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INFILTRATION, INDOOR AIR QUALITY AND ENERGY SAVINGS IN ISRAELI APARTMENT BUILDINGS

M. Poreh, S. Trebukov, S. Hassid and D. Wegner

Faculty of Civil Engineering,
Technion - Israel Institute of Technology, Haifa, Israel

ABSTRACT

Air infiltration rates in israeli apartments have been investigated as part of a project sponsored by the israeli Ministry of Energy. Widely varying values of effective leakage area, from 1.5 to 14 cm^2/m of crack length, were recorded; the "leakiest" apartments being the ones with wood windows and slat-type windows. The results of a developed multi-zone air movement model show that the wind speed has the highest influence on the rate of infiltration, and that tight main entrance doors and tight staircase windows, together with an open top staircase vent, give the best results from the point of view of both indoor air quality and energy savings. It is also shown that in israeli apartments the minimum fresh air requirements cannot be satisfied by infiltration alone, for a considerable portion of the time, thus setting a limit on potential energy savings available by improved air tightness. Weather-stripping and other improvements in air tightness can significantly affect maximum heating energy demand, which is of considerable importance for electrically heated apartments, particularly in the windy mountain region.

INTRODUCTION

Air leakage through envelope cracks, accounts for a large part of the energy losses in buildings. Although energy losses can be significantly reduced by weather-stripping openings on the envelope of a building, the reduction of infiltration below a minimum level is not desirable, not only for reasons of indoor air quality, but also in order to prevent condensation due to the high vapor content of indoor air. In this work, the air-tightness of several israeli apartments was measured using the blower door method. The measured values of the effective leakage area were used to calculate theoretically the energy losses through air leakage in typical israeli apartment buildings, and to identify methods for reducing infiltration losses without affecting indoor air quality.

EXPERIMENTAL PROCEDURE

The effective leakage area of a number of apartments in Israel was measured using a conventional blower door, consisting of an adjustable opening, that can be expanded or reduced to fit many entrance door sizes, a blower supplying a measured quantity of air to the housing unit, and manometers measuring the pressure difference across the door. From the graph of the flow, versus the pressure difference, the effective leakage area L can be derived. L is defined as the area of a perfect orifice which would give, at a pressure difference of 4 Pa, the same leakage flow as the cracks on the building envelope. Given that typical israeli buildings are made of masonry materials, it can be assumed that air leakage to adjacent apartments is negligible compared to leakage of air to the environment.

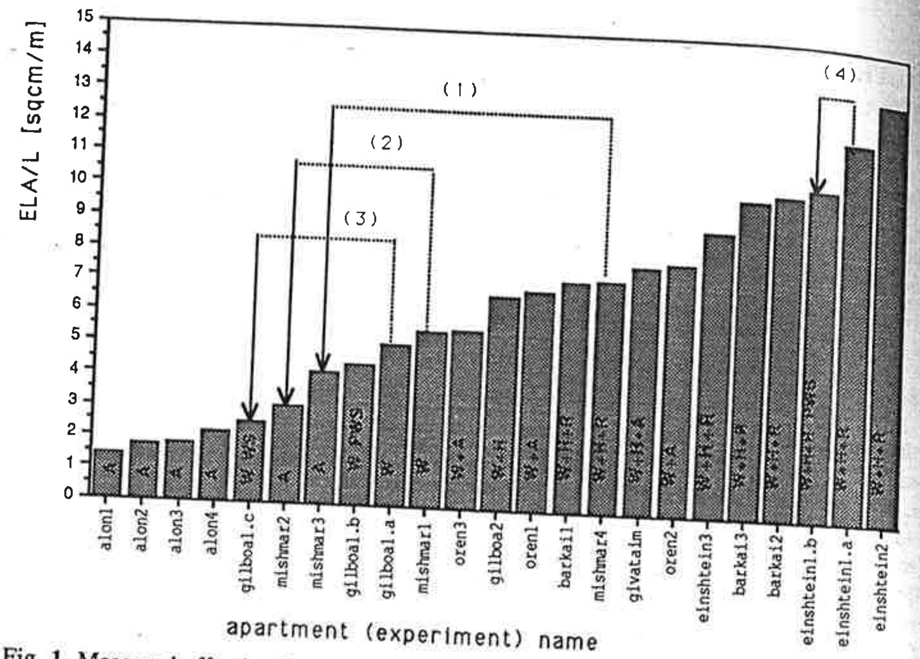

Fig. 1. Measured effective leakage area per unit crack length in israeli apartments. W: Wooden frame. A: Aluminum frame H: Built-in type openings R: Slat type openings WS: Weatherstripped PWS: Partially Weatherstripped . Arrows link similar apartments improved by research team.

