VALIDATION OF THE BUILDING THERMAL SIMULATION TOOL FOCUSED ON EFFECT OF EXTERNAL ENVIRONMENT

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ABSTRACT

In this study, the data related to the thermal performance of a single family house, such as room temperatures, incident solar radiations on external surfaces, form factors between external surfaces and outside environment were measured and compared with the simulated results using developed *EESLISMver6*.

EESLISMver6 which can take into consideration the effects of outside environment was validated using the year-round measured data of the house built in the dense housing area. In this research, the complicated-shaped house built in a suburb of urban areas was verified. Verification of room temperatures were performed, and the calculation result of *EESLISMver6* was very well in agreement with the measurement.

INTRODUCTION

In a single house, in order to examine the ideas for realizing good living environment by the low energy and low environmental impacts, the study on the energy consumed in the building including the effects of arrangement of adjoining buildings or trees is necessary. Moreover, indoor heat environment may also change with change of the outside environment by urban development etc. every moment. Therefore, it is also required for change of outside environment to predict the influence of indoor environment.

Asawa and Hoyano (e.g. Asawa et al., 2004) are developing the model which computes total skin temperature of residential external surfaces after reproducing complicated form of trees by 3D-CAD.

However, dynamic shading systems including trees and adjacent houses are still difficult to model. Therefore they may complicated procedure to implement the shadow calculation into the general simulation. So, they are often ignored in simulation for design at the practical stage.

The use in the practical stage can consider two, design support of a house, and urban development.

From such a viewpoint, development of the heat load simulation *EESLISM ver6* (e.g. Higuchi et al., 2007) in consideration of outside environments, such as an adjoining building and trees, has been continued until now.

The main features of *EESLISMver6* are as follows.

- The shadow of the outside surface can take into consideration the shadow by external obstacles (an adjoining building, trees, etc.), attachment obstacles (eaves, a balcony, etc.), and the building itself.
- Not only shadows onto windows but also shadows onto walls and roofs can be calculated.
- There is no restriction in arrangement of external obstacles. For example, the external obstacle may float or lean.
- Reduction of the reflected solar radiation of the ground due to shadows can be taken into consideration.
- Long wave radiation exchange is considered.

In this research, the complicated-shaped house (L shape house, a piloti, a balcony, etc.) built in a suburb of urban areas were surveyed, *EESLISMver6* was compared with the measurement, and the accuracy of this program was checked.

