EFFECT OF SOME ARCHITECTURAL AND ENVIRONMENTAL FACTORS ON AIR FILTRATION OF MULTISTOREY BUILDINGS

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1. Introduction

In Hungary, and all over Europe, most of the residential buildings have natural ventilation, that is largely influenced by the air-tightness of the building, the weather, architectural features of the building and aerodynamical character of the environment. Two separate research projects have been carried out to size up these effects. The primary target of the first project was to compile a wind pressure coefficient /CP values/ data bank especially for filtration and natural ventilation calculations. The wind being one driving force of natural ventilation has an important role in the ventilation flow rates. Wind forces are usually presented in form of pressure coefficients /CP/ where the mean pressure at any external point of the building envelope is normalised by the reference dynamic pressure, in our case that measured at the eave height of the building. Pressure coefficient differences between the windward and leeward surfaces are characteristic to the acting wind forces. This first project gave on opportunity to analyse the effect of environmental factors on pressure coefficients.

The second project was a case study where the above factors were analysed by a simple single-cell ventilation and filtration simulation program. Here not only the environmental factors but architectural features of actual buildings were also considered, and seasonal values of ventilation heat demand were calculated.

2. Analysis of wind pressure coefficients for filtration calculations

Simulating 3 types of atmospheric boundary layers (Fig.1.) in the wind tunnel of the ÉTI, 4 types of block buildings, each in 4, 6 and 10-story versions, were exposed to the wind in 3 exposure situation (Fig.2.). Overall analysis of the measured pressure coefficients lead to the results that are roughly sketched on Fig.3. For all building types, heights upwind terrain types. Regarding the difference between pressure coefficients on the windward side (CP1) and on the leeward surfaces (CP2) the environmental and shelter effects are illustrated in Table I. with mean values and range limit estimates.

The exposure situations of Fig.2., though arbitrary, still represent Hungarian traditional and new settlements, and no significant variation of the above values was found if the tested 2·H spacing between the sheltering and exposed buildings decreased to H.

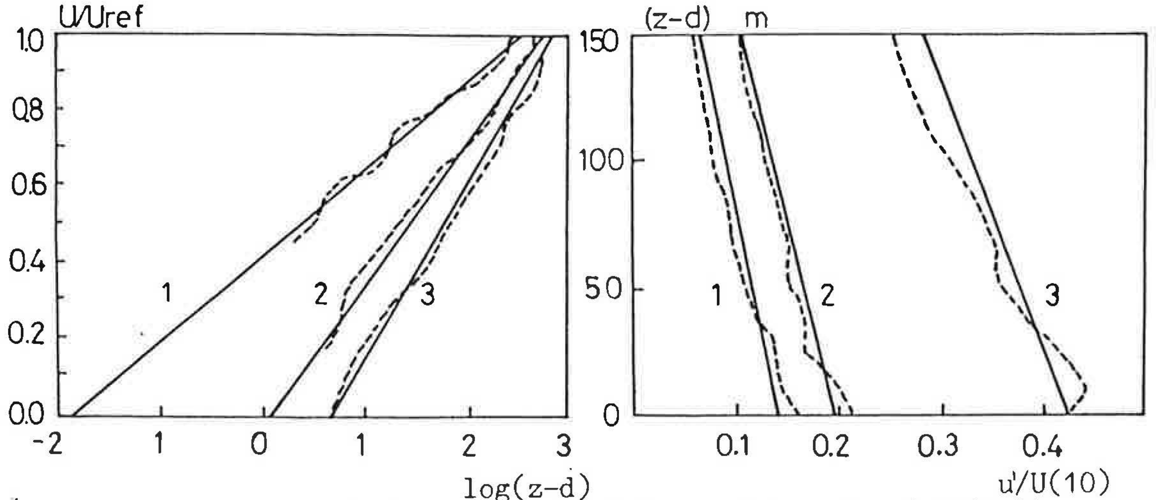

Fig.1. Mean wind speed (U/U_{ref}) and turbulence intensity ($u'/U(10)$) profiles simulated in the wind tunnel for flat (1), suburban(2) and urban(3) terrain types. Dotted line: measured values, full line: reference values.

