19th IMEKO TC 4 Symposium and 17th IWADC Workshop
Advances in Instrumentation and Sensors Interoperability
July 18-19, 2013, Barcelona, Spain

Data Acquisition for Green Roof

Gianluca Pizzuti[1], Francesco Lamonaca[2], Natale Arcuri[1]

[1] *Dept. of Mechanical Engineering, Energetic and Management, University of Calabria, Rende (CS)*
[2] *Dept. Computer Science Engineering, Modelling, Electronic and System, University of Calabria, Rende (CS),*
e-mail:{gianluca.pizzuti, natale.arcuri}@unical.it, {flamonaca }@deis.unical.it;

Abstract- Green roof represents a sustainable solution in urban environment providing several benefits such as ecological advantages, stormwater management and energy saving. Numerous studies have focused on the evaluation of the efficiency of green roof by monitoring thermo-physical variables. Whereas most of the studies have been conducted in cold weather conditions, only little research has been performed in Mediterranean climate. An extensive green roof, divided into four compartments, characterized by different layers and materials is built on the 46C Building at the University of Calabria (Italy), in order to analyse the effect of the diverse components on thermo-physical behaviour of the system. The experimental site is equipped with measurement instrumentation and data acquisition system to continuously monitor thermo-physical parameters, such as temperature and water content throughout the entire stratigraphy. The monitoring data will be used for evaluating the thermo-physical behaviour of the green roof in Mediterranean climate.

I. Introduction

The practice of green roof is a sustainable solution in urban context since it offers several advantages such as ecological benefits, stormwater management and energy saving. Green roof is generally composed by vegetative, drainage and storage layers and can be extensive and intensive.

In ancient time the hanging gardens was used only for esthetic purpose. Beautiful examples are in Ancient Greek, Roman Imperium and the Hanging Gardens of Babylon were one of the Seven Wonders [1] (see Fig.1a)). All this garden was developed in the Mediterranean area. Vice versa the idea of green roof as it is in the modern time, can be founded in the Viking and Celtic cultures [2] (see Fig.1b)). The concept of green roof is quite different from hanging gardens one, indeed the green roof is tough since the beginning as method to insulate the building from the cold climates. Nowadays the effort is to merge both the esthetic and insulation requirements. Goal of the research is to bring back the hanging gardens/green roof in the Mediterranean area as proposal to insulate from the hot climates.

The available solutions for green roof structure are usually classified in two categories: intensive and extensive. The intensive type requires higher cost of maintenance and is usually practicable. The extensive type is less expensive in terms of maintenance and generally is not accessible to the people.

a)

b) Celtic green roof

Figure 1. a) Hanging Gardens of Babylon, b) Celtic green roof.

Figure 2. Location of the green roof respect to the Mediterranean sea.

Numerous studies have analyzed the efficiency of green roof by monitoring thermo-physical variables, such as temperature and water content throughout the stratigraphy and in the building 'rooms underneath. Several studies have been conducted in cold weather conditions in many countries such as Germany, Sweden, USA, UK, China and Japan [3] - [7]. On the basis of these researches, some software tools like EnergyPlus [8] are available in order to design green roof and evaluate their efficiency. Due to the large dataset available for north climes, these tools are suitable for cold climate only. Aim of the paper is to develop a distributed measurement system to permit the continuous monitor and acquisition of the thermo-physical parameters of a green roof in Mediterranean climate. This study will allow to evaluate the suitability of existent simulators for such climate and, eventually, to furnish the dataset for further studies in order to customize the existent simulators or to develop new ones.

II. Distributed Measurement System

The distributed measurement system [9]-[12] is located on the green roof of the 46C Building at the University of Calabria (Italy). Fig.2 shows the position of the green roof as in the center of the Mediterranean Sea, and then well representative of the climate taken into consideration.
The green roof is divided into four compartments (see Fig.3), characterized by different layers and materials.

Figure 3. four compartments characterized by different layers and materials.

