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Aldehyde Emission from Indoor Thermal Environment of Herdsmen's Settlement House

Lei Zhang[a,*], Jingyuan Zhao[a], Jiaping Liu[b,c]

[a]College of Architecture, Chang'an University, Xi'an 710064, China
[b]State Key Laboratory of Green Building in Western China, Xi'an 710055, China
[c]College of Architecture, Xi'an University of Architecture and Technology, Xi'an 710055, China
zl.wc@ chd.edu.cn

This study aimed to analyse the winter indoor thermal environment of double-story commercial and residential building in herdsmen settlements of China Northwest mountain grassland area. The method of research is field testing and data calculation analysis; include indoor air temperature and humidity, outdoor air temperature and humidity, outdoor wind speed, thermal comfort index. The result shows the relationship between indoor thermal environment, envelope materials, heating methods, location of rooms and building type. In addition, the influence was quantified in 0~6.9 ºC in winter. Finally, put forward three strategies to enhance the winter double-story commercial and residential building indoor environment.

1. Introduction

In the Northwest of China, with the development of society and the improvement of people's living standards, the thermal environment in the building is a concern. In this paper the selected base in Sunan County, Kangle Village herdsmen settlement, Gansu province. Existing residential indoor thermal environment largely ignored the evolution and development of herdsman settlement double-story commercial and residential building. Thermal environmental shortcomings of the field investigation and analysis of settlement residential areas, not only to improve the quality of living, but is intended to guide regional commercial and residential buildings to go to energy-saving (He et al., 2011; Wang et al., 2018). Through experiment and demonstration research, the gradual realization of the modernization of rural construction and green ecological (Liu, 2006).Obvious plateaus climatic characteristics: about the annual average temperature 3.6 ºC, cool in summer and cold in winter (Zhou, 2004). Sunan County is cold region in the thermal partition (Zhang et al., 2015). Such climatic characteristics determine the area residential demand heating insulation in winter (Yang, 2003). Therefore, the double-story commercial and residential building for local, conducted a test of indoor thermal environment.

2. Methods

2.1 Object of study

With the implementation of the policy of settling the local Yugu herdsmen, two resettlement settlements were built in the ecological resettlement settlements according with the positions of the main traffic trunk road. Through practical research, the form of residential buildings away from the main traffic trunk road is a single-story residential building independent of the courtyard; the near the main traffic trunk road form of residential building is a double-story commercial and residential building. The test room for this study is a double-story commercial and residential building. The test room built in 2013, double-story frame structure, walls as the brick wall. Test point is located on the second floor of residential indoor. The building external wall thickness is 370 mm; interior wall thickness is 240 mm and part of the external walls of latex paint ordinary paint and paste decorative tiles. All exterior walls are not provided with insulation. The double-story commercial and residential building total construction area is 230 m^2, which living part in second floor of the construction area is 120 m^2 and commercial part in second floor of the construction area is 110 m^2. Winter indoor heating uses radiation to heat household heating mode, basic household use of solar water heaters. Indoor testing ground use

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80cm×80cm tile flooring. South to the living room window for double glass aluminium sliding window size is 3.6m×1.5m. The south bedroom-1 window is double glass aluminium sliding window size is 2.1m×1.5m. The south bedroom-2 window is double glass aluminium sliding window size is 2.1m×1.5m too. The north bedroom window is double glass aluminium sliding window size is 1.5m×1.5m. It is shown in Figure 1.

Figure 1: The test room- a double-story commercial and residential building

Formula for calculating thermal resistance of multi-layer structure:

$$R=\delta 1/\lambda 1+\delta 2/\lambda 2+\ldots+\delta n/\lambda n \quad (1)$$

Formula parameter: δ1, δ2, .., δn-Thickness of each layer (m), λ1, λ2, …, λn-Thermal conductivity of each layer [W/(m^2·k)].
Calculation formula of heat transfer coefficient of structure: K=1/ R0.
Heat transfer coefficient of building facades and windows: K1=1.51 W/ (m2·k) and K2=0.29 W/ (m2·k) (Mao, 2006).

