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Review article

Advancements in phase change materials for energy-efficient building construction: A comprehensive review

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A R T I C L E I N F O

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A B S T R A C T

The building sector, representing a significant share of energy consumption, accounts for 60 % of energy consumption, particularly in Heating, Ventilation, and air conditioning (HVAC). Phase change materials (PCMs), distinguished by their ability to store and release substantial heat in response to ambient temperature changes, emerge as promising solutions for integrating thermal regulation technologies in building design. While literature showcases studies demonstrating the incorporation of PCMs into various building materials, there is a dearth of comprehensive reviews covering their integration into building components. This study classifies PCMs based on material composition and the nature of phase change, presenting a brief overview to highlight their diverse applications in the thermal regulation of buildings. Further, it summarizes various studies on PCM incorporation in building materials such as roofs, walls, cement, bricks, paints, floors, and windows, bridging the gap in existing research. Solid-liquid organic PCMs are widely researched compared to inorganic and solid-solid PCMs for building applications. Solid-liquid PCMs require containment for liquid state handling during phase changes, mainly applied in encapsulated forms. Building components such as bricks and floors can incorporate PCMs in any encapsulated form. Based on the Review findings, adding PCM to cement plaster often reduces mechanical properties and increases cement porosity, impacting the hydration process, except when using dopamine-coated cenosphere PCM capsules. Phase change paints, primarily utilizing micro/nano encapsulated PCMs, reveal varying effects on paint properties based on the percentage of PCM capsules added, with peak temperature reductions of 1–6 °C observed in building applications. Solid-solid PCMs are primarily applied in windows, where PCM-filled glazed windows significantly reduce peak temperatures up to 9 °C. Reduction in peak temperatures from 1 °C–7 °C and heat loads by 19–59 % were observed for PCM integrated in Roof. South-faced walls equipped with PCM layers exhibit superior thermal performance compared to other orientations. In conclusion, this review consolidates recent advancements and provides valuable insights into PCM applications in various building components, serving as a valuable resource for researchers, engineers, and industrial experts.

1. Introduction

The rapid economic growth, the increase in the global population, and improved standards of living have led to swift urbanization and a subsequent surge in energy consumption [1–3]. Projections indicate a substantial rise in global energy consumption from 524 quadrillion BTUs in 2010 to 820 quadrillion BTUs by 2040 [4]. Currently, conventional and non-renewable fossil fuels, such as crude oil and petroleum, fulfill the majority of the world's energy needs (81 %). However, these fossil fuel reserves are depleting, and their continuous utilization poses significant financial and environmental implications, given that 75 % of greenhouse gas emissions worldwide result from energy production using fossil fuels [5–6].

According to a report from the International Energy Agency (IEA), the construction industry ranks as one of the most energy-consuming sectors [7] in the current decade, holding the third position after the energy-intensive industrial and transportation sectors [1]. The escalating energy consumption in buildings, driven by a growing global population and increasing standards of human comfort, is an urgent issue facing the scientific community worldwide. The focus on renewable energy is gaining momentum, aligning with the rising energy demands to meet supply needs. These challenges intensify the market for

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