GLAZED FACADES AND THEIR INFLUENCE ON INDOOR CLIMATE IN BUILDINGS

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Summary

Glazed façades are one of the most dominant features of contemporary architecture. They are used not only for their modern appearance, but also for energy saving purposes. This trend leads to increased transparency and daylighting in buildings. On the other hand, large glazed areas cause the glare effect and create a potential source of overheating. The indoor environment problems can result in necessity of increased ventilation and cooling and, consequently, in higher energy demands of the buildings.

The paper presents the case studies of two different glazed façades – the CFD simulation of summer conditions in the double-skin solar energy façade on a small office building, and the findings of indoor environment monitoring in a large administrative building with a passive single glazed façade. Besides, the influence of glazed area extent on energy demands of the building is illustrated with the help of simulation results.

Keywords: Glazed façade, overheating, indoor climate, thermal comfort, air conditioning

1 Introduction

Glazed façades are one of the most dominant features of contemporary architecture. Besides their attractive appearance, they can have a multi-functional usage. In case of double-skin facades, the cavity between an outer glazing and the building creates a buffer zone, which reduces heat losses of the building, as well as noise level in the interior. Integration of the façade into passive or active solar systems enables further energy savings [1–4]. On the other hand, large glazed areas in buildings create a potential source of overheating. It is necessary to use reflective glazing, sufficient shading system and ventilation of a cavity because of protecting the indoor climate condition against excessive temperatures during spring and summer hot days. The same problems can arise in case of large single glazed façades. Consequently, the necessity of ventilation and cooling can lead in increased energy consumption of these buildings.

The paper presents the case studies of two different glazed façades. First, the CFD simulation of summer conditions in the double-skin solar energy façade, installed on a small office building, is presented. Since the façade is exploited as a heat source for heat pump used for hot water heating, the outcome of energy simulation of its operation is mentioned as well. Second, the findings of indoor environment monitoring, which was carried out in the large administrative building with a passive single glazed façade, are presented. Moreover, the influence of extent of glazed area on energy demands of the building is illustrated.

2 Double-skin solar energy façade of small office building

The main aim of installation of the façade was to decrease the noise level in the interior of the building which is located in the neighbourhood of a motorway. Besides, the façade is exploited as a heat source for air-water heat pump used for heating and/or hot water preparing.

The façade with height of 5.6 m, length of 25 m, air gap width of 63 cm and total area of 123 m^2 (Fig. 1) is southwards oriented. The warm air is sucked from the façade through two stainless-steel tubes with slots in the upper part. The glass envelope is made of hardened glass sheets with thickness of 8 mm. The inner side of the façade is created with double-sheet windows in steel frames separated by a concrete structure of 2nd floor. The bottom of the façade is made of concrete too. The outdoor air enters the façade through the permanent slot near the ground level, with the cross-sectional area of 1.1 m^2. In order to suppress an excessive sunshine in summer season, the Venetian blinds are installed on the inner side of the glass envelope.

Fig. 1 Small double-skin solar energy façade

2.1 The CFD model of the façade

was treated in the work [5]. Regarding a complex shape of the façade and the way of the air suction, the simulation was solved as fully three-dimensional. A simplified geometrical model with computation grid of approx. 270.000 control volumes was created. Because of excessively long computational times (order of weeks), the steady-state simulation was performed only. On the other hand, it can be supposed, that – with respect to a limited number of massive structures in the façade – the steady state will be achieved in a relatively short time.

As the boundary conditions, the outdoor temperature and thermal resistance on both sides of the façade were used. The forced airflow operation was simulated using an outlet boundary condition, located in the half height of the suction tubes. The outlet velocity is adequate to the airflow rate of 1.1 $m^3.s^{-1}$.

The weather conditions were determined – regarding the steady-state simulation – according to an average outdoor air temperature and solar radiation intensity (for quite a clear day). The sun position corresponds to the noon time. The climatic data were taken from climatic tables [6].

