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COMPARISON BETWEEN TEMPERATURE REGIME OF A BUILDING WITH PARTIAL GREEN AND PARTIAL CONVENTIONAL ROOF

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Abstract: *The purpose of this paper is to realize a comparative study between the temperature regimes of a green roof and a conventional roof. The experimental system used for monitoring both the classic roof and the green roof, includes 9 digital temperature sensors, a data acquisition board and a PC. The measurements were made between 1 and 14 July 2012. It was highlighted the thermal inertial effect of the green roof, by reducing the variation range and by inducing a phase shift of the inside air temperature variation and waterproof membrane temperature variation. It was also observed the cooling effect to the outside air above the green roof.*

Keywords: *green roof, air temperature, roof temperature, heat transfer, data acquisition system.*

1. INTRODUCTION

In the current global warming period, urban environments faces a number of environmental problems such as increased urban air temperature and water pollution. To combat these problems it is intended to implement measures that are environmentally friendly and with long life period.

One of the measures satisfying requirements specified before is the placement of a vegetation layer on the buildings roofs in urban areas. The roof with vegetation and substrate layer is called "green roof" ([1] – [5]).

The concept of "green roof" has ancient origins. The first evidence of such a roof is dating back to antiquity when King Nebuchadnezzar II built the "Hanging Gardens of Babylon" ([1],[6],[7]). The mentioned green roofs were built to thermally insulate the buildings, because the climate of Babylon was hot and dry.

Green roofs are classified in three types ([8], [9], [10]), depending on the thickness of growing medium layer:

- Extensive – max. 15 cm of soil,
- Intensive – min. 15 cm of soil, and
- Semi-intensive – about 15 cm of soil.

Transformation of classical roofs in green roofs can provide many benefits both to the buildings and to the environment. Green roofs can reduce the:

- Air temperature of the environment ([3], [4], [5], [10], [11]);
- Air temperature inside the building ([10], [12]);
- Air and water pollution ([1], [3], [13], [14]);
- Storm water runoff ([1], [3], [14], [15] [16],);
- Urban noise ([17], [18], [19]).

A series of studies discuss about the temperature regimes of classic roofs and green roofs. These studies present higher summer values of roof surface temperatures for classic roofs than for green roof as indicated in table 1.

Table 1. Reported classic and green roofs temperatures

Reported classic roof temperatures		Reported green roof temperatures	
[°C]	References	[°C]	References
50	[20]	13.1…22.5	[6]
56	[21]	25	[22]
70	[6]	35.2	[21]
80	[10]		

Air temperature from urban areas presents an upward trend. This phenomenon may be due to low albedo values of the roofs, streets and paved areas surfaces. These can lead to the association of the urban areas with the term of "urban heat island" ([1], [3], [10], [23], [24], [25]). The air temperature from urban areas can be up to 9°C grater than in rural areas ([26]).

Air temperature inside the building with green roof is lower than air temperature inside the building with classic roof with 1…5°C. The scientific literature considers that green roofs are more a passive cooling method than a thermal insulation method ([12], [21], [24],).

The main purpose of this paper is to analyze by monitoring, the temperature regimes of a building with partial classic and partial green roof. The building is situated in Cluj-Napoca, Romania.

In this study was evaluated the potential of a green roof to reduce some temperatures like: the air temperature inside and outside the building, on the ceiling, etc.

2. MATERIAL AND METHOD

2.1 Site description

The studied green roof was installed in august 2011 on a building situated on the outskirts of Cluj-Napoca, Romania (46°47'39.84"N, 23°37'41.55"E). The green roof layers are: waterproofing membrane (bituminous membrane), drainage layer (gravel) and the growing media (soil layer). The length of the green roof is 6.3 m and the width is 5.78 m, resulting in an area of 36.41 m^2.

The grass species used in this experiment are: *Lolium perenne*, *Poa pratensis*, *Poa trivialis*, *Festuca rubra*, *Festuca arundinacea*. The structure of installed green roof respects the common structure of the green roofs presented in specialized literature. The installed green roof was irrigated every day, for 15 minutes, in the morning (7:00) and in the evening (18:00). The amount of water used per irrigation is about 50 litres of water (100 litres per day).

