SPRINGER BRIEFS IN APPLIED SCIENCES AND TECHNOLOGY · POLIMI SPRINGER BRIEFS

Simone Ferrari
Valentina Zanotto

Building Energy Performance Assessment in Southern Europe

POLITECNICO
DI MILANO

Springer

SpringerBriefs in Applied Sciences and Technology

PoliMI SpringerBriefs

More information about this series at http://www.springer.com/series/11159
http://www.polimi.it

Simone Ferrari · Valentina Zanotto

Building Energy Performance Assessment in Southern Europe

POLITECNICO
DI MILANO

Springer

Simone Ferrari
Politecnico di Milano
Milan
Italy

Valentina Zanotto
Amstein + Walthert AG
Zürich
Switzerland

ISSN 2191-530X ISSN 2191-5318 (electronic)
SpringerBriefs in Applied Sciences and Technology
ISSN 2282-2577 ISSN 2282-2585 (electronic)
PoliMI SpringerBriefs
ISBN 978-3-319-24134-0 ISBN 978-3-319-24136-4 (eBook)
DOI 10.1007/978-3-319-24136-4

Library of Congress Control Number: 2015950018

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media
(www.springer.com)

Preface

Due to the prevailing climatic conditions, buildings in most European countries are characterised by a greater need for heating than cooling.

Several simplifications can be generally adopted for the calculation of the thermal balance of a building when considering the heating side. In fact, the assessment of the heating energy needs of a building mainly depends on the amount of indoor air volumes to be renewed to ensure the well-being of the occupants, regardless of the construction features, and on the performance of the building envelope in preventing the heat loss through transmission. As a matter of fact, it is common practice in the building sector to consider the level of thermal insulation of the envelope as the first indicator for describing the energy quality of the building.

Actually, the warmer climatic conditions in areas of southern Europe strongly influence the building thermal energy balance in terms of cooling needs. Therefore, the glazed percentage of the building envelope and the way the openings are shaded should also be taken into account among the main indicators of the building energy quality. Another important indicator should be the thermal capacity of the construction, since it significantly affects energy performance in the case of daily variations in the direction of the thermal flux through the envelope over long periods of time (buffer effect during summer and intermediate seasons). Moreover, the useful effect of thermal mass during the warm season can even increase, depending on the way the building is ventilated (i.e. free cooling strategies): in the warmer areas, in fact, the ventilation rates usually exceed the amount strictly needed to guarantee the indoor air quality, often through window management by the users, as mechanical ventilation systems are rarely provided.

In order to properly take into account all these aspects, the assessments of the building energy balance should be performed by means of detailed evaluations (i.e. dynamic calculation procedures). In this case, however, the calculation methods are too complex to be widely adopted in common practice, even using proper simulation tools: an accurate physics model, with detailed boundary conditions defined at least on an hourly base (building usage patterns, climate, etc.), and therefore producing reliable results, can only be achieved by users with sufficient competence and experience.

Furthermore, the set-points regulating building climatization systems, defined as the "suitable indoor temperatures" providing comfortable thermal conditions, and therefore the corresponding values assumed for the building energy balance calculation, are still commonly defined according to the thermal comfort theory formulated by Fanger in the 1970s.

This approach bases the definition of thermal comfort on pure physics, neglecting social and psychological aspects of thermal perception, while in the Southern European context, and in particular in the Mediterranean region, the building solutions and users' habits reveal certain peculiarities. Buildings are in fact widely naturally ventilated even when active cooling systems are installed, because people are traditionally used to maintain contact with the outdoors, and are usually equipped with operable window shading devices. Under these conditions, the real cooling needs strongly depend on the comfort mitigation strategies adopted by the users, and the thermal expectations are strictly related to the mean outdoor climatic conditions of the considered period (thermal experience).

In this respect, the very narrow range of allowable indoor set-point temperatures defined by a completely steady-state approach for assessing building thermal energy needs is questionable.

The main alternative approach to determining, on a variable basis, comfortable environmental conditions is the adaptive approach, which has a dynamic form depending on a transient parameter, i.e. the external temperature. This approach was developed on the assumption that the occupants are an active part of the enclosed environment: i.e. they can interact with the construction and can affect the building boundary conditions regardless of the presence of an active climatization system.

Once again, however, this climatic-related indoor temperature can only be set by means of a detailed simulation analysis.

Another important aspect that can be properly taken into account only by performing a dynamic analysis is the operative temperature in the spaces, which considers the surface radiant temperatures and therefore more accurately represents the performances of the building envelope in contributing to overall thermal comfort sensation.

The operative temperature parameter can strongly influence the real building energy need, especially during summer when the solar radiation affects the glazed surfaces, and is commonly neglected in simplified building energy assessment, which considers only the air temperature. As a matter of fact, in the case of unfavourable radiant temperatures, the air temperature set-point is usually corrected by the users in order to adjust the indoor condition to compensate the radiative component, and the consequent overuse of the active climatization systems causes an unpredicted increase in building energy consumptions.

Summarizing, simplified procedures and assumptions have been common practice for a long time in assessing the energy performances of buildings in Europe: currently, the quasi-steady-state energy balance calculation method (the simplest among those provided for by EN ISO 13790) is still the main reference for implementing procedures at national level and is also widely adopted for the energy certification of buildings. Nevertheless, a proper evaluation of building energy performance, with particular reference to the southern climatic area, should be significantly more complex.

This book discusses the related issues, besides the theoretical basis, through several application case studies carried out with reference to the Italian context, considered as representative of southern Europe. These descriptions will support energy consultants and other interested parties in assessing building energy performance beyond the mere simplified standard assumptions. Furthermore, the numerous graphs and tables documenting the analysis of a set of typical building solutions can be easily adopted to serve as design tools for both new constructions and retrofits.

