

Chapter 9

Phase Change Materials in Buildings: Fundamentals, Applications, and Future Perspectives

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ABSTRACT

This chapter thoroughly explores Phase Change Materials (PCMs) and their applications in buildings. It begins by introducing the background, context, and objectives before delving into PCM fundamentals, covering types, phase change mechanisms, and key properties. Beyond theory, the chapter explores practical applications in thermal regulation, energy efficiency, HVAC systems, thermal energy storage, passive building design, heat recovery, and PCM integration. Discussion includes various PCM types—organic, inorganic, eutectic mixtures, and bio-based—alongside selection criteria for building applications. Methods to enhance PCM performance, such as nano-enhancements, microencapsulation, and hybrid solutions, are explored. The chapter addresses integration and design considerations and concludes with insights into future directions, trends, and implications for sustainable building practices.

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1. INTRODUCTION

Phase Change Materials (PCMs) are at the forefront of transformative change within the construction industry, heralding a paradigm shift towards enhanced energy efficiency and elevated thermal comfort standards in buildings. Their remarkable capacity to absorb and release substantial quantities of thermal energy during phase transitions, such as the conversion from solid to liquid or liquid to gas, while maintaining a consistent temperature, has ignited widespread interest and exploration. This intrinsic characteristic endows PCMs with the capability to actively regulate indoor temperatures, effectively mitigating temperature fluctuations and lessening dependence on conventional heating and cooling systems.

Amidst an escalating global demand for sustainable building practices, PCMs have emerged as a cornerstone technology in the battle against climate change and the pursuit of minimised energy consumption in the built environment. Therefore, fostering a comprehensive understanding of PCM applications, benefits, and challenges within building design and construction has become an imperative for advancing sustainability objectives and realizing the vision of energy-efficient buildings. By embracing PCM technology, stakeholders stand poised to catalyse the transition towards a greener and more resilient built environment (Chandel & Agarwal, 2017; Wang et al. 2022a; Kapasalis et al. 2024). Through strategic integration and utilisation of PCMs, they can actively contribute to meeting the evolving needs of occupants and society at large, while simultaneously aligning with progressive sustainability goals on both local and global scales.

The motivation behind this chapter on Phase Change Materials (PCMs) lies in addressing pressing challenges in sustainable building design. With a growing emphasis on energy efficiency and environmental conservation, PCM technology offers a promising solution. By elucidating PCM properties, applications, and benefits, this chapter aims to equip practitioners, policymakers, and researchers with the knowledge needed to effectively integrate PCMs into building design and construction. Furthermore, by highlighting challenges, opportunities, and best practices, the chapter seeks to foster innovation and facilitate informed decision-making in pursuit of more sustainable and resilient built environments.

Despite its comprehensive coverage, this chapter on Phase Change Materials (PCMs) in buildings has some limitations. Due to the vast scope of PCM applications, certain niche areas may not receive detailed examination. Additionally, the chapter may not delve deeply into specific technical aspects or emerging research trends within PCM technology. Furthermore, while practical applications are explored, the chapter may not provide exhaustive case studies or real-world examples. Finally, given the dynamic nature of sustainable building practices, some discussions on future directions and trends may lack complete foresight. Overall, while informative,

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