Experimental study of the heat exchange and accumulation processes of a green roof under summer conditions

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Abstract: *An experimental study has been carried out on a green roof by measuring the soil temperature at depths 3 cm and 10 cm. Additionally have been measured the temperature of the environment, the building and the temperature of a roof tile. A monitoring system has been installed, monitoring those parameters, using the program UniOWMon for work with a one wire network. The results for the variation of the investigated temperatures are presented graphically. The temperature gradients between the green/tile roofs and the building/environment are also presented.*

Keywords*: green roof, monitoring system, urban heat island*

INTRODUCTION

Decreasing the electrical energy consumption is one of the main priorities of the contemporary society. The high price of the electrical energy, caused by the decreasing conventional energy sources deposits as well as the high cost price of the renewable energy sources plants, enforce us to search for passive energy-free ways of saving energy. One of them is to use green roofs, which allow to reduce significantly the heat exchange through the roof [1,2]. Next to this direct profit, the green roofs maintain low roof temperature during the summer which reduces the urban heat island effect [3].

The goal of this study is to account the temperature gradient of the green roof in depth, the temperature gradients of the green roof/tile roof and the environment/building temperatures. This would allow to evaluate the possibilities for reducing the energy loses through the roof and the urban heat island effect.

OBJECT OF THE INVESTIGATION

An experimental study has been carried out in the village of Bojichen, Ruse district, where has been installed a monitoring system in a house with green roof, for the period from June 07 to June 31 2011. The object scheme and the sensors placement are shown in figure 1. The soil type is Chernozem.

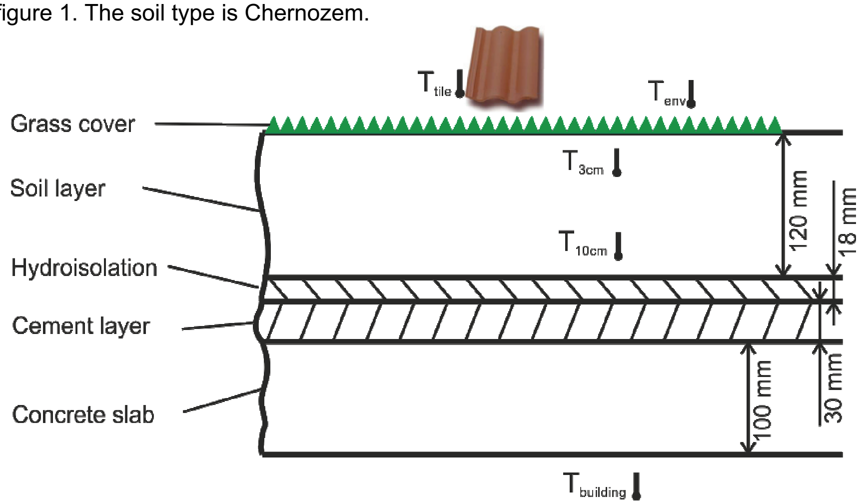


Figure. 1. A general scheme of the green roof and the monitoring system with the installed sensors.s

The depth of the soil layer is 120 mm and the width of the concrete slab is 100 mm. There are 30 mm of cement and 18 mm of hydro-insulation between them. The sensor measuring the environmental temperature (T_{env}) is placed at the under-roof space and the sensor for the building temperature ($T_{building}$) is placed near the ceiling. Inside the soil at depths 3 cm and 10 cm are installed two temperatures sensors (T_{3cm} and T_{10cm}), which have been hydro-insulated in advance, so that they don't cause problem when in contact with water. One temperature sensor (T_{tile})which is tightly attached to the bottom of a roof tile has been installed additionally.

The temperature sensors for the soil, the tile and the environment are of type DS18B20 with accuracy 0.1 $°C$ and the temperature sensor inside the building is of type DS18S20 with accuracy 0.5 $°C$.

All the sensors are connected to one of the COM ports of a personal computer and the connection with them is carried over a one wire network. The sensor information is collected with the specialized program UniOWMon v. 1.5 which is set to read the sensor information every 2 minutes and to store it into a database.

RESULTS OF THE EXPERIMENTAL STUDY

Because of a power supply problems during the experiment, the monitoring system has been turned offs for 3 days. That's why the results are presented in two sub-periods. The variation of the controlled temperatures from June 07 2011 to June 14 2011 are presented in figure 2 and the results from June 17 2011 to June 31 2011 - in figure 3.

