Investigation of the Impact of Natural Ventilation through Windows on Thermal Comfort

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Abstract

At Hermann-Rietschel-Institute systematic tests of the limits for the ventilation with openable windows are under way. The parameters temperature distribution and air velocity are the most attended values.

Window ventilation in office buildings has limits in application. An open window can remove cooling loads out of the room. With one window and a room with a depth of 5 m, the maximum cooling load is about 20 to 30 W/m². These limits are determined by air velocities within thermal comfort. Below 10°C outdoor temperature, thermal comfort can no longer be guaranteed due to high air velocities and low temperatures.

Keywords

Thermal comfort, office buildings, natural ventilation, displacement ventilation.

Introduction

Many HVAC systems built in the time between 1960 and 1980 have now reached the end of their lifetime and require retrofitting. When HVAC retrofits are performed in connection with building renovation, there is often a potential for reduction of thermal loads. In many cases, the question arises whether the installed HVAC system is still required to control thermal loads. Therefore the Hermann-Rietschel-Institute makes experimental investigations about the air flow when windows are open.

Experimental Investigations of the Room Air Flow

The question weather a renovated building should have airconditioning plant or free ventilation often revolves around arguments of energy consumption and investment. However they did not take into account, that there can be no thermal comfort in many cases of cooling loads and outdoor temperatures. For the buildings with HVAC-systems the room air flow is well known, but the flow when a window is open is mostly unknown.

In this research project the Hermann-Rietschel-Institute makes investigations on ventilation by opening the windows. The limits of free ventilation with windows are given by air temperature and air velocity. Now we have first results of the still ongoing investigations.

Testing Plant

The experimental investigations were conducted a specially equipped room at the Hermann-Rietschel-Institute. For the study of the room air flow with open windows, a test chamber was constructed. The results of previously conducted experiments and calculations served preliminary data. The test chamber has two areas. One of these areas simulates outdoor conditions using a cooling or heating coil. The second, larger area represents an office with its sources of heat.

Air velocity and temperature are measured while windows are open. Fig. 1 shows the layout of the test chamber.

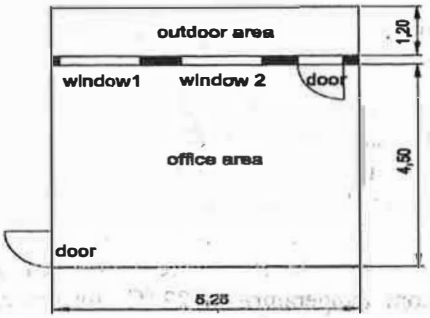

Fig.1: layout of the test chamber

There are two windows in the envelope element. The right window on each side can be tilted or open fully. The left ones open fully and the lower right windows are non-openable. Fig. 2 shows the elevation of the facade, viewed from the office area.

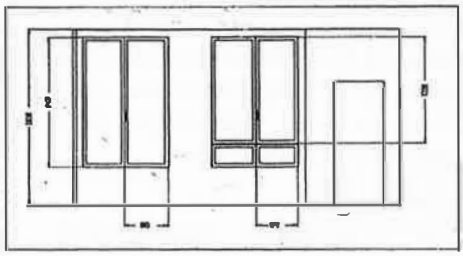

Fig.2: view of the facade element (interior elevation)

Air flow in winter when a window is open

The air flow in a room is caused by wind and thermal buoyancy. At high wind speeds, the windows closed due to drought. Therefore the thermal comfort most critical case was investigated, when the air exchange causes thermal buoyancy. The measurements are made at steady state conditions with windows open and the heat sources regulated to keep the air temperature in the room constant. The influence of radiators in respect to the room air flow will be investigated in the future studies.

In the middle european winter climate, outdoor temperatures are lower than indoor temperature. Due to the temperature difference there are differences in air density and pressure between inside and outside. They cause the air exchange when the window is open. The supply air enters at the bottom part of the window, the exhaust air exits at the top. The supply air enters with a low impulse into the room. If a window is tilted, there will be two air streams on each side of the window. Similar to the displacement flow (source flow) this window position creates a layer of fresh air across the floor (fig. 3).

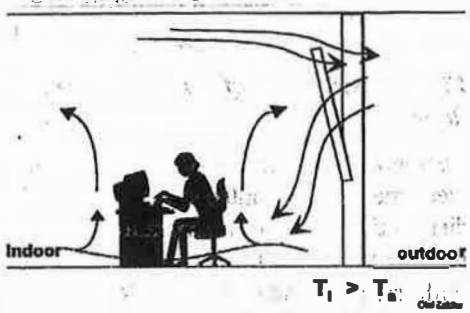

Fig 3: room flow when a window is in a tilted position

At warm objects or persons a buoyancy flow from this layer rises up. The warm air at the ceiling exits at the top of the window. Altogether the incoming mass flow is equal to the outgoing flow. In the measurements described in the following paragraphs the right window pane of the left window was tilt.

Air Velocity and Temperature at floor level

Thermal comfort is influenced by air velocity and temperature in the room. Velocities higher than 0.15 m/s will cause draught. Fig. 4 shows the distribution of the velocity in 0.1 m above the floor, at 22 °C and 30 W/m² cooling load. In this picture areas with similar velocities are shown. Near the window (up to a radius of 1,4 m), air velocity reaches values up to 0,18 m/s. In this area, thermal comfort cannot be achieved any more. Further away from the window air velocity is lower.

