ɛs. Since it is not ventilated and
:at of the attic contributes to the
ıce it facilitates convective heat

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air may flow.

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167.

allowing the use of his house
data.

THICK INSULATION CHANGES THE MEANING OF CROSS VENTILATION

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ABSTRACT Although most new houses in the Hokuriku region are equipped with air conditioners, some people living in farmhouses still feel that cross ventilation is more desirable. Comparative measurements were made between a new house and a farmhouse. Simplified simulations were also carried out to clarify the effects of thermal insulation and earth floors on cross ventilation in summer.

The role of thermal insulation in hot and humid regions is different from that in cold regions, where there is a large difference between outside and inside air temperatures. Insulation against solar heat by the use of awnings or "sudare" on windows and thick roof insulation is important for effective cross ventilation.

Solar-heat insulation greatly enhances the cooling effect of an earth floor, and slight changes in air movement due to cross ventilation generate a comfortable feeling. These combined effects would enhance the wisdom of farm inhabitants, and would also add a regional feature to their houses and life-style.

1. INTRODUCTION

In Japan, there are many traditional houses in which it is comfortable to live in summer. We visited one such traditional house in the Hokuriku region, and carried out measurements of the thermal environment inside the house. Most of these traditional houses have devices for thermal insulation and an earth floor, which enable the inhabitants to live comfortably. These devices have been used for a long time all over Japan, and they add a regional feature to each house.

In this study, we investigated the efficacy of cross ventilation, and used simplified simulation to clarify the effect of thermal insulation and earth floor on cross ventilation.

2. HOUSES AND LIFESTYLE IN HOKURIKU REGION

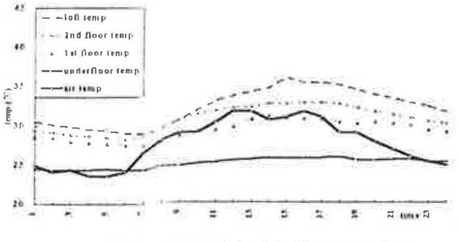
2-1 MEASUREMENTS OF THE THERMAL ENVIRONMENT

Many traditional farmhouses and "machiya" can still be found on the main island of Japan. Although these houses are not equipped with air conditioners, the inhabitants don't seem to feel any unpleasantness in summer. This is thought to be due to the cooling effect of cross ventilation.

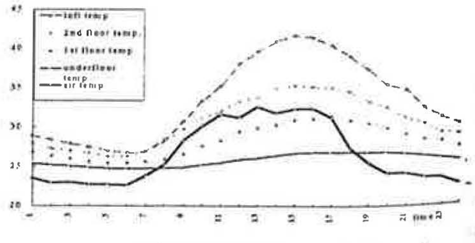
We conducted measurements of the thermal environments in a "machiya" and in a modern house in Hokuriku region to clarify the effect of cross ventilation. Thermo-recorders (ondo-tori RH) and a radiometer were used for the measurements. We asked the people living in the houses what they felt and thought about the comfort of their homes. Even though inhabitants of these houses know through experience that their houses are comfortable, they probably can't understand the reason why the hoses is comfortable. If it were not for the technique that keeps the reason, the wisdom would be forgotten. To avoid such a mistake, we think the inhabitants themselves must understand the characteristics of their houses and make efforts to make the most of them.

2-2 DIFFERENCE BETWEEN "MACHIYA" AND A MODERN HOUSE

The "machiya" which has lattice windows and earth floors, is one of the Japanese traditional houses. We compared the environment of a "machiya" with that of a modern house. <Fig.1> shows the variations of indoor and outdoor temperatures for a "machiya" on Aug.6, 1995. The indoor temperatures are not a great deal lower than the outdoor temperatures. However, the range of temperature variations is less than that of a modern house. This indicates that an appropriate amount of cross ventilation helps to exhaust heat, and solar radiation transmitting through the roof is not as strong as that of a modern house. In <Fig.2>, a drastic rise of temperature in the loft space can be seen. The inhabitants of this house were at home only at nighttime due to work commitments. In such a situation, the second floor space should not be regarded as a living space during the daytime.



