

Phase Change Materials for Energy Efficiency in Buildings and their Use in Mortars

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Abstract: The construction industry is responsible for consuming large amounts of energy. The development of new materials with the purpose of increasing the thermal efficiency of buildings is, therefore, becoming imperative. Thus, during the last decades, integration of Phase Change Materials (PCMs) into buildings has gained interest. Such materials can reduce the temperature variations, leading to an improvement in human comfort and decreasing energy consumption of buildings at the same time, due to their capability to absorb and release energy from/in the environment. In the present paper, recent experimental studies dealing with mortars or concrete-containing PCMs, used as passive building systems, have been examined.

Keywords: Thermal Energy Storage (TES), Phase Change Material (PCM), Building Materials, Passive Building Systems, Mortar, Concrete

1. Introduction

In recent decades, energy efficiency has been gaining high attention since energy crises took place in 1970. The energy demand and supply mismatch has always been a key concern science long. Energy management provides a feasible solution with greater reliability for upcoming future. On the other hand renewable energy power generation is considered hopeful solutions with compatibility of pollution free supply. Moreover, challenges are also faced for the uninterrupted power supply particularly for the peak load demands.

According to the literature, LHTES is the most attractive approach, due to its high storage capability and small temperature variations from storage to retrieval. In such a system, energy is stored during melting and recovered during freezing of a Phase Change Material (PCM).

2. Classification of PCMs

The first classification of materials used for thermal storage appeared in 1983 and was proposed by Abhat Based on chemical composition, a PCM can be classified as an organic, inorganic or eutectic compound (Figure 1).

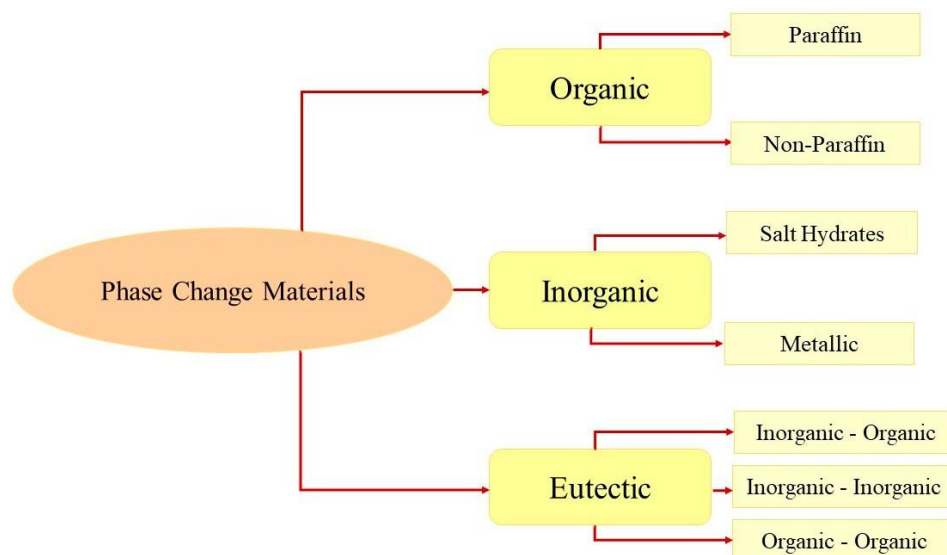


Figure 1 - Classification of PCMs

Type of PCM	Composition	Melting Temperature	Heat of Fusion (J/kg K)	Cost
Organic	Paraffin	-12 - 71	190–260	Costly
	Non-Paraffin	8 - 187	130–250	Highly Costly
Inorganic	Salt hydrates	11 - 120	100–200	Low Cost
	Metallic	30 - 96	25–90	Costly
Eutectic	Paraffin	4 - 93	100–230	Costly
	Non-Paraffin	-12 - 71	190–260	Costly

Table 1 - Main Features of the Different Classes of PCMs

3. PCMs in Building Materials

Human comfort requirements with respect to heat transfer all refer to properties of the air, except wall surface temperatures. The control of these properties in a broad sense is called air-conditioning. It includes any form of cooling, heating, and ventilation. Additional requirements to modify the condition of air, however not connected to heat transfer, are cleaning or disinfection of the air. The more common usage of the term air-conditioning is however for cooling and often dehumidification of indoor air.

For PCM- technology, the key parameters of human comfort requirements are the temperatures of the air and of the surrounding surfaces, because PCM can only influence these parameters. The relative humidity can be influenced indirectly, because it is a function of the air temperature. All others like air movement, noise level, etc. are boundary conditions for a system. If the application of PCM for heating and cooling of a building is a form of air-conditioning or not therefore depends on what definition is used for the term air conditioning.

4. Methods of Incorporation

Using one or more of the described elements in a house, a significant improvement in energy efficiency is achieved. Such an approach in construction allows activating thermal inertia and heat storage capability of each room, reducing the internal temperature fluctuations and improving the level of indoor thermal comfort.

Different methods have been used to incorporate PCMs in building materials, such as:

- Direct incorporation;
- Immersion;
- Use of micro or macro encapsulated PCMs;
- Addition of shape-stabilized PCMs;
- Addition of form-stable PCM composites.

It must be emphasized that the terms shape-stabilized and form-stable PCMs have been often considered as synonymous; the two methods, on the other hand, have some distinct characteristics, as following described.

