Climate adaptability construction features of a traditional thatched cottage from the Korean-Chinese in the Yanbian area

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Abstract. Traditional Korean-Chinese in the Yanbian area thatched cottages are well known to provide comfortable indoor environments using traditional heating methods, such as the Ondol, a stone slab that is used to maintain a comfortable heating level indoors. To determine the construction features for traditional Korean-Chinese thatched cottages, temperature, relative humidity, and black globe temperature were measured both indoors and outdoors to determine the heating capacity of various rooms in the building in September. Overall, the indoor temperature and relative humidity are relatively stable even when the outdoor temperatures and humidity fluctuated greatly throughout the day. The test results verified the superiority of the heating capacity of a traditional Korean-Chinese cottage.

1. Introduction
Modern people generally regulate temperature through technology such as air conditioning units and electric fans to improve their indoor thermal environment. As a result, this leads to large amounts of energy waste and exacerbates the global climate. In recent years, attention has been brought back to traditional heating methods that use “natural” or renewable energy, such as heating stones. The value contained in the technical principle of adapting to the local climate in traditional architecture is being reevaluated\cite{1,2,3}. Under the premise of preserving the traditional scene of residence and the unique lifestyle of the Korean-Chinese, the indoor thermal environment in a traditional Korean-Chinese thatched cottage was analyzed, which could provide inspiration and reference for future protection of traditional residences in the Yanbian area and inspire modern homes to use similar methods.

2. Overview of test objects
In the early 20th century, straw farming was one of the major industries in the Yanbian area, so most of the dwelling in this area have carried the straw-thatched roof\cite{4}. The investigation area is located in Longpu village, Bajiazi Town, Helong City, in the Jilin province. It is a well-preserved traditional Korean-Chinese thatched cottage for which permission was granted for use in the study The thatched cottage was built in the 1960s, where an 80-year-old elder and their son and daughter-in-law lived.
has a hipped roof made of straw, and the wall has a framework of wooden posts filled with loess with a wall thickness of 300 mm. The plane composition includes a “Jeongi,” a “Woobang,” a storage room, as well as a warehouse (Figure 1)\[5\]. The Jeongi serves as the main living space set in the center of the cottage and is mainly used for guest reception and dining and also as the bedroom space of the couples. The Woobang is used as the bedroom for the elderly. The most distinctive element in the residence is their heating mode — an “Ondol,” a heatable brick bed made of loess with high viscosity and slab stone that is 20-30 cm high. The Ondol is used for indoor temperature regulation.

3. Methods
The temperature and humidity in the hutch were monitored over a 24 hr period to determine the effects of the Ondol on indoor climate control. The tests were completed on September 18 at 00:00 to 00:00 on September 19. It was sunny throughout this day, with no precipitation. The test content and methods involved were as follows: (1) indoor and outdoor air temperature and humidity of each room were measured. Temperature and humidity were measured using a WSZY-1 manufactured by Tian Jian Hua Yi Company, with the temperature measurement range of -40°C to 100°C +/- 0.1°C, a humidity measurement range of 0.1 to 100% +/- 0.1% RH. The indoor measurement point was at a location 1.1 m from the Ondol, and the outdoor measurement point was in the shade covered with foil paper. (2) A black globe thermometer HQZY-1 manufactured by Tian Jian Hua Yi Company with the measurement range of -20-80 °C and the accuracy of 0.1 °C was used to indicate heat stress levels by measuring radiant heat. Locations were the same as before. (3) The indoor comfort and fuel consumption was indicated through questionnaires of the residents.

The instruments were laid out in the position, as shown in Figure 1. Measurements were performed continuously for 24 h, and data were collected every 10 minutes. The primary purpose of the test was to analyze the adaptability of a thatched cottage to the local climate through the test on climate adaptability of the thatched cottage.

![Figure 1. Planar graph and elevation drawing of the traditional Korean-Chinese thatched cottage.](image)

4. Analysis of the test results on the thermal environment
During the test period, the Ondol was heated at 05:00 on September 18 with six bundles of fuel straw. The Ondol was heated again 18:00 on September 18 with one bundle of fuel straw. The door of the warehouse was always kept open, and from 10:00 to 15:00 on September 18, two doors facing the south were opened (Figure 2). The diameter of one bundle of fuel straw was 300 mm (Figure 3).
4.1. Indoor and outdoor temperature and humidity results

(1) When the air temperature was tested outdoors, the instruments were laid out in the shade to reduce the influence of solar radiation. As shown in Figure 4, during the test period, the maximum outdoor air temperature was 24°C, and the minimum outdoor air temperature was 8.9°C, with an average outdoor temperature of 15.6°C. The maximum outdoor relative humidity was 82.9% RH, and the minimum outdoor relative humidity was 34.9% RH, with an average relative humidity of 64.6% RH. Overall, when the outdoor temperature was higher, the relative humidity was lower.