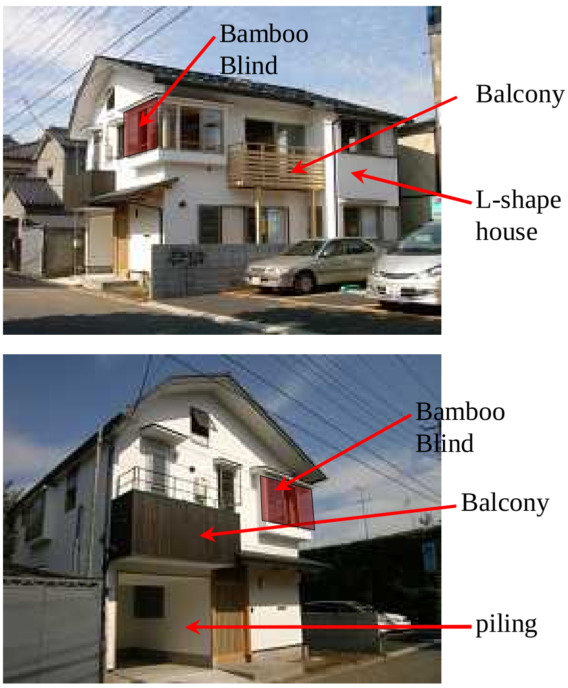

Figure 1 The surveyed house

Figure 2 Elevation

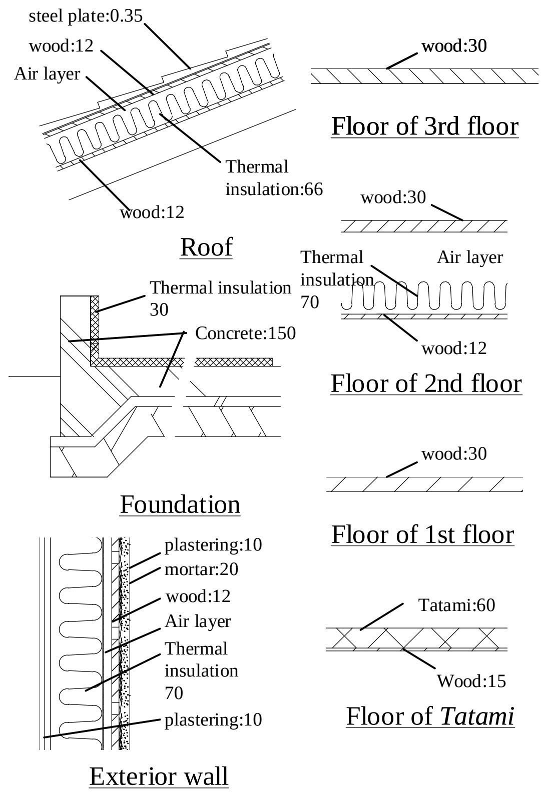

Figure 4 Composition of walls (Unit: mm)

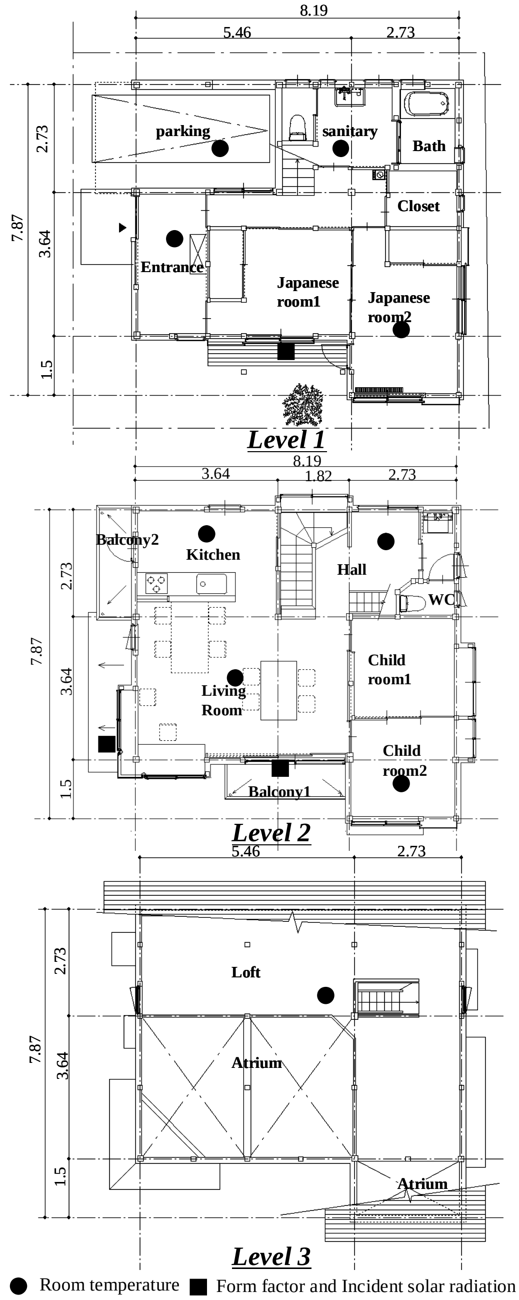

Figure 3 Plan and Measuring point

Entrance Living room Loft

Figure 5 Indoor photograph

SURVEY OUTLINE

Surveyed house outline

The surveyed house is shown in Fig. 1. This house is located in Tokyo Shinjuku-ku and is a two story wooden single-family house. A total floor is 112.5m^2. A family is four persons of parents and two children. The plan view and elevational view of each story are shown in Fig. 2 and Fig. 3.

