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Analysis on building energy performance of Tibetan traditional dwelling in cold rural area of Gannan

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ABSTRACT

This paper aims to investigate the typical indoor environment in Tibetan residential dwellings, which has particular architectural form and environmental adaptations. The field measurements during the summer month show that the traditional house presents high humidity, low temperature. And the indoor environment is much worse in winter. Tibetan architectural features and ethnic customs are taken into account in the creation of passive renovations that are applied with minimal effect on the overall architecture. Numerical simulations of the indoor thermal environment are conducted on the building models using DeST-h. Different renewal measures are evaluated in terms of how much they decrease annual energy consumption. Orthogonal experiments are designed to optimize an array of energy-saving building renovations to reduce energy consumption and improve indoor thermal comfort of Tibetan residential houses. Results show that there is an obvious reduction of energy consumption by combining appropriate renovations based on orthogonal optimization. The conclusion is that there are economic and environmental benefits of using natural passive methods without considering mechanical ways. The renovations are verified as effective for reducing energy consumption and improving indoor comfort in such Tibetan residential dwelling.

1. Introduction

A worldwide campaign to produce green buildings with less greenhouse gas emissions has been promoted in order to counter global climate change [1]. Consequently, countries and international organizations set the goal of energy conservation and greenhouse gas emissions reduction [2]. It is widely confirmed that energy use from buildings and cement production contributes a large proportion to the greenhouse gas emissions [2]. Researchers are paying more attention to discussing standards for energy consumption of the residential sector and focusing on the energy saving potential of existing dwellings. Many countermeasures such as solar energy have already come into effect due to lower carbon footprint [3,4]. High-efficiency equipment and energy saving apparatuses have been invented, allowing for the creation of novel energy supply systems [5,6]. Field study of building envelopes and household behavior [7–9] has become a popular method of investigation based on laboratory research. Energy needs for a comfortable indoor environment are created through the building design such as building envelopes, orientation, shading and natural ventilation along with energy efficient system and equipment [10].

With the background of generally improving living conditions and the policy of comprehensive development of rural areas, residential energy conservation and sustainable development in rural areas have already become key issues for the Chinese government. Analysis of energy consumption and energy savings potential based on field measurements and computer simulations for dwelling buildings is widely applied around the world. Results [11] show that the average primary energy consumption is much higher than the limit set in national regulations for apartment buildings subject to major renovation. The studied buildings show a high potential for energy savings [12]. Such situations exist in China as well. Compared with those of urban residential buildings, most of the houses relying on self-built and self-sufficient energy supply are widely distributed in the rural areas of China. By the year 2010, rural residential areas in the whole country are up to 23 billion m^2, which accounts for 50% of the total building construction areas [13]. In recent years, numbers of studies have been carried out on climate oriented building design to enhance thermal comfort conditions in the living space as well as reduce both the embodied and operational energy consumption. Chinese researchers have been paying close attention to the existing rural residential dwellings such as Yaodong dwellings located in the arid region of China [14], civilian

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construction in the hot summer and cold winter zone [15], local countryside houses in the northeast extreme cold areas [16–18], etc. The methods of field investigation and dynamical simulation are used to reduce energy consumption and improve indoor thermal comfort.

As a unique kind of rural building, Tibetan dwellings mainly are found in the Qinghai–Tibet Plateau of China and represent the principle of climate-responsive architecture, which still lacks experimental validation and quantitative analysis.

So far, research of traditional Tibetan dwellings has been focused on aspects of the culture and building structure. A few studies [19–24] involving the thermal environment of such dwellings took place in the Tibetan Autonomous region and Yunnan Province. Thermal environment and energy performance studies rarely covered the Anduo Tibetan dwellings, especially in the agricultural areas with dwellings constructed by means of a wooden framework and rammed earth wall in the northeast edge of the Qinghai–Tibet Plateau. For the sake of better understanding of the thermal performance and ecological suitability of Tibetan local-style dwellings in the Anduo energy-starved agriculture district because of inconvenient transportation, a typical self-built Tibetan traditional dwelling was selected for the measurement of the indoor temperature and humidity in summer and winter in this paper. Much energy in the buildings is directly obtained from burning wood, preliminary analysis and comparison of indoor energy performance is simulated as well.

2. Methodology

2.1. Description of Tibetan local-style dwelling

The testing location is distributed in an agricultural area with forest widely covering the whole region. Local two-story Tibetan dwellings are constructed relying on natural resources of wood and soil (Fig. 1(a)). Interior decorations are completely handmade, using a local high-quality kind of wood, as shown in Fig. 1(b). The living space on the first floor is formed in three bays without internal partitions so that it has a large interior space. To keep the integrity of interior wooden decorations, Tibetan residences discharge indoor smoke or vapor from an opening board in the middle of ceiling typically of size 1.5 m × 1.5 m which extends to the rooftop (Fig. 1(b)). Such Tibetan dwellings have been inherited and developed for years. Having a large indoor space and completely wooden decors are regarded as a symbol of wealth and family dignity in the ethnic culture of Tibetan farming areas. In addition to the large space, the indoor environment is greatly affected by the extraction of smoke through the central opening connecting the inner living environment with the outside.

As mentioned above, traditional dwellings are constructed using unique residential construction utilizing local natural resources. The buildings usually have two floors along with southern facing windows and doors. After choosing the location and foundation ramming, building envelopes for the first floor are formed by the

Fig. 1. Tibetan traditional dwellings: (a) two-story wooden framework; (b) flue channel; (c) outside view.