Renewable and Sustainable Energy Reviews 18 (2013) 327–349

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review of potential materials for thermal energy storage in building applications

Parfait Tatsidjodoung, Nolwenn Le Pierrès, Lingai Luo*

LOCIE, CNRS UMR 5271-Université de Savoie, Polytech Annecy-Chambéry, Campus Scientifique, Savoie Technolac, 73376 Le Bourget-Du-Lac Cedex, France

ARTICLE INFO

Article history:
Received 28 June 2012
Received in revised form
12 October 2012
Accepted 14 October 2012
Available online 17 November 2012

Keywords:
Thermal storage
Material
Sensible heat
Latent heat
Thermochemical heat
Building applications

ABSTRACT

In recent years, storage of thermal energy has become a very important topic in many engineering applications and has been the subject of a great deal of research activity. This paper reviews the thermal energy storage technologies suitable for building applications with a particular interest in heat storage materials. The paper provides an insight into recent developments on materials, their classification, their limitations and possible improvements for their use in buildings. Three major thermal energy storage modes (sensible heat, latent heat, thermochemical heat) are described emphasizing the main characteristics of the most suitable heat storage materials for each.

Contents

* Corresponding author. Tel./fax: +33 2 40 68 31 40.
E-mail address: lingai.luo@univ-nantes.fr (L. Luo).

1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2012.10.025

Nomenclature

m	material mass (kg)
C_p	specific heat (J/(kg K))
k	thermal conductivity (W/(m K))
e	effusivity (W $s^{1/2}$/(m^2 K))
P	pressure (Pa)
Q	energy (J)
T	temperature (K)

Greek symbols

ρ	density (kg/m^3)
α	thermal diffusivity (m^2/s)

Subscripts

i	initial
f	final
0	reference

1. Introduction

In 2010, the building sector accounted for 25% of the total final energy consumption in the world, the third largest after industry (32%) and transport (31%) [1]. Although this share is expected to decrease, buildings will still account for 20% of the total final energy demand in the coming years. Space heating and domestic hot water production are key applications in this sector: 53% and 16%, respectively [1]. The prospect of an increasing scarcity of fossil fuel and the upward trend of oil prices have led to a general interest in renewable energy resources that are more respectful of the environment. Solar energy is one of them. This resource is abundant and offers unrestricted access. Considering building applications, solar energy has been used for space heating/cooling as well as hot water and electricity production for many years. Unfortunately, solar energy is intermittent and there is a mismatch between the supply and demand periods. The peak of the solar irradiation occurs during the day when the heating demand is low, and the highest demand usually occurs at night or early in the morning, when sun irradiation is low.

Consequently, there is a need for heat storage so that the excess heat produced during supply periods can be stored for use during peak demand periods. To this end, one of the most widely used techniques for thermal energy storage is the sensible heat storage method. The concept is widely used, well known, and is the simplest and least expensive way to store energy [2–4]. In addition, other energy storage techniques such as latent energy storage and thermochemical energy storage appear to be promising given their great heat storage capacity and/or their low heat losses during the storage period.

For all the energy storage methods mentioned above, their performance is strongly dependent on the nature of the storage material chosen in the system. A material with a high heat storage capacity and good heat transfer characteristics will improve the performance of the heat storage system. Some other material parameters such as the cost, environmental impact, and safety conditions, also play an important role and therefore should be taken into account during the design of such systems.

The aim of this paper is to present a review of materials available for thermal energy storage in buildings. The temperatures concerned range from 0 to 100 °C. Indeed, building heat consumption covers both cooling (for air conditioning) and heating purposes (for space heating and domestic hot water production). Domestic food refrigeration and freezing will not be considered in this paper. Heat storage methods will be introduced with an emphasis on the thermophysical properties of the material used. One of the key properties is the energy density of the storage materials. In buildings, given that space is a critical feature, the volumetric energy density will be considered.

2. Sensible heat storage

One definition of sensible heat storage materials is that of materials that are not subject to a phase change during the temperature change of the heat storage process [5]. The amount of energy involved in a sensible heat storage process depends, as presented in Eq. (1), on the specific heat of the material ($C_p(T)$), the temperature change (T_f,T_i), and the amount (m) of material.

$$Q = \int_{T_i}^{T_f} mC_p(T)dT \quad (1)$$

It is important for sensible heat storage systems to use a heat storage material that has high specific heat capacity in addition to good thermal conductivity, long-term stability under thermal cycling, compatibility with its containment, recyclability, a low CO_2 footprint, and most important, low cost. Moreover, for building applications, high density is also essential. Various disadvantages are inherent to sensible heat storage systems. The most important of them are: their relatively low energy density (space limitation is usually a critical aspect, especially for building applications) and the system's self-discharge (heat losses), which can be substantial, particularly when long periods of storage are needed.

Sensible heat storage materials have been widely investigated. Most authors present these materials in two main groups: liquid and solid storage mediums. Liquids are most often water and thermal oil, and solids are rocks, bricks, concrete, iron, dry and wet earth, and many others.

2.1. Liquid storage materials

Table 1 shows a list of liquid materials used in sensible heat storage systems. These materials can be classified according to their operating temperature. Water has been widely used for heat storage as well as for heat transport purposes in energy systems.