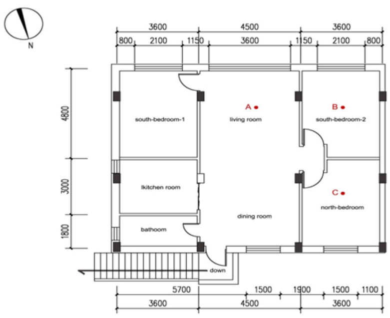

Figure 2: Test room testing point

2.2 Testing program

The test time and laboratory equipment: In order to better understand the measured thermal performance situation residential building wall in winter, the test carried out at selected local climatic conditions more typical (Chen et al., 2011). The test time is from 20 to Jan 21, 2015 at 13:00 on the 21th. 24 hours of continuous records. Laboratory equipment is the TR-72ui temperature and humidity recorder. The test data is air temperature and humidity (Wang et al., 2011). Laboratory equipment for the TES-1341 hot-wire anemometer. The test data is wind speed. The test point arrangement: Bedroom and living room is the main space is to use the family a long time, the use of higher frequency space, has a representative. Figure 2 shows the main test chamber testing point distribution, point A is located in the living room, point B is located in the south bedroom-2, and point C is located in the north bedroom. They are arranged in 1M off the ground. Test equipment and methods of operation are shown in Table 1.

Table 1: Test equipment and methods of operation

Test content	Test Equipment	Data sampling range, pitch and style
Indoor and outdoor air temperature, humidity	TR-72ui temperature and humidity recorder: (TEMP-20~70ºC, accuracy±3.0%, resolution±0.1%, RH 0%RH~100%RH, accuracy +/- 3%RH, resolution 0.1%RH)	At 13:00 on January 20, 2015 to at 13:00 on the 21st, Automatically records every 1 hour 1
Indoor wind speed	TES-1341 Hot-wire anemometer (0.1~30.0 m/s, accuracy±3.0%, resolution 0.01 m/s)	At 13:00 on January 20, 2015 to at 13:00 on the 21st, Automatically records every 1 hour 1

3. Methods

3.1 Test results

Each bedroom and living room in the test room test temperature for 24 hours. The test results shown in Figure 3.In a day, outdoor the lowest temperature of -11.8°C, appeared in 5:00 on the 21st, the highest temperature of 16.2°C, appeared in 13:00 on the 20st, with an average temperature of -1.25°C, the daily range of 28°C. Test point A is located in the living room, facing south, at 2:00-5:00 on the 21st higher temperatures, as high as 23.3°C; at 10:00 on the 21st the lowest temperature as low as 18.2°C; average temperature of 22.2°C. Test point B is located in the south bedroom-2, facing south, at 2:00-5:00 on the 21st higher temperatures, as high as 23.2°C; at 10:00 on the 21st the lowest temperature as low as 16.9°C; average temperature of 22.1°C. Test point C is located in the north bedroom, facing north, at 2:00-5:00 on the 21st higher temperatures, as high as 23.2°C; at 10:00 on the 21st the lowest temperature as low as 17.8°C; average temperature of 21.9 °C.
Each bedroom and living room in the test room test relative humidity for 24 hours. The test result shown in Figure 4. In a day, the outdoor air relative humidity minimum in about 14:00 on the 20st at 16.8%, maximum in about 7:00 on the 21st at 58.9%, average of 36.6%.Test point A is 12:00 on the 21st maximum humidity of 25.4%; 10:00 on the 21st minimum of 15%; average of 22%.Test point B is 5:00 on the 21st maximum humidity of 21.9%; 10:00 on the 21st minimum of 12.4%; average of 18.9%.Test point C is 13:00 on the 21st maximum humidity of 28.5%; 10:00 on the 21st minimum of 15.2%; average of 21.3%.
Figure 5 shows the test results within a day outdoor wind speed. The minimum wind speed values in the region appears one day in the winter of about 13:00 on the 20st to 0.03s/m, maximum wind speed values occurred at about 10:00 on the 21st for the 2.93 s/m.

