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# Textile fibre waste bindered with natural hydraulic lime

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The reuse of waste materials can contribute to improve the sustainability of materials. In the EU, consumers discard around 5.8 million tonnes of textiles per year and only the 25% is recycled. The aim of this paper is to present the results of the research conducted to use textile fibre waste in boards. They were bindered with the minimum hydraulic lime in order to reduce its environmental impact in comparison to other boards, while preserving its mechanical and physical requirements for the purpose.



## 1. Introduction

Residential sector has an enormous impact in the energy consumption and the $CO_2$ emissions. In the European Union, buildings are responsible of the 40% of the final energy consumption [1] and the 36% of the total $CO_2$ emissions. As consequence, in March 2007, the European Council defined the "20-20-20" objectives to be achieved in Europe at 2020 [1]. Although it mainly focused on energy demands, in order to satisfy minimum comfort requirements, a limitation of noise transference through constructive systems should be also taken into account.

In addition, the influence of the materials and construction processes, their energy efficiency in terms of low environmental impact has become increasingly urgent. From this point of view, waste materials can be reintroduced into the economic cycle and their use would contribute on the improvement of the life cycle assessment. Since 2002, different guidelines and legal framework had appeared in terms on waste management and promotion of recycling the waste in the European Union [2,3].

In the EU, consumers discard around 5.8 million tonnes of textiles per year. Only 1.5 million tonnes (25%) of these textiles are recycled by charities and industrial enterprises while the remaining, 4.3 million tonnes, goes to landfill or municipal waste incinerators [4]. Adding to this type of waste, there is also the one from the textile industry, which is coming out from the manufacturing process and does not need any special management through specific recycling companies. These wastes are composed by thread tails, fabric scraps, quality control rejects patches and so on. Only in Spain, in 2011, 301.600 tonnes of textile waste were generated, according to the information given by the CITYC (The Centre of Information about Textile and Clothing Industry, A.I.E.). In addition, textile fibres are manufactured, from a unique type of fibre as well as from the combination of several fibres, natural or synthetic, providing a huge variety of final products [5]. In Fig. 1, impact on the produced waste of each type of textile fibres in 2011 can be observed, in which should be highlighted polyester and acrylic fibres. This mixture in the wastes is another reason of their non-biodegradability which causes that this textile cutting waste from industries becomes an environmental nuisance and commonly ends in incinerators realising highly toxic fumes in the surrounding air [6]. Hence, the advantage of using these types of wastes is double: the reduction of their environmental impact and the reduction of the energy consumption in the production of new ones with their reintroduction in the production line. Several researches had been developed to introduce textile wastes into the building materials and increase their life cycle. The use of sludge coming from the production of textiles had been investigated to partial replacement of cement [7]. As well as the ash coming from textile factory wastes is introduced in fired bricks [8] and wall and

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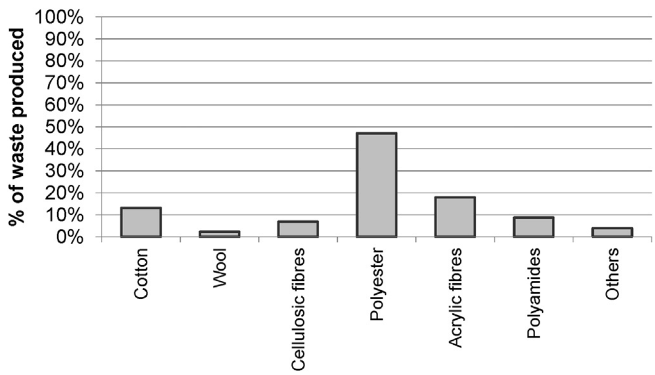


**Fig. 1.** Distribution of the type of textile waste produced in 2011 in Spain (Information provided by Cityc).

ceiling panels [9]. Furthermore, Algin et al. introduced cotton wastes (in mixture with stems, leaves, soils and lint) into concrete blocks [10]. However, the most common way to introduce these wastes is based on its use as fibres to increase strength, physical performance as well as durability by reduction of the cracking. Opposite to agro-based fibres, textile fibre shows a higher homogeneity in its performance [5]. From this point of view, textile materials have been used for decades in the construction sector. There are some advantages of textile fibre use in buildings. The weight of a fabric is 1/30 of the brick, steel or concrete. So that, less reinforcement can be used and also production cost can be decreased [11]. Their use as fibres instead of straws was highlighted in mud-brick structures [12–14] to get an earthquake-resistant material [12] and to reduce the thermal conductivity [13] as well as sound insulation material [14]. In hydraulic lime, textile wastes were introduced up to 0.5% for mortars [15] and up to 4% for renders [16]; while, in cement, they were introduce in cement bricks [17] as well as mortars [16,18]. Furthermore, textile wastes were also used in reinforced polymer concrete [6] and in lightweight concrete partitions [19]. In addition, other authors examined textile wastes possibilities in unsaturated polyester resin [20].

