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On the impact of urban micro climate on the energy consumption of buildings.

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Abstract

The energy consumption of urban buildings is affected by the surrounding microclimate which differs from standard weather data and by mutual obstructions between buildings, which decrease sunlight and wind potentials for internal solar gains and passive cooling. The building construction itself affects both outdoor and indoor microclimate. This research addresses these interdependences in respect with energy performance. An urban structures are investigated with a fixed value of H/W and solar orientation. The numerical method used is the building energy model (TRNSYS), for simulating building energetic and thermal responses to external and internal settings and the Sombrero software to evaluate the to evaluate the shading of surrounding buildings.

Keywords: urban canyon, convective heat transfer coefficient, CFD, fluid dynamic, thermal field

1. Introduction

A significant part of the world's energy consumption is used for heating and cooling of buildings With the global trend towards urbanization, the minimization of the energy consumption of buildings in urban areas has a great energy-saving potential. The microclimate in urban areas differs significantly from the climate in rural areas. The air temperatures are higher due to the urban heat island (UHI) effect and the wind speeds are lower due to wind sheltering by buildings. For these effects, the energy demand for space cooling in buildings can increase significantly, as studied by authors such as Santamouris et al. for Athens

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[1], or Kolokotroni et al. for London [2]. The urban microclimate is determined by different factors: local air velocity, temperature and humidity; solar irradiation and specular and diffuse reflections, surface temperatures of building and ground, and the respective long-wave radiation exchange, also with the sky. Even for buildings in an urban context, common practice in detailed building energy simulation (BES) still relies on stand-alone building configurations, not accounting for the influence of neighbouring buildings, except perhaps for shading.

Surface temperature distribution and air circulation play an important role on heat exchanges between the building and canyon air, that in turn influence pedestrian comfort and the energy demand of buildings [3 -7].

However, the urban climate and microclimate can strongly affect the building energy demand. Compared to standalone buildings, buildings in urban context experience higher ambient temperatures due to urban heat island effects and local heat rejection from other buildings, an altered radiation balance, due to the presence of surrounding buildings, and changed convective heat exchange, due to the different wind flow pattern.

Urban microclimate effects on energy demand were analysed by authors such as Yang et al. [8], who used the urban microclimate model ENVI-met [9] and the building energy software EnergyPlus [10] within the same simulation. The convection heat transfer coefficient (CHTC) between the façade and the surrounding air plays an important role in building energy performance. Knowledge of the CHTC is required to asses the energy performance of buildings and it is used in Building Energy Simulation programs (BES).

As demonstrated in the paper of Mirsadeghi et al. [11], the study of the convection coefficient assumes importance especially in summer, even with differences of ± 30% (compared to the average value between the various models designed for the calculation of the convection coefficient) as regards the annual energy requirement associated with cooling and the ± 14% in reference to the peak of the request hourly. In the winter season, however, the differences are more modest, although in any case important (± 6% deviation from the mean value).

In this paper it is analyzed how varied the buildings energy demand to change the evaluation of the convection coefficient and shading.

2. Numerical Model and simulation

TRNSYS 17.0 [12] is used as code for the BES in this study. TRNSYS 17 is a transient 3D multizone BES software for single building. Simulations are conducted for a one-year period with time steps of 1 h. Heat conduction through the walls is modelled as 1D transient heat flow using wall transfer functions. TRNSYS 17 uses CHTC correlations to describe the convective heat transport at the outside surface of the building. In classical BES of SA (stand-alone) buildings, solar irradiation on facade elements is considered as a gain, and long wave radiation as a heat loss to the cold sky.

In this paper we used the software Sombrero 3:01 [13] for calculating the shading and then, through a data reader, the values in output of Sombrero were used for the calculation of the solar radiation incident on our building.

