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EVALUATION OF NATURAL VENTILATION IN TRADITIONAL JAPANESE DWELLINGS AND ITS POSSIBILITIES OF TRANSPOSITION

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ABSTRACT *This paper deals with the relationship between the characteristics of ventilation and the architectural features on three types of Japanese houses representative of the recent historical evolution in the building of dwellings : a traditional well-ventilated house in a rural area, a typical postwar house with a central corridor and a multi-family house of high air-tightness in an urban area. The investigations were carried out based on 3-D numerical air flow simulations with realistic wind conditions. The results obtained by the simulations were correlated with peculiarities of the site and architectural features of the building to explain the observed indoor ventilation behaviors of the houses. Some observations are made in the conclusion for taking ventilation into account in an overall environmental approach, based on criteria for realcomfort and constraints related to different life styles.*

1. INTRODUCTION

Since the first air-conditioning system has appeared in the middle of this century, rapid technical progress has enabled a very comfortable indoor environment by means of mechanical controlling [1]. However, from an urban and environmental point of view, these technical solutions to create comfort have involved many problems like the production of carbon dioxide, air pollution and the phenomenon of a heat-island. This present situation is the result of various factors : ways of life, evolution of comfort standards, progress in technical equipment, and architectural or urban constraints. The result is that architecture progressively seems to cut itself off from its natural environment.

To illustrate this evolution of the design of buildings relative to the parameters of climate, the present research focuses on the way of processing the problem of natural ventilation in the Japanese dwellings. Traditionally, in the central parts of Japan, natural ventilation was a passive solution for improving indoor comfort in summer and architecture might take this potentiality into account. Nowadays, buildings have high air-tightness and use air-conditioning systems. How buildings respond to natural ventilation was differently efficient in the course of this century in Japan, and to determine which architectural elements are involved in it, three typical and historically representative Japanese houses were chosen for an investigation of aerodynamics.

The investigations were carried out with the help of numerical simulations on a traditional folk house (about 1900) in a rural area, on a typical house from the postwar period (about 1950) in a suburban area and, finally, on a modern house (about 1980) in an urban area.

The 3-D numerical aerodynamic calculations of ventilation were based on the geometrical modeling of the houses and the corresponding wind conditions in direction and velocity were established to constitute a realistic context for the considered zone. The results obtained in each model were correlated with peculiarities of the site and architectural features to explain the observed indoor ventilation behaviors of the different houses. In conclusion, some ways of research are proposed, for (re)introducing natural ventilation in today's buildings.

2. CHARACTERISTICS OF THE THREE TYPES OF HOUSES

After reviewing many types of Japanese dwellings [2], three typical houses were selected as significant models for simulating natural ventilation:

Type 1: One of the most popular Japanese houses up to about 1900, traditionally farmhouses with a large yard; The rooms are partitioned by sliding screens called "Fusuma". Removing the screens, this type is well-ventilated and also comfortable in a climate of high humidity. Inversely, rooms have little independence.

Type 2: Type with central corridor, it appears after 1950, in the typical residential areas. With the corridor in the direction east-west, the habitable rooms are independently arranged in the south areas; and equipment rooms are installed in the north ones.

Type 3: Contemporary house in an urban built-up area. This type is designed for high density areas, to be closed off from the outside environment and to be opened up around a courtyard. It benefits from high thermal insulation and high air-tightness for the efficiency of air-conditioning. Openings are thus very small. The simulated house consists of two stories inhabited by two families; calculations were limited to the first (ground) floor only, considering the windows in a closed position on the second floor.

The main specifications of each model are shown in Table 1 :

Table 1

Model House	**Type 1**	**Type 2**	**Type 3**
Style	Detached House	Detached House	Detached House
Structure *Floor Area*	Wood One-Story 77.76 m2	Wood One-Story 73.71 m2	Concrete (GF) Two-Stories 77.76 m2
Period *Environment* *Density*	1900 Traditional Rural Very Low Density	1950 Post-War Suburban Area Middle Density	1980 Contemporary Urban Very High Density
Architectural Characteristics	Four-Room type : no independant rooms partitioned by sliding screens (Fusuma)	Central-Corridor type Rooms towards south Services north	Closed type against exterior and open to a courtyard

Ventilation Characteristics	
Equipement	
Openings Ratio */ walls area* */floor area* */ volume of rooms*	