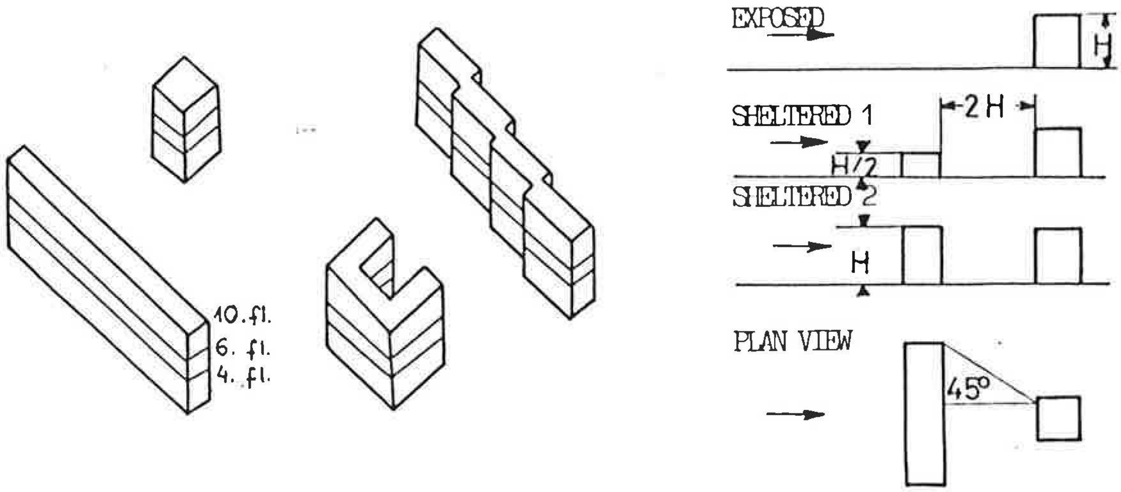

Fig.2. Tested house types and exposures

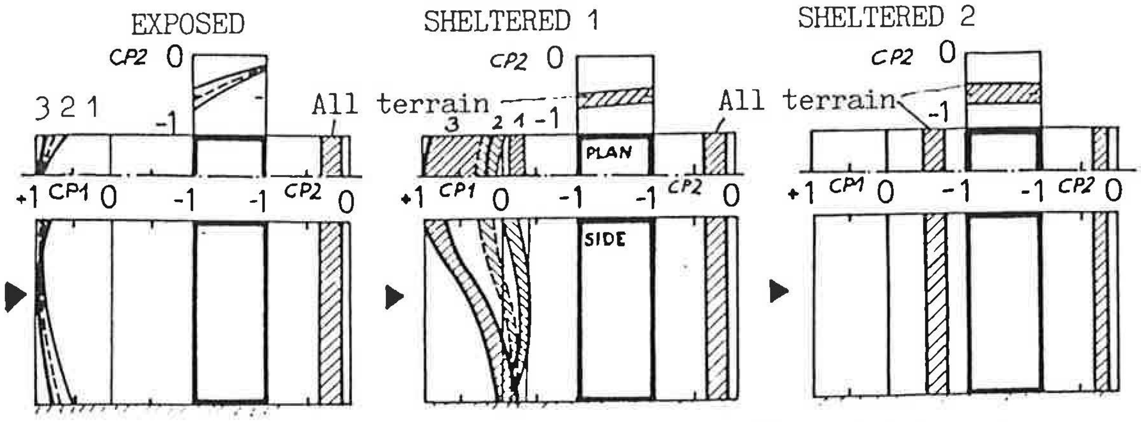

Fig.3. Variation of CP pressure coefficients with upwind terrain type and exposure at 0^{o} wind incident. (1) flat; (2) suburb; (3) urban terrain

Table 1. Characteristic effective wind pressure coefficients (CP1-CP2) for different upwind terrain types and exposures

Exposure	Upwind terrain type		
	Flat, rural	Suburban	Urban
Exposed, free	+1.3 ± 0.4	+1.2 ± 0.3	+1.2 ± 0.2
Sheltered 1	+0.1 ∓ 0.3	+0.3 ∓ 0.4	+0.6 ± 0.5
Sheltered 2	-0.3 ∓ 0.2	-0.3 ± 0.1	-0.3 ± 0.1

Using a single-cell simple simulation program for the calculation of the ventilation rate in a 10-storey building, as shown in the upper left corner of Fig.2. and taking the free exposure and flat upwind terrain as reference, the relative air-change rate for the other exposures and terrain types summed over 3 winter months are shown in Table 2. The air-tightness of the house was equivalent to N(50)=6.

