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ScienceDirect

Energy Procedia 133 (2017) 42–52

Energy Procedia

www.elsevier.com/locate/procedia

Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area, 12-13 May 2017, Matera, Italy

Thermal inertia of heavyweight traditional buildings: experimental measurements and simulated scenarios

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Abstract

This paper discusses the results of an experimental campaign aimed to describe the thermal performance of a traditional building located in Catania, Southern Italy. The building was built in the early 1900s with traditional techniques and local materials, namely basalt stones, and is currently used for residential purposes.
The results of the experimental campaign are exploited to calibrate a model for the dynamic simulation of the building with DesignBuilder. The calibrated model is then used to simulate how the same building would behave with a modern envelope made of a double leaf of bricks; other simulations take into account possible retrofit solutions, such as the installation of an insulating material either on the inner or the outer side of the walls, as well as the role of nighttime natural ventilation.

Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area

Keywords: thermal inertia; basalt stones; natural ventilation; dynamic simulations.

1. Introduction

Traditional and historic buildings in warm climates, such as in the Mediterranean area, typically show thick and massive walls made of local stones, which provide them with high thermal inertia. This feature allows these buildings to be resilient to the outdoor climate, especially in summer, when they can provide good indoor thermal

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Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area
10.1016/j.egypro.2017.09.369

Nomenclature

c_p	specific heat ($J \cdot kg^{-1} \cdot K^{-1}$)
DF	decrement factor (-)
R	thermal resistance ($m^2 \cdot K \cdot W^{-1}$)
s	thickness (m)
T	temperature (°C)
TL	time lag (h)
U	thermal transmittance ($W \cdot m^{-2} \cdot K^{-1}$)
λ	thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$)
ρ	density ($kg \cdot m^{-3}$)

comfort despite the severe heat waves experienced outdoors.

Several authors have studied and emphasized the thermal performance of traditional massive buildings in the Mediterranean area. Gagliano et al. carried out an experimental campaign to assess the transient behaviour of the massive walls of a historic building located in Southern Italy, dating to the end of the 1800s [1]. The walls are built with roughly squared blocks of basalt stones, and their thickness is of about 1.00 m. The study showed that the thermal inertia of the walls is significantly affected by the exposure (East or West) and by the exploitation of nighttime ventilation; the latter allows to effectively discharge the heat stored in the massive walls.

Cardinale et al. studied the thermal performance of two types of vernacular buildings (Sassi of Matera and Trulli of Alberobello), that are peculiar to some restricted zones in Southern Italy [2]. In this case, the walls are respectively made of sandstone and limestone, with a thickness ranging from 50 to 90 cm. In both cases, the experimental measurements highlighted that the indoor temperature in summer seldom exceeds 28°C, thus providing excellent thermal comfort, also thanks to natural ventilation.

On the other hand, Martin et al. measured the indoor temperature in a traditional building located in a village in central Spain, and compared the results with those recorded in a wooden house located in the same village [3]. The outer envelope of the traditional building is made of local stones, with a thickness of around 50 cm. In summer, the traditional stone house did not suffer from overheating: indeed, the peak indoor temperature was 27.5°C, which means around 9°C lower than in the wooden house.

Stazi et al. compared, by means of experimental measurements and dynamic simulations, the thermal performance of several wall configurations in temperate climates, including a traditional massive wall with a single layer of solid bricks and a more modern uninsulated brick-block cavity wall [4]. The outcomes of this study show that, in hot summer days, the internal surface temperature of the traditional massive wall can be up to 5°C lower than for the modern envelope, thus providing better thermal comfort indoors. However, when applying a 9-cm insulating layer to the traditional envelope, in order to improve the building performance in winter, the internal surface temperature may increase by around 3°C, especially with the insulation on the inner side. The only solution to improve summer thermal comfort while also insulating traditional massive walls is to leave a ventilated air cavity between the solid bricks and the outer insulation layer. Air ventilation in the cavity should obviously be prevented in winter [5]. Uninsulated massive walls also provide high thermal capacity in relation to internal loads, such as people, appliances and solar gains. However, internal insulation considerably affects this property, thus causing severe overheating in summer ([6], [7]).

However, in the last decades, there has been a transition from traditional massive buildings to lightweight envelopes; these are provided with a considerable thickness of insulating material that acts as a barrier against the outdoor climatic conditions. Even in case of retrofit of historic buildings, designers usually aim at providing insulation, often pushed by regulatory requirements, and do not consider the negative effects induced on the inertial capacity of the envelope. This issue may be particularly worrying if one takes into account the climate changes that are going to be experienced in the 21st century. Several studies foresee an increase by 1.5°C in annual mean temperature by 2050 and 3–4°C by 2100 in the Mediterranean area, under the assumption that the atmospheric concentration of carbon dioxide will increase up to 700 ppm by 2100 [8]. In temperate climates, this will produce a substantial shift from heating energy to cooling energy in buildings [9].