CHEMICAL ENGINEERING TRANSACTIONS
VOL. 46, 2015
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Peiyu Ren, Yancang Li, Huiping Song

ISBN 978-88-95608-37-2; **ISSN** 2283-9216
DOI: 10.3303/CET1546118

Test Study of the Indoor Thermal Environment in winter of Herdsman Settlement Residential Building in China's Western Mountain Grassland Area

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

[a] College of Architecture, Chang'an University, Xi'an, China,
[b] College of Architecture, Xi'an University of Architecture and Technology, Xi'an, China.
zl.wc@chd.edu.cn

This study aimed to analyze the winter indoor thermal environment of herdsman settlement residential building in China's western mountain grassland area. The method of analysis is field testing, include indoor air temperature and humidity, outdoor air temperature and humidity .The result shows the relationship between indoor thermal environment and envelope materials, heating methods, location of rooms. In addition, the influence was quantified in 0～15℃ in winter. Finally, advice put forward to promote the indoor thermal environment.

1. Introduction

With the development of society and the improvement of people's living standard, the indoor thermal environment is a concern which was confirmed (Li Baizhan et al (2007)). In this paper the selected base in Sunan County, Kangle Village herdsmen settlement, Zhangye City. Existing residential indoor thermal environment largely ignored the evolution and development of herdsman settlement residential buildings. Thermal environmental shortcomings of the field investigation and analysis of residential areas, not only to improve the quality of living, but is intended to guide regional houses to go to energy-saving, low-carbon path of development which was confirmed (He Wenfang et al (2011)). Through experiment and demonstration research, the gradual realization of the modernization of rural construction and green ecological which was confirmed (Liu Jiaping (2006)). Obvious plateaus climatic characteristics: about the annual average temperature 3.6 ℃, cool in summer and cold in winter which was confirmed (Zhou Wei (2004)). It is a cold region in the thermal partition. Such climatic characteristics determine the area residential demand heating insulation in winter which was confirmed (Yang Liu (2003)) and which was confirmed (Liu Jiaping (2000)). Therefore, the herdsman settlement residential building for local, conducted a test of thermal environment.

2. Objects and methods

2.1 Object of study

With the implementation of the state's settlement policy in the local Yugu herders, establish the first phase of herdsman settlement residential buildings in ecological immigrant settlements. From the actual research, only type of living Type: a single layer residential building with courtyard. The test room built in 2005, masonry structure, walls as the brick wall, three exterior walls, an interior wall. Brick wall thickness is 370mm, ordinary latex exterior paint brush, using interior and exterior wall insulation. Roof are wood purling system (board wide is 1.5~2cm, earth wide is 5cm, tile is on top) Outside the windows size are C-1 (1.5m×1.5m); C-2 (0.9m×1.5m). They are double glass aluminum alloy windows. The entrance door size is M-5 (2.5m×2.5m), single glass aluminum alloy door. It is shown in Fig-1. Formula for calculating thermal resistance of multi-layer structure: $R=\delta 1/\lambda 1+\delta 2/\lambda 2+----+\delta n/\lambda n$ (1) Formula parameter: δ1, δ2, ---δn—Thickness of each layer (m),λ1, λ2, ---λn—Thermal conductivity of each layer [W/(m·k)]. Calculation formula of heat transfer coefficient of structure: K=1/ R0. Heat transfer coefficient of building facades and windows: K1=1.51 W/ (m^2·k) and K2=0.29 W/ (m^2·k) which was confirmed (Mao Yan et al (2006)).

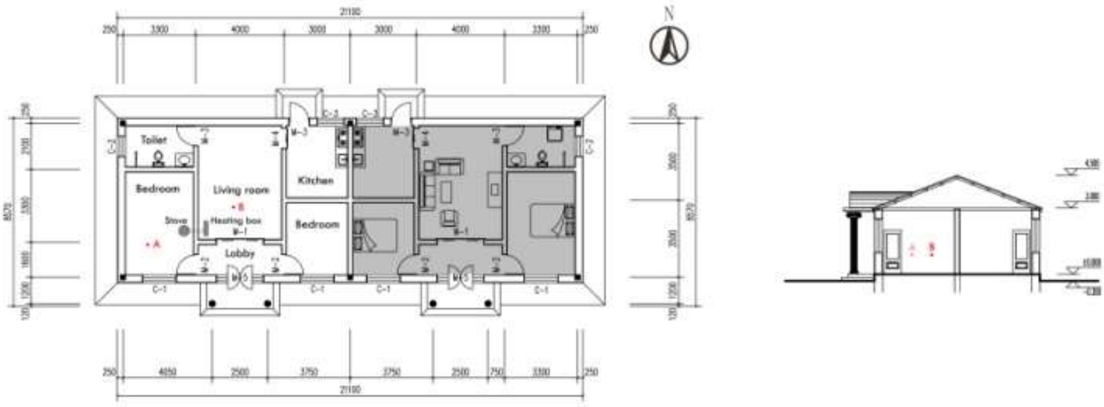
Please cite this article as: Zhang L., Liu J.P., Zhao J.Y., An F., 2015, Test study of the indoor thermal environment in winter of herdsman settlement residential building in china's western mountain grassland area, Chemical Engineering Transactions, 46, 703-708 DOI:10.3303/CET1546118

Figure 1: the test room-A single layer residential building with courtyard

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 which was confirmed (Chen Jing et al (2011)). The test time 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 which was confirmed (Wang Dengjia 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. Fig-2 shows the main test chamber testing point distribution, point A south bedroom, point B for the South to the living room. They are arranged in 1M off the ground. Test equipment and methods of operation are shown in Table-1. Fig-3 shows bedroom has a stove, living room with a heating box. The fuel used by the stove is coal, and heating box in the living room is connected with the stove and the chimney to the outside.