<Fig.1> a "machiya" in Komatsu city



<Fig.2> a modern house in Kaga city

A comparison of the two houses shows that there is a large difference between the loft temperature of a "machiya" and that of a modern house. It is thought that a rise in a loft temperature of a modern house is due to the lack of thermal insulation. In such a situation, even when the room is cross ventilated, inhabitants may feel unpleasantness and become to depend on air conditioners. But in a "machiya" which is insulated and

not equipped with air condit
outdoor temperature is high.
Thus, it is meaningful to insul

3. NUMERICAL ANALYS

3-1 SIMPLIFIED CALCUL

As mentioned previously,
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In this section, we focus on cr
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3-2 THE MODELS FOR CAL

In this section, we examine th
cross ventilation. At first, the actu
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are replaced with two periodical f
transmission is then obtained.
As mentioned previously, the pur
between models under the same
following six representative model

<Table1> Model

floor space(m2)	105	
from north to south(m)	7	
from east to west(m)	15	
height(m)	3	
		per floor
roof space(m2)	15	1
wall space(m2) north	32.4	0.31
south	32.4	0.31
east	21	0.2
west	21	0.2
window north	12.6	0.12
south	12.6	0.12

(mm)
Plaster Boa
Insulation
Air Space
RC
Board (insid
Window

ASSUMPTIONS

1) The annual minimum of average
winter, the room temperature is contr
2) The annual maximum of average d
The annual variation of the room ter

not equipped with air conditioner, it is said that the inhabitants feel cool even when outdoor temperature is high.

Thus, it is meaningful to insulate against solar radiation and to cross ventilate.

3. NUMERICAL ANALYSES

3-1 SIMPLIFIED CALCULATION

As mentioned previously, it is important for inhabitants to be aware of the characteristics of their own houses. The most desirable situation is for the inhabitants themselves to improve their environment and find their own lifestyle. Therefore, not only house designers but also the inhabitants themselves should know the advantages of their houses.

In this section, we focus on cross ventilation, which is one of the important factors for life in summer. In many traditional Japanese houses (such as "machiya" and farmhouses,), cross ventilation is regarded as a device that enhances comfort. The main purpose of the present calculation was to clarify the differences between various models. The thermal environments were analyzed by using the solution of periodical heat transmission. On the assumption that variations of temperature are repeated in the same way, we obtained the solution of unsteady heat transmission.

3-2 THE MODELS FOR CALCULATION

In this section, we examine the effects of thermal insulation and an earth floor on cross ventilation. At first, the actual variations in outdoor temperature must be replaced by Fourier's series with periodical functions to calculate the periodical heat transmission. To know reasonable aspects, the actual variations in outdoor temperature are replaced with two periodical functions (12h,24h), and the solution of unsteady heat transmission is then obtained.

As mentioned previously, the purpose of this calculation is to clarify the differences between models under the same weather conditions. Therefore, we constructed the following six representative models.

<Table1> Model

floor space(m 2)	105	
from north to south(m)	7	
from east to west(m)	15	
height(m)	3	
		per floor
roof space(m 2)	15	1
wall space(m 2) north	32.4	0.31
south	32.4	0.31
east	21	0.2
west	21	0.2
window north	12.6	0.12
south	12.6	0.12

<Table2> Six representative models

(mm)	case1	case2	case3	case4	case5	case6
Plaster Board	12	12	12	12	12	12
Insulation	0	25	200	0	25	200
Air Space	100	100	100			
RC				150	150	150
Board (inside)	12	12	12	12	12	12
Window	3mm single	3mm double	3mm triple	3mm single	3mm double	3mm triple

ASSUMPTIONS

1) The annual minimum of average daily room temperatures (θ_{min}) is 20 ℃. (In winter, the room temperature is controlled by heaters.)

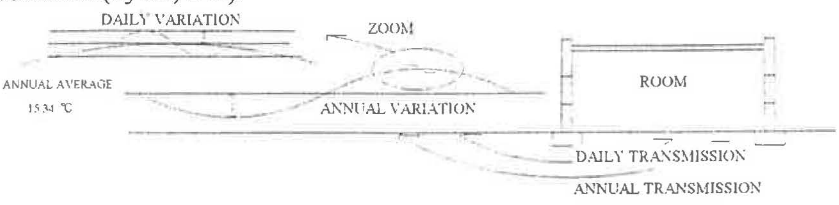
2) The annual maximum of average daily room temperatures (θ_{max}) is on August 1.

The annual variation of the room temperature (θ_y) is as follows.

$$\theta_{iv} = \frac{\theta_{max} + \theta_{min}}{2} + \frac{\theta_{max} - \theta_{min}}{2}\cos(w't + \tau') \qquad w' = \frac{2\pi}{365}$$

3) Room air is ventilated at the same air change rate throughout the day.

4) The heat transmitting through the earth floor is replaced with two periodical functions(1year, 24h).



<Fig.3> Model

4. RESULTS

Under the above assumption, the maximum of average daily temperatures of each air change rate is obtained by calculating annual thermal balance.

The results are as follows.

