A SYNERGY-FACADE IN A PASLINK TEST CELL

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ABSTRACT

This paper describes a modular facade system, which supplies the room behind with the necessary amounts of heat, light and fresh air. Aims of the development of this facade were both to achieve a high degree of comfort for the users and to save energy in comparison to a conventional facade.
The experimental investigations to assess and to optimize the facade system were performed in a PASLINK test cell. These test cells allow measurements of the thermal and solar performance of facade elements in original dimensions and under natural climate conditions. The described synergy facade was tested over a period of several months to allow as much combinations of operation states and weather conditions as possible. The standardized PASLINK test was adopted to the special needs of this facade.

KEYWORDS

Solar energy, PASLINK test, Thermal air collector

THE PASLINK TEST

The PASLINK test cells were developed within several European projects. They allow the assessment of the thermal performance of facade elements in original dimensions and under natural climate conditions. Meanwhile similar test facilities exist in 13 European countries. Figure 1 shows a view of the test site at the Brandenburg Technical University in Cottbus.

Figure 1: PASLINK test site at the university in Cottbus

The test component is mounted in an insulated frame at the south oriented side of the test cell. The interior temperature of the test cell can be controlled to any desired profile. All relevant temperatures and heat fluxes as well as the weather data are recorded continuously.

For the analysis of the experiments the test component as well as the test cell are modelled by a network of thermal conductances and thermal capacitances. The unknown values of the individual parts of the network are determined by a parameter identification procedure. Finally these values are used to calculate the integral parameters of the test component. In case of a simple passive facade these parameters are the heat transmission coefficient U and the total solar transmittance g. Due to the fact that the PASLINK test is an integral one (over the whole area of the test component), actually the results are the products of the parameters with the active facade area, namely (U·A) and (g·A). Figure 2 shows as an example a model of a simple wall.

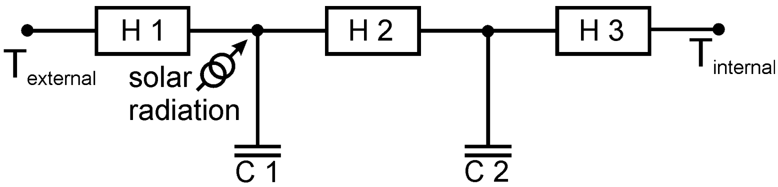

Figure 2: Example for a thermal model

THE SYNERGY-FACADE

At the solar centre in Frankfurt/Oder a modular facade system was developed. In contrast to conventional facades this system consists of passive as well as active elements. The so-called "Synergy-facade" provides the users with light, fresh air and heat according to the actual requirements. During the summer period the system can be used for cooling purposes. The aims for the development of this facade were to provide a high degree of thermal and visual comfort for the users and to reduce the amount of fossil fuels by using solar energy. Figure 3 shows the facade mounted on the PASKLINK test cell.

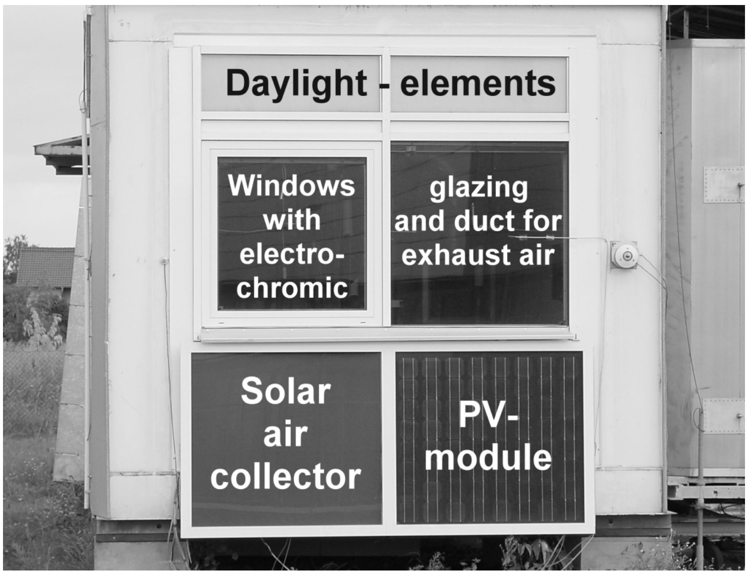

Figure 3: Exterior view of the described facade

Two special windows (applied for a patent) are located in the middle of the facade. They are composed of a heat protection glazing with electrochromic properties at the exterior side and a third pane at the interior side. The electrochromic glazing allows the adjustment of the transparency according to the needs. The double glazing and the third pane form a flow channel through which the room air is exhausted.

Two daylight elements above the windows redirect the light into the depth of the room. Below the windows a glazed solar air collector and a PV module are mounted.

The facade system is constructed modular, it can be varied to meet the particular requirements.