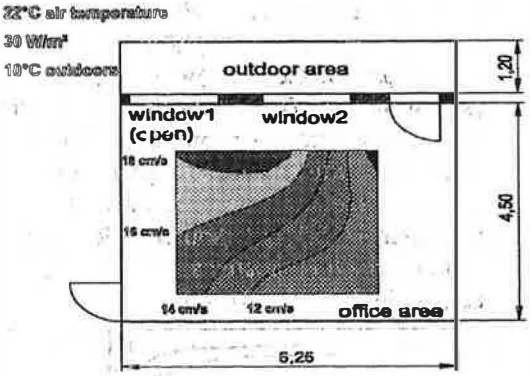

Fig. 4: distribution of velocity above the floor

Temperatures near the floor and air velocity were measured simultaneously. In fig. 5 the distribution of the temperatures near the floor are shown. The areas show the areas with similar temperatures. Near the open window, the temperatures are below 20 °C. Thermal comfort is not achieved at distances of less than 1.7 m from the window.

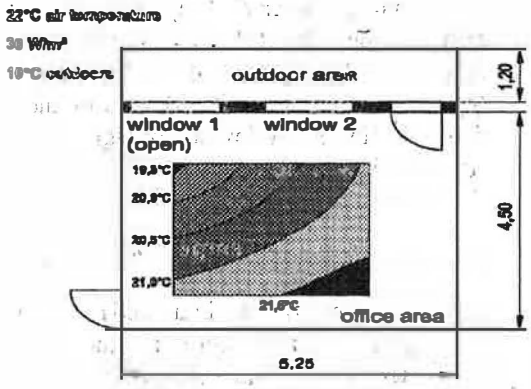

Fig. 5: distribution of the temperature above the floor

Specific Cooling Load when the Window is Open

The radiators in the perimeter zone compensate for the heat loss through heat transfer. The heat loss caused by the ventilation is thereby compensated by heat sources in the occupied area.

The supplied air brings a certain cooling capacity into the room. This cooling capacity depends on the size of the opening, the temperature difference between indoors, and outdoor and the cooling loads.

Fig. 6 shows the specific cooling capacity of various window positions as a function of the outdoor temperature. Air velocity is also indicated. The maximum cooling capacity is limited by the criteria for thermal comfort. The measurements were conducted at a room temperature of 22 °C. As shown in fig. 6, cooling loads up to approximately 20 W/m² can be removed under thermally comfortable conditions. When a room is occupied by more than one person, the persons near the open window will feel uncomfortable first, because of low temperatures and high velocities.

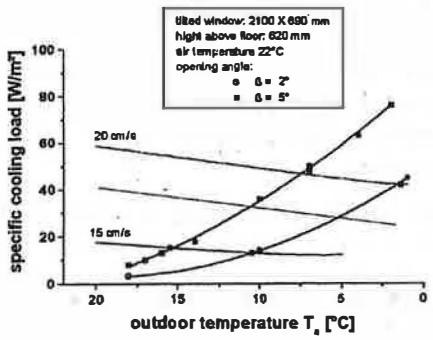

Fig. 6: specific cooling capacity through window ventilation

In fig. 7, temperatures near the floor at a distance of 1.4 m from the window are shown. These temperatures will be lower than 20 °C, if the cooling load is higher than 35 W/m².

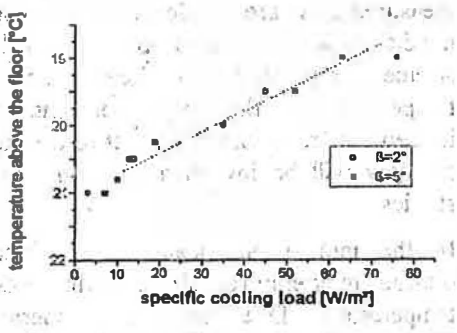

Fig. 7: temperatures near the floor as function of the cooling load

In the next figure (fig. 8) the velocities near the floor depending on the outdoor temperature are shown for two window positions. At temperatures lower then 10 °C air velocities reach critical values.

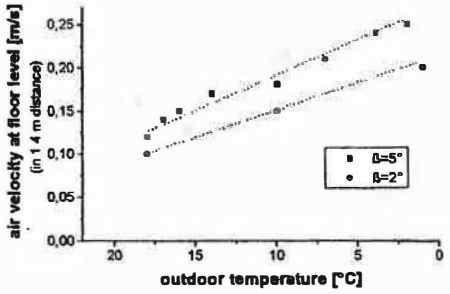

Fig. 8: air velocity above the floor as function of outdoor temperature

This diagram shows the relationship between the open area and the velocity. Smaller supply openings cause lower air velocities.

The supply air through a tilted window enters a room in two air streams. If the cooling load is calculated for the air streams instead of the room size, one air stream has a maximum compensation capacity of 350 W while meeting thermal comfort criteria. Consequently the maximum cooling capacity is given by the number air streams and not so much by the cooling load per m². Thus if window ventilation is used it is recommended to provide fore various types of window positions and sizes to control the supply air streams in accordance to the specific thermal requirements.

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