Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

APPLIED SCIENCE DIVISION

Presented at the Clima 2000 Conference,
Copenhagen, Denmark, August 25-30, 1985;
and to be published in the Proceedings

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March 1986

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Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

DISCLAIMER

LBL-17940
EEB-EPB-86-05
Presented at the Clima 2000 Conference, Copenhagen, Denmark, August 25-30, 1985, and published in the proceedings.

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March 1986

This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building and Community Systems, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

ABSTRACT

The simplified infiltration models now used to simulate incoming and outgoing air flows for single-zone structures, such as one-family houses, are not suitable for a high percentage of existing houses, whose floorplans classify them as multizone structures. Multizone infiltration requires extensive and complex information about the flow characteristics and pressure distribution inside the building, and thus has been too difficult to develop and to validate. Our purpose has been to devise a simplified multizone infiltration model. To this end, we have simplified the description of the air-flow distribution in a building by relying on lumped parameters. Further simulation runs are necessary to confirm that these parameters are sufficient for describing infiltration in buildings. This paper describes these parameters and the considerations involved in the development of our multizone infiltration model.

INTRODUCTION

Numerous computer programs have been developed to calculate the energy consumption in buildings due to infiltration. Those which treat the true complexity of flows in a multizone building, require extensive information about flow characteristics and pressure distribution. Therefore, simplified models have been developed. Most of these, including the LBL model (1), simulate the air infiltration of singlecell structures under given weather conditions. A high percentage of the existing buildings, however, have floor plans that characterize them more accurately as multizone structures, which cannot be treated by singlecell models. Although multizone models exist, most are either not available to the public or are written as research tools (2). Professional engineers and architects are in need of a simplified multizone infiltration model capable of providing the same accuracy as the existing singlezone models.

AIR-FLOW IN MULTIZONE BUILDINGS

The air-flow distribution for any given building is determined by pressure differences due to wind, thermal buoyancy, or mechanical ventilation systems acting alone or in combination. The distribution of openings in the building shell and the inner flow-paths also influence air-flow patterns.

In terms of air flow, buildings can be regarded as complicated, interlaced systems of flow paths (3). In this grid system the joints are the rooms of the buildings and the connections between the joints simulate the flow paths, which include flow resistances caused by open or closed doors and windows and/or air leakage through the walls. The grid points outside the building represent the boundary conditions for the pressure. Differences in air density, caused by differences between outside and inside air temperatures, result in further pressures in the vertical direction, again influencing the building's air flow.

In buildings with mechanical ventilation systems, the model should treat the duct system as another flow path in the building and the fan as another source of pressure differences; i.e. the fan lifts the pressure level between two joints according to the characteristic curve of the fan.

MULTIZONE INFILTRATION STUDIES

Experimental Work

It is difficult to measure infiltration in multichamber structures, and only few of the existing models have been validated properly. To identify the air movement into a building and its internal air-flows we have developed a multigas tracer measurement system. By using freons and sulfur hexafluoride as tracers, a large number of detectable gases are available. The tracer gases are injected in the different zones using the constant-flow method for each sampling period. The measurement equipment consists of a gas chromatograph with two columns, an electron capture detector, and a sampling mechanism for the gases of the different zones. Air from different zones is sampled for ten minutes, collected into sampling bags, and immediately analyzed. Weather data is recorded at the same time as infiltration is measured. For recorded wind data, surface pressure coefficients are measured on scale models in a boundary-layer wind tunnel. These pressure coefficients, together with weather data and airleakage data obtained by pressurizing the building, are used as input for a detailed multizone model. The measured infiltration data will be used mainly to validate the model; the predicted infiltration data will be used to learn about the mechanisms that cause infiltration.

Modelling

To simplify the description of the air-flow distribution in buildings, we searched for lumped parameters, corresponding to those used to describe other physical phenomena, e.g. the total thermal conductance of a zone for heat loss. A preliminary literature review revealed that, from the point of view of infiltration, a whole building can be qualitatively classified as one of four types distinguished by their internal permeability distribution and their construction type. Quantative parameters for the individual zones have been obtained by using a detailed computer model to simulate a large number of different floor plans.

