Proceedings of the 18th UK Heat Transfer Conference
9-11 September 2024, Birmingham
UKHTC2024-046

APPLICATION OF PCM IN EXTERNAL WALLS OF TYPICAL RESIDENTIAL BUILDINGS IN THE UK AND THEIR IMPACT ON BUILDING ENERGY CONSUMPTION

Yue Zhang[1], Siddig Omer[2]

[1]Department of Architecture and Built Environment, University of Nottingham, United Kingdom

[2]Department of Architecture and Built Environment, University of Nottingham, United Kingdom

1. ABSTRACT

This paper examines Phase Change Materials (PCM) in UK residential buildings to improve energy efficiency, focusing on a detached house in Nottingham. It assesses three PCM types on external walls' inside and outside, considering energy consumption impacts. The research uniquely simulates different housing forms—detached, semi-detached, and flats. By adjusting external wall boundary conditions to mirror varied thermal environments. It explores how these conditions affect heat dissipation in each building type. The research shows that the application of PCMs to the inner and outer walls of the building can effectively reduce the heat loss of the building and thus reduce the building energy consumption. PCM RT24 HC has the best performance among the three selected PCMS. In addition, for detached building, Semi-detached building and Flat, adding PCM to the outer wall of the building has the best effect, which can achieve 11.66%, 8.97% and 12.13% of building energy consumption reduction, respectively.

2. INTRODUCTION

This literature review integrates studies on the application of phase change materials (PCMs) in buildings. Utilizing PCMs' latent heat storage, these studies show significant improvements in building energy efficiency and thermal comfort. It also discusses innovative applications, challenges, and future directions of PCM technology in the building industry. PCM reduces energy consumption and promotes sustainable building practices by mitigating indoor temperature fluctuations, aligning with energy consumption data and sustainable solutions.[1] Studies show integrating PCMs into wall panels and concrete improves thermal comfort and reduces temperature fluctuations, focusing on energy performance and savings. Data confirm using PCMs in ceilings reduces discomfort hours and energy consumption.[2] The use of PCMs in roofing materials stabilizes roof temperatures and promotes natural cooling, maintaining comfortable indoor temperatures across climates and reducing peak energy demands.[3] Advances in PCM technology, including developing PCMs with optimal melting temperatures and enhanced thermal conductivity, focus on improving dynamic thermal management in buildings.[4] Innovations in microencapsulation technology enhance the thermal conductivity and stability of PCMs, facilitating their integration into building materials like concrete and wall panels.[5] Research focuses on improving PCM compatibility with traditional materials to prevent chemical degradation and enhance fire safety, and on developing advanced PCM composites to reduce lifecycle costs and enhance sustainability.[6] These

*Corresponding Author: laxyz69@Nottingham.ac.uk, Lazsao@exmail.nottingham.ac.uk

citations provide a detailed view of how the literature review aligns with existing studies, ensuring it is well-supported by academic and practical insights into PCM applications in building energy efficiency.

This project investigated the impact of three PCMs (PCM RT22 HC, PCM RT24 HC, and PureTemp23) on UK residential buildings by adding them to the inside and outside of external walls. The study focused on a double story detached house in Belper, Derbyshire (latitude 53°01'07.8", longitude 1°30'08.9"), which has windows on all sides for good lighting.

Table 1 Parameters of the selected PCMs

PCM	Phase Change Temperature (°C)	Thermal conductivity (Solid) (W/mK)	Thermal conductivity (Liquid) (W/mK)	Latent Heat (J/g)	Specific Heat (J/g)	Solid Density (kg/m3)	Liquid Density (kg/m3)
PCM RT22 HC	22	0.2	0.2	190	2000	760	700
PCM RT24 HC	24	0.2	0.2	200	2000	800	700
PureTemp23	23	0.25	0.15	201	2460	910	830

Figure 1 shows the Building Simulation in Energyplus:

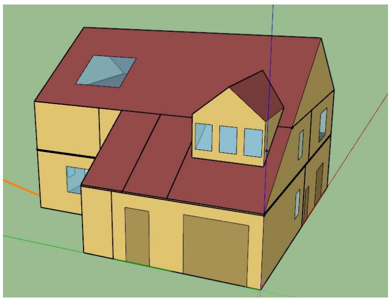

Fig. 1 Building simulation in Energyplus

3. METHDOLOGY

The research uses a detached building model in Sketchup and Openstudio, with energy consumption simulations in EnergyPlus, to evaluate the impact of three PCMs on energy reduction in typical British residential buildings. Simulations for semi-detached buildings and flats set the side wall boundary to adiabatic, with one internal wall in the semi-detached and two in the flat. The simulations provide data on gas, cooling electricity, total electric, and overall energy consumption, helping identify the most suitable PCM and its optimal placement for building renovations.

