Double Skin Façades: Two Case Studies

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ABSTRACT: The paper discusses the problems that are associated with the applications of the buffer zones in double-skin façades. The second skins in façades are designed in order to use the outdoor climate as much as possible for energy efficient and healthy indoor climate. Some aspects of double-skin façades are analysed and compared. A short description, advantages, main problems of modern double-skin glazed façades, and two case studies are presented.

1 INTRODUCTION

Building envelopes separate qualitatively different environments between which a steady energy, material and information transfer is going on. Parameters describing the internal environment are partly a function of a building envelope construction and a structural substance of a building in general, partly they are influenced by functional operations in the single building zones and partly by the building equipment that in dependence on climate factors maintains the required level of the internal climate. The external environment is subject to a dynamic change; in the Central European climate conditions is the yearly and daily difference of the majority of climate parameters significant. Without operation of the building equipment the required indoor comfort parameters of the residential, office and similar buildings cannot be achieved for each single moment of the year. In the course of design of building envelope physical parameters, the criteria should be applied that are expressing the portion the building envelope and the structural substances of buildings have on the indoor comfort provision. The reduction of energy demand of the building equipment by suitable building design is very often considered as the most decisive step for enhancing the energy efficiency of buildings.

Recently, the opinion became very popular that the physical properties of the building envelope should dynamically change in dependence on changes of the exterior environment and/or the indoor operations. The building envelope should behave in a way that the optimal parameters for living and work environment are achieved in dependence on exterior air temperature, sun radiation intensity and wind speed whereas the energy consumption is as low as possible.

A number of various concepts have appeared, e.g. "climatic active wall", "polyvalent wall", several types of "solar walls", "interactive façade", "intelligent wall" and similar. Relatively often the principle of a “buffer” or “compensation” zone is used for the construction of these types of walls. The purpose of such zone is the suppression of negative effects of the exterior climate on indoor environment. As a good example of the buffer zone a principle of double window is very often presented in the Central Europe. When enlarged the double window can be seen as glazed space adjacent to the room and when used for growing green one can speak about winter garden. If enlarged to the extent of the whole wall the double glazed façade originates. If the space between glazing panes is provided with ventilation and shading elements double glazed ventilated façade is obtained. This façade is very often called “climate façade”, “breathing façade” or “climate modulator”.

The walls of this sort are based on various concepts whereas very often the use of special kinds of glazing, movable sun control devices, transparent thermal insulation, PV-elements and other components is made. The most often a single glass sheet creates the outer glazing and the interior is separated from the buffer zone by thermal insulating low emission glass. The buffer zone is usually ventilated (Fig. 1).

From physical viewpoint there are no principal differences between winter garden and the double-glazed ventilated façade. However, in the concrete applications significant differences may occur – in the thermal interaction between buffer zone and the interior of building, in the efficiency of ventilating system etc.

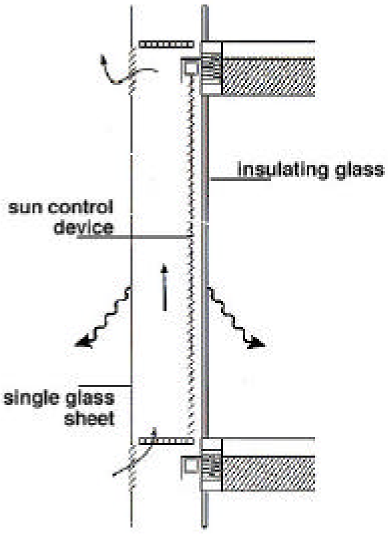

Figure 1. Typical example of double-skin façade

This paper discusses several aspects of the buffer zone design in relation to the overall concept of buildings. The main attention is paid to double-glazed ventilated façades. The presented case studies show that these types of external façades require many-sided technical and architectural skills to get faultless results.

2 CASE STUDY NO.1

Probably the best way to obtain an insight into capabilities of glazed environmental second skins is to present an example. An abstract corridor double skin façade has been selected for a demonstration. Figure 2 shows geometry of 3D model of the façade with an adjoined office space. Typically with building simulation one has to build 3D model of simulated system which must be well composed abstraction of a real system.

