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Review

The application of air layers in building envelopes: A review

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HIGHLIGHTS

- Air layer involved building envelopes are treated as a unified research subject.
- Recent studies on air layer applications and technologies in walls, windows, roofs are observed and traced.
- The performances of different types of ALIE systems and technologies are summarized and classified.
- Current research gaps and possible future research directions are provided.

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ABSTRACT

Air layer involved envelopes (ALIEs) have gained considerable popularity in modern building design and construction, owing to their great potential in improving the building thermal performance. Basically, the air layer functions as an extra insulation layer or as a ventilation channel. This paper presents a literature review on building envelopes that contain inner air layers by tracing recent studies on existing air layer involved applications and technologies in walls, windows, roofs. The structural characteristics, the driving forces, the effects of the inner air layers, and the benefits of different types of ALIE systems are summarized and classified. And then operation modes of air layer used in building envelopes are roughly classified into three types: the enclosed type, the naturally ventilated type and the mechanically ventilated type. At the end, this paper analyzes current research gaps and provides possible future research directions on air layer technologies in building envelopes.

Contents

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1. Introduction

1.1. Energy consumption in building sector

With the rapid development of economy and urbanization, the world is now facing a great challenge of an energy shortage, environmental pollution and climate change. Globally, all the energy produced can be consumed by several main sectors, that is, the residential sector, the commercial sector, the industrial sector and the transportation sector [1]. As reported, in 2011, the primary energy consumption proportions of industrial, transportation, residential and commercial sectors were 31%, 28%, 22% and 19%, respectively [2]. On the other hand, building energy demand has been identified as the largest energy consumer and accounts for the largest percentage of the total energy consumption [3]. The building energy expenditures in different countries is illustrated in Fig. 1, the primary energy consumed by buildings accounting for 23% in Spain, 25% in Japan, 28% in China, 39% in the United Kingdom, 40% in Europe, 42% for Brazil, 47% for Switzerland, and 50% for Botswana [4]. The United Nation Environment Programme [5] also reported that 30–40% of the world's total primary energy expenditure is consumed in buildings. As the situation evolves, energy consumption in the building sector may increase to as much as the sum of the industrial sector and transportation sector [6]. In China, industry, building and transportation are the three major energy consuming sectors, in which the building sectors account for the largest proportion and enjoy the biggest potential of energy saving [7]. Moreover, with the rapid increase of building areas, the acceleration of urbanization, and the continuous improvement of residents' living standards, the building sector will continue to dominate China's energy conservation and emission reduction process.

Thus, the energy conservation of the building sector plays a key role in solving energy problems all over the world [8]. Although the high energy consumption of building sectors maybe a warning sign, it provides an opportunity for implementing sustainable energy plans in building sectors. Therefore, there is a need to optimize a building's energy efficiency [9]. Energy efficiency becomes a key point in controlling energy use, as well as maintaining comfortable environment in buildings [10].

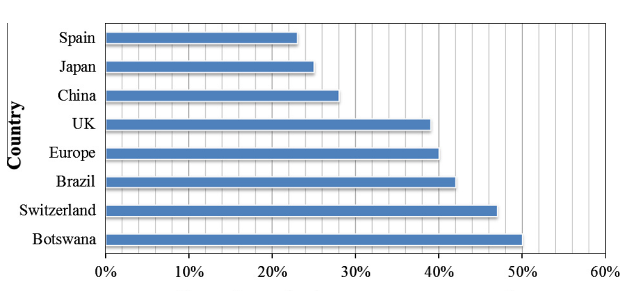

Fig. 1. Building energy expenditures in different countries.

1.2. Energy distribution in buildings

The energy consumption distributions in the building sector show large variations. Physical factors of a building, such as building orientation, geographical location, construction materials, construction categories, internal equipment and energy systems, lead to significant difference in building energy consumption [11]. The distribution of primary energy utilization in a commercial building is illustrated in Fig. 2. This figure indicates that the biggest proportion of energy consumption is the heating, ventilation and air-conditioning system (HVAC), which is the highest energy consumer in a building nowadays [12]. Then the lighting takes the second place. For this reason, the US Department of Energy highlighted the energy conservation potentiality of HVAC and lighting [13].

From surveys on office buildings in China, the energy consumption of HVAC systems accounts for a large proportion of the total primary energy use. Results showed that, in July and August, the proportion is 30–60% for 4 typical office buildings in Hong Kong, 24–54% for 105 office buildings in Beijing, the average proportion is 34.3% for 198 high-rise office buildings in Shenzhen, and 44.0% for 3 government office buildings in Wuhan [14]. So energy conservation for HVAC systems has become an important part of a national energy strategy.

The HVAC system is important in buildings as it helps to meet the requirements for thermal comfort [15]. The higher comfort level is achieved in a building, the more the energy is consumed [16]. Two measures can be taken to reduce the energy consumption in HVAC systems: one method is to manage the operation of the system properly on the premise of ensuring the reliability of critical loads [17]; the other is to improve the thermal performance of building envelopes, as the building envelopes are the interface between indoor and the outdoor environment which affect the indoor heat gain and heat loss [18]. The former belongs to the active energy efficient strategies, which involves improvements to HVAC systems, electrical lighting, and other indoor energy systems; while the latter can be categorized as passive strategies in which relevant improvements are made to building envelope elements [19]. Building energy efficiency can be increased by implementing either active or passive energy efficient strategies.