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Development and material properties of new hybrid plywood from oil palm biomass

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ABSTRACT

Shortage of wood as a raw material has forced wood-based industries to find alternative local raw materials. Currently, oil palm biomass is undergoing research and development (R & D) and appears to be the most viable alternative. This work examines the conversion of oil palm trunk (OPT) and oil palm empty fruit bunches (OPEFB) into new plywood and analyses its properties. We prepared five-ply veneer hybrid plywood (alternating layers of oil palm trunk veneer and empty fruit bunch mat) with different spread levels (300 g/m^2 and 500 g/m^2) of resins (phenol formaldehyde and urea formaldehyde). We then studied the mechanical and physical properties of the plywood. The results show that hybridisation of EFB with OPT improves some properties of plywood, such as bending strength, screw withdrawal and shear strength. The thermal properties of the plywood panels were studied by thermogravimetric analysis (TGA). The panels glued with phenol formaldehyde with a spread level of 500 g/m^2 showed better thermal stability than the other panels. Scanning electron microscope (SEM) was used to study the fibre matrix bonding and surface morphology of the plywood at different glue spread levels of the resins. The fibre–matrix bonding showed good improvement for the hybrid panel glued with 500 g/m^2 phenol formaldehyde.

1. Introduction

In wood-based industries, the shortage of wood as a raw material has recently become a great concern. Many plants that produce wood-based products, especially plywood and lumber, have already closed down. Wood-based industries are now facing a problem with the supply of raw materials, not only from natural forests, but also from rubber plantations. Annually, it is estimated that at least 20 million tonnes of solid wood is used in wood-based industries. Therefore, wood-based industries must find alternative sources of local raw materials, and oil palm biomass currently appears to be the most viable alternative. Oil palm trunk (OPT) is especially promising, as it can be utilised as a value-added product as well as in future wood-based industries, as stated by Mohamad et al. [1].

Oil palm is produced in 42 countries worldwide on about 27 million acres. Production has nearly doubled in the last decade, and oil palm has been the world's foremost fruit crop, in terms of production, for almost 20 years. In Malaysia, the total planted area increased to about 3.87 million hectares in 2004 as reported by Abdul Khalil et al. [2]. The current status of oil palm biomass in Malaysia during the year 2006 as stated by Anis et al. [3] showed that the total area of oil palm trees planted was 4.17 million hectares. Sumathi et al. [4] stated that oil palm mills generally generate substantial biomass waste. The amount of biomass produced by an oil palm tree, inclusive of the oil and lignocellulosic materials, is on the average of 231.5 kg dry weight/year. In the year 2008, oil palm empty fruit bunches and oil palm trunk contributed about 15.8 and 8.2 million tonnes, respectively, of oil palm biomass. As such, the oil palm industry must be prepared to take advantage of the situation and utilise the available biomass in the best possible manner mentioned by Yusof [5]. This residue can be considered as an alternative material for wood-based industries reported by Mohamad et al. [1].

Generally, oil palm trees have an economic life span of about 25 years. As a result of intensive production of primary oil palm products, there is an abundance of oil palm trunk that can be utilised. A large quantity of cellulosic raw material is generated in the form of felled trunks and fronds during replanting. Empty fruit brunches (EFB) are the other abundant source of residue. EFB are left behind after the fruit of the oil palm is harvested for the oil refining process. EFB amounting to 12.4 million t/y (fresh weight) are regularly discharged from palm oil refineries. Based on finding of Tanaka et al. [6], some of this is used as fuel, although most is left unused. To increase the added value of these residues, several studies have investigated the production of hybrid plywood from empty fruit bunches and oil palm trunk. In general, utilisation of

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biomass in lignocellulosic composites leads to several advantages such as low density, greater deformability, less abrasiveness to equipment, biodegradability and low cost mentioned by Abdul Khalil et al. [7].

Plywood has been successfully produced from oil palm trunk by using hardwood as the back and face of the veneers reported by Anis et al. [8]. The laminated veneer lumber can be manufactured from oil palm trunk using dried veneer by the conventional plywood manufacturing process, except that the arrangement of the layers are parallel to the grains as stated by Hashim et al. [9]. Currently, there is no information on the physical and mechanical properties of hybrid plywood made from oil palm trunk and empty fruit bunches. Therefore, this study seeks to determine the mechanical, physical and thermal properties of the hybrid plywood. A better understanding will help to develop productive uses for oil palm trunk and empty fruit bunch, mitigating environmental problems from waste biomass while also developing an alternative material to wood.

2. Experimental

2.1. Materials

Urea formaldehyde and phenol formaldehyde were supplied by the Hexion Specialty Chemicals Sdn. Bhd. Oil Palm Empty Fruit Bunch Fibres (OPEFB) were obtained in the form of mats from Ecofuture Berhad. Oil palm trunk (OPT) veneer was supplied by Kin Heng Timbers Industries Sdn. Bhd., Perak, Malaysia.

