G Model
ENB-7712; No. of Pages 10
ARTICLE IN PRESS
Energy and Buildings xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
Energy and Buildings
journal homepage: www.elsevier.com/locate/enbuild

Original article

# A numerical prediction of the passive cooling effects on thermal comfort for a historical building in Rome

Valeria Vitale*, Ginevra Salerno

*Department of Architecture, Roma Tre University, Via della Madonna dei Monti 40, 00184 Roma, Italy*

ARTICLE INFO

*Article history:*
Received 30 December 2016
Received in revised form 24 May 2017
Accepted 19 June 2017
Available online xxx

*Keywords:*
Heritage buildings
Passive cooling
Thermal mass
Natural ventilation
CFD simulation
Adaptive thermal comfort

ABSTRACT

In recent times, numerical simulations are increasingly gaining ground for the energy saving and thermal comfort evaluation of historical buildings.

In the present paper a transient 2D model of the Pavilion 2 B of the *Ex-Mattatoio* (Past abattoir) in Rome is presented, created by Computational Fluid Dynamics (CFD) software based on the finite element method (FEM). The simulations take into account time variations and interactions between indoor and outdoor thermal conditions, with the aim of evaluating different usage profiles and of estimating passive cooling effects in presence of natural ventilation and high thermal masses.

The main goal of this work is to show the CFD numerical models potential in quantifying the cooling effects and the indoor thermal comfort conditions, in order to enhance passive and hybrid strategies based on natural ventilation and nocturnal thermal masses precooling.



## 1. Introduction

Over the last years, many studies have underlined a growing interest towards the indoor climatic control and the energy efficiency of historical buildings [1]. This topic seems to be central especially when a process of reuse involve a modification of the intended use of the building, that could entail new requirements on thermal comfort and energy performance of the building itself.

Latest Italian and European regulations, based on adaptive thermal comfort theory [2], promote the use of passive cooling and natural ventilation strategies. However, it is often difficult to predict and quantify the thermal masses cooling by natural ventilation and the effectiveness of these passive strategies applied on historical buildings.

To date, the use of CFD numerical models represents a good way to go for studying these strategies, as confirmed by a growing literature [3–6]. Thanks to the overcoming of some limits and simplification of the multi-zone models, currently the most commonly used, CFD models can provide more detailed estimation of thermal storage in building masses, fluid flow motions and indoor temperature distribution, that are key factors in thermal comfort evaluation.

For these reasons, CFD analysis is beginning always more often to support and integrate the multi-zone models, in particular when there is the need to provide a detailed response about passive cooling effects [7].

## 2. Research aims

The main goal of the paper is to apply CFD models on a case study of the Italian architectural heritage, in order to estimate passive cooling effects on indoor conditions.

The simulations shown below have carried out with the purpose to determine the effectiveness of passive strategies in order to guarantee thermal comfort and contribute to energy saving through the HVAC[1] use reduction.

In this context, special attention has been paid to the methods for the indoor environment evaluation given in the ASHRAE and European standards EN 15251 [8]. According to these regulations, the comfort range depends on the strategy used to guarantee the indoor climatic conditions.

In fact, if the cooling is provided by a mechanical system the indoor temperatures range is based on Fanger method, in which thermal comfort indices are calculated with the PMV-PPD (predicted mean vote – predicted percentage of dissatisfied) criteria, as described in detail in EN ISO 7730 [9].

* Corresponding author.
*E-mail address:* valeria.vitale@uniroma3.it (V. Vitale).

[1] Heating, Ventilating and Air Conditioning.

http://dx.doi.org/10.1016/j.enbuild.2017.06.049
0378-7788/© 2017 Published by Elsevier B.V.

Please cite this article in press as: V. Vitale, G. Salerno, A numerical prediction of the passive cooling effects on thermal comfort for a historical building in Rome, Energy Buildings (2017), http://dx.doi.org/10.1016/j.enbuild.2017.06.049

**Nomenclature**

| | |
|---|---|
| $h_o$ | Coefficient of heat transfer by long-wave radiation and convection at outer surface, W/m$^2$ K |
| $T_s$ | Surface temperature, K |
| $T_o$ | Outdoor air temperature, K |
| $\alpha$ | Absorptance of surface for solar radiation, dimensionless |
| $E_t$ | Total solar radiation incident on surface, W/m$^2$ |
| $\varepsilon$ | Hemispherical emittance of surface, dimensionless |
| $\Delta R$ | Difference between long-wave radiation incident on surface from sky and surroundings and radiation emitted by blackbody at outdoor air temperature, W/m$^2$ |
| $U_v$ | Window thermal transmittance, W/m$^2$ K |
| $\mathcal{T}$ | Window solar transmittance, dimensionless |
| $\mathcal{A}$ | Window solar absorptance, dimensionless |
| $\mathcal{N}$ | Inward flowing fraction of the absorbed radiation, dimensionless |
| SHGC | solar heat gain coefficient ($SHGC = \mathcal{T} + \mathcal{N}\mathcal{A}$), dimensionless |