A study by Krischer and Beck (4) gave the first hint that such lumped parameters might exist. To calculate the maximum infiltration heat loss for a building (at design conditions for the heating system) they distinguished two house types: terrace houses and detached houses. They expressed the differences in terms of the ratio of the permeabilities of the leeward side and the windward side of the building envelope. In the latest issue of the German standard, DIN 4701 (5), a further distinction was made between construction types: shaft type and storey type, which differ in their vertical inside permeability between floors.

They defined the following parameter to describe the envelope permeability ratio (epr) for a given house type:

$$epr = \frac{D_{lee,\ envelope}}{D_{total,\ envelope}} \tag{1}$$

and equation (2) to describe the vertical permeability ratio (vpr) for a given construction type:

$$vpr = \frac{D_{shaft}}{D_{total,\ envelope}} \tag{2}$$

where D = permeability.

These parameters have been used to calculate the maximum air flow for the whole building. We are investigating to see if there exist parameters capable of describing the different zones of a building and the effect of their location in the building. (From previous simulations we know that a zone can be stack- or wind dominated, depending on the permeability distribution of the zone itself). We have carried out detailed simulations on a number of multizone buildings.

As an example Figure 1 shows the floor plan of an eight-storey building with three flats on each floor. (Details of the modelling assumptions are given in reference (3)). Whereas flat #1 and flat #3 have windows and balcony doors on two different facades, flat #2 has openings in one outside wall only. Using the flow coefficients prescribed by DIN 4701, and a typical meteorological year for Berlin, the average heating season infiltration rate for the whole building is 0.12 ach.

Figure 2 (note the logarithmic y-axis) shows the calculated infiltration for all the flats. Because of thermal buoyancy, the air pressure is very high at the top of the staircase shaft, and does not allow air flow into the shaft above the neutral pressure level (NPL) (7). The curve for flat #2 shows a progressive decrease in infiltration rates by a factor of 100 due to infiltration from ground level to top floor. The pressure distribution in the staircase shaft does not allow cross ventilation into flat #2 above NPL. The curve for flat #3 indicates little change in infiltration with building height, very likely because the permeabilities are evenly distributed between the two facades. Even with a large pressure gradient in the staircase shaft, the cross ventilation in the dwelling is not significantly disturbed. The floorplan for flat #1 shows an uneven outside permeability distribution between the two opposite facades, therefore, the infiltration for these flats is stack influenced.

These effects can be explained in terms of two new zone parameters. We define the outside permeability ratio (opr) of the zone, which describes the cross ventilation

$$opr = \frac{D_{zone\,,\,lee\,,\,outside\ envelope}}{D_{zone\,,\,outside\ envelope}} \tag{3}$$

and the inside permeability ratio (ipr) of the zone, which describes the stack influence of the zone

$$ipr = \frac{D_{zone\,,\,shaft}}{D_{zone\,,\,outside\ envelope}} \tag{4}$$

We found a strong relationship between the two ratios and the flow distribution in the building. With increasing values for opr and decreasing values for ipr the zones become more wind dominated. Consequently, increasing iprs and decreasing oprs show the opposite effect. These parameters may be useful in quantative analysis of multizone infiltration and ventilation.

CONCLUSION

We have determined lumped parameters, the outside permeability ratio (opr) and the inside permeability ratio (ipr), that simplify the description of air flows in multizone buildings. Further simulation runs with a detailed computer model are necessary to confirm that these parameters are sufficient for describing infiltration in buildings.

