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Review

PCM-mortar based construction materials for energy efficient buildings: A review on research trends

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ABSTRACT

The increasing concerns about climate change and environmental emissions have led to conservation of energy in buildings through the development of several energy-efficient technologies. Though, the energy requirements in buildings are being continuously addressed, factually, the buildings across the world consume almost one-third to one-quarter of the total energy being produced. From this perspective, the development and incorporation of the energy efficient materials and technologies in buildings in order to fulfill the cooling energy requirements have been gaining impetus, in recent years. The building envelopes which may seem to be consuming more energy can be modified by tailoring the construction materials, such as mortar, with heat storage materials for regulating the indoor temperature and achieving enhanced energy efficiency as well. The phase change material (PCM)-based thermal energy storage (TES) is one among the efficient technologies available, which seems viable to cater to the end-use energy demand through energy redistribution. This is possible because of the storage and retrieval of the latent heat during the phase change processes at nearly isothermal conditions. The prime intention of this article is to review the literature involving synergy of PCM and mortar for achieving energy efficiency in buildings. The review includes details regarding different PCM-mortar combinations along with details pertaining to, but not limited to, thermal and mechanical properties of the PCM-mortar. The period, post 2010, has been observed to be very productive with many researchers actively carrying out the investigations related to this very important area of research and hence the period between 2010 and 2017 has been specifically chosen for this review article. The selection and application of a variety of the PCM-mortar combinations in buildings have been extensively reviewed from the perspectives of porosity, supporting materials, thermal and structural properties. Furthermore, the advantages and limitations associated with each kind of mortar for its utility as PCM carrier have also been summarized.

Contents

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1. Introduction

Energy is the prime mover for all day to day human activities and its conservation through efficient utilization is crucial for economy of any country to sustain in the long run. Moreover, environmental pollution due to excessive usage of fossil fuels is of primary concern for all the countries of the world because fossil fuels are limited and are depleting at a faster pace. It has been observed that almost all the countries of the World are consciously trying to cut the usage of fossil fuels through technologies involving alternate energy resources. Incentive driven economic policies for the extensive utilization of alternate or renewable energy options is picking pace in majority of the countries of the World.

The countries grouped under the banner of organization for economic cooperation and development (OECD) have made a conscious effort of reducing the gap between power demand and supply by switching over to renewable energy based technologies. It may be noted that the global energy demand is increasing by 1.4% every year and the buildings alone, residential and commercial together, contribute 40% of global energy consumption [1].

Solar energy has been the primary energy source available to the entire globe around the year and energy received from this source by earth is estimated as 10,000 times that of global energy demand [2]. This energy resource can be used through a thermal storage medium like phase change material and decrease active energy consumption through heating, ventilation and air conditioning (HVAC) systems in buildings. This could be possible through incorporation of PCM in floors, walls and ceilings of buildings and satisfy all dimensions of sustainable development from social, economical and environmental points of view. PCM changes its phase with ambient temperature and can absorb and release heat during phase change and when incorporated into mortar, will serve as passive thermal regulator of indoor temperature. If PCM has to function as thermal regulator, its phase transition temperature should lie in the vicinity of ambient temperature. Though PCMs could be included in floors, ceilings and as storage medium for heat pumps and solar collectors, its application in walls of buildings is most sought after [2].

It has been reported that PCMs possess high energy storage density and temperature variation attenuating capacity [3]. Despite the fact that the construction material behavior becomes very complex with the inclusion of PCM, it has been verified on many occasions that the resulting composite is still acceptable as a construction material in general and light weight material in particular. Another distinctive advantage of using PCM is that it is typically a latent heat storage medium, occupying less volume when compared to sensible thermal storage media [3].

Leakage and compatibility with the mortar have been observed to be the major areas of concern as far as PCM use in mortars is concerned. However, these problems can be addressed by proper method of PCM incorporation in to mortar. The usual methods of incorporation of PCM in to the mortar, adopted by researchers, are direct mixing method, capsule bending method and immersion method [4].

The use of PCM is quite common in gypsum wall panel boards, concrete and mortar, as reported in the literature. Incorporation of PCM in prefabricated gypsum wall panels is a controlled process and hence they pose relatively less challenges when compared with mortars and concretes. In concretes and mortars, which are primarily in-situ products, careful process has to be devised and followed while adding PCMs in to the respective matrices.

While mortars constitute cement (or cementitious constituents), fine aggregates (river sand or crusher rock dust), viscosity modifying admixtures or super plasticizers along with water; concretes will have coarse aggregate chips in addition to all the ingredients which are available in a mortar. A separate research track has been followed with PCM enhanced concretes as concrete possesses higher thermal inertia when compared with mortars.

Also Concrete is considered a structural material while mortar is literally a functional material without much demand from the mechanical strength point of view. Most of the works have reported paraffin wax as the PCM being tried with concrete [5]. Few studies reported that there is a compromise from strength and fire resistance points of views when concrete is made with PCMs [6]. However, in this article, a detailed review of literature during the period 2010–2017 was taken up for the specific case of PCM enhanced mortars only.

- In addition to the current first section, complete literature review is presented in 4 more sections.
- Second section discusses about building energy consumption status and short description on latent energy storage system.
- Third section concentrated on different PCM and their thermal properties followed by different mortar-PCM combinations and thermal storage properties of PCM-mortar.
- The fourth section briefly describes numerical as well as experimental studies with the relevant properties which a decision maker may be interested in.
- The fifth section summarizes the review work reported in this paper on the PCM-mortar combinations for building applications.

Section details of the literature review are summarized and presented in Fig. 1 for quick reference. The last section concludes with key technical interpretations and recommendations. An overview of the contents of this paper is presented through Fig. 1. Fig. 2 depicts the rising interest in this research area, thus indicating that the world started focusing on passive temperature regulation strategies for indoor thermal comfort, achieved economically with reduced power consumption. Compatibility of mortars with different PCMs has also been thoroughly reviewed in this article to make it useful for the research community at large.

2. Energy consumption in buildings

2.1. Global energy scenario

Efficient utilization of energy has always been a matter of concern for the humankind. Buildings, belonging to different functional