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Test and Simulation of Air Flows in Multizone Dwelling Houses: the Alternative Method of Air Flows Prediction

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SYNOPSIS

One of essential problems of the present research related to building analyses is air flows determination. Air flows not only cause energy consumption but also influence air quality parameters, specially in a multizone (and high) buildings. The paper presents the main assumptions of the newly developed simulation method. The major departures are addressed which distinguish this alternative method from other multizone models. These include the principles of dividing a dwelling house into zones and the accomplishment of the simulation. This paper shows also the example results of simulation with their comparison to results of measurements in existing dwelling houses.

1. Background

The majority of existing models employ to a minimal degree results of tests used in existing buildings. It refers above all to models where individual flats are separated as individual spaces. In practice air flows and change for individual rooms can considerably differ [1]. Among other assumptions of existing models is the description of vertical shafts (staircases, natural ducts ventilation) as spaces with identical air parameters (for example - air temperatures). However, as obtained from measurements, these parameters can change with the heights of dwelling houses and the influence of forces acting [1, 2]. Simultaneously, these results can be used as examples of such division. Their division should be by conventional planes.
The above - mentioned conclusion constituted the basis for beginning the research study in 1990 that would give the mathematical model projecting a real inner structure and taking into account peculiarity of air flows across particular elements of this structure. In practice the task undertaken was to study the elements outside the area shaded with lines in the schematically presented in Fig.1 division of buildings into zones.

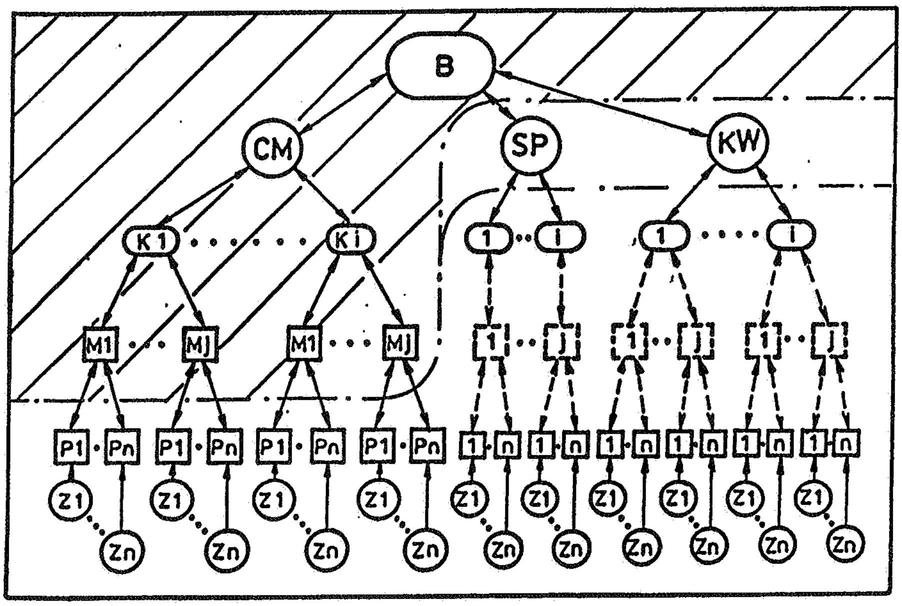

Fig.1. Structure of multifamily buildings (B - building; CM - habitable parts; SP - staircases; KW - ventilation ducts; K - number of floor levels; M - number of flats; P - number of rooms; z - external conditions)

2. New model conception and realisation of simulations

The basis of a new model conception were the above results of measurements in existing dwelling houses. According to them, the building is divided intọ two types of zones. First type zones are real spaces that result from existence of the internal partition walls. The second type constitute the zones that are the parts of communication shafts and natural ventilation ducts. Conventional zones are defined on the basis of various parameters determining air flows in vertical shafts of a building. Finally, the building is replaced by a spatial aerial system joining separated zones lengthwise the distinguished air flow paths. As a result, the internal space of a building (which is a continuum), is replaced by a set of discrete elements, that are mutually combined. This set creates a system that stands for a building and its discrete elements are nodes (look Fig.2). A node is described by the air capacity, focused in the middle of the zone, and the co-ordinates locating the