This 3D model is then attributed with thermal and optical properties of a building fabric (floor, ceiling, partitions, glazing, blinds and etc.), internal casual gains (from people, lights, equipment), heating, cooling system and controls. Specific is a modelling of natural ventilation caused by buoyancy and wind induced forces in a system of the façade and the office.

Façade is 3 m wide with air gap depth of 0.6 m. Outer glazing is clear float (10 mm) and inner façade glazing is a typical thermal insulation double glazing unit. Solar protection of the office is provided via aluminium venetian blinds located in the façade air gap. Double skin façade is naturally ventilated via lower and upper vents. Office is ventilated via window opening into the façade gap. Office internal heat gains are calculated for working hours at the typical level for two people with PC.

Figure 3 shows scheme of the mass flow network model. Model is composed from boundary and internal nodes (circles) flow connections (lines) and flow components (boxes). The boundary nodes represent external temperature and wind induced pressure on the façade face. Internal nodes represent unknown pressure in the individual thermal zones of the model. Flow connections define possible airflow paths in the system. Flow components (relating mass flow to pressure difference) represent individual openings such as inlet and outlet vents, walking grids, office windows and other façade leakages.

Building thermal model and mass flow model are coupled together at a simulation time step level to inter-exchange information related to inter-zone flows and resulting air temperatures or vice versa. This way an energy balance of a solution is preserved.

The real difficulty in modelling a ventilation of double skin façade lies in determination of pressure boundary conditions at inlet/outlet vents caused by the action of the wind. Problem is very complex and typical approach is to determine a local wind pressure coefficient C_p (-) that relates some reference wind velocity to a local pressure at the façade face. Figure 4 shows an example of a distribution of measured wind pressure coefficient in a wind tunnel experimental facility (AIVC, 1994).

With this approach typically only mean hourly pressures at the façade face are being resolved and the effect of wind gust is not considered. However this does not mean that the approach could not be

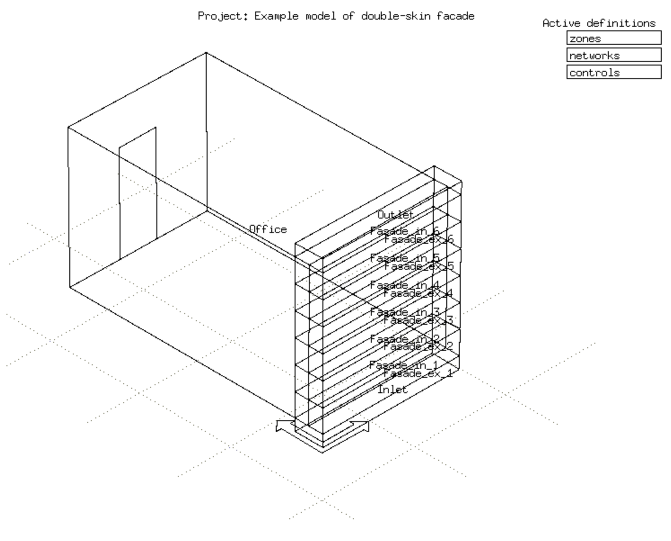

Figure 2. 3D geometry of building energy model of double skin façade

extended if sufficient short time step wind data are available.

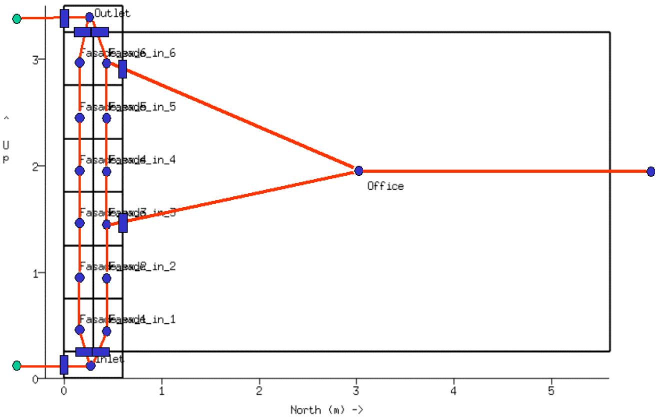

Figure 3. Façade cross section with a scheme of the mass flow network model of natural ventilation in façade and office

