THE EFFECT OF A NOVEL ROOF POND TO THE INDOOR AIR TEMPERATURE FOR PASSIVE COOLING

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ABSTRACT

The effect of a new passive cooling device to the indoor air is analyzed based both to experimental and simulating results. The tested device is a ventilated pond protected with an aluminum layer, placed on the roof of the examined building. The indoor air temperature of the building has been recorded, before and after the placement of the roof cooling technique. The record indoor air temperature is analyzed, in regard to the ambient conditions. Furthermore, the record indoor air temperature before the application of roof cooling technique has been assessed in order to create the digital model of the building, using the TRNSYS software. The climatic data of the experimental period are applied to the simulating model, in order to estimate the indoor air temperature that the building would have without the tested roof cooling technique. According to the simulation, the daily indoor air temperature fluctuation for the building without any roof treatment varies from 4.8 to 8.2^{o}C, while the corresponding values after the application of the Ventilated pond with Aluminum layer are significantly reduced, varying from 1.6 to 3.1^{o}C.

KEYWORDS

Roof Ponds, indirect evaporative cooling

1 INTRODUCTION

Evaporative cooling is widely considered as an effective passive cooling technique [Givoni, 2011]. Cooling towers [Givoni, 1997, Hamza 1995], cooling radiators [Erell, 1999, Dimoudi, 2006] and roof ponds are only few evaporative cooling techniques.

Roof ponds are an effective passive cooling and heating technique. A number of pond variations have been proposed differing in terms of function and constructional characteristics (e.g. water circulation, movable insulation, spraying system, protective materials etc [Spanaki et al, 2011].

Ventilated pond protected by a reflective layer has been proposed in small scale experiments [Spanaki et al, 2012]. According to the experimental results, the system results lower bottom pond temperatures comparing to other ponds, protected with different materials.
The present study aims to investigate the performance of the ventilated pond protected with reflective layer, in terms of indoor air temperature reduction. The system is placed on the roof of a small building, while the bottom pond and the indoor air temperatures are both recorded.
The records of the indoor air temperature of the building before the application of the investigated system on the roof are used in order to simulate the building. The simulating model is used in order to calculate the temperatures that the building would have without any roof treatment.
The aim of the present study is to assess the effectiveness of the ventilated pond with aluminium layer in terms of indoor air temperature.

2. DESCRIPTION OF THE INVESTIGATED POND

Roof pond is consisted by a wooden frame on roof's perimeter, as shown in Figure 1. The pond is filled with water up to 0.10-0.12m deep while water level is kept constant by a floater as shown in Figure 2. The aluminium layer is placed on wooden beams, as shown on Figures 3 and 4. The aluminium layer placed above water layer, reflecting solar radiation during daytime.


Figure 1: Wooden frame is the pond's perimeter.   Figure 2: Nylon for pond waterproofing and floater.

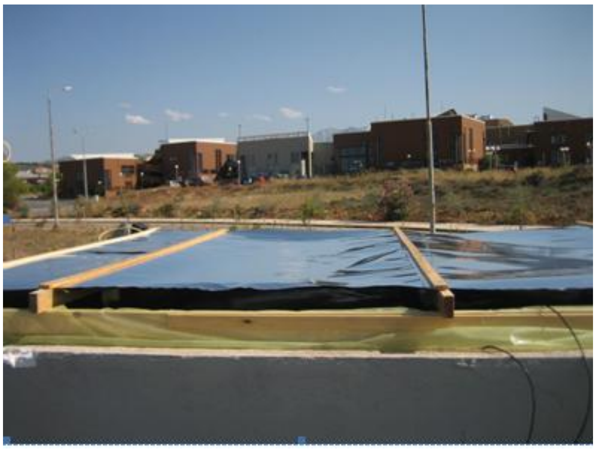


Figure 3: Ventilated Roof pond with aluminium layer.