In this study the heating and cooling demand of five five storeys residential buildings is analyzed. BES's are performed for a building situated in an urban environment with a street canyon in front the considered building. Street canyons with aspect ratios = 1 and orientation N/S is considered (aspect ratio H/W with H: height of the building, W: street canyon width). The building is assumed to be very long (100 m), and the height H and width W of the building is 20 m. The lateral walls of the buildings are modelled adiabatic assuming that they are connected to other buildings. The building envelope corresponds to a new well-insulated building with a high glazing fraction of 50%.

Table 1. Building envelope properties.

Materials	Thickness (m)	H (W/m^2K)
Vertical walls	0.3	0.3
Roof	0.365	0.3
Windows		1.4

Due to lower local air speed in urban areas, the convective heat flow at facades is smaller for buildings in street canyons than for stand-alone buildings. Allegrini et al. [14] found that the space cooling demands for a building in a street canyon differ up to a factor of 1.8 depending on the used CHTC correlations. Mainly the geometry of the building, the presence of neighbouring buildings and buoyancy are found to be important influencing factors for convective heat transfer at the building surface. Therefore the choice of the correct CHTC correlations is an important aspect to account for when modelling the effect of urban microclimate.

In this study are used three different CHTC: in a simulation it used the default value of TRNSYS of 25 (W/m^2K), in another it used the coefficient found in a study of Enea [15], which sets out the hc constant, calculated under the guidelines of the UNI-EN 11300, based on the data relative to wind speed measured in the urban area of Milan, in a finally other values calculated by the hour, from data related to wind speed available from TRNSYS software, measured by the meteorological station in the area of Malpensa, using the model of Liu-Harris [14]. It has been chosen this correlation because the CHTC values obtained are similar to those in a canyon when the flow is transversal to canyon axis with low longitudinal component. This correlation is based on experiments conducted on the facade of a building in an isolated rural area, partly shielded by rows of trees and a nearby building . Climatic data for the Milan city are used as input for the BES. The soil study in areas close to the buildings follow the results of Kroener et al. [16].

3. Results

Were performed five dynamic simulation summarized in Table 2.

Table 2. Description of different dynamic simulation performed.

Name	Description	Value of CHTC
Simulation A	Dynamic simulation of an isolated building	CHTC = 25 W/m^2k
Simulation A	Dynamic simulation with default Trnsys values of the CHTC and building shading.	CHTC = 25 W/m^2k
Simulation B	Dynamic simulation with Enea values [15] of the CHTC	CHTC = 8.4 W/m^2k
Simulation C	Dynamic simulation with Liu Harris correlation used for the CHTC evaluation.	CHTC = 1.53 v_{10} +1.43
Simulation D	Dynamic simulation with Liu Harris correlation used for the CHTC evaluation and external temperature increased of 1°C.	CHTC = 1.53 v_{10} +1.43

First, the space heating and cooling demand for five simulation are compared. The aspect ratio of the street canyon is 1. The building facades are oriented north-south. In Table 3 are summarized the principal values.

Table 3. Energy parameters for the different simulations.

Name	Max heating power (KW)	Average heating power (kW)	Max Cooling power (KW)	Average Cooling power (kW)	Heating demand (MWh)	Cooling demand (MWh)
Simulation 0	21.21	10.33	8.65	0.86	45.22	1.91
Simulation A	22.59	8	9.56	1.66	35.58	3.61
Simulation B	22.52	8.06	9.74	1.72	35.27	3.81
Simulation C	22.48	8.27	9.87	1.73	36.12	3.82
Simulation D	21.96	7.89	11.15		34.39	4.97

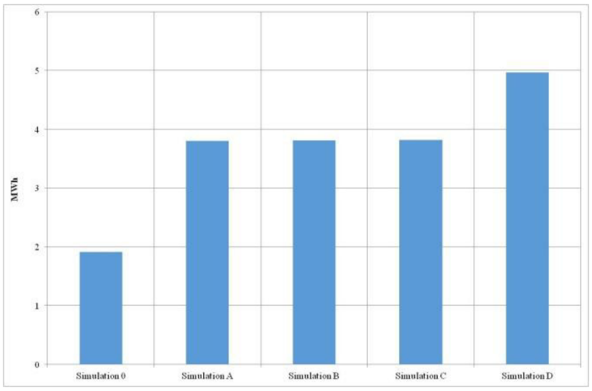


Fig. 1. Annual heating demands for five different simulations.