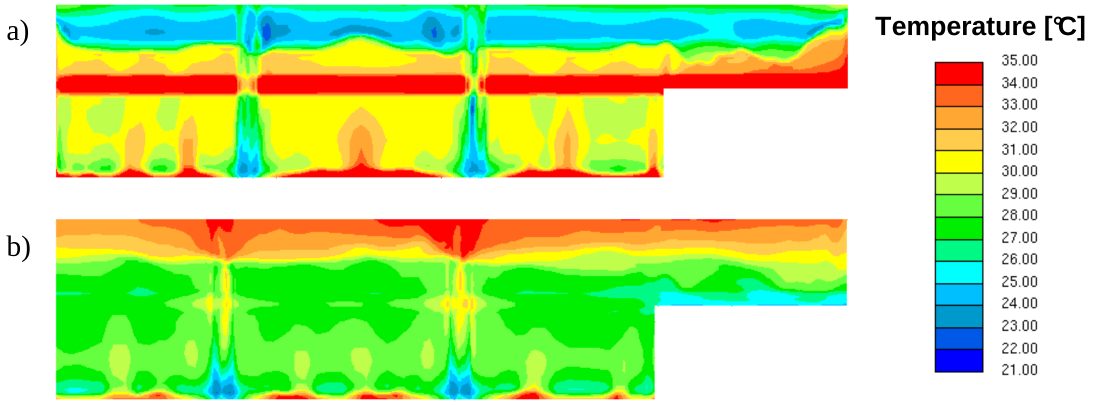

Fig. 2 Simulated air temperatures near inner surface of the double-skin façade (rear view) [5]
a) hot summer day, blinds pulled up b) the same weather conditions, blinds let down.

2.2 Outcomes of the simulation

Detailed overview of acquired outcomes, especially from the viewpoint of solar gains expected under various conditions (different gap width, season climate and shading blinds), was published in [7]. Nevertheless, for indoor climate affecting, the temperatures near the inner glazing are crucial. As can be seen from **Fig. 2**, their values are quite high on hot summer days – despite forced ventilation of the façade. After the blinds were let down, the temperatures falled down in overwhelming part of the inner skin. On the other hand, the hot air cumulates under the ceiling of the façade, which worsens the indoor conditions on the 2nd floor. This shortcoming can be partially eliminated using natural ventilation of the façade through auxiliary inlets, located in the top part of outer skin. However, this case has not been simulated.

Finally, it should be noticed, that the energy savings, following from the exploitation of the façade as a heat source for the heat pump, are not very significant (2-3 % of total energy consumption of the building) and resulting economic benefit is – regarding the pricing policy of the electricity producers – quite negligible [8].

3 Passive glazed façade of large administrative building

As a second case study, the single-skin glazed façade of administrative building of Health insurance company in Brno (Czech Republic) was investigated (**Fig. 3**). The façade covers the south and west elevations of the building; their areas are 750 m^2 and 375 m^2. The glazed parts have double-glazed units with argon filling framed in aluminium profiles in order to minimize heat losses during cold days without solar gains. The façade is protected with solar blinds and sunscreens against excessive solar radiation.

3.1 On-site measurement system

The monitoring of indoor conditions in a conference room, located on the 6th floor, was carried out during 2006–2007. Set of 11 thermocouples of J-type with 0.5 mm diameter (Omega) was mounted on both sides of the façade (Fig. 4a). Indoor and outdoor air temperatures were monitored as well. Two pyranometers (tm Tlusťák, Czech Republic) were used for solar radiation intensity measurement, both in horizontal and vertical planes. Four 8-channel measuring modules ADAM-4018 (Advantech, Taiwan), connected to a PC via RS-485 serial bus and converter ADAM-4520 [9–10], have recorded all parameters in one-minute time intervals.

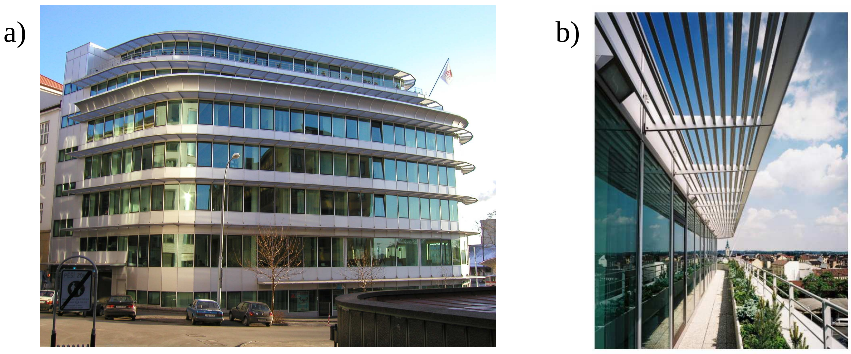

Fig. 3 Passive glazed façade of administrative building in Brno
a) the south-west elevation b) local view of the façade with the sunscreen.

3.2 Results of measurements

As can be seen from Fig. 4b, the glazed façade causes excessive overheating in times of intensive sunshine. During sunny summer days, temperature difference between night and day reaches 15 °C, noon temperatures compared to morning and afternoon ones about 10 °C. This temperature oscillation causes indoor thermal discomfort in the building. Shading system (window blinds and projected sunscreens, tinted window glazing) is unable to reduce the solar radiation impact sufficiently.

