The thermal mechanism of warm in winter and cool in summer in China traditional vernacular dwellings

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ABSTRACT

Yaodong is one representative of western China vernacular dwellings. Its indoor thermal environment is cool in summer and warm in winter. This study interprets the characteristic of warm in winter and cool in summer such as a dwelling by measuring the indoor, outdoor and wall’s temperatures in winter and summer. The human thermal comfort theory is used to evaluate thermal environment, and the periodic heat transfer mechanism is used to analyze the thermal transfer through the wall. The results show that the Yaodong thick wall effectively damping external temperature wave and keeping steady inner surface temperature are the chief causes of warm in winter and cool in summer in Yaodong, which lays a scientific basis for low energy building design.

1. Introduction

China traditional vernacular architectures have developed for a thousand years. They are abundant in variety, and have their own unique style. In northern China, the Yaodong and Quadrangle [1] have solid brick or earth wall to protect from the cold wind and keep warm. In southern China, the Sishuiguitang [2] and Yikeyin have light wall to protect from the damp, and are well ventilated. In southwestern China, the Dry railing bamboo huts [3] are built on the stilts to keep away from water and moist earth. All these vernacular dwellings are made of local material and have the maximum adaptability to local climate and topography [4]. They are architectures suited to local environment.

Many vernacular dwellings in western China have the characteristic of regionalism, especially the Yaodong. It locates in loess plateau and has the characteristic of warm in winter and cool in summer [4–6]. The loess plateau is made up of loosened earth and easily eroded. The climate here is temperate continental, scarce rainfall, hot summers and dry-cold winters. Under such harsh conditions, the local residents excavate cave in loess plateau to live, or construct buildings by loess. The images of them are shown in Fig. 1. Literature [4,5,7–9] indicate that such Yaodong has general adaptation to local environment, creates thermally comfortable indoor environment, reduces building energy consumption, and reflects the harmonious of architecture and nature. On the condition of low carbon and energy conservation, it is necessary to research why Yaodong has the feature of warm in winter and cool in summer.

The old-style Yaodong was damp and dark, and the occupants did not feel comfortable [6]. In that situation, the new-style Yaodong using passive solar energy technology, develops and is researched widely [10–12]. Professor Yang [7,10] improved the thermal environment of traditional Yaodong dwellings with solar energy, and analyzed the thermal environment of new solar-Yaodong house. Professor Liu [8] suggested a zero energy cave-dwelling solar house according to the thermal characteristics of the traditional cave-dwelling, and gave its design method. Professor Wang [6] introduced the indoor environment of old and new Yaodong dwellings by investigation, and gave some ideas of renewal of traditional dwellings. However, they just researched the thermal environment and design of new Yaodong, but not explained the thermal mechanism. In this paper, a new-style Yaodong is used to explain why Yaodong has the feature of warm in winter and cool in summer.

The field test was carried out for a series of days in winter and in summer. During consecutive test, we observed that the trends

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