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Thermal Environment of Chinese Residential Buildings with Different Thermal Insulation Materials in Hot-Summer-and-Cold-Winter Zone of China

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ABSTRACT

Field measurements of the indoor climate of the typical Chinese residential buildings with different thermal insulation materials located in Zhejiang Province of China were conducted in winter. The aim of the experiment was to evaluate the indoor thermal environment and its heating effects with different thermal insulation materials. In particular, the effect of different thermal insulation materials on the winter indoor thermal environment in the area of hot-summer-and-cold-winter zone of China is studied in this paper.

Keywords: Residential buildings; Thermal insulation materials; Field measurements; Hot-summer-and-cold-winter zone

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INTRODUCTION

Such a great population of country as China, energy and environment problem has become urgent issue in the development process. In China, building energy consumption makes up to nearly 20.9 percent of total national energy consumption (National Bureau of statistics of China, 2011). And the largest proportion of the building energy consumption is building daily energy consumption, which accounts for 80% (Li Nan, 2011) of the national total energy consumption. It includes building heating, air conditioning, water supply, cooking, lighting and electrical building energy consumption. And now, Chinese existed buildings and new constructions have the same prevalent problems of large energy consumption, low efficiency, and poor thermal insulation for building enclosure. All of them take the energy consumption of winter heating and summer air-conditioning in high level. In 1980s, Chinese government adopted a series of means for energy saving. Some of them have worked. The "Eleventh Five-Year Plan" issued a number of new standards for energy efficiency, which improved the energy saving level for existed buildings and new constructions.

However, a more formidable challenge followed with these achievements. The building total energy consumption inevitably rises continuously. There are two reasons. The first is new construction area increased rapidly from urbanization; the second is the residents' higher requirements for living in comfort.

The meeting of Annual Chinese Building Energy-saving in 2012 gave some useful research report. It illustrated that the heating energy consumption in Chinese northern cities is 16,330 TEC, which is 20% of the building total energy consumption and which is 16.6kgce per square meter; it also illustrated that the heating energy consumption in winter cold and summer hot zone is 1,240 TEC, which is 1.5% of the building total energy consumption and which is 2.4kgce per square meter (Tsinghua University Building Energy Research Center, 2012). Of course, the calculation of public buildings' energy consumption is included in northern cities' of China. The total energy consumption and energy consumption per unit area increased year by year in hot-summer-and-cold-winter zone of China, though the number of it is not large. It is different from the one in northern cities by energy saving steps. In addition to this increasing urban area, one important reason for its increase number is that people wasted heating energy for ignoring the thermal insulation effect of building enclosure when they abuse air conditioner to improve their indoor thermal comfort.

This phenomenon got great attention from government and scholars in China. With the support of the "Twelfth Five-Year Plan", the research group undertook on-the-spot survey on Hangzhou, the capital city of Zhejiang province of China, as a typical city, and confirmed that the thermal performance of building enclosure would influence the operation time of air conditioner and indoor temperature.

CLIMATE CHARACTERISTICS IN HOT-SUMMER AND COLD-WINTER IN CHINA

Standards of thermal design for civil buildings (GB 50176-93) of China divide the third climatic region into two parts: 0-90 days of the coldest month average temperature (0-10℃) 、of the hottest month average temperature (25-30℃) and day average temperature which is not higher than 5℃, and 40-110 days whose average day temperature is not lower than 25℃. This is called hot-summer-and-cold-winter zone in China, and also called the region of transition. The climate character is that summer is hot, winter is cold, the temperature difference is small in the day, annual precipitation is big and sunshine is less. The summer's character in this region is: the hottest month average temperature is 25-30℃, average relative humidity is 80% and the performance is sultry. The winter's character in this region is: the coldest month average temperature is 0-10℃, average relative humidity is 80% and the performance is cold and damp. Although the temperature in winter is higher then north region, sunshine rate is lower then north region. So, these regions need heating.

