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Adaptability research on phase change materials based technologies in China

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ABSTRACT

Latent heat thermal energy storage technologies based on phase change materials (PCMs) are found to be significantly efficient and viable methods for thermal energy storage. These energy storage techniques have been proved to be with positive effects on buildings energy efficiency. The integration of appropriate thermal energy storage system and selection of suitable PCMs plays a very dominating role in the upgrading of energy efficiency. Short and long term storage helps in the reduction of energy demand or shifting peak load for both heating and cooling. However, a comprehensive study for the application of these technologies adopting Chinese built environment is lacking which can relate to climate, energy storage and energy efficiency. The goal of this paper is to provide coherent picture of current status on PCM-based techniques that have been studied with the focus of application in China and analyse the selection and suitability of PCMs and techniques in Chinese regions. The results show that many PCMs and techniques are promising to be used in China however studies can be conducted with the consideration of changing climate rather than winter/summer only.

1. Introduction

Building energy consumption in China is concerned as the country has the biggest built up area in the world, reaching at about 55 billion m^2 till 2010 [1]. In China, building energy consumption has jumped by 40% since 1990–2014 in the nation's total energy use [2]. The growth trend of China's energy consumption in the building sector is considered to continue [3]. In 2011, buildings in China has consumed 28% of total primary energy [4] of which 69% of the energy consumed was generated from coal, making China as one of the largest carbon emission country in the world (about 8746 $MtCO_2$ in 2011 and 9153 $MtCO_2$ in 2015) [5]. In the last decades, with the growing need of comfort, energy consumed by heating, ventilation and air conditioning (HVAC) accounts for 40–60% of total energy consumption in the buildings [6–8]. The figures indicate a significant need in improving building energy efficiency and therefore reducing carbon emissions in China. Chinese government aims to reduce carbon dioxide emissions per unit of GDP by 40–45% by 2020 based on the 2005 level [9].

Thermal energy storage technologies can be utilised in buildings to increase energy efficiency and reduce the mismatch between supply and consumption [10]. Latent heat thermal storage (LHT) is one of the thermal energy storage methods using phase change materials (PCMs) as storage media, has been gaining research attention in decades [11–14]. PCMs become anticipated heat storage media in thermal energy storage systems due to their desirable thermal-physical, chemical, economic and environmental properties which are shown in Fig. 1 [15–17]. While it is also emphasized that few PCM can achieve all the desirable properties and a certain degree of compromise might be made in some cases [18].

To provide a comprehensive view of the development and the relevant research, the paper aims to present a regional study and review the research field of PCM-based techniques applied for buildings in China and analyse the suitability of the techniques in different regions of this country.

2. PCM characteristics and increasing research interest of PCM in China

2.1. PCM classification and characteristics

Latent heat thermal storage materials can be divided according to the change of state, namely solid to solid, solid to liquid, and liquid to gas. As far as chemical composition is concern PCMs (solid to liquid) can also be classified as organic, inorganic and eutectic showing in

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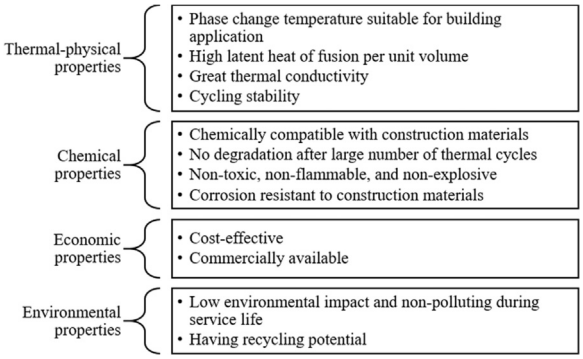

Fig. 1. Desirable properties in selection of PCM for building application [15–17].

Fig. 2 [15,19–25]. With regards to the PCMs used in buildings for thermal storage, paraffin and salt hydrates are more preferred due to their large-scale availability in the international market and low cost [10].

A comparison of the advantages and disadvantages of the PCMs have been demonstrated by various authors [11,12,25], summarised in Table 1.

2.2. Increasing research interest of PCMs in China

With the research program supported by the Chinese government, such as National Basic Research Program (973 and 863 program) and National Natural Science Foundation China (NSFC), latent thermal energy storages are gaining research interest since 2000s. This can be proved by a summary of funds provided from National Natural Science Foundation in China (Fig. 3) [26]. None project funded by the local government, Universities, and industries has been considered in these figures.

