Laboratory observation of interior surface heat transfer at balcony door

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Abstract. This paper informs about laboratory experiments studying heat transfer phenomena at the interior side of balcony doors. A well-insulated testing space representing a typical room with a balcony door equipped with floor heating and warm air heating was used. In the first step, an opaque panel with similar thermal transmittance as a triple glazed balcony door was installed in the opening for reference. A combination of temperature measurements and particle imaging velocimetry (PIV) was used here to study the surface heat transfer in detail for both types of space heat distribution and obstacles by curtains. From the measured data, the surface heat transfer coefficient along the height of the door was evaluated and discussed.

1. Introduction
Surface heat resistance at interior surfaces of buildings is described by standard values [1] for daily practice. It is well known that the space heat distribution in the room and the local differences in surface geometry can be of considerable importance for both total and local values. Standard values should be critically analyzed taking into account changed conditions in surface temperature due to higher thermal resistance of building envelopes and due to changed heat distribution in the rooms of energy optimized buildings. It is possible that the radiation component will be more significant.

Performed observations and laboratory measurements for window areas [2,3] showed clearly that the heat transfer can differ significantly at non-planar surfaces of the building envelope. Large differences in surface temperature can be seen at functional joints and edges of glazing and close by. Moreover, the air temperature and overall surface heat transfer in the window area can vary according to the depth and form of window linings.

We continued the research program to study the heat transfer phenomena in the area of balcony doors. New knowledge is expected about the separate and combined influence of door geometry (form of frames), their position within the building envelope (depth of side lining), the type of local space heat distribution, and the presence of obstacles (curtains in front of the door).

2. Experimental set-up

2.1. Testing room
The experiments are taking place in a well-insulated testing room with inner dimensions of 4.4 m x 3.1 m x 2.85 m (length x width x height) (Figure 1) under steady state conditions. The ceiling, floor, and two walls of the room were surrounded by controlled external environment. The remaining two walls were surrounded by controlled internal environment (adiabatic boundary).
The window from previous experimental studies [2] was replaced an opening for the balcony door (width 1.5 m x height 2.4 m). Floor heating and warm air heating was applied alternatively. The internal and external air temperature during the experiments were +22.5 °C and −12.5 °C, respectively.

![Figure 1. Testing room – vertical cross section through the balcony door.](image)

### 2.2. Instrumentation and first set of experiments

A reference plate instead of a real door was used to study the basic geometric influences, the effect of the choice of the space heating system, and the effect of shading by an interior curtain. The reference flat plate without extra framing had the thermal transmittance of 0.69 W/(m²·K) corresponding to a real triple-glazed balcony door. The plate was covered by an adhesive black matte foil and placed 200 mm deep in the opening. Detailed vertical temperature profiles were measured at both surfaces of the reference plate, near its internal surface (at distances 5, 15, 25, and 200 mm), and in the center of the room. Particle imaging velocimetry (PIV) [4] was used to map the velocity field close to the reference plate at two levels: 1.0 m above the floor and in the corner by the floor.

### 3. Experimental results

The character of air movement was illustrated by particle image velocimetry (Figure 2): a stable stream parallel with the surface in the central part of the balcony door and significantly changed the stream orientation closer to the floor.

![Figure 2. Velocity field in a vertical cross section close to the door opening. In the level of 1 m above the floor (a) and in the corner door/floor (b) measured by particle imaging velocimetry for air heating.](image)

Figure 3 shows the measured values of the surface heat resistance for all tested configurations: floor heating or warm air heating, without obstacle or with a textile curtain at the distance of 200 mm from the wall (i.e. 400 mm from the reference plate). The $R_s$ values are related to the air temperature measured in the center of the testing room at a height of 1 m above the floor. The values are adjusted for the effect of thermal coupling between the floor and the door opening (using 2D calculation in COMSOL Multiphysics based on the measured boundary conditions).
Figure 3. Interior surface thermal resistance $R_{si}$ $[m^2\cdot K/W]$ along the height of the door opening for floor heating and for warm-air heating. In both cases, alternatively covered by a textile curtain. The $R_{si}$ values are related to the internal air temperature measured in the center of the testing room at the height of 1 m above the floor.

4. Concluding remarks
The value of the heat transfer resistance varies with the height. It depends on the heat distribution. In both cases, the average value along the height of the window is close to standard value 0.13 $m^2\cdot K/W$ [1]. By presence of obstacles is the value higher, again depending on heat distribution. It can be concluded that the standard value can be used for heat loss calculation. For calculation of surface temperature and estimation of condensation risks higher values in the lower area of the door (min. 200 mm from the floor) should be used instead, e.g. 0.25 $m^2\cdot K/W$ to be on the safe side.

In general, the interior temperature which is used in the heat flow calculation is a subject of convention. Normally, it should represent the whole room. In specific cases, local interior temperature can be applied instead, e.g., for studying of the effects of very deep lining and/or curtains or other local obstacles. We have seen that the width of the boundary layer with the significant temperature change remains as expected within 15 – 25 mm from the surface.

Our experimental program continues with detailed studies on a changed geometry corresponding to real frames and to real balcony door, respectively. The only possibility how to study the problem more exactly and evaluate the eventually corrected surface heat transfer coefficients for specific cases is to perform a set of very precise laboratory experiments, very likely in combination with advanced modelling. It should be mentioned that we are facing several limits of the measuring technique, e.g., the acceptable size and accuracy of heat flow sensors for studying the surface heat transfer by frame profiles.

Acknowledgments
The authors would like to acknowledge EU project PowerSkin+ for a kind support.

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