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Solar water heating system integrated design in high-rise apartment in China

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ABSTRACT

With the development of urbanization in China, more and more high-rise residential buildings are constructed, mostly with 10–15 stories. Solar water heating system has been widely used in low-rise residential buildings in China, while its application in high-rise apartment is still in the initial stage. In this paper, the current application situation of solar water heating system in urban residential buildings of China is investigated. Additionally, demonstration projects of high-rise residential building are introduced, in which the application feasibility and limitation of solar water heating system are emphasized and some appropriate planning types of that are discussed. Finally, this paper analyzes the applicability of solar water heating systems integrated design in typical high-rise apartments from various aspects (such as architectural elevation, architectural plane and detailed construction) in the planning and designing phase.

1. Introduction

In 1958, solar water heater was first employed in China. The thermosyphon circulation solar water heater developed by Tianjing University was used in a 12.6 m^2 bathroom. Since the energy crisis in the 70s, renewable energy utilization has become a hot-spot issue around the world. Chinese government formulated a series of policies and regulations to encourage the development and application of solar water heater in the late 1970s. Later in 1987, the first all-class evacuated solar collector tube was produced in China and its industrial mass production was realized soon, which established the foundation of large-scale industrialization. The solar energy industry entered the primary stage since 1993 when the evacuated tubes occupied quite a large proportion of the market. With the rapid development of solar energy industry from 2001 to 2006, compact all-glass evacuated solar tube collectors had the majority of the market [1]. At present, the application of solar water heater in low-rise and multistoried residential buildings expands ceaselessly, from group buildings (see Fig. 1) to residential districts, villages and towns (see Fig. 2). The production of solar water heaters increased from 3.5 million m^2 in 1998 to 125 million m^2 in 2008, respectively with the annual average growth rate of 25% and 24%. Simultaneously, the area of solar water heaters per thousand people reached 96 m^2. It is well known that China has become the largest producer and consumer market of solar water heaters in the world, with the total output and storage capacity more than half of total world production, ranking first in the world [2].

There are two important issues involved in the integration of solar water heating system and building design. One is about solar water heating system, which is composed of solar collector, water storage tank, as well as water pipeline. In China evacuated tube solar collectors have been often applied in buildings, while in Europe flat plate solar collectors are more common. Although these two types of solar collectors have their own advantages and disadvantages in terms of technical performance, the flat plate collectors are more suitable for pressure system and secondary circulating system, easier to be installed, and with longer service life and better compatibility to building appearance. In the field of solar energy system, much research focuses on system performance. Zhai et al. [3] validated the practical energy performance of a solar energy system capable of heating, cooling, natural ventilation and hot water supply in Shanghai by experimental investigation in 1-year operation period. Pantic et al. [4] studied energy performance of three different open loop air heating building-integrated photovoltaic/thermal (BIPV/T) systems that utilize recovered heat for home heating.

The second issue is about the building design. The dominant type of residential buildings in China is high-rise apartment. By contrast, single family house, townhouse and multi-storied apartment are common in Europe and North America. Due to much higher occupancy in high-rise apartment, only installing solar collectors on the roof cannot supply enough hot water as required, therefore building

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Fig. 1. Chang Dao Green Garden in Zhejiang.

façade has to be utilized. This makes demand of the diversity and commercialization of solar collector products from such aspects as type, color, style, property, and size, for the sake of making full use of limited building facade. Standardized design method and process as well as proper design proposals about integrated design of solar energy system for high-rise residential buildings are needed urgently.

Few studies have deeply investigated application of solar energy system on the basis of reasonable and effective integrated design of solar collector and architecture facade construction. When using integrated approach, solar system becomes part of the overall building design. The solar elements are designed as architectural elements in attractive and visible wayside by multi disciplinary design teams with the consideration of esthetic compatibility [5]. Johnston [6] mentioned the advantages of traditional China buildings – roofing (eaves) at each storey, in addition to that on top of the building, for application of integrated solar energy system from the point of building morphology, considering solar energy collection and shading, as well as their matching to temporal and locational variations in energy demand. Then he discussed the energy saving potential of building-integrated solar system by comparing primary energy demand of solar-integrated building with that of similar building without solar panels. Considering different energy demand in different climatic condition, calculations were made for Beijing in winter, as an example of high space heating demand, for Hong Kong in summer, as an example of high air conditioning demand, and for Shanghai, as an intermediate example.

This paper discusses the applicability of solar water heating systems integrated design in typical high-rise apartments in China from such aspects as architectural facade, architectural plane and detailed construction in the planning and designing phase, based on the investigation on current situation and demonstration projects.

Fig. 2. Bolitai Solar village in Pingu in Beijing.

2. High-rise residential buildings in China

With the development of the urban residential construction, the urban population has been rising, which is more than 600 million by the end of 2008, rapidly advanced urbanization process encourages the fast development in the building industry. In order to keep the balance of urban ecosystem, protect the living environment, and satisfy people's increasing level of demand, it is an inevitable trend to build more and more high-rise residential buildings. Because of the situation of economic foundation and the social culture atmosphere in China, Urban residential buildings always have features of high-rise and high-density, especially in hot-summer and cold-winter zone. For example, in Shanghai, the number of high-rise buildings increases very fast due to the regional high population density and high housing prices [7]. As high-rise office buildings are becoming saturated, the construction of high-rise residential buildings appears to be on the rise. With the very big scale and fast speed residential building construction, energy consumption issue is becoming more and more prominent.

According to the latest statistics, building energy consumption accounted for 27.8% of terminal energy consumption of the whole society in China, which is close to 1/3 in developed countries [8]. Among the total energy consumption, the building sector accounted for 27.6% in 2001 and it is still increasing. It is predicted that the building energy consumption sector will inevitably be about 35% by 2020. Furthermore, building energy consumption per square meter in China is far more than that in developed countries, and this situation will not be change in recent years. Although heating period in China is shorter than other countries, heating energy consumption per square meter in China is still 3–4 times bigger than that in developed countries [9]. However, as Chinese people's living condition is getting better and better, air-conditioning systems are applied in most buildings and domestic hot water is supplied in most urban residential buildings for the purpose of indoor thermal comfort, which brings tremendous potential to the development and application of solar energy in buildings.

3. Architectural layout

The survey shows that south-north orientation, row layout and parallel arrangement are adopted in most residential buildings in China [10]. Table 1 displays the architectural layout of the typical existing high-rise residence communities using solar water heating systems in China. Note that, the distance between the buildings in these residence communities is calculated according to the local sunshine standard requirements. For example, in Shanghai, as specified in "Code for Planning and Design of urban Residential Areas" (GB50180-93) and "Technical Regulations of Urban Planning and Management in Shanghai", the distance between buildings must be designed to ensure no less than one hour sunshine time for each bedroom (more than one bedroom each family) of residential buildings on the winter solstice. As for buildings using solar water heater, the distance between them should be designed to meet the demand that the building envelope installed the solar collector can get no less than four hours sunshine duration in order for preferable performance of solar collectors [11].