

Passive house: a practice of low carbon and sustainable development in china

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Abstract. The construction field plays an essential role in addressing global environmental issues regarding contaminants, natural resources, and energy efficiency. According to the United Nations Environment Programme (UNEP), the building industry produce a huge amount of global carbon emission with a percentage of 38 and this figure is growing each year. Previous studies have analyzed many factors that have a significant influence on the sustainable performance of building. Passive house is a promising type of construction project with superior energy efficiency and less emissions. The main objective of this study is to analyze the environmental sustainability of passive house compared with conventional buildings and present the development of passive house in China. This paper analyzes the characteristics of passive house in different regions according to the climate zoning of China. Results show that the passive house, as a sustainable building, has a promising trend. The outcome also indicates that China needs more mature technology and professional personnel to further promote the development of passive house.

Keywords: passive house, conventional building, sustainability.

1. Introduction

Nowadays, greenhouse gases emissions (GHG) have become a serious environmental problem worldwide. As one of the largest industries in almost all developing and developed countries, the construction sector consumed nearly 40% of global energy, and the emissions like carbon dioxide discharged into atmosphere can rise the temperature and cause global warming [1].

Construction projects in different phases of their life cycle include construction, operation, maintenance, and demolition. These projects consume a huge amount of energy, resulting in urgent problems of pollution, waste, and emissions. After 2 or 3 years of construction, the operation and maintenance phases will last several decades and continuously pollute the environment. China, as a developing country, has a relatively large population and huge demand for housing construction but is short of resources. It is now facing a more urgent situation of finding a method or scheme to achieve the environmental sustainability.

Topics around low carbon design is complex, and most of the current studies conducted by domestic and foreign researchers of this issue mainly focus on energy-efficient materials. In such circumstance, this paper mainly focuses on passive house, a type of low-energy house. This paper will review the previous research of passive house, analyze the opportunities, and explore the current and future developing trend in China.

2. Conceptual basis of passive house (PH)

The concept of “Passive House” (PH) was first put forward in German. In 1988, Wolfgang Feist, a German, first introduced the definition of passive house and explained that passive house buildings do not need traditional cooling and heating system to achieve a comfortable indoor environment [2]. This type of building is a new energy-saving building concept advocated by some countries. It is a kind of building which can achieve constant temperature, humidity, oxygen, cleanliness, and stillness in four seasons through its fresh air system, the thermal insulation of ground, walls, doors, and windows, as well as the renewable energy including solar energy, geothermal energy, etc.

Passive house, as a type of low-energy design of buildings, is considered as an important approach to improve energy efficiency and reduce the potential possibility of the energy emissions associated with the consumption of fossil fuels [3]. Passive houses have strict technical requirements and energy consumption indicators, and if they do not meet the requirements, they will not be certified (Table 1).

Table 1. German passive housing technical index system [4].

Category	Indicators	
Energy consumption indicators	Primary energy consumption	<120 kW h/(m ² a)
	Heating energy demand	<15 kW h/(m ² a)
	Refrigeration requirements	<10 W/m ²
	Volume related air leakage at 50 Pa	<0.6 h ⁻¹
Indoor environment indicators	Indoor temperature	20~26°C
	Indoor carbon dioxide concentration	<1000 ppm

2.1. Passive house paradox

In energy-efficient residential buildings, to reduce the operational energy (OE), it is often necessary to increase the initial manufacturing energy consumption, which offsets some of the total life cycle energy (LCE) consumption savings achieved by high-performance design. This trade-off is caused by an increase in the quantity of materials and energy intensity used in assembling high-efficiency dwellings [5].

A research evaluated two houses in Belgium and found that in 80 years, the passive house used 3.8% more energy than a new standard house with the same geometry. It is found that the extra materials needed for a passive house resulted in the increasing of the energy efficiency (EE), causing a higher net energy consumption than buildings that were supposed to be less energy efficient [6]. A similar study found that the EE of a passive house accounted for 77% of the total life cycle energy (LCE) over 100 years. In summary, these studies highlight the significant and timely need to include EE in building energy efficiency certification, as this may lead to a net increase in total LCE [6].

