtained. Characterization is made by using an optical microscope and by inspection. It's found that the amount of NaOH used, the temperature of treatment, and the duration of the sample in the solution are very important factors. The sample with 5wt% of NaOH and 12hrs duration 6 is found to be a good result.

Fig 11: Optical microscopy of Bagasse before treatments

Table II
.Bagasse treatment with NaOH

NaOH wt %	Time
3	2hr
3	4hr
5	4hr
5	12hr

Among the 4-bagasse treated with different NaOH content, the one with 5 wt% soaked for 12hr gave a better clean surface.

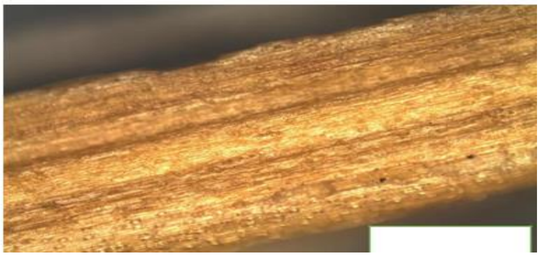

Fig 12: Optical microscope result of Bagasse treated with NaOH and alkaline

Table III
Natural Bagasse Treatment in NaOH and alkaline

Nature of Bagasse	Weight (gram)
Original	50
After treated with pressurized water and dried	45
After treated with 3wt % NaOH and alkaline	41
After treated with 3wt % NaOH and alkaline	38
After treated with 5wt % NaOH and alkaline	37
After treated with 5wt % NaOH and alkaline	35

This weight reduction occurs because alkali treatment with NaOH leads the bagasse fibers' surface to become clean by extracting hemicellulose and lignin, which causes a decrease of weight and an increase of fibers crystalline. The optimization of the interfacial properties in a fiber crystalline and polymer matrix by the hydrophilic character of natural fibers, some of the chemicals modified by using of different wt% NaOH concentrations was used to remove lignin and hemicellulose from the fibers surface, as Cellulose is a semi-crystalline polysaccharide made up of D-glucopyranose units integrated by means of β-(1-4)-glucosidic bonds and the higher amount of hydroxyl group in cellulose yields natural fiber hydrophilic properties. Thus, the fibers are reinforced by a hydrophobic matrix; it causes a very poor interface and poor water absorption resistance. Hemicellulose is a strong bond with cellulose fibrils, presumably by a hydrogen bond. Hemi cellulosic polymers are branched fully amorphous Structure and significantly lower molecular weight than Cellulose. Because of its chain structure containing many hydroxyl groups with acetyl branch, hemicellulose is partially soluble in water and hygroscopic. Lignins are amorphous, highly complex, usually aromatic Structure, and polymers of phenyl propane groups; however, they have the least water absorption of the natural fiber compositions.

B. Heat treatment recycling of PET

Heat treatment is started by identifying the glass transitions and melting of the PET sample as necessary.

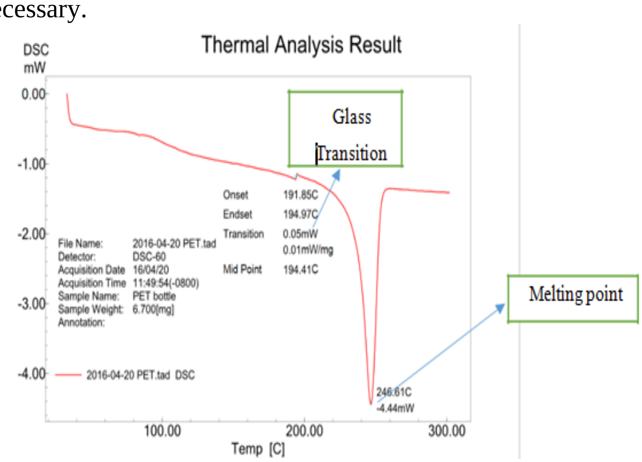

Fig 13:Sample characterization before recycling with DSC

Hot and Stirrer plate: It was found that the recycling of PET using hot and Stirrer resulted in a variety of samples. This was mainly due to the temperature variation from 265^0 C- 380^0 C. Unless the temperature is controlled, the PET will start to undergo degradation. Since it was done in the open air and lack of uniform heating, the sample prepared through this method took a long time to melt, and a high temperature above 300^0 C was needed for uniform melting. It was found that controlling the melt temperature is highly important; otherwise, the sample will change its color to black or grey asin figure below.

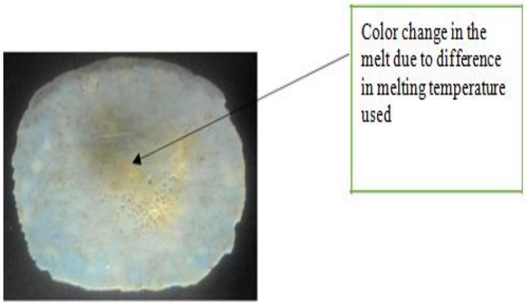

Fig 14: Result of Mechanically recycled PET

Furnace: The second method we used for melting the PET was furnace set at 265^0 C temperature after DSC characterization of the sample. It is found that the sample melted uniformly, and there was no color change as in a hot Stirrer. We have observed that the sugarcane bagasse can't withstand the melt temperature. And physical treatment for sugarcane bagasse can solve this problem.

