ISSN 2303-498X

UNIVERSITY PIM BANJA LUKA
UNIVERZITET PIM BANJA LUKA

XII INTERNATIONAL CONFERENCE ON SOCIAL AND TECHNOLOGICAL DEVELOPMENT - STED 2023

PROCEEDINGS

XII MEĐUNARODNA KONFERENCIJA O DRUŠTVENOM I TEHNOLOŠKOM RAZVOJU - STED 2023

ZBORNIK RADOVA

20 GODINA UNIVERZITETA PIM

Trebinje, June 15th-18th, 2023

Trebinje, 15-18. jun 2023. godine

WWW.UNIVERZITETPIM.EDU.BA

ISSN 2303-498X

20 GODINA UNIVERZITETA PIM

XII INTERNATIONAL CONFERENCE ON SOCIAL AND TECHNOLOGICAL DEVELOPMENT

PROCEEDINGS

XII MEĐUNARODNA KONFERENCIJA O DRUŠTVENOM I TEHNOLOŠKOM RAZVOJU

ZBORNIK RADOVA

Trebinje, June, 15-18, 2023
Trebinje, 15 - 18. juni 2023. godine

20 GODINA UNIVERZITETA PIM

2003-2023

XII INTERNATIONAL CONFERENCE ON SOCIAL AND TECHNOLOGICAL DEVELOPMENT

PROCEEDINGS

Co-organizers:

XII INTERNATIONAL CONFERENCE ON SOCIAL AND TECHNOLOGICAL DEVELOPMENT
XII MEĐUNARODNA KONFERENCIJA O DRUŠTVENOM I TEHNOLOŠKOM RAZVOJU

PROCEEDINGS

Publisher:
University PIM, Banja Luka, Republic of Srpska, Bosnia and Herzegovina

For publisher
Ilija Džombić, PhD, General Manager

Editorial board:
Dejan Kojić, PhD, Vice-Rector for Science
Darjana Sredić, MSc.

Design and Computer processing:
Ljubica Janjetović, PhD

Print:
„Vilux“ Banja Luka

Circulation:
25 Cipies

CIP - Каталогизација у публикацији
Народна и универзитетска библиотека
Републике Српске, Бања Лука

33:005(082)
62(082)
0/9(082)

МЕЂУНАРОДНА конференција о друштвеном и технолошком развоју (12 ; 2023 ; Требиње)
Zbornik radova / XII Međunarodna konferencija o društvenom i tehnološkom razvoju, Trebinje, 15-18. juni 2023. godine = Proceedings / XII International conference on social and technological development, Trebinje, June, 15-18, 2023 ; [editorial board Dejan Kojić, Darjana Sredić]. - Banja Luka : Univerzitet za poslovni inženjering i menadžment =University PIM, 2023 (Banja Luka : Vilux). – 647 стр. : илустр. ; 25 cm. - (Međunarodna konferencija o društvenom i tehnološkom razvoju = International conference on social and technological development, ISSN 2303-498X)

На насл. стр.: 20 godina univerziteta PIM. - Радови на срп. и енгл. језику. - Тираж 25. - Напомене и библиографске референце уз текст. - Библиографија уз сваки рад. - Сажеци на енгл. и срп. језику уз сваки рад.

ISBN 978-99955-40-70-8

COBISS.RS-ID 139321089

Trebinje, June, 15-18, 2023. Republic of Srpska, B&H

Organizing and Program Committee:

PhD Dejan Kojić, president, PhD Mladen Ivić, PhD Ljubica Janjetović. PhD Nikola Vojvodić, PhD Predrag Raosavljević, PhD Simonida Vilić, MSc Danijela Jokanović, MSc Nada Dursun, MSc Darjana Sredić, Ba Igor Šabić, Ba Ognjen Todorović.

