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COUNTERMEASURE OF ENERGY CONSERVATION OF FARM BUILDINGS IN RURAL AREAS OF COLD REGION IN CHINA

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ABSTRACT In order to evaluate the situation of energy conservation of farm buildings in rural areas of cold regions of China, this paper investigated and analyzed farm buildings in the Dashigou Village of the Heilongjiang Province. In this investigation, several instruments were used. The instruments used were a SCQ-01a Temperature Gathering Recorder, BES-A Overall Heat Transfer Coefficient of Building Envelope Detector and TVS—100 Portable Thermal Infrared Imager. The instruments were used to measure the indoor temperatures and the thermal irregularities in building envelopes were identified. Then the energy consumption was analysed. The result show that when the indoor temperature is low, it is not possible to guarantee comfort and the farm buildings consumed high amounts of energy. The study summarized these problems of energy conservation of the farm buildings in rural areas of this cold region. Additionally some countermeasures were provided based on the study. The first is integrated architectural design including the optimal shape coefficient for buildings and the fewer windows on the north side. The second is the improvement of heat insulating properties of walls by adding insulation material. And the last is improvement of heat insulating properties of doors and windows by reducing heat loss by infiltration. These countermeasures will improve human comfort in rural areas of cold region in China, and reduce energy consumption and greenhouse gas emissions.

Keywords: Farm buildings, Cold region in China, Situation of energy conservation, Countermeasures of energy conservation.

INTRODUCTION For more than 20 years, China's economy has maintained rapid development, but urban-rural differences are increasing. Questions such as pollution and energy consumption are also prominent day by day. According to Chinese goal of building energy-efficient, the building energy conservation work is to focus on the farm buildings on the next step.

The policy is to promote the construction of energy-efficient type of buildings. But the farm buildings are low-comfort and high-consumption, and cover an area of big. In order to improve the farm buildings, the current situation of the farm buildings is needed. This paper would show it through investigation, and some countermeasures were offered.

1. INVESTIGATION OF ENERGY CONSERVATION TO FARM BUILDINGS IN RURAL AREAS OF COLD REGION

1.1Natural Conditions

We select the farm buildings in the Dashigou Village of Hailin City in Heilongjiang Province as the objective to study. Hailin is located in the southeast of Heilongjiang Province， on the east slope of Zhangguangcai Ridge, the offshoot of Changbai Mountain, near the west side of Mudanjiang City. Hailin belongs to the mid-latitude in the temperate continental monsoon climate zone, which has long winters and short summers, freezes up to 5 months. The city's annual average temperature is 1.9-3.6℃, and annual extreme minimum temperature is -38.8℃. It is prevailing northwest wind in winter and southerly winds in summer. The rural energy construction is exemplary.

1. 2Construction Status

Dashigou village Province is located in Hailin of Heilongjiang, with low levels of economic development, the rural per capita net income is 3687 yuan, and rural per capita housing area is 20 m^2. Due to the way of domestic production and living, the farm buildings are separate apartments, each household has a front yard and a backyard, and there is large space around the building. Single house construction area is from the 50 m^2 to 100 m^2, and the building usually is a one-story brick structure with wooden frame. With the wall thickness of 370mm and the average heat transfer coefficient K=1.65W/(m^2•℃); using oblique roof, with a 200mm thick sawdust insulation, heat transfer coefficient K=0.40W/(m^2•℃); with the single Wooden windows, heat transfer coefficient K=4.80W/(m^2•℃); with the single wooden door as outside door, heat transfer coefficient K=4.65W/(m^2•℃). According to the calculations on the heat consumption of local buildings based on "Energy Conservation Design Standard for New Heating Residential Buildings JGJ 26—95", the index of heat loss of building is up to 84.9W/m^2.Dashigou village region in winter the average outdoor temperature is low, so the energy consumption for heating buildings is high. With serious damp kitchen wall and falling surface from the wall, their living conditions are poor. The farm buildings are heated mainly by means of heated kang and firewall. Initially the main fuel is the wood, while in recent years, as a result of restriction on the felling of trees as fuel, the residents mainly make use of logging twigs for fuel. Their saving burning wood result in the severe low temperature the indoor. Generally they choose sawdust to make insulation for the ceiling. Windows are mostly two-double wooden ones, and the ground doesn’t make any thermal insulation.

