

PHYSICAL CAVITY OF A DOUBLE-SKIN FACADE – EXPERIMENT IN-SITU



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Summary

Double-skin transparent facade of the Slovak National Bank building in Bratislava. Natural physical cavity and quantification of its parameters by method of experiment in-situ. Measuring technology. Example of processing of climate-dependent results of the experiment. Documentation of partial results from the experiment from critical summer period.

Keywords: Double-skin transparent facade, natural physical cavity, experiment in-situ, climate-dependent process – problem

1 Introduction

Building of the Slovak National Bank in Bratislava was built in 1997-2002. Sustainable development program of European building industry found response in its design and implementation to ecological and energy efficient architectural-technical solution of intelligent buildings. Double-skin transparent facade represents closer symbiosis between creation of artificial – architectural environment and nature expressed by unconventional idea of its climatic and energy concept (for example possibility of natural ventilation from cavity of the facade etc.). In terms of design we are talking about double-skin transparent facade with corridor type of cavity, with year-round open circuit and effective height equal to height of one floor. Outer skin of the facade is glazed with single safety glazing system (**Fig. 1**).

2 Subject, goal and methodology of this paper

Subject of this paper is natural physical cavity (dynamics of air flow – flow rate is based on natural convection and wind effect) of double-skin transparent facade with corridor-type cavity (width = 600 mm), with interlaced function (inlet – outlet) of air distribution channels (**Fig. 1**).

Goal of this paper is quantification of thermal, aerodynamic and energy regime of natural physical cavity of the double-skin transparent facade.

Methodology of this paper is experiment in-situ. That means under load of real conditions of the exterior climate on building.

