Applied Energy xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Applied Energy

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

Methodology of the cost-optimality for improving the indoor thermal environment during the warm season. Presentation of the method and application to a new multi-storey building in Berlin ☆

Fabrizio Ascione [a,*], Olaf Böttcher [b,1], Robert Kaltenbrunner [b,1], Giuseppe Peter Vanoli [c,2]

[a] University of Naples Federico II, DII – Department of Industrial Engineering, Piazzale Tecchio, 80, 80125 Napoli, Italy
[b] BBSR – German Federal Institute for Research on Building, Urban Affairs and Spatial Development, Department of Building and Housing, Straße des 17 Juni 112, 10623 Berlin, Germany
[c] University of Sannio, DING – Department of Engineering, Piazza Roma, 21, 82100 Benevento, Italy

HIGHLIGHTS

- Modern, well-insulated and highly glazed building can be uncomfortable in summer.
- Passive cooling is advisable and possible in heating dominated climates.
- The approach of cost optimality is here adapted to naturally ventilated buildings.
- Lightweight efficiency measures are tested for improving the summer comfort.
- Solar shadings and variation of daylighting have contrasting effects.

ARTICLE INFO

Article history:
Received 22 June 2015
Received in revised form 25 October 2015
Accepted 30 October 2015
Available online xxxx

Keywords:
Thermal comfort
Indoor overheating
Passive cooling
Cost-optimality
Optimization
Dynamic energy simulation

ABSTRACT

The issue of the summer indoor overheating in modern buildings is investigated. Indeed, mainly for heating dominated climates, usually there is a great attention to the design of measures for reducing the energy losses in winter, while the summer comfort often is secondary or neglected. On the other hand, just where the warm season is not so hard, passive energy measures have to be deeply exploited, in order to avoid the installation of air-conditioning systems, with positive effects on both the building and city scales (e.g., the reduction of urban heat islands). After a general overview of the overheating phenomenon, a case report is proposed, where, even if the summer ambient conditions are not extreme, thermal discomfort has been registered during the first years of operations. The office building, recently built in Berlin, fulfils the German requirements of energy efficiency and heat protection in summer. It is not equipped with mechanical systems for the space cooling. According to the new international approach of the cost-optimality, this study investigates strategies for improving the indoor conditions – evaluated by means of the adaptive criteria – during the cooling season, by analyzing various solutions for reducing the heat gains. By means of calibrated numerical models, validated by comparisons with measurements of indoor air temperatures (free-running building), transient energy simulations have been performed. The target of investigation is the research of the optimal solution of solar shadings (i.e., typology and management), in order to find the best compromise in terms of thermally comfortable hours, use of artificial lighting, operational and investment costs.

1. Introduction

The goal of the future construction activity is the design of buildings that require zero- or low-energy demand for their operation, by reducing the energy requests, by means of:

- adoption of high-efficient building envelopes and active energy systems,

☆ This paper was presented at the 7th International Conference on Applied Energy (ICAE2015), March 28–31, 2015, Abu Dhabi, UAE (Original paper title: "Summer overheating in a new multi-storey building in Berlin: numerical study for improving the indoor microclimate" and Paper No.: 105).

* Corresponding author. Tel.: +39 081 7682301 (Office); fax: +39 081 2390364 (Office).
E-mail addresses: fabrizio.ascione@unina.it (F. Ascione), Olaf.Boettcher@BBR.Bund.de (O. Böttcher), Robert.Kaltenbrunner@BBR.Bund.de (R. Kaltenbrunner), vanoli@unisannio.it (G.P. Vanoli).
[1] Tel.: +49 (0)30 18401 2770 (Office); fax: +49 (0)30 18401 2779 (Office).
[2] Tel.: +39 0824 305576 (Office); fax: +39 0824 325246 (Office).

http://dx.doi.org/10.1016/j.apenergy.2015.10.169
0306-2619/

- fulfillment of the energy demands through the in-situ conversions from renewable energy sources.

It is well-known that the buildings sector weighs on the European energy need and polluting emissions for around the 40%, such as declared in the "Energy Performance of Buildings Directive 2002/91/EU (EPBD)" [1]. The EPBD was accompanied by the publication of a large set of technical standards that concern all involved energy questions: from the kind of ratings for calculating the building performances (EN 15603/2007 [2]) to the methodologies for the evaluation, for instance, of the building heating and cooling demands (EN 13790/2008 [3]). With reference to the European Community, it is required an adaptation of laws and technical standards in order to take into account the different boundary conditions, with reference to the climates, the peculiar building technologies and building traditions. Indeed, the European guidelines underline the necessity of diversification. For instance, the same concepts of cost-optimality and peculiarities of nearly zero-energy buildings – such as established by the EPBD Recast 2010/31/EU [4] – should be specified at national level.