Hangzhou located in north of the east south coastal, capital of Zhejiang province of China. The longitude of the geographical position is 120 °12 ′, and its latitude 30 °16 ′. The high level is 20.23m, and its gross area is 16,600 km^2, total population is 8,700,400. Hangzhou city meet for the character of the summer hot and winter cold region, HDD18 is 1555, CDD26 is 175, and the average annual temperature is 17.0℃. The level of urbanization in Hangzhou is higher than other areas of Yangtze River Basin, residential building type are diversification, and the houses of two different periods were chosen for investigation in Hangzhou.

ANALYSIS OF THE BUILDING ENCLOSURE

In the hot-summer-and-cold-winter zone in China, the main form of the thermal insulation of wall is external insulation and internal thermal insulation. The investigation of two houses is for the exterior thermal insulation form.

Residential building A, founded in 2007, is a frame-shear wall structure type of small high-rise residential building, height 2.9m, the southern and Northern direction. The main building enclosure and thermal properties is shown in Table 1.

Residential building B, founded in 2001, is a frame structural type of small high-rise residential, 2.8m height, the southern and Northern direction. The main building enclosure and thermal properties is shown in Table 2. We can see that the residential building is constructed in two different times, and the thermal insulation materials are different. The thermal insulation the performance also has bigger differences. The thermal insulation of the residential building A is superior to that of the residential building B.

Measurement Outline

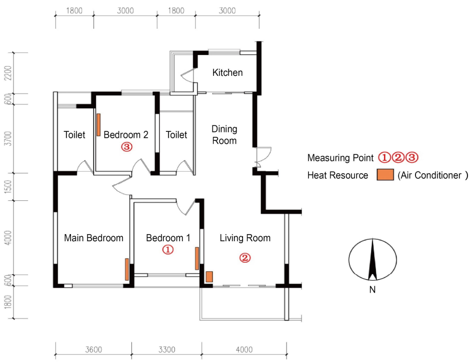

Figure 1. Measurement spots in the plan of test house A

The field test items include (1) global solar radiation, (2) outdoor wind direction and velocity, (3) outdoor air temperature and humidity, (4) indoor air temperature and humidity, (5) indoor globe temperature, (6) inside wall surface temperature and ground surface temperature. Table 3 shows the instruments for all corresponding parameters. The outdoor wind direction and velocity were measured with the anemoscope and anemometer on the top of a modern bricks house with flat roof, at bout 6 m high. The results of global solar radiation, outdoor wind velocity and wind direction were recorded once an hour manually. The air temperature and humidity were recorded automatically every thirst minutes. The sensors for measuring outdoor air temperature and humidity were shaded with aluminum shading devices. The indoor air humidity, global temperature and wind velocity were measure at a height of 1.1 m from floor level. Figure1 and Figure 2 show measurement spots of indoor thermal environment of the houses.

House A adopts split air conditioner for heating. The indoor temperature and humidity test point selection are living room, south direction bedroom 1 and north direction bedroom 2, test point shown in Fig.1. We didn't test master bedroom because there is no people live in it during test period. Test time is from 16 o'clock of 28th December, 2011 to 16 o'clock of 30th December, 2011, total of 48 hours.

House B use split air conditioner for heating. The indoor temperature and humidity test point selection are south direction living room, south direction main bedroom, and test point shown in figure2. Test time is from 19 o'clock of 28th December, 2011 to 19 o'clock of 30th December, 2011, total of 48 hours.