1.3Heating System Status

As the common heating system for the northern rural areas, firewall and heated kang agree with the rural lifestyle. Through burning fuel in the stove to heat and mainly relying on the surplus heat of three meals a day for heating, rather than other fuel-consuming, it maximizes energy saving heating. Heated kang and firewall are brick up, being a simple construction, whose thermal stability is good. The raise of temperature is slow, but the heat from heated kang and firewall distribute continuously for a long time when stopping the heating.

1.4Types of Energy sources and consumption Status

Through investigation, energy for living and heating play the main role in the current energy consumption in this region. Among them, the energy for heating in winter can make use of the surplus energy supplied in daily life. In this region with less types of energy, wood, coal and a small amount of liquefied gas are the main fuels. Electric energy use is mainly for lighting and appliance.Taking one household as an example, the annual use of wood in the household is $100m^3$, which is mainly used for heating and cooking; the use of LPG is 15kg, mainly used for cooking in summer; the annual use of coal is 1000kg, mainly for winter heating and cooking ; annual electricity consumption is the 1000kWh, mainly used in everyday life.

2. COLD TEST AND THE RESULT OF RURAL RESIDENTIAL ENERGY CONSUMPTION ANALYSIS

2.1Introduction to Test Equipment

2.1.1SCQ-01a Temperature Gathering Recorder (Figure 1), based on single chip technology, is a new generation of low-power field test instrumentation, which applies to temperature measurements such as building energy conservation, environmental monitoring, and otherwise. Measuring range: -30℃-50℃; measurement accuracy: ≤ 0.5℃; sampling period: 10 to 24 seconds.

2.1.2BES-A Overall Heat Transfer Coefficient of Building Envelope Detector (Figure 2) is a new generation of test instrumentation with a new generation of single chip and integrated circuit technology and high-precision, low power. The detector is suitable for building heat transfer coefficient field testing and laboratory testing, as well as temperature, heat flux of high-precision detection. Temperature measuring range: -40℃-100℃; resolution: 0.01℃; accuracy: ≤ 0.2℃. Heat flux density measuring range: 0-± 20mV; resolution: 0.001 mV; measurement accuracy: ≤ 0.02 mV.

2.1.3TVS—100 Portable Thermal Infrared Imager (Figure 3) is manufactured by Japan Aviation Electronics, to detect objects on the surface temperature field. The main technical indicators are as follows: temperature range L range: -10~120℃; H range:50~ 300℃; temperature measurement accuracy: the full range of 2%; temperature resolution: 0.2℃.

Figure 1 Temperature Gathering Recorder

Figure 2 Overall Heat Transfer Coefficient of Building Envelope Detector

Figure 3 Portable Thermal Infrared Imager

2.2Test Object

To compare indoor temperature difference between the energy-saving buildings and the local residential buildings, SCQ-01a Temperature Gathering Recorder were placed in four housings, 1 #, 2 #, 3 # placed in the local ordinary residential buildings, 4 # placed in the hotel which is the energy-saving building, 5 # was placed outdoor. The locations of the four buildings are shown in Figure 4

