Evaluation on thermal comfort of electric heating films system in residential building

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ABSTRACT
The electric heating films system is evaluated by analysing indoor environment of some houses in one residential district in north China. Some parameters of the indoor environment, which include indoor average air temperature, inner surface temperature and vertical distribution of the indoor air temperature were measured. Based on the measurement data, the characteristics of indoor thermal environments are analysed. The results show that the indoor air temperatures can meet the resident requirement, and the heat comfort of the rooms measured is satisfied. According to the analyses, the characteristic of electric heating film system is summed up, and the advantage of this system is pointed out. Finally, some conclusions are drawn as a reference to guide the designing of electric heating film system applied in residential building and other similar buildings.

INDEX TERMS
Heating; Thermal comfort; Measurement technique; Residential building

INTRODUCTION

The residential building district is located in Shijiazhuang City of North China. All of the buildings of this district are heated by electric heating film system. From January 2002 to March 2002, the indoor environments of some typical rooms were surveyed. According to the results, the efficiency of electric heating film was evaluated.

From 29 January to 13 March, indoor air temperature, and each inner-surface temperature of some typical rooms detailed by the hour were recorded. From 7 February to 13 March, parameters of thermal comfort of some typical rooms detailed by the hour of certain time were recorded.

MEASUREMENT

Description

Different from conventional heating system, heat distribution by electric heating film is mainly by radiation. Therefore, the real effective heating can hardly be expressed only by measuring the indoor air temperature. In order to evaluate the real effective heating, some items decided as follow were measured in this research—vertical distribution of indoor air temperature, inner surface temperature, factors on thermal comfort and outdoor air temperature.

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Measuring Points

Considering that there are three different styles (villa style, townhouse style, and multi-storied style) in this district, in the measuring plan was decided that only representative rooms would be checked in this research.

To measure the indoor air temperature distribution in the vertical direction, the most disadvantaged rooms of Unit 102 of first floor and Unit 302 of third floor of multi-storied D6 were selected. The measuring points were grouped along the centre of the selected room, the elevation of lowest point being 500 mm from the ground. A standard room (Suite 302 of third floor) of multi-storied D6 was selected, to measure the surface temperatures, which included wall outer surface, wall inner surface, window inner surface, roof and ground surfaces. Regarding arrangement on roof surface, whether the measurement points are near the films or not were taken into account. Of the townhouse style building F2, a top floor room of Suite 201 and a standard floor room of Suite 101 were selected to measure the indoor air temperature distribution in the vertical direction. The measuring points were grouped along the centre of the selected room, the elevation of lowest point being 500 mm from the ground. The living room of villa B1 was selected to measure the indoor air temperature distribution in the vertical direction. The elevation of the lowest point was 1000 mm from the ground.

Data Recording

The air temperature was measured by RHLOG digital temperature automatic recorder, which can set start time and time step in advance. The time step of this study is 1 h.

RESULTS AND DISCUSSION

Outdoor Air Temperature

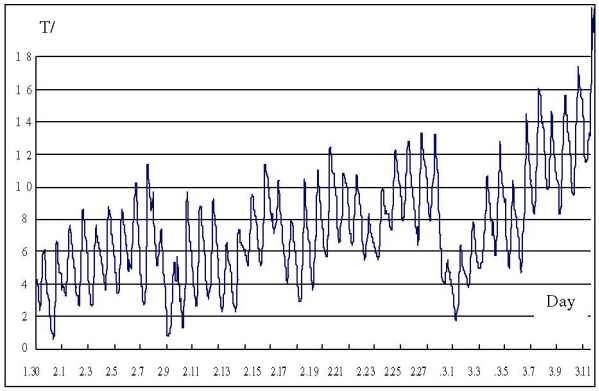

Figure 1 The Outdoor Air Temperature

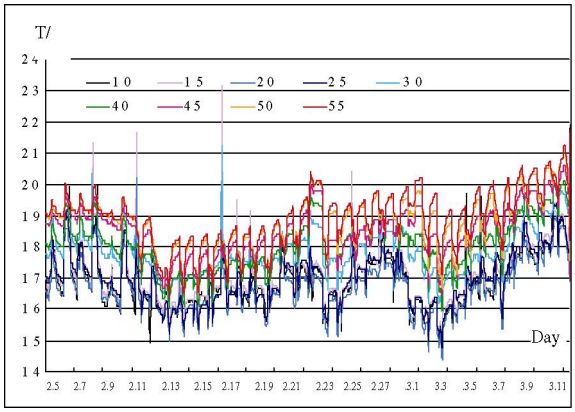

Figure 2 The air temperature in Villa Style building

The outdoor air temperature measurement in Shijiazhuang started at 10:00 a.m. on 29 January and ended at 12:00 a.m. on 13 March (shown in Figure 1). During this time, the maximum temperature is 17.39°C and the minimal is 0.57°C.