Presented in Figure 1 are the measured values of the effective leakage area per unit crack length for several apartments. Best from the point of view of air-tightness are apartments with aluminum window frames, or apartments with weather-stripped wood-frames. Not far from this category are apartments which have been improved by their occupants or by the researchers during the study. Worst is the air-tightness in apartments with wooden balcony doors, built-in-wall and slat-type windows, averaging a crack-length related effective leakage area three times larger than the ones in the best category. Weatherstripping all openings (windows, shutter boxes and doors) is shown to reduce the effective leakage area by the order of 50 % and partial weather-stripping by the order of 20 %.

AIR MOVEMENT MODEL FOR ISRAELI APARTMENTS

A model has been developed to describe inter-zone air movements in a typical israeli apartment block (with no forced ventilation through ducts, no heating system in the staircase). The model is based on the following assumptions:

(1) The wind velocity at height H is assumed to vary according to the power law:

$$V_b = a\, V_m\, (H_b / H_m)\, \gamma \qquad (1)$$

where V_b is the characteristic wind speed at the building height H_b, a is a shielding factor, V_m is the wind speed measured at height H_m at the closest meteorological station and γ is the wind profile exponent, varying from 0.14 for open country to 0.25 for urban conditions.

(2) The envelope is divided into 16 parts
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$$P(z) = C_p\, r\, (V_b$$

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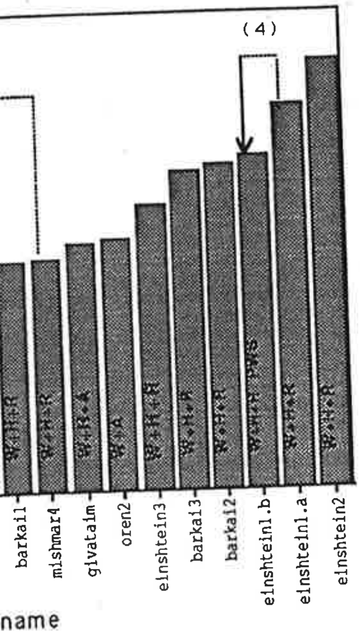

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L being the effective leakage area of the opening, C a coefficient, K_T a temperature correction and n an exponent (n=1/2 for doors and n=2/3 for windows).

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The influence of the wind speed on infiltration is depicted in Fig. 2, for both open and closed top vent. It is shown that for small wind speeds (< 1m/s) infiltration does not tend to zero, due to the stack effect. The influence of the vent decreases with increasing wind speed.

In Figure 3, the average heating requirements of the apartments are shown, as a function of the entrance apartment door effective leakage area Lo and the condition (open (o) or closed (c)) of the staircase door, the staircase window and the top vent. It is shown that the ideal situation occurs when the building entrance and the staircase windows are closed but the top vent is open, since in that case the increased air flow through the apartments does not result in increased heating requirements. At the same time, in such a situation, the contaminated air leaked through the apartment entrance door is vented out and not allowed to enter the neighboring apartments. Note, however, that there are large differences between the different apartments.