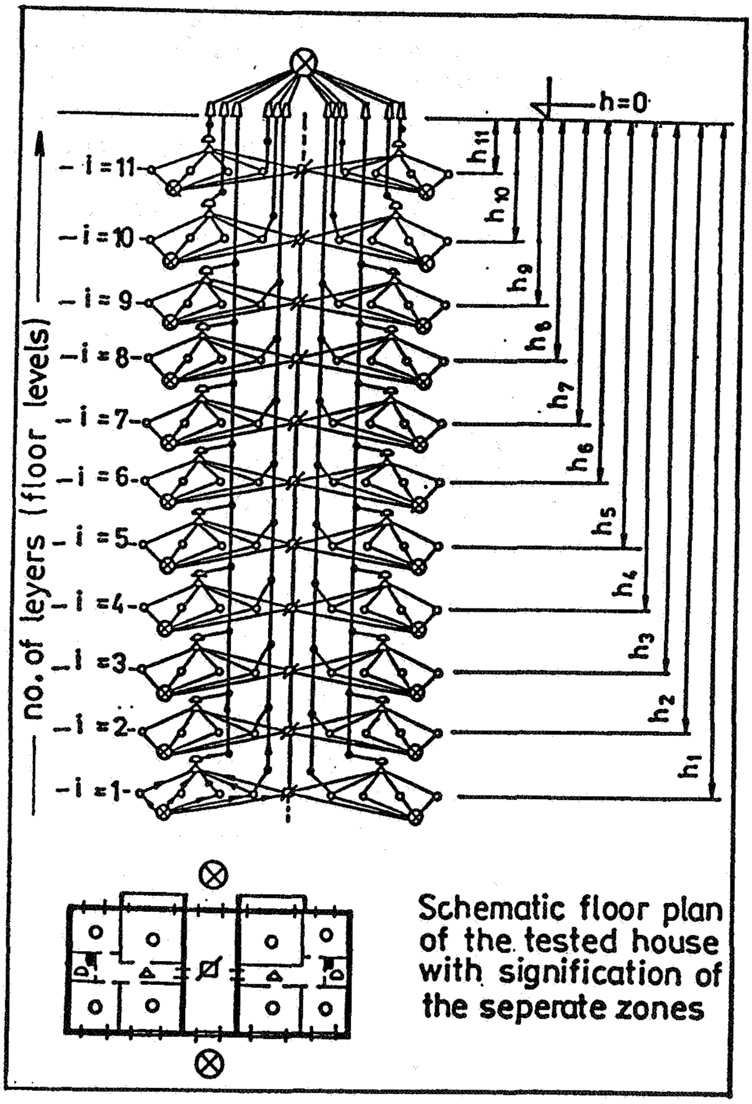

Fig.2.
The substitute system for one of the tested buildings (example)

zone in the building. The description of the system is completed with the input data fixing the state and the influence of the driving forces, and the air flow paths. Due to the lack of satisfying iteration methods for sets of non-linear equations (the large number of zones), the method of elementary balances was applied to solve the air flows in the system. This method accomplishes essential advantages. The main one is a possibility of physical interpreting of complex processes proceeding in complicated systems. This method has never been used before in the simulation of the air flows in multizone building. Therefore, in order to use this method, the iterative conception must be elaborated. This conception is presented in Appendix. For simulation of air flows in the substitute systems a new alternative computer program SYMVENT was elaborated. This program was presented in the previous works of the author [2, 3]. The program has many advantages; one of them is the possibility of constructing such a system that allows to simulate air flows detailed to any degree (i.e. agglomeration of inner spaces and driving forces, especially for declaration of wind pressure description).

3. The example results and comparisons

To illustrate the results of simulation, certain factors influencing the tested processes, such as the natural ventilation ducts, staircases, wind effect were sorted out. These results, presented below refer to a separated space (e.g. the real zones) located in 10-storey dwelling house.
By modification of the layer in the substitute system in respect of the ventilation ducts, the staircase division and also for detailed wind pressure coefficients determination (for each window), the new network system was obtained. Next, by making simulation in the conditions of measurements the total air change (e.g. WP(C)) from simulation and tests (by means of tracer gas method) were compared. Selected results of measurements (m) and their comparisons to simulation results (o) are presented on Fig.3. To estimate the correlation between calculated and measured air change rates, regression coefficients squares were calculated. This coefficient is about 0.89 for the system with modification (after modifications of the substitute system this coefficient was about 0.59). It is one basic proof of usefulness of the presented method.