Table 2. Relative total winter air-change rates of the same building in different exposures and environment

Exposure	Ambient terrain type		
	Flat, rural	Suburban	Urban
Exposed, free	1.00	0.97	0.95
Sheltered 1	0.74	0.70	0.68
Sheltered 2	0.66	0.67	0.67

The values of Table 2. are to demonstrate the order of magnitude of the effect of environmental factor for one single ten-storey building with internal staircase shaft, and an estimated average air-tightness.

3. A case study

In the preliminary design for a new housing development on a 0.7 km^2 empty land in a South-West district of Budapest two alternates were considered. The first consists of low rise, 3-4-storey buildings with saddle roof of 45 degree pitch, arranged into rectangular ensembles of corner and row elements, with low rise communal and commercial buildings. This version is very similar to traditional urban housing. The second version was made up of medium rise, 10-storey block buildings, typical in recently built housing developments in Hungarian towns, and the same communal buildings were assumed /Fig. 4. /. The houses and the assumed air-tightness classes of the windows are shown on Fig.5.
Main target of the sutdy was to determine the effect of the obviously different aerodynamic character of the two versions on filtration and ventilation heat losses. The method of the comparison was wind tunnel testing followed by computer simulation based on experimental data from the tests.

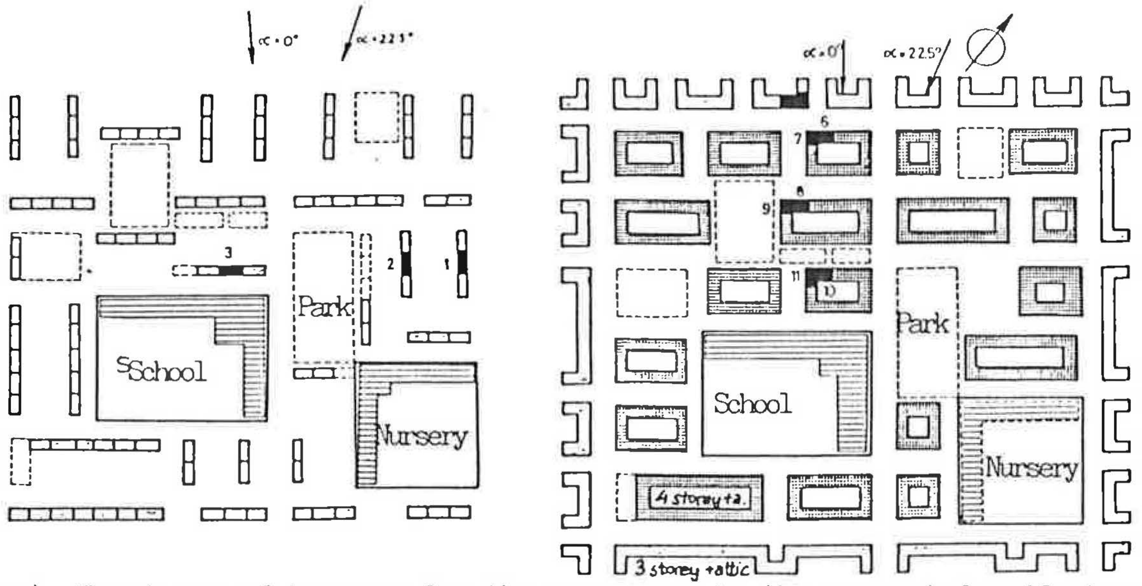

Fig.4. Two types of housing for the same area in the case study. 10-storey block version /left/, 3-4-storey, saddle roof buildings /right/. Black coloured elements were pressure tapped in the wind tunnel test.