During the last years, high-efficient new buildings have been built all around Europe, by adopting strategies and solutions aimed at reducing the energy demand for the space heating. The high attention to the efficiency for the space heating has mainly two motivations: (a) this energy use has the highest weight and impact among the various building services, (b) the European cultures and politics in matter of energy efficiency in buildings have been historically developed in "heating dominated climates".

This caused high attention to thermal insulations and to strategies for increasing the solar gains (e.g., large fenestrations on the south-, west- and east-facades). The combination of both these choices could cause, also in cold climates, overheating phenomena during the warm season. More in detail, in the central period of the summer season, when the ambient temperatures cannot allow a sufficient free-cooling by means of the voluntary opening of windows (i.e., natural ventilation), the use of mechanical cooling systems could be necessary for highly glazed and high-insulated buildings. Air-conditioning systems and equipment are quite common in Mediterranean Countries. Conversely, the active cooling is not common, and not recommended, in other European countries and thus, if suitable strategies for the solar protection and solutions for removing, naturally, the heat gains from the buildings are not designed, the summer discomfort could be frequent. This criticality mainly concerns the buildings of the tertiary sector, where the endogenous gains are high and the architectural choices usually prevail on the energy issue. It implies new constructions characterized, sometimes, by a poor livability in summer and this cannot be easily repaired because of architectural questions, a kind of reluctance in refurbishing new architectures, difficulties in solving the problem without being invasive. Finally, the question should be addressed since the design phase. In particular, the solar protection and the heat removal should be primary aims also in heating dominated climates, by taking into account the difficulties of refurbishing measures applied after the construction phase. All told, if the choice is to avoid the active space cooling, a great effort is required into designing passive strategies for limiting the indoor overheating in summer.

This paper, with reference to a German case study, proposes some investigations, based on the concept of the cost-optimality, for improving the indoor summer conditions in a naturally ventilated building.

The multi-storey building (Fig. 1) is used for offices. It has comfort standards and building technologies quite high-tech, in line with equipment and technologies of contemporary architecture, and thus issues, investigations and outcomes here proposed can be quite generalizable. More in detail, during the first two years of operations, overheating problems have been verified in summer, mainly due to the solar gains entering through the large windows. In this regard, this study investigates possible energy efficiency measures for improving the thermal behavior of the transparent envelope, in order to reduce the solar gains without penalizing the achievable daylight provision, according to the approach of the cost-optimality.

2. Summer overheating in naturally ventilated buildings: literature state of art

For naturally ventilated buildings, the thermal comfort during the warm season is usually investigated by means of an adaptive approach, such as proposed by international methods (e.g., ANSI/ASHRAE 55/2013 [5], EN 15251/2007 [6]). The topic is quite

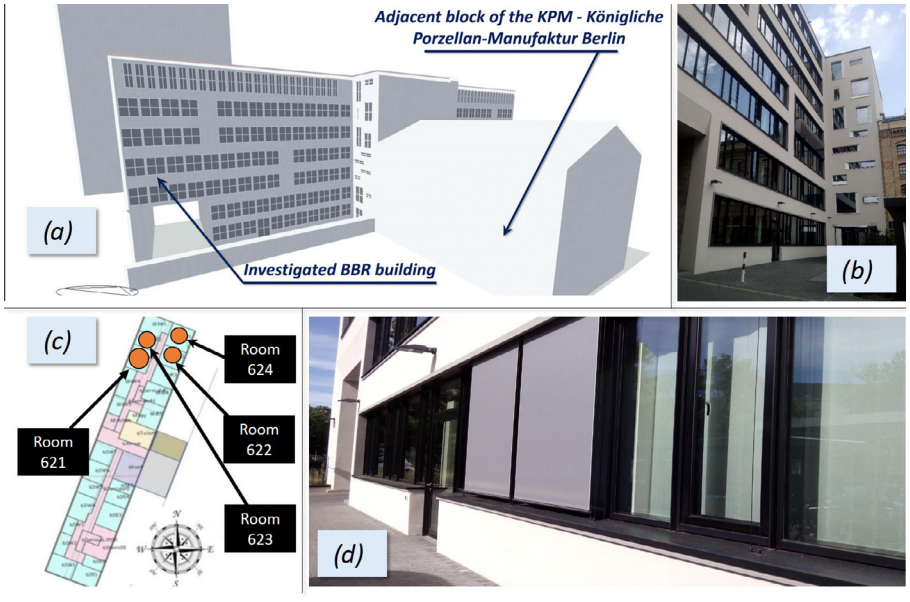

Fig. 1. Pictures and model of the investigated building in Berlin: (a) 3D model, (b) entrance, (c) plan of the sixth floor and (d) west façade.

Please cite this article in press as: Ascione F et al. Methodology of the cost-optimality for improving the indoor thermal environment during the warm season. Presentation of the method and application to a new multi-storey building in Berlin. Appl Energy (2015), http://dx.doi.org/10.1016/j.apenergy.2015.10.169