PERFORMANCE ASSESSMENT OF ACTIVE FACADES IN OUTDOOR TEST CELLS

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ABSTRACT

In the scope of the Belgian "Active Façades" project, a full-scale testing of active façades has been realized in outdoor test cells. The aim is to develop a methodology for assessing this kind of façades and to obtain a better understanding of their behaviour and their performances. In order to perfectly control the outdoor conditions (influence of the sun, convective losses at the outdoor façade, …) and to improve the measurement accuracy, partly artificial boundary conditions have been created by placing a so-called "outdoor cold box" (opaque) in front of the tested façade. The effect of the sun on the façade is simulated by the use of heating foils placed in the test component. This original testing configuration allows an accurate study of the heat exchange process inside the façade (convective effects and long wavelength radiation). The transmission, reflection and short wavelength radiation heat transfer are well known and have been simulated via accurate existing calculation software.
The overall performances under real outdoor conditions (combination of all effects - conduction, radiation and convection) have been obtained by the combination of test results and simulation results.
The experiments have allowed assessing the impact of different parameters: airflow rate, air cavity width, air direction, etc…

This paper presents the adopted methodology, the measurement set-up and some results of the parametric study.

KEYWORDS

Active façade, outdoor test cell, full-scale testing, thermal and solar performances.

INTRODUCTION

Striking developments in glass technology, HVAC systems and control techniques have led to the application of active façades. These façades are designed in order to improve the indoor climate of a building by means of active and/or passive techniques. Climate façades or double-skin façades are two examples of active façade concepts that are currently built. In short, an active façade is usually composed by two glazing layers separated by a ventilated air cavity. The differences between the concepts lay in the air cavity ventilation strategy (with inside or outside air), in the position of the insulated glazing, etc.
This technology receives nowadays a lot of attention and is in the middle of a discussion on its advantages and disadvantages. Few data are currently available on the performances of these façade concepts and on the influence of different design parameters. A major difficulty specific to this kind of façades is that their thermal and solar performances are not constant but depend on different variable parameters: the airflow rate into the cavity, the air inlet temperature, the height of the façade, the control strategy of the solar shading device, etc.
In the scope of the Belgian "Active façades" project, a full-scale testing of active façades has been realized in outdoor test cells. The aim is to develop a methodology for assessing these

façades (also by highlighting the possibilities and difficulties for carrying out full-scale testing) and to obtain a better understanding of their behaviour and performances. The experiments have allowed assessing the impact of different parameters (airflow rate, air cavity width, air direction, etc.) on the active façade performances.

OUTDOOR TEST CELLS

Testing under real boundary conditions

A full-scale testing of active façades has been realized in the so-called PASLINK outdoor test cell. The most common use of a PASLINK test cell is to test a specific component under realistic outdoor testing conditions. An example is given in figure 1(a). The main objective of such tests is to identify the UA- and gA-values of the tested component. This requires the determination of the heat balance at the level of the test cell. A typical test duration is of (approximately) 10 days.

Figure 1: (a) PASLINK test cell with translucent component, (b) Outdoor cold box

This methodology could also be applied for testing active façades. Nevertheless this way is not very attractive in this case for the following reasons:

- long test duration,
- difficulty to study the impact of certain parameters (e.g. gap width, air flow rates, location of screens,…).
- problem of measurement accuracy (e.g. the reliable measurement of surface temperature on glazing is far from evident in case of solar radiation).

This explains why it was appropriate to adapt the testing configuration.

Partly artificial boundary conditions

Partly artificial boundary conditions have been created. This makes it possible to obtain a better understanding of the system behaviour. The heat balance is now made at component level.

With respect to the boundary conditions, the major modifications are the following :

- use of a so-called "outdoor cold box". This opaque box is placed in front of the test component and allows creating the following boundary conditions : no solar radiation on test component, no effect of rain, no sky radiation, controlled air velocity in front of the test component (figure 1(b)).