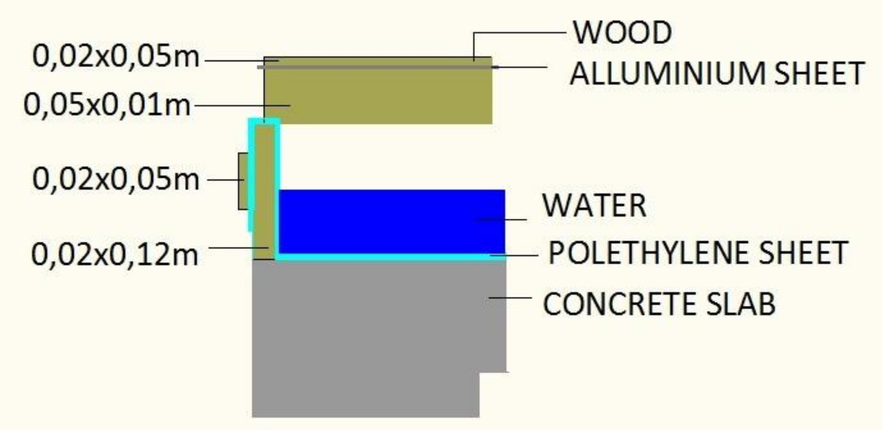
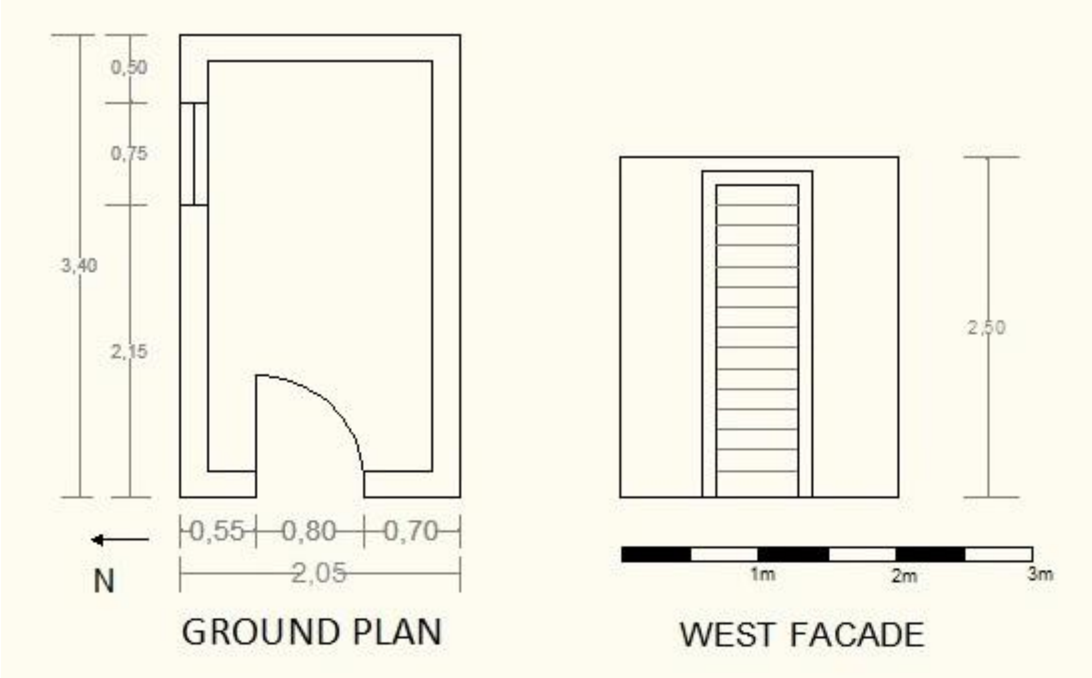


Figure 4: Section of the Ventilated Roof pond with aluminium layer.

