POLYTECHNIC OF TORINO
FACULTY OF ARCHITECTURE 1
Degree in Architecture
Honors theses

Green technologies for Architecture
Theoretical and experimental analysis of the thermal behaviour of the green roof
by Federica Fiorina
Tutor: Marco Filippi
Co-tutor: Valentina Serra

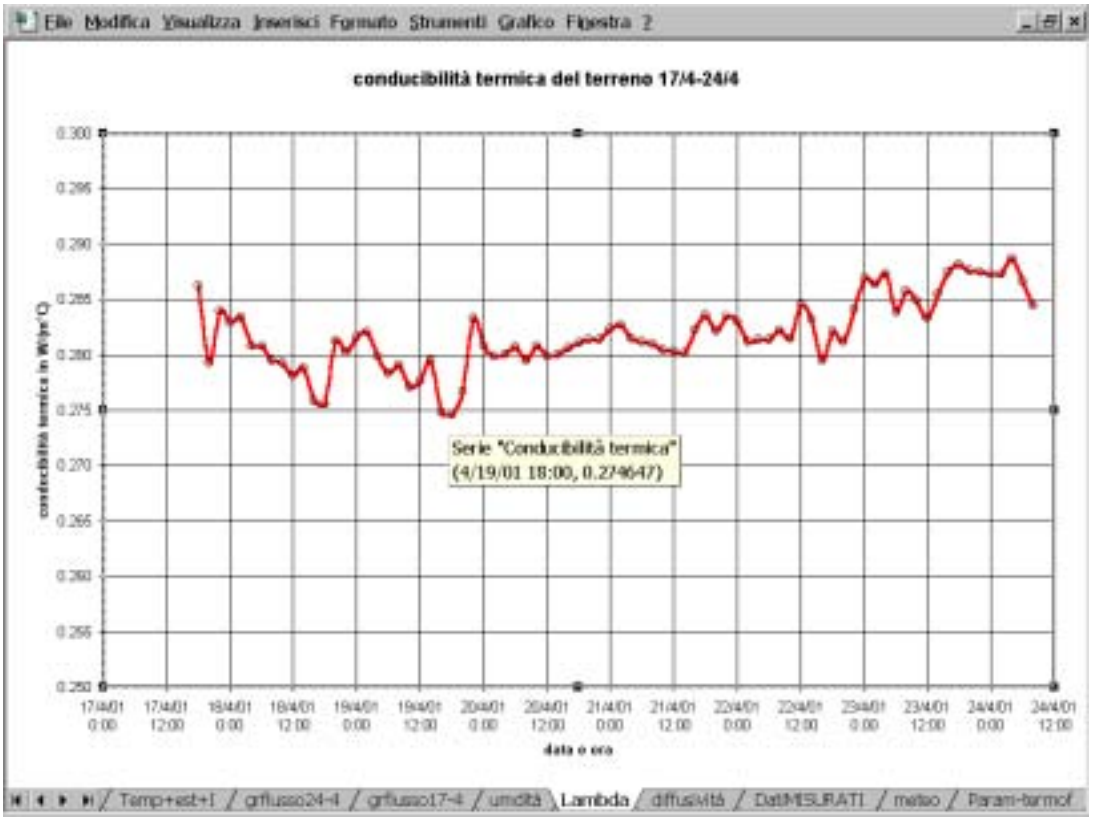
Over the past few years the better understanding of the limited amount of the non renewable energy sources has stirred up a debate on the ecological and environmental problems. This has also involved architectural research. The number of examples of "green architecture" around the world witnesses to the central role that Nature plays in the contemporary culture of living and reveals a more and more widespread tendency of designers to use eco-technologies with the intent to reduce both the impact on the natural environment and the energy consumption of buildings.

Among the different technologies based on the integration of vegetation and buildings, the "green roof" has recently become very popular. The success of this particular covering system is based on the many aesthetic, ecological and economical advantages related to it. An especially interesting aspect is the contribution that the "green roof" can give to the thermal behaviour of the building, thanks to its specific structure (a complex succession of layers which ends up externally with a mixture of ground and expanded materials): this leads to an increased thermal insulation during the winter time, and to a reduced heat load during the summer.

A wide and extensive investigation, both at a national and international level, on the status of the research analyzing and quantifying the thermal behaviour of the "green roof" shows that theoretical and experimental studies on this subject are extremely limited. Consequently, the hypothesis of the contribution to the energy savings, still has to be demonstrated with quantitative data. The direct consequence of the limited amount of available information on the "green roof" is that designers do not make a conscious use of this technology, especially regarding the effects that this choice can have on the ambient conditions of the building and on the comfort of its occupancy.

The objective of this work is therefore to achieve a deeper insight into the different aspects linked to the heat transmission through the green roof by means of experimental data and a theoretical analysis carried out with the help of simulations models.