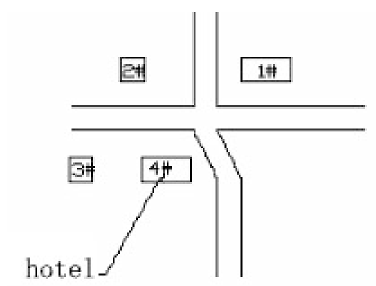

Figure 4 Locations of the buildings

2.3Analysis of Test Results

2.3.1Analysis of Test Results from SCQ-01a Temperature Gathering Recorder

Figure 5 is the temperature data collected by temperature gathering recorder from the five temperature measuring points. The time interval is 10 minutes, which can be seen from the figure, and the effective time period is from 12:50 of Feb.28nd, 2006 to 12:40 of Mar.6, 2006. All the test data of five temperature measuring points are normal. After that, the thermometers are gathered into the same indoor room, that is, since then the temperature is measured for the same room, which can prove the good agreement on measuring equipment through the consistent temperature acquired. Determine the test temperature in Figure 5, the effective time period from 12:50 of Feb.28nd, 2006 to 12:40 of mar.6, 2006. During this time, the temperature is effective.

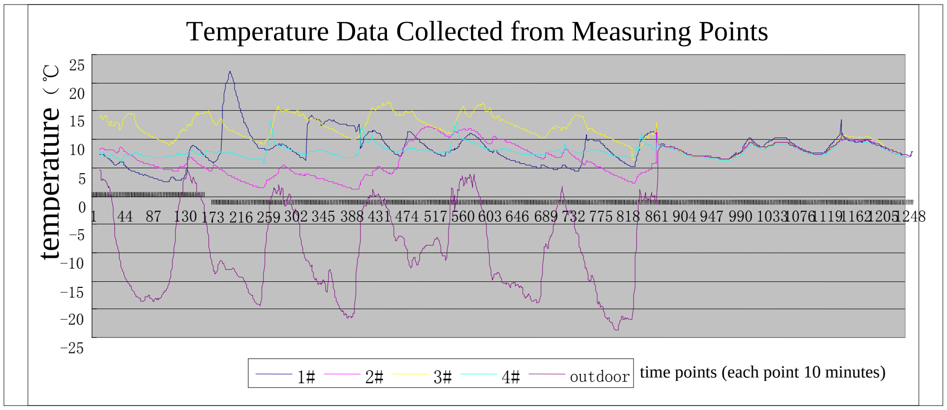

Figure 5 Temperature Fluctuations at Test Point

Figure 5 shows the maximum temperature of outdoor in 11:10~11:30, the maximum temperature of 6.07℃; the minimum temperature basically in 5:50~6:20 or so, the minimum -22.35℃, 6-day test period of average temperature -8.33℃.

The figure shows around 6:30~6:50 the indoor temperature of 1 # building began to rise, and compared with the daily temperature, the fluctuations at room temperature at the same time is great, from 3.81℃ to 13.8℃, basically 6~9℃, average 8.26℃; around 12:00 ~ 13:00 especially from 12:40~12:50, the temperature began to decrease, and the temperature concentrated in the 10~12.5℃, average 11.03℃; around 18:10~18:40 or so the temperature began to rise, and the temperature concentrated in 9~11℃, the average temperature 10.03℃; around 22:00~22:10 or so the temperature began to drop, and the temperature concentrated in 9~13℃, the average temperature of 12.22℃; the average temperature of 6 -day test period of 9.66℃.

Around 6:30~6:50 the indoor temperature of 2 # building began to rise, and in contrast to the same time every day, the fluctuations at room temperature at the same time is great, from 2.43℃ to 11.87℃, basically 6~9℃, an average of 6.41℃; At 12:00~13:00 especially 12:20~12:50, the temperature began to decrease, and the temperature concentrated in the 6~12℃, an average of 9.16℃; 17:40~18:00 or so the temperature began to rise, the temperature between 5 and 11℃, the average temperature of 8.28℃; around 18:40~19:00 or so the temperature began to drop, and the temperature concentrated in 5~11℃, the average temperature of 8.89℃; the average temperature of 6-day test period of 7.37℃.