Villa Style

The vertical distribution of indoor air temperature in living room of the villa is shown in Figure 2. During the measurement, after avoiding the unauthentic data, the maximal indoor air temperature was 21.21°C on 13 March, and the minimum was 14.42°C on 4 March since a delay of the cold snap occurred on 2 March. The reason could be result that, when heated by radiation method, the temperatures of the construction rose marginally and the stronger thermal storage allowed very little outdoor influence on the indoor air temperature.

The vertical distribution of indoor air temperatures of the villa were measured during 21 and 25 February, and these followed the grads from low bottom to high ceiling (Figure 3). The temperature of the space around human occupants (about 2 m from the ground) was maintained at around 17.5°C. Since the electric heating film works via the radiation heating method, the temperatures of the inner walls are relative higher. Therefore, the difference of temperatures of vertical distribution is not distinct, and is about 2°C. The measured data show that these phenomena are the same over the whole measurement period of the villa.

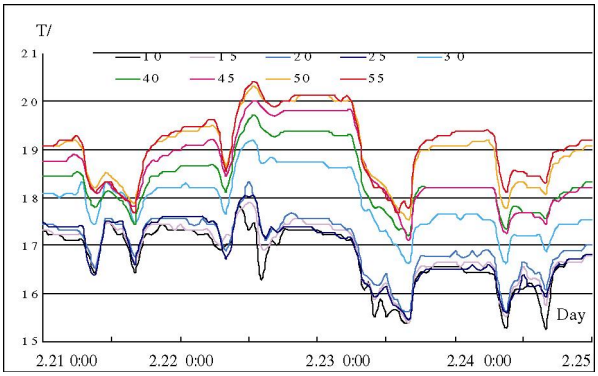

Figure 3 The air temperature in Villa Style building over 4 days.

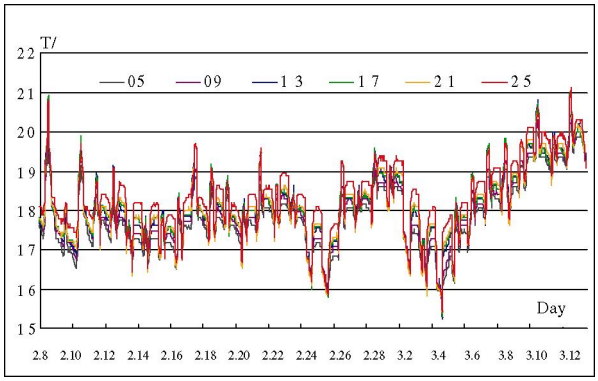

Figure 4 The air temperature distribution in room F101-2.

Townhouse Style Building

The vertical distribution of indoor air temperatures of room F101-2 is shown in Figure 4. During the measuring period, the maximum temperature is 21.13°C at 11 a.m. on 12 March, and the minimum is 15.24°C at 2 p.m. on 4 March (the probability of manual turning off of the electric heating films is *not* excluded).

Four-day data (21–25 February) are selected to observe the characteristic of vertical distribution of indoor air temperatures (Figure 5). During the selected period, similar to the villa, the air temperatures followed the gradations from low bottom to high ceiling, and the temperature of the space in which human occupants were present (about 2 m from ground) was maintained at around 18°C. However, compared to villa, the difference of temperatures of vertical distribution is lower, which is within 1°C. This could be explained by the fact that the temperatures of the inner wall surfaces were quite uniform by accepting thermal energy from the neighbouring room. Therefore, the difference of indoor air temperatures in the vertical direction is not high, and this uniformity is obviously of benefit to indoor thermal comfort.

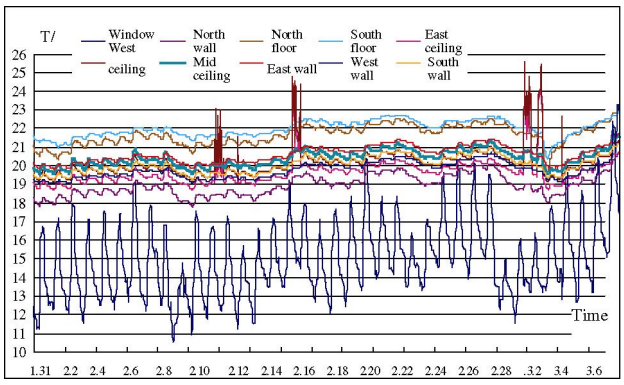

Figure 5 The air temperature in F101-2 during 4 days.

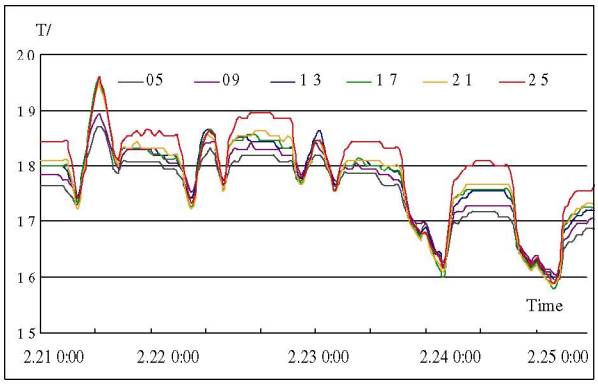

Figure 6 The inner surface temperatures of room D301.

