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Woven hybrid Biocomposite: Mechanical properties of woven kenaf bast fibre/oil palm empty fruit bunches hybrid reinforced poly hydroxybutyrate biocomposite as non-structural building materials

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HIGHLIGHTS

- The polyhydroxybutyrate is targeted as matrix for green composite.
- The mechanical test of KBFw/EFB hybrid reinforced PHB biocomposite with 11 layers is determined that it has capability to replace with some wood and woody production.

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ABSTRACT

Green or Biocomposite materials encompass biopolymers and natural fibers (NFs) from renewable resources, which is helped to eliminate non-renewable waste, reduce raw material usage, and lessen greenhouse gas emissions. This paper aimed to assess and develop specific biocomposite in terms of mechanical properties, which prepared by lamination and compression molding method. The woven kenaf bast fibre (KBFw) is deliberated as reinforcement in this study due to the high tensile strength which was hybridized with oil palm empty fruit bunches (EFB) due to high toughness of EFB for covering the impact properties of biocomposite. The polyhydroxybutyrate (PHB) is a common biodegradable polymer that is targeted as matrix for green composite. The triethyl citrate (TEC) was chosen as plasticizer for improving flexibility and handling of PHB films. The scanning electron microscope was used to understand and investigate the tensile-fractured surface of different hybrid biocomposite. The results show that the tensile and flexural properties would be increase when NFs with higher tensile strength was used as skin fibre in term of hybrid composite. Conclusively, the flexural stiffness of biocomposite increase when the KBFw PHB biocomposite is hybrid with FEB reinforcement. The tensile and flexural test of KBFw/EFB hybrid reinforced PHB biocomposite with 11 layers (sample E) is determined that sample E has capability to replace with some wood and woody production.

1. Introduction

The construction industry consumes astonishing amount of materials, most of which derive from non-renewable resources or resources that require considerable time to be renewed [1]. Green or biocomposite materials from renewable resources encompass of a biopolymer and Natural Fibers (NFs) [2–4]. These materials are being investigated with the aim to decline impacts to environmental and human health from building materials [5,6]. The most research and development on biocomposites have been targeted in the packaging, automobile, medical, and interior design industries [7–9]. However, some important research has been accompanied on biocomposites [10–12] that have been considered in construction applications. In recent years, scholars [13–18] suggest the usage of different type of NFs and biocomposites in

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construction industry. Yan, L; and Chouw, N (2013) emphasized the potential of using NFs to achieve a sustainable construction with experimental investigation of a composite column consisting of flax fibre reinforced polymer (FFRP) and coir fibre reinforced concrete (CFRC) [13]. In 2014; Yan et al. experimentally examined various column parameters on axial compressive and flexural behavior of a new type of flax fibre reinforced polymer-confined concrete, which is termed as FFRP–CFRC [14]. They Confined concrete strength was predicted and compared with experimental results. Another research study in 2015 investigated the flexural behaviour of plain concrete (PC) and coir fibre reinforced concrete (CFRC) beams which externally strengthened by flax fabric reinforced epoxy polymer (FFRP) composites [15]. Regarding to use biocomposite as building materials; CoDyre et al (2016) explored the effect of foam core density on the behavior of sandwich panels with novel bio-composite unidirectional flax fibre-reinforced polymer skins, with a comparison to panels of conventional glass-FRP skins [16]. Mak et al (2015) researched on Structural sandwich panels with considering the potential for replacing conventional glass fiber-reinforced polymer (GFRP) skins with bio-based skins made of unidirectional flax fibers and a resin blend consisting of epoxidized pine oil [17]. And, Yan et al (2106) studied improvement Effect of alkali treatment on microstructure and mechanical properties of coir fibre reinforced-polymer composites and reinforced-cementitious composites as building materials [18].

Green composite is one existing class of materials and products which can improve the sustainability in composite science [19,20]. Sealy (2015) emphasized to use cellulose fibers as reinforcement in green composite that promise a sustainable and renewable term as alternative to petroleum-based plastics [21]. The use of renewable resources reduces the needs for petrochemicals and minerals, resulting in less natural resources depletion effect on the planet [22,23]. Inherently green or biocomposite made from renewable resources is biodegradable and change naturally by bacteria into substances without any harm to environment [24,25]. In fact, biocomposites and other green materials help eliminate non-renewable waste, reduce raw material usage, and cut fossil-fuel consumption [26]. In biocomposite, NFs are stronger and stiffer than polymeric matrix [27,28], but the important role for distributing stresses to fibers belongs to the binds between matrix and fibers. In biocomposite, biopolymer as matrix can play significant role as protection of fibers and total behaviors of biocomposite depend on: kinds of fibers, matrix, distribution of fibers on matrix, etc.