Wall object composition is shown in Fig. 4. The outer wall is plastering on mortar. The inner wall is plastering or cedar board tension on a gypsum plasterboard. Indoor photographs are shown in Fig. 5.The roof is a steel plate. The foundation is the airtight raft foundation. The window is used as double layer clear glass (3mm+A6+3 mm). The heat loss coefficient is meeting the next-generation energy-saving standard in Japan by the 2.6[W/m^{2}K]grade.

Although the south adjoining land is used as a parking lot, a residence may be built there in the near future. Therefore, in consideration of reduction in lighting, or the increase in heat load, living spaces (sitting room, a kitchen, etc.) are arranged on the second floor.

The feature about the form of the surveyed house is shown in Fig.1. Since the form of this house is L shape, this house receives the shadow by self during the morning. Moreover, the piloti is made into the garage. The balconies were installed in the outside of the south terrace window of a living room, and the outside of the west door of a kitchen. There is a bamboo blind in the outside of the west window of living room. These features need to be considered on a simulation.

All four persons are out in the daytime of a weekday for having two incomes.

House arrangement is shown in Fig. 6. The west side faces a 6m road. The north side and the east side have an adjacent buildings. Since the south side is a parking lot, sunny is good.

Survey outline

A survey period is for one year from August 19, 2007 to August 31, 2008. A measurement item is the form factors from the window surface to outside environment, the room temperatures, the skin temperatures, the incident solar radiations on the windows and electric energy.

A measurement point is shown in Fig. 3. The form factor was photoed with the fish-eye lens for orthogonal projection from the center of the south window and west window of the second floor living room. The installation height of the temperature-and-relative-humidity meter was slightly higher than general height, and was set to FL+1.7m so that it might not become the obstacle of a life of a resident. The solar-radiation meter was fixed to the wall of the

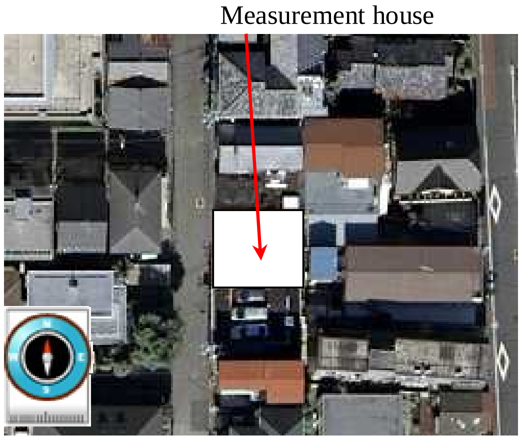

Figure 6 house arrangement

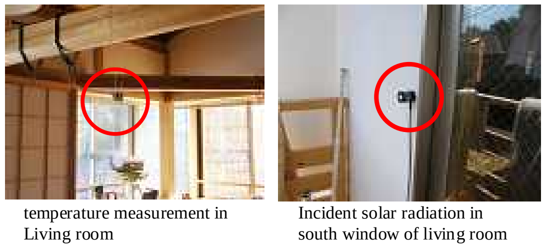

Figure 7 Survey apparatus

Table 1. Simulation Case

			Eaves	Balcony	concaved surface	Tree	Adjcent houses	Those composites
Measurement			✓	✓	✓	✓	✓	✓
A	simulation	Adjacent houses	✓	✓	✓	✓	✓	✓
B		No adjacent houses	✓	-	✓	-	-	✓