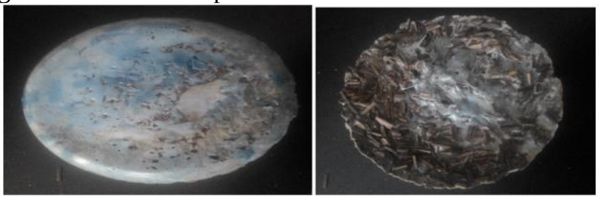

Fig 15: Sample for mixing of PET and Bagasse

Hot plate: it is found that melting the PET with this method resulted in complete sample degradation. This was because the hot plate used doesn't give uniform heating and has no temperature control.

C. Bagasse polyester resin composite

The second method of sample preparation was using a polyester risen matrix. Unlike the recycled pet matrix, the polyester was found to be highly compatible with the sugarcane bagasse. As it is shown in the figure below, it is found to have good dimensional stability. Since at room temperature is that the mix is done, no burning and degradation of fiber. Unlike the recycled PET matrix, polyester can be very advisable since no physical or thermal stability is needed.

Fig 16: Bagasse Polyester resin composite

The result of the Vickers hardness test shown in ***Figure 17***is a reference that can inform about the tenacity characteristics, including resistance to material deformation, penetration by an abrasion, drilling, applying impacts, scratching by the material. The Vickers hardness test is applied to the composite materials, and it measures the resistance to the indenter penetration in diamond form. Our composite shows a hardness of 180 HV10, indicating that our material has a good hardness compared to other materials.

Hardness test

Fig 17: Hardness value image of Polyester bagasse

Optical microscope

Figure 18: Polyester bagasse composite Optical microscope result

The structural insulated panel enclosure system

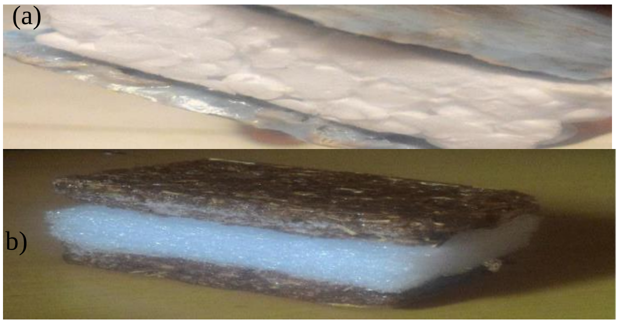

Fig 19:Structural insulated panel. (a). recycled PET facing and (b) sugarcane bagasse polyester resin composite.

VII. CONCLUSION AND RECOMMENDATION

A. Conclusion

The sustainable life of tomorrow's generation is based on the present research and development towards eco-friendly industrial systems and production processes. In this process, recycling waste materials such as PET bottle, sugarcane bagasse, and polystyrene (Thermo foam) were performed. PET bottle was recycled through secondary recycling method-mechanically. Alkali treatment of bagasse fiber was performed, but the absence of physical treatment for Bagasse appears vital for its thermal stability. Polystyrene (Thermo foam) was used as an insulating foam core without any further process.

This research aims to show that the recycling and re-using process is the best alternative to treat waste polymers and sugarcane bagasse in comparison with the old methods (direct burning of waste polymers or burying underground), which causes negative impacts on the environment in the formation of dust particles, fumes, and toxic gases.

The result proposes this recycling process idea as the best methodology to use the resulting material as an alternative construction material as it is cost-effective and environmentally friendly. This effort could be very useful in recycling the above-mentioned west materials. However, the sugarcane bagasse should have further treatment to make it thermally stable for incorporating it in PET melt. Nevertheless, using the recycled PET without the Bagasse could also be possible. The bagasse polyester resin composite can be a better alternative for using it as a facing SIP material.

B. Recommendation

I. Fiber preparation:

From our experiment on sugarcane fiber preparation and alkaline treatment

- ✓ From this experiment, we found that to completely remove the pitch and lignin from the rind, which is highly Cellulose, enough NaOH has to be used. The duration time affects, so proper care for duration and treatment temperature is necessary.
- ✓ To check whether the pitch and the lignin part is removed completely, scanning electron microscope and chemical analysis should be considered.
- ✓ Sugarcane bagasse and PET treatment at high temperatures were found to be highly incompatible. Besides, the sugarcane bagasse was found to have low-temperature stability. Either surface treatment of sugarcane bagasse for high-temperature stability or room temperature processing of PET should be considered.
- ✓ During Bagasse fiber preparation for polyester composite, it is good to use the grinding machine to get more fibrillated fiber.

***PET recycling*:**

The pre-recycling preparations of the sample are very helpful for recycling. Removing unnecessary materials from the samples, proper washing, and size reduction will be very helpful.

- ✓ They are characterizing the sample before recycling is a very important step. DSC and DTG will help to distinguish different temperatures of the sample.
- ✓ Controlling temperature during melting is necessary. Otherwise, the sample will experience degradation, which can be seen by the change in color of the final PET product appear to be black or gray.
- ✓ An alternative methodology for PET recycling should also be considered, especially for the incorporation of natural fibers.

Composite preparation:

- ✓ It is also important to use a blender like a mixer and pressing machine to get a more strong and uniform surface.

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