Plan *Profile*

Figure 2: Test room testing point

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:(Measuring range: temperature -20 ~ 70℃, accuracy±3.0%, resolution±0.1%, relative humidity 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 (Measuring range: 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. Results and analysis

3.1 The test results

Each bedroom and living room in the test room test temperature for 24 hours. The test results shown in Fig-4 In a day, Outdoor the lowest temperature of -13.9 ℃, appeared in 7:00 am, the highest temperature of 12.2 ℃, appeared in 13:00 pm, with an average temperature of -1.6 ℃, the daily range of 26.1 ℃. Test point A is located in the bedroom, facing south, noon 12:00 higher temperatures, as high as 23.8 ° C; 0:00 am the lowest temperature as low as 13.8 ° C; average temperature of 20.1 ℃. Test point B is located in the living room, facing south but through the foyer to the outside, 1:00-2:00 am the highest temperature up to 23.3 ℃; 12:00 pm the lowest temperature as low as 8.2°C; average temperature of 21 ℃.

Each bedroom and living room in the test room test relative humidity for 24 hours. The test results shown in Fig-5. In a day, the outdoor air relative humidity minimum in about 17:00 pm at 16.1%, maximum in about 8:00 am at 58.7%, average of 35.4%. Test point A is 19:00 pm maximum humidity of 36.5%; 13:00 pm minimum of 16.2%; average of 30%. Test point B is 11:00 am maximum humidity of 31.7%; 13:00 pm minimum of 15.8%; average of 26.5%.

Fig-6 shows the test results within a day outdoor wind speed. The minimum wind speed values in the region appears every day in the winter of about 6:00 am to 0s/m, maximum wind speed values occurred at about 10:00 am for the 2.32 s/m.

3.2 Data analysis

3.2.1 Temperature analysis

Living room *Bedroom*

Figure 3: Test room interior condition

In winter, test area outdoor temperature difference reached 20℃, the average temperature is below 0℃. 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 which was confirmed (Alheji Ayman Khaled B et al (2014)) Bedroom and living room one day average temperature difference is within 1℃, the description of the two rooms the same effect as an indoor heat better building insulation which was confirmed (Liu Dalong et al (2010)). Bedroom highest temperature, solar radiation intensity, solar radiation through windows and outdoor directly connected to the bedroom heat. Bedroom lowest temperature, people go to bed at night to minimize the stove temperature by keeping the body tuck right temperature. Living room highest temperature, indoor completely closed and only one side wall insulation is good. Living Room temperature is the lowest; the living room door is fully open to the outside through the hall open, cold outside air directly into the room so that the temperature is lowered.

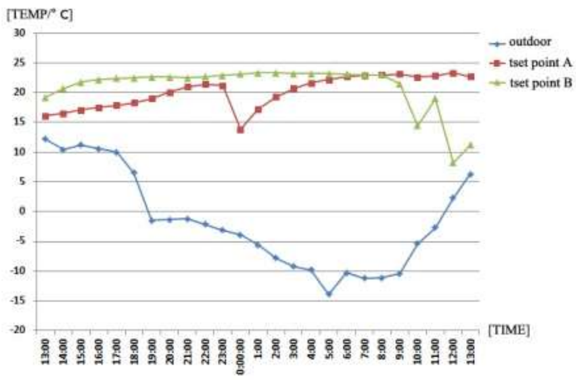


Figure 4: Indoor and outdoor air temperature in winter

Relative humidity analysis: In winter, test area outdoor humidity test in 8:00 to reach the maximum is caused by melting snow after sunrise, the lower the daily average humidity, outdoor relatively dry which was confirmed (Zhu Yiyun et al (2010)). Bedroom and living room average indoor relative humidity less than 40% relatively dry interior. Bedroom and living room are the lowest humidity at 13:00, intensity and interior the stove and the heat release value at that time the largest outdoor solar radiation. The largest bedroom and living room humidity, people produce a lot of water vapor in indoor activities and the doors and windows closed.

