Simulating Heat Transfer Performance for Double-Walls Concrete Residential Building Envelope in Mediterranean Climate

Julia Nerantzia Tzortzi[1*] and Rola A. Hasbini[2]

[1 & 2]Politecnico di Milano, Department of Architecture, Built Environment and Construction Engineering, Advanced Construction Materials & Innovative Buildings Technologies, Milan, Italy

[*]julia.georgi@polimi.it

Keywords: Mediterranean Dwellings, Double Walls Concrete Building Envelope, Simulation, Heat Transfer, Greenhouse Gases Emissions Reduction

1. Introduction

Factually, carbon dioxide or CO_2 is the main global warming agent. In Europe, 36% of CO_2 emanates from the building sector which consumes 40% of the energy (European Commission, 2020). To meet Paris agreement, researchers are investigating construction techniques, which can be applied to new and/or renovated buildings, to achieve NZEB (Net Zero Energy Buildings) or nearly NZEB (MOOC, 2021).

The efficient energetic performance of a building envelope being largely tied to its thermal performance, a related improvement is, hence, one of the primary goals (COMSOL Multiphysics® webinar, 2022). In this perspective, this research focuses on a simple construction technique: the double-wall concrete for buildings envelopes. In Mediterranean climatic zone, this type of construction reduces heating/cooling loads; greenhouse gases emissions related to the energy consumption are, therefore, reduced.

1.1 Methodology

To prove the argument of decreased heating loads requirement by reverting to a double-concrete wall construction in residential buildings, we adopted the following methodology: first, a virtual laboratory is set in COMSOL Multiphysics® version 6.0 simulation software where parameters related to the internal and external temperature are initially set as well as those related to proposed materials properties; second, a prototype residential apartment plan is drawn first with a single-concrete-wall construction and then with a double-wall concrete; third, the heat transfer performance through both layouts is simulated.

Similarly, two simulations for peak summer temperature are, also, performed for both the single and the double-concrete wall building envelope respectively.

2. The Simulations

2.1 Definitions

For this research, a computer simulation is defined as virtual modelling representation of a physical reality for analytical study. Furthermore, a parametric computer simulation is defined as a variables-based representative computer model which can be manipulated for various studies while based on the originally modelled one.

2.2 Methods

Framing the analysis within the Mediterranean climatic zone, peak external temperature is set to 0 °C (winter) while internal temperature is set to 23 °C (comfort level). A prototype single-bedroom studio is proposed consisting of only two-rooms: one living room with a kitchen counter and one bedroom with a toilet. For the same layout, the simulation is conducted, first, for the single-concrete-wall construction building envelope, and then, for the double-wall concrete one.

The simulations are performed as an application of COMSOL Multiphysics® Heat Transfer module for Buildings and Constructions (COMSOL Multiphysics® software, 2022) – Stationary Study. Some of the considered parameters are indicated in the Table 1 below.

Table 1: Heat Transfer Simulation Parameters

Parameters	Type	Figure
Parameter 1	External Temperature	0 °C
Parameter 2	Internal Temperature	23 °C
Parameter 3	Atmospheric Pressure	1 atm
Parameter 4	Convective heat transfer coefficient	4 $W/m^2.K$

Other parameters related to the geometry of the proposed dwellings layouts are indicated in the drawings below – Fig. 1 and Fig. 2. The dwellings layouts were drawn on AutoCAD 2023 (AutoDesk).

Figure 1. Prototype dwelling with a single concrete wall as a building envelope[1]

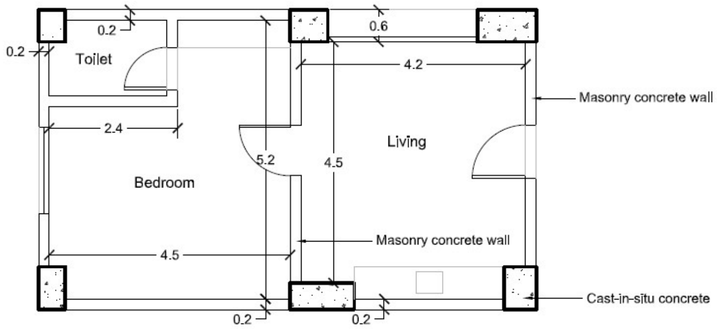
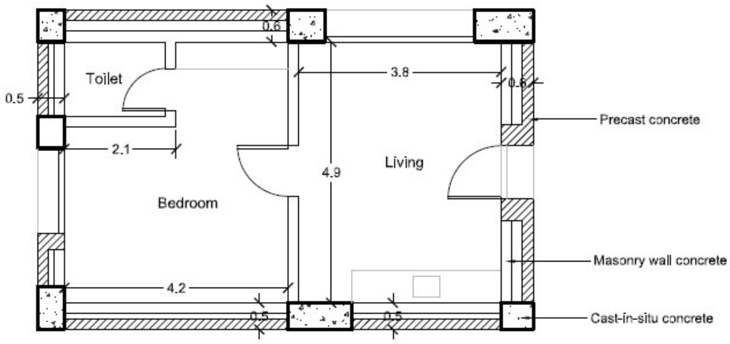


Figure 2. Prototype dwelling with a double-wall concrete as a building envelope[2]



2.3 Results

Within the wall space, the first simulation shows interference of the internal temperature with the external one while the second simulation shows non-interference, except at structural jointing continuous elements – Fig. 3 and Fig. 4. Hence, a double-wall concrete envelope would insulate the inner heated space from the external cold environment due to the effective presence of the interstitial air space.

