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ASPECTS REGARDING THE INTEGRATION OF PHASE CHANGE MATERIALS IN BUILDINGS

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Abstract: *This paper aims to provide an overview of the technologies for the use and implementation of PCM (phase change materials), in order to identify possible applications in energy efficiency and the reduction of carbon dioxide emissions from buildings, while addressing the same time new and existing buildings, while achieving a balance between the technical proposal and the basic. The integration of renewable sources of energy, corelated with the implementation and integration of phase change materials into buildings, offers the possibility to achieve the reduction of energy dependency, by using the latent heat storage to increase the thermal inertia without significantly increasing the weight of the building and structure.*

Key words: *Phase change materials, PCM, thermal energy storage, energy efficiency.*

1. Introduction

In the global context where we are talking about the depletion of classical combustible resources, the impact of their use on the environment, the increase in greenhouse gas emissions and the progressive increase in global temperatures, we find that the integration of renewable energy sources new construction but also the adaptation of existing buildings with the clear purpose of reducing energy consumption and at the same time the carbon footprint of buildings.

We have to keep in mind that every growing economy brings a few social and economic issues, like the rise in living costs, the lack of living space and green spaces, the urban agglomeration, due to the continuous expansion of the construction sector, and one of the more concerning issues, the permanent rise in utility costs.

One of the most concerning issue in every emerging city, is the chaotic development of the construction sector, where we see the expansion of a city beyond its borders, and at the same time the reorganization of the buildings inside it, often with high constructions. But with this rapid expansion comes a bigger problem, the existing utility networks become undersized, inefficient, and cannot assure the normal functioning rates. The integration of renewable sources of energy, corelated with the implementation and integration of phase change materials into building structures and elements, will reduce the energy consumption and help the heating and cooling loads of

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the building.

This paper aims to provide an overview of the technologies for the use and implementation of PCM (phase change materials), in order to identify possible applications in energy efficiency and the reduction of carbon dioxide emissions from buildings, while addressing the same time new and existing buildings, while achieving a balance between the technical proposal and the basic investment, so that the operating costs of the building are limited over the entire period of operation with a reasonable investment.

2. The Properties and Classification of Phase Change Materials

Matter can exist in several distinct forms, called phases, depending on the potential energy in the atomic forces holding the particles together, the pressure on the substance and the thermal energy of the motion. Phase transition (or phase change) is used to describe the transitions between solid, liquid and gaseous states of matter. During a phase transition certain the properties of the medium change due to temperature, pressure, or others. Phase transitions are common in nature and used today in technology development

There are three main phases of substances, gas, liquid and solid, see Fig. 1. We will not refer to the plasma phase.

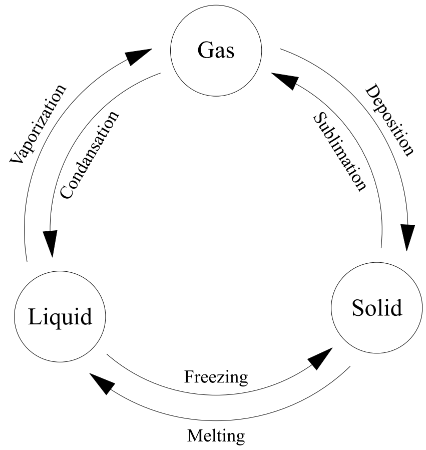

Fig. 1. *Types of phase transitions*

Phase change materials, or in short PCM, can be defined as materials that can store and release large amounts of energy in the form of heat. Although phase shifts can be made between all three phases of the substances (gas, liquid or solid state), the most commercially viable condition is that of liquid state and solid state. This transformation, from solid state to liquid state, is known as the melting- solidification cycle, at a given temperature range of a selected thermal application. The energy resulted from the phase change, or melting- solidification cycle, is absorbed or released as the latent heat of fusion. Latent heat is absorbed into the material without increasing its temperature [2].

When a PCM is in its solid phase, it will absorb heat as the external or ambient temperature increases. The PCM temperature will reflect the outdoor temperature until the PCM melting point is reached.