In the winter mode the cold external air at first flows through an air gap behind the PV module. Thereby the air is preheated and the module is cooled. Afterwards the air flows through the air collector and is heated up further. In case the air is still colder than the exhaust air from the room (e.g. if the solar radiation is too low) fresh and exhaust air are conducted through a heat exchanger.

In the summer mode (what is not explained in detail here) the fresh air flows into the room without preheating, and the exhaust air is used to cool the backside of the PV module.

During the PASLINK experiments some additional measurements were performed, e.g. the determination of several comfort parameters and the measurement of the illumination level distribution. In figure 4 the sensors for the light measurements can be seen.

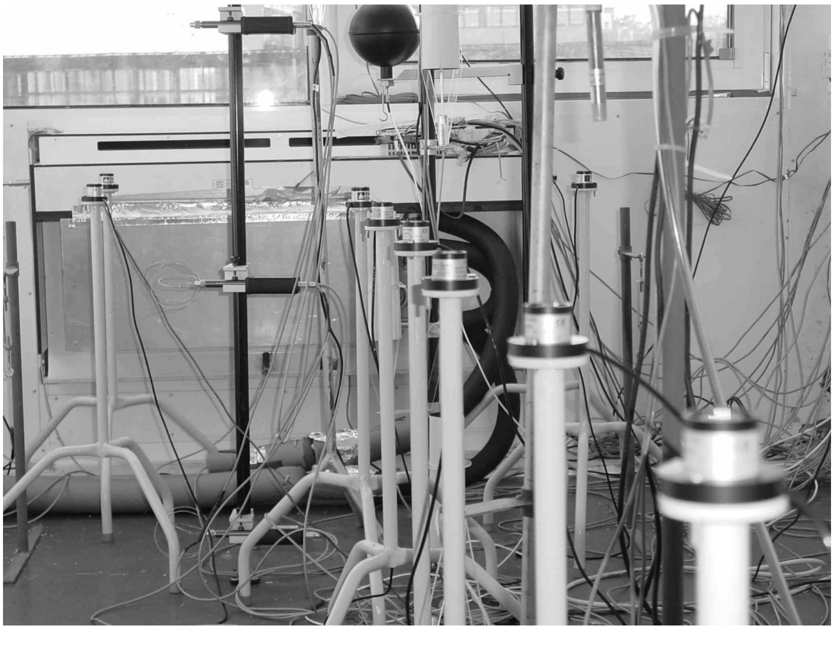

Figure 4: Interior view of the test cell

In case of such an active facade with forced air flows the dispersion of air within the room is of particular interest, since the thermal comfort critical depends on this dispersion. To visualize the air flow some experiments with artificial fog were done at different operating states of the facade. An example is shown in figure 5.

Figure 5: Visualization of air flows by means of artificial fog

EXPERIMENTAL INVESTIGATIONS

For the characterization of the described facade the usual and standardized parameters U and g are not sufficient, particularly since the facade can be run in several modes. Therefore a long-term measurement over a period of several months was performed. In doing so all interesting modes of the facade were investigated.

To get information about the passive heat losses at first a moveable cold box was mounted in front of the facade and the usual PASLINK test was executed. Thereby all fans of the facade were switched off and all flaps were closed. The result of this test is the (U·A)-value of the facade, which describes e.g. the heat losses during the night (when the ventilation system is switched off). The determined value was (U·A) = 10.7 W/K. Related to the active area of the facade ($A = 7.4\ m^2$) the U-value is $U = 1.4\ W/m^2 \cdot K$.

All of the subsequent tests were performed under natural climate conditions. The analysis of these experiments must take into account the active components as well as the different operation modes of the facade.

The active ventilation of the room by the integrated ventilation system causes an additional energy loss which depends on the temperature difference ΔT between interior air and exterior air and on the air flow rate ΔV/Δt. To compensate this loss an additional heating power P is needed. This heating power can be calculated according to

$$P = \rho_{air} \cdot c_{air} \cdot \Delta T \cdot \Delta V/\Delta t \qquad (1)$$

In this equation ρ_{air} is the density and c_{air} is the specific heat capacity of the air. The air flow rate could be estimated by a measurement of the air velocity using a hot wire anemometer. The resulting energy loss by ventilation was ΔP/ΔT = 11 W/K. This value is reduced by the effect of the heat exchanger. In the thermal model of the facade this air change can be taken into account by an additional conductance between interior air and exterior air (figure 6). Since the ventilation was operational only during the day, the value of this conductance was taken as a time-dependent function with $H4_{night} = 0$.