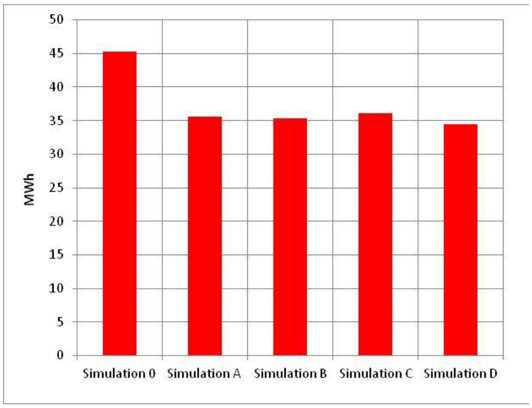
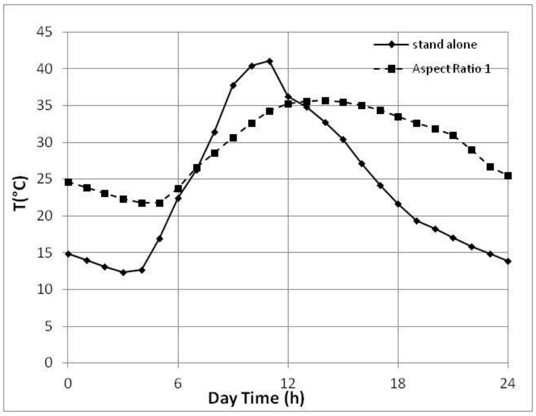


Fig. 2. Annual cooling demands for five different simulations.

Comparing the stand along building and the building in street canyon, we generally observe a reduction of heating demand and an important increase of the cooling demand for the building in a street canyon configuration (Figs 1 and 2). Several urban phenomena explain this observation. One of the main reasons is that solar radiation becomes entrapped inside the street canyon, leading to higher building facade temperatures, and thus to lower heating and higher cooling demands in the street canyon configuration. From the figures 1 and 2 it can be seen how the CHTC coefficient is not very sensitive to the determination the heating and cooling demand.

Figs. 3 and 4 shows the wall temperatures for the facade ext in the stand alone configuration and street canyon configuration. The wall temperatures are analyzed for a 24h time period during the summer.

As you can see from the figures the temperatures of the facade is on average higher in the summer for both the ground floor to the fourth floor. The temperature of the fourth floor is closer to the temperature of a building block as it was reasonable to imagine.



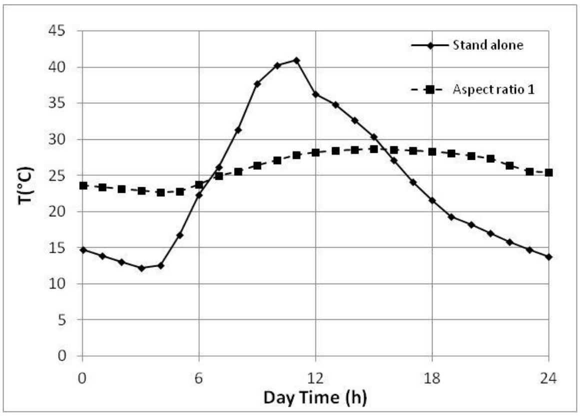


Fig. 3 The wall surface temperature for the east façade of the four floor for a stand alone building and building surrounded by street canyon with aspect ratio =1

Fig. 4. The wall surface temperature for the east façade of the ground floor for a stand alone building and building surrounded by street canyon with aspect ratio =1.

3. Conclusion

The space cooling and heating demands for a stand-alone building and buildings in an urban street canyon are compared for the moderate European climate of Milan (Italy). It is found that the space cooling demand for all building types is higher and that the space heating demand is lower for buildings in a street canyon configuration than for the same stand-alone building.

