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BIODEGRADABLE HEAT INSULATION COMPOSITES BASED ON POLY(B-HYDROXYBUTYRATE) AND DATE PALM WOOD

By

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Abstract

Residential buildings are the highest contributor to energy consumption. As a result, there has been a concerted effort to spearhead research in sustainable thermal insulation materials. It was found that 20% energy saving could be achieved using thermal insulation for residential buildings in UAE. Wood plastic composite is a relatively new generation of composite material and especially for construction and building applications due to the hollow tubular structure of wood that provides a high thermal and acoustical insulation capacity.

The composite wood-based materials have several advantages like mitigating carbon emissions and reducing the adverse environmental impact due to their biodegradability, sustainability, renewability, and recyclability. Thus, in the first part of this study, the thermal insulation capabilities of date palm fibre (DPF)–reinforced Poly (β-hydroxybutyrate) (PHB) composites were investigated. In the second part, the surface of DPF was modified to overcome the limitations in the bio-composite using chemical treatments and coating the surface of DPF with biodegradable polymers and fire retardants.

The obtained composites were fabricated via melt blending, hot-pressing, and annealing. The effects of raw and modified DPFs loading on the fabricated composites were investigated to evaluate the physical, thermal and mechanical properties. Also, the obtained results of the developed composites were investigated and confirmed by Scanning Electron Microscopy (SEM), Differential Scanning Calorimeter (DSC), Fourier-transform Infrared Spectroscopy (FTIR), Thermal Gravimetric Analysis (TGA), and bomb calorimeter.

The results showed that the incorporation of DPF into the PHB matrix increased the thermal stability of the composites. The composites containing 30 wt.% DPF showed the maximum compressive strength (65 MPa) and exhibited thermal conductivity and thermal diffusivity of 0.092 $W/(m.K)$ and 0.041 mm^2/s, respectively. Regarding the chemical treatments, the alkaline treatment was used to clean the surface of DPF from impurities. The Alkaline treatment showed an increase in the tensile strength of 20% composite from 16 MPa to 21 MPa. Also, the silane treatment reduced the hydrophilicity of DPF which enhanced the interfacial adhesion between the date palm fibre (DPF) and Poly (β-hydroxybutyrate) (PHB). The silane coupling agent 3-Aminopropyltriethoxysilane (APTES) was used with two grafting solvents (Acetone and Ethanol). Similarly, the composites coated with biodegradable polymers (Polylactic acid and Polyhydroxybutyrate) showed a drastic enhancement in terms of water resistance and compatibility.

Silane-Ethanol composites (PHB-SE) showed higher tensile strength than the Silane-Acetone composites (PHB-SA) likewise a higher water resistance. The 40% PHB-SE increased the tensile strength by 87.5% and reduced the water uptake by 21%. The obtained thermal conductivity of the developed composites is ranged between 0.0901 $W/(m.K)$ and 0.1065 $W/(m.K)$ which possess an appropriate thermal insulation capacity. The chemical additive was used to enhance the fireproofing using Ammonium Dihydrogen Phosphate (ADP). Also, it reduced water absorption due to the forming of furan compounds. Lastly, the thermal conductivity was reduced from 0.0916 $W/(m.K)$ to 0.0523 $W/(m.K)$ for whole composites. ADP increased the thermal stability and flammability resistance.

These findings suggest that this fully bio-based composite can be a potential candidate for construction-related applications with an extended service life which could be considered as a replacement for used petroleum-based insulation material (Polystyrene).

Keywords: Green thermal insulator, Polyhydroxybutyrate, Natural waste, Date palm fibre, Biodegradable construction materials