- use of controlled heating foils (for which the supplied power can vary in a large range) to simulate the effect of solar absorption by the shading device situated in the active façade cavity.

The aim of the heating foils is to simulate the solar radiation absorbed by the shading device. In reality, the absorption, reflection and transmission process is more complicated (see figure 2 (a)).

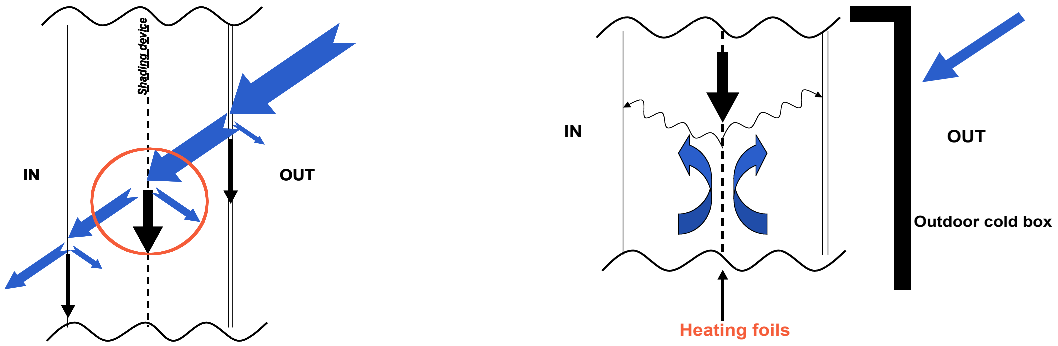

Figure 2: (a) Simplified representation of absorption, reflection and transmission of solar radiation, (b) Heat exchange process due to the absorption of the solar radiation by the shading device

The realized measurements focus on the study of the heat exchange process of the solar radiation that is absorbed by the shading device (see figure 2(b)). The transmission, reflection and short wavelength radiation heat transfer are well known and have been simulated via accurate existing calculation software (e.g. WIS software). The complementary effects like absorption in the glazing are considered at a later level.

The overall performances under real outdoor conditions (combination of all effects – conduction, radiation and convection) have been obtained by combination of the results obtained from these PASLINK tests and simulation results.

A further advantage of the developed methodology is that one measurement with a particular configuration can have different physical interpretations. For instance, a 200W heat power supplied in the shading device can be interpreted as an 400W incident solar radiation on a shading device characterized by a solar absorption of 50% or whatever equivalent combination of solar radiation / shading device solar absorption.

Test set-up

In principle, any type of active façade concepts could be tested with this test facility : climate façade, double skin façade and other hybrid concepts.

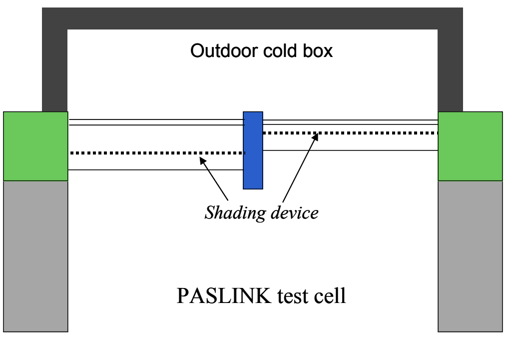

Figure 3: scheme for parallel testing (exemple of 2 different cavity widths with different positions of the shading device)

Furthermore, an interesting possibility of this test facility is to be able to carry out parallel testing. This allows testing two different configurations of active façade at the same time with identical indoor and outdoor boundary conditions (figure 3).

Monitoring equipment

The monitoring equipment consists in the following measurements (see figure 4):

- Temperature measurements: surface temperatures (on glazings and shading device) and air temperatures (air cavity, inlet and outlet),
- Heat flow measurements : heat flux meters placed on the internal and external glazing panels of the active façade,
- Air flow control : the mechanical ventilation inside the air cavity is controlled and the airflow rate is continuously measured,
- Temperature field along the façade : by means of IR (infrared) camera,
- Smoke visualisation : the airflow patterns in the cavity can be visualized.

