Influence of Ventilation Mode on Passive Cooling Effect - a proposal of Flex Vent System -

Yuichiro Kodama¹, Koji Takemasa², Futoshi Miyaoka¹ and Chikako Hasui¹

¹Kobe Design University, Kobe, Japan
²Hiroshima Jogakuin University, Hiroshima, Japan

ABSTRACT: Ventilation is one of the most important techniques for cooling. Especially in a hot-humid climate like Japan, cross ventilation has been considered as almost the exclusive method for cooling in traditional light structure houses which have little thermal mass inside. On the other hand, the effect of night ventilation is clearly recognized in buildings that have heavy thermal mass inside since passive design came to be established scientifically. However the cooling effect depends not only on the building design and the climate condition, but also on the mode of ventilation -when and how the ventilation is operated. In this paper, is proposed the Flex Vent System: a ventilation mode where plenty of natural ventilation operates during the period: 18°C < AT <27°C (AT: ambient temperature) throughout the year. Next, the passive cooling effect is discussed based on the results of a series of parametric simulation studies using a design tool that was developed by the authors. The cooling effect is verified in two ways: 1) hourly indoor temperature fluctuation without air-conditioning and 2) monthly cooling load of air-conditioning throughout the year.

Keywords: cooling effect, passive design, ventilation mode, thermal mass, saving energy

1. AIR-CONDITIONING AND PASSIVE COOLING

Air-conditioning, the powerful indoor-climate control system, is popularizing rapidly all over the world. As the widespread use accelerates, housing design itself is changing drastically, and buildings are being designed to adapt to the pre-set air-conditioning system and to minimize the cooling load of air-conditioning. This kind of change can be regarded as the evolution of housing design; however, it can also be found that this design strategy at times contradicts with that of passive design, especially in passive cooling. Ultimately, it is desired to integrate the two but, in principle, it is preferable that passive cooling ideas have priority over air-conditioning strategies because passive design is advantageous in creating a living space and communities which are responsive to the environment. It may be possible to build an energy-efficient AC system in a space which is completely isolated from the natural environment; however, this kind of environment may not be desirable for the sustainable community in the future.

It is the final goal to minimize AC load in hot-humid climate with design concepts as following:
1) Responsive to social- and natural environment,
2) Porous form of building and
3) Interface between indoor- and outdoor space.

2. SETTING OF BUILDING CONDITIONS

In the Flex Vent System, the basic principle is that the house has windows open and plenty of ventilation which operates during the period: 18°C < AT <27°C (AT: ambient temperature) throughout the year. In other words, windows will be adjusted only when they feel too cold or hot.

The model house and its building conditions for the simulation are shown in Fig.1 and Tab.1. It is a model of a wooden shingle house with a floor area of 80m². The house is well insulated and thermal mass and shading devices can be added optionally.

Figure 1: Simulation Model
In the Flex Vent System, the air change ratio was always 30 times/hour in the ventilating mode and 0.5 times/hour in the other mode. Air conditioning operated when the room temperature exceeded 27°C (DT=27°C) with the air change rate (ACR): 0.5 times/hour (Fig.2). The humidity was not considered in this simulation.

3. SIMULATION RESULTS

3.1 Effects of shading, thermal mass and ventilation mode

The simulation was proceeded with PC, an interactive design tool which was developed by the authors. The thermal performance was predicted by this dynamic simulation and the simulation results were shown with indicators such as hourly temperature fluctuation of indoor-air, surface- and inner temperature of specific building components and hourly auxiliary heating/cooling load.

The location was Tokyo. The weather data was easily selected from a database prepared for 420 sites in Japan.

Some output data of the simulation in August (Tokyo) is shown in Fig.3-Fig.5. Fig.3 shows the result of the model with as little thermal mass as the normal wooden house and no eaves for shading. In the daytime and evening when the ambient temperature exceeded 27°C, the room air temperature without AC rose up to 35°C even when Flex Vent System was introduced. When no Flex Vent was introduced, the cooling load in August increased by 5%. The effect of Flex Vent was not substantially remarkable in July and August; however, it became more noticeable in...
September because Flex Vent worked effectively in the daytime and at night.