Students: *Brankica Perišić, Srđan Pejanović, Mina Anđelić, Marija Ratković, Nikolina Kašiković, Aleksandar Maletić.*

Scientific and Program Committee:

Dr Dragan Đuranović, president, University PIM, Banja Luka, ***B&H;*** *Dr Darina Dupláková, Technical University of Kosice,Faculty of Manufacturing Technologies with a seat in Prešov, Institute of Advanced Technologies, Prešov,* ***Slovakia;*** *Dr Maja Fošner, Faculty of Logistics, University of Maribor, Celje,* ***Slovenija****; Dr Savo Ashtalkoski, American University of Europe, Skopje,* ***North Macedonia;*** *Dr Milena Marinović-Cincović, University of Belgrade, Vinča Institute of nuclear Sciences, Belgrade,* ***Serbia****; Dr Jelena Pavličević, University of Novi Sad, Faculty of Technology, Novi Sad,* ***Serbia****; Dr Irena Petrušić, Faculty of Management, Herceg Novi,* ***Montenegro****; Dr Svetlana Karić, Academy of vocational studies in Šabac,* ***Serbia****; Dr Dragan Domazet, Belgrade Meropolitan University,* ***Serbia;*** *Dr Tigran Petrosyan, Yerevan Haybusak University, Yerevan,* ***Armenia****; Dr Dragan Brenjo, Food safety agency of Bosnia and Herzegovina,* ***B&H****; Dr Boris Dorbić, scientific-expert association "FUTURA", Šibenik,* ***Croatia****; Dr Ilija Džombić, University PIM, Banja Luka,* ***B&H****; Dr Mladen Ivić, University PIM, Banja Luka,* ***B&H****; Dr Mile Vasić, European Marketing and Management Association,* ***B&H****; Dr Ognjen Bakmaz, The College of Service Business, Sokolac,* ***B&H****; Dr Osman Khan, Institute of Customer Management,* ***United Kingdom****; Dr Perica Bošković, Faculty of Science, Split,* ***Croatia****; Dr Yajnya Dutta Nayak, P.G. Dept. of Commerce, Khallikote Auto. College, Berhampur, Odisha,* ***India****; Dr Martin G. Abrahamyan, Yerevan Haybusak University, Yerevan,* ***Armenia****; Dr Svetlana Radchenko, Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Prešov, Institute of Advanced Technologies, Prešov,* ***Slovakia****; Dr Lucia Knapčíková, Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Prešov, Institute of Advanced Technologies, Prešov,* ***Slovakia****; Dr Bojan Rosi, Faculty of Logistics, University of Maribor, Celje,* ***Slovenija****; Dr Tomaž Kramberger, Faculty of Logistics, University of Maribor, Celje,* ***Slovenija****; Dr Isaac Lera, University of the Balearic Islands, Dept. of Mathematics and Computer Science, Balearic Islands,* ***Spain****; Dr Benea Marius Calin, Politehnica University Timisoara, Faculty of Engineering Hunedoara,* ***Romania****; Dr Ayse Aroguz, Istanbul University-Cerrahpasa, Engineering Faculty, Istanbul,* ***Turkey****; Dr Milena Špírková, Institute of Macromolecular Chemistry, Prague,* ***Czech Republic****; Dr Yaroslav Kusyi, National University "Lviv Polytechnic", Lviv,* ***Ukraine****; Dr Irena Ashtalkoska, American University of Europe, Skopje,* ***North Macedonia****; Dr*

NOTE:

The authors have full responsibility for the originality and content of their own papers

CONTENT
SADRŽAJ

ORIGINALAN NAUČNI RAD – ORIGINAL SCIENTIFIC PAPER

PCM APPLICATION IN LIGHT CONSTRUCTION BUILDINGS IN VARIOUS CLIMATES

Biljana Vučićević, Dragoslav Mrđa, Valentina Turanjanin, Predrag Škobalj, Milica Mladenović

University of Belgrade, „VINČA" Institute of Nuclear Sciences - National Institute of the Republic of Serbia, Laboratory for Thermal Energy and Engineering, 11000 Belgrade, Serbia, bee@vinca.rs, dmrdja@vinca.rs, valentin@vinca.rs, p.skobalj@vinca.rs, mica@vinca.rs

