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Different Strategies for Improving Summer Thermal Comfort in Heavyweight Traditional Buildings

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Abstract

In order to exploit the passive energy potential of the building envelope, it is important to provide a right combination of insulation thickness, heat capacity and night-time ventilation. In this paper, this issue will be tackled with reference to an historic building in Catania (Southern Italy). The building was built at the end of the XIX century, and its opaque envelope is entirely made with lava stones, which is typical of traditional architecture in this area.

Starting from the current configuration of the building, many hypotheses for refurbishment are considered, combined with different strategies for passive cooling, such as night-time ventilation, use of shading devices and adoption of highly-reflective coatings. The effectiveness of each solution in terms of summer thermal comfort is evaluated through dynamic thermal simulations carried out with EnergyPlus.

The results show the synergic effect of these strategies, as well as their individual impact, and allow to draw some general conclusions about the behaviour of heavyweight buildings under moderately hot weather conditions.

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1. Introduction

In summer conditions characterized by wide diurnal temperature variations, as learned from the historic traditional architecture and demonstrated by some studies [1-4], good indoor conditions can be achieved only by

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using a building shell with appropriate thermal mass and insulation level. Moreover, the compliance with the national building codes about thermal insulation is not sufficient to provide energy savings for space cooling [5], and the position of the insulating material in the outer walls represents a key issue [6].

The heat capacity of the building envelope has inspired many studies since dynamic numerical simulation became accessible. For instance, the works referenced in [7-11] report on the thermal behaviour of different heavy walls in simple case studies, under particular boundary conditions and for energy or economic purposes.

However, there are few works that take into account the thermal capacity of the building envelope, and its combination with the level of insulation, under the perspective of thermal comfort. In fact, as long as the building is controlled by an HVAC system, its transient behaviour is under-exploited and its potential for passive cooling masked or distorted. In this context, this paper will analyze the transient behavior of a massive building by looking at thermal comfort in summer, showing the best passive solutions for reducing/avoiding the risk of room overheating.

Nomenclature

ACH	air changes per hour [h^{-1}]
T_{op}	operative temperature [°C]
r	solar reflectance [-]
ITD	Intensity of Thermal Discomfort [°C·h]

2. Methodology

The main goal of this paper is to show how the thermal capacity of the building envelope, its insulation level, the use of blinds and of light colors for the external walls, as well as the adoption of appropriate ventilation strategies, are useful for improving summer thermal comfort in buildings. To this aim, a parametric approach was conducted in order to explore the individual contribution of each technical solution, and possible synergic effects.

The results of the simulations have been interpreted considering not only a classic parameter such as the operative temperature T_{op}, but also taking into account an indicator recently introduced in [12], namely the *Intensity of Thermal Discomfort* (ITD). The ITD represents the time integral of the positive differences between the current operative temperature and a threshold value that defines the upper limit for comfort:

$$ITD = \int_P \left(T_{op}(\tau) - T_{lim}\right)^+ d\tau \qquad (1)$$

In this study, the definition of the threshold value T_{lim} is based on the adaptive approach, as described in [13][14]; in particular, the threshold operative temperature corresponds to the upper limit of Category I, which is the most restrictive one. The threshold value is not constant in time, but it is updated daily as a function of the running mean outdoor air temperature [14]. In order to use this indicator, the building is simulated in a free-running mode to obtain the time profile of the indoor operative temperature. As the building is used for residential purposes, the calculation of the indicator is based on the 24-h profile of the operative temperature.

Moreover, in order to stress the transient behavior of the building envelope, no internal heat gains are considered. Thanks to this approach, the comparison between the different design solutions will be based on physical and measurable parameters, thus allowing an easy but comprehensive identification of the best strategies needed to achieve summer thermal comfort.

3. Case study

The building used as a case study is an historical three-storey building located in the city center of Catania, a hot humid city in Southern Italy (37°28'N, 15°3'E). The building is partially shaded on its northern, western and southern façades (see Fig. 1). As concerns its outer shell, the external walls are made of lava stones (70 cm), covered with a thin layer of lime plaster (2 cm per side); the roof is made of traditional “coppi” clay tiles (2 cm) that lie on a