ACKNOWLEDGEMENTS

This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building and Community Systems, Building Systems Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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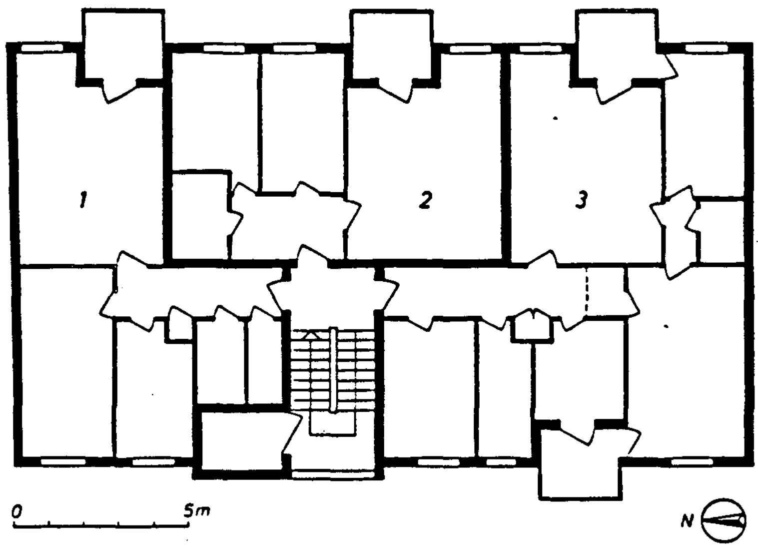

Figure 1: Floor Plan Brunsbuettler Damm 37

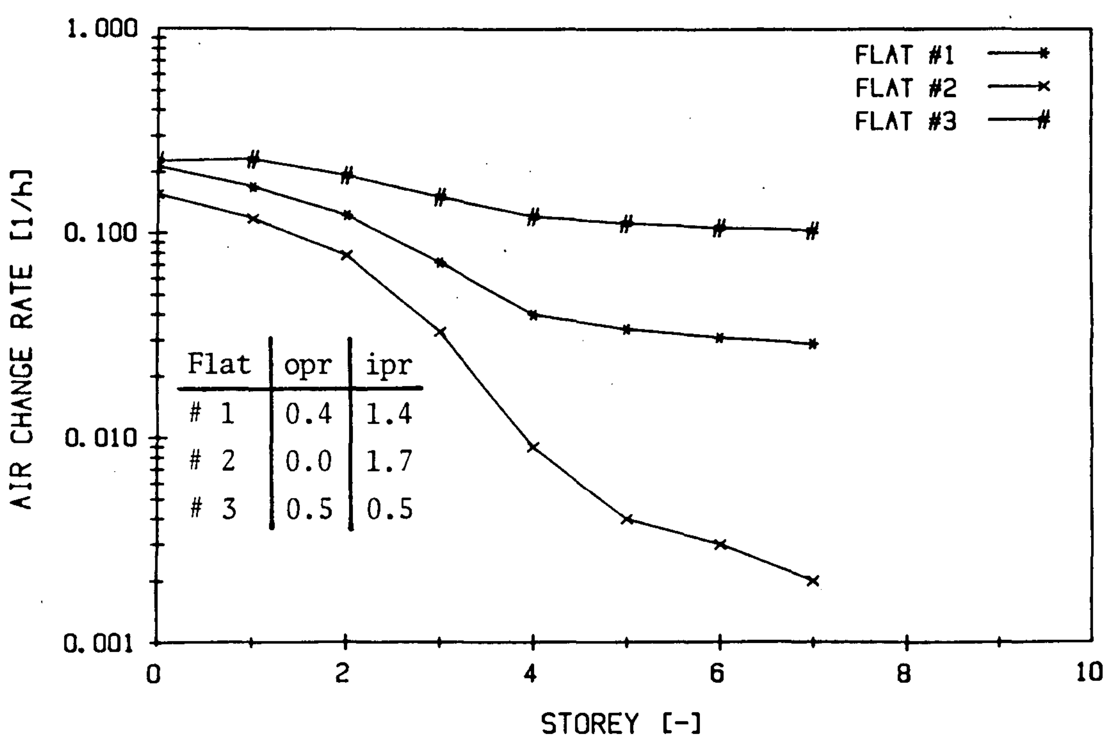

Figure 2: Air Change Rate due to Infiltration

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