2.2 Experimental setup

The roof of the analyzed building was divided in two equal areas, of which one was covered with green roof. The uncovered area represented the reference roof. Each area represents the roof of different chambers with similar dimensions.

Building used for this experiment is an electrical equipment repair shop. In this building works a person for 8 to 10 hours per day starting at 8:00 AM. Entrance into the room with classic roof it is made through the only door which communicates with the exterior.

The access into the room with green roof it is made from the room with classic roof through a door, the two rooms being adjacent and separated by a concrete wall. The door between the two rooms remained open during the working hours.

The room with classic roof has windows which were closed during the measurements period. The windows of the room covered with green roof remained open during the working hours.

The buildings door was open several times for long periods of time during the working hours.

Temperatures inside and outside the building were monitored using digital temperature sensors (model DS18B20+ from Maxim Integrated™). The wires of all temperature sensors have been waterproofed.

Inside of each chamber were placed two temperature sensors (a total of four sensors), one measuring the ceiling temperature and the other one the air temperature. The temperature sensors locations are shown in figure 1.

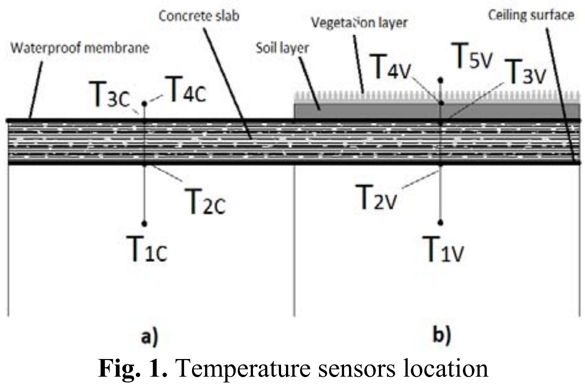

Fig. 1. Temperature sensors location
a) reference roof; b) green roof

The sensors placed outside the building are measuring the temperature of the:

- Waterproof membrane of classic roof (T_{3C}) and the green roof surface (T_{3V});
- Air at 7 cm above the classic roof waterproof membrane surface (T_{4C});
- Soil surface of the green roof (T_{4V}) (7 cm above the waterproof membrane surface);
- Air at 7 cm above the soil surface (T_{5V}).

A home made data acquisition system was designed and manufactured for the experiment. Schematic representation of the temperatures acquisition system is presented in fig. 2.

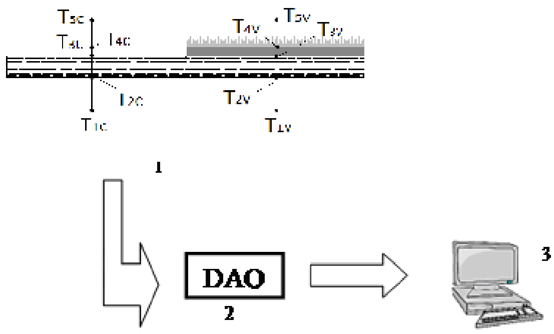

Fig. 2. Structure of temperature acquisition system
1) temperature sensors; 2) data acquisition board (DAQ); 3) local PC

DAQ (2), specially designed for this experiment, takes the information from the digital temperature sensors (1) and send it to the local PC (3), were software reads and save data in a ".txt" file. Acquisition software displays in a window instant readings from all temperature sensors. Saved data represents the values corresponding to one minute interval.

3. RESULTS AND DISSCUSIONS

The measuring period is 1…14 July 2012. In this period the acquisition system worked without interruption. During this time a number of 2016 set of values (corresponding to the number of lines written into '.txt' file) were saved on local PC. Each line contains 11 columns with: date, time and the 9 values corresponding to temperature sensors readings in the second '00' of each minute during the measuring period.

In this paper are represented graphically values acquisitioned every 10 minutes (2016 values) for all temperatures measurement points presented in fig. 1. The analysis was made based on entire saved data.

