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Characterization of new composite material based on date palm leaflets and expanded polystyrene wastes

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HIGHLIGHTS

- Date palm Leaflets-Polystyrene Composite, LPC, is formulated and characterized.
- LPC is a new insulating material based on palm leaflets and polystyrene wastes.
- Physical, mechanical, thermal and morphological LPC properties are investigated.
- LPC proprieties are discussed and compared with those of conventional materials.
- LPC is a renewable material; it can be totally recycled at the end of its life.

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ABSTRACT

In the aim of environmental protection and valorization of vegetal resource, an experimental study on an innovative Wood-Plastic Composite material (WPC) based on Date Palm and expanded Polystyrene, EPS, Wastes is performed. Date palm leaflets waste are used as the reinforcement and EPS waste dissolved in gasoline is used as a matrix. Several combinations of reinforcement sizes (0.1–0.315 mm, 0.315–0.5 mm and 0.5–1 mm) and fiber-to-matrix weight ratios (70, 75 and 80 wt%) were considered to investigate the properties of the Leaflets-Polystyrene Composite (LPC). In this study, physical, mechanical, thermal and morphological characterizations were carried out in order to determine: the bulk density, the flexural modulus, the maximum stress and the thermal conductivity of LPC. Therefore, Pycnometer density measurement, three-point bending test were performed and transient plane heat source (hotdisc) method was used. Furthermore, a characterization by scanning electron microscopy (SEM) was realized to observe the fibers/matrix bond. The LPC showed good adhesion state of the fiber–matrix interface and acceptable mechanical properties with a flexural modulus and a maximum stress that can achieve 0.78 GPa and 2.84 MPa, respectively. The LPC has a density between 542 and 824 kg/m^3 which are comparable to those of usual materials like hard-and-soft wood, MDF and other WPC found in the literature. The thermal characterization tests of the LPC have shown also an average thermal conductivity within the range of 0.11 and 0.16 W/m·K. The LPC can be used in the field of building construction as a good thermal insulation as well as a structural component in sandwich structures. Moreover, LPC material is obtained from wastes and can be totally recycled at the end of its useful life.

1. Introduction

The reduction of energy consumptions is one of the most important challenges of future buildings [1,2]. According to Asdrubali, D'Alessandro and Schiavoni [2], the buildings consume about 40% of the world global energy, 25% of the global water, 40% of the global resources. furthermore, buildings are also responsible of about 1/3 of greenhouse gas emissions of the whole globe [2].

Today's buildings are the cause of several environmental problems due to the production of conventional materials they use such as cement, bricks and steel. Indeed, these kind of materials consumes a lot of thermal and electrical energy which invoke air, water and land pollution [3]. Thereby, a new look should be

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Nomenclature

A	Small particle size of the reinforcement, 0.1–0.315 mm
b	Width of specimen, mm
B	Medium particle size of the reinforcement, 0.315–0.5 mm
C	Large particle size of the reinforcement, 0.5–1.0 mm
E_f	Flexural modulus, GPa
F	Applied load, N
h	Thickness of the test specimen, mm
l	Length of specimen, mm
L	Support span length, mm
$m_{gasoline}$	Mass of gasoline, g
$m_{polystyrene}$	Mass of expanded polystyrene, g
wt%	Weight proportions
y	Deflection, mm

Greek symbols

σ_{Max}	Maximum stress, MPa
ρ	Density, kg/m^3
λ	Thermal conductivity, W/m·K

Abbreviations

DPCC	Durian Peel and Coconut Coir
DPWF	Date Palm Wood Four
EPS	Expanded Polystyrene
KC	Kenaf Core
LPC	Leaflets-Polystyrene Composite
MDF	Medium Density Fiberboard
mix	Mixture of palm leaves and plastic waste (PC, PS and PVC)
PC	Poly-Carbonate
PS	Polystyrene
PVC	Poly-Vinyl Chloride
SEM	Scanning Electron Microscopy
WPC	Wood-Plastic Composite material
WW	Wastes of Wood

addressed to the buildings materials where the renewable and the recyclable aspects must be one of the main selection criteria. One of the technological advances of nowadays that can easily meet the requirements imposed by the aforementioned challenges are the composite materials [4–6]. Indeed, the last decades have witnessed a considerable increasing in the use of composite materials in virtually all the industrial domains such as aeronautic, automotive and civil engineering [7,8].