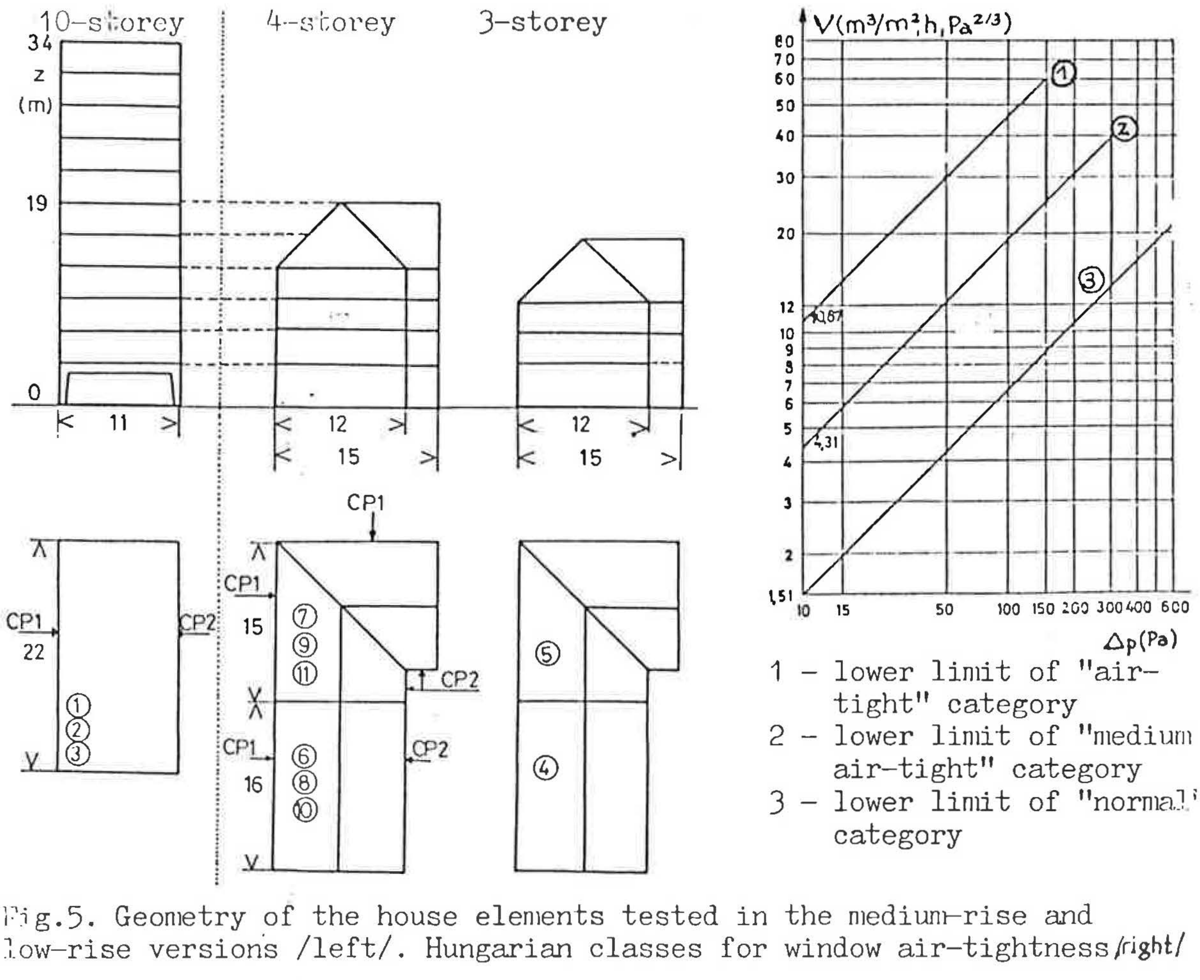

Fig.5. Geometry of the house elements tested in the medium-rise and low-rise versions /left/. Hungarian classes for window air-tightness /right/

For the prediction or estimate of the filtration and ventilation heat losses of the buildings simplified computer simulations can be used. Though other design data were reasonably assumed for the analysis, wind pressure data might not be assumed in an analysis that targeted the comparison of the effect of aerodynamical character of the two different versions. Therefore wind pressure measurements were performed on representative elements of the two housings.

4 corner and 4 row house elements of the low-rise version, marked with black (Fig.4. and 5.) were measured and 3 sections of the 100-odd similar ones of the medium rise housing. These were assumed to be representative in size, shape and position, and with an approximation the whole housing might be regarded as ensembles of multiples of these buildings. Besides, there was no wind direction of outstanding frequency of occurence, that made the estimate more reliable. Some results of the pressure measurements are presented on Fig.6. where CP1 and CP2 are assigned to parts of building envelope as shown on Fig.5. as well as wind direction.

