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# Development of kenaf-glass reinforced unsaturated polyester hybrid composite for structural applications

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ABSTRACT

The main aim of this paper is to develop kenaf-glass (KG) fibres reinforced unsaturated polyester hybrid composite on a source of green composite using sheet moulding compound process. Unsaturated polyester resin (UPE) and KG fibres in mat form were used at a ratio of 70:30 (by volume) with treated and untreated kenaf fibre. The kenaf fibre was treated with 6% sodium hydroxide (NaOH) diluted solution for 3 h using mercerization method. The hybrid composites were tested for flexural, tensile and Izod impact strength using ASTM D790-03, ASTM D618 and ASTM D256-04 standards respectively. The highest flexural, tensile and impact strength were obtained from treated kenaf with 15/15 v/v KG fibres reinforced UPE hybrid composite in this investigation.

Scanning electron microscopy fractography showed fibre cracking, debonding and fibre pulled-out as the main fracture mode of composites and kenaf treated 15/15 v/v KG reinforced hybrid composite exhibited better interfacial bonding between the matrix and reinforcement compared to other combinations.


## 1. Introduction

Recently, there has been an increased interest in the use of biocomposites due to environmentally aware consumers to preserve the world [1–3]. Hybrid composites have proven to create a balance effect within the fibres incorporated in the composite material. The types of fibre can be natural fibres or man-made based synthetic fibres. The combination of renewable and synthetic materials appear to be the outstanding structural materials which come from natural fibre that is viable and abundant reinforcement for the replacement of expensive and non-renewable synthetic fibre [4]. Structural natural fibre composites, intended for indoor use, are usually made from low-cost adhesive which is not stable to moisture, while exterior-grade composites are made from a thermosetting resin that is higher in cost but stable to moisture [5]. Performance of structural natural fibre composite can be improved further by improving the properties of natural fibre especially agro-based fibre using chemical modification techniques [6,7].

The study on hybridization of natural–natural fibres, natural-synthetic fibres and synthetic–synthetic fibres in a single matrix has been performed [8]. The use of lignocelluloses both agricultural and wood based [9–11] and wastes [12] as fillers and reinforcement in hybrid composite have shown promising effect on the improvement of mechanical properties of composite. However, the limitation of fibre loading in hybrid composite is generally showed a maximum of 50%. The study on the performance of the mechanical properties of hybrid banana/glass fibre reinforced polyester composite has been done by Hanifawati et al. [13,14]. They found that both flexural and tensile properties can be improved by the combination of these two fibres.

Kenaf fibre is processed from a vegetable fibre that grows abundantly and used in many applications, mostly because of their high mechanical properties. In the last few years, kenaf fibre is known as *Hibiscus cannabinus*, L has been chosen as reinforcement with synthetic fibres to the combination of common polymers as matrix such as polypropylene (PP) [15], polylactic acid (PLA) and thermoplastics natural rubber (TPNR) [16] in hybrid composites. The availability of natural or bio-fibre such as kenaf in Malaysia makes the hybrid composite competitively lower cost and feasible to be produced industrially for a wide range of applications, especially for structural applications. The main drawback of using kenaf fibres in thermoplastics is the high moisture absorption of the fibres and composites. In order to avoid this problem the fibres can be treated after encapsulating in the plastic followed by a mercerization process [17] which promotes good adhesion between the fibre and the matrix.

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**Table 1**
Properties of fibre and unsaturated polyester resin.

| Properties | Material | | |
|---|---|---|---|
| | Kenaf fibre | Glass fibre | UPE |
| Density (g/cm$^3$) | 1.4 | 2.5 | 1.1 |
| Strength (MPa) | 284–400 | 2000–3000 | 55 |
| Modulus (GPa) | 21–60 | 70 | 4.5 |
| Elongation at break (%) | 1.6 | 2.5 | 5 |
| References | [10,16] | [10,22,23] | [23,24] |

Hybridization of natural fibre especially kenaf and synthetic fibre is a very good approach to enhance the mechanical properties and moisture resistance of the resulting hybrid composite [18–20]. Davoodi [21] investigated hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam and showed that the mechanical properties of bio-composite improved but the impact strength reduced compared to the common glass matrix thermoplastic (GMT). However, in their study the mercerization process was not employed on the kenaf before preparing hybrid epoxy composite. A very few attempts have been taken on the combination of kenaf and glass reinforced polymer matrix hybrid or bio-composite. Therefore, in this work an attempt has been taken to develop hybrid composite combining natural and synthetic fibre from the kenaf and glass fibre respectively by means of a sheet moulding compound process with total reinforcement of up to 30% (by volume) and mechanical properties were studied in order to recommend the optimum hybrid composite for structural application.