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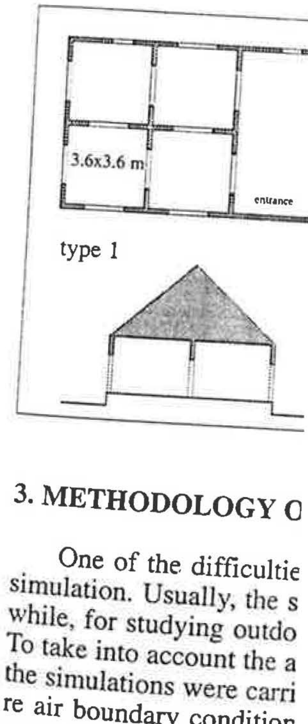

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Type 3
Detached House
Concrete (GF) Two-Stories 77.76 m2
1980 Contemporary Urban Very High Density
Closed type against exterior and open to a courtyard

Ventilation Characteristics	Very open No insulation	Open with ventilation	High Air-tightness Mechanically ventilated
Equipement	Very Limited Small carbon heater	Limited Oil Heater	Air-Conditioned with automatic controlling
Openings Ratio			
/ walls area	0.217	0.125	0.078
/ floor area	0.271	0.165	0.122
/ volume of rooms	0.100	0.061	0.051

Conditions of opening of doors and windows for simulations were considered as expressed in the schematic plans of Figure 1. The entrance door was regarded as in the closed position throughout the calculations. The south façades are facing the wind.

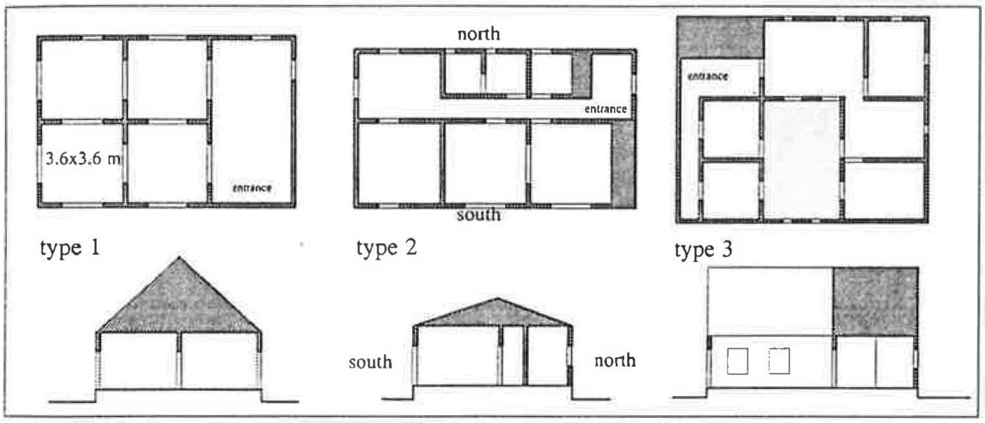

Figure 1

3. METHODOLOGY OF SIMULATION

One of the difficulties of the analysis of indoor aerodynamics is the bounds for simulation. Usually, the study of indoor air movements are limited to the inside area while, for studying outdoor conditions, the outside of buildings are only considered. To take into account the aerodynamic incidence of the building on indoor ventilation, the simulations were carried out simultaneously in indoor and outdoor areas, therefore air boundary conditions at the different apertures of the building result from the general outside air movement and pressures.

Wind conditions : In this study, each house is supposed to be situated on a flat plain without representations of natural and built surroundings, inside a numerical wind tunnel. The approaching wind is the same in each simulation and comes from the south, the prevailing wind direction in summer in Tokyo with a mean velocity of 3m/s at height of 10m. The profile of the wind imposed at the entrance of the tunnel is assumed to follow a power law in which the power exponent equals 0.28.

Mode of Calculations : To calculate the three directional components of the air inside and around each building, the CFD application code N3S, elaborated by EDF

[3], was used. The resolution is based on a Finite Element Method and a k-e turbulent model. The flow is supposed to be iso-thermal. The same friction conditions (wall function) are applied as boundary conditions on all surfaces (soil, inside and outside walls, roof).

Mesh discretization : For each simulated case, a 3-D mesh was realized with tetrahedral elements with a density stronger inside the house, as shown in Fig. 2. The relatively important number of nodes is about 80 000 for each house.