(2) Figure 5 shows the variation curve of the temperature and humidity observed in each room. The average temperature in the Jeongi was 21.8°C, with a maximum temperature of 25°C and a minimum temperature of 18.6°C. The average temperature in the Woobang was 21.7°C, with a maximum temperature of 24.8°C, and a minimum temperature of 17.7°C. The average temperature in the storage room was 21.1°C, with a maximum temperature of 23.4°C, and a minimum temperature of 18.8°C. The average temperature in the warehouse was 16.9°C, with a maximum temperature of 22.6°C, and a minimum temperature of 12.5°C. Overall, except for the temperature in the warehouse, the temperatures throughout the cottage fluctuated only slightly throughout the day, especially compared to outdoor temperatures. The Jeongi and Woobang are the primary living spaces, and the maximum temperature mainly occurred between 11:00 am and 3:00 pm because these rooms face the south. The changes in the indoor temperature and solar radiation during the daytime tended to be consistent. The daily minimum temperature occurred at about 5:30 am, and the residents started a fire and cooking at 5:00 am. The two doors on the south side were opened when they made a fire. Thus, the lowest temperature appeared at this time. The storage room was less affected by solar radiation because it faces the north.

The average temperature in the Jeongi was the highest. Beyond the fact that solar radiation would heat the room during the day, there are other reasons that the residents make a fire and cook every day. During the day, the surface of the Ondol becomes an effective heat source in the room. Heating through Ondol is an effective measure to raise the indoor temperature, and it is also in line with the living habits of the Korean-Chinese.

The residents start a fire and cook at 05:00 to have the indoor temperature gradually increase after 06:00. Furthermore, during this period, water vapor was produced when cooking, thus the humidity in the room also increased. The outdoor air humidity significantly fluctuated with a difference of about 50% RH between the maximum and minimum values. However, the fluctuation of the highest and lowest values for indoor relative humidity in each room was within 20% RH (Figure 6). The average RH in the Jeongi, Woobang, and storage room were 53.9% RH, 53.5% RH, and 54.9% RH, respectively.

Overall, it appears that a traditional thatched cottage can adequately regulate temperature and humidity within the heat and humidity limits prescribed in GB/T5701-2008 Indoor Thermal...
Environment Conditions for Human Occupancy [6]. The heating mode of the Korean-Chinese uses an Ondol as the heating element and the indoor space as a heat storage element. There is an ample space for heat storage and small heat dissipation fluctuation throughout the day. The indoor temperature fluctuates in the range of 2-3 ℃ after the Ondol has been heated at night. Therefore, the traditional thatched cottage of Korean-Chinese has suitable airtightness and thermal stability, which also verifies the superiority of construction technology for Korean-Chinese traditional residence.

During the test, the temperature and humidity in the warehouse fluctuated greatly and were significantly influenced by the outdoor climate conditions. This is because the warehouse is a place for straw storage rather than living. During the period from June to October, the warehouse doors are kept open for ventilation to maintain a dry place for straw storage. The straw is used as fuel, as well as to repair the roof.

4.2. Analysis of black globe temperature and subjective survey results
As shown in Figure 7, the black globe temperature ranged from 17.2 to 25.8℃, with an average of 21.3℃. The black globe temperature in a traditional Korean-Chinese thatched cottage is influenced not only by solar radiation but also by the heating temperature of the Ondol. Because of the shading effect of the eaves in a traditional Korean-Chinese thatched cottage, the cottage is less affected by solar radiation, and the indoor black globe temperature fluctuation was, therefore, also less. In the subjective questionnaire surveys on temperature, residents living in the thatched cottages all felt comfortable with the effective temperature.

5. Conclusions
Through field surveying and mapping as well as the thermal environment tests of the traditional Korean-Chinese thatched cottage, traditional Korean-Chinese thatched cottage is able to adequately regulate comfortable temperature and humidity levels within the building[7]. However, the goals of a thermal environment inside a building also include high energy efficiency. During this test, it was
found that without the assistance of the heating facilities (i.e., the Ondol), it is hard to reach a goal of high efficiency.

The traditional Korean-Chinese thatched cottage itself is undergoing great changes in recent years. Under the previous self-built traditional system, a great deal of climate adaptability experiences has been accumulated in the thatched cottage. In the contemporary era and responding to changes in external conditions and internal needs, sustainable development could further be continued through the superiority of traditional construction techniques. It is necessary to explore the building technology in line with the local economic development level and construction technology based on the principle of adjusting measures to local conditions and using local materials[8].

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References
[1] Jin Hong, Zhang Lingling. Continuity and Development of Energy-saving Spirit in Traditional Rural Housing. New Architecture. 2002. 17-19.
[2] He Quan, Liu Jiaping, lü Xiaohui. Appropriate technologies of ecological architecture for the rural areas in the northwest China. Sichuan Building Science. 2009. 243-247.
[3] Jin Hong, Shao Teng, Jin Yumeng, Kang Jian. The Application of Passive Technology on Rural Houses in Severe Cold Regions. Journal of Human Settlements in West China. 2016. 115-118.
[4] June-Bong Kim. Korean Folk Dwellings in China. Ethnic Publishing House, Dec. 2007. 22.
[5] Xu Yali, Gao Songhua. A Comparative Study of Korean and Han Nationality Cottage Construction Characteristics in Yanbian Area. Chinese & Overseas Architecture. 2017. 64-67.
[6] GB／T5701-2008 Thermal environmental conditions for human occupancy.
[7] Liu Jiaping. Architectural physics. 2009.
[8] Jin Hong, Ling Wei. Low Energy Consumption, Low-tech and Low Cost: Study on the Design for Rural Energy-saving Housing in Cold Region. 2010. 14-16.