When, instead, the thermal comfort is achieved by passive cooling strategies the thermal comfort indices are given by Adaptive Thermal Comfort method, that pay more attention to cultural, social and behavioural aspects of the users [10]. This method derives from statistical studies carried out on existing buildings and allows to use more convenient temperature ranges, since the study revealed that often the people are more tolerant than Fanger method suggests.

Due to the fact that using the Adaptive Thermal Comfort range the temperatures can be greater than 26 °C Fanger upper comfort limit, EN 15251 enhanced a passive approach based on natural ventilation to control the indoor environment with the aim of energy consumption reduction.

With regard to thermal comfort theory and related European standards previously mentioned, the simulations shown below provide different building usage profiles in order to verify the indoor condition in relation of the use or not of passive cooling strategies.

The three building usage profiles are:

- Without natural ventilation (Nov);
- With only nocturnal ventilation (10hV);
- With nocturnal and diurnal ventilation (24hV).

The first two profiles include the use of the HVAC system to guarantee diurnal thermal comfort and for this reason the operative temperature obtained from these simulations shall be compared with Fanger thermal comfort range; the third simulation not include the HVAC system use and that's the reason why the operative temperature get from these simulation will be compared with the Adaptive Thermal Comfort range.

## 3. Description of the case study

The case of study presented is the Pavilion 2B of the *Ex-Mattatoio* (Ex-slaughterhouse) of Testaccio in Rome (Italy), designed and built by Gioacchino Ersoch [11] for the Municipality of Rome in the late 1800s, currently restored and converted to spaces of the Department of Architecture of Roma Tre University (Fig. 1).

Originally, the building was a slaughterhouse facilities for farm livestock: a one-story large hall with gable roof, *lunette* windows on masonry walls and with six transverse partitions that divided the space into seven adjacent stables.

**Fig. 1.** The Pavilion 2 B of the *Ex-Mattatoio* in Rome after the restoration, photo by © Stefano Cerio.

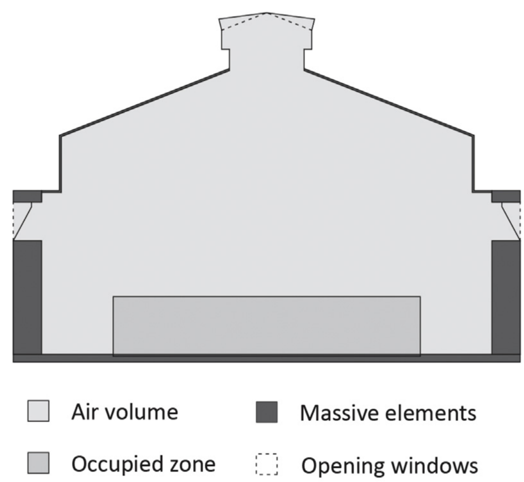


**Fig. 2.** 2D CAD geometry representing the cross section of the Pavilion 2B.

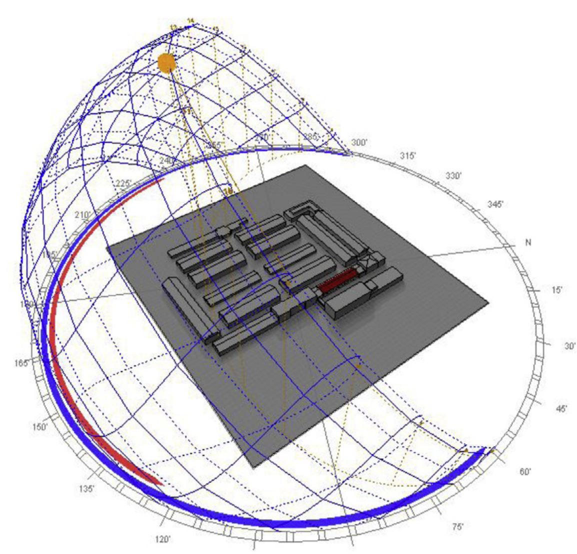

**Fig. 3.** 3D solar radiation model representing the Pavilion 2 B (red) and the adjacent pavilions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Please cite this article in press as: V. Vitale, G. Salerno, A numerical prediction of the passive cooling effects on thermal comfort for a historical building in Rome, Energy Buildings (2017), http://dx.doi.org/10.1016/j.enbuild.2017.06.049