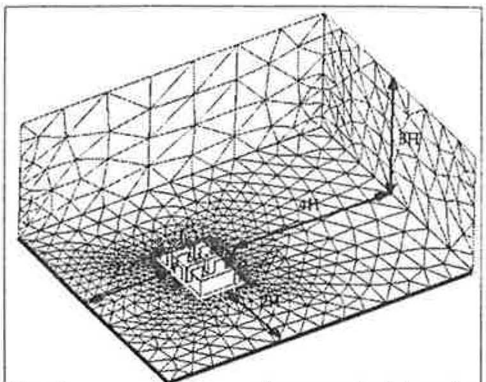
Fig. 2 the numerical domain

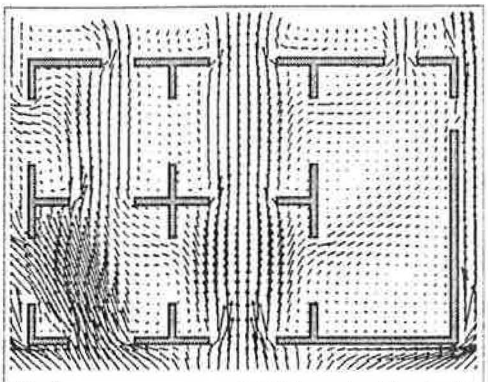
Fig. 3 type 1 : velocities h=1m

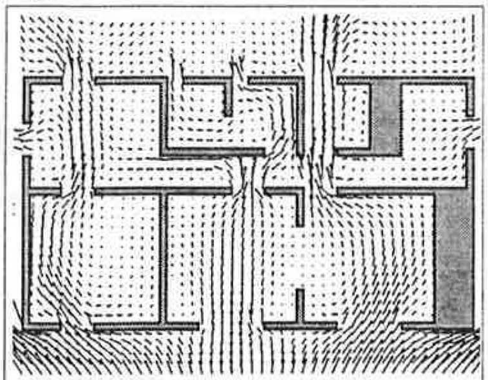
Fig. 4 type 2 : velocities h=1m

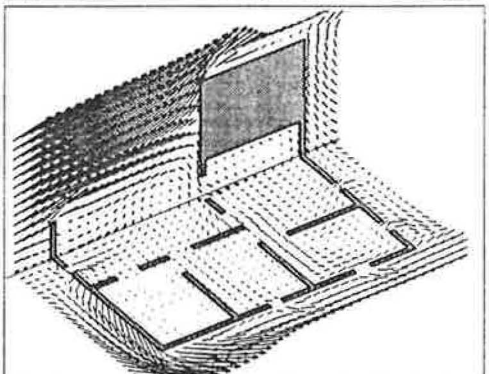
Fig. 5 type 3 : velocities h=1m

4. RESULTS OF THE AIR FLOW SIMULATIONS

Type 1 (shown in Fig. 3), the rural house, represents a typical cross ventilation example due to the large openings symmetrically disposed on the two main façades. However, three zones can be identified : the central one with a direct flow throughout; the left one with a deflected flow towards the lateral openings of the west façade, strengthened by the deviated direction of the wind around the building; and the right one, less ventilated, due to the closure facing to the wind, that corresponds to the closed entrance door. The air velocities at the two southern openings reach 2m/s, providing a high level of ventilation inside the rooms (about 1.5m/s in the living spaces). No important lateral interactions (in east-west direction) can be seen because of the

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5. CONCLUSION

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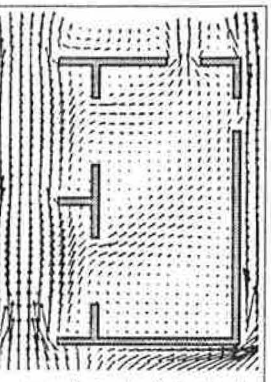

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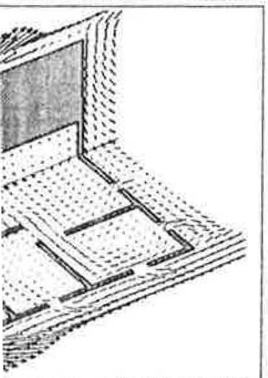

type 3 : velocities h=1m

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relatively strong crossing air flow and of the inside uniform pressure. Therefore, the east space of the kitchen and the entrance has a poor level of ventilation. We may notice that there is no significant variation of the air flow according to the height, so the level near the floor is well ventilated, which is important for the Japanese way of life.