When the external temperature reaches the melting point of the PCM, it starts to melt, it changes phase, from solid to liquid.

During the phase change process, the PCM will absorb large amounts of heat without almost any change in temperature.When PCM reaches the melting point maintains a constant temperature until all melts. During this time PCM offers a cooling effect.

The time at which PCM will provide a cooling effect is determined by the melting enthalpy of PCM, also called latent fusion melting heat. Enthalpy varies depending on the PCM material itself, enthalpy being measured in J/g or kJ/kg. The higher the value, the more PCM will provide a higher cooling effect. The inverted cycle occurs as the ambient or ambient temperature cools down. PCM, now in its liquid phase, can release the heat it absorbs as the outside temperature decreases. During this time, PCM solidifies and provides a heating effect [3].

When a PCM is in solid state, it absorbs heat, creating a cooling effect, and when the PCM is in liquid state, it can release the heat, thus creating a heating effect, as seen in Fig. 2.

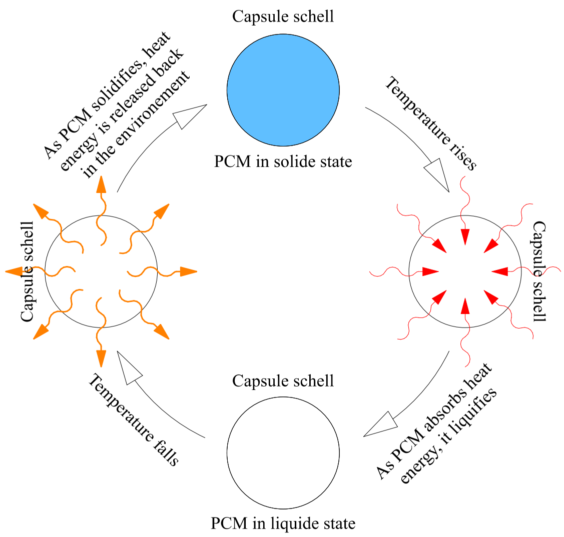

Fig. 2. *Phase change transformation from the solid to liquid form*

This oscillates happen between the two phases and hold the heat around its melting point. The most common PCM is water, which, by cooling, turns into ice and, by heating, turns into water, being a PCM used refrigeration. Ice as a refrigeration solution has been used in the past and is still being used. The ice-water phase change involves microscopic motions witch have a macroscopic effect, depending on the microscopic and macroscopic motions, local interactions and the interior forces [1]. Energy storage through solid-liquid phase change is a transient process, in which the material is absorbing or releasing energy as it melts or solidifies [2].

When using PCMs for TES, the most important material property is the heat storage capability, the enthalpy as a function of temperature. PCM materials have a strong change in enthalpy in a short temperature range. In an idealized case, the enthalpy changes suddenly at a phase change temperature. The heat stored is then called latent heat, whereas heat stored with a temperature change is called sensible heat [4].

We distinguish there main groups of PCMs like organic, inorganic and eutectics, which have appropriate characteristics like melting temperature within the practical range of application [3], shown in Fig. 3.

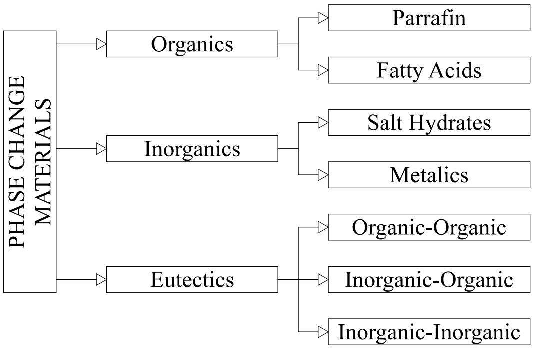

Fig. 3. *Phase change materials classification*

Organic phase change materials are divided in paraffin and non-paraffin, fatty acids, and in general they do not suffer from phase segregation and crystalize without super-cooling [9]. Inorganic phase change materials are divided into salt hydrates and metallics. In this category, the metallics do not ensure the desired melting temperature and weight penalties, so they are not suited to be used in building systems. Hydrated salts consist of an alloy of inorganic salts and water, and their transformation involves hydration or dehydration of the salts, which resemble typical melting and freezing. [12].

