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Climate responsive strategies of traditional dwellings located in an ancient village in hot summer and cold winter region of China

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ABSTRACT

Global warming and energy shortage have aroused a great interest in climate responsive strategies of vernacular dwellings during recent years. This study focuses on a qualitative analysis of ancient dwellings located in the village of Xinye, in the hot summer and cold winter region of China. Furthermore, a typical ancient dwelling located in the village was selected for assessment of its indoor thermal environment on the basis of an on-site monitoring, carried out in summer and winter. Whole annual thermal performance of the dwelling was also investigated using EnergyPlus simulations. The field measurements were used to outline the effectiveness of the climate responsive strategies.

According to the analysis, the climate responsive strategies of the dwellings are mainly focused on natural ventilation, sun shading and thermal insulation, illustrated by different building aspects such as the building location, building group layout and orientation, internal space arrangement, opening design and among other variables. Thermal simulations reveal that the traditional dwelling located in Xinye village is well adapted to the local climate during summertime, although the indoor thermal comfort is not fully satisfactory during wintertime.

1. Introduction

Improving building energy efficiency is one of the most effective ways to deal with the issue of energy shortage and global warming in order to achieve a sustainable development [1]. It is also well known that adopting passive design strategies is an optimal way to enhance building energy efficiency [2]. Passive design means that the building can respond *per se* to the local climate and weather conditions; i.e. it can use free renewable energy resources, such as the solar radiation, convective flows due to wind and ground coupling for instance to maintain indoor comfort in an appropriate range and thereby reducing the need of mechanical systems and minimize the building energy demand [3,4]. Climate responsive strategies, which are widely concealed in the traditional vernacular dwellings all over the world, are typical passive design. Many researchers are currently investigating vernacular architecture for that reason [5–17]; their results show that climate responsive strategies can enable buildings to be environmentally friendly, low-energy consuming and sustainable on a longer term. Traditional vernacular dwellings are outcomes of accumulated construction wisdom examined for centuries, resulting in optimal use of local materials/resources and adaptation to the local climate without using mechanical equipments [18].

A specific geographical region of China is characterized by hot summer and cold winter conditions. Social habits added to severe climatic conditions lead to much larger energy demands in buildings compared to other regions of the country [19]. With the current urbanization trend and increase of living standards, the residential buildings energy demand is increasing even more. Low energy design guidelines for architects and designers are accordingly needed in order to decrease the energy consumption of residential buildings in these areas. Traditional vernacular dwellings of this region are not only beautiful, but they can also partly adapt to climatic conditions. Unfortunately most of the dwellings have been abandoned and/or demolished gradually, although their indoor thermal environment is more comfortable than the one of modern residential buildings [20]. Therefore and in order to improve the

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energy efficiency of residential buildings in this Chinese region, the climate responsive strategies of traditional vernacular dwellings in Xinye, an ancient village of this area, were comprehensively investigated. A typical traditional dwelling was selected in order to be able to assess its indoor thermal environment using on-site monitoring as well as building performance determined by means of energy simulations.

The main objectives of this study are to: (i) identify climate responsive strategies of traditional dwellings in the village of Xinye which can be useful to the current architectural design and construction of modern residential buildings, (ii) assess the indoor thermal comfort of traditional dwellings in the village by the means of on-site monitoring, and finally (iii) investigate the effectiveness of derived passive design strategies for mastering the indoor thermal comfort by the means of building energy simulation.

2. The ancient village of Xinye in the Zhejiang province of China

2.1. Overview of Xinye natural environment

2.1.1. Topography

China is a country with a vast territory showing diverse climatic conditions, as indicated in the Thermal Design Code for Civil Building of China [21] the country is divided into five different climatic regions: severe cold region, cold region, hot summer/cold winter region, hot summer/warm winter region and mild region. The ancient village of Xinye is located between Jiande City on the Northwest and Lanxi City on the Southeast, in the middle region of the Zhejiang province. It is a typical traditional vernacular settlement established in the mountainous and hilly area of the hot summer/cold winter region (Fig. 1). It is characterized by a 119.33°East longitude, 29.33°North latitude and an altitude of about 89 m above the sea level. The village is bounded by the Yuhua Mountain on the Northwest and the Daofeng Mountain on the Northeast, resulting in the fact that its climate is strongly influenced by the valley breeze coming down from the two mountains.