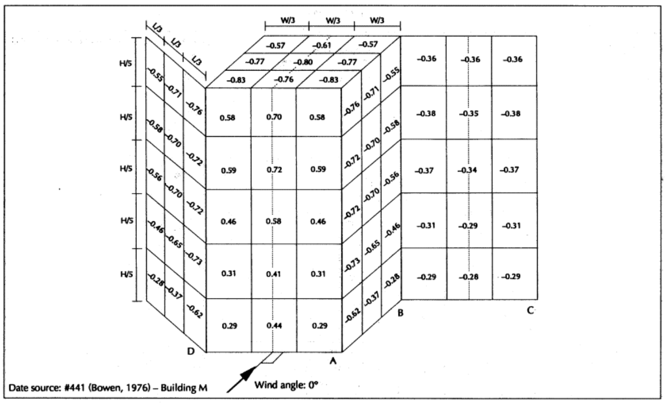

Figure 4. An example of measured wind pressure coefficient distribution on building façade (AIVC, 1994)

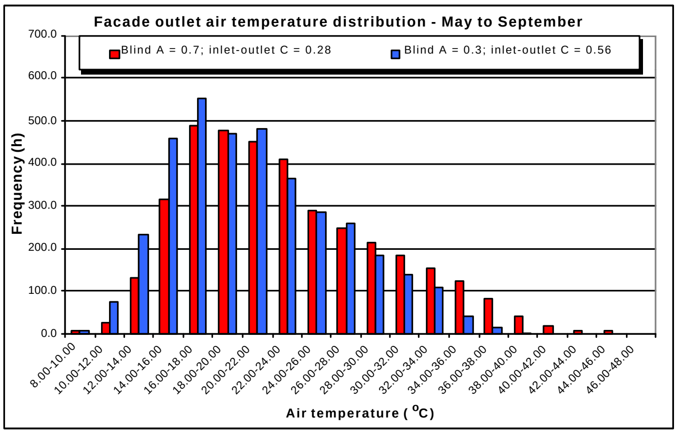

Figure 5. Comparison of façade air temperature for two different design options

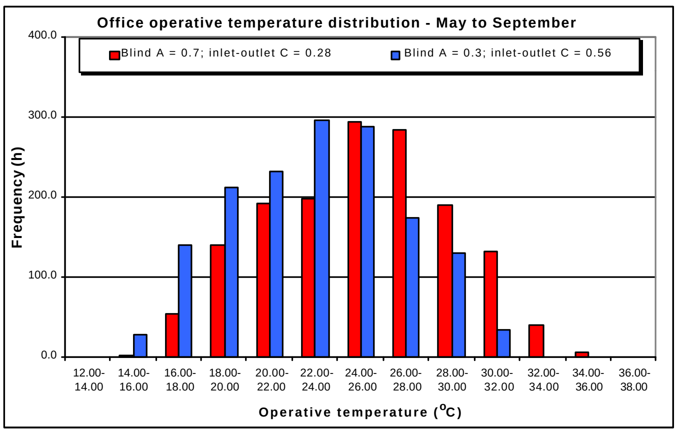

Figure 6. Comparison of office operative temperature for two different façade design options

The real power of the building simulation is the ability to assess performance of the system at the design stage and carry out number of parametric optimisations. Figures 5-6 show example of a comparison for two different façade inlet and outlet vents and blind design. The first alternative uses façade vents with flow coefficient of C = 0.28 ($m^3/s.Pa^n$) and second alternative with flow coefficient of C = 0.56 ($m^3/s.Pa^n$). At the same time the first alternative has blinds with solar absorption of A = 0.7 and the second alternative with solar absorption of A = 0.3.

It is obvious from Figures 5-6 that these two design changes have a significant effect on levels of thermal comfort in the office space.

3 CASE STUDY NO. 2

This case study introduces the assessment of operation of the ventilated double skin façade of the Brno City and Province Library (Czech Republic). The assessment focuses on ventilation of the buffer zone (Fig. 7). The outer glazing of the double-skin façade can be opened (using small swivel window panes) whereas the opening gaps are approximately 10 mm broad. At each floor a steel walking grid is placed for the maintenance purposes.