Since the target was a comparison of the seasonal heat demand of filtration and ventilation a great number of runs became necessary. The meteorological input data were split into two parts. The frequency of wind directions and the joint probability of wind speed and outdoor temperature were separately treated. The resolution of this later was 3 m/s increments from 0,5 m/s to 9,5 m/s and 8^{o}C increments from -14^{o}C to $+10^{o}$C respectively. As parameters of the analysis 3 classes of airtightness of the windows, as shown on Fig.5., and 3 ventilation alternates were assumed. The 3 ventilation modes were:

a. filtration only + occasional intensive aeration trough windows to maintain a minimal air change of 0,5 ACH if filtration is not sufficient to do that;
b. filtration + permanent slight opening of a fraction of windows, as observed, analysed and described by LYBERG (1) + occasional aeration to 0,5 ACH;
c. filtration + controllable vents below each window as described by PENZES et. al. (2) + occasional aeration to 0,5 ACH.

For modes a.-c. one individual venting duct /a flue/, leading over the roof was assumed to each flat.
This approach did not counted for other leakages that might, and certainly would, occur in the actual buildings. Therefore it is reasonable to present the assumed overall air-tightness of the buildings in terms of N(50), that is the ACH at 50 Pa pressurization, to enable a wider comparison of the results. This is shown in Table 3.

Table 3. Assumed overall air-tightness of the simulated buildings in N(50) as function of window tightness class and ventilation modes

Vent.mode	Air-tightness class of the windows		
	1.	2.	3.
a.	2,8-3,2	3,6-3,8	5,6-6,2
b. (x)	3,0-(5,6)	3,7-(6,6)	5,9-(9,0)
c.	3,8-4,1	4,7-5,1	6,7-7,4