2.2. Preparation of hybrid plywood

The OPT veneers were cut to the dimensions of 600 mm × 300 mm × 4.0 mm and were later dried to approximately 10–12% moisture content. The determination of moisture content was carried out in accordance with BS EN 322:1993. The moisture content of the samples was measured by placing the samples in a drying oven at a temperature of 103 ± 2 °C until constant mass was reached. The empty fruit bunches were cut in the form of mats with dimensions of 600 mm × 300 mm × 6 mm. The samples were then arranged into 5-ply hybrid plywood alternately consisting of oil palm trunk and empty fruit bunches, as shown in Fig. 1. The layers were glued using urea formaldehyde (UF) and phenol formaldehyde (PF) resin with a glue spread rate of 300 g/m^2 and 500 g/m^2 before being cold pressed for 10 min. They were then hot pressed for 25 min at a temperature of 120 °C for urea formaldehyde (UF) and 150 °C for phenol formaldehyde, at approximately 200 bars (3000 psi) pressure.

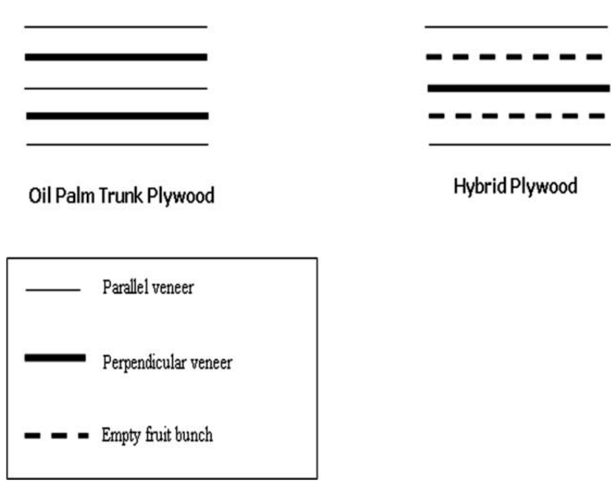

Fig. 1. Arrangement of oil palm trunk plywood and hybrid plywood.

2.3. Mechanical testing

Three types of mechanical testing were conducted in this study: bending, shear and screw withdrawal. A minimum of 10 samples were tested in each case.

2.3.1. Bending test

The bending test was performed according to BS EN 310:1993 using an Instron Model 4204 Testing Machine. The bending test was carried out using rectangular strips with dimensions of 240 mm × 50 mm × 12 mm. The lengths, widths and thicknesses of the samples were measured and recorded. Samples were tested at a crosshead speed of 10 mm/min and span of 240 mm. All the specimens were conditioned at an ambient temperature of 25 ± 3 °C and at a relative humidity of 30% (±2%) before testing.

2.3.2. Shear test

The shear test was performed according to BS EN 314-1:2004 using an Instron Model 4204 Testing Machine. The shear test was carried out using rectangular strips with dimensions of 135 mm × 25 mm × 12 mm. The lengths, widths and thicknesses of the samples were measured and recorded. Samples were tested at a crosshead speed of 1.5 mm/min. All the specimens were conditioned at an ambient temperature of 25 ± 3 °C and at a relative humidity of 30% (±2%) before testing.

Two treatments were conducted for the shear test: interior pretreatment (INT) for urea formaldehyde plywood and water boil proof pretreatment (WBP) for phenol formaldehyde plywood.

i. Interior (INT) pretreatmentThe samples were immersed for 24 h in water at 20 ± 3 °C and
ii. Water boil proof (WBP) pretreatmentThe samples were immersed for 4 h in boiling water, then dried in the ventilated drying oven for 16–20 h at 60 ± 3 °C, then immersed in boiling water for 4 h, and finally cooled in water at 20 ± 3 °C for at least 1 h.Before the water treatment, the length and width of the shear area were measured to an accuracy of ±0.1 mm and recorded. The shear test was carried out on wet test pieces from which a wiping can be realised. The shear test pieces were arranged in the centre of the clamping devices in such a way that the load could be transmitted from the testing machine, via the ends of the test pieces, to the shear area without any transverse loads. If slipping occurs, it was allowed only in the initial stage of the loading. This clamping was made on the faces. The load was applied at a constant rate of motion so that rupture occurred within 30 ± 10 s. Samples were tested at a crosshead speed of 1.5 mm/min. All the specimens were conditioned at an ambient temperature of 25 ± 3 °C and at a relative humidity of 30% (±2%) before testing.

2.3.3. Screw withdrawal test

The screw withdrawal test was performed using an Instron Model 4204 Testing Machine. The length, width and thickness were measured and recorded. The test was carried out in accordance with BS 5669: 1989 (With Modification), as followed by the Malaysian Forest Research Institute (FRIM). The screw withdrawal test was carried out using rectangular strips with dimensions of 75 mm × 75 mm × 12 mm. Samples were tested at a crosshead speed of 5 mm/min. All the specimens were conditioned at an ambient temperature of 25 ± 3 °C and a relative humidity of 30% (±2%) before testing.