Journal of Building Engineering 5 (2016) 34–40

Contents lists available at ScienceDirect

Journal of Building Engineering

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

Thermo physical characterisation of recycled textile materials used for building insulating

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ARTICLE INFO

Article history:
Received 7 July 2015
Received in revised form
9 October 2015
Accepted 31 October 2015
Available online 4 November 2015

Keywords:
Textile waste
Building insulating
Thermal conductivity
Thermal diffusivity
Tablecloth
Linters

ABSTRACT

A recycled textile materials were thermo physically characterized in terms of thermal conductivity and diffusivity. Two samples waste linter (W_L) and tablecloth (W_T) were produced by shredding and mixing. Thermal conductivity and diffusivity were experimentally determined by means of the Box Method equipped with a flash. The Parker equation and Degiovanni equation were used to evaluate the thermal diffusivity. Studied properties were compared to other usual building insulating materials. Results show that the thermal conductivity of W_T and W_L were 0.033 W/mK and 0.039 W/mK, respectively. In addition, the thermal diffusivity was found to be about 5.8×10^{-3} m^2/h in the case of W_T and about 3.8 m^2/h$\cdot 10^{-3}$ for W_L sample. Therefore, the recycled textile materials have competitive thermal properties and could be used in the building insulations materials.

1. Introduction

Currently, the building sector is a heterogeneous field where the characteristics of each building depend on the climatic conditions. In addition, this sector has a high-level energy consumption and CO_2 emissions. For example in UE, the energy consumption and the CO_2 emissions are estimated to about 40% and 36% respectively [17].

According to a literature review [4,10,11,13,14,19,20,24,28,29], a good insulation in building could save about 65% in domestic energy consumption. To achieve this target many materials have been developed. New approaches are focusing not only on the energy efficient but also upon ecological and environmental properties. Therefore, the textile materials, specially reused textile waste, have been selected to perform new research according to its good properties: toxicities absorbents, air purifier, humidity comfort, vibration absorbency and radioactive emissions: materials having a high affinity towards man.

Textile materials have been used in construction sector for decades and their use has been rapidly increased since synthetic fibre production [3,12]. Some relevant studies are concerning the effect of used raw materials such as flax and hemp [12] or untreated and treated textile materials like jute, flax and hemp [22,25]. Also Vrána and Gudmundsson studied the use of cellulosic fibres in building and compared to a stone wool material [26]. Some researchers focused on the reuse of some textile waste like wool ([30]; Hemp technology, 2013; Sheepwool Insulation, 2013; Black Mountain, 2014; [18]), recycled carpet [21,27] or cotton fibres mixed with ash and barite [3]. In addition, textile materials were used as reinforcement in building [9,15] or as radioactive absorbent materials like cotton [3].

According to Turkish Standards TS 825 and Institute of German Standards DIN 4108 [8], if thermal conductivity of a material is less than 0.06 kcal/m h °C (0.06966 w/m °C=0.07 w/m K)), this material will be considered as “thermal insulator”. If its conductivity is higher than the critical value, 0.060 kcal/m h °C, then it will be classified as “construction material” [3,23].

Thus the insulation performance of building envelops is determined by the thermal properties and method of insulation in use. Researches and studies on insulation method and materials have been conducted. Nevertheless, until now relevant and fundamental data on various applied insulation materials and insulation systems in recent building is still lacking.

In this work, thermo physical characterisation of two recycled textile waste materials used in order to use them for building insulating is studied. The thermal conductivity and diffusivity were experimentally determined by means of the box method equipped with a flash. The results show that the used materials have completed thermal properties and could be used as building insulators compared to others known materials used in this field.

2. Materials and methods

In this section, the production of reused textile waste materials, climatic conditioning and the box method equipped with a

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http://dx.doi.org/10.1016/j.jobe.2015.10.007
2352-7102/

Nomenclature

A	area (m^2)
C	overall coefficient of heat through the walls of the waste box (W/K),
C_p	the specific heat capacity (m^2/h)
R	electric resistance, used to heat the box (B) (Ω)
R_{th}	thermal resistance
T	temperature (°C)
t_h	thickness (m)
U	terminal voltage of the heating resistance (V)
W	textile waste

Greek symbols

ρ	density (Kg/m^3)
α	thermal diffusivity (m^2/h)
δ	penetration depth (m^2)
λ	thermal conductivity (W/m k)

Subscripts

a	ambient
B	box B
co	cold side
c	cooper (a sample holder in cooper)
h	hot side
I	of sample i, or material i
L	linters
s	sample
T	tablecloth
th	thermal
$total$	materials arranged in series
$Tseries$	total resistance, equivalent to the resistances connected in series

flash will be presented. The thermal conductivity and diffusivity determination of used materials will be investigated.

