Energy and Buildings 78 (2014) 25–34

Contents lists available at ScienceDirect

Energy and Buildings

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

Influence of the urban environment on the effectiveness of natural night-ventilation of an office building

Rubina Ramponi [a,b], Isabella Gaetani [c], Adriana Angelotti [c,*]

[a] Architecture, Built Environment, Construction Engineering Department, Politecnico di Milano, via Ponzio 31,20133 Milano, Italy
[b] Building Physics and Services, Eindhoven University of Technology, P.O. box 513, 5600 MB Eindhoven, the Netherlands
[c] Energy Department, Politecnico di Milano, via Lambruschini 4, 20156 Milano, Italy

ARTICLE INFO

Article history:
Received 6 August 2013
Received in revised form 7 February 2014
Accepted 1 April 2014
Available online 13 April 2014

Keywords:
Natural ventilation
Urban environment
Passive cooling
Airflow network
Building energy simulation

ABSTRACT

The effectiveness of natural night-ventilation in the urban environment depends on local climate characteristics, but also on solar shading and wind shielding effects of the surrounding buildings. However, the impact of the latter factors on the effectiveness of night-ventilation is often disregarded, altering the predicted building energy performance. Building Energy Simulation tools coupled with Airflow Network models allow estimating the effect of the urban environment on the cooling energy savings due to night-ventilation. Nevertheless, external sources of wind flow data are needed to account for the wind shielding effect of surrounding buildings.

In this paper, the cooling effectiveness of night-ventilation for an office building placed in the center of urban areas of increased density is analyzed for three European locations. The energy demand of the unventilated building is first assessed, also considering the effect of environmental albedo and a simplified Urban Heat Island scenario. Then, night-ventilation rates and energy savings for the ventilated building are calculated to estimate the variation of the cooling effect of night-ventilation. Results show a strong reduction of the energy savings in high-density urban areas and point out that a detailed description of the surroundings is crucial to assess the suitability of passive cooling solutions.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Natural night-ventilation is an important passive cooling technique for reducing summer energy consumption in the built environment [1]. The cooling effect is achieved by combining natural night-ventilation with the high thermal inertia of the building structure [2–4]. In fact, the building structure acts as heat storage during the day and releases the absorbed heat during the night, when the cooling effect of natural ventilation is leading [5]. Besides the thermal properties of the building structure, the cooling potential of natural night-ventilation is strongly affected by the local climate. The latter is the result of meteorological conditions, the effect of urban morphology and other microclimatic variables, e.g. environmental albedo or the Urban Heat Island (UHI) effect. The UHI effect is caused, among other things, by the combined effect of urban geometry, thermal properties of the surfaces, the anthropogenic heat, the greenhouse effect and the emissivity of the surfaces [6].

The influence of the meteorological conditions on the cooling potential for night-ventilation depends on the combined impact of night-time wind speed and air temperature. Whereas the outdoor wind speed and profile affects the ventilation rate across the building, the outdoor night temperature represents the heat sink temperature for the building heat dissipation. The importance of the local outdoor temperature level is pointed out by Artmann et al. [7], who defined a Climatic Cooling Potential (CCP) index based on the indoor-outdoor night temperature differences. The CCP index aims to identify the suitability of the climate for night cooling. For instance, the CCP map of Europe [7] shows high potential for night-cooling over the whole of Northern Europe and still significant potential in Central, Eastern and even in some regions of Southern Europe.

In addition to the meteorological conditions, local climatic modifications primarily due to the urban morphology affect the night-cooling potential. On the one hand, the presence of adjacent buildings has a beneficial solar shading effect during the cooling season. On the other hand, the wind shielding effect of the surrounding buildings alters the wind pressure distribution on the envelope and reduces the ventilation rates [8,9]. The wind flow within the urban canyons is strongly influenced by the urban

* Corresponding author. Tel.: +39 02 23995183.
E-mail address: adriana.angelotti@polimi.it (A. Angelotti).

http://dx.doi.org/10.1016/j.enbuild.2014.04.001
0378-7788/© 2014 Elsevier B.V. All rights reserved.