Fig. 4 shows the result of the model with eaves (50cm depth). The fluctuation of room air temperature without AC showed some improvement by Flex Vent but it was insufficient. The eaves reduced 25% of the cooling load in August.

Fig. 5 shows the result of the model with eaves (50cm depth) and added thermal mass. The passive cooling effect was clearly observed, where the minimum ventilation was operated in the daytime to discharge overheated air and the maximum ventilation was operated at night for cool air intake. The thermal mass inside the house worked well to store "night coolness" for the next day.

AC was necessary only in August and almost 80% of the annual cooling load could be reduced. The room air temperature without AC was 27.7°C at its peak, 26.5°C on average and 24.5°C at its lowest through three typical days in August. The fluctuation was nominal and almost no AC was necessary.

Fig. 6 also shows the effect of the Flex Vent System on reducing the annual cooling load. Fig. 7 shows the effects of the ACR at the ventilation mode in the Flex Vent System. As the ACR increases, a notable reduction of annual cooling load results in the model with heavy thermal mass. In the model with light thermal mass, this effect was insignificant.
3.2 Influence of boundary temperature setting of flex vent system

In the Flex Vent System, plenty of ventilation operated according to the ambient temperature which was set previously. In Fig.8, the fluctuation of room air temperature shown when the setting temperature boundary (18°C < AT < 27°C, AT: ambient temperature) was changed. The effect on monthly cooling load is shown in Fig.9. There was no remarkable difference between the boundary of 18°C < AT < 26°C and that of 18°C < AT < 27°C. The reason why the latter has slightly higher performance may be that the wider range allowed more ventilation for cooling.

4. CONCLUSION

In the Flex Vent system, minimum ventilation operates in order to discharge overheated air when it is hot outside and plenty of ventilation operates to take in cool air when it is cool outside. In conclusion, it is shown definitely through parametrical simulation

Flex Vent System reduces the annual cooling load remarkably, especially in houses with thermal mass inside.
studies that this system can remarkably reduce the annual cooling load, especially in houses that have enough thermal mass inside. (Fig.10) This simulation studies were carried out under the climate in Tokyo. Further studies in a different climate will be carried out in the next step. It is essential to develop passive cooling design strategies toward a sustainable future.

5. APPENDIX - Flex Vent at the case study house

The case study house, privately built, is located on the riverbank of the Yoshino river, crossing steep mountain valleys in Shikoku island, Japan. The site slopes down slightly to the south and is covered with chestnut woods. Being receptive to rich natural surroundings was a wish of the client's family who hoped to live close to nature, feeling the changes in seasons, weather and time.

The main floor was raised to minimize the earthwork, resulting in fewer footprints on the original landscape. This was done to avoid the risk of river floods as well. The building, east-west axis of rectangular shape, has large south windows designed as “solar glazing” and small north windows. The house is well insulated and has thermal mass inside that works as cool storage in the summer as well as heat-storage for the direct gain heating system in the winter.

This building is heated mainly by a passive solar system and cooled by night ventilation. It has an auxiliary floor heating system and no AC system. The ventilated air volume is adjusted manually by controlling the windows according to the outdoor climate condition.

The climate of this region is temperate. In the winter, it is sunny and relatively cold in the mountain valley and the mean air temperature is 2°C in January. In the summer, it is hot and humid and the mean air temperature in August is 26°C, but the temperature often drops down to comfort level at night.

Fig.13 shows the passive cooling performance when the above mentioned Flex Vent System is introduced. The Flex Vent effect in this house is obviously found.

![Figure 11: Lower floor plan](image1)

![Figure 12: Upper floor plan](image2)

![Figure 13: Room temperature fluctuation with Flex Vent System (simulated). August, Motoyama-Kochi.](image3)

![Photo 1: A view from south](image4)
REFERENCES


* ‘SOLAR DESIGNER’, http://qcd.co.jp/