Three compartments comprise the following layers: slope layer, root barrier, protection and storage layer, drainage layer, filter layer and soil substrate. A supplementary layer, consisting of insulation element, is solely added in one of these stratigraphies. Of these three compartments, two are populated by plants *Carpobrotus edulis, Dianthus gratianopolitanus, Cerastium tomentosum.* These plants are typical of the Caporizzuto Island. They are selected because they require few amounts of waters and cares. One compartments is left free in order to permits the grown of seeds of typical plants of the neighborhood that are spread by wind. The forth compartment, devoid of any layers, represents the reference section. It has the same characteristics of the other roofs of the University of Calabria Buildings.
In each stratigraphy the materials are characterized by different mechanical and thermo-physical properties.
To monitor thermo-physical parameters in the four compartments of the green roof and the building's rooms underneath, a data acquisition was installed. Four sampling points were set up in each compartment to measure throughout the entire stratigraphy (see Fig.4) the following variables:

- Temperature and soil humidity (by using RHT sensors);
- Surface temperature in the slope layer (by using T sensor);
- Surface temperature of the roof structure (by using T sensor).

Fig.4 shows how the sensors are placed in the stratigraphy. Due to the fact that some sensors are built in the roof structure and it is not possible to easily substitute them, it is decided to use a wired sensor network in order to guarantee robustness and avoid the problem of limited life time.
The temperature sensors are resistance temperature detectors (RTDs) PT 100. The relative humidity and temperature (RHT) sensors are devices which monitor the water content in the soil. The RHT sensors are more accurate than the other sensors based on the resistance measurement, since they consist of 4-fork detectors which measure the relative dielectric constant. Each measurement is automatically performed based on the calibration provided by the sensor. This calibration aims to reduce the effect of temperature variations and natural decay of components on the measurements [13].
In the compartment including the insulation layer an additional T sensor was installed to measure the temperature gradient generated by the placement of this supplementary element. In the fourth compartment (used as reference), without any layers, the surface temperature is solely monitored.
Tab.1 shows the used sensors with their operative ranges and accuracy.

Table 1. Used sensors.

	Operative range	**accuracy**
Soil moisture sensor TerraSense SMT2	from 0 VWC to field saturation	± 2 %
Soil temperature sensor TerraSense SMT2	- 30 + 60 °C	1 %
RTD PT100	-50, 250 °C	0.8 %

All the signals are sent to the Data acquisition board NI-cDAQ-9188 [14] to be converted in digital signals and then to be processed by PC.

Preliminary Experimental Results

The data are acquired each 30 minutes and stored in a database for successive elaborations. Each day, the PC updates a central database on the servers of the WEB Farm of the University of Calabria (WFU). The duplication of the database allows: (i) to make robust the system to loses of data, (ii) to make the data available online deploying the capability of the servers available at the (WFU) while (iii) devoting the PC only for the data acquisition.
The output of the sensors are both current or voltage variations. Such signals are conveyed into cables, which are then joined to the connectors provided by the National Instruments. In particular, the NI Connector-9205 is used for the voltage measurements, NI Connector-9217 for resistance measurements, NI Connector-9481 for current measurements.

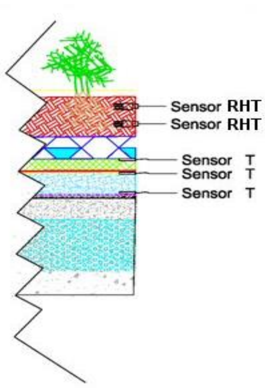

Figure 4.Positioning of the sensors in the roof layers.

The modules are inserted in the chassis of the NI-cDAQ-9188, which is able to manage eight acquisition modules.
Fig.5 shows a) the trend of the temperature under the ceiling and in the room a) before the realization of the green roof in September and b) after its realization in December.

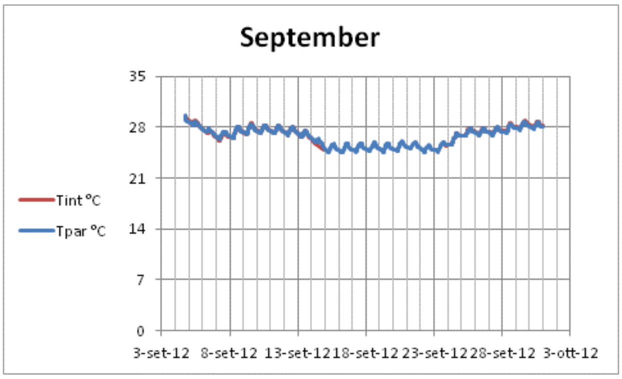

Figure 5. a) Data September

Due to the different months and seasons the mean value of the temperature must not be taken into account. The advantages of the green roof are highlighted by the reduced abrupt variations of the temperatures after the green roof realization (Fig.5b)).