The opportunity to monitor the thermal behaviour of a green roof and to execute a specific experimental analysis came up as a part of a consultancy contract between the Energetic Department of the Politecnico of Turin and the Technological Park "Environment Park".

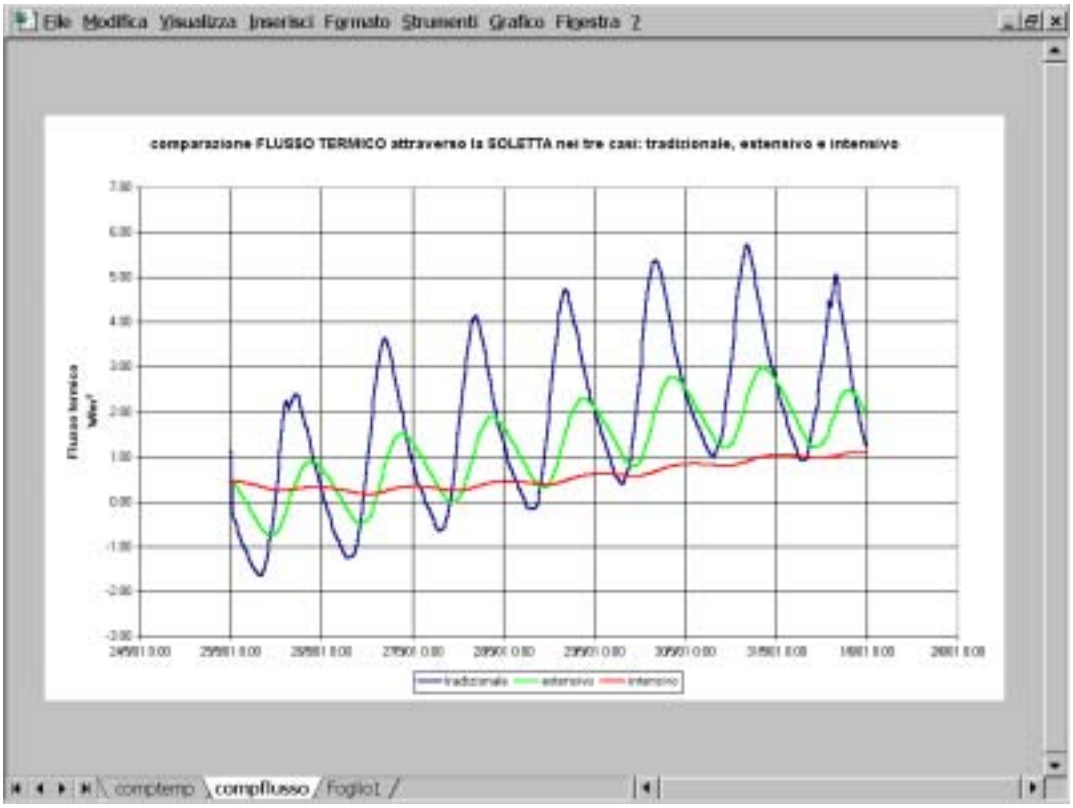


The measurements started in April 2001 and resulted in the definition of the thermal flows through the layers of the green roof, the temperature of each layer and of the ambient underneath, the thermal conductivity and diffusion, and the water content of the ground.

The monitoring with thermal sensors and thermal flow meters installed at different depths produced interesting results. A database of thermal conductivity, valid for grounds lightened with expanse materials under various humidity conditions, was measured.

At a theoretical level the thermal analysis was carried out through a numerical simulation. With this objective a simulation model, called *Simulink,* has been developed. The model represents the green roof as a discrete unity of elements and calculates the thermal behaviour of the roof in dynamic regime (temperature of the layers and thermal flows through them).

The validation of the simulation model was done by the comparison of the theoretical results with the experimental data. Once the validity of the model was confirmed, *Simulink* has been used to evaluate the different behaviours of some alternative solutions (in a defined climatic contest). The results of the analysis (based on the comparison of three different covering solutions: flat roof, traditional green roof and extensive green roof for a period of one week) highlighted an effective increase of the thermal inertia of the green roof, with a related decrease of the thermal flow through the covering package.



Comparison of the thermal flow through the roof in three cases: traditional, intensive and extensive “green roof”. The energy balance shows that the presence of the cultivable substrate reduces the amount of thermal energy entering the ambient; compared to a traditional flat roof (with an impermeable layer protected with stones) the thermal energy going through an intensive green roof (with thick substrate) is reduced to one third.

Simulink allows to compare different solutions (in the same climatic condition) or to verify the behaviour of a single solution in different climatic conditions. It proved to be a very useful tool to help the designer both in the preliminary definition phase of a project as and in the verification phase of the final design.

For informations: ffiorina@tiscalinet.it