

# Thermal Conductivity of Oil Palm Fibre - Polyethylene Hybrid Composite

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## ABSTRACT

Hybrid composite boards were manufactured from oil palm trunk (OPT), frond (OPF), empty fruit bunch (EFB) and polyethylene. The objective of this study was to measure the thermal conductivity of hybrid composite boards. The thermal conductivity of the boards was measured using Quick Thermal Conductivity Meter (QTM-D3). In this study, hybrid boards with different types of oil palm fibres and plastic content (5%, 12% and 20%) were used as the samples for experiment. Statistical analysis showed that the fibre types did not affect thermal conductivity values significantly. However, fibre types did influence the density of the boards. The correlation between density and thermal conductivity showed that density affected the value of thermal conductivity but it was not significant. The results showed that the values of thermal conductivity for this type of hybrid board were very low. Therefore, the hybrid composite boards are suitable for use as insulating boards.

## ABSTRAK

Papan komposit hibrid diperbuat daripada batang (OPT), pelepah (OPF), tandan kosong (EFB) dan polietilena. Tujuan kajian ini untuk menentukan konduktiviti terma papan komposit hibrid. Konduksian terma bagi sampel ditentukan dengan menggunakan Quick Thermal Conductivity Meter (QTM-D3). Sampel yang digunakan dalam kajian ini adalah daripada papan gentian sawit yang dicampurkan dengan plastik mengikut peratusan kandungan yang ditentukan (5%, 12% dan 20%). Dari analisis statistik, didapati jenis gentian tidak mempengaruhi nilai konduktiviti terma tetapi ia mempengaruhi nilai ketumpatan papan tersebut. Korelasi di antara ketumpatan dengan konduktiviti terma menunjukkan bahawa ketumpatan papan hibrid sedikit sebanyak mempengaruhi nilai konduktiviti terma tetapi

tidak memberikan kesan yang bererti. Keputusan kajian menunjukkan nilai konduktiviti terma bagi bahan biojisim sawit ini adalah rendah. Oleh itu, papan hibrid ini sesuai digunakan sebagai papan penebat.

**Keywords:** composite hybrid board, polyethylene, thermal conductivity, density.

## INTRODUCTION

Thermal conductivity (K) is one of the thermal-physical characteristics of a material. The unit for K is Watt per metre Kelvin, ( $W m^{-1} T^{-1}$ ). Under room conditions, K is very high for conductors, such as metals, but for gases, K is very low, less than  $0.01 W m^{-1} T^{-1}$ . Materials with  $K < 1 W m^{-1} T^{-1}$  are classified as insulators (Parrot, 1975).

The K of a material (*Table 1*) depends on its chemical composition, phase situation and crystal structure (Siau, 1984). For example, metals are known to have good K and are classified as conductors. However, wood and cellulose materials such as oil palm residues are insulators. In wood or oil palm residues, there are vessels in their structure with entrapped air which is a poor conductor. The insulating properties of wood have numerous advantages and contribute greatly to the *fire-resistant* properties of wood as compared with the highly conducting metals, which soften at high temperatures.

In this study, experiments and analyses were performed on hybrid composites of oil palm residues (trunk, frond, EFB) and plastic. The residues were mixed with adhesive and plastic at different contents. The influence of the plastic content on the K of the hybrid boards was investigated.

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**OBJECTIVES OF THE STUDY**

**The objectives of this study were:**

- to determine the Ks of hybrid boards made of oil palm biomass and plastics; and
- to investigate the effect of plastic content on the K of oil palm hybrid boards.

**TABLE 1. THERMAL CONDUCTIVITIES OF MATERIALS**

Material	W m <sup>-1</sup> T <sup>-1</sup>
Wood, G= 0.45M=12% ⊥	0.13
Wood, G= 0.45M=12% ∥	0.31
Wood, G= 0.70M=12% ⊥	0.18
Wood, G= 0.70M=12% ∥	0.47
Cell-wall substance ⊥	0.44
Cell-wall substance ∥	0.88
Water, free	0.69
Air, dead	0.02
Douglas-fir plywood	0.12
Hardboard, medium density	0.11
Particleboard, medium density	0.13
Asbestos cement board	0.58
Cement mortar, common brick	0.72
Concrete	0.94
Stone, lime, sand	1.80
Glass	1.05
Fibreglass	0.04
Expanded polyurethane	0.02
Silver	418
Copper	386
Aluminium	202
Stainless steel	16

Notes: ⊥ - perpendicular; ∥ - parallel; G - specific gravity; M - moisture content.

