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Insulation materials for the building sector: A review and comparative analysis

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ABSTRACT

The energy consumption of a building is strongly dependent on the characteristics of its envelope. The thermal performance of external walls represents a key factor to increase the energy efficiency of the construction sector and to reduce greenhouse gases emissions. Thermal insulation is undoubtedly one of the best ways to reduce the energy consumption due to both winter heating and summer cooling. Insulation materials play an important role in this scenario since the selection of the correct material, its thickness and its position, allow to obtain good indoor thermal comfort conditions and adequate energy savings. Thermal properties are extremely important, but they are not the only ones to be considered when designing a building envelope: sound insulation, resistance to fire, water vapor permeability and impact on the environment and on human health need to be carefully assessed too.

The purpose of the paper is to provide a review of the main commercialized insulation materials (conventional, alternative and advanced) for the building sector through a holistic and multidisciplinary approach, considering thermal properties, acoustic properties, reaction to fire and water vapor resistance; environmental issues were also taken into account by means of Life Cycle Assessment approach. A comparative analysis was performed, considering also unconventional insulation materials that are not yet present in the market. Finally a case study was conducted evaluating both thermal transmittance and dynamic thermal properties of one lightweight and three heavyweight walls, with different types of insulating materials and ways of installation (external, internal or cavity insulation).

Contents

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1. Introduction

In the last decades the attention towards energy and environmental issues has grown exponentially and many international and national policies have been developed in order to guarantee a more sustainable future to the planet. Within this context, the European Union [1] paid particular attention to the building sector, since it is responsible for 40% of the total energy consumption in Europe. Furthermore, the unrealized energy efficiency potentials in the building sector are enormous and the massive adoption of energy savings measures in this sector could represent a solution for a strong decrease of greenhouse gases emissions [2]. The external envelope of a building plays an important role since it strongly affects the surrounding microclimate [3–5] and it is a border between the internal and the external environment, influencing the thermal comfort of the inhabitants [6,7] and the energy losses during the operating phase [8,9]. In the context of sustainability, Life Cycle Assessment of buildings components and also of entire buildings has become more and more important, in order to take into account the whole energy uses starting from the construction up to the demolition [10,11]. Several environmental buildings assessment protocols such as LEED or BREEAM [12] are now widespread in order to rate the actual sustainability of a building. The largest part of buildings energy consumption can still be attributed to the operating phase, which is influenced by several factors like the efficiency of the HVAC systems [13], windows and door thermal insulation [14–17], losses through thermal bridges [18] and opaque wall thermal performance [19]. The development of the latter feature in the last decades has led to optimum thermal performance of vertical walls in terms of thermal transmittance. Moreover the incidence of the thermal losses through the opaque walls on the whole energy losses of the building represents a large amount [20], so the use of adequately insulated walls has become essential. Within this context, the insulation material is the layer that mainly contributes to the overall thermal behavior of the opaque walls during winter and summer seasons, responding to the external conditions with its specific thermophysical properties [21]. Insulating materials must guarantee acceptable performance throughout the whole life cycle of the building, but thermal performance is not the only parameter that should be addressed when selecting an insulator; the choice of these materials in the building sector is starting to be inspired by a holistic approach, which considers also non-thermal features such as sound insulation, resistance to fire, water vapor permeability and impact on the environment and on human health. Consequently the market of eco-friendly, local and sustainable insulation materials, characterized by decent insulation performance and low embodied energy [22], is rapidly growing [23]. At the same time innovative insulators, such as VIP (Vacuum Insulation Panels), GFP (Gas Filled Panels) and aerogels, which combine thinness, lightness and extremely low values of thermal conductivity, are entering in the market [24]. Furthermore several studies have showed that the use of PCM (Phase Change Materials) as thermal storage systems in buildings can bring to significant energy savings [25,26]; however this class of materials has not been analyzed in the present paper.

The main goal of the paper is to provide an overview of the insulation materials for the building sector taking into account the main commercialized products that cover three areas: conventional, alternative, advanced. Each material was described considering several features, in order to give a global view of the products. A review of the main international standards for the evaluation of the product characteristics constitutes the first part of the paper; thermal and acoustic properties, water vapor resistance, reaction to the fire and