Biopolymers may be obtained from renewable resources, synthesized microbially, or synthesized from petroleum-based chemicals [29]. Polyhydroxybutyrate (PHB) is one of the most common biodegradable polymer and it will be studied as matrices for biocomposites in this research. The mechanical properties are reported to be equal or even better than traditional thermoplastics [30]. The PHB is an organic and biodegradable polymer [31] that is well known as a carbon and energy reserve produced by a variety of microorganisms, and its synthesis is favoured by environmental stresses such as nitrogen, phosphate or oxygen limitation [32,33]. There are a lot of inexpensive carbon sources and high productivity as basic feed stocks for PHB production. Among such substrates, molasses [34], starch [35], whey from the dairy industry [36], surplus glycerol from biodiesel production [37], xylose [38], and plant oils [39] are available. Fig. 1 shows closed carbon cycle in PHB production integrated in a sugar mill with ethanol [40].

Additionally, there are some research which highlighted regard to the successful replacement of synthetic fibres by bio-fibres [81,82]. Bast fibers, as majority of NFs; are proposed to compromise several advantages as replacements for synthetic fibers (e.g. glass) in composites [41] like giving the potential for reduced weights, and less damaging to machinery and personnel during the manufacturing process due to less abrasive than glass particles [42]. Kenaf bast fiber (KBF) has a great potential as a reinforcing fiber in composites due to high strength-to-weight/stiffness-to-weight ratio in comparison to other fibers. It has the highest carbon dioxide absorption of any plant (1 ton kenaf absorbs 1.5 tons of atmospheric CO_2), a valuable tool in the prevention of global warming and priority for choosing as Green materials [43]. Bast fibre as majority of NF is offered desirable characters specifically for hybrid composite based on mechanical properties and moderately high specific strength and stiffness. Table 1 shows properties of some bast fibres with oil palm EFB.

Furthermore, study of lignocellulose fibres has revealed that the properties of fibres can be better used in hybrid composites for using as an alternative to synthetic fibre composite [48,49]. Hybrid composites which contain two or more types of fibre and matrix could cover the lack in one fiber properties with another one [50,51]. The hybrid term is used to impart fancy effect, reduce cost of the end product, and find out suitable admixture of natural origin to mitigate the gap between demands and supply [52]. Among of the all NFs, Oil palm Empty Fruit Bunches (EFB) is hard and tough and found to be a potential reinforcement in composite applications [53]. The primary advantages of EFB hybrid composite are its low density, non-abrasiveness, and biodegradability. Hybridization of EFB with jute fibres [54,55], sisal [56,57], and glass [58,59] implied to enhance physical and mechanical properties of EFB hybrid composites to be used in various applications like construction industry. Based on the study of hybrid composite with bast fibres (like jute) and EFB [60,61], it has highlighted the promising material properties based on the high tensile strength of bast fibres (jute) and the toughness of EFB. Therefore, any hybrid composite of two fibres will exhibit the desirable properties of the individual constituents.

Tensile strength (TS) is one of the NF' mechanical property that defined the strength of material expressed as the greatest longitudinal stress it can bear without tearing apart. As can be seen from Table 1 TS (930 MPa) of kenaf fibers is higher than the TS of hemp (690 MPa). It can be used as reinforcing materials to make useful structural composites material with acceptable mechanical and physical properties in construction industry. However, the toughness of kenaf fiber is quite low and it leads to the low impact properties for composite. Therefore, in order to get composite with good tensile and toughness property, kenaf fibre need to be hybrid with other natural fibre such as EFB. EFB is oil palm fiber that has good toughness compare to other fibers.

The research aimed to assess and develop KBF_w/EFB hybrid reinforced PHB biocomposite as non-structural components for building material in terms of mechanical properties. The novelty of the study is hybridization of KBF_w and EFB fibres which would affect on tensile and flexural properties of KBF_w /EFB hybrid reinforced PHB biocomposite.

2. Materials and Methods

2.1. Materials

The woven KBF_w and EFB mats were obtained from Innovative Pultrusion Sdn Bhd, Malaysia. The properties of kenaf and EFB fibre are shown in Table 2. Polyhydroxybutyrate (PHB) granules was obtained from Goodfellow Cambridge Ltd in England. Table 3 shows the various properties of PHB, polypropylene (PP), and polyethylene (PE); and Table 3 shows similarities in the physical and mechanical properties of PHB, PP, and PE [84,85]. The others chemical materials included: ethanol used for alkaline treatment, 3-(triethoxysilyl) propylamine for silane coupling agent treatment, triethyl citrate used as plasticizer, and chloroform for mixing PHB biopolymer' granule with plasticizer were obtained from Mdigene Sdn Bhd, Malaysia.