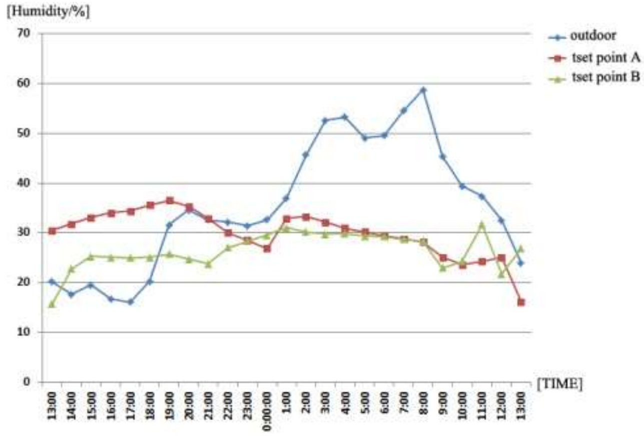


Figure 5: Indoor and outdoor air relative humidity in winter

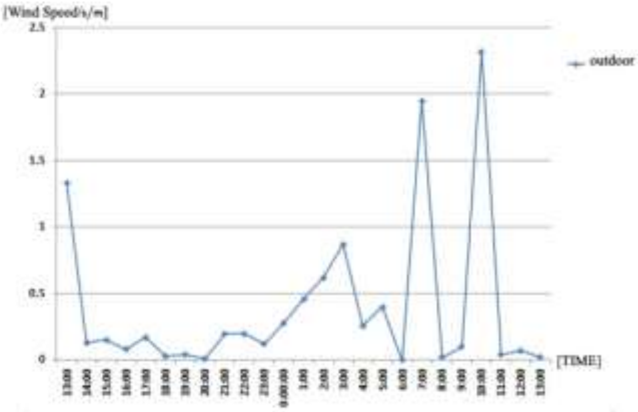


Figure 6: Outdoor wind speed

3.2.2 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 which was confirmed (Xia Bo et al (2013)). Calculation formula: M-W-C-R-E=0 (S=0) (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 is the use of simulation CFD calculated PMV and PPD values to the bedroom and living room in winter south typical time points, which corresponds to the value -3 ℃ ~ 3 ℃ ASHRAE 7-level metrics (-3 cold, cold -2, a little -1, 0 lukewarm, a little heat, heat 2, 3 hot) was confirmed(Yang Liu et al (2003)) and (Zhang Weijie et al (2010)). Table-2 shows 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 bedroom PMV value is 1 in 14:00 with indoor hotter and the other time indoor thermal environment in a comfortable range, living room PMV value below 0 and PMV value is -2.38 in 14:00 with indoor cooler, living the worst indoor thermal environment, discomfort in more than 90%.

4. Discussion

Table 2: Typical winter time indoor PMV-PPD index

Time	B.T (℃)	L.T (℃)	B.RH (%)	L.RH (%)	T. R (clo)	M. R (met)	W. S (s/m)	M.T1 (℃)	M.T 2 (℃)	B. PMV	B. PPD	L.PMV	L. PPD
07:00	23	22.9	28.7	28.8	1	1.2	0.3	22.4	22.5	-0.16	5.5	-0.16	5.5
14:00	20.7	16.5	22.8	31.8	1	1	0.3	16.0	20.4	1	26	-2.38	90.5
21:00	22.5	21	23.8	32.9	1	1	0.3	20.5	22.0	-0.7	15.4	-1.2	36.1
05:00	23.2	22.2	29.4	30.2	2	0.7	0.3	21.7	22.7	-0.8	20.2	-1.1	31.2

Figure 7: Sun room location

Through the winter of the herdsman settlement residential building indoor thermal environment of residential building indoor thermal environment test and analysis, the construction system of the passive control is weak. The winter indoor must increase the active control of coal stove heating, ensure comfort of indoor thermal environment system. In this regard, the passive control technology to improve the building indoor thermal environment strategy.

4.1 Effect of exterior wall

Hollow clay brick will replace the solid clay brick of the exterior wall, it can make the heat preservation performance double, quality 20%-40%, and can strengthen the wall strength. The external wall should be set up in order to enhance the insulation and heat preservation of the building, and reduce the heat loss which was confirmed (Zhang Lei et al (2014)).

4.2 Effect of exterior roof

Building indoor ceiling and the roof to form a closed layer of good air, the roof of the building external should strengthen insulation layer thickness and the common solid tiles instead of hollow tiles which can effectively guarantee the indoor temperature to reduce heat loss.

4.3 Effect of exterior doors and windows

Building south room can increase overall sun room, the materials can be used plastic hollow glass, and the windows are small area flat open. Between the 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 (Zhao Jie et al (2007)). Sun room location is shown in Fig-7.

5. Conclusions

In summary, the construction of residential building must be to provide a good indoor thermal environment as a precondition. Through Kangle Village herdsmen settlement residential building in winter indoor thermal environment of field testing, the research found that China's western mountain grassland area herdsmen settle residential building indoor thermal comfort slightly worse performance because the building insulation and ventilation and poor performance caused by active heating the stove. Therefore, for the Western climate mountainous areas, residential buildings should adopt solar heating design, exterior wall building, roof structure and type of door and window to improve the measures to improve the indoor thermal environment of comfort and energy save. Through these aspects, we can not only improve the indoor thermal environment comfort, but also can reduce the use of conventional energy, and reduce the carbon emissions in the process of residential building.

Acknowledgments

The research work was supported by the Fundamental Research Funds for the Central Universities No. 310841151098 and National Natural Science Foundation of China under Grant No. 50921005.

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