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Investigating the effect of thrombus wall containing phase change materials on the reduction of energy consumption (Case study: a model building in different climatic conditions)

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Extended Abstract

Introduction

The continuous growth in global energy consumption and the substantial contribution of buildings to total energy use and carbon dioxide emissions have intensified the need for sustainable and energy-efficient building design strategies. A significant portion of building energy demand is associated with heating, ventilation, and air-conditioning systems, highlighting the importance of passive solar solutions. Trombe walls, as one of the most widely studied passive solar systems, have attracted considerable attention due to their simple structure, low operating cost, and ability to store solar thermal energy. However, their performance is often constrained by low thermal efficiency, high thermal inertia, and strong dependence on daytime solar radiation. Recently, the integration of phase change materials (PCMs) into Trombe walls has been proposed as an effective approach to overcome these limitations.

Role of Phase Change Materials

Phase change materials are capable of storing and releasing large amounts of thermal energy through latent heat during melting and solidification processes, while maintaining an almost constant temperature. This characteristic helps reduce indoor temperature fluctuations and improve thermal comfort. When integrated into Trombe walls, PCMs enhance thermal energy storage capacity and extend the effective heating period into nighttime hours. In this study, several commercially available PCMs with different phase change temperatures were evaluated to assess their suitability for various climatic conditions.

Methodology

A real residential building equipped with a Trombe wall was selected as the case study, and its energy performance was analyzed under four major climatic zones of Iran: hot–dry, cold, temperate–humid, and hot–humid climates. Energy simulations were conducted using DesignBuilder software based on real climatic data. Different scenarios were considered, including a building without a Trombe wall, a Trombe wall without PCMs, and a PCM-integrated Trombe wall designed according to the thermal comfort temperature of each climate. The effects of building orientation and climate-adapted HVAC systems on annual energy consumption were also investigated.

Results and Discussion

The simulation results revealed that the performance of Trombe walls is highly dependent on climate, PCM properties, and building orientation. In some climates, the conventional Trombe wall without PCMs led to an increase in energy consumption. In contrast, incorporating appropriate PCMs significantly reduced the annual energy demand of the building. The highest energy savings were achieved in the cold climate, where the PCM-integrated Trombe wall effectively reduced heating loads and improved overall HVAC performance. Additionally, building orientation was found to play a crucial role, with a specific orientation leading to minimum annual energy consumption.

Validation and Economic Assessment

To validate the simulation outcomes, the building model was also analyzed using Revit software, showing good agreement with the DesignBuilder results. From an economic perspective, the additional cost associated with PCM

integration was relatively low compared to the achieved energy savings. The reduction in annual energy consumption resulted in a short payback period, indicating that PCM-integrated Trombe walls are not only technically effective but also economically viable, particularly in cold and heating-dominated climates.

Conclusions

This study demonstrates that PCM-integrated Trombe walls can serve as an effective passive solar strategy for reducing building energy consumption, particularly in cold and hot–dry climates. The results emphasize the importance of climate-specific design, appropriate building orientation, and the integration of compatible HVAC systems to achieve optimal performance. While the application of such systems in humid climates may be limited, their technical and economic advantages in colder regions make them a promising solution for sustainable building design. Overall, the findings provide valuable insights for architects, engineers, and policymakers seeking to enhance building energy efficiency through passive solar technologies.

Key words: Trombe Wall, Phase Change Materials, Energy Consumption Reduction, Simulation, Design Builder.

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