ABSTRACT

Incorporating phase change materials (PCM) into building structures as passive latent heat thermal energy storage technologies offers a potential solution for reducing energy demand and regulating thermal comfort in occupied buildings. Integrating PCM into lightweight walls can improve their thermal performance by increasing building heat capacity and decreasing energy consumption. The effects of phase change materials (PCMs) added to the thermal envelope of lightweight residential containers on building thermal comfort are investigated in this study. The simulations were run for the summer period because it is difficult to achieve thermal comfort without using a lot of energy at that time. Thermal comfort is highly dependent on both, climatic conditions and the materials used to construct the building's thermal envelope, and the simulation was performed for weather conditions in five different geographic locations using TRNSYS simulation software. The paper examines the effects of PCM on indoor air temperature, specifically on reduction of maximum air temperature and temperature fluctuations.

Keywords: Building, PCM, Phase-change material, Thermal comfort, TRNSYS.

INTRODUCTION

Trends in the construction of residential spaces all over the world change every day. The construction of massive buildings is increasingly being pushed out by the construction of cheap, lightweight structures designed to withstand extreme weather conditions such as heavy rains, strong winds and powerful earthquakes. Also, these are objects that can be quickly and easily assembled and, if necessary, dismantled and moved to another location, and their modularity allows that, by combining the stacking of containers, light objects can be adapted to all needs. Thus, apart from housing workers on construction sites, for offices, tobacconists, markets or smaller catering facilities, containers also began to be used as facilities for occasional stays during the weekend or annual vacation. The two largest student cities in the Netherlands and England are built from containers and a large number of students live in them every day. An increasingly popular trend is, of course, choosing a residential container for everyday life. More and more families in the world are deciding to choose a residential container for their permanent living space (Varmus, 2023).

Aside from the installation of insulating materials in the container's outer shell, one of the main disadvantages is that lightweight buildings do not have a large thermal capacity, which has a significant impact on the thermal comfort for people who live in them. Incorporating phase-changing materials (PCM) into the thermal envelope is one method for improving the thermal capacity of lightweight construction buildings (Roth et al., 2017).

PCMs are primarily used to increase the building envelope's capacity for heat storage and to reduce both internal temperature changes and energy demand. Thermal energy absorption, storage, and release are the three steps of the PCM principle. PCMs can store a significant amount of thermal energy by switching from one phase to another over a very narrow temperature range. The transformation from solid to liquid state is frequently used in building construction where the phase transition occurs at constant temperature.

A significant number of works about PCM use in buildings have recently been published. It is important to remember that research must be conducted for each climate to determine which phase-changeable material or combination of materials will have the greatest impact on reducing energy consumption and payback time (Panayiotou et al., 2016; Jayalath et al., 2016).

The researchers (Al-Absi et al., 2022) investigated the thermal performance of PCM-based panels created for exterior wall finishes by fusing microencapsulated PCM with cement render and foamed concrete using experimental methods. The panels were subjected to repeated heating and cooling cycles in order to determine how well they performed thermally when compared to panels without PCM. During the PCM melting process, the internal surface temperature of the PCM-based panels decreased by up to 7.35°C.

A dynamic energy simulation program was used in the study (Wi et al., 2020) to apply an analysis of the enthalpy-temperature function based on the thermal properties of 22 different types of shape-stabilized phase change materials (SSPCM). The SSPCM was used to improve the energy efficiency of buildings while also improving the low heat storage performance of wooden structures. The indoor temperature behavior during heating and cooling periods was investigated to confirm the improvement in building heat storage performance. By maintaining the thermal inertia of SSPCM, the peak summer temperature was reduced by 4.1 °C.

In paper (Li et al., 2015), researchers investigated lightweight buildings integrated with phase change material (PCM) in order to improve the thermal performance of lightweight buildings. EnergyPlus software with a building model validated by experiment data is used to investigate the improvement of the indoor thermal environment with PCM under typical weather conditions in China's five climate zones. The findings show that PCM can effectively control indoor temperature rises and fluctuations. In temperate regions, the PCM can improve the indoor thermal environment of lightweight buildings for the majority of the year.