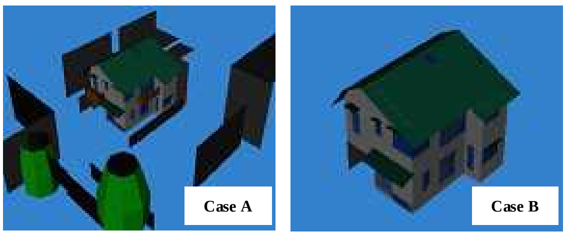

Figure 8 Input result of Outside obstacles

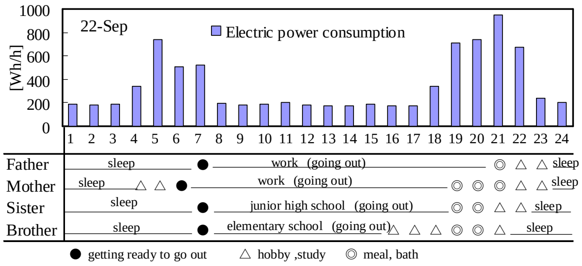

Figure 9 Family's life schedule and electric power consumption in 22-Sep

side of a window in order that trouble might appear in opening and closing of a window, if it installed in the central part of the window. Measurement scenery is shown in Fig. 7.

Simulation outline

EESLISMver6 was used for the simulation. A simulation pattern is shown in Table 1 and Fig. 8. Since CaseA is reproducing actual building arrangement, it is taking into consideration the shadow by all the external obstacles. In CaseB, although the shadow by an adjacent buildings, trees, and a balcony is not taken into consideration, only the shadow by eaves or the building itself is taken into consideration.

Fig. 9 are family's life schedule and electric power consumption. Although Fig. 9 showed the electric energy on September 22, other days were almost the same. The schedule of indoor generation of heat was set up with this survey data.

The window opening schedule is shown in Table 2. In September, since the room temperature was over 30 degrees C after going home, the windows of the living room, the entrance and the loft have been opened.

The measurement was compared with these 2 cases. The AMEDAS meteorological data of Nerima city near the surveyed house was used for meteorological data (e.g. Architectural Institute of Japan, 2005). The amount of insolation measured on the roof of the environmental test facilities of Kogakuin University (KTC) was used. The calorific capacity of furniture and a visible beam or a timber was taken into consideration. The calculation period was set to September 1 to September 30, and calculation by natural room temperature was performed.

The survey in the on-site circumference was performed and external obstacles, such as an adjacent buildings, were inputted. Furthermore, as shown in Fig. 6, the size and position of the adjacent buildings were presumed with the sky photograph by *google earth.*

CALCULATION RESULT

Form factor from the window to outside

Fig. 10 shows the orthogonal projection picture of the outside environment photoed from the south window and the west window of the living room. The form factor from the south window to sky, ground, housing itself, external obstacles, trees and attachment obstacle were 0.235, 0, 0.218, 0.065, 0.008 and 0.474, respectively. The form factor from the west window to the sky, ground, housing itself, external obstacles, trees and attachment obstacle were 0.397, 0.242, 0.035, 0.211, 0.082 and 0.034, respectively.

Comparison with calculation and the measurement of the form factor to the outside environment from the

Table 2. Window opening schedule

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
south window (Living room)																				open (10)					
Sky window (Loft)																				open (2)					
south window (Entrance)																			open (5)						

():Ventilation frequency [times / hour]

South window

West window

Figure 10 The picture of the exterior seen from the Living room window by fish-eye camera

south and west windows of the living room is shown in Fig. 11. The form factors to sky, ground, the building itself, the external obstacles, the trees, and the attachment obstacles from the south window in Case A (adjacent houses case) were 0.239, 0, 0.218, 0.080, 0.011, and 0.451, respectively. Case A was almost equal to the measurement.

However, in Case B (no adjacent houses case), since there were not an adjacent buildings and a balcony, the form factors of the ground and the sky were large.

The form factors to sky, ground, the building itself, the external obstacles, the trees, and the attachment obstacles from the west window in Case B were0.380, 0.224, 0.022, 0.214, 0.068 and 0.092, respectively.

Also in the west window, Case A was almost equal to the measurement.