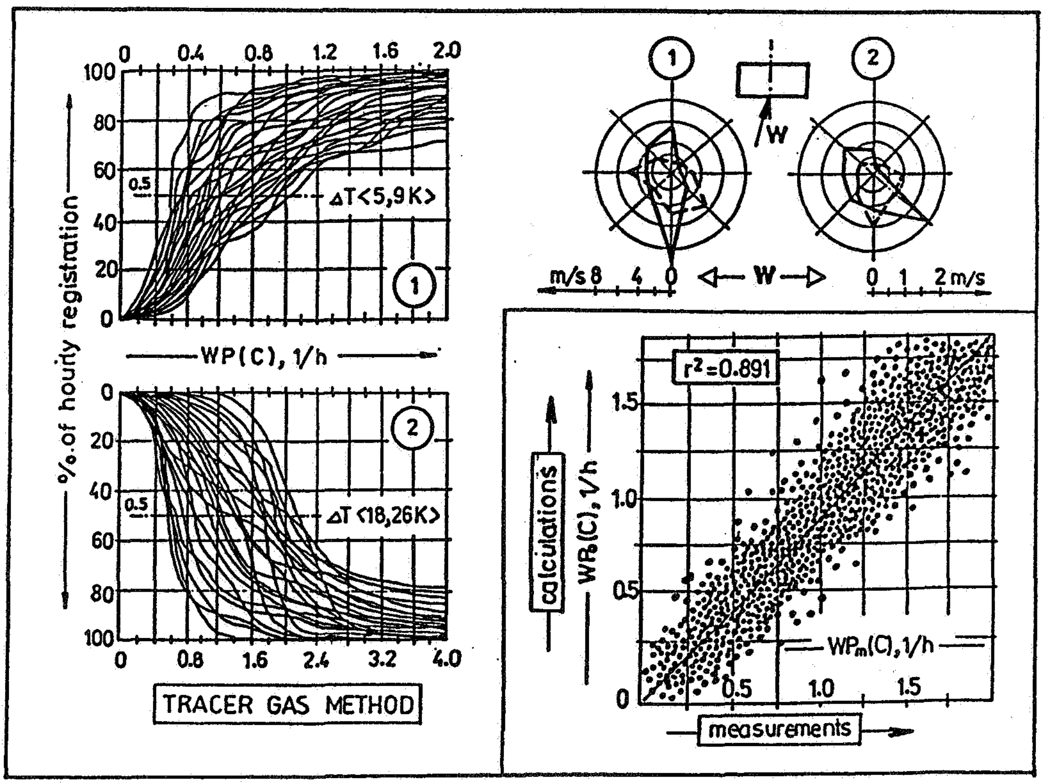

Fig.3. The results of tests of air change - WP(C) - in the rooms situated in one of the tested buildings and correspondence of calculated (o) and measured (m) WP(C)

Among the other advantages of this method, the attention was paid to the correctness of the prevailing division of building area. The example results of these comparisons are illustrated in Fig.4. In the middle part of this figure the changing both of acting forces and air exchange for two selected flats in one of the tested buildings are demonstrated (in the heating season according to the Silesian reference year). These results refer to the flats as a single zone. Around this middle, part, the particular air flows through separated rooms are presented (as a effect of SYMVENT used for the same parameter of the building and external climate). The more characteristic for comparisons of these results is the difference between both cases of simulation that may be substantial assumption for indoor air quality studies.