Figure 7. The Province Library in the Brno City

3.1 *Model of the double-skin façade*

In order to simulate the operation of this double-skin façade the computer software ESP-r has been used (ESRU, 1996). The established thermal model and the mass flow network model have been coupled together as in the previous case study. The overall performance of the façade and its parts were monitored. Following operational schemes of the façade were modelled (Fig. 8):

– Swivel windows panes are closed – P_Z,

– Swivel windows panes are open – P_O.

Just for comparison other two operational schemes were analysed:

– Swivel windows panes with special sealing profiles – closed – U_Z,
– Swivel windows panes with special sealing profiles – open – U_O.

3.2 *Boundary conditions*

All operational schemes assumed a calm state. This means that the airflow in the buffer zone is caused by local pressure differences based on temperature differences only and has so far upwards direction. The climate data of the Bratislava test reference year are used similarly as in the case study No. 1. From among the days of the whole year the warmest day preceded by two other warm days was selected for simulation (date 17. 07.). The maximum temperature for this day is 31.4 ºC at 14:30, direct sun radiation 820 W/m^2, diffuse sun radiation 185 W/m^2. Beyond that the state with pulled up jalousie was entirely considered. This means that the sun radiation penetrates the interior glazing and reaches the indoor space. In the mass flow network model the influence of jalousie was not considered. Only the main façade elements have been modelled: inlet/outlet anti-rain jalousie, walking grid at each floor, façade gaps and openings. For the sake of more precise description of the air temperature gradient in the façade each floor is divided into three zones, the first floor has 4 zones.

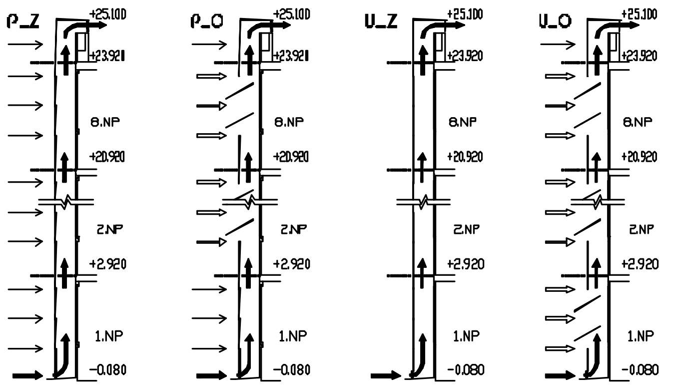

Figure 8. The operation schemes of the investigated double-skin façade. The black arrows represent the airflow through inlet/outlet openings; the white arrows stand for the airflow through façade gaps.

3.3 *The results of the computer simulation analysis*

The following result analysis is restricted to those factors only that affect the air temperature in the given investigated zone. The main of these factors is the airflow that infiltrates/exfiltrates through the façade gaps and openings.

Figure 9 shows the airflow between single façade zones and the exterior. This airflow is caused by pressure difference whereas the underpressure can be allocated to the bottom part and the overpressure to upper part of the buffer zone. It is easy identifiable by the air flow direction – in the bottom floors the air comes in the buffer zone through façade gaps and openings (positive values), in the upper floors flows in the exterior (negative values). The airflow direction changes at the fifth floor – zone 5_2, 5_3. Interesting is the comparison of air temperatures in the zone 1_1 for cases P_O and U_O. It would seem that the air temperature in the zone 1_1 at the level of first floor (case U_O) and under the assumption that the façade is completely open is lower than in case when the façade is open from the second floor upwards only. In the case P_O come in through the jalousie 0.1752 kg of the air per second whereas in the case U_O it is 0.0792 kg/s only. In the case P_O it is caused by the temperature rise in the zones 1_1 to 1_4, which at the same time increases the air flow speed. In the variant U_O the majority of the air comes in through the opened windowpanes at the level of the first floor (zones 1_2 – 1_4), because the inlet anti-rain jalousie has significantly higher air flow resistance. From this reason less air enter the zone 1_1 through the jalousie and, therefore, less air leaves the zone 1_1. At the same time the air temperature rises. The figure 10, variant P_O, distinctly shows that in the zones 1_1 – 1_4 the warmed up air has even higher temperature than the air in the zone 8_1. The most distinct temperature rise is in the case U_Z and equals to Δt = 11.76 ºC. In the case U_O the air temperature in the buffer zone does not significantly differ from the exterior air temperature.