[1] Drawing is not to scale

[2] Drawing is not to scale

Figure 3. Heat transfer through single-wall concrete building envelope for peak winter temperature in Mediterranean climatic zone. Simulation by Authors using COMSOL Multiphysics® version 6.0[3].

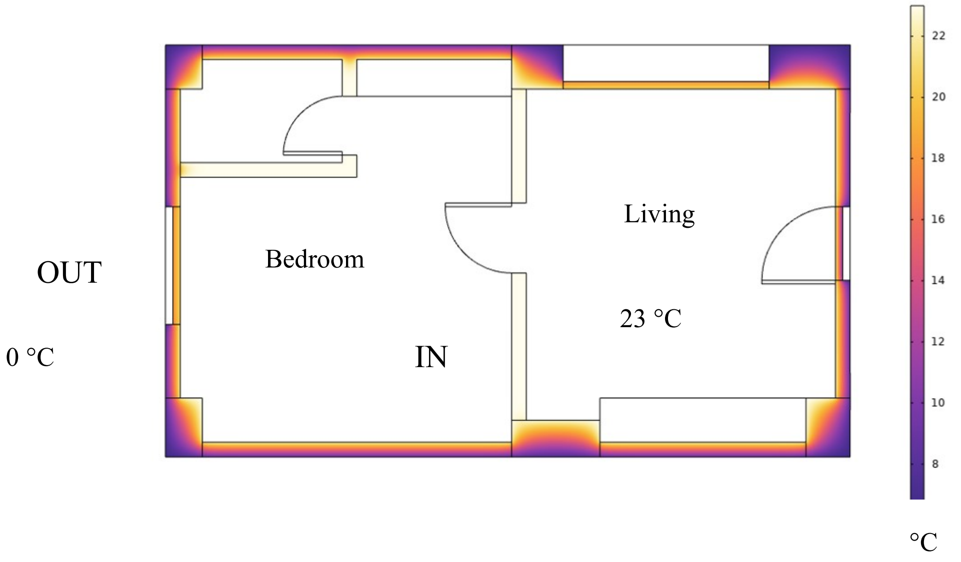
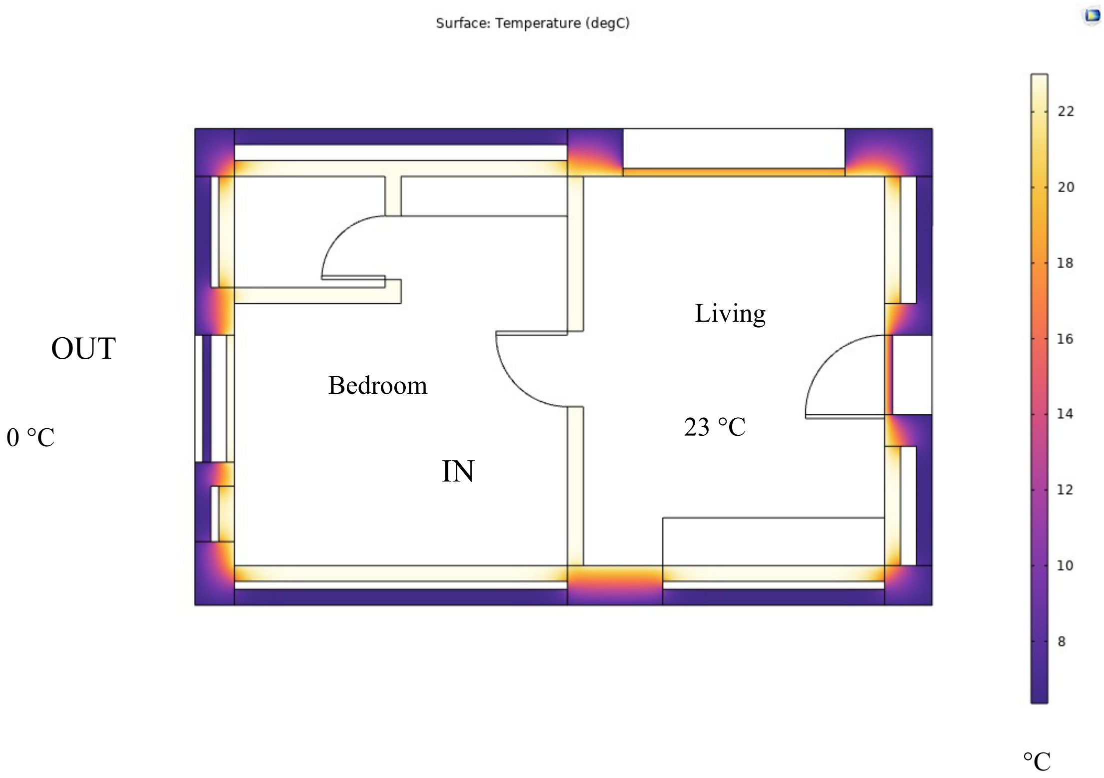


Figure 4. Heat transfer through double-wall concrete building envelope for peak winter temperature in Mediterranean climatic zone. Simulation by Authors using COMSOL Multiphysics® version 6.0[4].