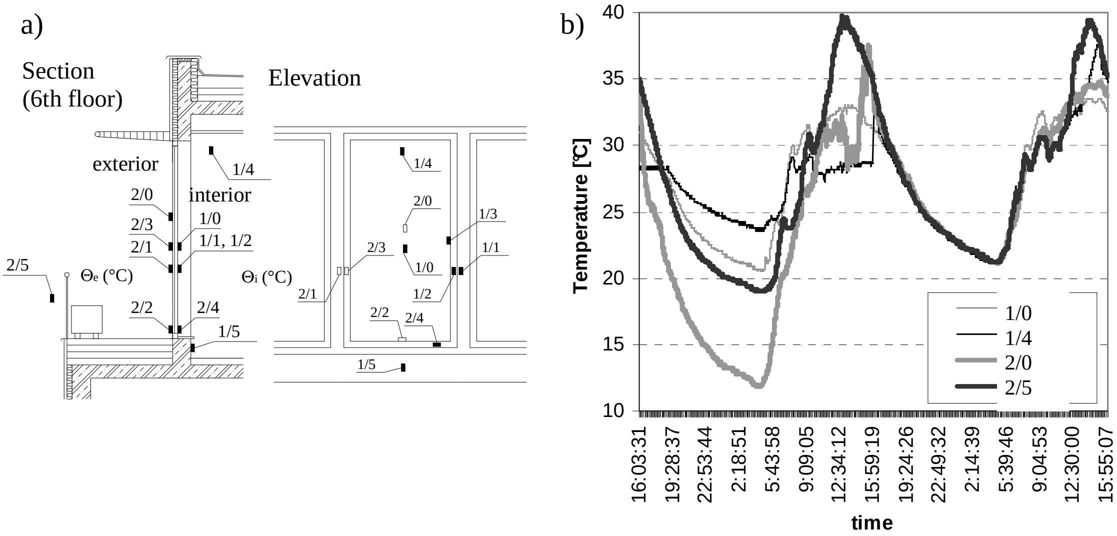

Fig. 4 On-site measurements of single glazed façade thermal conditions.
a) Location of temperature sensors on the sixth floor façade elements.
b) Temperature development on selected summer days (from 16th to 18th July 2006).

3.3 Computer simulation

Computer simulation was carried out for the estimation of the influence of glazed area aperture on annual heating and cooling energy demands. The computer program TRNSYS was used for this purpose. The meeting room of the investigated building (with floor area of 11,1 m × 8,6 m) was chosen for the evaluation. The overall heat loss coefficient (U-value) of the glazed system (including the aluminium profiles) is 1.8 $W.m^{-2}.K^{-1}$, g-value 63 %. The calculation for the building with fully glazed façade (100 %) was compared to the design variations with 85, 70, 55, 40, and 25 % of the maximum façade glazed area (Fig. 5). It is apparent that fully glazed façade causes higher energy consumption of the building. It is necessary to use additional shading systems and/or solar collectors utilised solar energy to reduce it.

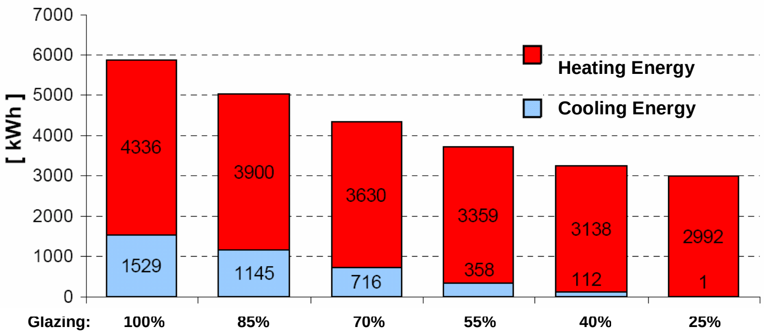

Fig. 5 Simulation results of heating and cooling energy demands for various glazed façade areas

4 Conclusions

Temporary architectural trends of glazed façades have brought transparency and daylighting into the buildings. On the other hand, large glazed areas carry a danger of building’s overheating which can result in necessity of ventilation and cooling and, therefore, increased energy consumption of buildings.

The monitored data, as well as simulation results, confirm the above-mentioned conclusions. Both investigated buildings show a tendency to overheating during spring and summer seasons. Consequently, increased energy demands to ensure acceptable indoor climate could be expected.

The outcomes show that such buildings need careful design in order to ensure their optimal performance with respect to good indoor environment and acceptable energy demands.

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