<Table3> The annual maximum of average daily temperatures (θ_{max}) (℃)

air change rate	case 1	case 2	case 3	case 4	case 5	case 6
n = 1	35.69	35.74	35.77	35.67	35.74	35.77
n = 1.5	35.3	35.06	34.69	35.27	35.06	34.69
n = 3	34.36	33.7	32.93	34.34	33.7	32.93
n = 5	33.5	32.66	31.85	33.48	32.66	31.85
n = 10	32.27	31.45	30.81	32.26	31.45	30.81
n = 20	31.21	30.6	30.19	31.2	30.6	30.19

On the condition that the daily thermal balance of each part of variation is equal to 0, the range of variation and time lag in the degree of each period is obtained (12h, 24h).

<Table4> Amplitude (℃) and time lag in degree (°)of variation

T=24h	case1		case2		case3		case4		case5		case6	
air change rate	amplitude	time lag	amplitude	time lag	amplitude	time lag	amplitude	time lag	amplitude	time lag	amplitude	time lag
n=1	5.9	-214.32	4.23	-215.81	1.84	-224.53	1.27	-233.99	0.97	-238.12	0.98	-224.08
n=1.5	5.8	-214.32	4.19	-216.09	1.93	-225.51	1.34	-234.61	1.05	-238.73	1.03	-226.59
n=3	5.54	-214.42	4.09	-216.86	2.17	-227.12	1.53	-235.64	1.28	-239.49	1.25	-230.22
n=5	5.27	-214.71	3.99	-217.75	2.41	-227.87	1.75	-235.98	1.52	-239.35	1.48	-232.42
n=10	4.83	-215.72	3.86	-219.39	2.76	-227.93	2.76	-235.23	1.97	-237.65	1.91	-233.57
n=20	4.4	-217.58	3.75	-221.18	3.08	-227.25	2.58	-233.07	2.47	-234.56	2.41	-232.44
T=12h												
air change rate	amplitude	time lag	amplitude	time lag	amplitude	time lag	amplitude	time lag	amplitude	time lag	amplitude	time lag
n=1	2.56	-69.25	2.26	-93.62	0.8	-77.6	0.42	-104.25	0.34	-63.79	0.39	-53.82
n=1.5	2.45	-67.5	2.05	-89.3	0.82	-75.03	0.43	-101	0.36	-63.17	0.41	-54.21
n=3	2.23	-63.42	1.79	-79.73	0.83	-68.88	0.45	-92.98	0.4	-61.46	0.45	-54.1
n=5	2.08	-59.77	1.55	-71.83	0.83	-63.41	0.48	-85.21	0.45	-59.54	0.49	-53.58
n=10	1.65	-54.77	1.13	-62.12	0.81	-56.37	0.53	-73.56	0.52	-56.13	0.53	-52.12
n=20	1.28	-50.76	0.95	-54.99	0.78	-50.99	0.59	-63.07	0.59	-52.51	0.61	-50.07

The calculation results showed a steep rise in room temperature in case 1(Fig.4) (non-insulated model). this is due to both a rise in outdoor temperature and an increase in the amount of solar radiation. On the other hand, in the thickly insulated model, (case 3,Fig.6; case 6,Fig.9), as the effect of solar radiation is less, and the effect of the earth floor is large, the room temperature is maintained at a low level. As can be seen in Figs.4 and 5, cross ventilation itself is not such an effective device against solar radiation. It is important to combine cross ventilation with thick thermal insulation and an earth floor. Each of them strengthen the role of the others.

In Figs. 7,8,9, a steep rise in the room temperature can not be seen. In case 4 (non-

insulated model, RC), how
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thermal mass of concrete.
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The main role of cross ven
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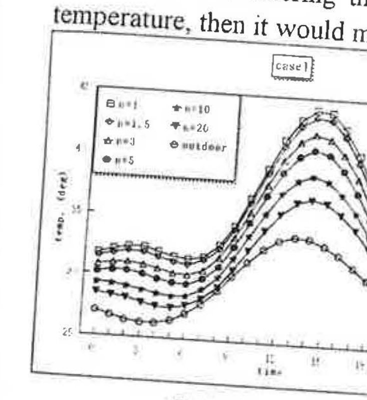
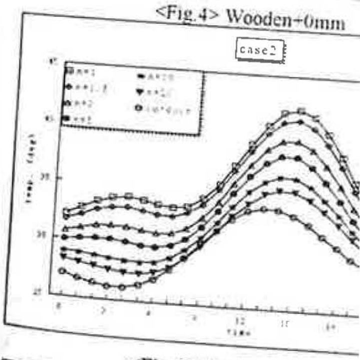
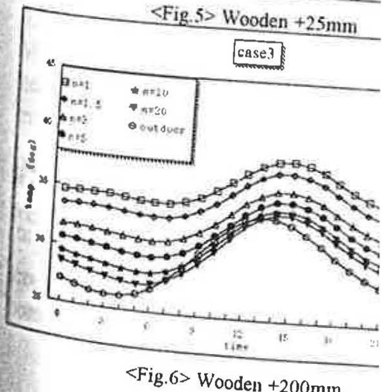