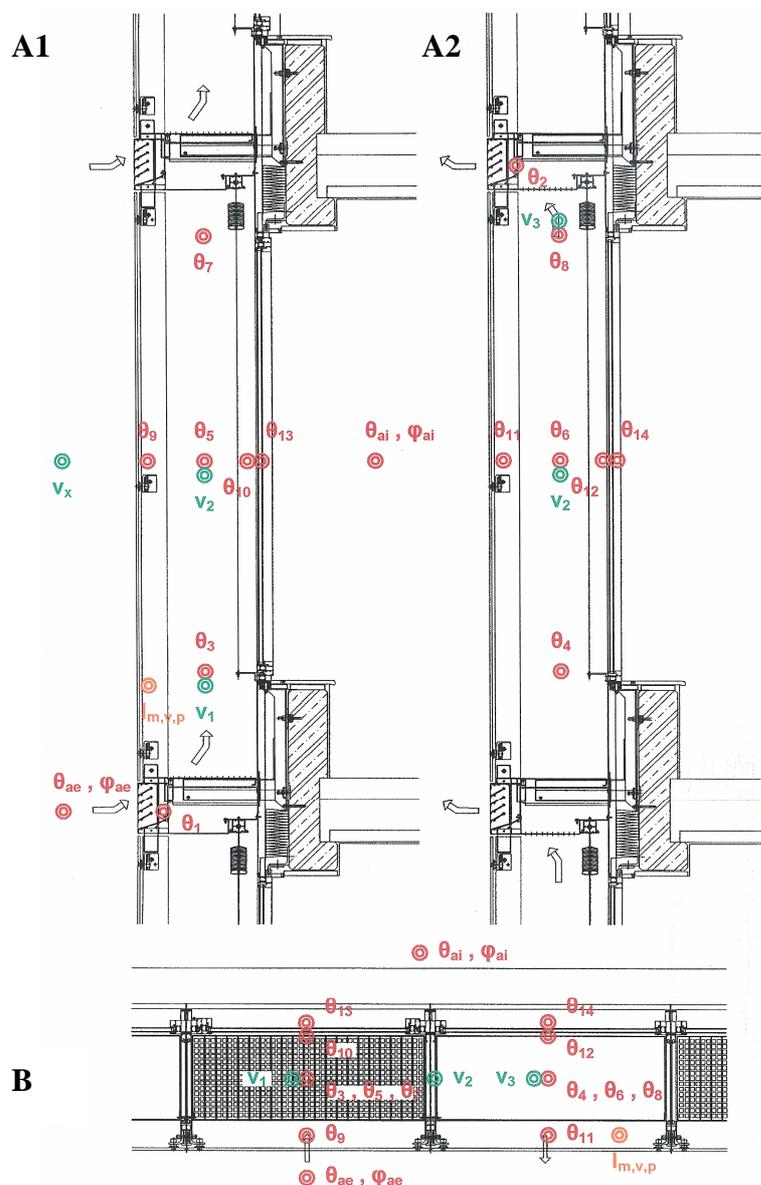


Fig. 1 Examined physical parameters of the double-skin transparent facade
 A1 – vertical section – inlet module, A2 – vertical section – outlet module,
 B – horizontal section through inlet and outlet modules

3 Experiment in-situ. Basic data, physical parameters, measuring technology

Experiment was carried out on 17th floor, 56.3 m above terrain. Orientation of the experimentally examined part of the cavity was SW (240°). Duration of the experiment was 18 months (6 months test series, 12 months measurement).

We monitored the following physical parameters in the experiment (**Fig. 1**) :

A. Temperature

- θ_{ae} air temperature of exterior climate (°C) (**Fig. 3**),
- θ_{ai} air temperature of interior climate (°C) (**Fig. 3**),
- $\theta_1 = \theta_{a,INLET}$ temperature of air at inlet to facade (°C),
- $\theta_2 = \theta_{a,OUTLET}$ temperature of air at outlet from facade (°C),
- $\theta_3 = \theta_{am,d1}$ air temperature in lower part of the cavity – inlet module (°C),
- $\theta_4 = \theta_{am,d2}$ air temperature in lower part of the cavity – outlet module (°C),
- $\theta_5 = \theta_{am,s1}$ air temperature in central part of the cavity – inlet module (°C) (**Fig. 4**),
- $\theta_6 = \theta_{am,s2}$ air temperature in central part of the cavity – outlet module (°C),
- $\theta_7 = \theta_{am,h1}$ air temperature in upper part of the cavity – inlet module (°C),
- $\theta_8 = \theta_{am,h2}$ air temperature in upper part of the cavity – outlet module (°C),
- $\theta_9 = \theta_{sim,OUT,1}$ temperature on internal surface of the cavity outer skin of the double-skin facade – inlet module (°C) (**Fig. 5**),
- $\theta_{10} = \theta_{sim,INT,1}$ temperature on internal surface of the cavity inner skin of the double-skin facade – inlet module (°C),
- $\theta_{11} = \theta_{sim,OUT,2}$ temperature on internal surface of the cavity outer skin of the double-skin facade – outlet module (°C),
- $\theta_{12} = \theta_{sim,INT,2}$ temperature on internal surface of the cavity inner skin of the double-skin facade – outlet module (°C),
- $\theta_{13} = \theta_{si,1}$ temperature on internal surface of the double-skin facade inlet module (°C) (**Fig. 5**),
- $\theta_{14} = \theta_{si,2}$ temperature on internal surface of the double-skin facade outlet module (°C),

B. Relative humidity

- φ_{ae} relative humidity of external climate air (%) (**Fig. 3**),
- φ_{ai} relative humidity of internal climate air (%) (**Fig. 3**),

C. Air flow

- $V_1 = V_{m,d1}$ air flow in lower part of the cavity – inlet module ($m.s^{-1}$),
- $V_2 = V_{m,s1-2}$ air flow in central part of the cavity on boundary between inlet and outlet module ($m.s^{-1}$) (**Fig. 6**),
- $V_3 = V_{m,h2}$ air flow in upper part of the cavity – outlet module ($m.s^{-1}$),

