Construction and Building Materials 38 (2013) 155–160

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

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

# Textile waste as an alternative thermal insulation building material solution

Ana Briga-Sá [a,b], David Nascimento [a], Nuno Teixeira [a], Jorge Pinto [a,c], Fernando Caldeira [d], Humberto Varum [e,*], Anabela Paiva [a,b]

[a] University of Trás-os-Montes e Alto Douro, 5001-801 Vila Real, Portugal
[b] C-MADE, University of Beira Interior, 6201-001 Covilhã, Portugal
[c] I3N, University of Aveiro, 3810-193 Aveiro, Portugal
[d] University of Fernando Pessoa, 4249-004 Porto, Portugal
[e] University of Aveiro, Civil Engineering Department, 3810-193 Aveiro, Portugal

## HIGHLIGHTS

- Study of a new sustainable building material.
- Textile wastes reuse.
- Innovative sustainable solutions for non-structural applications (thermal insulation).

## ARTICLE INFO

*Article history:*
Received 18 March 2012
Received in revised form 2 August 2012
Accepted 14 August 2012
Available online 21 September 2012

*Keywords:*
Textile waste
Thermal conductivity
Eco-efficient building solution
Sustainability

## ABSTRACT

The adoption of more sustainable behaviors, particularly in what concerns to the reduction of energy consumption and the emissions of greenhouse gases, is nowadays a priority. The construction sector is one of the key areas of intervention, which carries a high consumption of resources such as materials, energy, and water. Thus, it is essential to adopt more efficient actions during all stages of the construction process, including the use of more sustainable materials. The reuse of different types of waste in the construction or rehabilitation of buildings can contribute significantly to sustainability.

In this research work, the potential applicability of woven fabric waste (WFW) and a waste of this residue, named woven fabric subwaste (WFS), as thermal insulation building material was studied. Experimental work was conducted using an external double wall, with the air-box filled with these two types of waste, to determine their thermal characteristics. Two heat flowmeters and four surface temperatures sensors were placed on the wall surface to determine the thermal conductivity of the wastes.

The obtained results show that the application of the WFW and WFS in the external double wall increases its thermal behavior in 56% and 30%, respectively.

The thermal conductivity value of the WFW is similar to the values obtain for expanded polystyrene (EPS), extruded polystyrene (XPS) and mineral wool (MW). The value of this parameter for the WFS is approximately equal to the values for granules of clay, vermiculite or expanded perlite. Therefore, applying these wastes as a possible thermal insulation material seems to be an adequate solution. Environmental, sustainable and economical advantages may result from this practice.



## 1. Introduction

The high energy consumption, the climate changes and the scarcity of natural resources require a human behavior more ruled by sustainable criteria to ensure the living of modern society and guarantee the future of the coming generations.

Taking into account that the construction sector carries out a high consumption of resources such as materials, energy, and water, it is imperative the use of more sustainable construction solutions.

The integration of ancient construction techniques and the reuse of materials and waste can contribute significantly to sustainability. The adaptation of construction techniques of the past to the current constructions has been made at various levels, particularly in what concerns to the use of earth and renewable energy sources such as solar energy. Work has been developed in order to recover the use of earth as a building material, namely as adobe, taipa and tabique [1–3]. The use of solar energy is also an important way to turn buildings more sustainable and more energy efficient. The use

* Corresponding author. Tel.: +351 91 9369393; fax: +351 234 370094.
*E-mail address:* hvarum@ua.pt (H. Varum).

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http://dx.doi.org/10.1016/j.conbuildmat.2012.08.037

of passive solar systems was a technique commonly used in the past which has been lost a long time due to the emergence of new materials and technologies. However, recent studies show that their integration in the building envelope improves its thermal performance and increases its level of sustainability [4–7].

In addition to these techniques, the reuse of materials is also an area of great interest and with potential application due to the high amount of waste that is produced around the world in the most varied activities. So, it is important to analyze the reuse of materials and different types of waste in buildings construction [8–10]. Their integration can be carried out as thermal or acoustic insulation, structural reinforcement, or as coating and finishing material, among others. Different materials and waste with different origins have been studied. Research has been developed to study the potential application of natural material as thermal insulation [11–15] and of industrial and agricultural solid waste as a raw material to obtain lightweight bricks [16] or as concrete and soil reinforcement [17,18].

Textile waste integrates the group of reusable materials that can be included in the building construction and which have different possibilities of application. These textile wastes may have origin in the textile industry or may simply result from clothes that are no longer used. The study of the performance of these types of wastes in the construction should be partly based on the behavior of the tissues when they are used as clothing. The primary function of clothing is to protect the human body from cold and heat, in order to keep thermal comfort conditions. This can be acquired ensuring an appropriate heat transfer between the human body and the outside environment. In this regard, studies to analyze the phenomena of heat transfer through the textile fabrics have been developed. These studies show that their thermal insulation properties are highly related to the properties and configuration of their components, namely to the capillary structure, surface characteristics of yarns and air volume distribution in the fabrics [19–21].