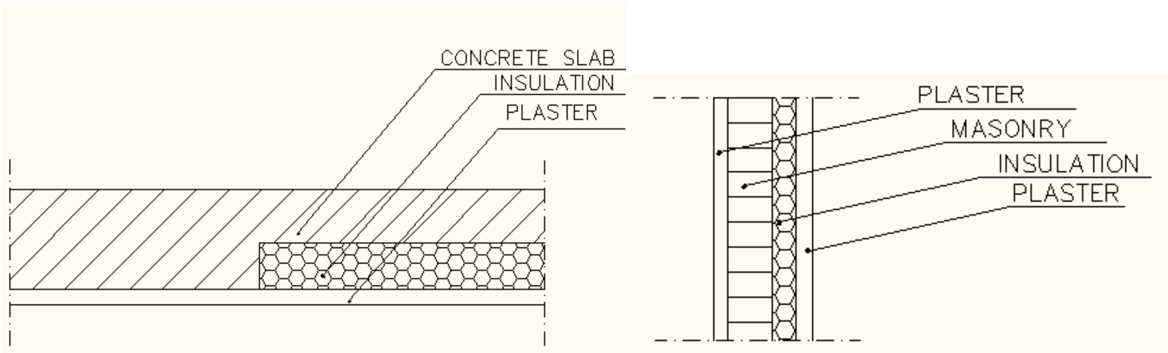
3. BUILDING DESCRIPTION

The small building that is record during the experiments is shown on Figure 5. The area of the roof is $6m^2$, as shown on Figures 6 a and b. Section of building envelope are shown on Figures 7 a and b. The roof is partly insulated, as shown in the infrared photo on Figure 8.

Figure 5: Photo of the building with the investigated pond on the roof.



Figures 6 (a) Ground Plan and (b) west facade of the building.



Figures 7 (a) Roof and (b) Wall section of the building.

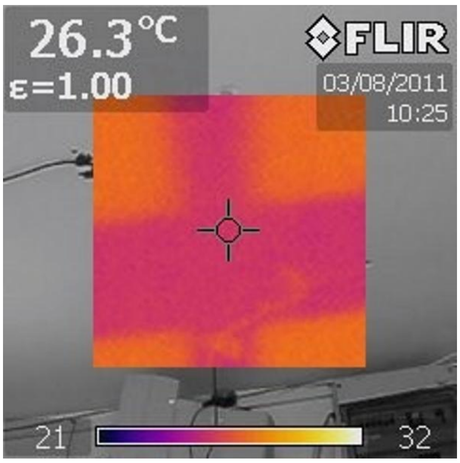


Figure 8: Photo of building ceiling taken with infrared camera.

4. EXPERIMENTAL SET-UP

The experimental records refer to the period between June and August 2011, on the Campus of Technical University of Crete in Chania – Greece. The climatic data on the site of the experiments was obtained from meteorological station of the Institute of Environmental Research, of the National Observatory of Athens. The altitude of the site is 137m, while the exact coordinates are: latitude 24 ° 04 '09 "E and longitude and 35 ° 32' 00" N.

The temperatures are recorded with 8 temperature recorders T-Logg 100 placed in the bottom of the pond. The internal conditions are recorded by 2 loggers temperature - humidity T-Logg 100E brand Greisinger electronic. The loggers have a resolution of 0.1°C and accuracy of measured values ± 0.5°C. Minisoft and GSOFT 40K software is used for data transferring.

Table 1: Thickness and U-values of the Builings envelope

Building element	Thickness (m)	U-value (W/m^{2}K)
Walls	0.26	0.806
Concrete roof	0.16	1.033 (mean U-value)
Windows		5.680

Table 2: Properties of building envelope used in simulation, that are included in the *.bui file of the TRNBuild Software. The Boundary temperature for floor is 27^{o}C.

	Area (m2)	Thickness (m)	U-value (W/m^{2}K)	Solar Absorptance of wall Front	Solar Absorptance of wall Back
Wall	32.76	0.26	0.806	0.3	0.3
Roof	7.00	0.16	1.033	0.8	0.75
Floor	7.00	0.19	2.901	0.8	0.8
Windows	2.13		2.830		

