XI INTERNATIONAL CONFERENCE
INDUSTRIAL ENGINEERING AND ENVIRONMENTAL PROTECTION 2021
IIZS 2021, October 07-08, 2021, Zrenjanin, Serbia

IMPACT OF GREEN ROOFING ON THE ENERGY PERFORMANCE OF A DETACHED PASSIVE RESIDENTIAL BUILDING WITH A TROMBE WALL

Ana Vukadinović[1], Jasmina Radosavljević[1], Amelija Đorđević[1]
[1]Faculty of Occupational Safety, University of Niš, Republic of Serbia
ana.vukadinovic@znrfak.ni.ac.rs, jasmine.radosavljevic@znrfak.ni.ac.rs amelija.djordjevic@znrfak.ni.ac.rs

Abstract: Use of passive systems in detached residential buildings reduces the energy required for heating. Green roofing on such buildings has numerous environmental and energy-related benefits. This paper examines the impact of different green roof types on the energy properties of a detached residential building with a Trombe wall. The method applied is dynamic simulation using the EcoRoof simulation model within the EnergyPlus™ software package. The location of the analyzed building is the city of Niš, Serbia. The results indicate that the use of extensive green roof type in the analyzed model building with a Trombe wall reduces the total energy required for cooling by 3.45%.
Key words: green roof, detached residential building, Trombe wall, energy properties

INTRODUCTION

Construction industry accounts for approximately 40% of the total energy consumption, while also being responsible for about 36% of CO2 emissions [1]. Increased greenhouse gas emissions and the resulting negative environmental effects have urged architects worldwide to reinvestigate the technology of bioclimatic architecture as well as passive solar systems. The use of solar energy in solar and bioclimatic architecture is justified both economically and environmentally [2]. Implementing passive systems in detached residential buildings helps reduce the use of conventional energy-generating products for heating and cooling. Such buildings require special design, because their efficiency depends on the factors such as climate, terrain, terrain inclination, distance from other buildings, orientation, greenery, shading, and so on.

PASSIVE SYSTEM WITH A TROMBE WALL

In 1967, Félix Trombe used the patent for a massive solar wall to build a passive system into a detached residential house in Odeillo in the Pyrenees, which was later named Trombe wall (TW). The Trombe wall consists of a massive wall painted a dark color, made of a material with excellent thermal storage properties, most commonly brick or concrete. The exterior of the wall is shielded with glass forming an air gap of 2-10 cm. When penetrating the glass, sunlight hits the Trombe wall and heats it [3].

METHODOLOGY

This paper examines the influence of green roofing on the energy properties of a residential building with a Trombe wall in a humid continental climate in the city of Niš, Serbia. An analysis is performed of the required energy for heating and cooling of a building with a Trombe wall with extensive, semi-intensive, and intensive green roofing (Table 1). The method used to determine the building's energy properties is dynamic simulation by means of EnergyPlus™ software.

Green roof model

A green roof is an open space or garden built as a com plex biophysical structure allowing vegetation to grow over a roof structure. Depending on substrate thickness, vegetation type, maintenance, irrigation, and construction cost, green roofs are classified into extensive, semi-intensive, and intensive green roofs

The EnergyPlus™ dynamic simulations were carried out using the EcoRoof simulation model to examine the energy performance of a model building with a Trombe wall passive system and a green roof [10]. EcoRoof considers the heat exchange inside the plant canopy, the influence of plant canopy on heat transfer, evapotranspiration, and heat storage in the substrate. The input parameters for the simulation model include substrate thickness and thermal properties, plant canopy volume, plant height, plant moisture transpiration, substrate moisture, and irrigation. The basic input parameters for the green roof model variants MODEL GR1, MODEL GR2, and MODEL GR3, defined in EnergyPlus™, are given in Table 2. The green roof surface area is 92.16 m2.

Model of a detached passive building with a Trombe wall and a green roof

The reference model of a detached passive building with a Trombe wall has only the ground floor, with a floor surface area of 92.16 m2. The floor base is 14.4 m long and 6.4 m wide. The building height is 3 m.
The Trombe wall is made of 0.2 m thick concrete and shielded with air filled double glazing placed 0.10 m in front of the wall. The Trombe wall covers the entire length of the south-facing façade (14.4 m). The wall also contains top and bottom ventilation openings with the dimensions 0.5x0.2 m. The window-to-wall ratio of the east-, west-, and north-facing façades is WWR=20%.

Table 2. EnergyPlus™ input parameters of the green roof over the model building with a Trombe wall [9]

Parameter	MODEL GR1	MODEL GR2	MODEL GR3
Green roof type	Extensive	Semi-intensive	Intensive
Vegetation height (parameter range 0.01-1.0 m)	0.15 m	0.50 m	1.0 m
Leaf area index (LAI) (parameter range 0.001-5.0)	2	3.5	5
Leaf albedo	0.22	0.22	0.22
Emissivity of leaves	0.95	0.95	0.95
Stomatal resistance (parameter range 50.0-300.0 s/m)	150	150	150
Thickness	0.15 m	0.35 m	0.50 m
Substrate albedo	0.14	0.14	0.14
Substrate emissivity	0.90	0.90	0.90

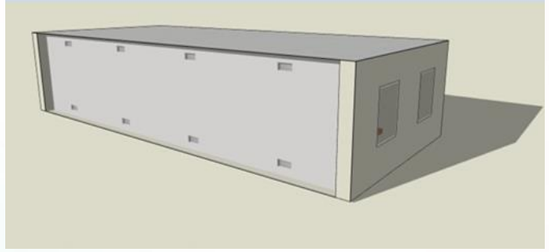

Fig. 2. 3D representation of the detached building model with a Trombe wall

RESULTS

EnergyPlus™ dynamic simulations were carried out and energy properties for the heating and cooling periods were determined for the defined reference model building with a Trombe wall without a green roof and for its green roofed variants (MODEL GR1, MODEL GR2, and MODEL GR3). The simulation results for the annual and monthly heating and cooling energy requirements for the climate of Niš are shown in Tables 4.

Table 4. Total annual heating and cooling energy requirements of the model building with a Trombe wall and without a green roof and of its green roofed variants MODEL GR1, MODEL GR2, and MODEL GR3

	Energy required for heating [kWh]	*Reduction of energy required for heating [%]*	*Energy required for cooling [kWh]*	*Reduction of energy required for cooling [%]*
Reference model (without a green roof)	6064.13	Ref.	3155.26	Ref.
MODEL* TWGR*1	6064.13	0%	3155.26	0%
MODEL*TWGR*2	6073.332	+0.15%	3105.94	-1.56%
MODEL*TWGR*3	6100.03	+0.59%	3046.29	-3.45%

CONCLUSION

This paper presented a comparative analysis of the energy properties of a detached passive residential building with a Trombe wall and the addition of different green roofing types (extensive, semi-intensive, and intensive). It was determined, using the method of dynamic simulation, that the use of extensive green roofing did not improve the energy properties of the building. In addition, the heating energy requirements when using semi-intensive and intensive green roofing were higher compared to the reference model without green roofing. The biggest changes in the energy properties were found when intensive green roofing was used, as it reduced the cooling energy requirements by 3.45%.

ACKNOWLEDGEMENT
This paper is a result of a research supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia according to contract no. 451-03-9 / 2021-14 / 200148.