Around 6:30~7:20 or so indoor temperatures of 3 # Building begin to rise, and in contrast to the same time every day, the fluctuations at room temperature at the same time is great, from 7.68℃ to 12.64℃, basically in the 8~12℃, an average of 10.18℃; 15:50~16:00 the highest temperature, the temperature concentrated in the 10~17℃, the maximum temperature of 17.86℃, minimum 9.75℃, the average temperature of 14.42℃; the average temperature of 6 -day test period of 13.75℃.

4 # was placed in the hotel which is the energy-saving building. Because of the absence of guests, the heating of the hotel choose a low heating temperature on duty. 6:30~7:10 or so the room temperature began to rise, and in contrast to the same time every day, the fluctuations at room temperature at the same time is great, from 7.11℃ to 9.17℃, basically in the 7~9℃, an average of 8.34℃; 8:00~9:10 a sudden rise in temperature, the temperature concentrated in the 6 to 12, up 14.68℃, minimum 7.74℃, an average of 10.53℃; the average temperature of 6-day test period of 9.26℃.

1 # -4 # pooled analysis of the temperature of the buildings, as shown in Table 1.

Table 1: Summary to temperature measuring points

	1#	2#	3#	4#	outdoor
Maximum temperature℃	23.28	13.67	17.93	14.68	6.07
Lowest temperature℃	3.81	2.43	7.71	7.11	-22.35
Average temperature℃	9.66	7.38	13.76	9.26	-8.33

It is evident that the overall temperature is low, the hours with rising room temperature is concentrated in the time of cooking. But the average temperature of 3# is higher, possibly because the family has a baby, and homeowners who want to enhance the room's heating. The buildings heating mainly relies on fuel burning for heating the kang, the room with kang has a regular temperature rules and the indoor temperature is higher. It can be seen from Figure 7, the indoor temperature of 3# building changed most orderly, and 2 # building temperature is lower. In general, room temperature is still too low, and relatively the living conditions are poor.

2.3.2Analysis of Test Results to Thermal Infrared Imager

Thermal Infrared Imager is mainly for measuring the internal and external surface temperature of the building to check the thermal defects of building.
Take 2# building as an example to analyze the results of room test. We test the surface temperature and its thermal defect on north wall of the kitchen on the north side and the east wall of the inside and outside the eastern bedroom of # 2, which is shown as Figure 6.

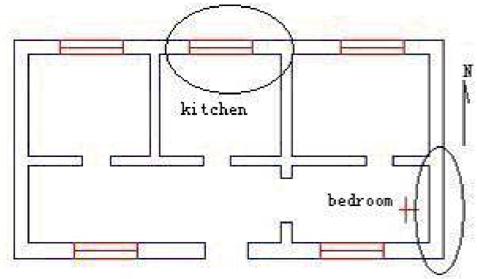

Figure 6 2#residential layout of measurement points and the infrared test area map

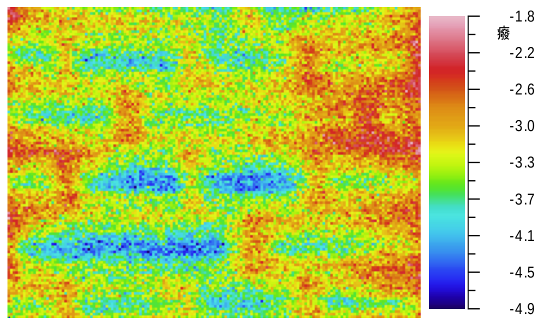

Figure 7 average temperature of the north side outside wall of the north side room -3.03℃

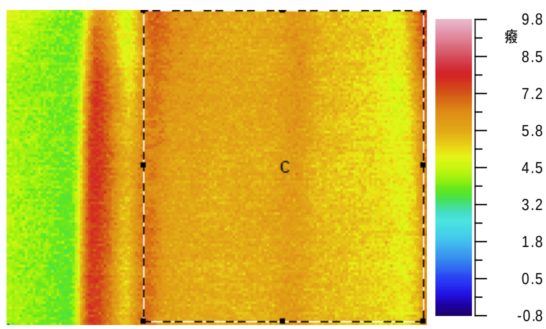

Figure 8 average temperature of the north side wall of the north side room 5.65 ℃ (without windows)