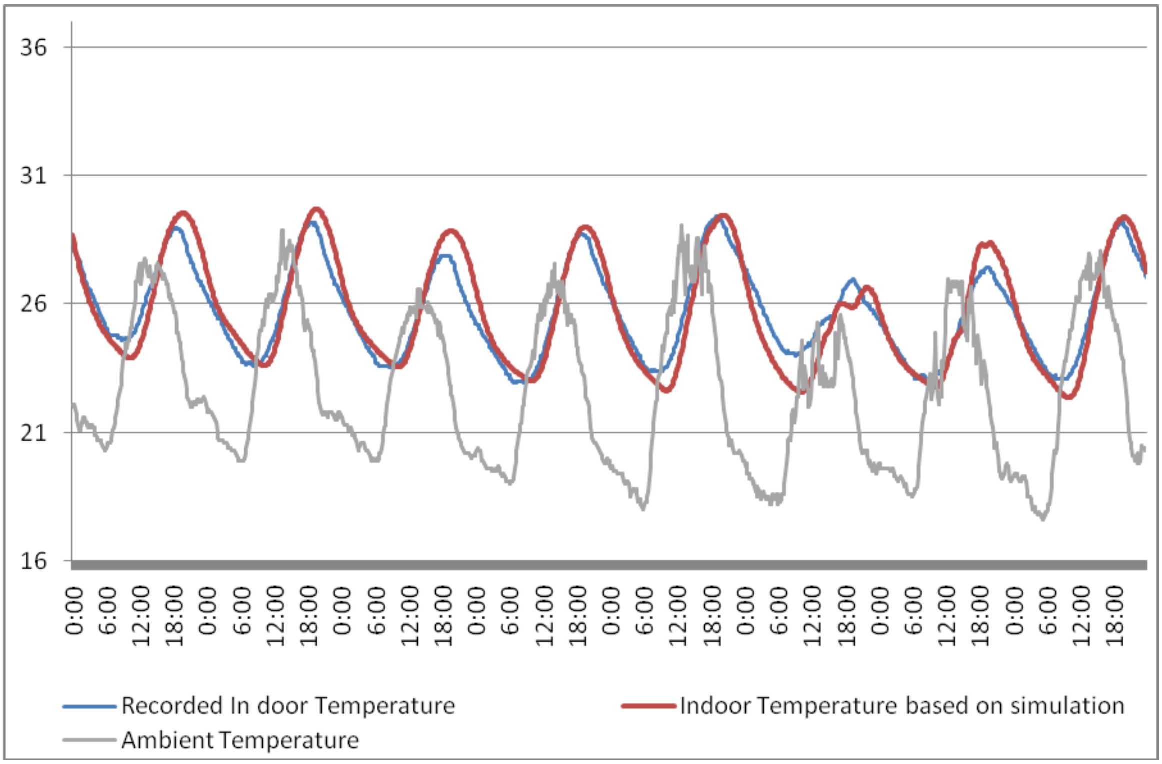


Figure 9: Indoor air temperatures according to experiments and simulation, before the application of the system in building's roof.

5. BUILDING SIMULATION

The indoor air temperature of the building before the addition of the investigated system on the roof has been recorded for a 22 days period.
The building is simulated using the parameters listed on Tables 1 and 2. The climatic data of the 22 days period are used in order to simulate the building without any roof treatment. The calculated indoor air temperatures are compared to the experimental ones, in order to validate the model. As shown in figure 9, the maximum variation of experimental and simulating values are 12%.

