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REVIEW ARTICLE

# Influential aspects on melting and solidification of PCM energy storage containers in building envelope applications

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**ABSTRACT**

Phase change materials (PCMs) incorporated building envelope for thermal energy storage (TES) considerably enhances building thermal energy and improves indoor comfort. Amongst other methods, macroencapsulation provides a flexible and efficient PCM utilization among practical incorporation methods during a long time of service. Nevertheless, there is still arguement regarding PCM thermal performance during melting and solidification phases due to macroencapsulation containers, not to mention PCM's poor thermal conductivity. A brief overview of possible practical integration methods of PCMs with building elements is presented along with the main advantages and drawbacks in this work. This is followed by the popular incorporation techniques in building applications giving special attention to the macroencapsulation method and its role in improving building performance. The main influential aspects of macroencapsulated PCM performance during the melting and solidification, namely the shape, material type, compatibility with PCM type, and enhancement methods of encapsulation containers, are highlighted and discussed. We believe that this work analysis and conclusions provide a clear understanding of the main trends and gaps in this research area for further investigation and optimization studies by researchers, engineers, and developers.

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**KEYWORDS**
PCM; macroencapsulation; encapsulation material; building energy; melting and solidification

## 1. Introduction

The building sector is considered as one of the most critical sectors in terms of energy consumption. Globally, buildings are responsible for 30–40% of national energy consumption and 40–50% of greenhouse gas emissions (Abd Rashid and Yusoff 2015). Building envelope is a critical key for maintaining building energy as it directly controls the heat energy between indoor and outdoor environments under hot and cold locations (Biswas et al. 2019)(Al-Yasiri, Al- Furaiji, and Alshara 2019). According to the International Energy Agency (IEA), most expenditures and investments in the building sector have been spent on building envelopes. Furthermore, envelope constructions and renovations worldwide are responsible for 36% and 39% of final building energy and energy-related $CO_2$ emissions, respectively, in the year 2018 (International Energy Agency, UN Environment Programme 2019). Official global bodies and research centers have tended to adopt different methods to reduce energy consumption in buildings by implementing different strategies and technologies (Azuatalam et al. 2020)(International Energy Agency (IEA) 2013)(Luo et al. 2020). Researchers in the last few decades turned to incorporate phase change materials (PCMs) with building constructions thanks to their ability to manage the heat energy through the building envelope during phase transition and bridge between the supply and demand of energy (Madad, Mouhib, and Mouhsen 2018)(Zeinelabdein, Omer, and Gan 2018).

PCM is one of the most advanced and preferred TES technologies for saving energy and providing thermal comfort in the buildings (Al-Yasiri and Szabó 2021; Frigione, Lettieri, and Sarcinella 2019; Plytaria et al. 2019; Song et al. 2018; Tunçbilek et al. 2020a). In this regard, Rathore and Shukla (Rathore and Shukla 2020) experimentally investigated the effect of PCM (-36–40°C melting temperature), macroencapsulated using aluminum pipes and embedded inside the envelope of a cubicle under Indian weather conditions. The study reported that the PCM cubicle peak temperature was reduced by 7.19–9.18% compared to a conventional cubicle that have the same design and characteristics but without PCM. Moreover, a time delay of 60–120 min and cooling load reduction was achieved by 38.76%. Mohseni and Tang (Mohseni and Tang 2020) numerically studied the energy-saving and thermal comfort earned from incorporating a PCM layer into building envelope elements under Australian climate conditions. They investigated a range of melting temperatures (19–29°C) with 5 mm and 10 mm thicknesses to specify the optimal case. Results showed that the best melting temperature was seasonal in which the best performance in summer was reported for 25°C whereas 21°C was optimal for the winter season. Moreover, the cooling and heating energy consumption was reduced by 23% and 12%, respectively, when the PCM thickness increased from 5 to 10 mm. The study concluded that a maximum of 6146 kg/year of $CO_2$ could be saved and a payback period of 16.6 years was the shorter time for

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