(x) - weather dependent aeration habits gave varying values

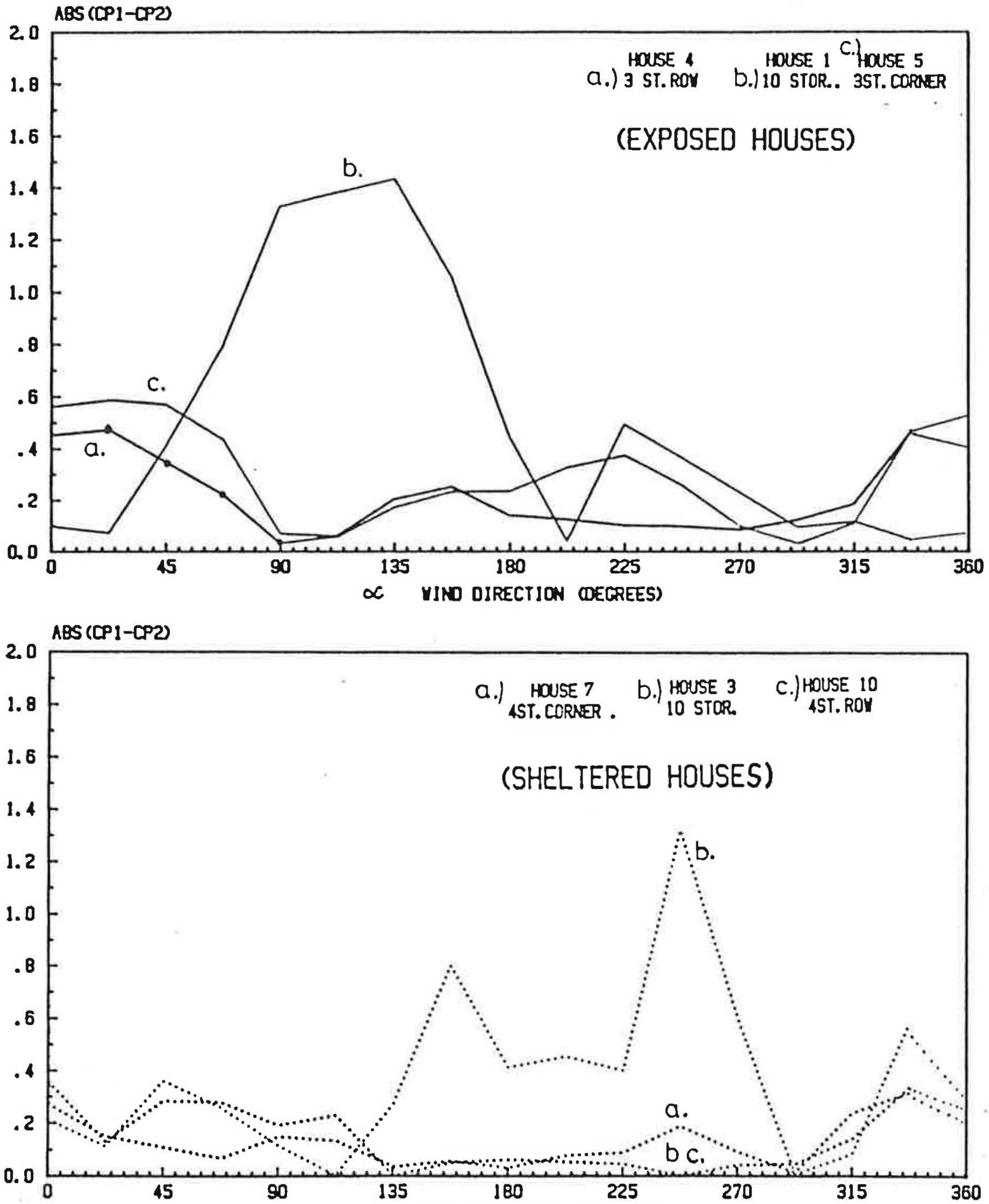

Fig.6. Variation of the ABS (CP1-CP2) with the wind direction for exposed and sheltered houses of the two housing alternates in the case study. House 3 on the lower figure is only partially sheltered(b.)

Typical examples of the results are shown on Fig.7., and Fig.8., for house 1,4,6 /see Fig.4.). House 1 is a section of a 10-storey block-type row-house in exposed position in the medium-rise version. House 4 and 6 are 3 and 4-storey pitched-roof row houses of the low-rise version. The bar charts show the seasonal heat consumption due to air-change normalized by the heat demand of a permanent 0,5 air-change hour as a function of the equivalent air-tightness classes. The values of $Q/Q_{0,5}$ are corresponding to three winter months from 1st December to 28th February. Any excess of $Q/Q_{0,5} = 1$ means excess air-change rate and heat loss over the necessary minimum.

Fig.8. shows the percentage of time when the air change rate is over the nec essary minimal 0,5 ACH. Similar charts might have been drawn on all the 11 examined houses. There were differences between houses of the same volume and leakage due to different degree of shelter in accordance with Table 2.

4. Conclusions

The following conclusions can be drawn from the project on variation of CP values and filtration and natural ventilation /winter/ flow rates with environmental factors

. the shelter of adjacent buildings has a much more marked effect on wind pressures and resulting ventilation rates than the character of the attacking wind,
. the order of magnitude of the architectural and natural environment on the ventilation rate of the same building is up to 35 % decrease if the reference situation is a free-standing building in a flat, rural terrain. This agrees with WIRÉN'S findings (3),
. the effect of the structure of the ancoming wind is only a couple of percent on the resulting ventilation rate, if the stack effect has about 50 % share in driving the air-flow through the building.

From the case study we concluded, that

. Of the two housing alternates the low rise version aerodynamically better matched the suburban environment. The lower houses at the perimeter create a harmonic transition to the surroundings. The pitched roofs also contribute to this.
. In cases where the total heat losses coincided with that of the 0,5 ACH, the filtration air change had never exceeded that rate, for no house, no meteorological situation. This means that either the air leakage was underestimated or, if the building turned out to be really as tight as that, the necessary minimum of ACH cannot be achieved without uncontrolled opening of the windows by the habitants, that in turn, would certainly increase the ACH above the necessary.
. In case of natural ventilation one has to compromise between the conflicting requirements of providing the minimal aeration all the time and avoiding excess ventilation. If the house is much to air-tight it is left to the habitants to provide the minimal air-change by occasional opening of windows. Controllable or semi-automatic air-vents may improve the quality of control.