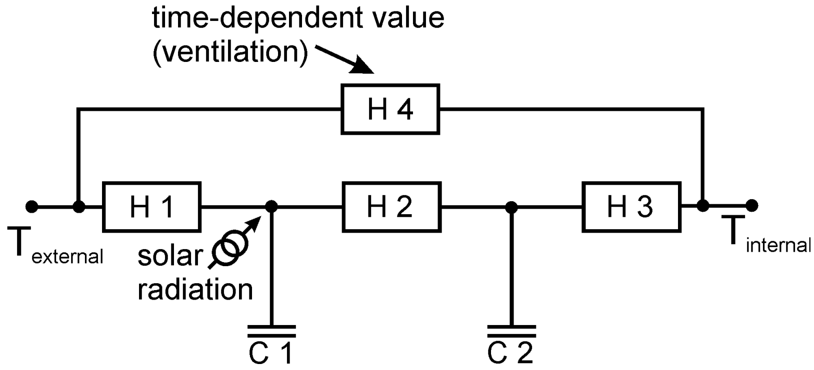

Figure 6: Extension of the model from figure 2 due to active ventilation

The analysis gave a value of $H4_{day} = 5.3$ W/K. Compared to the estimated loss without heat exchanger of $\Delta P/\Delta T = 11$ W/K it can be derived that the heat exchanger compensates approximately half of the energy loss. This means that the heat exchanger works perfect, it gains the maximum possible amount of energy from the exhaust air. This is also validated by temperature measurements, which show that the temperatures of both air flows are equal after having passed the heat exchanger.

Solar radiation further raises the temperature of the supply air. In that case the heat exchanger is deactivated by a bypass and the heated air flows directly into the room. In the analysis the value of the parameter H4 was set to H4 = 0 during these periods, because despite of the operating ventilation system no energy losses occur.

The analysis of two test periods with the lowest and the highest possible transparence of the electrochromic glazing resulted in $(g \cdot A)_{min.\ transparency} = 1.9\ m^2$ and $(g \cdot A)_{max.\ transparency} = 2.6\ m^2$. These values are the sum of the energy gains caused by the windows $(g \cdot A)_{windows}$, caused by the daylight elements $(g \cdot A)_{daylight}$ and caused by the solar air collector $(g \cdot A)_{collector}$:

$$(g \cdot A)_{total} = (g \cdot A)_{windows} + (g \cdot A)_{daylight} + (g \cdot A)_{collector} \qquad (2)$$

From data provided by the manufacturer the energy transmittance of the daylight elements was known to be $(g \cdot A)_{daylight} = 0.26\ m^2$. To separate now the remaining parts $(g \cdot A)_{windows}$ and $(g \cdot A)_{collector}$ additionally a test period with deactivated ventilation system was analysed. This way it was possible to determine the individual parts of the total energy transmittance. The results were:

$g_{windows} = 0.12 \ldots 0.44$ (limits at minimum and maximum transparency, respectively)

$g_{collector} = 0.5$

The estimated efficiency of 50 % for the thermal air collector (together with the thermal gains from the PV module) also could be validated by the temperature curves shown in figure 7 for a selected day.

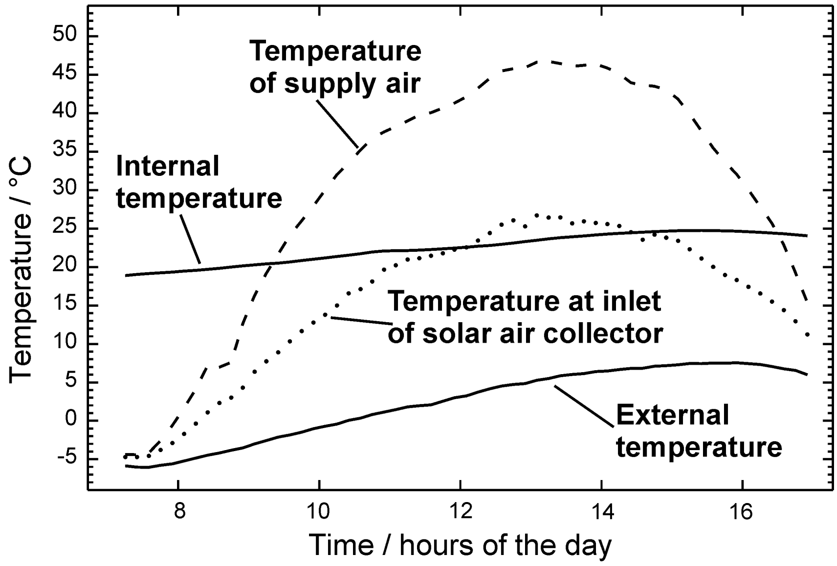

Figure 7: Heating up of the supply air

The figure shows a maximum temperature difference between exterior air and supply air of approximately $\Delta T = 40$ K. From eqn. (1) a power entry of P = 470 W can be calculated. The maximum value of the vertical solar radiation at this day was approximately I = 400 Wm^{-2}. With a total area of A = 2.7 m^2 (air collector and PV module) the total solar power is P_{solar} = 1080 W. This is approximately twice the amount of the usable power, what verifies the calculated efficiency of 50 %.

SUMMARY

The described experiments show that the principle of the PASLINK measurements can be adopted to more complicated active facades, if the measurement procedures and the analysis methods are adjusted.

The investigated facade system allows a significant reduction of the energy consumption combined with a high thermal and visual comfort for the users. A further development of the system is planned.

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