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Experimental and Simulation Study of Passive Cooling of Building by Incorporating Phase Change Material

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***Abstract*—** In the present work, the thermal management system (TMS) for cool energy storage have been designed and studied experimentally. The room air temperature, ambient temperature and PCM temperature at different locations are measured continuously. The different types of PCMs and main criteria that govern their selection are reviewed. This review is targeted on PCM technologies improved toserve the building industry. Various PCM technologies reviewed for building applications are studied with respect to technological potential to improve indoor environment, increase thermal inertia and reduction of energy use for building operation. What is more, in this review special attention is laid to discussion and identification of proper methods to correctly determine the thermal properties of PCM materials and their composites and as well procedures to determine their energy storage and saving potential. The purpose of the paper is to highlight useful technologies for PCM application in buildings with concentration on room application and to indicate in which applications the potential is less significant.

Key words: Phase Change Material, Thermal Energy Storage System, Latent heat

I. INTRODUCTION

In general, heat storage is a very interesting technique todecrease energy use in the buildings and to reduce the cost of operationof buildings. Therefore, during recent decades a variety ofheat storage solutions for the building market have been developed.Some of the advantages of heat storage in the buildings areas follows: Reduction of peak power for heating and cooling, Possibility to shift peak heating and cooling loads to the low tariff hours,Shifting temperature peaks to non-working hours, Improvement of indoor environment, and Efficient utilization of passive heating and cooling loads.

Thermal energy storage (TES) can be divided into sensible heat storage and latent heat storage systems. The paper starts with a summary of recent reviews on PCM materials and as well the technologies implementing PCM in building application. The outcome of the summary of reviews is to sort out the most important groups of PCM applications related to building solutions and also to indicate which research areas are of most interest.Phase change material can storage or release energy through its morphology change mechanism. Phasechange means the material change from one state to another one, in which process the temperature issteady, however there are a lot of energy exchanged at the same time. Phase change materials can bedivided into inorganic phase change materials, organic phase change materials and composite phasechange materials. Organic phase change materials become the research focus because in its phase changeprocess the parvafacise phenomenon is hard to happen, and it is easy to be overcooled.

II. LITERATURE SURVEY

Over the last decades, several reviews on latent heat storage materials and systems have been published. In the following, some of the most significant ones are shortly summarized.

In[1], Simulations and experimentations of the studied application point out to that the proper use of PCM in buildings may contribute to improve the interior thermal comfort, smoothing the temperature fluctuation and reducing the thermal peaks. To select the appropriate Phase Change Material and its correct switch temperature is necessary to take into account the local climate, the building characteristics, its orientation and occupation profile, as well as the purpose and type of PCM application

In[2], the focus of the review is on cooling systems with PCMsrelated to buildings. A review is carried out focusing on the informationconcerning the following four types of cooling systems: freecooling applications, encapsulated PCM systems, air-condition andsorption cooling systems. It was concluded that PCMs have a positiveimpact on the energy use for cooling the buildings. On theother hand, the authors indicate that the problem with heat transferbetween PCM and the fluid and the amount of the materialneeded for thermal storage constitute the major challenge to makePCM solutions economical and attractive from an energetic pointof view.

In[3], Environment Friendly Cooling of building using phase change material inside the conventional buildingmaterial (brick) was studied. It is quite evident from the preceding reviews that the thermal improvements in a building due to the inclusion of PCMs depend on the melting temperature of thePCM, the type of PCM, the percentage of PCM used inside the conventional material, the climate, designand orientation of construction of the building. When PCM is applied inside the buildingmaterial (brick) the heat

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entering the room reduces considerably. PCM offers the resistance for the heat flow and heat transfer was reduced. This research attempts toselect a suitable material for regions with hot humid Climatic condition.

In[4], the latest developments of PCM and various applications in the buildings are shown.The review also presents a very broad list of latent heat storage candidates that were listed in the other recent reviews and publications. The review pays special attention to the thermal properties and issues related to encapsulation of PCMs.

In 2013, A thorough analysis on previous studies with thefocus on the characteristics of PCMs and theirintegration with LHTES systems has been conductedto extricate the pertinent parameters that contribute tothe performance of these systems and thus thebuilding’s energy efficiency. From the results obtainedin the studies, the microencapsulation of PCM withingypsum wallboards was proved to be the mostefficient LHTES system through its performance inmitigating both the peak cooling and heating loads aswell as reducing off peak seasonal energy consumption.

The consequent review [5], (on PCMs application in buildings)elaborates on researches dealing with passive performance of PCMin the buildings, load shifting and as well active building systemswith PCM. In the paper, there is a summary and a comparison ofthe performance of various simulated technologies utilizing PCMsover the last years.

In[6], carries out a compilationof researches on PCM slurries and PCM emulsions. The reviewpresents information on various PCM emulsions and slurries andheat transfer phenomena, and indicates some of the applications.One of the key conclusions of the review is that, at present, itcannot be determined whether PCM emulsions and PCM slurriescan improve the heat transfer phenomenon and installations withwater based systems used as reference one. One of the reasons whyit is presently difficult to indicate the potential of this type of materialis due to very few installations and experimental examplesconducted so far.

In[7], was published which reviews thermal energy storagesystems using PCM capsules. The paper presents developedlatent heat thermal energy storage systems and aspects related toheat storage, such as, encapsulation, heat transfer, applications andmaterials properties.

