



Simulation approach of indoor thermal comfort improvement with use of Phase Change Material

Stéphane Guichard, Karim Beddier, Frédéric Miranville, Harry Boyer

► To cite this version:

Stéphane Guichard, Karim Beddier, Frédéric Miranville, Harry Boyer. Simulation approach of indoor thermal comfort improvement with use of Phase Change Material. Environment and Electrical Engineering and 2017 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), 2017 IEEE International Conference, IEEE, Jun 2017, Milan, Italy. <hal-01564382>

HAL Id: hal-01564382

<https://hal.science/hal-01564382v1>

Submitted on 19 Jul 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

Simulation approach of indoor thermal comfort improvement with use of Phase Change Material

Guichard Stéphane and Beddiar Karim

Cesi LINEACT Laboratory
EiCESI Campus
Saint-Pierre of La Réunion, France
sguichard@cesi.fr, kbeddiar@cesi.fr

Miranville Frédéric and Boyer Harry

Physics and Mathematical Engineering Laboratory for
Energy, Environment and Building (PIMENT)
University of La Reunion, France
frederic.miranville@univ-reunion.fr, harry.boyer@univ-reunion.fr

Abstract—This paper deals with lightweight building simulation with phase change material on the North and the South walls. Givoni bioclimatic chart is used in order to compare results from study with and without phase change material. The results clearly show that the use of phase change material has a positive effect on inside air temperature thermal comfort was improved.

Keywords— Phase Change Material; Thermal Comfort; Numerical Simulation; Givoni bioclimatic chart;

I. INTRODUCTION

The process of global warming is nowadays fully recognized by everyone, as resulting from human activities, especially the building sector. As the world, Reunion Island, located in the Indian Ocean, with a tropical and humid climate, is not exception to this reality and because of its location, must set an example in the field of sustainable development. For this reason, May 1st 2010, thermal, acoustic and ventilation standards regulations were approved and are applicable to new residential buildings. It is important to highlight that before the regulation, buildings in Reunion Island had different thermal performances [1].

Despite phase change materials (PCMs) are not yet officially considered as an element of construction for existing insulation according to current regulations, their performance due to their properties are still studied by many researchers. Indeed, PCMs being able to store and release energy as latent heat during from solid to liquid and vice versa at nearly constant temperature are another possibility to contribute to the passive building design. Indeed, the use of them enhances the thermal energy storage so thermal comfort should be improved.

To evaluate the thermal effect of PCM on the thermal comfort, the paper deals with a numerical study of a monozone building, represented the first chosen building construction in La Réunion, which was first equipped with and then without PCM. The aim of study was to show if PCM, panels integrated in building may contribute for improving building energy performances in Reunion Island.

To perform the numerical study, a building simulation code, called ISOLAB, was previously empirically validated with field experimental data is used. Thermal comfort tools

from ISOLAB study were presented in details in [2].

Mainly, the article focuses on thermal comfort study approach of the presented case. This explains the reason why the study case and the building simulation code are briefly described. We then present the simulation results and finally the conclusions.

II. THE STUDIED TEST BUILDING

A cubic-shaped building composed by a single window on the South wall and a glass door on the North wall is studied. As depicted in Figure 1, the building is considered as an office with an interior volume of 27 m³.

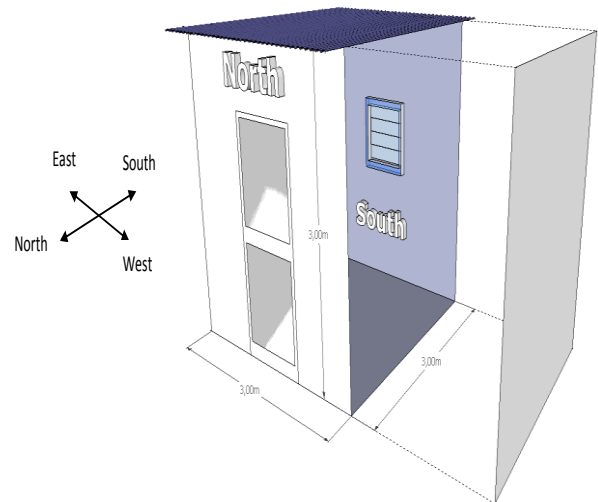


Fig. 1. The studied test building [1].

According to Table I, the test building is considered as a lightweight construction with a low thermal mass and not well-isolated also by referring current regulations. Those types of building could be encountered in La Reunion. For the building with PCMs, PCMs are located between plasterboard and polystyrene on North and South walls. During this simulation study, building is considered as closed, without ventilation of the enclosure and the roof. PCM property is given in Table II.

The authors wish to thank Fonds Social Européen and La Région Réunion for their support and funding of the first author's thesis.