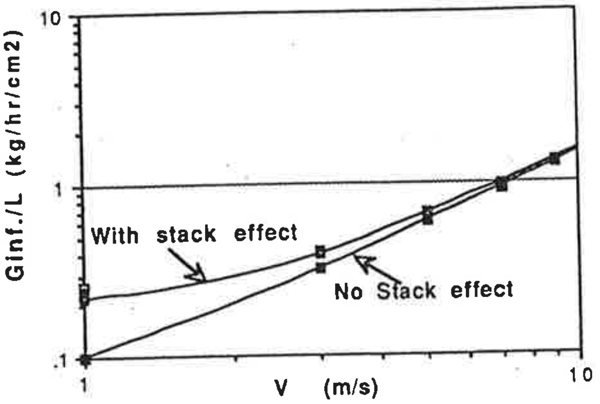
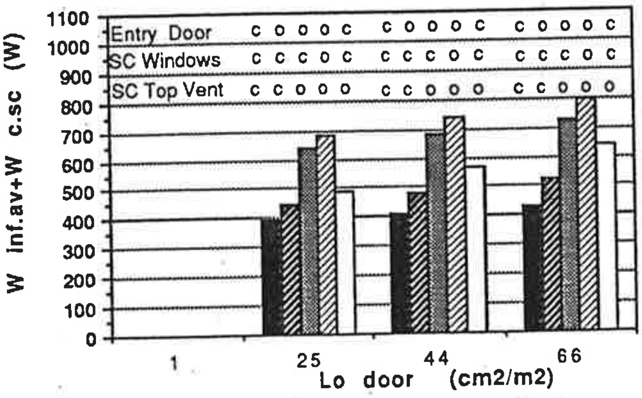


Fig. 2. Average apartment infiltration Ginf per unit ELA as a function of wind speed with stack effect (Temp. Difference 10°C) and without stack effect (No Temp. Difference). Open top staircase vent. L is the effective leakage area of each apartment (windows and entrance door).



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In Figure 4, the hour-to-hour variation in infiltration is shown, for the month of January in Bet-Dagan, typical of the inner coastal area of Israel (data of Schweitzer(1976)). One can see that whereas there are large periods of time during which infiltration is insufficient to satisfy the ventilation requirements, there are strong peaks in infiltration (and,consequently, energy requirements). This shows that weatherstripping will not always result in energy

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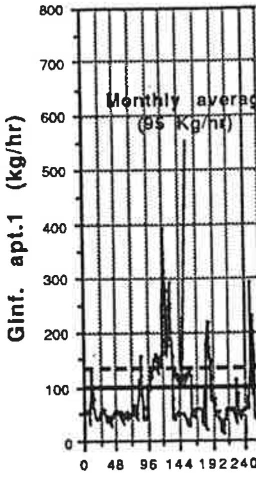

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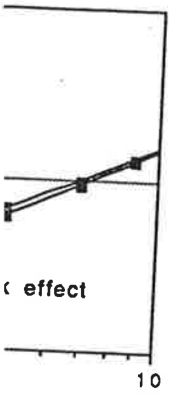
	Good	2740
	Excellent	1420
Jerusalem Mountain	Bad	10425
	Mediocre	6306
	Good	4200
	Excellent	2100



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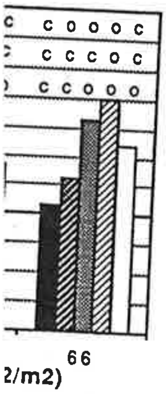

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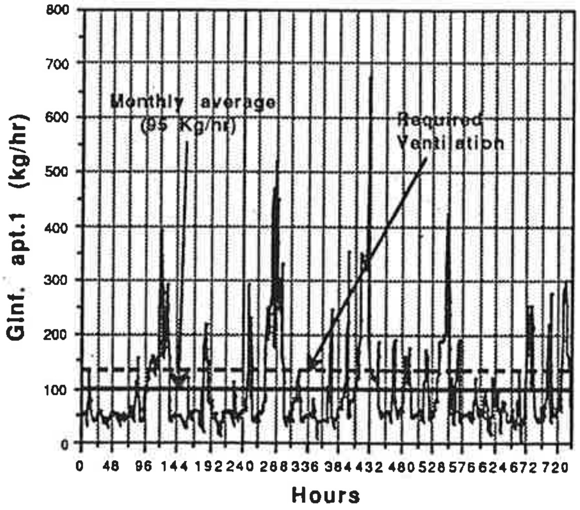