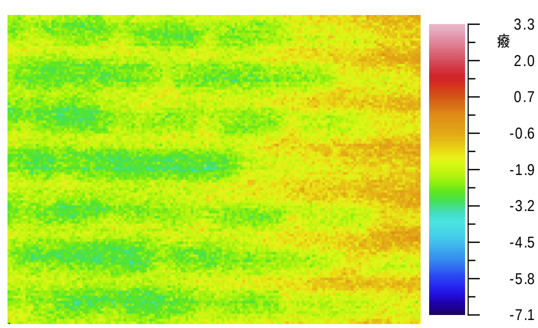

Figure 9 average temperature of the east side outside wall of the north side room -1.83 ℃

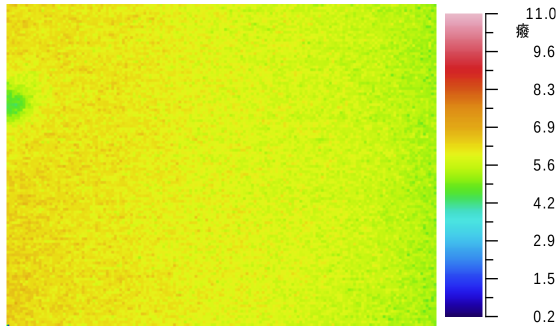

Figure 10averag e temperature of the north side wall of the north side room 5.87 ℃ wall

According to Figure 7-10, the outdoor brick can be seen, and the mortar joint of outdoor brick indicates that the temperature of the mortar joint is much higher.

Suppose analysis and calculation based on the data of the north side of the room: Wall heat transfer coefficient 6.256W/m^2•K; Wall heat flux q=6.256×(7.98-5.65)= 14.58W/m^2; Wall thermal resistance, R=0.595m^2•℃/W; Heat transfer coefficient K = 1.327 W/m^2• ℃.

Suppose analysis and calculation based on the data of the east side of the room: Wall heat transfer coefficient 6.204W/m^2•K; Wall heat flux q=6.204×(7.98-5.87)= 13.09W/m^2; Wall thermal resistance, R=0.588m^2•℃/W; Heat transfer coefficient K = 1.339 W/m^2 • ℃.

Similarity of the two data indicates that the data is credible. Calculated by this method to test the wall heat transfer coefficients of 1#, 3#, 4# building were: 1.734W/(m^2•℃), 1.542W/ (m^2•℃), 0.57W /(m^2•℃)

2.4The Basic Conclusions of the Investigation Test

Through investigation and on-the-spot testing of residence we draw the following basic conclusions:

①North China, especially in Heilongjiang area, compared with the south, building layout is scattered, mostly detached building, which caused the problems such as larger shape coefficient of building, with larger cooling area.

②Most of the structure with 370mm enclosure walls, failed to take energy-saving measures, and it has a bad energy-saving effect. The thickness of roof insulation is inadequate. The ground is without thermal insulation, resulting in large loss of indoor heating in winter.

③Meanwhile, the deterioration of indoor air quality, the room is mildewed, especially the kitchen.

④Currently there is energy consumption and low indoor temperature in the local buildings, and the lowest average temperature is only 7.38℃, and the highest is 13.76 ℃. The living environment is poor.

3. ENERGY CONSERVATION MEASURES FOR THE FARM BUILDINGS

3.1Integrated Architectural Design

3.1.1Adjust the layout of living space

According to characteristics of peasant life, based on the needs of residents, scientifically organize the space for the main functions such as living, sleeping, meeting and other auxiliary function such as cooking, washing, and storage. On the condition of meeting the function, the kitchen, storage and other auxiliary rooms are designed in the north, and bedroom, living and other major rooms are designed in the south.