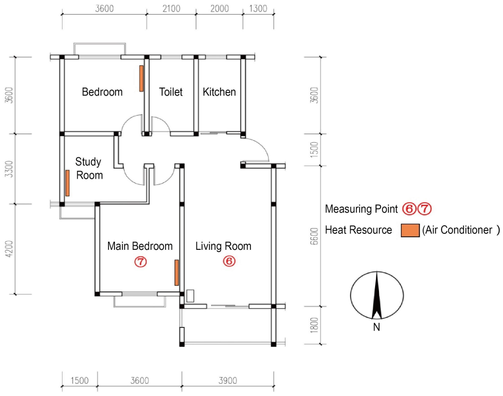

Figure 2. Measurement spots in the plan of test house B

Table 1. The A house building enclosure and its thermal performance

Structure parts	Structure	U-value [W/(m^2·K)]	SC
Roofing	40 thick and C20 rigid waterproof concrete surface layer	0.45	
	10 thick low strength mortar isolation layer		
	Waterproof layer		
	20 thick 1:3 cement mortar screed-coat		
	The thinnest part 30 thick light aggregate concrete 2% sloping layers		
	50 thick PU insulation board		
	100 thick reinforced concrete roof board		
Exterior wall	Exterior wall coating 5 thickness of crack resistant mortar composite fiberglass mesh layer 30 PU thick insulation board Bonding layer 200 thick aerated concrete block 10 thick plastering mortar	0.54	
Interior door	Thermal insulation door	1.76	
Exterior door	Aluminum alloy hollow glass door, 5+12A+5	2.3	
Exterior window	Aluminum alloy hollow glass door, 5+12A+5	2.3	0.55
Balcony door	Aluminum alloy hollow glass door, 5+12A+5	2.3	0.55

Table 2. The B house building enclosure and its thermal performance

Structure parts	Structure	U-value [W/(m^2·K)]	SC
Roofing	40 thick C20 rigid waterproof concrete surface layer	0.96	
	10 thick low strength mortar isolation layer		
	Waterproof layer		
	20 thick 1:3 cement mortar screed-coat		
	The thinnest part 30 thick light aggregate concrete 2% sloping layers		
	30 thick EPS insulation board		
	100 thick reinforced concrete roof board		
Exterior wall	Exterior wall coating 5 thickness of crack resistant mortar composite fiberglass mesh layer Powder particle sizing EPS 40 thick Interface treating mortar 240 thick KP1 clay porous brick 14 thick cement mortar	0.97	
Interior door	Thermal insulation door	3.0	
Exterior door	Plastic steel glass window	2.8	
Exterior window	Plastic steel glass window	2.8	0.60
Balcony door	Plastic steel glass window	2.8	0.60

Table 3. Measured parameters and instruments

Measured parameter	Instrument	Precision	Notes
Temperature of indoor/outdoor air	RH Thermo Recorder	±0.1ºC	Auto acquisition per 30 minute
Relative humidity of indoor/outdoor air	RH Thermo Recorder	±1%	Auto acquisition per 30 minute
Global solar radiation	MS-42 pyranometer	±0.1W/m^2	Manual acquisition per hour
Global temperature	Standard black ball thermometer	±0.1ºC	Manual acquisition per hour
Temperature of envelop surface	Proces-II apparatus (Type T thermal couple)	±0.1ºC	Auto acquisition per 30 minute
Air velocity	Hot ware anemoscope	±5% of the measured value	Manual acquisition per hour

Winter Survey Results

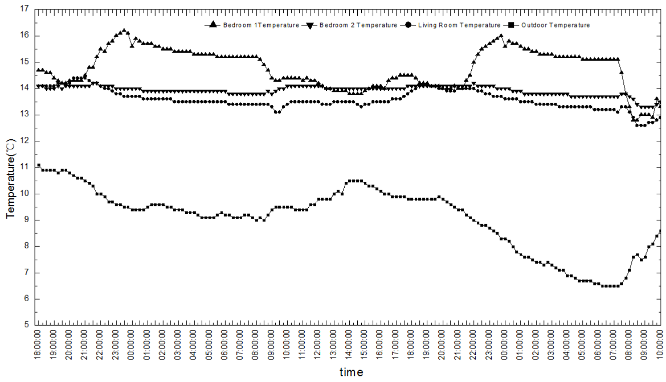

Figure 3. Air temperature in test house A

Through the inquiry and survey, we learned that people use air conditioning from early Dec. in 2011 approximately. The user of house A choose a split air conditioning system of heating, and the facility works like this: it turns on regularly according to the activity status and the temperature in living room, and from 21:00 to 24:00 in the night in bedroom 1, in which it turns off in the day; it turns on irregularly in bedroom 2 due to children's activities. The temperature of air conditioning is set on 26℃～27℃.The split air conditioning system in house B works as below: it turns on regularly according to the activity status and the temperature in living room, and from 23:00 to 7:00 next day in master bedroom.