Eutectics phase change materials are mixtures of organic and/or inorganic compounds, which can be organic-organic, inorganic-organic and inorganic-inorganic mixtures. A eutectic is a minimum melting composition of two or more components, each of which melts and freezes congruently [6][10].

The thermal properties are considered as a decisive criterion for choosing the most suitable PCM, highlighting the PCM fusion temperature as the most relevant parameter [3]. On the market, the most commonly used PCMs are salt hydrates, fatty acids and esters, and various paraffins. Recently also ionic liquids were investigated as novel phase change materials. Since PCMs transform between solid–liquid in thermal cycling, encapsulation is the obvious storage choice. Encapsulation of PCMs can be done by macro-encapsulation, micro-encapsulation and molecular-encapsulation.

3. Building Integrated Phase Change Materials

The use of phase change materials (PCM) offers the possibility to achieve the reduction of energy dependency, by using the latent heat storage to increase the thermal inertia without significantly increasing the weight of the building and structure.

The use of PCM to ensure the thermal inertia, allows the reduction of heat loses in winter and the heat gains in summer. The use of solar gains, night cooling and off-peak electricity will reduce the temperature fluctuations and peak temperatures, increasing the indoor comfort conditions, saving energy and running costs, for both the heating and cooling seasons [3]. Phase change materials use the principle of latent heat thermal storage to absorb energy in large quantities when there is a surplus and releasing it when there is a deficit. Using PCMs can reduce peak heating and cooling loads, resulting in a reduce in energy usage and consumption. The benefit is the ability to maintain a constant comfortable indoor environment, due to smaller temperature variations [7].

Thermal energy storage with phase change materials (PCMs) offers a high thermal storage density with a moderate temperature variation and has attracted growing attention due to its important role in achievement energy conservation in buildings with thermal comfort [14]. Thermal energy storage with phase change materials (PCMs) offers a high thermal storage density. In the field of buildings and installations there are many applications, namely, cooling and heating, heat recovery, passive cooling, active cooling, applications in air conditioning systems and heat pumps, applications in energy storage system, industrial applications and so on. On the market these are the most important PCM building applications like: gypsum board and interior plaster products, ceramic floor tiles, concrete elements (walls and pavements), Trombe walls, windows, concrete or brick, underfloor heating, ceilings and roofs, thermal insulation materials, furniture and indoor appliances and so on.

Various researchers have studied and developed a vast variety of gypsum boards and plaster products with the main purpose of integrating PCM materials into these lightweight construction materials to increase their thermal mass. These products have the capability to decrease the temperature fluctuations in existing and renovated buildings as well new lightweight buildings. PCM materials have been successfully integrated in wall materials such as gypsum wallboards and concrete to enhance the thermal energy storage capacity of buildings, with particular interest in passive solar applications, peak load shifting [13].Ceramic tiles are an extensively used material for paving, and present the potential for improving the thermal comfort inside buildings due to their ability to reduce indoor space temperature fluctuations, and by associating them with a underfloor electric systems the energy consumption can be transferred for off-peak periods, providing energy savings. The thermal response within concrete walls witch containing PCMs has been reviewed by Ling et al. [8], and show that among the PCM types, the organic PCM and particularly paraffin wax PCMs seem to be the most suitable latent heat storage materials that can be used in concrete. The main reason is the chemical stability and inactivity in the alkaline environment of concrete, with an appropriate transition temperature of about 26 °C (which is the human thermal comfort temperature) and with a low degree of super-cooling, being relatively inexpensive and having a desirable thermal stability. The concept of Trombe wall was patented by E.S. Morse in the nineteenth century and developed and popularized in 1957 by Felix Trombe and Michel. In 1967, in Odeillo, France, they built the first house using a Trombe wall [3,14]. Some examples of heating-based type of Trombe wall are the photovoltaic (PV) Trombe wall, which was invented by incorporating solar cells with classic Trombe wall. The PV- Trombe wall not only provides space heating, but also generates electricity. The wall employs an external reflective thermal insulation blinds to avoid direct solar gain. Due to solar radiation can strike the indoor floor or its adjacent walls directly through a window, the design of windows should be considered including the size and position. Solar radiation level has an important influence in generating air movement in a Trombe wall channel. Generally, Trombe wall efficiency increases with increasing of solar radiation. Moreover, for a building with Trombe walls located in the north hemisphere, the south-facing facade (with 45° variations) seems to be the most effective orientation in capturing the solar gain. The wind speed and direction are related to the heat loss coefficient and wind pressure. The Trombe wall tends to perform better if the wind speed is small, and in this direction, further investigation should be carried out in the future [8]. In window construction the glazed areas and the shading devices have a significant role over the energy building consumption. The improvement of the thermal performance through the glazing area of the building can be accomplished by resourcing to new materials, geometries and new techniques to produce solutions with higher energy efficiency [11].