Because thermal comfort is highly dependent on both climatic conditions and the materials used to construct the building's thermal envelope, this study investigates the effects of phase change materials (PCMs) added to the thermal envelope of lightweight residential containers on indoor air temperature. The simulations were run for seven days during the hottest summer period using a typical meteorological weather file. Geometry of lightweight object, built-in materials and weather conditions in five different geographic locations were simulated using TRNSYS simulation software. The study looks into how PCM affects indoor air temperature, specifically how it reduces maximum air temperature and temperature fluctuations.

MODEL AND SIMULATION

The basic type of housing container shown in the Figure 1 was chosen for the analysis of the impact of incorporating phase-changing materials into the thermal envelope. The floor of this container consists of plasticized sandwich panels. On both sides of panels are metal sheets 3mm thick, inside is PU filling 50mm (conductivity 0.13 kJ/hmK, heat capacity 2.09 kJ/kgK, density 40kg/m^3), finish cement chipboard 20mm thick with thermal conductivity 0.26 W/mK, heat capacity 1.15 kJ/kgK and density 1250-1400 kg/m^3. Ceiling/Roof panel is made of galvanized metal sheet RAL9002 on sides with 100mm thick mineral wool filling (conductivity 0.18 kJ/hmK, heat capacity 0.9 kJ/kgK, density 80 kg/m3). Walls consists of galvanized sandwich panel with 60mm mineral wool filling (conductivity 0.18 kJ/hmK, heat capacity 0.9 kJ/kgK, density 80kg/m3) and windows are with glass type 4/16/4 with Ar (u-value 1.27 W/m^2K).

Figure 1. Lightweight structure for people to stay in.

Google SketchUp software was used to create the geometry of the observed house required for thermal behavior modelling (Figure 2). TRNSYS3d for Google SketchUpTM was used as a plug-in to enter the geometric data into the building model. The thermal performance of an lightweight object with one thermal zone is modeled by the TRNSYS module Type56.

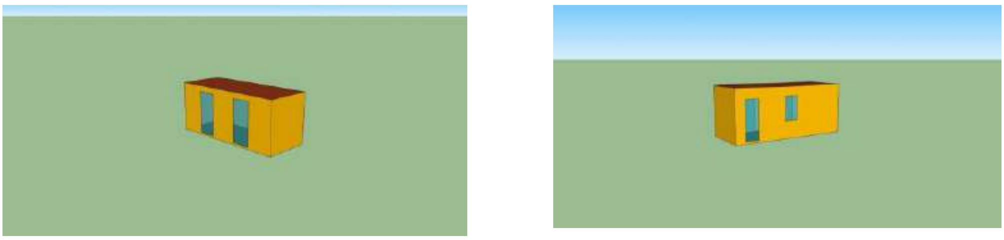

Figure 2. SketchUp model of a lightweight construction object.

With the aim of comparing the internal temperature in the container without PCM and in the container with embedded PCM material, simulations of the thermal behavior of the object without and with PCM (Figure 3) were performed in the Simulation Studio of the TRNSYS software package. To simulate the behavior of a PCM completely placed inside the envelope, a specially developed TRNSYS module Type1270 was used, which means the PCM is not directly adjacent to the zone air. This module is intended to interact with Type56 and can model a PCM located anywhere along a Type56 wall's thickness.

The phase change material is placed in the ceiling and in the south wall panels of the container. The commercial phase change material ENRG BlanketTM-Q25 from Phase Change Energy Solutions producer was chosen for this purpose. Its latent heat of fusion is 255 J/g and its phase change temperature is 25 °C.

The simulation was run for the summer period of July the 1^{th}-8^{th} (for a period from 4344^{th} to 5088^{th} hour observed since the year's beginning), with a simulation step of 5 minutes based on typical meteorological year's weather file.