Research is actually focused on incorporation of natural resources as constituent in composite materials [6]. In fact, the use of natural resource in the formulation of materials is not a new concept; our ancestors used straw to strengthen bricks made from mud for house building [9]. Today, the choice of natural resources is inevitable and it is mainly due to the low cost, renewable nature, good biodegradability, and significant thermal and mechanical properties added to the final product [10,11]. However, wood is considered as an excellent construction organic material and can be used as reinforcement with different forms and dimensions to increase the thermo-mechanical properties of construction materials. In the same context, the plastic is also considered as a key of innovation of many products in various sectors such as construction, health care, electronic, automotive, packaging and others. According to PlasticsEurope [12], The global production of plastic has reached about 322 million tons in 2015 and has increased by almost 4% over 2014. This indicate the important percentage of plastic waste ended up in the landfill and it is well known that plastics may take up to billions of years to naturally degrade [13].

Considering the complementary performances of the previous materials, a new concept was born in the 1970s, known as Wood-Plastic Composites (WPC). These new materials have close mechanical and physical properties to solid wood [14], with improved hygrometric properties, in almost cases. The term WPC refers to any composites that contain plant-derived reinforcement (wood and non-wood fibers) and thermosets or thermoplastics matrices [15,16]. According to Mohamed et al. [17], the worldwide industry sector of natural fiber reinforced polymer composites reached U$2.1 billion in 2010. For this purpose, several investigations have been conducted in this research area in order to highlight the properties and mechanical behavior of WPC material based on natural fiber of different plants. Wambua et al. [18], among others, have studied the mechanical properties of polypropylene composites reinforced by different natural fibers (sisal, kenaf, hemp, jute and coir). The authors found that, in most cases, the specific properties of natural fiber composites compare favorably with those of glass. Chikhi et al. [19] have experimentally studied the effect of date palm fibers on thermal conductivity, water absorption and mechanical properties of gypsum-based materials. This biocomposite exhibits good thermal and mechanical performances which enable it to be used as thermal insulation materials.

Nowadays, solid wastes generated from agricultural and industrial production activity remain also one of the most solicited renewable resources in the formulation of composite materials [3]. Indeed, the past few years were marked by a dramatic increase in the use of agricultural waste from natural fibers such as leaves from flax, jute, hemp, pineapple, sisal and date palm for making a new type of environmentally-friendly composites [6,20,21]. Algeria (In north of Africa) has a great resource collected from the agricultural waste of date palm (Phoenix Dactylifera L.) [20,22]. Every year, an average of fourteen new leaves and eight bunches per palm can be retained [23]. Agoudjil et al. [23] reported that some farmers use partially this palm wood but the bulk of the material is discarded as waste. Indeed, the formulation of a reinforced composite materials based on this kind of waste can be an excellent solution from an environmental point of view. According to AL-Oqla, Alothman, Jawaid, Sapuan and Es-Saheb [24], the use of date palm fibers, with different types of polymer, can improve the mechanical, thermal and acoustical properties.

Al-Sulaiman et al. [25] fabricated panels of date palm leave reinforced composites, were two types of matrix were selected. The authors have found that all panels exhibit a very low thermal conductivity. Al-Juruf et al. [26] used dry leaves of date palm fronds and suitable binders (Portland cement, gypsum and mixture of Hydraulic cement et gypsum) to obtain thermal insulating material for buildings. They concluded that the palm leave panels are well appropriate for the development of efficient and safe insulating materials. Dehghani et al. [27] have studied the mechanical, thermal and morphological properties of date palm leaf fiber reinforced with recycled poly-ethylene-terephthalate. The authors showed that the addition of date palm leaf fibers enhance the mechanical proprieties. However, the incorporation of the date palm leaf fibers affected the thermal stability of the composite by lowering it. Finally, the authors concluded that the recycled poly-ethylene-ter ephthalate/date palm leaf fiber composite appears to be a good alternative to obtain environmentally friendly products.