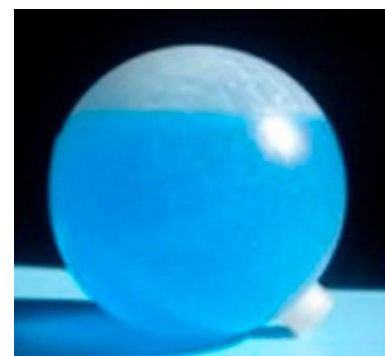
Two encapsulation approaches are reported in literature for PCMs: micro-encapsulation (Figure 5 a, b) and macro-encapsulation (Figure 5 c) methods. In order to guarantee a long-term. Stability of the whole system, the PCM and the container material should display no chemical interactions, irrespective of the encapsulation method.



(a)



(b)



(c)

In the micro-encapsulation method, small PCM particles, ranging from 0.1 μm to 1 mm, are wrapped in a thin solid shell. The latter is usually constituted by natural or synthetic polymers; in general, a shell of a high molecular-weight polymer is used. The employed polymer must be compatible with both the PCM and the construction material in which it is applied.

In the case of polymers, the PCM and the supporting material are melted and mixed at high temperatures. Then, the polymeric support is cooled below its glass transition/melting temperature, solidifying, while the PCM, that is still in the liquid state, fills the empty space of the support (Figure 3).

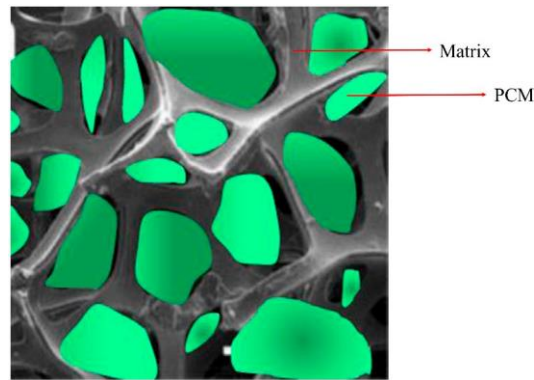


Figure 3 - Example of Shape-stabilized Composite PCMs

In order to improve the thermal conductivity of shape-stabilized PCMs, some additives can be added [19]. In particular, the shape-stabilized PCM composites show enhanced thermal conductivity with the incorporation of carbon-based nanostructures (CNs), namely: expanded graphite (EG), compressed expanded natural graphite (CENG), nano-graphite (NG), exfoliated graphite nanoplatelets (xGNPs), graphene, nitrogen-doped graphene (NDG), graphene oxide (GO) or multi-wall carbon nanotubes (MWCNTs).

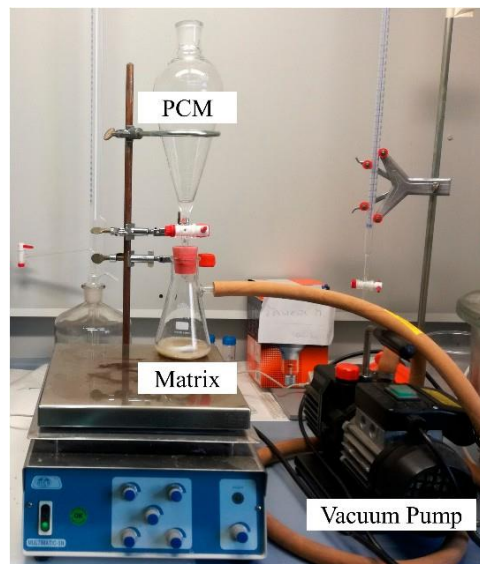


Figure 4 - Vacuum Impregnation Equipment used to Prepare Form-stable PCM Composites

5. Main Issues: Shrinkage, Cracking and Leaking

The addition of microcapsules of PCM significantly affects the shrinkage of the mortar; the higher the amount of PCM, the higher the shrinkage. To avoid cracking, the shrinkage phenomena taking place during the curing process must be limited. Some works also examined the capability of PCMs to mitigate early-age temperature rise in cementitious materials caused by exothermic cement hydration and the resultant risk of thermal cracking.

5.1 Durability

Very recently, different studies have been undertaken to assess the durability of mortars containing PCMs. Several aspects have been investigated; in particular, the structural integrity of the PCM during the production of the mortar composites, the possible interactions between the PCM and the other components, and the matrix durability. For this latter evaluation, the resistance to water absorption, freeze/thaw tests, and biological colonization have been mainly used.

6. Outlook for Future Works

Future research works on mortar/concrete containing PCMs are still needed to refine the methods of preparation, mitigate the strength reduction and overcome the durability issues. Possibly, different sustainable, green PCMs/support couples should be identified along with eco-efficient and low costly methods for the production of mortar/concrete containing PCMs.

Experimental studies conducted in the field would be useful to document the performance and potential of the PCM in a real context. Moreover, it would be desirable to develop simple but certified simulation tools that easily replicate the service conditions of PCM integrated into mortar or concrete in order to assess, using few tests, both the performance and durability of these materials.

7. Conclusions

In this chapter optimization was carried out for maintaining temperature of the building nearly constant to 30 °C with respect to outer ambient average temperature of 42° C. A simulative validation was performed with specified design parameter to compare variation in inside heat load with respect to outdoor ambient conditions.

Furthermore, according to heat load, for maintaining desired range of indoor temperature the given set of quantities of PCM and conventional vapor compression type air conditioning system were compared with the varying thickness of insulation.

During the comparison techno economic aspects for AC system, PCM and insulation was taken into consideration like physical life, economic life and Annual rate of interest. Based on the simulation the optimized annual cost against the thickness of insulation was identified.

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