<Fig.4> Wooden+0mm



<Fig.5> Wooden +25mm



<Fig.6> Wooden +200mm

$$w' = \frac{2\pi}{365}$$

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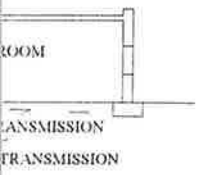
placed with two periodical



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(℃)

e 4	case 5	case 6
35.67	35.74	35.77
35.27	35.06	34.69
34.34	33.7	32.93
33.48	32.66	31.85
32.26	31.45	30.81
31.2	30.6	30.19

art of variation is equal to 0,

riod is obtained (12h, 24h).

	case5		case6	
ag	amplitude	time lag	amplitude	time lag
3.99	0.97	-238.12	0.98	-224.58
4.61	1.05	-238.73	1.05	-226.39
5.84	1.28	-239.49	1.25	-230.22
5.98	1.52	-239.35	1.48	-232.42
5.23	1.97	-237.65	1.91	-233.57
3.07	2.47	-234.56	2.41	-232.14
ag	amplitude	time lag	amplitude	time lag
4.25	0.34	[illegible]	0.39	-53.82
-101	0.36	[illegible]	0.41	-54.21
[illegible]	0.4	-61.46	0.45	-54.1
5.21	0.45	-59.54	0.49	-53.58
3.56	0.52	-56.13	0.55	-52.12
3.07	0.59	-52.51	0.61	[illegible]

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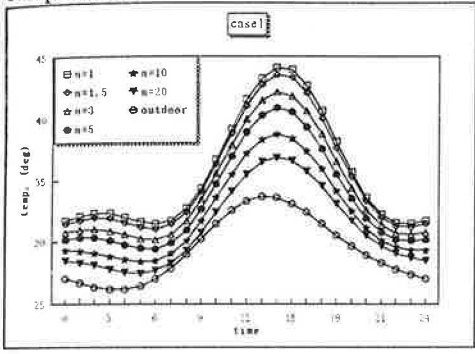
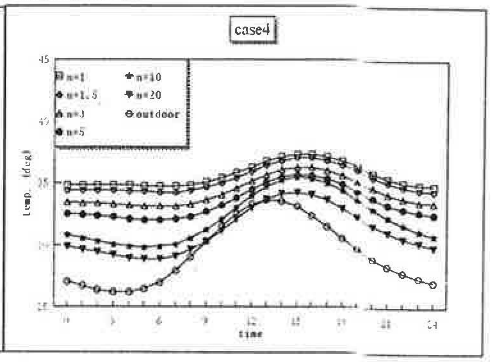
insulated model, RC), however, the maximum temperature is higher than that in cases 5 and 6. In the models made of RC, changes in room temperature are small due to the thermal mass of concrete. In the non-insulated model (case 4), the room temperature is always higher than the outdoor temperature, but in the thickly insulated model (case 6), the room temperature is lower than the outdoor temperature during the daytime.

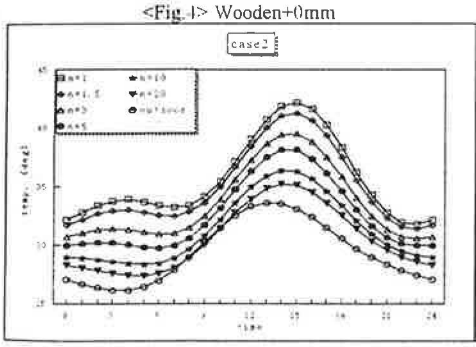
The main role of cross ventilation is to exhaust excess heat. However, if the amount of heat entering the house is very high, cross ventilation is not so effective. In the thickly insulated model, a large volume of air exchange is not so necessary due to the small amount of heat entering the house. So inhabitants can feel slight change of room temperature, then it would make dwellers comfortable.



