Construction and Building Materials 138 (2017) 276–284

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

On thermal characteristics and microstructure of a new insulation material extracted from date palm trees surface fibers

Mohamed E. Ali *, Abdullah Alabdulkarem

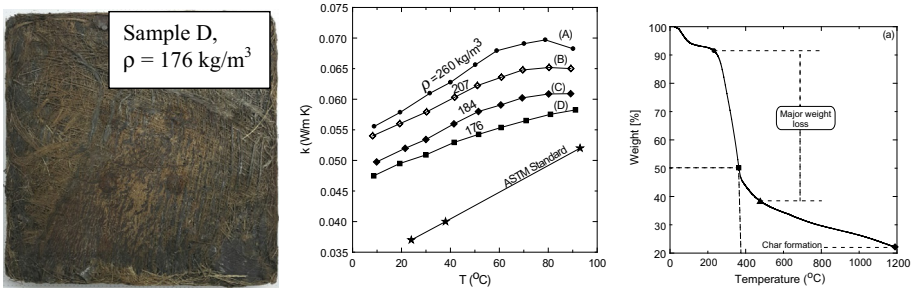
King Saud University, College of Engineering, Mechanical Engineering Department, P. O. Box 800, Riyadh 11421, Saudi Arabia

HIGHLIGHTS

- Thermal and microstructure of date palm tree surface fibers (DPSF) are obtained.
- Thermal conductivity of the proposed insulation material are 0.0475 and 0.0697 W/mK.
- TGA and DTGA indicate the degradation and decomposition of fibers starts at 232 °C.
- DSC analysis is performed and the endothermic transition starts at 243 °C to 382 °C.
- Cornstarch resin is used to bind the fibers that makes the insulation pure natural.

GRAPHICAL ABSTRACT

Cornstarch resin is used to bind date palm trees surface fibers (DPSF) in samples could be used for thermal insulation in buildings. The thermal conductivity of (DPSF) of the samples is obtained in the range 0.0475 and 0.0697 W/m-K for different densities as seen below. Thermogravimetric Analysis (TGA and DTGA) indicates that the degradation and decomposition of the fibers starts at 232 °C where the sample loses only about 8.5% of its original mass and loses about 62% of its weight (triangle symbol) at about 475 °C. The average range of the fiber's diameter is 12–580 μm.



ARTICLE INFO

Article history:
Received 27 August 2016
Received in revised form 5 February 2017
Accepted 6 February 2017

Keywords:
Building insulation material
Date palm trees date surface fibers (DPSF)
Thermal conductivity analysis
Scanning electron microscopy
Differential scanning calorimetry
Thermogravimetric analysis
Organic natural fibers

ABSTRACT

Date palm trees surface fibers (DPSF) are one of the most common environmental waste in the Middle East. Thermal and microstructure of date palm tree surface fibers (DPSF) reveal that they could be used as a new building insulation material. Cornstarch is used as a resin to bind the fibers, which makes the insulation material totally natural. Thermal conductivity of the proposed insulation material is measured for four different densities and the results show that the minimum and maximum values are 0.0475 and 0.0697 W/m-K, respectively. The Scanning Electron Microscopy (SEM) analysis of the fiber diameter shows the average range of the diameter is 12–580 μm. Fourier Transformation-Infra Red (FT-IR) spectra of the fibers is obtained and shows that there are strong stretching peaks at 2918.45 and 2850.6 cm^{-1} which may be due to the presence of Alkane (C-H) functional group. Thermogravimetric Analysis (TGA and DTGA) indicates that the degradation and decomposition of the fibers starts at 232 °C where the sample loses only about 8.5% of its original mass. The Differential Scanning Calorimetry (DSC) analysis is performed and shows that the endothermic transition starts at around 243–382 °C with a peak at 369 °C. Three points bending test is used to determine the maximum flexural strength σ and the Young's Modulus E for some specimens of bounded fibers and relationships between load-deflection and flexural strength-deflection are obtained. The proposed natural material is comparable to conventional insulation material with the advantages of being safe to human beings as well as utilizes waste material.

* Corresponding author.
E-mail address: mali@ksu.edu.sa (M.E. Ali).