Source: Siau (1984).

**FOURIER'S LAW**

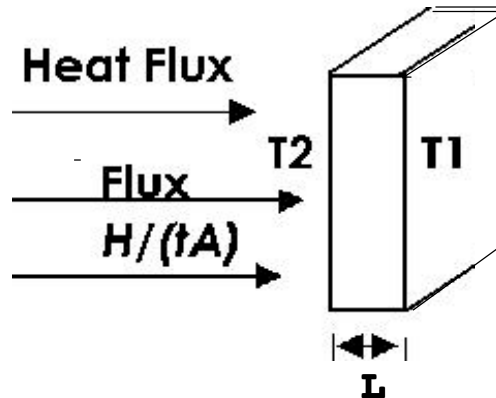
The first clear statement on the proportionality of heat flow and the temperature gradient was made in 1822 by Fourier in his *Theoric Analytique De La Chaleur* (Parrot, 1975). The steady-state flow of heat is described by Fourier's Law, which is analogous to Darcy's Law for the transport of liquid. The K of a material is equal to the flux divided by the gradient. Mathematically, it may be stated as:

$$K = \frac{H / tA}{\Delta T/L} = \frac{HL}{tA \Delta T} \quad (1)$$

where,

- K = thermal conductivity, cal/cm°C, or W m<sup>-1</sup> T<sup>-1</sup>;
- H = quantity of heat transferred in calories, Cal;
- t = time interval, s;
- L = length of flow path in the transfer in medium, cm;
- A = cross-sectional area perpendicular to the direction of flow, cm<sup>2</sup>; and
- ΔT = temperature differential between the heat-transfer surfaces separated by L, °C.

It is evident from Equation (1) that K is numerically equal to the rate of heat flow (in cal s<sup>-1</sup>) through a unit cube of material (1 cm a side) between two opposite parallel surfaces having a temperature difference of 1°C. The significance of the terms in Equation (1) is explained in *Figure 1* (Siau, 1984).



*Figure 1. Heat flow through a material.*

**MATERIALS AND METHODS**

**Sample Preparation**

Most of the experiments were conducted at the Malaysian Palm Oil Board (MPOB) Headquarters, Bandar Baru Bangi. The effects of the different oil palm fibres and plastic content on the K of the hybrid boards were investigated. Twenty-four samples were made from three types of fibres (frond, trunk and EFB). Each fibre was mixed with four different plastic contents (0%, 5%, 12%, and 20%). The glue used was urea formaldehyde with 10% resin. Each test sample had three replications. The boards for the test samples were manufactured using the non-woven process at the Forest Research Institute of Malaysia (FRIM) in Kepong. Fibre preparation was done at the Biomass Section at MPOB Headquarters. The fibres were produced by cold refining. The test for K was done at the

Advanced Oleochemicals Technology Centre (AOTC) of MPOB in Bandar Baru Bangi.

### Data Analysis

An analysis of variance (ANOVA) was carried out with K as the dependent variable and fibre type, and plastic content as the independent variables. The density of the samples was used as the covariate.

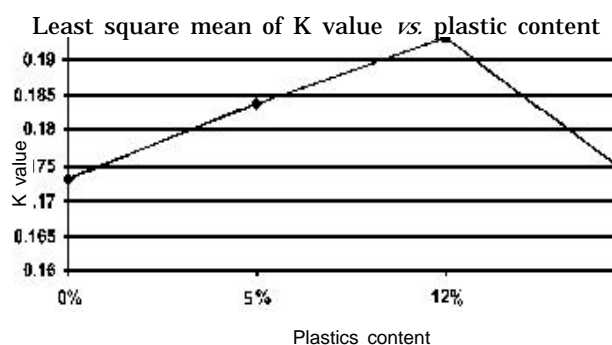
## RESULT AND DISCUSSION

### Effect of Plastic Content

The plastic content used for the hybrid boards was 0%, 5%, 12% and 20% by weight. From the ANOVA, one independent variable gave a significant value at  $P \geq 0.05$ . It indicated that between the different plastic contents, the K was significantly different, *i.e.* the plastic content significantly influenced the K value of the boards.