3.1.2Control the shape coefficient of building

Shape coefficient is an important factor to affect building energy consumption. Taking the current four typical style (floor area 60-120 m^2), for example, the shape coefficient distribution is 0.7-0.88, which even much more doubled the city multi-storey residence. Excessive shape coefficient is extremely unfavourable for rural buildings energy conservation. Therefore, it is reasonable to increase the depth of buildings and adopt two or more vertical layout together to reduce the shape factor.

3.1.3Reduce the convection heat loss

In the winter of cold area, the entrance is only open parts of farm building, and also the major parts to control convection heat loss. Therefore, the aspect of the entrance should avoid the dominant wind direction in winter, and add additional foyers, which constitute good transition space for insulation function.

3.2 Improve the insulating performance of farm buildings

3.2.1Adopt the new wall materials based on local conditions

Energy-saving wall materials should be the new materials with lightweight, high strength, insulation, and heat insulation, which can take the place of clay brick, and can be selected according to different situations of different areas. Single-wall insulation materials can not meet the energy requirements, so compound wall technology should be promoted for farm building.

3.2.2Select a reasonable wall insulation energy conservation scheme

In some buildings in the rural areas, using solid clay brick as dominant material, brick itself, with great heat transfer coefficient and great heat loss. Within or outside the stickers affixed insulation can be used on existing buildings to solve the problem of brick itself in insufficient insulation situation. For the new building, you can use composite wall, such as thermal insulation material installed in the wall within the inside wall insulation composite, insulation materials installed in the outer wall external thermal insulation composite wall and the insulation materials will be placed in the wall in the middle of the sandwich compound wall. Among these three kinds of composite wall, we should try to adopt external thermal insulation composite wall.

3.2.3Design strategy for roof

Roof structure differs with roof materials, and the most common one is the wood tile roof. The common material for roof insulation is sawdust, rice husk, straw and other local materials. The roof design can still follow the traditional structure, but should increase the thickness of insulation material in accordance with the energy-saving requirement.

3.3Strengthening the thermal insulation of windows and doors

3.3.1Control the window-wall area ratio

The geographical location of latitude where the farm buildings locate should be considered. And local winter sunshine should be considered too. The size of the window should be minimized under the condition of meeting the case of natural light.

3.3.2 Changes in the form of window

Now the window in farm building is mainly single-layer aluminum or wood, and to improve the insulation performance of windows, you can use double-glazed windows, single double glazed windows, a glass window of a membrane that is setting a layer of transparent plastic film inside the window to form air layer around 2cm between the layers, thus to reduce the heat loss of windows.

3.3.3Improve the air tightness of windows

The heat loss resulted from the cold air infiltration can not be ignored either, window heat loss caused by the cold air infiltration from cracks accounts for about 1/3-2/3 of total heat loss. Setting the closed gas-tight article is one of the necessary measures. We should choose the seal accurate across sections, soft and good elasticity, fire resistance, stable.

CONCLUSION In terms of dealing with the change of climate and reducing the emissions of carbon dioxide and other greenhouse gas, building energy conservation problems is one of the many urgent problems in China. As most of China's cold rural areas are in a weak economic foundation of northern areas, the cold rural construction forms a feature of large quantity and wide distribution, so the task of energy conservation and emission reduction will be extremely difficult. According to the current conditions of rural buildings, the thesis put forward the integrated architectural design to improve the insulating performance of residential building envelope and technical measures of reducing cold air infiltration doors and windows, which are effective approaches to solving this problem. Only the good job on the building energy conservation in China's rural areas, particularly in cold rural areas can, to a considerable degree, help Chinese government to fulfill the aim of energy saving and emission reduction, and play active role in dealing with the global climate change around the world.

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