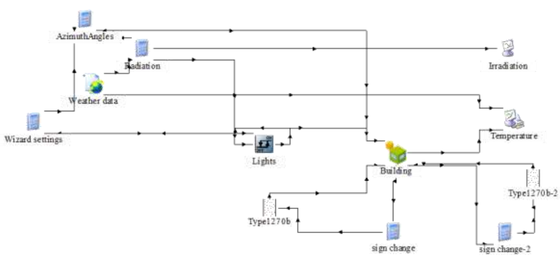

Figure 3. Simulation studio component scheme.

RESULTS AND DISCUSSION

The simulation was done for five different locations: Banjaluka, Beograd, Kopaonik, Podgorica and Split. The simulation results of the model of lightweight object without and with added PCM are shown at graphs in Figures 4-8. Each graph represents three air temperatures, namely: ambiental temperature (red), zone indoor temperature of the basic model without PCM (blue) and the zone indoor temperature of the model containing PCM (black). The basic model and the model with PCM clearly have different air temperatures in the observed zone. As the temperature outside changes, so does the temperature difference. The difference between the air temperatures in zones of the observed models increases as the outside temperature rises and decereses as the outside temperature is declining.

The temperature differences range from 8.8 °C to 11 °C, as shown in Table 1. Since Kopaonik mountain has the lowest external air temperature in relation to the chosen PCM material, the difference was as expected, the smallest. The biggest difference was found in Banjaluka, which doesn't have the highest outside temperatures, like Podgorica for instance, but has cooler nighttime temperatures that favorably influence the cooling of PCM material and thus enhance the conditions for PCM application.

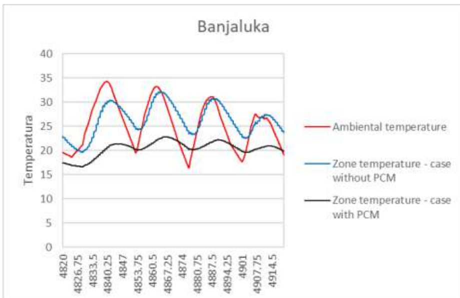

Figure 4. Indoor temperature difference in lightweight object without and with PCM placed in Banjluka.

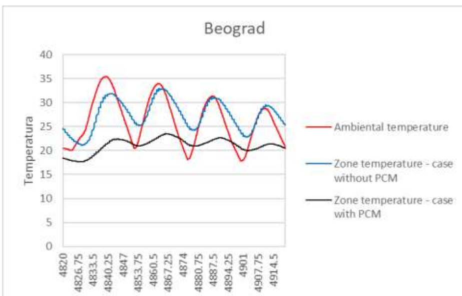

Figure 5. Indoor temperature difference in lightweight object without and with PCM placed in Beograd.

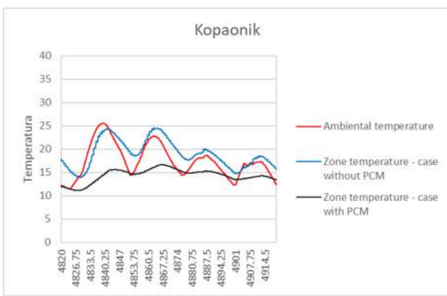

Figure 6. Indoor temperature difference in lightweight object without and with PCM placed at mountain Kopaonik.

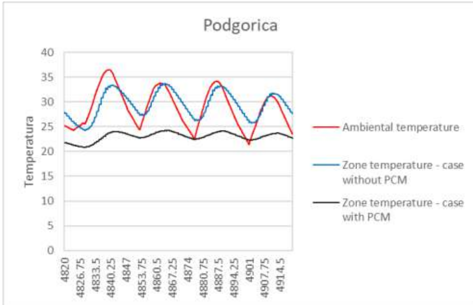

Figure 7. Indoor temperature difference in lightweight object without and with PCM placed in Podgorica.