The K values between the non-plastic hybrid board and hybrid boards with 5% and 12% plastic were very different. *Figure 2* shows the least square means for the hybrid boards with 0% to 20% plastic. When the plastic content was increased from 0% to 12%, K increased from  $0.172 \text{ W m}^{-1} \text{ T}^{-1}$  to  $0.195 \text{ W m}^{-1} \text{ T}^{-1}$ , but with 20% plastic, K value was only  $0.177 \text{ W m}^{-1} \text{ T}^{-1}$ , little higher than the non-plastic board. Increasing the plastic content beyond 20% did not significantly increase K. The 12% plastic content yielded the optimum K for the board. Adding any more plastic would lower the K value although the change would not be significant. A lower K value means a lower K, or a better insulator.

With less plastic (5% and 12%), it melted very fast during the hot pressing and seeped in between the fibre strands. When the board was exposed to the environment, it absorbed moisture from the air. Therefore, when the board was exposed to heat, it became a better conductor because of the trapped moisture. This resulted in the K value increasing from  $0.172 \text{ W m}^{-1} \text{ T}^{-1}$  to  $0.195 \text{ W m}^{-1} \text{ T}^{-1}$ .



*Figure 2. Trend of thermal conductivity at different level of plastic content.*

However, by adding more plastic, more of the fibre strands became encrusted. Not being exposed, the absorption of moisture was reduced. Thus, the K of the board became lower.

For the board without plastic, the K value was also low due to the greater amount of moisture absorbed by the board. The hybrid boards warped when exposed to heat. This indicates that distribution of heat transfer on the surface of the board was uniform.

A material with a high K value less than  $1 \text{ W m}^{-1} \text{ T}^{-1}$ , is classified as an insulator. The results showed that the hybrid boards are good insulators because their K values were very much less than  $1 \text{ W m}^{-1} \text{ T}^{-1}$ .

### The Effect of Raw Materials

The ANOVA on the K for the different fibres (trunk, frond and EFB) were not significant. This means that the type of fibres did not affect the K value of the hybrid boards. The K values were not significantly different from each other. As far as the K value is concerned, the trunk, frond and EFB fibres can be mixed to make the hybrid boards.

### Correlation between Density and Thermal Conductivity

The final analysis was to investigate the correlation between density and K of the boards. This analysis was done by using the Excel statistical package. The graph in *Figure 3* shows the distribution of the two variables.

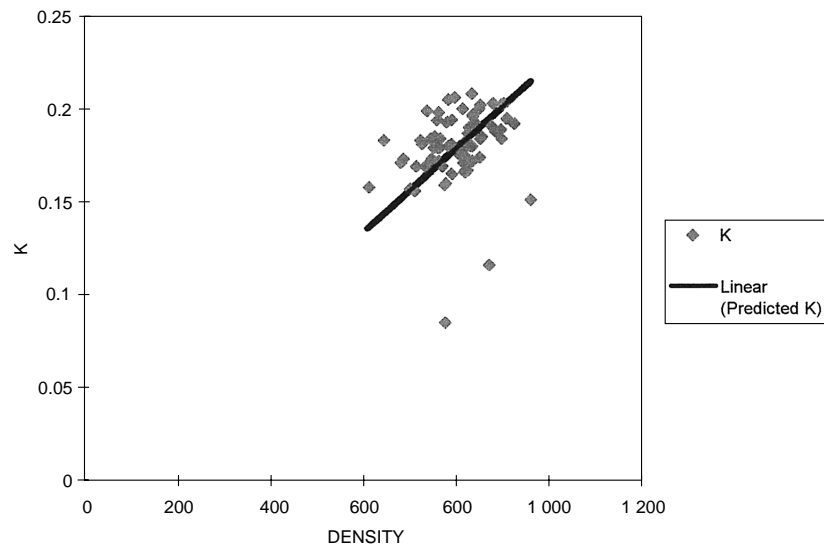


Figure 3. Correlation between thermal conductivity and density.

The graph shows that increasing the density of the boards will increase the K. According to Christie and Geankoplis (1993), a solid material with a high density can transfer more heat to the other side of a block. The results in this correlation study support this. The hybrid board (EFB) using 12% plastic had a high density ( $896 \text{ kg m}^{-3}$ ) and gave the highest K ( $0.196 \text{ W m}^{-1} \text{ T}^{-1}$ ).

### CONCLUSION

This study showed that the plastic content in the hybrid boards affected K. A plastic content of 12% gave the highest K. Further increasing the plastic content will not significantly increase the K value. The fibre type, such as trunk, frond or EFB fibre, did not affect the K value significantly.

The density of the hybrid board decreased significantly when more plastic was added. Increasing the density increased the K of the board. However, the increase was not significant. This study indicated that the hybrid boards would make good insulating boards. The addition

of plastic to the hybrid boards also increased their dimensional stability.

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