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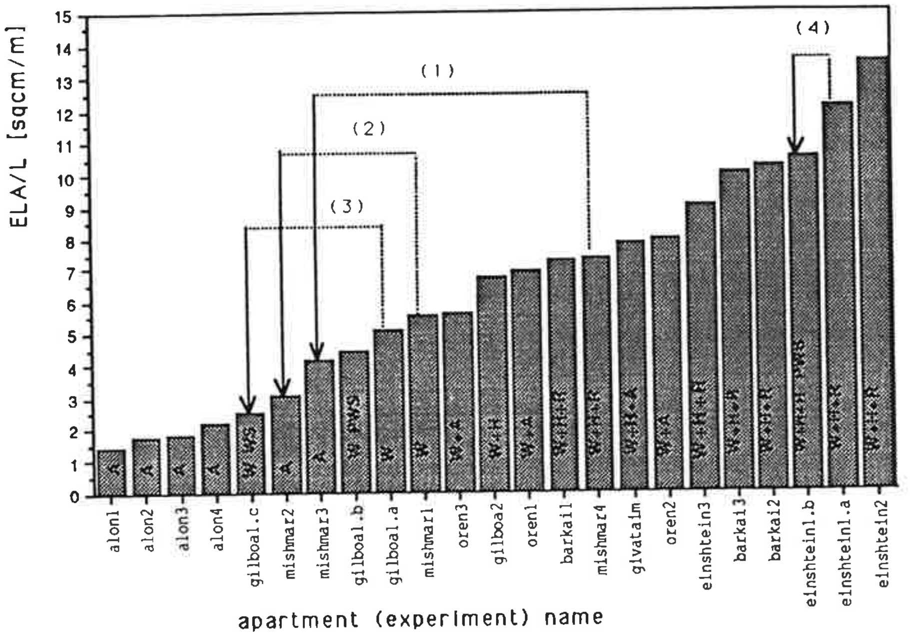

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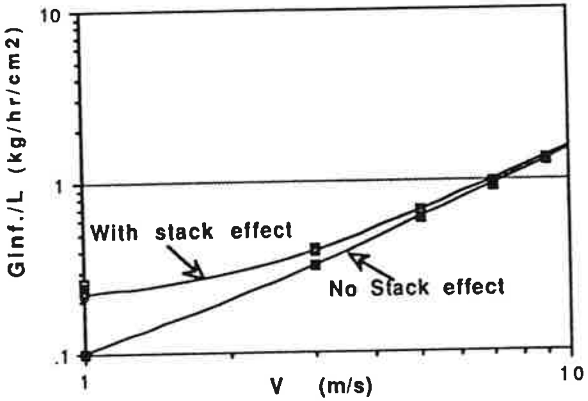

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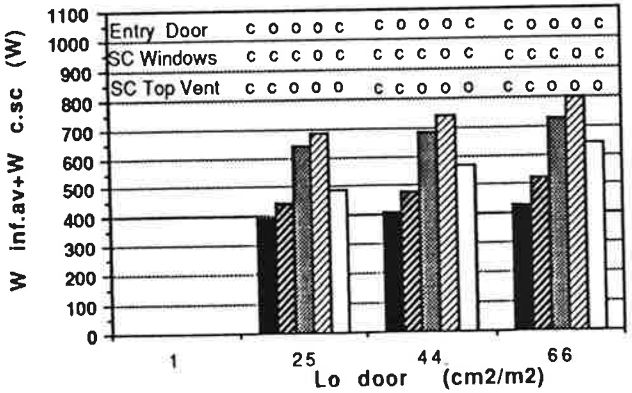

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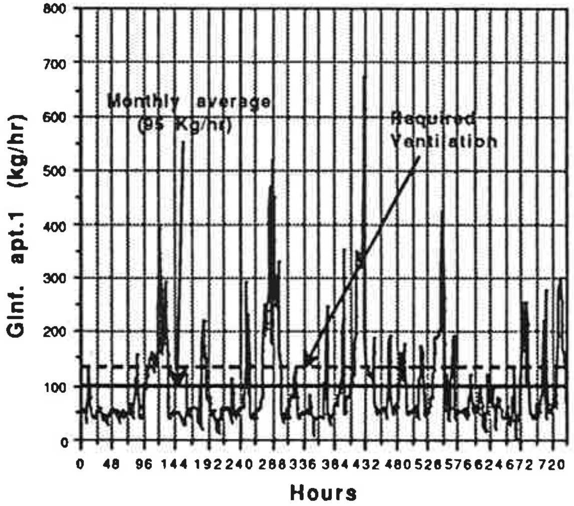