From the perspective of LCE, the passive house paradox explains an important energy trade-off in the design and construction phases of efficient housing. Therefore, it is very important to understand the energy contribution of EE and OE to the total LCE of high-efficiency residential buildings to obtain a reliable and cost-effective reduction of total LCE within the life cycle of residential buildings [7].

2.2. Internal operation mechanism

Passive house is a building designed and built with the function which can keep the indoor environment in a comfortable temperature without the active heating and cooling systems [4]. Using advanced energy-saving design concept and construction technology, the thermal insulation, heat insulation, and air tightness of the building are greatly improved, and the heat (cold) in the indoor waste gas is recycled through the efficient heat (cold) recovery device of the fresh air system, thus substantially reducing the heating and cooling requirements of the building.

Passive house includes solar heat gain control, heat recovery ventilation, airtight thermal bridge, free thermal envelope, all electric cooking, high efficiency appliances and lighting, hot and heating/cooling water, and on-site energy generation [8]. The windows are made of layers of special glass, with special

insulation in the wooden window frame, so it has good insulation and air tightness to reduce the energy used for heating and cooling. Building's ventilation is linked to the thermal circulation system, with heat recovery and refrigeration functions, so its heat recovery power and refrigeration is 80-90%, which can minimize energy loss (Fig.1).

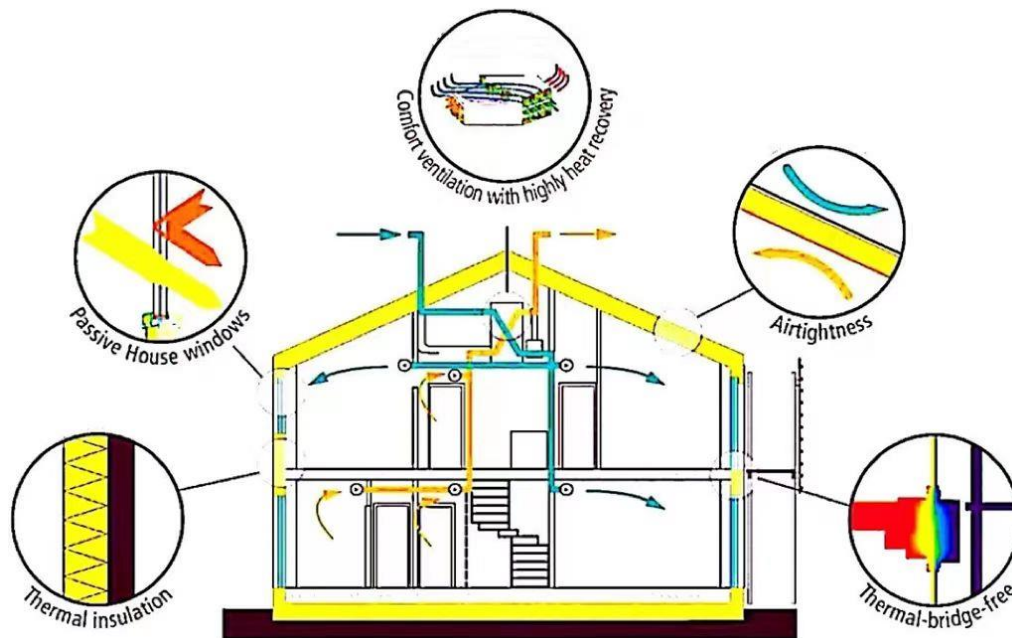


Figure 1. Sectional view of passive house with internal system (Source from internet).

Therefore, passive house, as an energy-efficient design of buildings, is seen as a critical objective to improve energy efficiency and reduce the potential possibility for energy emissions.

3. Passive house in china

Passive house is a building designed and built with the function which can make the indoor thermal environment constantly in comfortable temperature without the operation of heating and cooling systems, which means it should achieve the environmentally friendly goal with less energy consumption compared with conventional buildings.

After being first proposed in German in 1988, passive house then got attention and was introduced in China by German Energy Agency in 2009. China has caught the step of the development followed by the previous developed countries. In 2013, the Ministry of Housing and Urban-Rural Development of China cooperated with German Energy Agency to build the first passive house, a high-rise residential project (Water Front) in Qinhuangdao and they finally succeeded. Now, passive housing demonstration projects are already popping up all over China.