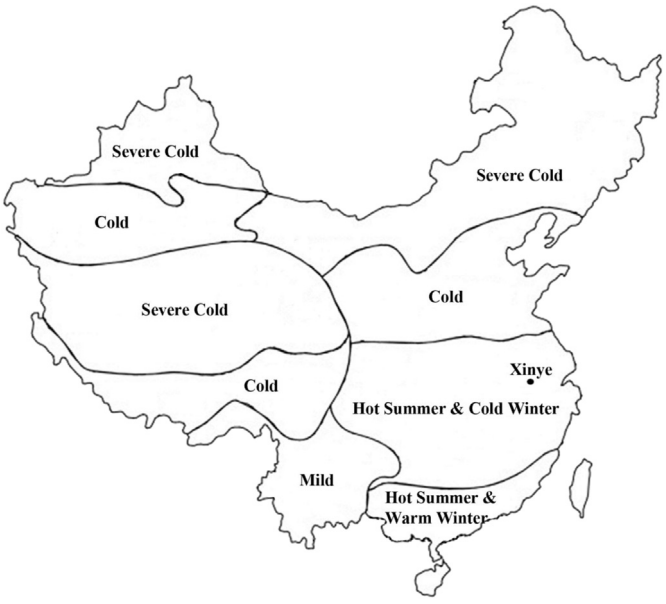

Fig. 1. The map of five climatic regions of China illustrating the site of Xinye (modified from Ref. [22]).

2.1.2. Climate

The village of Xinye belongs to the subtropical monsoon climatic region; due to the mountainous topography of the area, the village experiences long hot-humid summers and cold-cloudy winters, while summers usually have a rainy period which can last for one month. Getting the meteorological data for the village is not easy since it is quite isolated without any meteorological station.

Table 1 shows the monthly climatic data of Jiande City, which is the nearest city from Xinye located about 30 km far from the village; the monthly mean temperature peaks at 28.1 °C in July and drops down to 4.9 °C in January. The summer months of May through September have a mean temperature of 24.9 °C, while the winter months of November through February show an average temperature of 7.7 °C. The summer months account also for the largest rainfall (178.8 mm on average), especially in the rainy month of June (279.5 mm). The summer months show the longest sunshine hours (893.8 h as total) while the winter months have the shortest (284.7 h as total). Unfortunately, the relative humidity and wind speed data are not available at the corresponding meteorological station.

2.2. Description of the traditional dwelling

Xinye is one of the most ancient Chinese villages in China; it is more than 700 years old and dates back to Song Dynasty of China. Owing to its remote site, the village is almost isolated from the outside world; therefore it is protected from external influences, especially concerning the traditional vernacular dwelling. The current population of the village is around 3000 people. More than 200 ancient dwellings have been preserved in the village, which includes 15 dwellings built during the Ming Dynasty, 150 during Qing and about 50 in the Republic of China.

2.2.1. Building forms

The basic architectural form of the traditional dwelling in the village of Xinye has been formalized during the Ming Dynasty. There are two types of basic modules designated by “The folio shape building” and “The three-wings building”.

As shown in Fig. 2, the “Folio shape building” is similar to the traditional courtyard house of northern China, but is comparatively higher and more compact. The “Three-wings building”, which is the most common one in Xinye, is almost half size of the folio shape however with similar architectural form. The most remarkable feature of this traditional dwelling is the small inner patio in the centre of buildings, while all the other spaces are situated around it, including the bedroom, the living-room and etc. These dwellings are normally two-storey high; two bedrooms and a living-room in the ground floor and a large space in the first floor. There is no ceiling between the attic and the first floor which is used as storage or a temporary living space. The first floor is larger than the ground floor which creates an internal veranda around the patio. The difference between the “Folio shape building” and the “Three-wings building” is in having the semi open space; the former type benefits from a spacious semi open space (living-room) occupying half of the ground floor just in front of the patio, while the latter does not have such a space but a smaller living-room located between the two bedrooms. Additionally, the entrance door is usually located on the external wall surrounding the patio of the ground floor.

A typical layout of an ancient house in the village of Xinye, as shown in Fig. 6, was chosen to pursue quantitative analysis of its thermo-physical performance; this house just consists of a “Folio shape building” on its Eastern side and a “Three-wings building” on its western side.