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DISCUSSION

Infiltration in israeli apartments has been shown to depend on the wind speed and the effective leakage area of doors and windows. The stack effect is usually small, due to the mild outside temperatures and is limited to low wind speeds. The energy losses also depend on the configuration of the staircase, the optimum solution being an open top staircase combined with a closed staircase door and windows.

Theoretically, considerable energy can be saved by weatherstripping the windows. However, at times of low wind speed, it is necessary to increase the supply of fresh air to obtain a reasonable IAQ. In the absence of mechanical ventilation, people have to open the windows for long periods, particularly in the inner coastal area during the night. However, even in the windy mountain region,effective weatherstripping aimed at reducing maximum peaks of energy demand can lead to poor IAQ during long periods. It appears that mechanical ventilation is the key to resolving the conflict between IAQ demands and the desire to save energy. The results of weather-stripping are, of course, different in the inner coastal zone, characterized by low wind during nights, and for the much windier mountain area, characterized by a large wind speed throughout most of the winter.

ACKNOWLEDGEMENTS

This work has been sponsored by the Ministry of Energy and Infrastructure of the State of Israel. Financial support of the Ministry of Immigration and Absorption is also acknowledged.

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EVALUATION OF MECHANICAL DOMESTIC VENTILATION SYSTEMS: THE FRENCH APPROACH

Jacques Ribéron, Jean Georges Villenave, Jean-Robert Millet

Heating, ventilation and air conditioning department, Centre Scientifique et Technique du Bâtiment, Marne la Vallée , France

ABSTRACT

In France, the ventilation must continuously supply fresh air to the habitable rooms and exhaust stale air from the service rooms. The ventilation rate should be adjustable to the needs of the occupants.

The requirements for the heat loss due to ventilation are set in the French regulation for new residential buildings. A simplified calculation method has been developed to take into account building characteristics (air leakage), ventilation systems and meteorological data. We describe how detailed numerical simulations, using CSTB tools, have been used to define such a method and to assess directly the performances of the innovative ventilation systems. Research is now going on for determining the best indoor air quality criteria, especially for DCV systems responding to airborne contaminants.

INTRODUCTION

Ventilation of buildings is necessary both to insure adequate indoor air quality and to protect the building itself against condensation and mould growth. On the other hand, ventilation rates must not lead to excessive energy consumption. Mechanical ventilation systems, which have been common in France since the sixties, comply with these requirements. These systems have been improved in recent years and new techniques such as humidity-controlled ventilation are widely used. This paper overviews the various mechanical ventilation systems in use in residential buildings and outlines their advantages and drawbacks. It also addresses the methods for efficiency assessment of these ventilation systems with regard to heat loss and indoor air quality.

MECHANICAL VENTILATION SYSTEMS

Since 1969, the French regulation on residential building ventilation is based on general and continuous air renewal. The air circulation in the dwelling must be arranged in such a way that fresh air comes into the habitable rooms (living room, bedrooms) by air inlets and contaminated air flows straight to the exhaust vents located in the service rooms (kitchen, bathroom, toilets). In this way, air is transferred from the rooms with a higher air quality to the rooms with a lower one (see figure 1).

Exhaust systems

The mechanical exhaust systems are composed of self-regulated air inlets, exhaust vents, an exhaust network and a fan to exhaust the polluted air out of the dwelling. The principle of a self-regulated air inlet is based on progressive modification of the air passage section of the inlet according to the pressure difference across the inlet. The change in section keeps the air flow constant over a wide range of pressure differences (see figure 2). These inlets, which have been in widespread use for more than fifteen years, help prevent uncomfortable draught when the wind pressure is too high [1]. Also, they help reduce heat losses due to cross-ventilation.