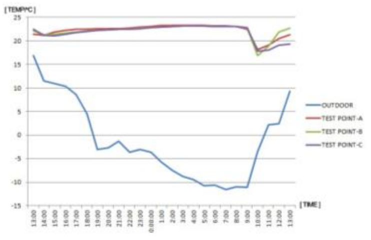

Figure 3: Indoor and outdoor air temperature in winter

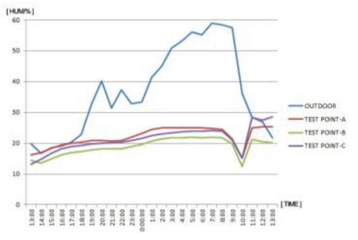

Figure 4: Indoor and outdoor air relative humidity in winter

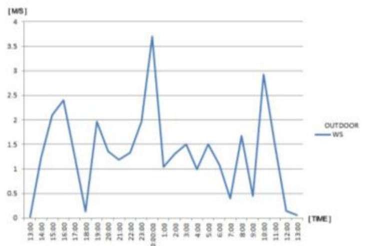

Figure 5: Outdoor wind speed

3.2 Date analysis

Temperature analysis: In winter, test area outdoor temperature difference reached 28°C, the average temperature is below °C. Outdoor average wind speed is lower than 1s/m, less impact on the building of cold. Building needs insulation, mainly cold outside air through the building's exterior into the interior through heat conduction (Alheji et al., 2014). Bedroom and living room one day average temperature difference is within 0.05°C, the description of the three rooms the same effect as an indoor heat better building insulation. The higher temperatures and the small differences between the three test rooms indicate that centralized radiant heating plays a major role in indoor temperature effects while the south living room and bedroom are less affected by outdoor solar radiation. The same building doors and windows closed well, to maintain the stability of the indoor temperature. Description of the premises used in the central radiant heating is continuous 24-hour heating. House floor commercial space is very small temperature on the second floor of the indoor living space, commercial space on the first floor also explained a 24-hour continuous heating, while the doors and windows closed during the day. Three o'clock in the morning 3:00 the highest temperature in three rooms, indicating that people have fully fallen asleep at this time, the windows closed, the indoor air does not flow high temperature and constant. At 10:00, three lowest room temperature, indicating that the time indoor ventilation opening doors and windows, indoor and outdoor air flow, temperature decreases. South bedroom temperature is higher than the north bedroom, solar radiation intensity, and solar radiation through windows and outdoor directly connected to the bedroom heat. North bedroom temperature is the lowest; the north bedroom facade no solar radiation, conduction of cold air into the room through the walls, the temperature received some influence and lowers the temperature.
Relative humidity analysis: In winter, test area outdoor humidity test in 9:00 to reach the maximum is caused by melting snow after sunrise, test area outdoor humidity test in 13:00 to reach the minimum is caused by the largest amount of evaporation due to the most intense solar radiation., the lower the daily average humidity, outdoor relatively dry (Zhu et al., 2010). The south bedroom-2 average indoor relative humidity less than 20%

relatively dry interior. Bedroom and living room are the lowest humidity at 10:00, at that time solar radiation is gradually enhanced and direct indoor, at the same time people go out to outdoor, indoor without any wet environment. Living room is the highest humidity at 12:00; people eat lunch and drink plenty of water, producing large amounts of water vapor. The south bedroom-2 is the highest humidity at 6:00; people wake up and get wet outside the window and into the room. The north bedroom is the highest humidity at 13:00, people use mops with water to clean the ground.

Thermal Comfort Analysis：Calculation of indoor thermal comfort thermal comfort model is set up on the basis of P.O. Fanger with PMV-PPD index evaluation thermal comfort (Xia et al., 2013).Calculation formula:

$$M\text{-}W\text{-}C\text{-}R\text{-}E=0\ (S=0) \tag{2}$$

The body must be in a state of heat balance, so that the body's heat dissipation of the environment is equal to the body's heat, and the amount of heat storage is 0.

Table 2: Typical winter time indoor pmv-ppd index (living room)

Time	LR TEMP (°C)	LR HUM (%)	Thermal Resistance (clo)	Metabolic rate (met)	WS (m/s)	Mean radiant TEMP (°C)	LR PMV	LR PPD
05:00	23.3	25.0	2	0.7	0.3	22.7	-0.79	18.2
07:00	23.1	24.7	1	1.2	0.3	22.4	-0.18	5.7
14:00	21.2	19.4	1	1	0.3	20	-1.31	40.8
21:00	22.6	20.6	1	1	0.3	22.1	-0.72	16.0

Table 3: Typical winter time indoor pmv-ppd index (south bedroom)

Time	LR TEMP (°C)	LR HUM (%)	Thermal Resistance (clo)	Metabolic rate (met)	WS (m/s)	Mean radiant TEMP (°C)	LR PMV	LR PPD
05:00	23.2	21.9	2	0.7	0.3	22.8	-0.83	19.6
07:00	23.1	21.9	1	1.2	0.3	22.4	-0.20	5.8
14:00	21.3	13.6	1	1	0.3	20.2	-1.34	42.5
21:00	22.5	18.1	1	1	0.3	21.8	-0.75	17.0

Table 4: Typical winter time indoor pmv-ppd index (north bedroom)

Time	LR TEMP (°C)	LR HUM (%)	Thermal Resistance (clo)	Metabolic rate (met)	WS (m/s)	Mean radiant TEMP (°C)	LR PMV	LR PPD
05:00	23.2	23.9	2	0.7	0.3	23.1	-0.8	18.6
07:00	23.1	24.0	1	1.2	0.3	22.4	-0.19	5.7
14:00	21.1	14.7	1	1	0.3	20.1	-1.34	42.2
21:00	22.4	20.2	1	1	0.3	21.1	-1.02	26.8