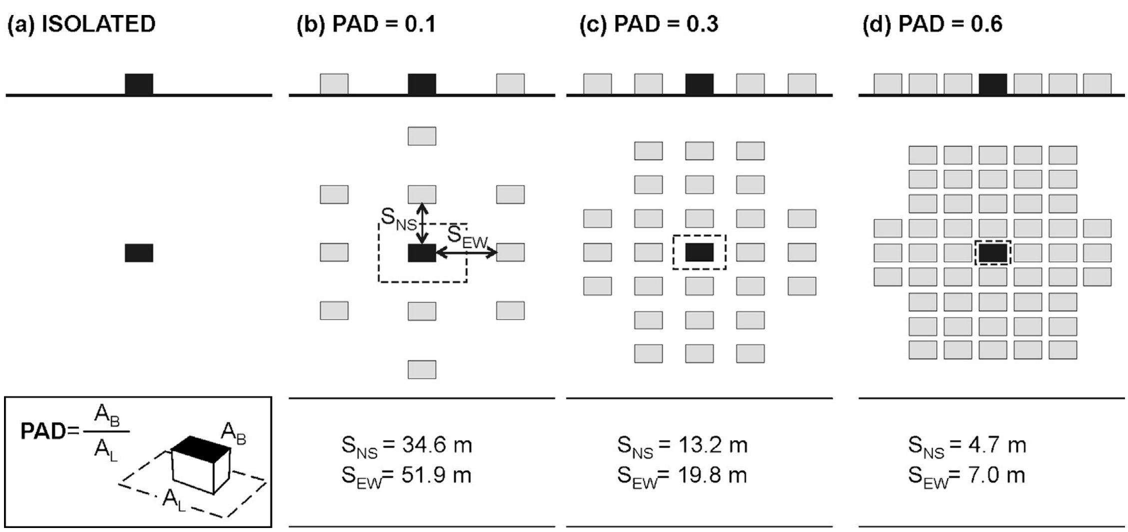

Fig. 1. Top view of the cases analyzed, i.e. isolated reference building (a), PAD 0.1 (b), 0.3 (c), and 0.6 (d); definition of the PAD and size of the streets along the North–South (S_{NS}) and East–West (S_{EW}) direction.

morphology which is described by the building packing density and building arrangement. Various morphological parameters are used to measure the building packing density either focusing on the street canyon scale or on the neighborhood scale [10–12]. The building and the canyon aspect ratios are often used at street canyon scale, while the Plan (PAD) and Frontal (FAD) Area Densities are defined for the neighborhood scale. The PAD represents the ratio between the plan (A_B) and the lot area (A_L), as in Fig. 1 (a), while the FAD is defined as the ratio between the frontal (A_F) area of the building and the lot area (A_L). At increasing Plan and Frontal Area Densities, the main flow goes from an isolated flow regime, to a wake interference flow regime, to a skimming flow regime [11,12], affecting the wind-pressure on the building facades.

The impact of urban morphology on the cooling demand of buildings can be estimated using Building Energy Simulation (BES) tools with embedded Airflow Network (AFN) models to predict the natural ventilation contribution from the wind pressure on the building envelope [13–15]. Weather datasets were developed to represent local climatic conditions in BES simulations and can be modified to take into account different climatic scenarios, such as the UHI effect [16,17]. As regards to the urban morphology, the solar shading of adjacent buildings can be explicitly modeled, but the variation of the wind-pressure on the building surfaces is rather difficult to model. Pressure coefficients for non-isolated buildings can be extracted from external databases, measurements, or numerical models [18–20]. However, the latter two are considered more reliable as they are able to model similar geometric and wind conditions [18].

In spite of their strong counteracting influence on the energy performance of a non-isolated building, most of the past studies addressed the effects of the solar shading and the wind shielding separately. Among others, van Moeseke et al. [9] and Schulze and Eicker [21] analyzed the impact of the local wind modifications due to the urban environment using BES/AFN tools. Van Moeseke et al. [9] evaluated natural ventilation rates in an office building in Uccle, Belgium, for a typical summer day. During the simulation day, constant wind speed and direction were assumed, but the upstream wind profile as well as the C_p values on the building facades varied to reproduce an open, a suburban and an urban environment which caused significant reductions in the Air Changes per Hour (ACH) for given wind incident angles. Similarly, Schulze and Eicker [21] calculated the monthly average ACH for different natural ventilation strategies in an office building and found that the average ACH values obtained for purely wind-driven cross-ventilation vary from 11.7 to 8.0 and to 4.7 h^{-1} assuming an upstream wind profile for country, urban and city terrain, respectively. A different approach to assess the cooling potential of night-ventilation is proposed by Geros et al. [2], who used experimental wind field and air temperature data measured inside and outside ten urban street canyons in Athens (Greece) as boundary conditions for BES/AFN simulations. The energy performance of a single-zone room located inside and outside the canyons shows an overestimation of the cooling efficiency of night ventilation when undisturbed climatic conditions outside the canyon are used. Finally, the impact of solar shading by adjacent buildings on the heating/cooling demand is studied with BES tools, e.g. by [22–24]. Results are clearly climate-dependent, but in general a significant influence is found, meaning that the solar shading of the surrounding obstacles should be included. In conclusion, to the best of the authors' knowledge, there is a lack of systematic studies that consider both wind shielding and solar shading effects in the urban environment and evaluate their combined impact on the cooling energy savings for natural night-ventilation.

The present study provides a systematic analysis of the impact of the urban environment on the effectiveness of natural night-ventilation for a low-rise office building (reference building). The reference building is analyzed as isolated and as placed in the center of simplified urban areas composed of uniform buildings of Plan Area Density (PAD) equal to 0.1, 0.3 and 0.6. These PAD values were chosen to consider different urban wind flow regimes [12] but also to take into account realistic obstruction distances [24]. The energy demand of the reference building and the natural ventilation effectiveness are evaluated with EnergyPlus and the embedded AFN model [25]. The validity of the integration of EnergyPlus with the AFN model for natural ventilation has been reported in previous studies [13,26]. Applications of BES/AFN tools to evaluate the effect of the urban environment on the energy performance of non-isolated buildings are still rather limited. In this study, the geometry and albedo properties of the surrounding buildings are explicitly modeled to consider the solar shading effect on the reference building. Furthermore, the impact of building packing density on the wind velocity profile is taken into account by adopting experimental wind pressure coefficients achieved by Quan et al. [27,28]. Finally, the influence of the local weather is assessed by considering

Download English Version:

https://daneshyari.com/en/article/6733243

Download Persian Version:

https://daneshyari.com/article/6733243

Daneshyari.com