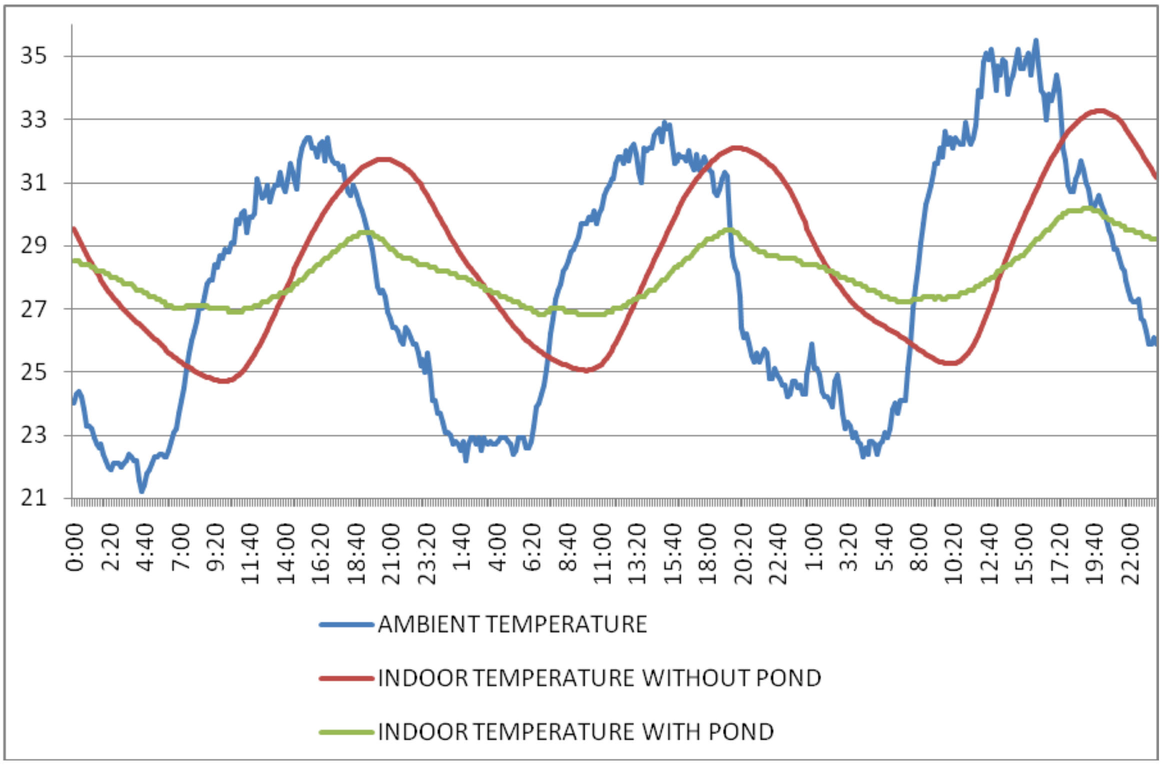


Figure 10: Indoor air temperatures according to experiments and simulation, after the application of the system in building's roof.

6. THE EFFECT OF THE VENTILATED ROOF POND WITH ALUMINIUM LAYER TO THE INDOOR AIR TEMPERATURE

Figure 10 shows the indoor air temperature of the building with the ventilated roof pond, according to the experiments, and the indoor air temperature the building would have without any roof treatment, according to the simulation.

For the whole period of experiments the fluctuation of the indoor air temperature for the building with the Ventilated pond with Aluminium layer varies from 1.6 and 3.1^{o}C. The corresponding value for the building without any roof treatment varies from 4.8 to 8.2^{o}C. As a result, the proposed technique results a reduction of indoor air temperature to the 40% compared to the building with roof pond. The indoor air temperature fluctuation of the building with the ventilated pond with aluminium is the 25% of the ambient air temperature fluctuation.

Furthermore, the mean maximum indoor air temperature in the building without any roof treatment reaches 31.7°C, almost equal to the maximum ambient air temperature (32.4 °C). The corresponding mean maximum indoor air temperature in the building with the ventilated pond with the aluminium is decreased at 29.0°C. The increased heat capacity of water increases the minimum indoor air temperature by 1.3°C.

7. CONCLUSION

The present investigation proposes a new passive roof cooling technique. The ventilated pond with aluminium layer can easily be constructed with common materials. According to the experiments, the system reduces the indoor air temperature fluctuation.

Further research can further investigate alternative durable and strong materials that can be used for the construction of the system. Furthermore, issues related to the thermal performance of the system in respect to climatic conditions should be also investigated.

Acknowledgements

The present investigation is a part of a Phd study supported by the Greek State Scholarships Foundation.

References

1. Dimoudi A., Androutsopoulos A., The cooling performance of a radiator based roof component, Solar Energy 80 (2006) 1039–1047
2. Erell E., Etzion Y, Analysis and Experimental verification of an improved cooling radiator, Renewable Energy 16 (1999) 700-703
3. Givoni B, Performance of the "shower" cooling tower in different climates, *Renewable Energy,* Vol. 10, No. 213, pp. 173-178, 1997
4. Givoni Baruch, Indoor temperature reduction by passive cooling systems, Solar Energy 85 (2011) 1692–1726
5. Hamza A. , Ali H., Taha I. M. S., Ismail I. M. , Cooling of water flowing through a night sky radiator, *Solar Energy* Vol. 55, No. 4, pp. 235 253, 1995
6. Spanaki Artemisia, Kolokotsa Dionysia, Tsoutsos Theocharis, Zacharopoulos Ilias (2012), Theoretical and experimental analysis of a novel low emissivity water pond in summer, Solar Energy 86, 3331–3344
7. Spanaki Artemisia, Tsoutsos Theocharis, Kolokotsa Dionysia (2011), On the selection and design of the proper roof pond variant for passive cooling purposes, Renewable and Sustainable Energy Reviews 15, 3523–3533