Inside air temperature variation from the two monitored chamber is presented in fig. 3.

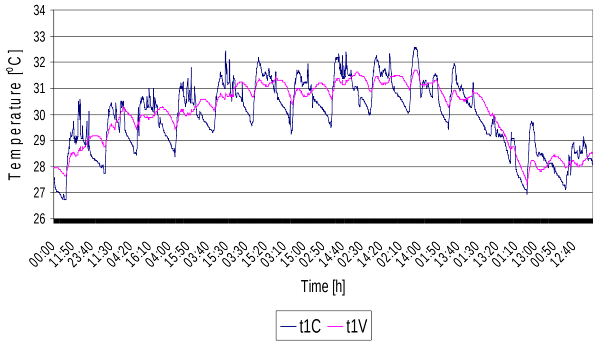

Fig. 3. Inside air temperature variation

On fig. 3 it can be easily observed that the air temperature inside the room with classic roof (t_{1C}) presents higher variations between day and night, compared with the air temperature inside the room with green roof (t_{1V}). Temperature t_{1C} varies by up to 3.81°C between day and night, while t_{1V} varies by up to 2.18°C.

The air temperature inside the room covered with green roof (t_{1V}) can be with up to 1.87°C lower then air temperature inside the room with classic roof (achieved between 14:00 and 16:00). Also was observed that during the night t_{1V} is higher then t_{1C} with up to 1.19°C (achieved between 6:00 and 7:00).

There were no significant differences between the mean air temperatures values measured in both rooms. This may be due to operating conditions of both rooms (windows/ door opened for long period of time).

Ceiling temperature variation is presented in figure 4.

The ceiling temperature of the room with green roof (t_{2V}) follows the same trend with the ceiling temperature of the room with classic roof (t_{2C}). Temperature t_{2V} is lower than t_{2C} in 98.14% of measured values. The maximum difference between values of temperatures t_{2C} and t_{2V} in studied period is of 1.98°C.

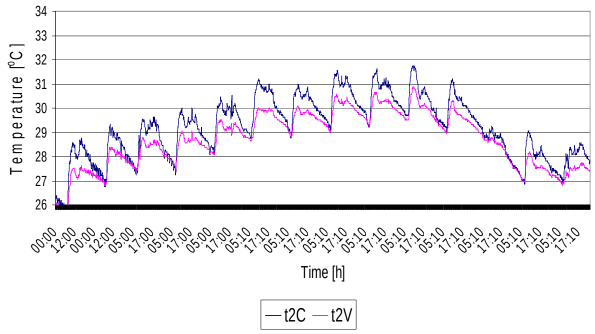

Fig. 4. Ceiling temperature variation

Differences between ceiling temperatures may be due to the water used for irrigation of green roof. In periods when the green roof wasn't irrigated the differences between the ceiling temperatures were situated in range 0.06…1.07°C.

Classic and green roof waterproof membrane temperature (t_{3C}, t_{3V}) was measured during the experiment period. Variation of both temperatures is presented in figure 5.

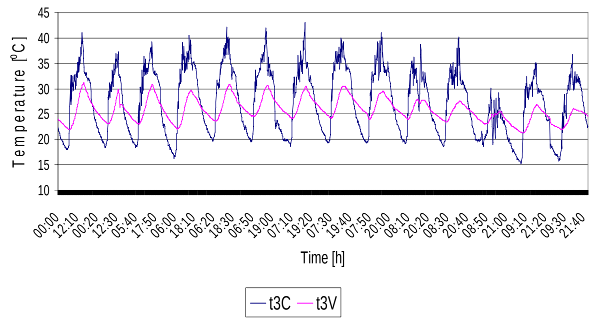

Fig. 5. Roof waterproof membrane temperature variation

By studying the representation of roof waterproofing membrane temperatures from fig. 5, can be observed high variations of t_{3C} values, between day and night (up to 24.37°C in 7.07.2012).