For near the same indoor heat source, comparison can be done for temperature results measured from A house and house B, shown in Figure 4 and Figure 5.

From the results, the whole day mean temperature of the bedroom of house A was 14.36 ºC higher than the house B, that of 13.03 ºC, during the test period. It shows that the house A was warmer than house B in winter. This is due to lack of sufficient thermal insulation in house B compared with the house A. The whole day temperature fluctuating breadths of the bedroom of the house A and the house B during the test period are 1.5 and 1.6ºC, respectively, nearly the same. This is due to the same of air conditioner for heating in the bedroom. The diurnal air temperature of the living room in house A was 1.6ºC, lower than that of the living room in house B, 2.7ºC. This illustrates that the living room tends to play a role of thermal buffer for bedroom. But the role of thermal buffer for bedroom with good external thermal insulation is bigger that of with bad internal thermal insulation. From the results, it clearly shows that the house A is warmer than the house B in winter.

The diurnal air humidity of the living room was stable as compared with great fluctuations of outdoor air relative humidity. The average relative humidity in the bedroom of the house A and outdoor was 61% and 64% respectively. The average relative humidity in house B and outdoor was 64.4% and 64.5% respectively. Similar to the test results of air temperature in winter, this is supposed to the effect of thermal insulation of the external walls which perform the role of a temperature conditioning materials in order to stabilize room air humidity. Because of the bad thermal insulation between bedroom and living room in winter, there was clearly air temperature difference between the bedroom and living room in house B.

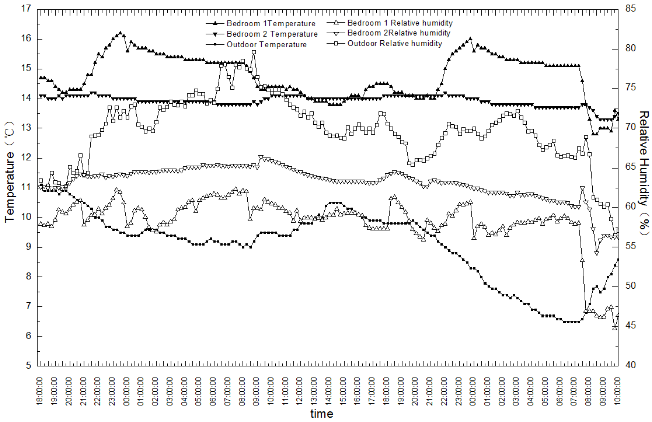

Figure 4. Air temperature and relative humidity in test house A

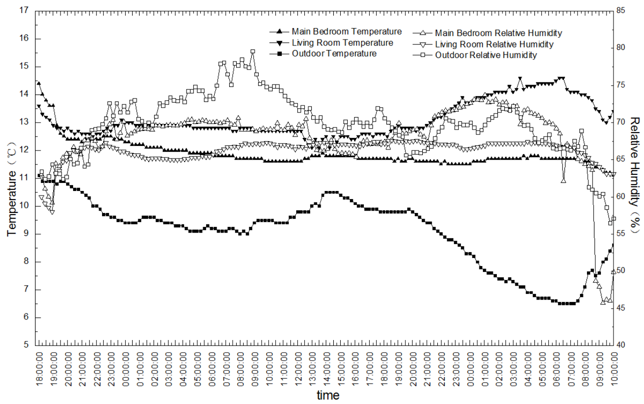

Figure 5. Air temperature and relative humidity in test house B

CONCLUSIONS

Field measurements of indoor thermal environment of the typical residential buildings in hot-summer-and-cold-winter zone of China were conducted in winter. Field measurements and analysis gives us more quantitative understudying of the winter thermal environment of the residential buildings with external thermal insulation walls. The effects of external thermal insulation walls on heat storage and moisture conditioning are confirmed. The indoor thermal environment of the house with external thermal insulation walls in winter is considerably comfort in the hot-summer-and-cold-winter zone of China. According to the measurements, it can not be concluded the houses with external thermal insulation walls were warmer than that of houses without external thermal insulation walls in winter. Further research is needed to determine the detailed thermal environment of residential building, such as PMV, materials thermal properties. More work is required.

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