D. Solar radiation

- $I_{m,v,SW}$ global solar radiation falling on vertical plane with a SW aspect ($W.m^{-2}$),
- $I_{m,v,p}$ global solar radiation falling on vertical plane with a SW aspect transmitted through outer transparent skin ($W.m^{-2}$) (**Fig. 7**),

E. Wind

- $v_{w,x}$ velocity ($m.s^{-1}$) and wind direction (N, NE, E, SE, S, SW, W, NW)

In the experiment in-situ, the above mentioned parameters (**Fig.1**) were scanned and recorded:

- air temperature : $\theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6, \theta_7, \theta_8, \theta_{ai}, \theta_{ae}$: by shielded sensors Pt 100 from HAYASHI DENKO Co., Ltd., Tokyo, Japan
- surface temperature: $\theta_9, \theta_{10}, \theta_{11}, \theta_{12}, \theta_{13}, \theta_{14}$: by sensors Pt 100 from HAYASHI DENKO Co., Ltd., Tokyo, Japan

- relative air humidity: φ_{ae} , φ_{ai} : by converters MWPA 12-3321423 from SENZORIKA s.r.o., Prague, Czech Republic
- velocity of air flow : v_1 , v_2 , v_3 : by converters EE61-VC5 from E+E Elektronik, Austria
- global solar radiation : $I_{m,v,p}$, $I_{m,h}$: by pyranometers CM11 from KIPP&ZONEN B.V., the Netherlands
- wind – velocity and direction: v , (N, NE, E, SE, S, SW, W, NW): by automatic mobile weather station IMS AMS 111 from MicroStep - MIS, Slovak Republic

Continuous record of scanned physical parameters was processed by data acquisition switch unit AGILENT 34970A from AGILENT TECHNOLOGIES, CA, USA.



Fig. 2 Data acquisition switch unit



Fig. 3 Temperature and humidity converter



Fig. 4 Sheltered probe for air temperature measurement



Fig. 5 Probes for surface temperature measurement



Fig. 6 Probes for air flow velocity measurement



Fig. 7 Solarimeter

4 Results of the experiment

From this extensive and long-term experimental research of physical regime of the cavity of double-skin transparent facade we picked only the critical summer period (with highest

energy efficiency) for this paper and we chose a period of typical nice summer weather in it (Fig. 8).

From sequence of measured values of examined physical parameters we can observe:

- Interaction between air temperature of exterior climate θ_{ae} (°C) and thermal comfort temperature θ_{ai} (°C) for office work in light to medium dress corresponds with designed climatic and energy concept of the building. For $26 \leq \theta_{ae}$ (°C) ≤ 32 the temperature of interior climate is in range $22 \leq \theta_{ai}$ (°C) ≤ 27 .
- In the cavity of double-skin transparent facade air flow through the cavity occurs under any climatic load of building throughout the whole year (also in windless weather). This fact is a basic assumption of correct physical function of double-skin transparent facade and indicates that its cavity is correctly aerodynamically dimensioned (total aerodynamic resistance).
- In windless weather ($v_w \leq 0,5 \text{ m.s}^{-1}$) air flow from convection is vertically rising in the natural cavity of the double-skin transparent facade. Its velocity is $0,1 \leq v_m \text{ (m.s}^{-1}) < 0,3$ depending on temperature of exterior climate θ_{ae} (°C) and the effect of global solar radiation on external (vertical) transparent wall of a specific aspect $I_{m,v,SW}$ (W.m^{-2}).
- When velocity of wind is $v_w > 0,5 \text{ m.s}^{-1}$ there is air flow from convection and wind effect in the natural cavity of the double-skin transparent facade. Its velocity is $0,3 \leq v_m \text{ (m.s}^{-1}) < 1,5$. Its direction depends on distribution of highly variable aerodynamic coefficient of external pressure C_{pe} (-) on building.