2.1. Shredding and production of the tablecloth textile waste

Various textile wastes fulfil the storage silos. At this stage, the uniformity and the composition ratio of each component should be considered. For this purpose, the variable metering device, item (2), is used. The material, then in its final composition, is passed to the collection conveyor, item (3). This blended material is passed to a cutting mill (4). Subsequently a pneumatic system, item (5), conveys the material to a mixer, item (8). From the mixer the material is passed to the delivery system, item (11) and, by means of this material delivery system, the material is uniformly and continuously conveyed to a double-band conveying press. In this press the still voluminous material is compressed. For insulation material lower densities are attained, but for products to be used for higher load as, for instance, sound insulation on flooring, high densities are necessary. After having left the pressing section, item (12), after a curing time of approximately 3–4 min for the purpose of hardening the binding agent, the compressed material passes the duration zone, item (13). The endless material band is automatically cut to the desired length and finally, the piled on pallets.

Two recycled textile samples used in this study are:

1. Waste Linters, W_L (Fig. 2a): taken from the output of cutting mill (4) (see Fig. 1).
2. Waste Tablecloth, W_T (Fig. 2b): taken from the cutting table (14) (see Fig. 1).

2.2. Climatic conditioning

Before testing, samples were conditioned at a test atmosphere: 23 °C ± 0.5 and 50 ± 5%. The used climatic chamber is equipped with a high accuracy electronic scale connected to a recorder and monitoring the sample weight until equilibrium is established.

2.3. Material structure

The longitudinal views of the textile waste tablecloth were determined by scanning electron microscope (SEM), the Samples were observed initially in their original form in idle state. Two random samples were selected from this specimen for observation purpose. Fig. 3.

2.4. Box method

In order to test the samples (table cloth and linters), a sample holder in copper is used (Fig. 4). It is placed between two boxes (A) and (B). A uniform temperature is imposed in the box (B) by modifying the voltage (V) applied across the plate. An electronic ohmmeter is used to measure the heat resistance (R), in order to evaluate the amount of heat produced in the system by joule effect.

The thermal gradient imposed between box (B) and (A) creates a heat flow between the two faces of the sample as said (placed in a copper lid). The measurement is performed in a few hours (generally not exceeding 3 to 6 h) to allow the system steady state. The box (A) is insulated using an expanded polystyrene thick layer. A heat exchanger based on a cryostat-controlled temperature using a glycol–water mixture is used to fix the Box (A) temperature (T_A) lower than the ambient one (T_a). The heating set up is controlled by a variable electrical transformer. Five temperature sensors were used to record temperature as follow: two probes, respectively, placed in the top and back side of the sample (T_h and T_c). (T_a) is used to record ambient temperature. The (T_A) and (T_B)sensors are used to record temperature in the Two boxes (respectively (A) and (B)), as shown in Fig. 5.

The same setup was used to determine the thermal conductivity and diffusivity. For the first mentioned, the heating source is a heating resistance. For the last one a flash heating was used.

2.5. Thermal conductivity determination

Two cubic samples (Tablecloth waste sample: W_T) of 27 × 27 × 2 cm^3 were prepared. Samples were, first, dried in a drying oven at 50 ± 2 °C and weighted at 24 h interval until equilibrium is established (the loss in weight did not exceed 1% in a 24 h). Then samples were placed in a copper lid with 27 × 27 × 4 cm^3 and examined according to the box method process.

In the same way, the linters sample (W_L) of the same weight is prepared, conditioned and placed in the cubic copper lid and examined in the box method.

The steady state is obtained by controlling the temperature changes (T_B)in the box (B) and the ambient temperature(T_a) and it is reached when $T_B - T_a < 1$ °C.

The measurement is based on the principle of energy conservation in the system consisting of the Styrofoam box and the