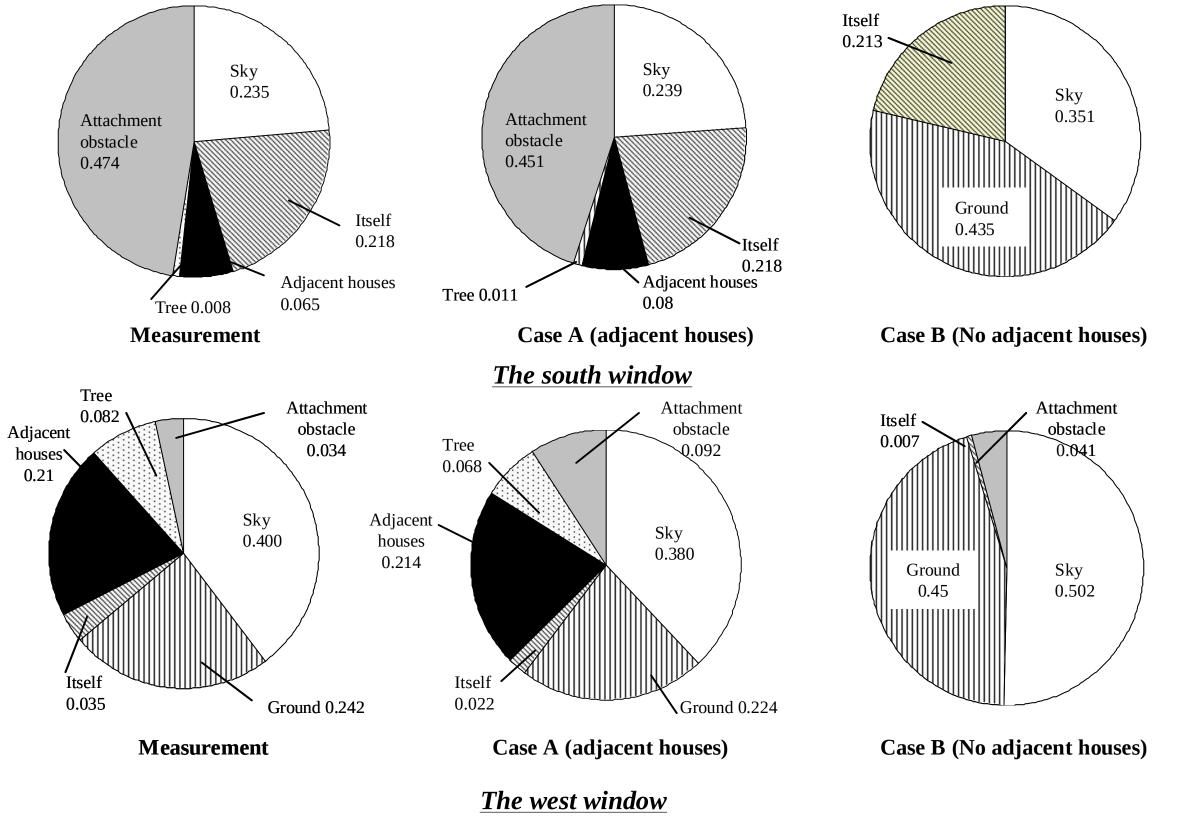

Figure 11 Form factors from the windows of living room to outside

Incident solar radiation

Fig. 12 shows comparison of the incident solar radiation to the south window of the living room in September 20 to September 22. The daily total incident solar radiation of the measurement, Case A (adjacent houses case) and Case B (no adjacent houses case) was 12.73 [kW/m^2], 18.15[kW/m^2], and 18.27[kW/m^2], respectively in September 21. Since this house is L-shape form, the south window of the living room does not receive direct solar radiations around till 8:30. Case A and Case B can be taken into consideration about this influence.

Fig.13 shows comparison of the incident solar radiation to the west window of the living room in September 20 to September 22. The daily total incident solar radiation of the measurement, Case A and Case B was 3.59[kW/m^2], 5.62[kW/m^2], and 14.54[kW/m^2], respectively in September 21. In Case B, since the bamboo blind was not installed, the incident solar radiation was extremely large. On the contrary, in Case A, since the bamboo blind was installed, it was about equal to the actual measurement.