Table2, Table3 and Table4 are the use of simulation CFD calculated PMV and PPD values to the bedroom and living room in winter typical time points, which corresponds to the value -3°C~3°C ASHRAE 7-level metrics (-3 cold, -2cool, -1a little cool, 0 lukewarm, 1a little heat, 2heat, 3 hot) (Zhang et al., 2010). Table-2, Table-3 and Table-4 show the typical time point of the winter season. In 7:00, 14:00 and 21:00, the indoor people wearing clothes mainly thin sweaters and thin jacket with thermal resistance is 1clo. In 5:00 people wearing long sleeved underwear covered with a thick quilt with thermal resistance is 2 clo. In 7:00, the indoor people began more activities after getting up with metabolic rate is 1.2 met. In 14:00 and 21:00, the indoor people sit quietly with metabolic rate is 1 met. In 5:00, the indoor people lie in bed with metabolic rate is 0.7 met. The living room PMV value is -1.31 in 14:00 with indoor cooler and the other time indoor thermal environment in a comfortable range. The south bedroom PMV value is -1.34 in 14:00 with indoor cooler and the other time indoor thermal environment in a comfortable range. The north bedroom PMV value is -1.34 in 14:00 and -1.02 in 21:00 with indoor cooler and the other time indoor thermal environment in a comfortable range. All other times the test room PMV value is less than 0, ranging between -1-0, better indoor comfort little biased a little cool, PPD values are below 20%.

4. Discussion

Through the winter of the herdsman settlement residential building indoor thermal environment of double-story commercial and residential building indoor thermal environment test and analysis, the construction system of the passive control is weak. The winter indoor must be mainly through the active control system - centralized household to radiant heating system, ensure comfort of indoor thermal environment system. The centralized household heating system is produced by burning coal heat through a long pipeline for transmission, easy to produce large amounts of carbon emissions to the outdoor environment, while large heat loss caused by large energy consumption situation. In this regard, the passive control technology to improve the building indoor thermal environment strategy and it conducive to energy conservation.

4.1 Effect of wall insulation

Building external wall insulation should be used outside the insulation, because the external insulation to protect the main structure, so that the wall structure layer is relatively stable at room temperature, to avoid the structural layer of hot and cold changes, can largely eliminate temperature cracks, extend its service life. External wall insulation polyurethane foam commonly used in construction, this construction program more practical, life is better than other insulation materials. However, the existing organic thermal insulation material is not suitable for pasture use in mountainous grasslands in Northwest of China. There is a disadvantage that the price is high and it is difficult to self-degrade and easily cause environmental pollution. Therefore, insulation materials should be combined with the actual situation in the region should adopt the combination of raw soil plus forage as insulation material. This local natural material after processing has the advantages of small thermal conductivity, low cost and environmental friendliness. It is made into a mixture of raw soil and pasture mixed with frame structure. For energy-saving house roof insulation should be used polystyrene insulation board; insulation thickness should be not less than 2.5 cm. Under normal use and maintenance conditions, the external wall insulation works of the useful life of not less than 25 years (Zhang and Liu, 2014).

4.2 Effect of exterior windows

The two south bedroom and living room of building can increase overall sun room, the materials can be used plastic hollow glass, and the windows are small area flat open. Between the south bedroom and the living room and the sun room set all glass aluminum alloy landing push and pull the door, residents can according to seasonal changes in climate, the amount will be the door open or closed, and can ensure that the indoor temperature, ventilation and lighting. Sun room can be excessive daytime heat storage in the night, when the sun 'holding a certain temperature, better play the role of the climate buffer which was confirmed. Sun room location is shown in Figure 6.

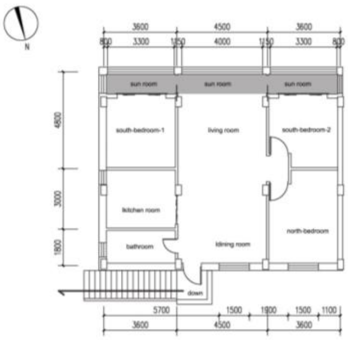

Figure 6: Sun room location

5. Conclusions

In summary, the herdsmen to settle residential building construction must provide a good indoor thermal environment as a precondition. Through indoor thermal environment in the field test, the study found that the typical period in winter herdsman settle better double-story commercial and residential building residential building indoor thermal comfort performance, mainly due to the use of active systems - centralized household radiation to heat heating system, using a 24-hour heating. This heating loss is large, building does not save energy. But also through the on-site investigation found that such building exterior insulation technology behind the indoor insulation effect have a negative impact. Therefore, based on the climatic characteristics of mountainous grassland in Northwest of China, the double-story commercial and residential buildings should employ advanced technology of external wall insulation, as a natural material selected place insulation, change the way of opening windows and add sunlight to improve the comfort and energy saving measures of indoor thermal environment.

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