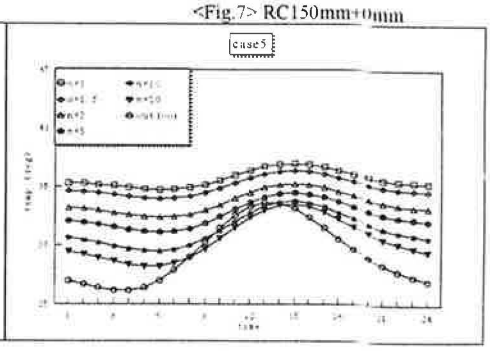
<Fig.4> Wooden+0mm



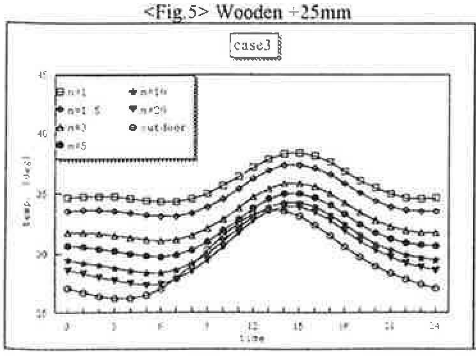
<Fig.7> RC150mm+0mm



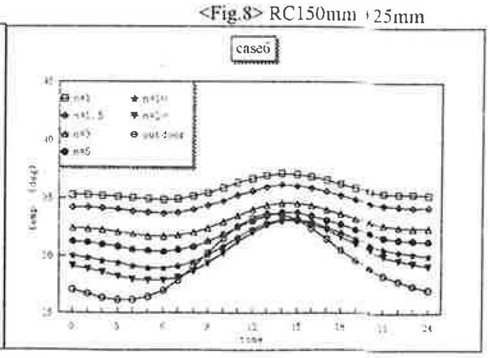
<Fig.5> Wooden +25mm



<Fig.8> RC150mm +25mm



<Fig.6> Wooden +200mm

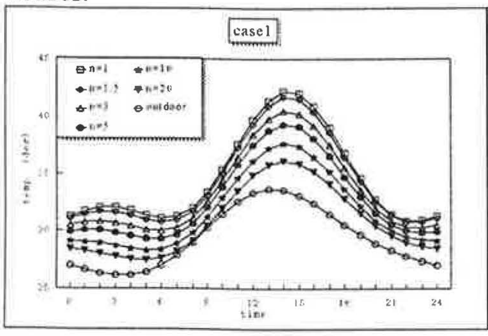


<Fig.9> RC150mm+200mm

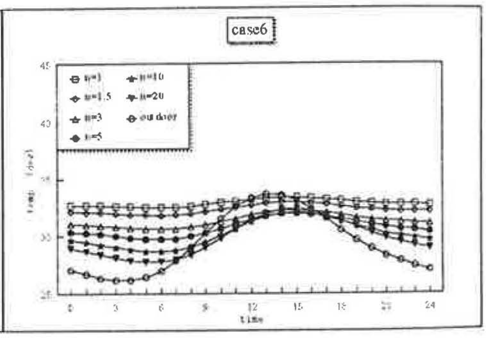
5. CONCLUSION

Although cross ventilation and an earth floor are not very effective alone, when they are combined with thick insulation, the earth floor is very effective, and it becomes possible to feel naturally cool, which is a characteristic of an earth floor. In the same way, the effect of cross ventilation alone is less than that of solar radiation. An earth floor is most effective in a thickly insulated model. In such a house, the room temperature doesn't rise greatly. Therefore, a large volume of air exchange is not needed. In the case where only a small amount of heat enters the house, the role of cross ventilation is to facilitate a slight change in temperature rather than to exhaust unnecessary heat. "Sudare" and awnings are very effective in thickly insulated houses.

In non-insulated houses (Fig,10), however, a great deal of heat enters the house, a "sudare" or awning are not so effective and do not enhance the wisdom of inhabitants. On the other hand, in thickly insulated houses (Fig.11), the devices of inhabitants such as a "sudare" and an awning are very effective and meaningful. In such a situation, the inhabitants themselves pay attention to their environment, and they can improve their houses.



<Fig.10> Wooden +0mm with Sudare



<Fig.11> RC 150mm + 200mm with Sudare

The feeling that we feel when we walk into a "machiya", is due to the combination of devices. This technique of using a combination of devices has been handed down by ancestors over the years.

In hot and humid regions, the role of insulation is to prevent solar radiation from entering the house and to give important roles to cross ventilation and earth floors.

Thus, we think that thick insulation changes the meaning of cross ventilation.

REFERENCES

1) N,Aratani K,Suzuki (1993) A guide to the solution of thermal environments for architects

2) W,Nagai (1996) Cooling effect of thermal-mass and displacement ventilation in thermal-insulated houses

SHINYU

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ABSTRACT Recently, the
acid rain, are becoming se
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matter, we introduce experim
The basic ideas are 'envi
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1.INTRODUCTION

MITUI HOME has put the syst
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