The obtained air velocities are relatively high for insuring strong ventilation conditions in summer. However, the peculiarity of the house with its sliding panels that can be moved and adjusted according to the desirable level of air, enables an interesting flexibility for managing air flow. In addition, the rural area of low density in which this kind of house is located, benefits from pleasant summer vegetation.

Type 2, the house with the central corridor (Fig. 4) represents a relatively well ventilated solution according to a different functional principle from the one observed in type 1. The windward openings are large whereas they are reduced on the leeward façade, implying a closing effect due to differential pressure between the two façades. This different level of pressure produces concentrated air flow through the doors between the south rooms and the corridor. The incoming velocity, about 0.7m/s, is much less than that in type 1 and the inside mean velocity is an insensible level of only 0.2 to 0.3m/s. As mentioned in type 1, the air flow deviated nearby the corners of the windward façade creates local effect that interacts with the positioning of the windows. It is the reason why the room on the west side has an heterogeneous ventilation. Finally, the different size and disposal of windward and leeward openings involve a internal profile of air velocity, with low velocities near the floor level.

The arrangement of rooms along the corridor enables a differentiated control of the ventilation for each room, for example by closing the corresponding doors. The relatively low level of ventilation observed in this simulation may be, in reality, even lower due to the medium density of the built area around this type of houses.

Type 3 shown in Fig. 5 presents an extremely lower level of ventilation compared to the two first types, because of poor windward opening areas. The wind mainly hits the south façade at the second level and splits into two main flows. One passes over the house creating an important depression area and a recirculation zone behind the house; the other is deflected downwards to the south openings of the north rooms. The incoming air results in this deflected effect more than that of the flow passing through the slits of the courtyard windward wall because the strong velocity flow in the narrow apertures is rapidly diffused in the courtyard. In the north room, the incoming air velocity is about 0.5 m/s in downward direction, therefore vertical recirculation can be seen in this room, with lower velocity in the upper zone. The air of this room deviates to the east adjacent room that benefits from two windows on the north and the east side with the strong negative wind pressure. On the other hand, the side wings of the house have a very poor level of ventilation.

The overall disposition of rooms around the courtyard does not benefit from the natural indoor ventilation; however, it is interesting to note here the role of the upper volume to produce the main air stream for the ground level dwelling.

5. CONCLUSION

These aerodynamical simulations reveal clearly the differentiated ventilation efficiency in response to the variations in plans of the houses representative of 1900, 1950 and the present and also in response to the values of opening ratios shown in Table 1. These results seem to express, over time, a more and more "closed"-ness of the dwellings, as if the progressive use of mechanical means to assure the indoor comfort puts apart the house from its natural environment. However, these first conclusions, uniquely based on natural ventilation, are to be formulated considering the various factors in case of designing dwellings.

Thus, even if the traditional Japanese houses are well ventilated, they do not provide very good indoor conditions in winter; besides, they do not adhere to the present thermal criteria and do not adapt to the way of life today. Inversely, the less ventilated house of the 1950's, with its internal layout and its south exposition, seems to apply bioclimatic principles, providing a correct behavior in accordance with seasonal conditions. The contemporary house cannot acquire naturally well ventilated conditions as a consequence of insufficiency of large openings facing the wind. But the choice of mechanical ventilation may be one of the only desperate solutions for the houses in high density and polluted urban areas.

In current conditions, it seems there are no direct transpositions of ventilation arrangements observed in the traditional houses. Obviously, interesting principles are used in these examples, such as the inside layout providing flexibility with sliding panels and disposal of openings according to the wind, may be reintroduced in the present design of buildings. But a global new approach is necessary for designing integrated and sustainable solutions. Taking ventilation into consideration cannot be an exclusive preoccupation; but multiple factors and environmental constraints must be simultaneously considered. Therefore, an integrative solution for natural ventilation requires :

- to be able to diversify the different architectural ways and means to improve indoor ventilation, and beyond the only usual arrangements of windows in façades;
- to be able to provide comfortable thermal conditions throughout the year, resolving often opposite or contradictory requirements according to the seasons;
- to be able to design urban environments that deal with the problems of pollution, noise and climatic conditions including the use of outside public spaces and creation of interesting surroundings for dwellings.

The often corrective solutions proposed by technological improvements and the systematic use of air-conditioning devices must not inhibit investigations for taking into account parameters of the environment in architectural and urban design.

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THE
LIGHTING

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ABSTRACT

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1. INTRODUCTION

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