http://dx.doi.org/10.1016/j.conbuildmat.2017.02.012
0950-0618/

1. Introduction

Natural fibers are very promising and have great potential as eco-friendly raw materials to be used especially in thermal insulation [1]. Furthermore, natural fibers are biodegradable and have a low environmental impact. Natural fiber composites were likely to be environmentally superior to glass fiber composites in most cases for several reasons such as lower environment impacts compared to glass fiber production, higher fiber content for equivalent performance, end of life incineration of natural fibers resulted in recovered energy and carbon credits [2]. The market for insulation materials is competitive both on performance and on cost. Natural insulation materials are a niche market today. It should be noted that hemp is currently used as a natural insulation material. The environmental performance of hemp based natural fiber has been reported by [3] where they have quantified carbon storage potential and CO_2 emission as well as compared their results with fiber glass composites. Their results showed that hemp-based mat thermoplastic has compatible or even better strength properties as compared to conventional flax based thermoplastics. Structural panels and unit beams have been manufactured out of soybean oil based resin and natural fibers (flax, cellulose, pulp, recycled paper, chicken feathers) using vacuum assisted resin transfer molding technology [4]. Composite panels out of plant oil based resin and natural fiber mats made of flax, cellulose, pulp and hemp have been mechanically tested and found to be suitable in housing construction materials [5]. Laboratory scale periodic cellular beams and plates have been made from industrial hemp and flax fibers with unsaturated polyester resin [6]. The results of [6] indicated that those beams could compete with components made from conventional materials. Review analyses for the production process, structure, properties and suitability of agro-based bio fibers for various industrial applications have been conducted [7]. Mechanical properties of short natural fiber reinforced composites have been reported [8]. Their results showed 3 to 30% improvements in tensile and flexural properties. Four fibers from banana and coconut trees were incorporated in cementitious matrices as an insulation material [9]. Thermal degradation analyses and microstructure tests for different local fibers from different trees were performed [9]. A brief review of the most suitable and commonly used biodegradable polymer matrices and natural fiber reinforcements in eco-composites was reported [10]. Experimental characterization and water absorption of treated and untreated natural fiber composites were carried out [11]. Their results show that natural fiber composites absorb more water than glass fiber composites. A review article about pre-treatments of natural fibers and their applications as reinforcing material in polymer composites were reported [12]. Structural composition and thermal decomposition of fibers made of chemically treated hemp have been presented [13]. His differential thermogravimetric analysis (DTGA) showed that the major degradation of the fiber occurred at temperature between 250 °C and 375 °C. The accessibility of alkali treated coir fiber has been reported [14] where they used differential scanning calorimetry and infrared spectroscopy. Coconut and sugarcane fibers were developed as a biodegradable fibrous thermal insulation [15]. Their results show that the thermal conductivity at 70 kg/m^3 of the sugarcane and coconut fibers is 0.05094 W/m-K (at 24 °C) and 0.04884 W/m-K (at 21.8 °C), respectively. Some insulation materials are hazard to human beings when fire occurs [16]. Therefore, organic foamy materials are not recommended to be used in building walls as insulators. Recently, a new insulating material extracted from the fruit's fiber of calotropis procera plant using corn starch solution as a binder has been reported [17]. Their results show that the average thermal conductivity at 130.47 kg/m^3 is 0.045 W/m-K, which is close to the ASTM standard value. It was also shown that their new developed insulation material could absorb sound as well. A patent on calotropis procera (apple of sodom) trees as an insulation material was filed [18]. Recently, [19,20] has reported the morphology and thermal properties as well as sound absorption characteristic of calotropis procera (apple of sodom) fibers as a promising new natural insulation material. Thermal conductivity measurements were investigated for oil palm, coconut and sugarcane fibers as insulation materials for buildings [21]. The results showed that the measured thermal conductivity is within the range normally used for thermal building insulation. According to Food and Agriculture Organization [22], Saudi Arabia is the third largest date producing countries, with capacity of 1.2 million metric tons/year. Date palm trees produce large quantity of waste which has many applications such as paper pulp production, fibers for composite materials, and activated carbon [23–25]. Date palm trees produce large quantity of waste palm leaves. Each date palm tree produces about 20 kg of dry leaves per year as waste. Burning waste leaves is considered as a common practice in some places, posing environmental atmospheric pollution [26]. Utilization of date palm waste, rather than burning them, is very important to the environment and has economic benefits as well. In addition, 11 million tons per year of agricultural waste is in Saudi Arabia. Most of the waste belongs to date palm trees, which if not utilized properly, could cause environmental challenges. Such waste is renewable resource that can have a large economical benefits [27–28]. Waste of date palm such as: date palm leaflets (DPL), date palm rachis (DPR), date palm trunks (DPT) and date stones (DS) were studied [29] to see the possibility of using such materials for energy recovery, with low emission factors of gaseous and particle patter (PM) in the exhaust which have the most important impact on the environment. An insulation material from date palm dry leaves, which were crushed, to small bits have been developed [30]. Different binders were used such as liquid wood glue, primer and granular wood glue to bind the crushed dry leaves. Their developed material had thermal conductivity of 0.353, 0.258 and 0.227 W/m-K based on the binder. The thermal conductivity of date palm leave (DPL) ranging between 0.17 and 0.24 W/m-K when phenol formaldehyde was used as a binder, and 0.16 and 0.20 W/m-K when bisphenol was used as a binder [31]. The mechanical and physical properties of date palm surface fibers (DPSF) reinforced concrete in hot and dry climate were reported [32]. The potential of using DPSF as reinforcement in polymeric materials was investigated [33]. In their study, chemical, physical and mechanical properties of DPSF were reported. The thermo-physical and chemical properties of the date palm wood (petioles and bunches) are investigated by [34]. Their results showed that an average thermal conductivity of 0.083 W/m-K for both petioles and bunches of the date palm trees. A detailed review about building insulation products made of natural or recycled materials such as reeds, bagasse, cattail, corncob, cotton stalks, date palm, durian, oil palm fiber and others are reported [35].

The main objective of this paper is to investigate the date palm trees surface fibers (DPSF) as a new insulation material extracted from the date palm trees, which is wasted in huge amount and was never investigated in the literature. In addition to that, morphology, thermal analyses and bending test are also performed on the date palm trees surface fibers (DPSF).

2. Fibers Extraction and preparation

Number of date palm trees planted in Saudi Arabia is close to 23.5 million trees, occupying an area of 150,744 hectares. The number of date palm trees planted in Riyadh region alone is about 5.5 million trees [36,37].