According to the statistics of the last fifteen years, the Chinese government energetically support the research in PCM and this kind of tendency keeps growing regularly. Nearly £6 million have been invested in the PCM research since 2000 [26]. Chinese government funded over 120 projects in 2014, which are four times the previous year funded 30 projects. The year 2013, Chinese government provided nearly £0.9 m grand for the researchers in this area, which is about £0.8 m more than that of 2000 and 2001, being the year with the highest funds provided.

With the abundant financial support from the Chinese government, the academic output is distinct. This can be depicted by the number of publications. Fig. 4 shows the number of journal papers on PCMs applied with building walls published from countries [27]. Clearly, China contributes to the most publications, almost reaching double of the publications from the UK, United States and Spain.

3. Current status of energy storage technologies in the buildings in China

In general, the PCM-based energy storage techniques applied to the buildings in China can be divided into two main categories (i) active systems and (ii) passive systems. In terms of active systems, heat charging and discharging are mainly facilitated by pumps or fans consuming electricity. For passive energy storage system, temperature difference is the driving force. Fig. 5 shows several sub-categories that are reviewed in the present study.

3.1. Passive storage techniques studied in China

In order to store thermal energy and meet the human comfort criteria, PCM-based passive storage techniques have been studied. In such applications phase change materials should be able to absorb and release thermal energy close to ambient and indoor air temperature. In most of the cases PCMs is either embedded into building structures or envelopes. The combination of building structure, energy storage, solar thermal and management systems offers new opportunities for exploiting natural energy for improving the building thermal performance and minimising the impact on the environment.

3.1.1. PCMs in bricks

Insulation properties of a paraffin hollow block wall have been investigated by Wang et al. in Changchun [29]. Paraffin composition was used to fill the hollow brick, shown in Fig. 6. Various ratios of weight for liquid and solid paraffin have been tested based on the transition temperature (19–30 °C) and the latent heat storage capacity (11–94 kJ/kg). Stated by the authors, 7:3 is the best ratio of weight for liquid and solid paraffin with transition temperature of 25–31 °C and latent heat storage capacity at 65 kJ/kg. The PCM wall was experimentally tested by using a heating fan to heat the composite wall and the temperature change of the wall was recorded. Totally, 20 tests with the duration of five to six hours for each test have been carried out. It was found that applying the PCM can reduce the temperature fluctuation of the wall by 20–30%.

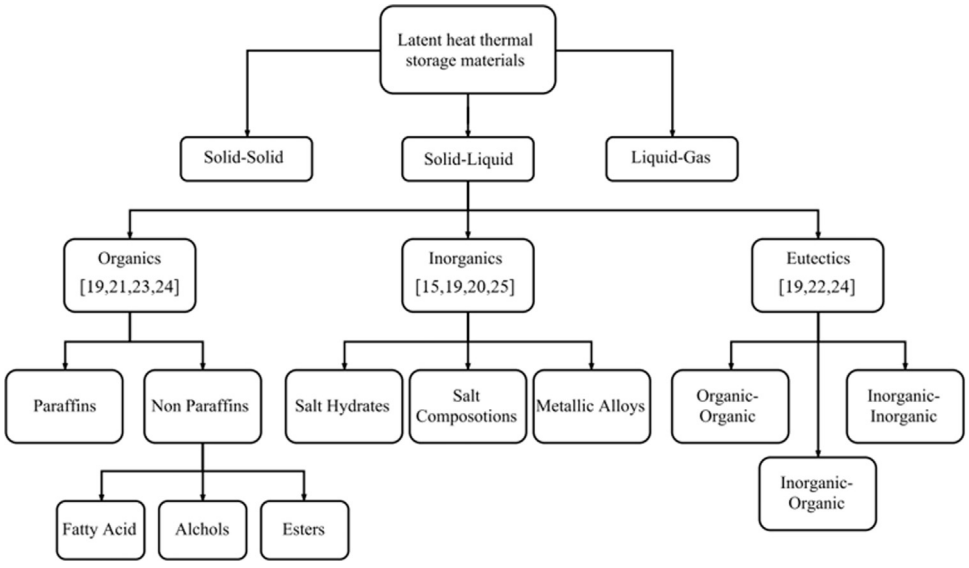

Fig. 2. Classification of PCMs [15,19–25].