Thus, the knowledge of thermal, mechanical and physical performance of various types of textile fabrics and their residues is essential to optimize its use as a raw material in the building construction.

Different textiles fibers are analyzed as a material to produce lightweight concrete, as reinforcement of cement mortars elements [17,22–24], or as fibrous insulation materials [25–27].

However, regarding the use of textile waste, further investigation is needed. The work developed so far is based essentially on the use of textile waste in the production of bricks and lightweight materials [28–31], more particularly using cotton combined with other materials, such as limestone powder, fly ash, barite, and paper. Sound insulation, thermal conductivity, bending strength and radioactivity are some of the properties studied.

In order to contribute to the scientific knowledge in this area, research work has been developed to study the use of woven fabric waste (WFW) and a waste of this residue, named woven fabric subwaste (WFS), as an alternative solution to commercial insulation materials, such as extruded polystyrene (XPS) or expanded polystyrene (EPS) products.

Experimental work was carried out to examine the influence of introducing each one of these textile wastes in the thermal performance of a external double wall. The heat transmission coefficient ($U$) of the double wall with the air box filled with these types of waste was determined. These results were used to calculate the value of thermal conductivity of WFW and WFS.

This paper is structured as follows: firstly, the textile waste is briefly put into context; secondly, the adopted methodology and the experimental setup are presented. Also, the equipment and the external double masonry wall model are described in detail; thirdly, the obtained experimental results are analyzed and discussed. The thermal transmission coefficient of the two studied technological solutions and the thermal conductivity of the two analyzed textile waste types are quantified and delivered; finally, the main conclusions of this research work are drawn.

## 2. Textile waste context

In the European Union (EU), around 5.8 million tonnes of textiles are discarded by the consumers per year. Only 1.5 million tonnes (25%) of these textiles are recycled by charities and industrial enterprises. The remaining 4.3 million tonnes goes to landfill or to municipal waste incinerators [32]. Adding to this type of waste, there is also the textile waste from the textile industry. This shows that there is a enormous source of secondary raw material that is not used, but can be re-injected into the market.

Thus, environmental concerns with the waste resulting from the textile industry have been increasing. This issue has been addressed by the European policies in order to define laws to regulate the management of waste.

In order to encourage recycling in the EU, the Directive 2008/98/EC [33] has been published on December 2008, as a recast of the Waste Framework Directive (WFD), Directive 2006/12/EC [34].

In Portugal, the main textile waste become from wool, cotton and synthetic and artificial fibers, according to the Technical Guide of the Textile Sector [35]. In 2009, 293,000 tonnes of textile waste were produced, according to National Plan for Waste Management [36].

After visiting several textile factories laboring in the north part of Portugal, it was found that there is a substantial amount of waste resulting from this industry.

Clothes, woven fabrics and threads are among the most common types of waste. Composition, texture and size are some material properties which may vary sharply as far as textile waste is concerned. Cotton, wool, linen, silk and acrylic are some possible composition of a textile product. On the other hand, the structure, the thickness and the arrangement of the threads are some parameters that contribute for the possible different textures that a textile fabric may have. For instance, taking into account that a textile waste results from the clothing process, in which there is an optimization of the fabric piece preparation, waste with different size and shape will result from this process. Therefore, the different properties of the materials may increase the difficulty of studying possible textile waste applications. Considering that a mixture of these materials is also very likely to occur then this complexity is even more evident.

The two types of textile waste studied in this research work, WFW and WFS, are presented in Fig. 1a and b, respectively.

Both materials are 100% acrylic. The density of the WFW and the WFS products was specifically quantified in this research work and the respective approximate values are 440 kg/m$^3$ and 122.5 kg/m$^3$, respectively.

In the building industry application context, the potential of using these two types of textile waste as an alternative thermal insulation solution for external double walls is emphasized in the following sections.

## 3. Methodological strategy and experimental setup

The methodology used to analyze the thermal insulation potential of the two textile waste types considered in this research was based on experimental work according to ISO 9869 entitled *Thermal Insulation: Building Elements – In Situ Measurement of Thermal Resistance and Thermal Transmittance* [37].

In order to apply this methodology to WFW and WFS to determine their thermal conductivity, an external double wall model was built. This wall was specifically built up in a test room, having as basis an existing simple external wall, composed by a cement based brick masonry wall with cement based coating mortar in both sides, southwest oriented. The chosen orientation was related to the existing