## 2. Experimental

### 2.1. Materials and methods

The woven E-glass fibre (E-GF) type TGFM-450 chopped strand mat supplied by local supplier was used for the fabrication of hybrid composite in this investigation. The chopped strand mat size was 15 mm × 15 mm × 0.15 mm. The unsaturated polyester resin was mixed with hardener at a ratio of 100:14. The properties of both fibres and UPE are shown in Table 1 while the composition and the designation of the hybrid composites for this study are shown in Table 2.

### 2.2. Mercerization process of kenaf fibre

In order to enhance the fibre–matrix adhesion a surface treatment was employed on kenaf fibre which is known as mercerization.

**Table 2**
Composition and designation of the hybrid formulations.

| Designation | | Composition of hybrid formulations |
|---|---|---|
| Untreated | S1 | UPE (70 vol%) + chopped mat E-GF (30 vol%) |
| | S2 | UPE (70 vol%) + untreated Kenaf (7.5 vol%)+ chopped mat E-GF (22.5 vol%) |
| | S3 | UPE (70 vol%) + untreated Kenaf (15 vol%)+ chopped mat E-GF (15 vol%) |
| | S4 | UPE (70 vol%)+ untreated Kenaf (22.5 vol%) + chopped mat E-GF (7.5 vol%) |
| | S5 | UPE (70 vol%) + untreated Kenaf (30 vol%) |
| Treated | S2 | UPE (70 vol%)+ untreated Kenaf (7.5 vol%) + chopped mat E-GF (22.5 vol%) |
| | S3 | UPE (70 vol%) + treated Kenaf (15 vol%) + chopped mat E-GF (15 vol%) |
| | S4 | UPE (70 vol%)+ treated Kenaf (22.5vol%) + chopped mat E-GF (7.5 vol%) |
| | S5 | UPE (70 vol%) + treated Kenaf (30 vol%) |

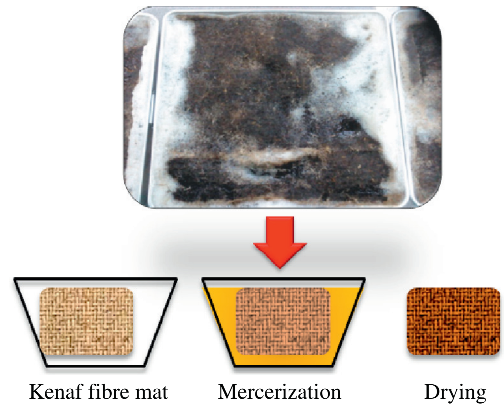


**Fig. 1.** Mercerization process of kenaf fibre.

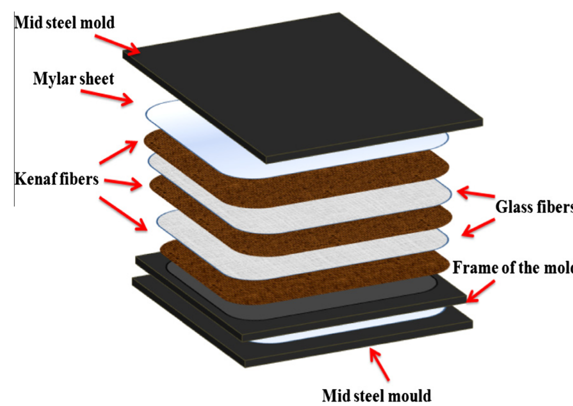


**Fig. 2.** Sequence of fibres and matrix in between mould for hybridization.

The mercerization process steps of kenaf fibre treatment is shown in Fig. 1.

Mercerization process of kenaf fibre in a mat form directly procured from the local supplier and then the mercerization process was done using 6% NaOH diluted solution for 3 h followed by natural drying at ambient temperature for 24 h in the clean dry chamber. The kenaf fibre then was rinsed with distilled water and dried at room temperature for 72 h followed by oven drying for 24 h at 60 °C.

### 2.3. Fabrication method of hybrid composite

Two thick mild steel plates each weighs 1 kg and dimension of 20 mm × 20 mm × 4 mm are used to perform the hybrid composite fabrication. The mild steel plates are polished using carbide abrasive paper of grade 240 to smoothen the surface thus ensuring better sample flatness upon fabrication.

Before sheet moulding process begins, it is important to treat the mould surface with a release agent to prevent adhesion of the fibre composite to the mould and to ease removal of the fabricated parts. The component may otherwise bond permanently to the mould causing the composite to be scrapped. Therefore, release agent in a form of sheet (commercial name is Mylar sheet) was used in order to avoid the above problem, a mould release agent was used to ensure the surface of the fibre composite is smooth upon curing. The thickness of the sheet is 0.01 mm and was supplied by Hightech Polymer Sdn. Bhd. The mould was closed and kept for curing at room temperature at approximately 25 °C and 0.5 barr pressures for 30 min in the SMC machine to minimise the voids. After curing, composite was separated from the mould