Multi-storied Building

Room D301 of multi-storied style

The inner surfaces temperatures of room D301 are shown in Figure 6. The figure shows that the window had the minimum temperature (10.5°C) and the ground had the maximum temperature (22°C). Because there was less heat loss from the walls, the indoor air temperature was maintained at a relative high level (about 19°C). So, the operating time of the electric heating films was not too long, the surface temperatures of the eastern and western sides of the ceiling did not exceed 26°C and the variation between them was small. During the measuring period, the maximum indoor air temperature of room D301 is 21.63°C at 2:00 p.m. on 1 March and the minimum is 18.74°C at 7:00 a.m. on 5 March.

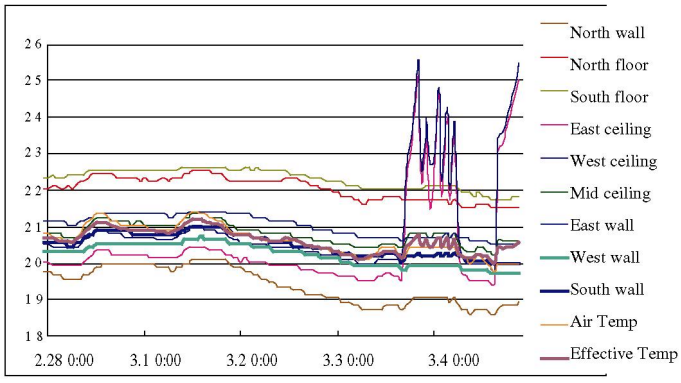

Figure 7 The air temperature in D301 during 4 days

The data of measured temperatures from 28 February to 4 March are shown in Figure 7. The air temperature of the area of human activities is within 19.5 and 21.5°C, and it does not differ from the inner surface temperature obviously. Radiant heat from the electric heating film makes all inner surfaces temperature higher. Because of thermal storage of walls and good thermal insulation, the indoor air temperature can remain at a satisfying level even after the electric heating film is turned off. Air temperature within the occupied zone of room D301 is maintained at about 20°C, which is higher than those of both villa and townhouse style. It is due to the more uniform inner surface temperatures and radiant heat of multi-storied residences caused by the heat transmission between rooms.

Multi-storied residences have good thermal insulation performance. If preheating is done by electric heating film for a while, the air temperature of mid-storey can be still maintained at a higher level (about 20°C) even when the electric heating film has been turned off for a long time. The air temperature is almost equal to inner surface temperatures. Rooms at top floor or ground floor have more heat exchange with outdoor, so air temperatures of occupied zones in these room are relatively lower and are maintained at 17°C or so. The air temperature is very close to non-heating surface temperature. Radiant heating in this condition can meet the thermal comfort demand.

Thermal Comfort

The parameters of thermal comfort, which include air temperatures of dry-ball and blackball, average air velocity, relative air humidity, water vapour pressure and average radiation temperature, were to be measured. According to GB/T18049-2000 (Chinese National Standard GB/T18049-2000, 2000), the measured results were calculated into PMV and PPD of GB/T18049-2000. The values of PMV and PPD are given in Table 1.

Table 1 The measured values of PMV and PPD

Date and time		PMV	PPD
	2:30 p.m.	–0.16	5.5
	2:50 p.m.	–0.18	5.7
February 7	3:10 p.m.	–0.18	5.7
	3:30 p.m.	–0.17	5.6
	3:50 p.m.	–0.32	7.1
	1:00 p.m.	0.52	10.7
March 13	2:00 p.m.	0.50	10.2
	3:00 p.m.	0.63	13.2

During the measuring time, the average PMV values are –0.202 on 7 February and 0.55 on 13 March, the maximal values are –0.32 and 0.63, the corresponding PPD average values are 5.92 and 11.37, the maximal values are 7.1 and 13.2. Table 1 shows that PMV values were all within ±1, based on ISO7730-1994, the rank of thermal comfort is COMFORT, and PPD values were under or around 10%, so the thermal comfort in the measured room is satisfied.

CONCLUSIONS

Based on the analyses and evaluation on the effect of using electric heating film systems in residential buildings in Shijiazhuang, some conclusions are drawn.

Under the local weather conditions, all the measured indoor air temperatures of the rooms reached the designing demand. The vertical distribution of indoor air temperatures was also satisfied. The inner surface temperatures were higher than normal, which indicated the advantage of radiation heating. All the thermal comfort values reached COMFORT degree. The evidences above shows that electric heating film used in residential building of north China can meet the dweller’s demand. From the point of view of thermal comfort, electric heating film system has some distinct advantages over traditional convection heating systems.

REFERENCE

Chinese National Standard GB/T18049-2000, 2000, Moderate thermal environments—Determination of the PMV and PPD indices and specification of the conditions for thermal comfort, eqv ISO7730-1994, Standardization Administration of China.