Energy and Buildings 69 (2014) 525–534

Contents lists available at ScienceDirect

Energy and Buildings

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

Experimental assessment of a zinc-titanium ventilated façade in a Mediterranean climate

Francesca Stazi[a,*], Ambra Vegliò[a], Costanzo Di Perna[b]

[a] Dipartimento di Ingegneria Civile, Edile e Architettura (DICEA), Facoltà di Ingegneria, Università Politecnica delle Marche, Via Brecce Bianche, 60131 Ancona, Italy
[b] Dipartimento di Ingegneria Industriale e Scienze Matematiche, Facoltà di Ingegneria, Università Politecnica delle Marche, Via Brecce Bianche, 60131 Ancona, Italy

ARTICLE INFO

Article history:
Received 27 June 2013
Received in revised form 8 November 2013
Accepted 9 November 2013

Keywords:
Ventilated façades
Experimental study
Ventilation channel
Energy saving
Energy efficient building
Solar passive design

ABSTRACT

An experimental study was carried out on ventilated façades with zinc-titanium cladding in a hot-summer Mediterranean climate. The aim was to investigate the thermo-physical performance, verifying the effect of the following parameters: (i) the height of the ventilation channel; (ii) the external climate conditions (direct solar radiation, wind); (iii) the exposure to sunlight; (iv) the type of external facing. The study involved the simultaneous monitoring of walls with zinc-titanium cladding with ventilation channels of different heights (4 m, 8 m and 12 m) and different exposure (south, east and west). The data obtained were also compared with those measured on ventilated walls with clay cladding (12 m south-facing wall).

The results allowed to experimentally verify for the studied façades the strong relationship between difference in internal-to-external air temperature and airflow rate and to demonstrate that while the wind pressure strongly influences the lower walls airflow rate, it does not affect the higher walls performance. The exposure of the wall causes only a slight shift in the onset of the stack effect. The Reynolds number was calculated and the different air flow conditions in the ventilation channel were identified. Linear relationship between the external air temperature and air temperature in the gap were identified for each studied wall. The qualitative comparison with ventilated façades characterised by a massive clay cladding showed that the cladding's inertia influences the time in which the stack effect becomes more effective: during the night for low inertia claddings and during the daytime for massive ones.

1. Introduction

New European Directives [1,2] on energy performance, to promote energy efficiency within the European Union, underline the problems caused by the increasing proliferation of air conditioning systems in European countries and stress the importance of adopting strategies which contribute to improving the thermal performance of buildings during the summertime. In this regard, ventilated façades (a recently developed technology for passive cooling) are of considerable interest since they help to improve the internal climate conditions and determine a reduction in the use of thermal energy during the summertime. In hot-summer Mediterranean climates, ventilated façades (especially those with opaque facing) have recently aroused great interest because they resolve the problem of the durability of the outer finishes of the external insulation layer (mainly caused by cracking as a result of aggressive solar radiation) without the drawback of summertime overheating which is necessarily caused by double skin glazed façades. Ventilated façades with opaque cladding are generally characterised by the presence of one continuous insulation layer next to the internal mass and another external layer of protective cladding which is fastened to the wall using mechanical systems. A naturally ventilated channel is thus created between the insulation layer and the cladding.

Many authors have used analytical models to describe how the thermal and energy performance of ventilated façades is influenced by some characteristics:

i. the width and height of the ventilation channel [3,4];
ii. the factors connected with the site (solar radiation, wind and exposure) which determine the local microclimate [5,6];
iii. the type of external cladding, the characteristics of the materials which are laid adjacent to the channel [7,8] and the material of the inner layer [7]. The cladding may be made of a thin metal (e.g., zinc-titanium) or a thicker solid material (e.g., brick, ceramics, cement) [9] and may be permeable or watertight [10]. The behaviour of the ventilation channel may vary according

* Corresponding author. Tel.: +39 071 2204783; fax: +39 071 2204378; mobile: +39 328 3098217.
E-mail addresses: f.stazi@univpm.it, fstazi@yahoo.it (F. Stazi).

0378-7788/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.enbuild.2013.11.043

to the reciprocal positions of the thermal insulation and the inertial mass.

Recent experimental studies on ventilated façades mostly describe the development of mock-ups aimed at validating a simulation model. In 2011 one group of researchers [9] developed a prototype for comparing ventilated walls with and without radiant barriers, focusing their attention on the convergence between measured and simulated values. Another group of researchers [11] presented a study of ventilated walls with metal cladding, demonstrating, by means of a scale model, the importance of climate variables (sun and wind). The work by Giancola et al. [12] is of considerable interest since it was carried out on a real case study in a Mediterranean climate. The wall analysed has a clay cladding, is south-facing and has a maximum height of 5 m. Studies on ventilated walls with integrated PV panels have recently been published [13,14].

