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VALIDATION OF A SIMULATION PROGRAM FOR THE ESTIMATION OF THERMAL PERFORMANCE OF RESIDENTIAL HOUSES USING THE DATA FROM THE YEAR ROUND MONITORING

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Introduction

As the computer simulation is a very accurate method for estimating the thermal performance of residential houses, a generalized simulation program, MALTEP 2.0 has been developing for the prediction of the heat loads and room thermal environment of residential houses. However, the validation of the program had not been sufficiently made especially for a long period as throughout winter season or year-round. In order to examine the agreement between the simulation and the measurement, the computer simulation was carried out using the data obtained from the monitoring of three experimental houses for the six months winter.

Simulation Program

The algorithms used in the program are based on the multi-room concept (1), since a residential house generally consist of conditioned and unconditioned spaces. The implicit finite difference method is applied for calculating the heat transfer of walls, roofs and floors. The simulation program is able to apply to any type of ordinary residential houses for the estimating the thermal performance for a year.

Three Experimental Houses

Three full scale experimental houses called PSH1, PSH2 and STD had been built in the suburbs of Tokyo, in March 1983 in order to validate the predicted performance by the simulation for the development a standard type of the passive solar house. The each house has 123m2 of floor area and the same floor plan with wooden-framed construction as shown in Fig. 1. PSH1 is a well insulated house with 150mm thick insulation and double glazed windows with the night insulation. The concrete floor slab and the brick interior wall are used as the thermal storage elements. PSH2 is the same as PSH1 but heating and cooling were not used throughout a year. STD is a typically insulated house with 50mm thick insulation and single glazed windows without specific thermal storage elements. Heat pump air-conditioners were installed in the living room, the children's room and the bed room of both PSH1 and STD for heating and cooling.
The experimental houses were designed to simulate the occupation by the program timers which controlled the heat generation by lamps, domestic appliances, human bodies, and cooking.

If the experimental houses are built in a city area, solar radiation may be shaded by houses located in the south. Therefore, 5m tall wall was set up in front of the experimental houses in order to simulate the shadows.

Fig. 1 Floor plan of the experimental houses

L : Living room
BR: Bed room
CR: Children's room
JR: Japanese room
K : Kitchen
E : Entrance
CP: Car port
T : Toilet
B : Bathe room
F : Exhaust fan

Input Data for the Program

The input data used to validate the program are as follow;

1) Measured weather data with this experiment at 30 minute interval from October 1983 through March 1984.

2) Schedule of the internal heat generation of the experimental houses.

3) Using the measured values, the input ventilation rates were 0.3 air change per hour when exhaust fans in the kitchen and the toilet were not used and 1.0 air change per hour when the fans were used.

Results of the Comparison

Hourly Profile

Figure 2 shows the temperatures and the heating loads of the living room and the bed room in PSII on the typical clear days in January. The room temperatures were measured at 1.5m above the floor at the center of the room. The measured heating loads were estimated from the air flow rate through the air-conditioners and the temperature differences between the inlet air and the outlet air. The temperature profile of the simulation and
Fig. 2 The Temperatures and the heating loads of the living room and the bedroom in PSH1.

- Solar radiation on horizontal surface
- Wind vector
- Living room temperature
- Living room heating load
- Bed room temperature
- Bed room heating load

Schedule:
- Heating 20°C
- Lighting 280W
- Human 400W
- T.V. 100W
- Fan (Living)
- Fan (Kitchen)

DATE Jan. 6, 84 Jan. 7, 84
Table 1. The monthly and the seasonal heating loads of PSH1

<table>
<thead>
<tr>
<th>Room</th>
<th>Heating Load</th>
<th>1983</th>
<th>1984</th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Living room</td>
<td>Simulated</td>
<td>602 1804</td>
<td>2210 1792</td>
<td>1561</td>
<td>7970</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Measured</td>
<td>489 2696</td>
<td>3286 3198</td>
<td>2352</td>
<td>12022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bed room</td>
<td>Simulated</td>
<td>42 184</td>
<td>259 239</td>
<td>184</td>
<td>908</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Measured</td>
<td>33 155</td>
<td>205 280</td>
<td>226</td>
<td>899</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children's room</td>
<td>Simulated</td>
<td>46 218</td>
<td>331 343</td>
<td>293</td>
<td>1231</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measured</td>
<td>38 155</td>
<td>171 389</td>
<td>372</td>
<td>1125</td>
<td></td>
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<tr>
<td>Total</td>
<td>Simulated</td>
<td>690 2206</td>
<td>2800 2374</td>
<td>2038</td>
<td>10109</td>
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<td></td>
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<tr>
<td></td>
<td>Measured</td>
<td>560 3006</td>
<td>3662 3867</td>
<td>2950</td>
<td>13821</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. The monthly and the seasonal heating loads of STD