TABLE I. ARRANGEMENT OF THE TEST BUILDING WITHOUT PCM

Element	Composition (from exterior to interior with thickness of material)	Remark(s)
Opaque vertical walls (North, South, East, West)	Concrete 100 mm thick/ polystyrene 10 mm thick/plasterboard 13 mm thick	$U_{walls}=1,6 \text{ W.m}^{-2}.\text{K}^{-1}$
Window	Aluminium frame, 8 mm clear glass	Blind-type 0.8x0.8m, South Wall
Glass door	Aluminium frame, 8 mm clear glass	Glass in upper and lower parts, 0.7x 2.2m, North Wall
Roof (inclination 0°)	Corrugated galvanised steel 1 mm/ glass wood 45 mm thick Plasterboard 13 mm	$U_{roof}=1 \text{ W.m}^{-2}.\text{K}^{-1}$
Floor	Concrete slabs 24 mm thick on 10 mm thick polystyrene	$U_{floor}=1.9 \text{ W.m}^{-2}.\text{K}^{-1}$

TABLE II. CHARACTERISTICS OF USED PCM [1]

Parameter	Value	Unit
Thermal conductivity : λ_s/λ_l	0.2/0.2	$\text{W.m}^{-1}.\text{K}^{-1}$
Heat Capacity: C_p/C_{pl}	2000/2000	$\text{J.kg}^{-1}.\text{K}^{-1}$
Latent heat: L_m	230000	J.kg^{-1}
Phase change temperature: T_m	25	$^{\circ}\text{C}$
Heat density: ρ_s/ρ_l	880/770	kg.m^{-3}
Thickness	10	mm

III. ISOLAB CODE AND PCM MODEL

Description of PCM model integrated in the building simulation code, called ISOLAB, has already been presented in details in refs [2], [3]–[5]. Here, only a brief description is given.

A. ISOLAB code

ISOLAB is a prototype of building thermal software able to simulate the dynamic thermal behavior of a multi-zone building according to its description and climate files of its location. It also integrates the hygrothermal phenomena and ventilation influence [2]. Nodal descriptions of buildings and finite-difference scheme of the time variable one-dimension heat equation are used and a backward Euler method is used to determinate the temperature fields of the whole building. Also, in the case for building without PCMs, the building simulation code was validated with the International Energy Agency for Building Energy Simulation Test procedure. For more information, the interested reader may refers to [3].

B. PCM model in ISOLAB

Since May 2013 a thermal model, called MCPBat, dedicated to PCM thermal behavior based on the apparent heat capacity method has been elaborated respecting the state system formalism of ISOLAB code and, was fully-coupled with it. This model is able to predict the behavior of this kind of material integrated in building envelopes [1]. To ensure

reliable prediction of the thermal behavior of the whole building, the PCM model was empirically validated with field experimental data from a building integrated PCMs in the complex roof. In addition, the PCM numerical thermal model was validated according to the PIMENT laboratory's methodology. It is important to highlight that the indoor air temperature of the building with or without PCM is predicted with a relative maximal error of accuracy of $\pm 0.5^{\circ}\text{C}$. For more details, the interested reader may refers to [2], [5], [6].

IV. NUMERICAL SIMULATIONS

A. Climatic data

Eleven days of June of 2011 are chosen in order to ensure the phase change and regeneration of PCM. Climatic data and simulation assumptions were presented in details in [1]. Here, outside air temperature and relative air humidity are depicted in Figure 2.

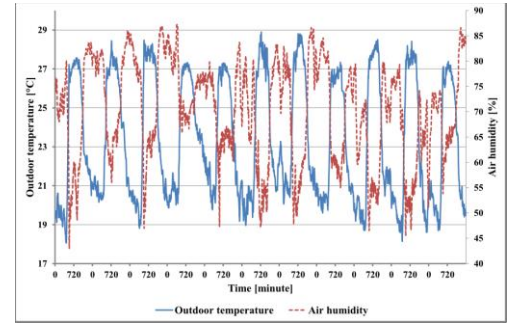


Fig. 2. Outside air temperature and relative air humidity for the chosen period.

B. Results and discussion

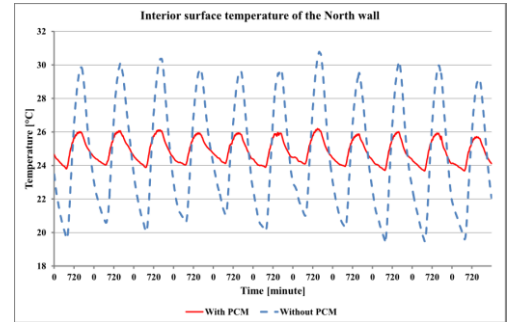


Fig. 3. Interior surface temperature of the North wall.

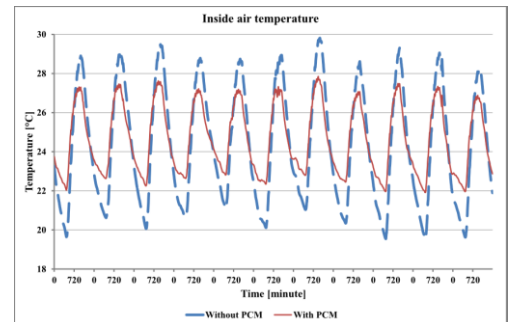


Fig. 4. Time-temperature profile for air within the building.