From the thermal perspective, PCM windows work like the optically transparent or translucent Trombe walls, which usually consist of a single or multilayer glazing panel made of conventional glass, integrated with a layer of a transparent or translucent PCM product [3]. Adding PCMs directly into concrete has shown some promising results through lower thermal conductivity and an increase in thermal mass at specific temperatures. How- ever, PCM concrete has shown some undesirable properties such as lower strength, uncertain long-term stability and lower fire resistance [5].

Studies made on PCM floor are concentrated on two aspects, the first one is the integrating PCMs into floor materials or the biding of a PCM-TES (thermal energy storage system) with floor heating systems. Implementing PCMs into roof systems offer a possibility of being able to absorb the incoming solar energy and the thermal energy from the surroundings to reduce temperature fluctuations on the inside [3].

A point that has not been investigated with the same affluence, but should be mentioned, is the possibility of using PCMs in furniture and other indoor appliances.

4. Conclusions and Analysis

The use of PCM materials is a viable solution and is suitable both for new constructions and for existing constructions, being possible to integrate them both in civil and industrial constructions. Integration of PCMs into buildings, whether we are referring to the building envelope or integrating them into the interior, or in the building's technical equipment, are designed to increase the energy storage capacity inside the building and to rationalize this energy, with the clear goal of achieving the energy efficiency of the building by reducing energy consumption. An important factor in the use of PCMs is the intelligent temperature management concept, which allows the integration of a self- managed automation system with no operating or maintenance costs.The choice of PCM materials should be made according to the requirements of the construction, the mounting method, the selection of their criteria, taking into account the freezing and melting point, but also the chemical composition specific to the PCM material used.

By using PCM materials we are not only talking about energy efficiency and optimization, we also mean creating an indoor microclimate that will ensure and maintain indoor thermal comfort while at the same time reducing the operating costs throughout the life of the system.In a building, the heat transfer process is a complex process that is subject to external influences due to the climatic area, and internal due to the solar radiation flow entering the building and the thermal and cooling loads. A high-energy building must have an energy-efficient shell and a watertight construction that ensures the thermal comfort of occupants with minimal energy consumption.

Inner thermal comfort can be defined as a subjective notion that is permanently and directly connected to the well-being and psychological well-being in accordance with the indoor environment, depending on air quality, indoor temperature, acoustic quality, water quality and lighting quality artificially from the inside and natural lighting.

PCM materials have the potential to reduce energy consumption in buildings, being able to store and release large amounts of energy by changing the phase to a certain temperature. The PCM materials are unique in that they offer a passive thermal adjustment system, in other words, it does not require any electrical or thermal energy to create a decrease or increase in the interior temperature, having the advantage that they can be used again and again, there being no restriction on the number of operating cycles.

The use of PCM materials in both new and rehabilitated constructions will lead to a substantial reduction of thermal energy, thus improving the overall building efficiency, which will lead to energy optimization of buildings and also to reduce pollutant emissions in the external environment.The use and integration of PCM materials into the building component would lead to thermal efficiency, lower consumption and operating costs, and will help, in particular, reduce the carbon dioxide emissions of the building. This integration can be done in all construction categories, both civil and industrial, provided that the physical, chemical and constructive characteristics of PCM materials are timely chosen to meet all the necessary conditions.

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