3.1. Chinese design

China, with a broad territory and large climate span, is divided into five types of building thermal engineering zones, namely severe cold, cold, hot summer and cold winter, hot summer and warm winter, and mild, via setting the average temperature of the coldest month as the main index [9]. Compared with Europe, China is more strict on the performance of passive house because of its different climate zones, so it is necessary to formulate targeted plans for different thermal zones [10]. Tianjin residential apartment was studied as a case model to research the passive house design in cold areas using a three-stage multi-objective optimization method. Meanwhile, the performance parameters of window-to-wall ratio, exterior window and wall were optimized to make the energy saving rate reach 88.2% [11]. Taking

the rural residence in the severe cold region represented by Inner Mongolia as an example, the heat transfer coefficient of the envelope was reduced by setting XPS insulation board and three layers of insulating glass. After the passive transformation, an energy saving rate of 74.8% could be achieved [12].

In 2010, Hamburg House, China's first passive housing certified by Germany, was completed in Shanghai (Fig.2). It is the case pavilion of Hamburg, Germany, for the Shanghai World Expo. Compared with ordinary houses, the energy consumption of this building can be saved by 90%, and the indoor constant temperature is about 25°C in all seasons. The building mainly uses human heat, solar energy, geothermal and other resources, and the disposable energy consumption is less than 50 Kwh/ (m²·a) [13].

In northern China, the first passive house compliant with the German passive house standard was built in Harbin, the severe cold climate area of China [14]. This ultra-low energy residential building has tighter envelopes to tolerate poor outdoor air pollution, which was compared with conventional buildings to research the characteristics of indoor PM2.5 [15].



Figure 2. Hamburg house, the first passive house in china (source from internet).

3.2. Development opportunities

With the increase of urban floor space and the growing demand of residents to improve indoor comfort environment, China's energy supply faces major challenges. If the passive house is successfully constructed, it can significantly reduce the demand of energy use, thus realizing the energy saving and emission reduction in the field of construction. "Carbon neutrality" has become a hot topic. China will use energy in an appropriate way that is low-carbon, more efficient, safe and clean in order to promote the green transformation in transportation, construction, industry and other sectors [16].

In southern China, some areas have obvious climate difference between summer and winter, and winter is too cold, however, these places belong to non-heating areas where buildings are not equipped with central heating systems. Residents normally use air condition for heating, which emits huge amount of carbon dioxide. However, providing a central heating system for this area to keep indoor temperatures above 16°C in winter is simply not feasible in the view of energy of supply because of the huge number of buildings. So building passive house is an optimistic choice to solve this problem.

In terms of construction methods, China's residential buildings have a huge amount of construction, and the building types are mainly high-rise buildings. Passive housing projects in Germany, on the other hand, are dominated by single buildings with small volumes, mostly low-rise buildings. Compared with Germany, the construction of passive houses in China is much more complicated, therefore, Chinese-style innovation has become the focus of the development of this industry [13].

4. Conclusion

This review consists of studies and efforts relevant to the previous research of creating the energy efficiency in construction industry. Passive house is an essential way to achieve carbon balance and sustainable development, and it is also a development trend of the construction industry. Under this situation, China has been exploring and practicing passive housing technology in order to achieve the goal of green development and high-quality passive housing. Studies on building air tightness, envelope, fresh air system and other aspects of passive housing show that passive housing can reduce the consumption of coal and other disposable energy as well as carbon dioxide emissions, and it is of great help to alleviate the increasingly severe urban ecological problems.

However, passive house in China is still in the development stage and faces some difficulties. With the development of Chinese real estate and the saturation of urban space, in addition to the new passive houses, China's old buildings will also face energy-saving renovation. Due to the relatively little research and policy in this aspect, there is a problem of immature technology. In addition, China's domestic passive building projects have not been completed on a large scale, so there is a lack of professional technicians and construction personnel to ensure that the buildings meet the energy consumption targets. The future research should focus more on how to introduce foreign advanced technology as well as improving and applying it in combination with China's local conditions.

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