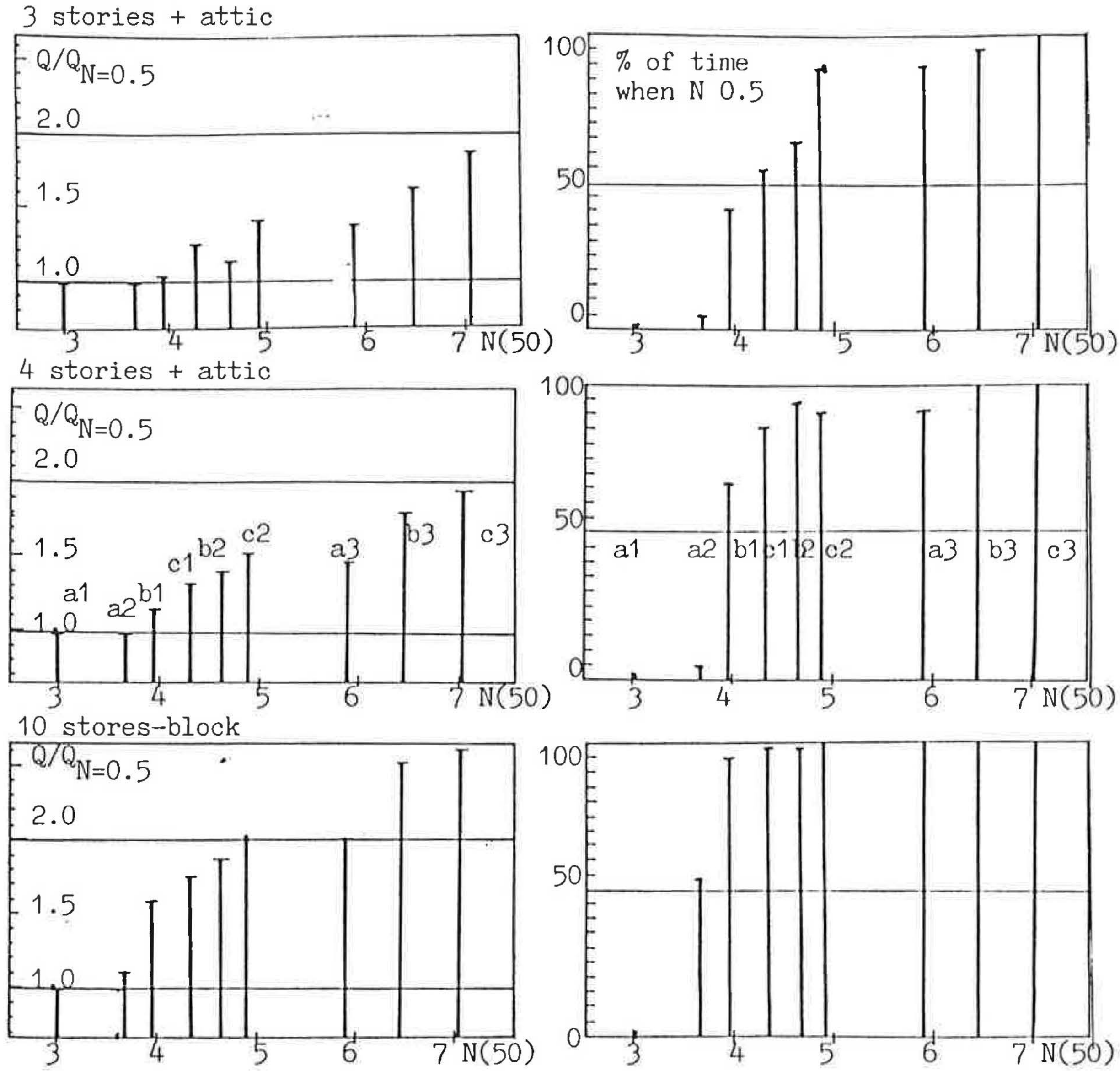

Fig.7. Effect of the equivalent air-tightness /N(50)/ on ventilation heat demand for three buildings of the case study /left/

Fig.8. Variation of % of time when N 0.5 without occasional aeration by the occupants /right/

5. References

(1) LYBERG,M.D.: Use of Windows by Residents. Proc.of Conf.Window in Build. Design Göteborg, Sweden, 1984 pp.: 344-349.

(2) PÉNZES,Gy.-SZALAY Z.: Complementary venting structure. Proc. of Conf. Window in Build. Design and Maintainance,Göteborg,Sweden 1984. pp.: 473-478.

(3) WIRÉN B.G.: Effects of Surrounding Buildings on Wind Pressure Distributions and Ventilation Losses of Single-Family Houses Part I., Bulletin of S.I.B., M85:19, Gävle, Sweden 1985.