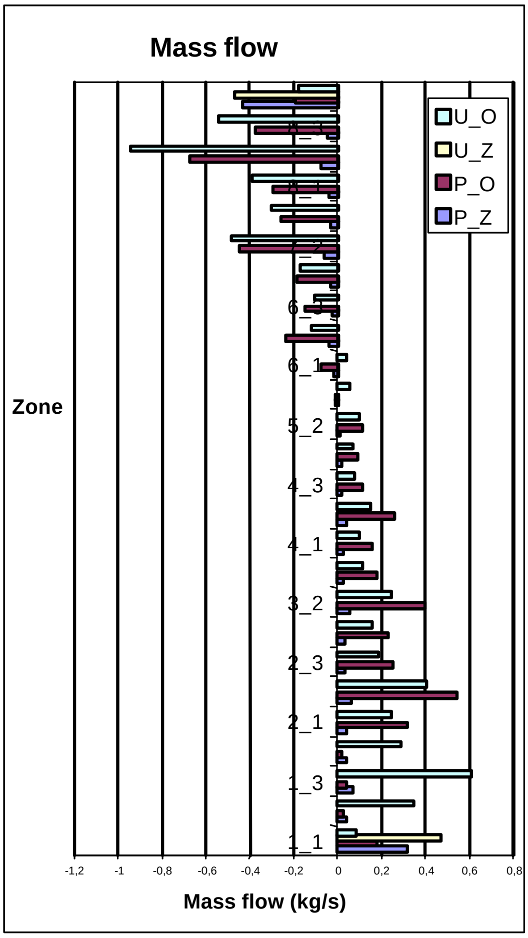

Figure 9. The airflow in kg/s between single façade zones and the exterior

From this analysis is evident that in dependence on the way the façade gaps and openings are operated the air flow in the buffer zone can change in a broad range - even under the critical situation of total wind calmness.

During calm days the temperature of the double-skin façade affects the temperature of the adjacent air and terrain. The air entering the buffer zone is warmer in the range of about 5ºC than the test reference year values.

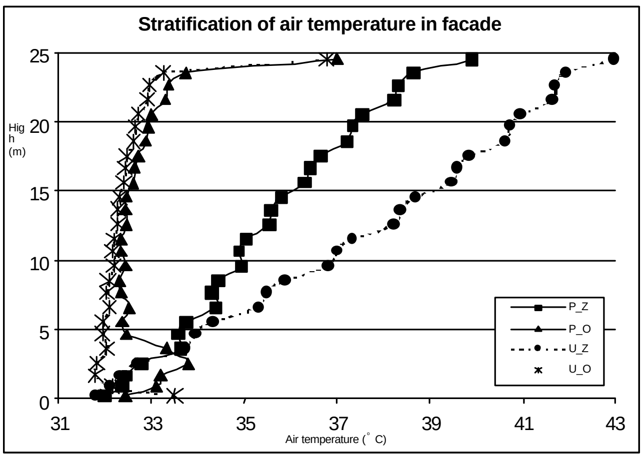

Figure 10. The course of air temperature along the façade for each investigated variants, at 14:30 on 17. 07.

4 CONCLUSIONS

Buildings with double glazed ventilated façades require careful and tailor-made design. If the design is well balanced and the building built well operated (usually automatically) the results can be successful. From the presented case studies is clear that even small changes in the double-skin façade parameters can have significant impact on its properties.

The goals that are to be achieved by using the double glazed ventilated façades can also be fulfilled by other ways financially and technically less complicate. It is obvious that the technical possibilities of the double glazed ventilated façades are very often overestimated. On the other hand the opportunities for the use and further development of traditional building envelopes are a little underestimated.

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