Energy and Buildings 114 (2016) 275–282

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Preliminary study of the impact of urban greenery types on energy consumption of building at a district scale: Academic study on a canyon street in Nantes (France) weather conditions

Benjamin Morille*, Marjorie Musy, Laurent Malys

Ecole Nationale Supérieure d'Architecture de Nantes, CERMA UMR 1563 & Institut de Recherche des Sciences et Techniques de la Ville, France

ARTICLE INFO

Article history:
Received 4 March 2015
Received in revised form 7 June 2015
Accepted 8 June 2015
Available online 29 June 2015

Keywords:
Urban vegetation
Building energy consumption
District scale
Urban climate simulation

ABSTRACT

The urban population rise leads town planners to increase the building density in order to avoid an urban sprawl what can induce higher risks of the heat island occurrence and increases buildings needs for air conditioning. Urban vegetation such as trees, grass areas, green walls and roofs can be a solution to mitigate it.

The aim of the study is to evaluate the influence of various greenery types on cooling needs and to classify them according to their ability to mitigate it.

Numerical simulations were carried out for canyon street configurations. The 3D numerical tool takes into account the unsteady building thermal behaviour using the SOLENE thermo-radiative model coupled with the outside airflow computed with the CFD tool Code_Saturne. A parametric modelling study considering different kinds of buildings permits to identify the most efficient greenery types and to investigate the interactions between each of them.

Green walls and trees appear as the most efficient to reduce cooling needs. The less insulated and the more glassed the buildings are, the more efficient these devices are. The impact of grass areas and green walls applied on neighbouring buildings is only sensible without trees in the street and green cover on the studied building.

1. Introduction

In a context of a constant urban population rise, the increase of the building density is one solution to avoid an urban sprawl. The modifications of city morphological characteristics can deteriorate the urban heat island issue. Moreover, added to the temperature rise due to the global warming, it may lead to a strong increase of building energy consumption for cooling. Thus, solutions are required to control urban heat island effect and cooling energy consumption. The use of vegetation can be one of these solutions. The assessment of the usefulness of vegetation in urban context was the objective of the VegDUD project funded by the French National Research Agency. Among the advantages of city greening that were evaluated, its benefits on the energy consumption are prime of interest: it needs to be demonstrated and quantified.

Nowadays, numerical tools become more and more powerful to evaluate building energy consumption and investigate complexities and non-linearity of various physical phenomenon. Green walls and roofs models have been integrated into tools like TRNSYS [1–3] or EnergyPlus [4] but urban environment is rarely taken into consideration so that the indirect influences of trees, grass area and green walls cannot be evaluated. Thus, the evaluation of various urban greenery types influence requires to consider the whole urban situation in order to take into account morphological characteristics of urban scene as well as the urban heat island effect. ENVI-Met model is able to evaluate vegetation influence on urban climate [5–7] but is mainly used for external thermal comfort and does not include yet a thermal model for buildings. *SOLENE-microclimat* is now able to couple the SOLENE radiative model with the CFD tool Code_Saturne, considering the thermal behaviour of buildings and integrating green devices models that take into account energy and humidity transfers [8]. Nevertheless, it only can compute the energy consumption for one single building. TEB [9,10] includes both thermal model to evaluate energy consumption at city scale and simplified vegetation model. Yet, it only considers urban situation through average morphological parameters and the building is considered as only one homogeneous zone.

In order to evaluate the influence of various greenery types on building energy consumption at the district scale, the use of

* Corresponding author.
E-mail addresses: benjamin.morille@ec-nantes.fr (B. Morille), marjorie.musy@ec-nantes.fr (M. Musy), laurent.malys@cerma.archi.fr (L. Malys).

http://dx.doi.org/10.1016/j.enbuild.2015.06.030
0378-7788/

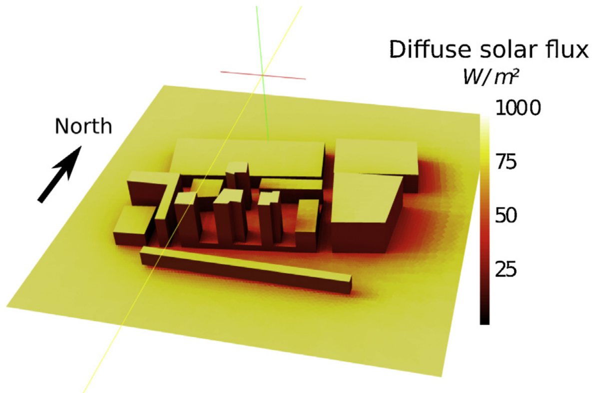

Fig. 1. Example of diffuse solar flux on an urban scene evaluated using SOLENE.