A survey of the available literature showed that there is a lack of experimental studies on real buildings aimed at quantifying the importance of the features specified below which some authors have only investigated analytically.

The current research study is aimed at experimentally assessing the efficiency of ventilated façades with metal zinc-titanium cladding, verifying the effect on performance of several different parameters: (i) the height of the ventilation channel; (ii) the factors connected with the site (exposure to sun and wind); (iii) the type of cladding. The study identifies the trends in air velocity inside the channel and the temperature distribution within the layers, for all the cases studied. These data may be useful for other authors for the calibration of numerical models of ventilated walls, which are extremely complex given the considerable variability in performance caused by the non-linearity of the processes involved.

2. Stages and methods

2.1. Stages

The current experimental study, carried out during the summertime on a school building, involved the following activities:

- contemporary summertime monitoring of ventilated walls with zinc-titanium cladding, characterised by different heights of the ventilation channel (4 m, 8 m and 12 m) and different exposure (south, east and west); data processing and assessment of the thermo-physical behaviour;
- qualitative comparison with the data measured during a previous experimental campaign on a ventilated wall with clay cladding (12 m south-facing wall).

2.2. Case studies

The building used for the case study (Fig. 1) is located in Ancona (Central Italy – latitude: 43°35′03.72″ N; longitude: 13°31′29.79″ E; altitude: 67 m), characterised by a hot-summer Mediterranean climate (Köppen climatic classification) and by 1688 degree days (climate zone D [15]).

The school has a cylindrical main building with four floors above ground level used as offices and a number of lower structures with one or two floors (h_{max} = 8 m) which house the laboratories and classrooms. Some of the walls of the building are ventilated and present a zinc-titanium cladding.

To verify the effect of the type of cladding, the data obtained during the experimental campaign were compared with the findings from a previous study [16] of ventilated walls with an external clay façade, carried out on a school building located in the same climate area.

The layers of the studied walls are shown in Fig. 2 and Table 1.

2.3. Experimental methods

Monitoring was carried out during the summertime between 22 July and 29 August 2011.

The following measurements (Fig. 3) were performed in accordance with UNI EN ISO 7726:2002 [17]:

1. investigation of the outdoor environmental conditions adjacent to the walls using external weather stations with direct and global pyranometers, a combined sensor for the speed and the direction of the wind and a thermo-hygrometer;
2. detailed analysis of the thermo-physical conditions of all the ventilated walls at the inlet openings and at the ventilation channel mid-height by means of:
   - a set of RTD sensors to measure the surface temperatures of the different layers;
   - hot-sphere thermo-anemometers to record the velocity and the temperature of the air in the ventilation channels;
   - heat flux metres to calculate the transmittances and to measure the incoming and outgoing heat flux through the insulated wall (positioned on its internal side);
3. investigation of the internal environmental conditions by means of micro-climate stations with a thermo-hygrometer to record the temperature and the relative humidity of the internal air.

The characteristics of the probes are as follows:

- thermo-resistances: tolerance in accordance with IEC 751;
- heat flux metres: tolerance in accordance with ISO 8302; sensitivity of 50 μV/(Wm^2);
- hot-sphere anemometers: accuracy of 0.03 m/s;
- pyranometers: uncertainty < 2%.

Data takers DT500 were used with:

- voltage: resolution 1.3 μV; range ± 25 mV; tolerance ± 0.16% of full scale;
- RTDs, 4-Wire: resolution 0.01 °C; range Pt100 (100 Ω); tolerance ± 0.17% of full scale;
- analogue to digital conversion: accuracy 0.15% of full scale; linearity 0.005%.

3. Results and discussion

3.1. Climate conditions

Fig. 4 shows the climate conditions of a significant period extrapolated from the summertime monitoring data. The global solar radiation, the external air temperature and the wind speed are reported. The period is generally characterised by sunny days with only a few days of variable or cloudy weather conditions.

The *external air temperature* on a typical day ranges between 20 °C and 30 °C, with peaks of up to 37 °C on some of the hottest days and minimum temperatures of 13 °C during the night-time. The maximum *wind speed* ranges between 1 m/s and 5 m/s.

3.2. Effect of the wind and solar radiation with respect to the height of the ventilation channel

Fig. 5 shows the temperature and the air velocity in the ventilation channel for the two south-facing walls of 4 m and 12 m for a selected period.