<table>
<thead>
<tr>
<th>Room</th>
<th>Heating Load</th>
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<th>1984</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Living room</td>
<td>Simulated</td>
<td>1997 4140</td>
<td>4944 4211</td>
<td>3959</td>
<td>19151</td>
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<tr>
<td></td>
<td>Measured</td>
<td>2331 5756</td>
<td>6224 6061</td>
<td>4692</td>
<td>25064</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bed room</td>
<td>Simulated</td>
<td>343 536</td>
<td>598 540</td>
<td>532</td>
<td>2549</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measured</td>
<td>285 527</td>
<td>565 532</td>
<td>515</td>
<td>2424</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children's room</td>
<td>Simulated</td>
<td>460 933</td>
<td>1130 1025</td>
<td>917</td>
<td>4465</td>
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<tr>
<td></td>
<td>Measured</td>
<td>126 883</td>
<td>1147 1234</td>
<td>850</td>
<td>4240</td>
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<td></td>
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<tr>
<td>Total</td>
<td>Simulated</td>
<td>2800 5609</td>
<td>6672 5776</td>
<td>5308</td>
<td>26165</td>
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<tr>
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<td>Measured</td>
<td>2742 7166</td>
<td>7936 7827</td>
<td>6057</td>
<td>31728</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The monthly heating loads are MJ/month
**The seasonal heating loads are MJ/season
the measurement are very similar except the followings;

1) When the air-conditioner were operated, the disagreement occur in the living rooms, since the room air temperature swung and was not kept the constant temperature.

2) When strong wind blows, the simulated temperatures are higher than the measured temperature, because the ventilation rates increase by the strong wind, however, ventilation rates in the simulation are not changed with wind velocity.

In the bed room, the simulated heating loads and the measured heating loads show good agreement, however, in the living room, the simulated heating load is about 30% less than the measured heating load.

The Monthly and the Seasonal Heating Loads

Tables 1, 2 show the monthly and the seasonal heating loads of PSH1 and STD. The seasonal heating loads are the total of the monthly heating load from November 1983 to March 1984, since the heating started in November in the experimental houses. In the bed room and the children's room, the simulated monthly heating loads are larger than the measured monthly heating loads in early winter, but the simulated loads become smaller in mid winter.

For the seasonal heating load of the bed room and the children's room, the disagreement between the simulation and the measurement are very small, but simulated heating load of living room are 20-30% less than the measured heating load.

Conclusions

This first attempt to validate the simulation program with the long term measurement of the experimental houses shows that this program is able to reproduce the room temperature profile and the heating load of the bed room and the children's room with small error. However, the heating load of the living rooms were smaller than the measured heating load, since shading by the wall located in the south were not sufficiently estimated and ventilation rates were constant. However, the difference is small enough to use the program for the practical design.

References


(2) M. Udagawa, K. Ishida, H. Shibuya: Effects of insulation and heat capacity on the thermal performance of residential houses. CLIMA 2000
K. Ishida, M. Udagawa: Validation of a Simulation Program for the Estimation of Thermal Performance of Residential Houses Using the Data from the Year Round Monitoring. The purpose of this paper is to validate the simulation program using the data obtained with the long term measurement of the three experimental houses. The computer simulation were carried out with measured weather data from October 1983 to March 1984. The results of the comparison between the simulation and the measurement showed the following: The profiles of the temperatures are quite similar. Although the heating loads by the simulation and the measurement showed good agreement for the bedrooms, the simulated heating loads of the living rooms were smaller than the measured load. However, the difference was small enough to use the program for the practical design.

RESUME

K. Ishida, M. Udagawa : Validation d'un Programme de Simulation pour Performances Thermiques d'Habitations Résidentielles avec l'Aide des Données Annuelles de Contrôle. Le but de cette étude est de valider le programme de simulation à l'aide des données mesurées à long terme sur les trois habitations expérimentales. La simulation sur ordinateur a été effectuée avec des données météorologiques allant d'Octobre 1983 à Mars 1984. Les résultats de la compaéation entre la simulation et les mesure effectives ont montré ceci: les profils des températures sont à peu près semblables. Bien que les charges de chauffage simulées et mesurées aient montré un accord pour les chambres à coucher, les charges de chauffage simulées des salles de séjour étaient plus petites que les charges mesurées. Toutefois, la différence était suffisamment petite pour que le programme puisse être utilisé dans un but pratique.

ZUSAMMENFASSUNG