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A review on the properties of cellulose fibre insulation

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ABSTRACT

The building sector is constantly innovating in its use of materials with regards to sustainability. There is a need to use cost effective, environmentally friendly materials and technologies which lessen the impact of a construction in terms of its use of non-renewable resources and energy consumption. Cellulose fibre insulation is an eco-friendly thermal insulation material made from recycled paper fibres. It offers good thermal properties and has a low embodied energy. However due to lack of expertise in its application and properties, cellulose insulation is not widely used in comparison to more traditional insulation materials. The present paper reviews the available research on cellulose fibre insulation, its manufacture, installation, and performance. The paper focuses the physical properties of cellulose insulation, the environmental factors that affect these properties, and possible means of future innovation.

Contents

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Table 1
Embodied energy per kg of different insulation materials, data from Ref. [18].

Insulation material	Embodied energy (MJ/kg)
General Insulation	45
Cellular Glass	27
Cellulose	0.94–3.3
Cork	4
Fibreglass (Glasswool)	28
Flax (Insulation)	39.5
Mineral wool	16.6
Paper wool	20.17
Rockwool	16.8
Woodwool (loose)	10.8
Woodwool (Board)	20
Wool (Recycled)	20.9

1. Introduction

Energy efficiency in buildings is an important factor in contributing to the reduction of greenhouse gas emissions The building and construction sector accounts for 30%–40% of world-wide energy consumption [47], with a large part belonging to the need to heat and cool buildings. It is with that in mind that many countries are looking to improve the energy efficiency of buildings with better insulation materials and technologies applied to the building envelope, with directives such as the European directive 2010/31/EU which states that new constructions in 2020 will have to consume 'nearly zero-energy' [14].

The main role of thermal insulation materials in a building envelope are to prevent heat loss and provide thermal comfort for a building's interior. The factor that characterizes an insulation material's effectiveness is its thermal conductivity λ (measured in W/mK). The lower a material's thermal conductivity, the more effective it is as an insulator, thus requiring a thinner layer to provide the same interior temperature. Traditional insulation materials include glass fibre, stone wool, expanded polystyrene, and polyurethane foam. While these materials are efficient in maintaining thermal comfort to a buildings interior, they are made with non-renewable resources and have a high embodied energy. Consequently, there is an increasing interest for alternative insulating materials that come from renewable or recycled fibres. Natural fibres such as jute, flax and hemp have shown to be suitable alternatives to mineral insulation and are the subject of numerous research projects [23].

One such material is cellulose fibre insulation (CFI). Comprising mostly of recycled paper fibres, cellulose is increasing in popularity due to its eco-friendly nature and favourable thermal and acoustic properties. Even amongst other insulation materials CFI presents some of the lowest embodied energy per kg of material, as is shown in Table 1 [18]. Despite growing interest, Cellulose and other natural insulation materials still only represent a low percentage of total European market share [29]. This is partly due to the fact that cellulosic fibres, while having favourable thermal properties, still have some disadvantages compared to traditional fibres. Some factors such as its high hygroscopisity, potential for combustibility and for fungal growth can limit CFI from having a more widespread usage in construction and renovation projects. Proper knowledge of these limits, their causes and their effect on the properties of the insulation material are necessary to ensure that sustainable materials such as CFI become more common in the building sector and thus help contribute to the reduction of the environmental impact of construction and renovation projects.

The aim of this paper is to review the available information regarding cellulose fibre insulation (CFI). First the general context on CFI is given, including its background and main methods of fabrication and installation are presented. The available research on the properties of CFI is exposed, as well the different conditions that affect these properties. Finally the paper comments on possibilities for future investigation on the material and improvements of its properties.

2. A background on CFI

2.1. Composition

Cellulose fibre insulation is mainly composed of ground paper fibres treated with inorganic additives that act as fire retardants and mould growth inhibitors. Its consistency is similar to that of cotton wool. The source material for the cellulose fibres are usually recycled newspaper, coming from either unsold or recovered papers. Newsprint is generally manufactured by mechanical pulp. Recycled newsprint or chemical pulp could also be incorporated. As with most lignocellulosic fibres, newsprint is comprised of a mix of cellulose hemicelluloses and lignin. Unlike chemical pulping, mechanical pulping results in little removal of lignin content. Mineral and organic additives, such as kaolins, china clay or cationic starch are also incorporated into the paper pulp in order to improve such properties as paper opacity, moisture retention, and strength. The inks typically used in the paper are produced from inorganic carbons, with the chromatic inks coming from organic pigments. The average proportions of the main components in newsprint and office paper (chemical pulp) are presented in Table 2 [50].

2.2. Production

As a final product, cellulose insulation can come in two forms: as a prefabricated panel, in which the cellulose fibres are moulded with polyester or a similar binder or, more commonly, the loose fibres are sold in bulk form to be manually applied on attics, ceilings, or walls. The first use of cellulose fibre as an insulation material can be traced back to 1919 in Canada [40], but it was until the 1950s that commercial cellulose insulation products became commercially available in the US, where it was mostly used for attic retrofitting. CFI surged in popularity in the US in the 1970s due to an increased interest in energy performance following the American oil embargo of 1973.

In a typical production process of CFI (see Fig. 1), newspaper arrives in bulk to the manufacturer and is then sorted to remove any foreign objects. Items such as clips and plastics are removed, but also low quality or humid paper is also sorted. The newsprint passes through a feeding conveyor (1) then is torn to smaller pieces that are between 2 and 4 cm in diameter in a shredder (2). The fibres then pass through a cyclone separator (3) in order to remove any remaining staples or other metallic elements. The fines from the shredded paper are blown through a filtering unit (4). The material then goes through a fiberizer (5) which uses high

Table 2
Average component proportions of newsprint and office paper, [50].

	Cellulose %	Hemicellulose %	Lignin %	Extractives %	Proteins %	Ash %
Office paper	67.4	13	0.93	0.7	0.31	11.6
Newsprint	48.3	18.1	22.1	1.6	0.44	2