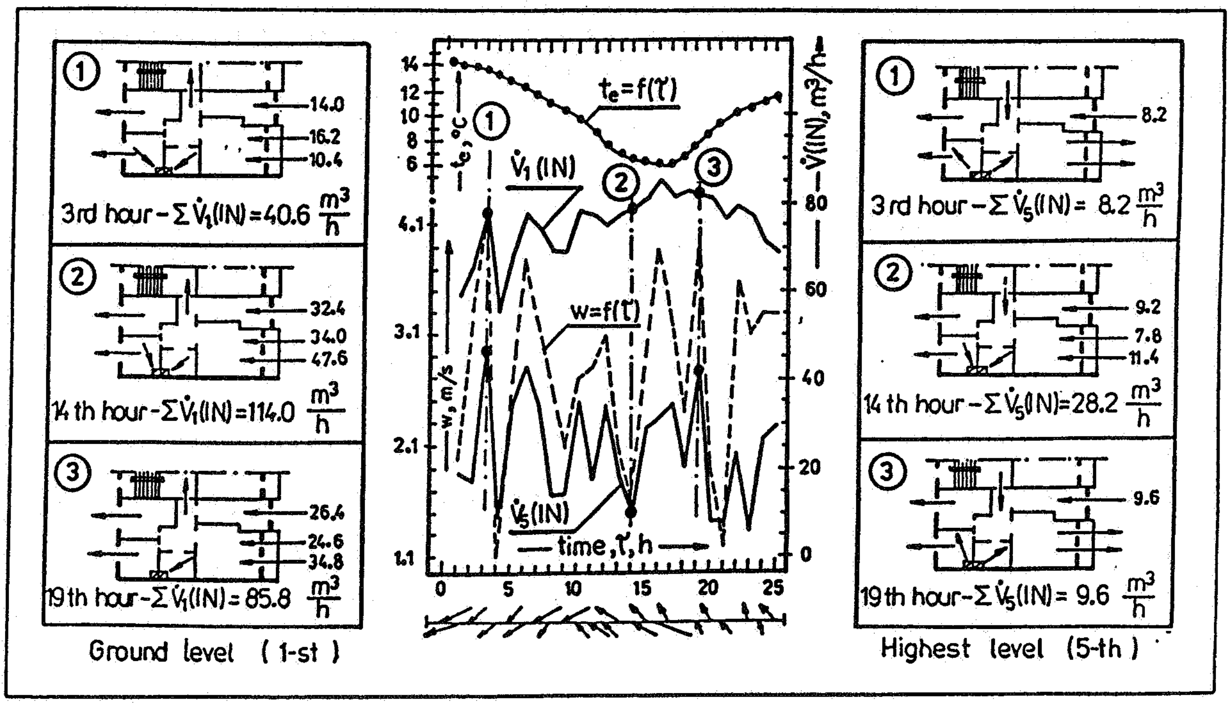

Fig.4. The results of simulation (description in the text)

4. Conclusion

Great possibilities both in the creation of substitute systems (with its descriptions) and the realisation of the simulation decide of the practical usability of the above presented conceptions. The possibility of both the physical (in regard to particular rooms) and the mathematical verification (in regard to other concepts) should also be mentioned among the advantages of the method. This method does not exclude the further development of investigation methodology.

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Appendix

<u>Description of the iterative solution method</u>

The initial assumption is that in separate zones (cubature V_{ji}) in moment of time τ pressure are p_i. The mass connection with neighbouring zones "j" is

$$\Sigma\, m_{ji} = \Delta m_i \tag{1}$$

where m_{ji} - are the mass of air inflowing (and/or outflowing) to the tested zone, and Δm_{ji} is the increment of air mass in this zone. The increment of the air mass in the constant volume (e.g.V_i) caused the increase of pressure in the zone "i". According to the mass conservation law, the left side of the equation (1) must equal zero in steady - state conditions. This conditions imply the increments of mass driven to zero for subsequent iterations (e.g. $\Delta m_i \to 0$). Apart from the influence of air density changes (error about 1÷2%) the mass balance can be replaced by air volume balance

$$\Sigma\, V_{ji} = \Delta\vartheta_i \tag{2}$$

where $\Delta\vartheta_i$ is the increment of air volume in zone "i" under the same conditions as in the relation to the increment of air mass.
All the air fluxes flowing through zone "i", because of the influence of neighbouring zones "j", are determined by equations

$$V_{ji} = S_{ji}\left|p_j - p_i\right|^{\alpha_{ji}} \operatorname{sgn}\left(p_j - p_i\right)\frac{p_i}{p_j}\Delta\tau \tag{3}$$

where S, α - air flow coefficients and exponents different for different element and flow paths, and $\Delta\tau$ - length of time division determined as difference $\Delta\tau = \tau_{k+1} - \tau_k$ (k - following iteration number). The realization of calculations depends on the qualification of air quantity rises (e.g. these increments of air volume) in each temporal steps $\tau_{k+1}, \tau_k, \ldots$. The addition of these increments of air volume to the zones cubature V_i caused the change of pressure in this zone. The increase of pressure can be expressed by

$$p_i^{\,*} = p_i\frac{V_i + \Delta\vartheta_i}{V_i} \tag{4}$$

where p_i * is the pressure in zone "i" for τ_{k+1}, after the single step of iteration.

For the system including great amount of zones, the essential condition was the introduction of changes referring to the length of time step. This problem was solved at assumption that the air flow would be simulated by the series of flowing basic air amount flows in such a way as not to cause essential changes of pressures. The most optimum acquired conditions of stable calculations are received, when the basic amount of air (elementary) does not exceed 10 percent of the smallest of zones. It is about 0.005 ÷ 0.010 m^3 for multifamily buildings and concerns the single time step. The input value of this step is equal to $1\cdot 10^{-6}$s, one can increase or decrease it repeatedly by choosing a proper command.

After putting in preliminary data, the flow of basic air amount in the following time steps through all the nodes of system take place; these conditions must be fulfilled for each zones.

$$\Sigma\, V_{ji} \to 0 \qquad \text{for} \qquad \begin{cases} k = 0, 1, 2, \ldots\ldots \\ \Delta\vartheta_i^{\,k+1} \le \Delta\vartheta_i^{\,k} \end{cases} \tag{5}$$

The foregoing method with its original assumptions and supplements was used in the computer program SYMVENT. The source code of the program was written in Turbo Pascal V.5.5. The code consists of the main program and 6 modules comprising the procedures of starting calculations, reading and recording files with the description of the building structure.