Room temperature

Fig. 14 shows the room temperatures of the entrance, living room and a loft in one week on September 19 to September 26. The mean temperature of the loft in the measurement, Case A(adjacent houses case), and Case B (no adjacent houses case) was 28.8^{o}C, 28.0^{o}C, and 28.2^{o}C, respectively.

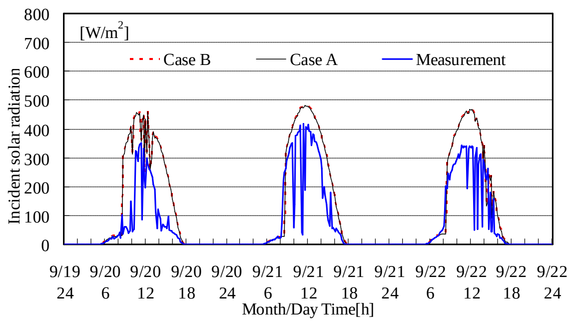

Figure 12 Incident total solar radiation on south window of the living room, Sep.20-Sep.22

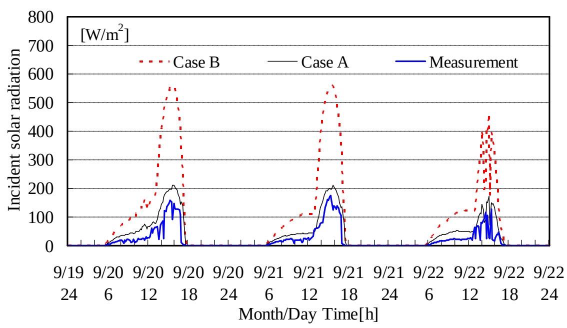

Figure 13 Incident total solar radiation on west window of the living room, Sep.20-Sep.22