Lower variations of t_{3V} values, between day and night, can be also observed, up to 9.19°C in 1.07.2012. Maximum difference between t_{3C} and t_{3V}, registered in analyzed period, was 14.69°C, registered in 4.07.2012 at 10:50.

Soil and vegetation layers are shading the roof waterproof membrane during the day time and this explains the lower values of t_{3V} during the measurement period. Another possible explanation of t_{3V} values is the presence of water from irrigation, because of the evaporation phenomenon.

Thermal mass of soil layer provides phase shift to waterproof membrane temperature variation, so t_{3V} has higher values then t_{3C} during the night, as it can be seen in figure 5.

A comparison between air temperatures above the two types of roofs is presented in figure 6.

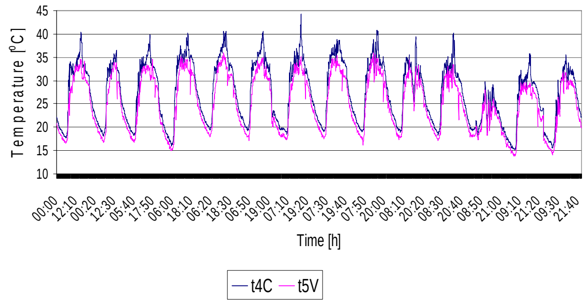

Fig. 6. Air temperature above the roof surface variation

Air temperature above the classic roof was higher than the air temperature above the green roof in 99.3% of studied period. The maximum difference between t_{4C} and t_{5V} during the analyzed period was 9.12°C.

About 58.48% of measured values for t_{4C} are higher than t_{5V} with minimum 2°C.

It is possible that the values of t_{5V} are lower than t_{4C} due to evapotranspiration phenomenon (evaporation of water from soil and the transpiration of the grass).

7. CONCLUSION

The purpose of this paper was achieved. Temperature regime of a building roof, partial green and partial classic was monitored and analyzed.

Two weeks of monitoring the roof temperature regime indicated that the presence of green roof reduced the temperature of air above it and the ceiling temperature of the covered room.

The presence of green roof can reduce the air temperature inside the covered room with up to 1.87°C between 14:00 and 16:00.

During the night, the air temperature inside the covered room was higher with up to 1.19°C then the air temperature inside the uncovered room.

Ceiling temperature under the green roof was reduced with up to 2.56°C. This effect may due not only to the presence of the green roof, but also to the water used for irrigation. Thus in periods when the green roof was not irrigated, the ceiling temperature was reduced with maximum 1.07°C

The presence of green roof reduced the waterproof membrane temperature variation between day and night. The green roof represents a barrier between solar radiation and waterproof membrane during the day and a source of heat during the night (because of its thermal mass). Also, the presence of water can explain the lower values of temperature at this level.

The reducing of temperature variations intervals and the induced phase shift for the inside air temperature and for the waterproof membrane temperature, highlighted the inertial effect of the green roof.

Air temperature above the classic roof was higher then air temperature above the green roof in 99.3% from whole analyzed period.

Using green roofs at large scales in urban areas, urban air temperature may be reduced. In this way "urban heat island" phenomenon may be mitigated.

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Comparație între regimul termic al unei clădiri cu acoperiş verde şi acoperiş clasic

Rezumat: *Principalul obiectiv al acestei lucrări este realiza un studiu comparativ între regimul de temperatură al unui acoperiş verde şi al unui acoperiş clasic. Sistemul experimental utilizat pentru monitorizarea celor două tipuri de acoperiş, clasic şi verde, cuprinde 9 de senzori de temperatură digitali, o placă de achiziție de date şi un PC local. Monitorizarea regimului termic a celor două acoperişuri a fost realizată în perioada 1 – 14 Iulie 2012. Diferența maximă dintre temperaturile măsurate la nivelul membranei hidroizolatoare ale celor două tipuri de acoperişuri este de 14.88°C. Diferența maximă dintre temperatura aerului din interiorul camerei cu acoperiş clasic şi temperatura aerului din camera cu acoperiş verde este de 1.87°C.*

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