---

[3] Drawing is not to scale

[4] Drawing is not to scale

The simulations are based on the European norm EN 15026 (COMSOL Multiphysics® documentation, 2022). COMSOL Multiphysics Heat Transfer Module capabilities are based on the three modes of heat transfer: conduction, convection, and radiation (COMSOL Multiphysics®, 2022).

2.4 Discussions

Adequate separation of the internal heated wall layer from the cold one implies decreased internal heating load requirement to reach/stabilize internal comfort temperature.

Reduction of heating/cooling loads results in a reduction of the related greenhouse gases (GHG) emissions. Whether for new or for renovated building envelopes, the double wall construction effectively contributes in reducing the GHG from the building sector. Further enhanced insulations techniques would, efficiently, minimize those GHG emissions.

Limitations of the study are related to the virtual set-up where the impact of orientation, sun, prevailing wind direction and, overall yearly heating/cooling loads amount are not calculated. Furthermore, for model simplification, the impact of construction details, such as precast panels specific shapes and fixations, is not taken into consideration; steel reinforcement in structural elements, mortar and material finishes have been neglected through the study. Finally, the study being Stationary, time related changes were not analysed.

2.5 Further studies

Similar simulations were conducted for the peak Mediterranean summer conditions, i.e. an external temperature of 35 °C and an internal air-conditioned temperature of 22 °C. For the case of the double-concrete wall, the simulations showed separate cooling behaviour of the internal concrete wall from the external hot one.

However, the life cycle assessment of the proposed double-walls concrete construction needs to be reviewed in comparison with the single concrete wall construction for the building envelope for an assessment of an overall reduced GHG emissions.

The impact of suggested further measures, such as the initial orientation of the building structure and the provision of natural ventilation for the enhancement of the building envelope thermal performance, requires serious parametric investigations. Also, construction technical considerations, such as adequate finishing and thermal insulation characteristics, are additional factors to be optimized within the context of the building envelope best heat transfer performance.

3. Conclusion

In conclusion, wise construction assessment of the building envelope together with the adoption of advanced simulation tools may effectively minimize CO_2 and other GHG emissions from Mediterranean dwellings and from the building sector, in general.

Concerned with the impact of double-concrete walls construction in optimizing heat transfer between outer and inner spaces, for Mediterranean residential buildings, this study has proven the efficient reduction of heating load requirement; thus, the effective reduction of related greenhouse gases emissions.

Future research would simulate various other possible climatic conditions adopting different building envelope techniques and materials. Collected in a dedicated database, classified results would help professionals chose optimum construction techniques and materials for the building envelope.

Acknowledgment

This paper is one of the outputs of the research undertaken by the Authors, at the Department of Architecture, Built Environment and Construction Engineering at Politecnico di Milano, as related to the topic "Green Parametric Solutions for the Building Envelope". The Authors are grateful to Politecnico di Milano doctorate academic society for providing extensive adequate research environment. Special appreciations are expressed towards Dr. Carlo Andrea Castiglioni for his valuable technical guidance and support of the research.

References

COMSOL Multiphysics® Version 6.0., Bost, C. and Dubois, C. (2022). Energy Performance of Buildings [Online recorded webinar]. Available: https://www.comsol.com/support/learning-center/article/How-to-Optimize-Energy-Performance -of-Buildings-41991 [accessed on 29/9/2022].

COMSOL Multiphysics® Version 6.0 – documentation (2022). Condensation risk in a wood-frame wall - Dynamic modelling of heat and moisture transport [Online]. p. 3. Available: https://www.comsol.com/model/download/928571/models.heat.wood_frame_wall.pdf

COMSOL Multiphysics® Version 6.0 (2022). Heat Transfer Module. Available: https://www.comsol.com/heat-transfer-module [accessed on 30/9/2022].

COMSOL Multiphysics® Version 6.0 software (2022). Application Library. Path: Heat_ Transfer_Module / Buildings_and_Constructions / wood_frame_wall

European Commission (2020). In focus: energy efficiency in buildings [Online]. Available: https://ec.europa.eu/info/news/focus-energy-efficiency-buildings-2020-lut-17_en [accessed on 3/10/2022].

MOOC (Massive Online Open Courses) (2021). *Deep Renovation for Energy Efficient Residential Buildings*, Politecnico Di Milano, Certified Course accomplished on August 27, 2021.