SOLENE-microclimat which is able to describe in detail the vegetation can permit to enhance parametric models.

The first objectives of this preliminary study were to identify the greenery types that have the greatest influence on the energy consumption. As it was demonstrated that the influence of greenery types depends on the kind of building [8], this study considers low and high insulated buildings and low and high glassed buildings. The studied greenery types are: green walls and roofs, trees and grass areas. Green walls are considered through their direct and indirect impacts. In order to well identify which of the greenery types are the most efficient, and understand at best the interactions between each other, a *parametric modelling study* was conducted. After short preliminary studies to determine the suitable conditions to launch the numerical simulations, the *parametric modelling study* was carried out with *SOLENE-microclimat*, evaluating the cooling energy consumption in a summer period at a daily scale. Thanks to the results analysis, the greenery types are classified according their influence for each kind of buildings. As a discussion, limits of the study and further ways to investigate are finally exposed.

2. Materials and methods

The use of *SOLENE-microclimat* is here briefly explained, then the data of the simulations are detailed and the *parametric modelling* combinations for the *study* are finally presented.

2.1. SOLENE-Microclimat

SOLENE (Fig. 1) is a simulation tool which was first developed at the CERMA laboratory in order to assess radiation process in urban situations from a 3D surface mesh. It computes sky irradiance (direct and diffuse fluxes) which can be evaluated from measurements data or from a sky model [11]. Considering radiative proprieties of materials, solar beams interreflexions and infrared radiation balance, it estimates wall temperatures using radiosity algorithm [12].

Thermal balances on walls (Fig. 2) and soils (Fig. 3) taking into account material inertia permit to realize unsteady simulations and to assess evolution of surface temperatures [13,14].

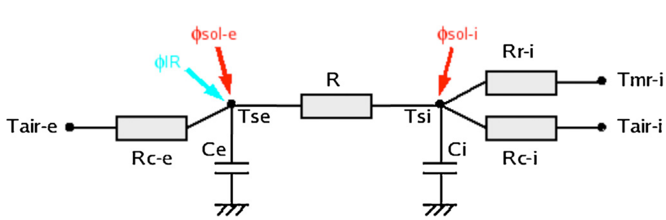

Fig. 2. Wall thermal model representation [15].

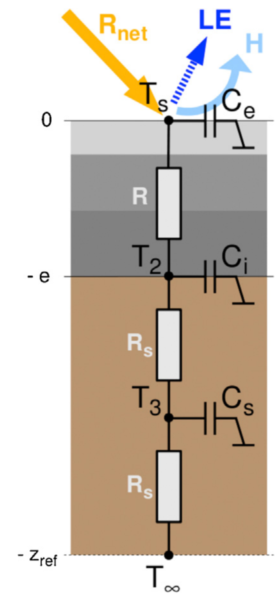

Fig. 3. Soil thermal model representation [15].

Trees influence (Fig. 4) is taken into account [15,16] considering they contribute to the attenuation of the solar radiation as well as they modify the infrared radiative balance since the leaf temperatures of trees are mostly different from those of building surfaces.

The last developments implemented in the tool is the impact of green walls and roofs which considers (Fig. 5):

- a modification of the air temperature near the wall (T_a),
- a modification of the leaf temperature (T_f) because of evapotranspiration ($\varphi_{lat,f}$) of leaves which is mainly depending of short wave radiation absorbed by the leaf ($\varphi_{swr,f}$). This temperature is considered to interact with the other surfaces of the urban scene because of long wave radiation exchanges,
- a modification of the wall temperature (T_{es}) because of evaporation of the substrate ($\varphi_{lat,es}$) which is added on the building wall and because of the attenuation of the solar radiation reaching the wall or the roof ($\varphi_{swr,es}$).

All details of this model and its validation are given in the paper of [17].

A building thermal model [18] (Fig. 6) was developed in the tool in order to compute the real thermal variables inside the target building whose energy consumption shall be evaluated. The principle of this module is based on a multizone building nodal network model [19] where each storey corresponds to a zone (Fig. 6). A free evolution of inside air temperature can be considered, energy needs can be evaluated as the energy required to maintain a given temperature. In the present case, a mixed solution is chosen: a free temperature is considered but energy input can be added to avoid the temperature becoming higher than 26 °C.

In SOLENE-microclimat, the airflow in the urban scene can be calculated by resolving equations of conservation: momentum, mass continuity, energy, species transport and using k-ε turbulence model [8]. This computation is realized by the CFD tool Code_Saturne [20] (Fig. 7) which is coupled with the other components previously detailed. For this study, the coupling is used at a low level since for each time step, the wind speed distribution is only determined from wind speed and direction measurements in order to estimate the heat convection coefficient distribution on each surfaces of the urban scene.