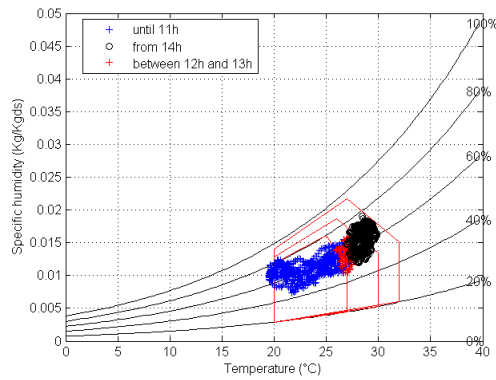


Fig. 5. Givoni bioclimatic chart without PCM.

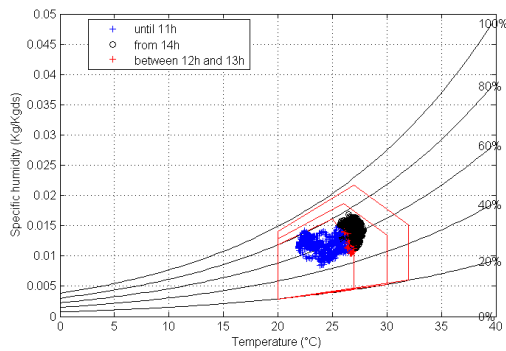


Fig. 6. Givoni bioclimatic chart with PCM.

Figure 3 and Figure 4 shows that PCMs integrated on the building envelopes can improve thermal mass of walls. The results indicate that heat transfer from the outside to the inside of building is curbed by the use of PCMs. As displayed in Figure 4, the building air temperature of the non-PCM building is higher than the other one. The averaged difference temperature between the two cases is approximately of 2°C. Results are also discussed in [1]. Using Table 1 and based on current regulations, the results from the test building without PCM were expected due to its low thermal performances related to U values. So the use of PCM seems a solution to increase thermal mass of building envelopes. The comparison between Figure 5 and Figure 6 for the chosen configuration clearly shows that for the latter figure many markers are outside of the comfort zones, mainly in the comfort zone 1 until 11 a.m. and in location and then requiring a heating system to achieve thermal comfort. With the thermal comfort study according to Givoni's psychrometric chart, the thermal comfort for the PCM building could be achieved by the simple use of natural ventilation or with the door opened or/and with the window opened. It will be then easier to reach thermal comfort with the PCM building that with the non-PCM building.

V. CONCLUSION AND FURTHER WORK

In this work, PCMs contribute to enhance the thermal energy storage for the low thermal mass of lightweight constructions. Indeed, the results show that these materials are able to improve human comfort. In the chosen configuration,

the peak temperature of the PCM building is up to 2°C less than the non-PCM building. From a current regulation viewpoint, PCM should be considered as an element of construction in order to improve the building energy efficiency by enhancing the storage energy. In Reunion Island, to overcome the problems related to different energetic performances for buildings built before 1st May 2010, the use of PCM seems a potential solution. In add, these materials avoid often using energy-hungry systems and could be decrease the energy bill by correctly placed them. To confirm the given results an experimental investigation in actual conditions will be conducted and will be presented in a future publication. The study will be completed with Predicted Mean Vote and Predicted Percentage of Dissatisfied indexes.

ACKNOWLEDGMENT

The authors wish to thank the PIMENT Laboratory of the University of La Reunion for the numerical studies performed with ISOLAB code.

REFERENCES

- [1] S. Guichard, F. Miranville, B. Malet-Damour, D. Bigot, H. Boyer, et T. Libelle, « Numerical Study of a Building Using Phase Change Materials (PCMs) in Reunion Island », *International Journal of Materials, Mechanics and Manufacturing*, p. 255-258, 2016.
- [2] S. Guichard, F. Miranville, D. Bigot, B. Malet-Damour, K. Beddiar, et H. Boyer, « A complex roof incorporating phase change material for improving thermal comfort in a dedicated test cell », *Renew. Energy*, vol. 101, p. 450-461, 2017.
- [3] F. Miranville, « Contribution à l'étude des parois complexes en physique du bâtiment: modélisation, expérimentation et validation expérimentale de complexes de toitures incluant des produits minces réfléchissants en climat tropical humide », *Université de la Réunion*, 2002.
- [4] F. Miranville, P. Lauret, M. Medina, et D. Bigot, « A simplified model for radiative transfer in building enclosures with low emissivity walls: Development and application to radiant barrier insulation », *J. Sol. Energy Eng.*, vol. 133, no 2, p. 021009, 2011.
- [5] S. Guichard, F. Miranville, D. Bigot, et H. Boyer, « A thermal model for phase change materials in a building roof for a tropical and humid climate: Model description and elements of validation », *Energy Build.*, vol. 70, p. 71-80, 2014.
- [6] S. Guichard, F. Miranville, D. Bigot, B. Malet-Damour, T. Libelle, et H. Boyer, « Empirical Validation of a Thermal Model of a Complex Roof Including Phase Change Materials », *Energies*, vol. 9, no 1, p. 9, 2015.