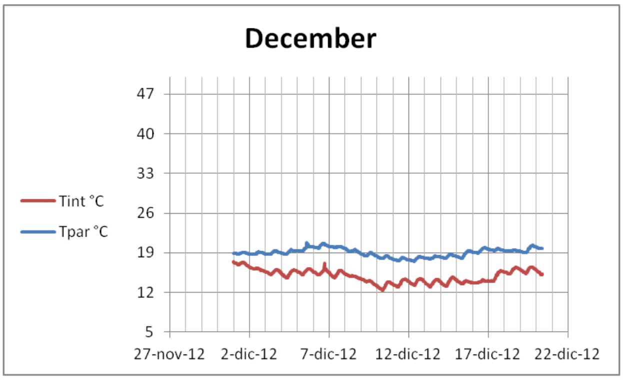

Figure 5. b) Data December

This phenomenon highlight the improvement of the insulation properties of the green roof respect to the traditional one. Further studies are devoted to evaluate the efficiency of the realized green roof.

II. Conclusions

In the paper a data acquisition system for green roof located in Mediterranean climate is presented. The aim is to furnish a suitable dataset to customize existent simulator and informatics tools evaluating the efficiency of the green roof also for the Mediterranean climate. Considerations on the first acquired data are reported. The experimental results highlight reduced abrupt variations of the temperatures after the green roof realization, due to the better insulation properties of the green roof respect to the traditional one. The on goling research is devoted to the evaluation on the energy efficiency obtained by the realized green roof.

References

[1] I. Finkel, “The Hanging Gardens of Babylon,” In The Seven Wonders of the Ancient World, Edited by Peter Clayton and Martin Price, Routledge, New York, 1998, pp. 38.
[2] British Columbia Institute of Technology, “What is the history of green roofs?”, Centre of Architectural Ecology.
[3] J. Mentens, D. Raes, M. Hermy, “Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century?” in Landscape and Urban Planning 77, 2006, pp.217-226.

[4] J.C. Berndtsson, “Green roof performance towards management of runoff water quantity and quality: a review”, in Ecological Engineering 36, 2010, pp.351-360

[5] Jianjun Ye, Shixiao Yu, Hua Zhang, Wennian Xu, "Study on rainwater retention effect of an extensive green roof," International Conference on Mechanic Automation and Control Engineering (MACE), 15-17 July 2011, vol. 2 pp.6908-6911.

[6] Hai-yan Yan, Miao Chen , "Experiment study on extensive roof greening in Jiaozuo, Henan province, China," International Conference on Electric Technology and Civil Engineering (ICETCE), 22-24 April 2011, pp.3142-3145,

[7] Arcuri N. , De Simone M. , Reda F. , Bevilacqua P. , Pizzuti G. , " Energy analysis for the realization of a green roof on a University building". Atti del convegno "EuroSun2012", Rijeka (Croatia), 18-20 September 2012, 2012, Croatian Solar Energy Association Rijeka:Rijeka (Croatia), 2012.

[8] DOE, 2007. Getting Started with EnergyPlus-Essential Information you need about Running EnergyPlus, U. S. Departmnet of Energy

[9] F. Lamonaca, D. Grimaldi, “Trigger Realignment by Networking Synchronized Embedded Hardware”, IEEE Transaction on Instrumentation and Measurement, Vol.62, Issue 2, 2013, pp. 38-49.

[10] F. Lamonaca, D. Grimaldi, R. Morello, A. Nastro, "Sub- μs Synchronization Accuracy in Distributed Measurement System by PDAs and PCs' triggers realignement", Proc. of I2MTC 2013– IEEE International Instrumentation and Measurement Technology Conference, Minnesota, USA, 6-9 May, 2013.

[11] E. Garone, A. Gasparri, F. Lamonaca, "Clock Synchronization forWireless Sensor Network with Communication Delay", American Control Conference, June 17 - 19 2013, Washington, DC, pp. 1-6.

[12] F. Lamonaca, A. Gasparri, E. Garone, "Wireless Sensor Networks Clock Synchronization with Selective Convergence Rate", IFAC Intelligent Autonomous Vehicles Symposium (IAV '13), Gold Coast, Australia, 26-28 June 2013.

[13] NetSens srl Italy-Soil moisture and temperature sensor. Available at http://www.netsens.it/en/soil-moisture-temperature.php

[14] NI Corporation CompactDAQ 8-Slot Ethernet Chassis. http://sine.ni.com/nips/cds/view/p/lang/en/nid/208990