4. RESULTS and Analysis

Table2: Energy Consumption of three types of Buildings with 4cm PCM RT24 HC inside of the external all

Name of Technology	Reduction of Gas (%)	Reduction of Cooling ELEC (%)	Reduction of ELEC (%)	Reduction of Total Energy (%)	Total carbon emission reduction (%)	Total energy cost reduction (£)
Detached	11.43%	13.85%	13.77%	11.66%	11.71%	258.86
Semi	9.06%	2.21%	8.12%	8.97%	8.95%	159.48
Flat	12.64%	3.25%	7.28%	12.13%	12.01%	181.85

The total energy consumption of the flat significantly decreased due to a rise in indoor temperature after the model modification. Despite the reduced heat exchange area between the external wall and the outside, the increased indoor temperature led to a larger temperature difference, boosting heat exchange and enhancing the insulation effect. In contrast, the semi-detached building showed little change in the indoor-outdoor temperature difference, likely due to different thermal zone settings. Future studies should consider how PCM additions affect indoor temperature fluctuations and energy-saving outcomes. Overall, higher indoor temperatures lead to reduced energy consumption, showing a significant impact on efficiency.

5. CONCLUSIONS

This study simulated the effects of adding three different PCMs to the inside and outside of building external walls. PCM RT24 HC significantly reduced energy consumption across various building types. When applied to the exterior of detached buildings, gas load reduction was greater compared to interior application. However, adding 4cm of RT24 HC to the inside of the external wall raised indoor winter temperatures, resulting in 11.43% gas load reduction, 13.85% cooling electricity savings, 11.66% total energy reduction, 11.71% carbon emission reduction, and £258.86 in annual energy cost savings. Applying 4cm RT24 HC to semi-detached and flat buildings also reduced energy consumption. The best results were seen with 11.66%, 8.97%, and 12.13% reductions in energy use for detached, semi-detached, and flat buildings, respectively. This study emphasizes the importance of building structure and PCM placement for optimizing energy efficiency and guiding retrofit strategies for sustainability.

6. REFERENCES

[1] S. Kenzhekhanov, S. A. Memon, and I. Adilkhanova, "Quantitative evaluation of thermal performance and energy saving potential of the building integrated with PCM in a subarctic climate," *Energy,* vol. 192, 2020, doi: 10.1016/j.energy.2019.116607.

[2] H. Wang, W. Lu, Z. Wu, and G. Zhang, "Parametric analysis of applying PCM wallboards for energy saving in high-rise lightweight buildings in Shanghai," *Renewable Energy,* vol. 145, pp. 52-64, 2020, doi: 10.1016/j.renene.2019.05.124.

[3] Y. Qu, D. Zhou, F. Xue, and L. Cui, "Multi-factor analysis on thermal comfort and energy saving potential for PCM-integrated buildings in summer," *Energy and Buildings,* vol. 241, 2021, doi: 10.1016/j.enbuild.2021.110966.

[4] P. K. S. Rathore and S. K. Shukla, "An experimental evaluation of thermal behavior of the building envelope using macroencapsulated PCM for energy savings," *Renewable Energy,* vol. 149, pp. 1300-1313, 2020, doi: 10.1016/j.renene.2019.10.130.

[5] P. K. Singh Rathore, S. K. Shukla, and N. K. Gupta, "Potential of microencapsulated PCM for energy savings in buildings: A critical review," *Sustainable Cities and Society,* vol. 53, 2020, doi: 10.1016/j.scs.2019.101884.

[6] R. Kalbasi, "Usefulness of PCM in building applications focusing on envelope heat exchange – Energy saving considering two scenarios," *Sustainable Energy Technologies and Assessments,* vol. 50, 2022, doi: 10.1016/j.seta.2021.101848.