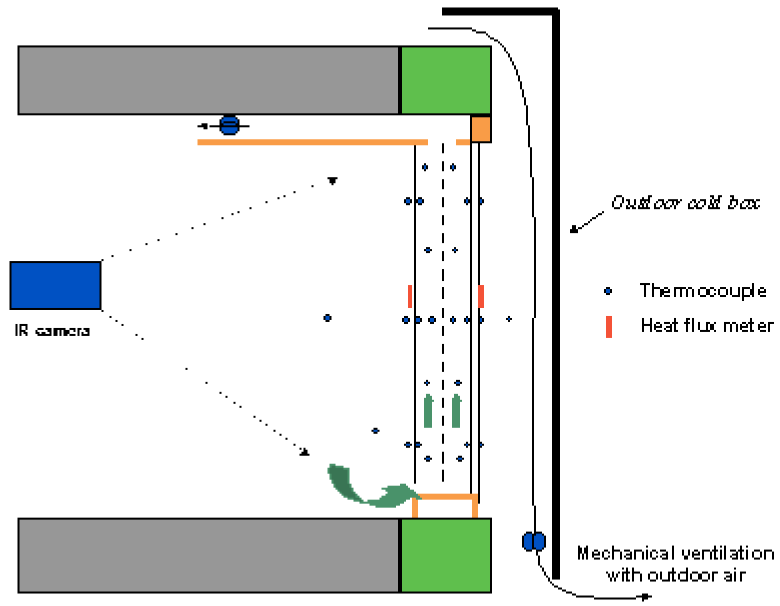

Figure 4: monitoring equipment

EXPERIMENTAL RESULTS

Test configurations

The development of this original testing configuration makes it possible to study the influence of the following parameters on the thermal and solar performances of active facades: airflow rate, direction of the airflow, air cavity width, position and type of the shading device, etc.
The impact of these parameters can be analysed one by one separately, the others being constant. This possibility represents a big advantage compared to a classical monitoring.

Results on climate façades

In this section one presents some results of measurements carried out on climate façades. The stress will be put more on the types of results than on a complete set of detailed measurement results.

The tested climate façade is constituted by the following elements (see figure 4):

- A clear double-glazing placed at the outside
- A single glazing placed at the inside,
- An air cavity between the two glazing panels (200 mm width) mechanically ventilated with inside air. The air is exhausted via a mechanical ventilation system,
- A solar screen integrated in the air cavity

Two series of measurements have been carried out :

1. Without heating foils power (represents the situation without solar radiation)
2. With different heating foils power steps (represents the situation with different solar radiation levels)

In each case, the analyse of the measurements consists in :

- the identification of different heat flows (heat flow through the internal pane and external pane, heat flow supplied/extracted by ventilation air, etc.)
- the identification of different temperature profiles (along the cavity height, cross-section through the active façade at different heights, etc.)
- various ways for expressing performances as equivalent U-value, equivalent efficiency of a heat exchanger, equivalent g-value (solar factor), etc.

