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A review of the performance of buildings integrated with Phase change material: Opportunities for application in cold climate

Habtamu B. Madessa*

Institute of Building and Energy Technology, Oslo and Akershus University College of Applied Sciences, NO-0130 Oslo, Norway

Abstract

Buildings generally need serious attention in order to reduce global energy consumption and greenhouse gas emissions. Phase Change Materials (PCMs) that change phase just above normal room temperature are a promising means of reducing cooling-energy demand, and improving thermal comfort in buildings. This paper reviews the literature from studies of the thermal performance of different types of PCM and different ways of integrating them into buildings. Based on this review, the paper closes with an investigation of the potential for application of PCMs in passive-house standard dwellings and office buildings in the Nordic climate.

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Keywords: Passive house; Phase Change Materials (PCMs); Cooling systems; Lifecycle assessment

1. Introduction

Buildings account for approximately 40% of the total energy use in Europe [1, 2]. A significant amount of this goes to space heating and cooling. In a bid to reduce this energy use and its related environmental impacts, all EU/EEA member states have tightened their national building regulations in line with European directives (most recently EPBD-Recast). These changes promote higher levels of thermal insulation along with lightweight building structures in order to minimize energy demand. However, initial studies have revealed that these energy-efficient buildings can experience problems with thermal discomfort due to elevated indoor air temperatures in warm weather[3]. One interesting way of easing this problem is to incorporate Phase Change Materials (PCMs) into the building fabric, in order to increase the effective heat storage capacity of lightweight buildings. PCMs are also

* Corresponding author. Tel.: +4745004121; *E-mail address:* Habtamu-Bayera.Madessa@hioa.no

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incorporated building components other than fabric in order to increase the energy effectiveness of the building.

Best practice use of PCMs involves exploiting diurnal swings in outdoor temperature, whereby absorbed heat during the daytime is released at night when the outdoor and indoor air is cooler. Thus, PCMs serve to dampen the amplitude of indoor temperature swings and thus reduce peak indoor temperatures. This ensures better thermal comfort for occupants, while at the same time reducing, or avoiding the need for mechanical space cooling.

Several authors have investigated, both theoretically and experimentally, the thermal performance of PCMs incorporated into standard buildings for the passive cooling of building spaces [4-7].

In this paper, reviews on thermal energy performance of PCMs incorporated at various elements of buildings are presented. A through discussion on the possible applications of PCMs on buildings designed according to passive house standards is also included.

2. Phase Change Materials (PCMs)

PCMs are materials that undergo a phase transition between liquid and solid when heated or cooled, much like H_2O changing between ice and water. At the temperature at which phase change occurs, PCMs store incoming thermal energy in the form of latent heat (charging, melting) and reject it when being cooled (discharging, solidifying). PCMs used in buildings must fulfil the following fundamental criteria [1, 8, 9]; PCMs should undergo phase change near to the operating temperature of the building space, at the range of 20 °C to 32 °C [9, 10], they should also have good thermal conductivity and high latent heat per unit volume of the building material; and they should not pose a risk to health or the environment.

2.1. Classification of PCMs

PCMs exist in different forms (Fig.1) and are manufactured so as to perform at the required temperature range. Paraffin and salt hydrides are the most commonly used PCMs for application in buildings. The pros and cons of PCMs are discussed elsewhere [9, 11].

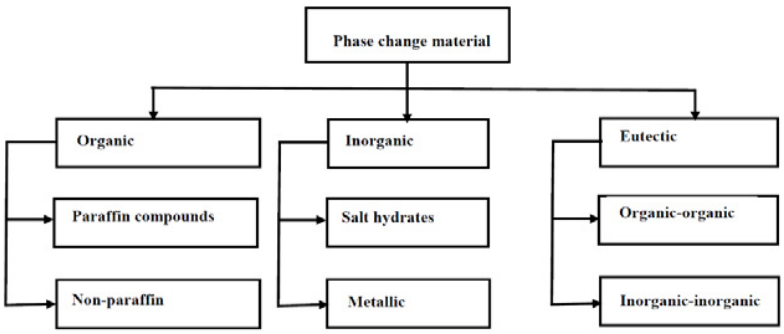

Fig. 1. Classification of PCMs [8, 9, 11-14].

2.2 PCM integration methods

Incorporating PCMs into lightweight indoor surfaces (walls, ceilings or floors) is an effective way of increasing their effective thermal capacity. Another means of application is incorporating a PCM in the building's thermal envelope (external walls/roof, windows/shutters, ventilation system), such that the PCM can more easily discharge heat at night to the environment. In all cases, the integration method should be carefully assessed. The three most widely used techniques of integrating PCMs into building elements are immersion, direct incorporation and encapsulation [1, 5, 15-19].

- Immersion involves immersing the building material into melted PCM; the material absorbs the PCM by capillary action.
- In the case of direct incorporation, the PCM is added directly into the construction material during the production