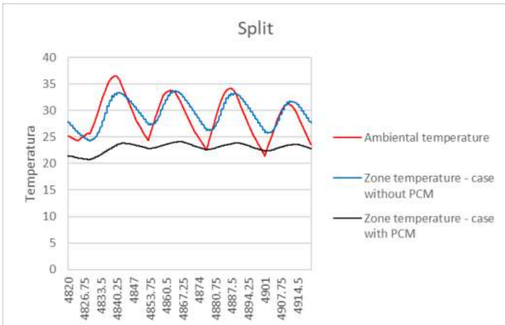

Figure 8. Indoor temperature difference in lightweight object without and with PCM placed in Split.

Table 1. Indoor temperature difference.

Locations	**Temperatures**			
	Ambiental temperature, °C	***Zone temp. (without PCM), °C***	***Zone temp. (with PCM), °C***	***Temperature difference, °C***
Banjaluka	33.5	30	21	11
Beograd	35	31.4	21.5	9.9
Kopaonik	24.3	23.9	15.1	8.8
Podgorica	36.1	33	23.8	9.2
Split	36.2	33	23.7	9.3

CONCLUSIONS

This study examines how the thermal envelope of lightweight residential containers with added phase change materials (PCMs) affects the temperature of the interior air. The simulations for five different locations were run by using of TRNSYS simulation software and typical meteorological weather file for seven days during the hottest part of the summer between July the 1^{th} and 8^{th}. It specifically looks at how chosen commercial PCM material ENRG BlanketTM-Q25 reduces the maximum air temperature and temperature variations in relation to indoor air temperature.

It‘s found that the air temperature in the building of light construction decreased from 8.8°C at Kopaonik to 11°C in Banjaluka as a result of the installation of PCM in the ceiling and in the south-facing exterior wall in all 5 locations.

There is a weaker nighttime cooling of the PCM in the envelope in cities with high daytime temperatures and relatively high nighttime temperatures, and the temperature differences between the cases with and without PCM are a little less pronounced.

Therefore, the best results of PCM application are found in places with high daytime, but also relatively low nighttime outdoor air temperatures with the selection of the appropriate PCM material for that geographical area.

ACKNOWLEDGEMENT

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia; grant number 451-03-47/2023-01/ 200017.

LITERATURE

Al-Absi, Z.A., Hafizal, M.I.M., & Ismail, M. (2022). Experimental study on the thermal performance of PCM-based panels developed for exterior finishes of building walls. *Journal of Building Engineering*, *52*, 104379.

Jayalath, A., Aye, L., Mendis, P., & Ngo, T. (2016). Effects of phase change material roof layers on thermal performance of a residential building in Melbourne and Sydney. *Energy and Buildings*, *121*, 152-158.

Li, Y., Wang, Y., Meng, X., Wanga, M. & Longa, E. (2015). Research on Indoor Thermal Environment Improvement of lightweight Building Integrated with Phase Change Material Under Different Climate Conditions. *Procedia Engineering*, *121,* 1628 – 1634.

Panayiotou, G. P., Kalogirou, S. A., & Tassou, S. A. (2016). Evaluation of the application of Phase Change Materials (PCM) on the envelope of a typical dwelling in the Mediterranean region. *Renewable Energy*, *97,* 24-32.

Roth, K., Westphalen, D. & Brodrick, J., (2017). Technology of phase-changing materials for construction. *KGH – Klimatizacija, grejanje, hlađenje*, *36*(4), 31-33.

Varmus d.o.o. (2023). Report. Retrieved July 12, 2023 from https://varmus-kontejneri.com/zasto-da-se-odlucite-za-zivot-u-stambenom-kontejneru/

Wi, S., Chang S.J., & Kim, S. (2020). Improvement of thermal inertia effect in buildings using shape stabilized PCM wallboard based on the enthalpy-temperature function. *Sustainable Cities and Society*, *56,* 102067.

UNIVERSITY PIM
UNIVERZITET PIM

Despota Stefana Lazarevića bb
78000 Banja Luka
Tel/Fax. +387 51 378-300
e-mail: stedconference@gmail.com
web: stedconference.com