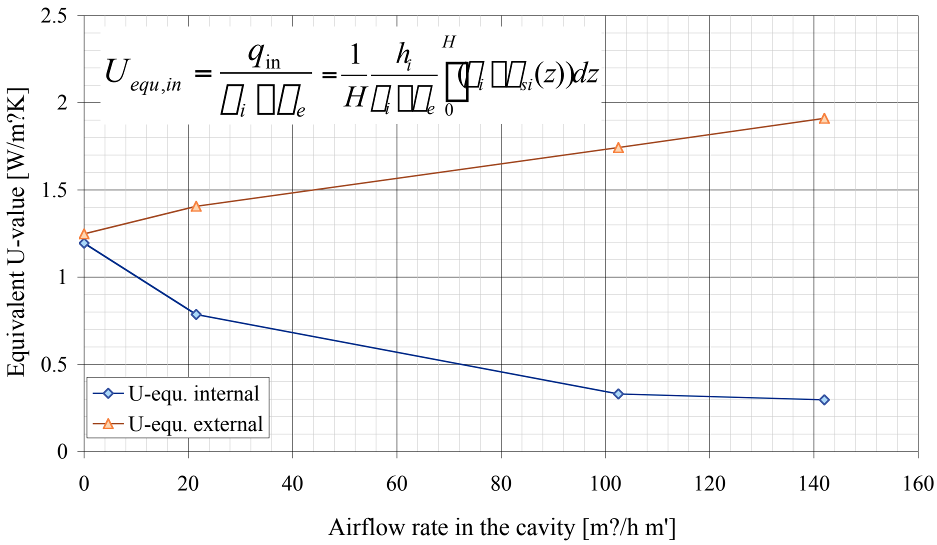

Figure 5: Equivalent U-value at the inner and outer panes in function of the airflow rate in the cavity

Figure 5 shows the effect of the airflow rate in the cavity on the equivalent U-value at the inner (respectively outer) glass pane of a climate façade (2.10 m high). This U-value represents the conduction losses through the inner (respectively outer) pane of 1 m_ for a temperature difference of 1 K between indoor (room temperature) and outdoor. This kind of façade allows improving the indoor thermal comfort in winter situation. The major comfort problems in office buildings are generally encountered in a summer situation. The U-value is not the only element to take into account when assessing the energy performance of the façade. Ventilation losses and solar gains (g-value) have also to be taken into account.

In Figure 6, one can see the temperature profile across the façade and along the cavity height in the case where the airflow rate is 45 m_/h.m and the solar radiation level is 220 W/m_ measured on a vertical surface.

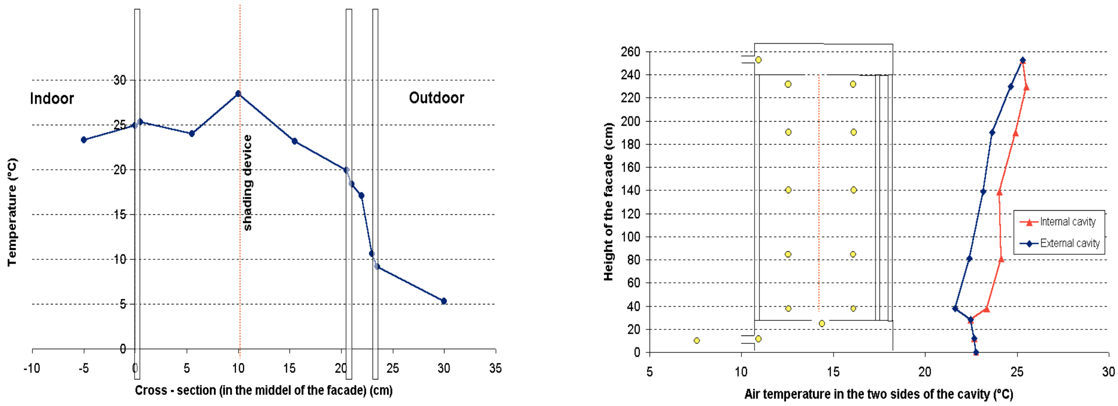

Figure 6: Temperature profile (°C) across the active façade and along the cavity height

CONCLUSIONS

Testing advanced façade elements like active façade in real outdoor conditions is necessary to accurately assess their performances. Some physical phenomena like the heat exchange process of the solar radiation that is absorbed by shading device cannot easily be simulated. Real-scale testing becomes necessary to study this kind of phenomena. The developed testing methodology in outdoor test cells allows realizing parametric analyses of various active façade concepts. It allows obtaining a better understanding of the behaviour of these façades and their thermal and solar performances in winter and summer situation. The lack of normalized calculation procedures to determine the energy performance of this kind of ventilated façade concepts forces every building designer to develop his own assessment procedure. The work realized in the "Active Façade" project must allow better assessing the energy performance of such advanced façade concepts.

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