Finally, I hope that this book, bringing together results from some of the most significant researches that I have promoted and coordinated in recent years on the issue, will contribute to increasing awareness of the actual consequences of architectural design choices, contrasting the trends to construct excessively light, largely glazed and improperly sealed buildings, and to encouraging the definition of more suitable energy policies for the building sector in the Southern European context.

Milan
July 2015

Simone Ferrari

Contents

Chapter 1
Building Envelope and Thermal Balance

Abstract From the thermal balance point of view, in addition to air mass transfer due to infiltration and ventilation, building energy performance strictly depends on the characteristics of the envelope, in that it constitutes the boundary between the indoor and outdoor environments. Most of the currently available building performance assessment methods evaluate the heat exchange through the envelope by the means of a steady-state analysis, leading to the diffusion of strict regulations regarding the heat transmittance of the envelope elements. Although this approach is simple to use, it does not take into account the dynamic behaviour of the construction materials, which tend to store heat and release it after a certain length of time (Van Geem 1987). This phenomenon, usually referred to as thermal inertia or thermal mass, strongly affects the heat transfer process, influencing the building thermal energy need. This chapter summarises the theoretical basis of building thermal balance and heat transfer through the envelope. Furthermore, the different implications when considering the dynamic and the steady-state assessment methods are presented with the help of a practical example.

Keywords Building thermal balance · Heat transfer through building envelope · Dynamic and steady-state heat transfer · Building heat capacity · Thermal inertia · Climatic chamber tests

1.1 Building Thermal Balance

The building (or the considered thermal zone of a building) heating and cooling need calculation is mostly based on the air volume heat balance, which takes into account all the different heat flows affecting the indoor environments (Eq. 1.1). In order to simplify the calculation, the only sensible heat balance is considered, neglecting the thermal effects due to the water contained in the air (Cengel 2008).[1]

---

[1] These effects are usually taken into account only when a complete air conditioning process is considered.

S. Ferrari and V. Zanotto, *Building Energy Performance Assessment in Southern Europe*, PoliMI SpringerBriefs,
DOI 10.1007/978-3-319-24136-4_1

$$\sum \Phi_j = M \cdot c_{p,air} \frac{d\theta_{air}}{dt} \tag{1.1}$$

where

$\Sigma\Phi_j$	is the summation of the heat flow rates involving the air volume (W)
M	is the air volume mass (kg)
$c_{p,air}$	is the air specific heat capacity (J/(kg K))
θ_{air}	is the air volume temperature (K)
t	is time (s)

The climatization system aims at maintaining a constant indoor air temperature, and so the second half of the balance usually equals zero. The summation of the sensible heat flows involving the air volume is defined in Eq. 1.2.

$$\sum \Phi_j = \Phi_{env} + \Phi_{ven} + \Phi_{\text{int}} + \Phi_{sol} + \Phi_{sys} \tag{1.2}$$

where

Φ_{env}	is the heat flow rate from the envelope (W)
Φ_{ven}	is the heat flow rate due to air mass exchange (W)
Φ_{int}	is the heat gain due to internal heat sources (W)
Φ_{sol}	is the solar heat gain through the transparent elements (W)
Φ_{sys}	is the heat flow rate due to climatization system (W)

The balance is therefore solved using the heat flow rate due to the climatization system as dependent variable, as in Eq. 1.3.

$$\Phi_{sys} = \Phi_{env} + \Phi_{ven} + \Phi_{\text{int}} + \Phi_{sol} \tag{1.3}$$

The components of Eq. 1.3 have been traditionally analysed either in a detailed dynamic way or in a simplified way, which reduces the complexity of the underlying equations imposing steady-state boundary conditions. If the first approach guarantees a high accuracy level in reproducing the energy and mass flows occurring in the building, the latter one provides ease and flexibility in indicating the building performance.

1.1.1 Heat Flow from Envelope

The heat flow from the envelope is generally defined according to Eq. 1.4.

$$\Phi_{env} = \sum_{i}^{N_{el}} h_{s,i} A_i \left(\theta_{s,i} - \theta_z \right) \tag{1.4}$$

where

h_s	is the surface convective and radiative heat transfer coefficient (W/(m^2 K))
A	is the surface of the envelope element (m^2)
$\theta_{s,i}$	is the internal surface temperature of the envelope element (°C)
θ_z	is the indoor desired temperature (°C)
N_{el}	is the number of envelope elements

This parameter is essentially determined as the result of the external variability in terms of air temperature and solar radiation on the opaque elements of the envelope, which is determined by the general heat conduction equation (see Sect. 1.2).

1.1.2 Ventilation

The heat flow due to air mass exchange is defined according to Eq. 1.5.

$$\Phi_{vent} = \sum_{i}^{Nflow} \dot{m}_j c_{p,air} \left(\theta_{air,e} - \theta_z\right) \tag{1.5}$$

where

$\dot{m}$	is the air mass flow rate (kg/s)
$c_{p,air}$	is the air specific heat capacity (J/(kg K))
$\theta_{air,e}$	is the outdoor air temperature (°C)
N_{flow}	is the number of air flows

The calculation of this part of the heat balance is based on the same equation both in the steady-state and dynamic approaches, except for the time-step and therefore the application schedules.

The main parameter characterizing this heat flow is the air flow rate, also defined “discharge rate”, which can be either determined in detail according to opening size and presence of wind or in simplified ways according to standard air change rate values connected to the building use and provided by international and local regulations.

1.1.3 Internal Heat Sources

The heat production due to internal sources is a summation of the heat production of people, lighting and equipment present in the thermal zone. Similarly to the previously described discharge rate, also this component of the heat balance is based on the same calculation in the steady-state as well as in the dynamic approach, except for the time step and the application schedules.