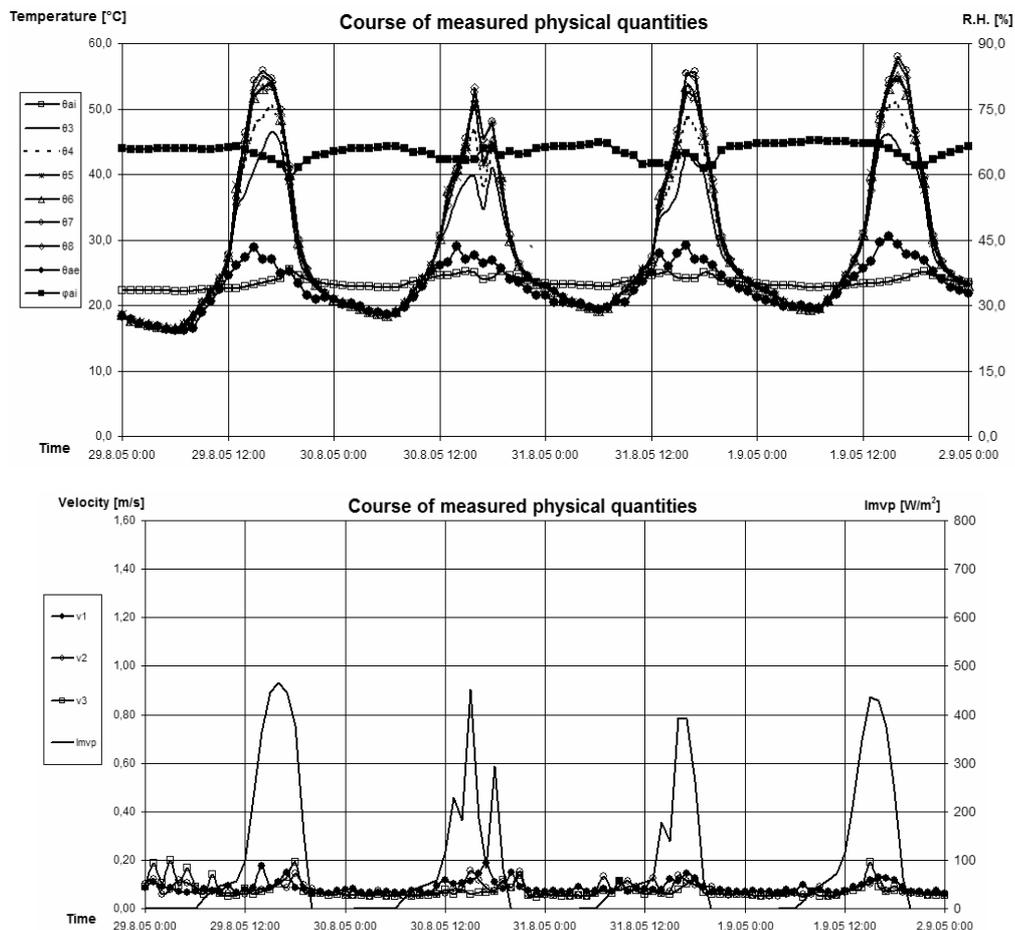


Fig. 8 Course of measured physical quantities in the period of typical nice summer weather

- in the period of nice windless summer weather with maximal temperature of exterior climate $\max \theta_{ac} \approx 30 \text{ }^\circ\text{C}$ and the effect of global solar radiation on outer transparent skin of the double-skin facade $\max I_{m,v,SW} \approx 600 \text{ W}\cdot\text{m}^{-2}$ is the maximal temperature rise in the experimentally examined natural physical cavity of the double-skin transparent facade $\max \Delta\theta_{am} \approx 25 \text{ K}$.

5 Conclusions

Extensive long-term experimental research offers abundance of new pieces of knowledge about thermal, aerodynamic and energy regime of natural physical cavities of double-skin transparent facades.

This experimental research represents equally irreplaceable standard for fine-tuning of dynamic simulation software for numerical calculation experiments of this climate-dependent problem.

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