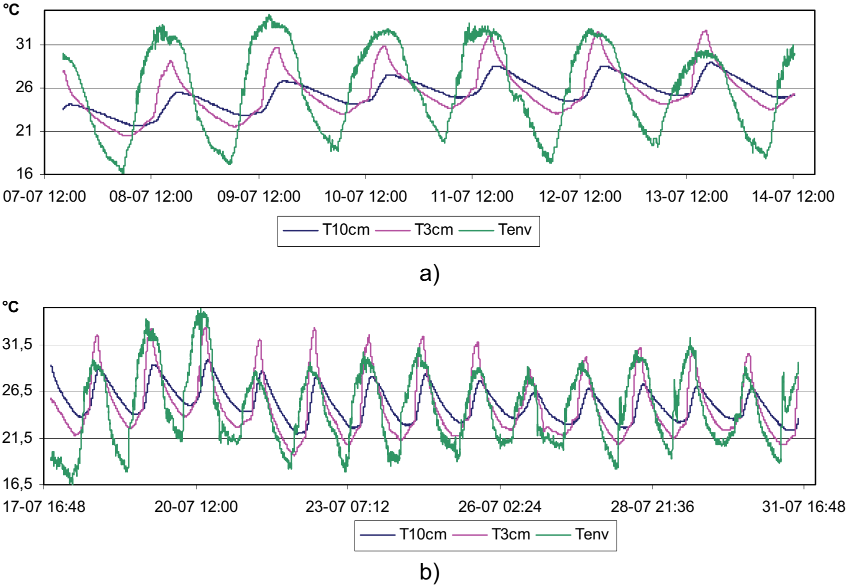


Figure. 2. Variation of the soil temperatures at depths 10 cm and 3 cm and the environment temperature for the period: a) June 07 - June 14; b) June 17 - June 31

From figures 2 could be seen that the variation of the environment temperature has low influence on the temperature of the soil at depth 10 cm and the daily temperature gradient does not exceed 4 $°C$. Analogical is the daily gradient between the environment and the soil temperatures at depth 3 cm, which reaches 9 $°C$. This is an expected behavior because the soil has relatively high specific heat capacity and density, and with the increase of the depth an increased period of time is required for the soil to temperate.

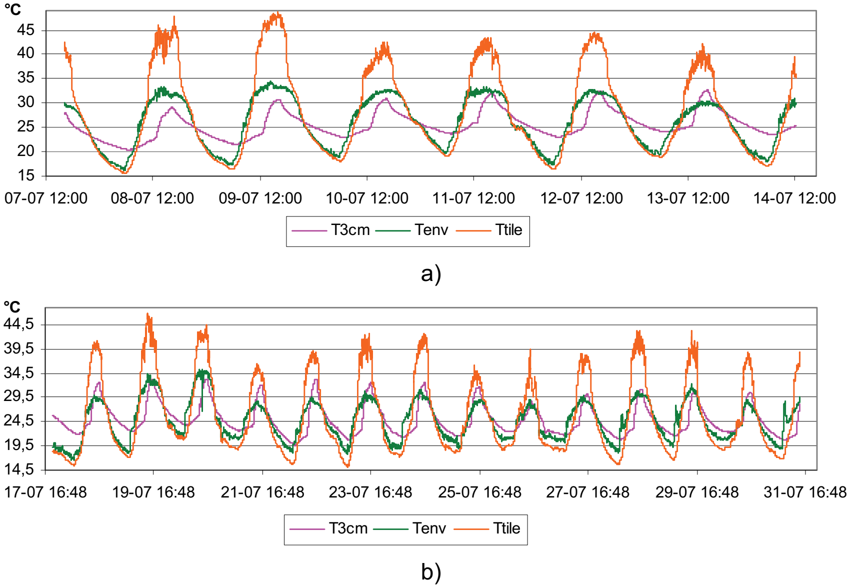


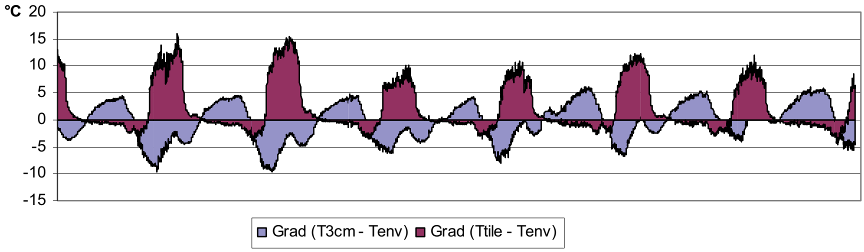
Figure. 3. Variation of the soil temperature at depth 3 cm, the tile and the environment temperature for the period: a) June 07 - June 14; b) June 17 - June 31

The temperature variation of the roof tile could be seen in figure 3. During the day hours, when the tile receives the largest solar energy flux, its temperature surpasses significantly that of the environment and the soil (at depth 3 cm). During the night hours it's temperature levels with the environmental one.