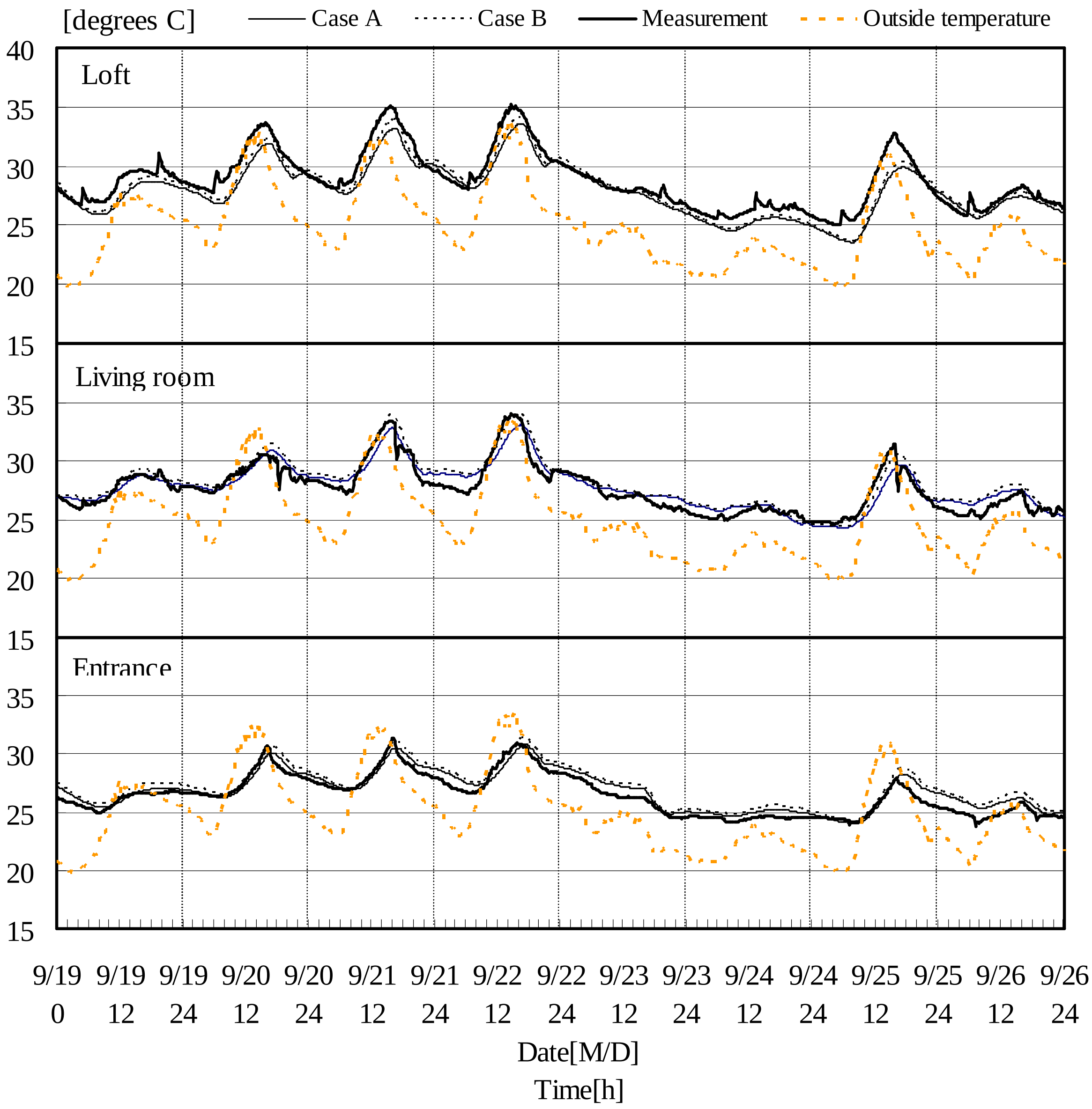

Figure 14 Room temperture of entrance,living room and loft

The averages of the difference of room temperature with Case A and the measurement and it with Case B and the measurement were 0.95°C and 0.80°C, respectively. The mean temperature of the living room in the measurement, Case A, and Case B was 27.7°C, 27.8°C and 28.1°C, respectively. The averages of the difference of room temperature with Case A and the measurement and it with Case B and the measurement were 0.61°C and 0.67°C, respectively. The mean temperature of the entrance in the measurement, Case A, and Case B was 26.5°C, 26.8°C, and 27.1°C, respectively. The averages of the difference of room temperature with Case A and the measurement and it with Case B and the measurement were 0.51°C and 0.69°C, respectively.

The Case B and Case A was almost equal. This result is because the south window of the living room, the sky window of the loft, and the window of the entrance were opened, immediately after going home.

CONCLUSION

Development of the simulation program (*EESLISMver6*) which can take the influence of outside environment into consideration has so far been continued.

In this research, a single family house built in a suburb of urban areas was examined. The house was provided with the complicated external surface with a piloti, two balconies, L shape form, the bamboo blind etc. was surveyed. *EESLISMver6* was compared with the measurement, and the accuracy of this program was checked.

The simulation was calculated by two patterns. Since CaseA is taking into consideration the shadow by all the external obstacles. In CaseB, although the shadow by an adjacent buildings, trees, and a balcony is not taken into consideration, only the shadow by eaves or the building itself is taken into consideration.

As a result, the form factor to the outside environment from the window of the living room in Case A (no adjacent house case) was almost equal to the measurement.

Since this house is L-shape form, the south window of the living room does not receive direct solar radiations around till 8:30. Case A and Case B can be taken into consideration about this influence. The effect of bamboo blind was able to be taken into consideration especially in the west window of living room.

In every room, the room temperature of the simulation result was almost as near as the measurement. This result is because the shadow by eaves or the building itself is taken into consideration also in CaseB. From now on, it verifies also about the winter influenced by the obstacle which separated distantly.

As mentioned above, the calculation result of *EESLISMver6* was very well in agreement with the measurement. *EESLISM* can predict the room temperature and heat load in the complicated-shaped house built in a suburb of urban areas.

From now on, it surveys on annual evaluation or different conditions (a plan, building arrangement, etc.) and the verification about the accuracy of EESLISMver6 is continued.

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