Nowadays, thermal and acoustic insulation materials play an important role in achieving buildings' efficiency. Textile materials were also evaluated as both thermal and acoustic materials when blends with fly ash and epoxy resin [11]. Briga-Sá et al. carried out an experimental work to examine the influence of introducing woven fabric waste and woven fabric subwaste in the thermal performance of an external double wall [21]. Zhou et al. [22] published an article about the use of cotton stalk fibres by high frequency hot pressing to achieve a thermal insulation material with a result that could be similar to a commercial product called Boltherm 501 for acoustic insulation composed of textile fibres. Regarding other waste materials, a new composite board with low-thermal conductivity made from a mixture of solid wastes from tissue paper manufacturing and corn peel into a urea formaldehyde resin solution was reported by Lertsutthiwong et al. [23] while wasted newspapers were used in aerated lightweight concrete panels by Soon-Ching and Kaw-Sai [24].

On the other hand, the use of chemical binders is common in the case of the board production in spite of their disadvantages due to the contaminants emissions to the internal spaces and toxicity to humans as well as their fire performance. To avoid them, it was selected the use of natural hydraulic lime which is a binder with a lower embodied energy than cement and a higher water vapour permeability. The latter could be advantageous in the case of insulation panel in order to avoid water condensation and given its strong bond [25]. However, its use as binder in textile wastes boards had not been thoroughly investigated up to now, except for Pinto et al. [16] centered their research on the use of a low percentage (up to 4%) of textile wastes as fibre reinforcement as alternative to polypropylene fibres [26–28]or other type of fibres such as glass, basalt [29] or hemp [30].

Hence, this paper summarizes the results of the research conducted in order to propose the use of textile fibre wastes in boards. They were bindered with the minimum amount of hydraulic lime in order to reduce its environmental impact in comparison to others boards, while preserving its mechanical and physical requirements for the purpose.

## 2. Materials and methods

### 2.1. Materials

The materials used in this research were natural hydraulic lime as main binder and textile wastes as fibrous and lightening material. A natural hydraulic commercial lime, designated NHL-5 (according to UNE EN 459-1:2011) was employed. It was supplied by FYM-Italcementi group and commercialized by the Arrigorriaga factory. According to the company, the hydraulic lime is mainly composed by portlandite (38%), followed by 28% of $C_2S$ and 21% of calcite, while its fineness is 9837 $cm^2/g$ and its bulk density is 769 $g/cm^3$.

Textile waste was supplied by Texlimca S.L., and was a by-product mainly composed of cotton as was concluded after burning them. A mixture between organic and synthetic fibres is shown in Fig. 2. Fibres were about 4–82 cm long and 0.05 mm–0.4 mm of thick in dry state. No preparation of the fibres was included in order to minimize board production costs.

### 2.2. Preparation

The incidence of the water content on the boards as well as the binder content was evaluated by some preliminary tests in which two different methods were applied. Firstly, fibres were saturated in water before getting mixed with the lime paste, while in the other case fibres were used in dry state. In both cases, lime paste was added to the maximum amount of textile wastes its water content varying from 1:0.5 to 1:2 (lime: water), by mass. Table 1 shows the composition of the three different mixtures. As a result of those preliminary tests it was found that the use of dry fibres generated a material with a higher porosity than the use of saturated fibres, which could be interesting to reduce the bulk density of the boards. At the same time, 1:0.5 dosage ratio was discarded because of the awkward workability of the mixture, given its low water content. Concerning the procedure, water was gradually added to the lime up to fixed amount. The mixture was manually blended for 300 s for homogenisation. Later, lime paste was added to the textile wastes placed into 240 × 240 × 30 mm moulds for thermal conductivity tests and 240 × 90 × 30 for mechanical and physical ones. At the same time, specimens of 29 mm of diameter were prepared to perform the measurement of the sound absorption coefficient at normal incidence as well as the stereomicroscopy observations. Three different specimens were prepared in all cases. Cured samples were unmolded after 7 curing days and kept under laboratory conditions up to 28 days of curing time, when they were tested. In addition, in the case of thermal and acoustic analysis, samples were desiccated in a drying chamber at 40 °C ± 5 °C for 15 days to ensure a complete curing without modifying their mineralogical structure [31]. All tests were performed on three samples.