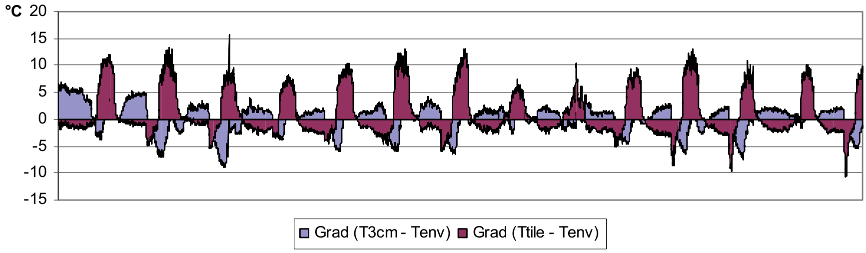
At some moments during daytime the temperature gradient between the roof tile and the soil at depth 3 cm reaches 20 $°C$. This difference is caused by the phenomenon evapotranspiration from the grass [1]. This is a process of water evaporation from the soil and the green plants, which consumes a great part of the accumulated solar energy, which in turn reduces the soil's temperature.

The temperature gradients between the soil/tile surface and the environment are presented in figure 4. It is easy to notice that the roof tile surface contributes to the increase of the environment temperature, thus increasing the urban heat island effect. The green roof has the opposite effect and during daytime it maintains lower temperature than the environment. During nighttime the soil maintains slightly higher temperature than the environment but their temperature gradient does not exceed 5 $°C$.

Because of some technical problems, the building temperature has only been measured from June 20 to June 31. The temperature gradients between the soil layer close to the concrete roof and the building ($Grad(T_{10cm} - T_{building})$) as well as the roof tile and the building ($Grad(T_{tile} - T_{building})$) are presented in figure 5. It is easy to notice the large amplitudes of the tile roof and the relatively low ones for the green roof.



a)



b)

Figure. 4. Temperature gradients between the soil layer close to the concrete roof and the environment as well as the tile and the environment for the period:
a) June 07 - June 14; b) June 17 - June 31

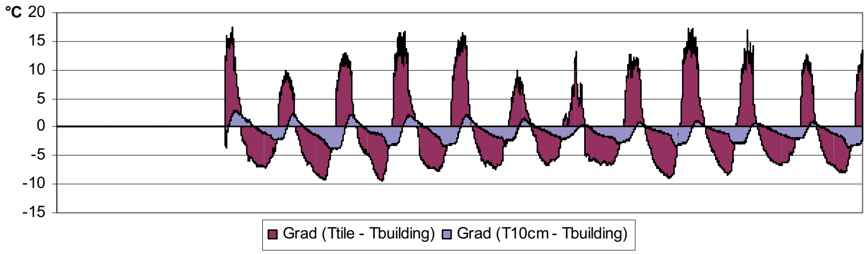


Figure. 5. Temperature gradients between the soil layer close to the roof and the building as well as the roof tile and the building for the period June 20 - June 31

CONCLUSIONS

The analysis of the experimental results show that the green roof maintains relatively low daily amplitude of the temperature gradient between a green roof and the building temperature (less than 5 $°C$), while the same amplitude for the temperature gradient between a roof tile and a building temperature exceeds 20 $°C$. This would lead to a significant variations of the building temperature. It is well known that this gradient is proportional to the sensible heat flux through the roof, hence the energy loses through a green roof are many times lower than those through a tile roof.

It has been also determined that the tile roof increases the urban heat island effect, while the green roof decreases it. This is caused by the fact that the two roof construction types create heat fluxes with different direction. For a tile roof the accumulated solar energy is used to increase the environment and building temperatures, while for a green roof a large portion of this energy is lost in the process evapotranspiration.

Based on the exposed facts it follows that the use of green roofs could improve significantly the insulation of the roof and decrease the urban heat island effect.

More studies are required to investigate the two roof types behavior under winter conditions, which is a topic for future investigations.

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Докладът е рецензиран.