This study shows the importance of accounting for the local urban microclimate, when predicting the energy demands for buildings in urban areas.

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References

[1] Santamouris M, Asimakopoulos D. N. Energy and Climate in the Urban Built Environment. London: *James X James*, 2001. Print.

[2] Kolokotroni M, Ren X, Davies M, Mavrogianni A. London's urban heat island: Impact on current and future energy consumption in office buildings. *Energy and Buildings* (2012) 47, 302–311

[3] Bottillo S, De Lieto Vollaro A, Galli G, Vallati A. CFD modeling of the impact of solar radiation in a tridimensional urban canyon at different wind conditions. *Solar Energy* (2014) 102, 212-222.

[4] Bottillo S, De Lieto Vollaro A, Galli G, Vallati A. Fluid dynamic and heat transfer parameters in an urban canyon. *Solar Energy* (2014) 99, 1-10.

[5] Galli G, Vallati A, Recchiuti C, de Lieto Vollaro R, Botta F. Passive cooling design options to improve thermal comfort in an Urban District of Rome, under hot summer conditions. *Int. J. Eng. Technol* 5 (2013), 4495-4500.

[6] de Lieto Vollaro R, Vallati A, Bottillo S. Differents Methods to Estimate the Mean Radiant Temperature in an Urban Canyon. *Advanced Materials Research* (2013) 650, 647-651.

[7] de Lieto Vollaro A, De Simone G, Romagnoli R, Vallati A, Botillo S. Numerical study of urban canyon microclimate related to geometrical parameters. *Sustainability* (2014), 6 (11), 7894- 7905.

[8] Yang X, Zhao L, Bruse M, Meng Q. An integrated simulation method for building energy performance assessment in urban environments. *Energy and Buildings* (2012) 54, 243-251

[9] ENVI-met. 2009. ENVI-met 3.1. Homepage by Bruse M. and team, www.envi-met.com.

[10] Crawley D.B., Lawrie L.K., Pedersen C.O., et al. EnergyPlus: New, capable, and linked. *Journal of Architectural and Planning Research* (2004) 21 (4), 292-302

[11] Mirsadeghi M, Cóstola D, Blocken B, Hensen J.L.M. Review of external convective heat transfer coefficient models in building energy simulation programs: Implementation and uncertainty. *Applied Thermal Engineering* (2013), 56, 134-151.

[12] TRNSYS 17.0, Transient System Simulation Program, SEL, University of Wisconsin/ TRANSSOLAR, Stuttgart, 2010.

[13] Sombrero 3.01 Group for Building Physics & Solar Energy / Fachge. http://nesa1.uni-siegen.de/..

[14] Allegrini J, Dorer V, Carmeliet J. Analysis of convective heat transfer at building facades in street canyons and its influence on the prediction of space cooling demand in buildings. *Journal of Wind Engineering and Industrial Aerodynamics* 104–106 (2012), 464–473.

[15] Caputo P, Costa G, Zanotto V. *Rapporto sulla validazione del modulo edificio*. Enea (2011).

[16] Kroener E, Vallati A, Bittelli M. Numerical simulation of coupled heat, liquid water and water vapor in soils for heat dissipation of underground electrical power cables. *Applied Thermal Engineering* (2014) 70 (1), 510-523.

Biography

Andrea Vallati was born in Roma, Italy, on October 16, 1970. He received the M.S. degree in Mechanical Engineering, and the Ph.D. degree in Applied Physics, from University of Ancona (Italy) in 1997 and 2001, respectively. From 2006 he served as Assistant Professor at the Department of "Fisica Tecnica " of the same University. Since 2005 he is Professor of Energy and Applied Physics at the Faculty Engineering of “'Sapienza” University of Rome. He is author or co-author of about 40 scientific works, published in prominent international journals and conferences on heat transfer, thermodynamics and acoustics.