Based on the summary of reviews, the conclusion is that thereare an extensive number of publications and reviews dealing withthe subject of latent heat storage. What is more, it can be concludedthat in the most cases the focus is on including and repeatinga bit of information about everything: general information aboutheat transfer, thermal properties and a list of available PCMs. Eachreview focuses on several types of PCM applications in the building,and do not elaborate on other systems and solutions. As a result, theholistic overview of possibilities and the potential of PCMs applications in buildings are ambiguous. In addition, the extensive numberof reviews and publications published over the years and some ofthe information found in the earlier sources is incompatible withthe findings presented in the more recent publications.

III. Study and classification of PCM applications

Numerous workers corroborate that PCM materials and applications can decrease the temperature fluctuation in the interior of buildings, been a potential way to reduce their energy consumption. However, despite theoretical excellent performance, the PCM and its applications are often difficult to use effectively, due the very complex behavior of these materials and the diversity of factors that affect their efficacy. In the following sections, the difficulties related to the materials, the factors that affect the successful use of the PCM and the classification of the PCM buildings applications are presented.

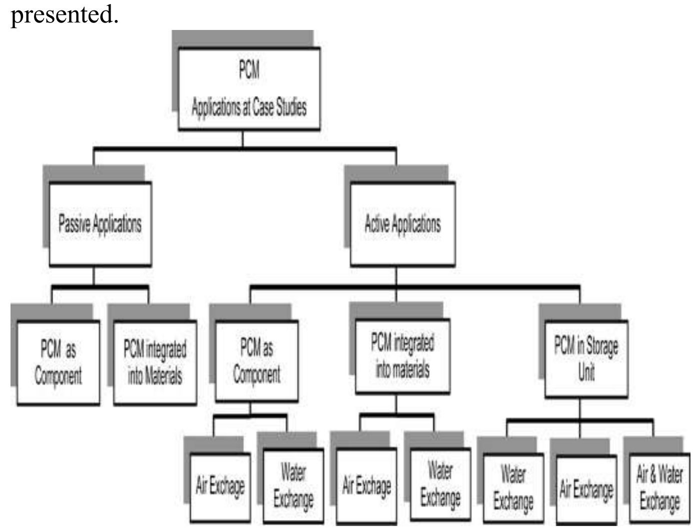

Fig 1

1) Difficulties and factors related with PCM successful use

Phase Change Materials inherent difficulties reside in determining their relevant thermo-physical properties, establishing the scaling effect and the understanding of their complex heat transfer process. The scaling affect the PCM behavior is important due the performances of materials in large containers differ from those in microcapsules.The analysis of heat transfer in the PCM present many difficulties related with the complexity of dealing with a chemical compound in the transition stage with variable properties, a moving solid–liquid boundary depending on the speed at which the latent heat is absorbed or release at the boundary and that may be in three states: solid, liquid and mushy (solid/liquid) during the transition phase. On the other hand, the successful use of PCM buildings applications depends on many factors, such as local climate, building design and orientation, the location of PCM, type and amount of material used, the switch temperature, the encapsulation method, way of PCM is charged/discharged, complementary strategies used, equipments design and selection, system control and operational algorithms and utility rate policy. Due to the complexity of PCM behavior, the diversity of factors that need be analyzed, the fact that PCM main storage capacity is just the range of temperature close to the switch point, determining the PCM application performance is much more complicated than the traditional thermal mass. Experimental research with prototypes or using full scale test cells need to be used to get more precise idea about the effect of the PCM in buildings, and to adjust or corroborate the numerical model and simulation algorithms.

2) Classification of PCM buildings applications

The studied applications have been organized according a PCM classification that have been drawn up by the authors taking into account two main issues, the way that PCM are incorporated in buildings and the factors related with their successful usage. The first level of classification is related to the possibility of the PCM to be incorporated in a passive or active system. Here, passive applications are the ones that do not use mechanical devices or systems. The heat or cold are stored or released automatically when the air temperature rises or falls beyond the PCM melting point. The passive systems can take advantage of the direct and indirect solar gain, as well as the internal thermal gains. On the contrary, as for the active application, the PCM thermal energy charging and discharging is achieved with the help of mechanical equipment . The second level of classification is related to how PCM are used in the buildings, three different possibilities have been identified: PCM as components, PCM integrated into construction materials and PCM in storage units. When the PCM element is one of the layers or parts of a construction section, they have been classified as “component”. On the other hand, when the PCM is mixed with, impregnated or incorporated to a construction material, they are classified as “integrated”. These two categories can be used in both, passive and active applications. However, the third category, PCM in storage units, can only be applied to active systems, and it is generally thermally separated from the building by insulation . For active applications, an additional classification level related to thermal energy exchange medium: water, air or both has been identified.

IV. METHODOLOGY

1) Pcm In Concrete

The general purpose of combining PCM in concrete materials isto further increase heat storage of heavy construction materials. Acombination of the high latent heat capacity of PCM and the highdensity of heavy weight concrete is an interesting concept for thenew technology for storing heat in building constructions and thusenergy savings for heating and cooling of buildings.An experimental investigation on the full-scale performance ofPCM concrete set-ups was carried out. The study investigated the use of PCM in concrete floors. Four chambersof the same size were constructed; two with PCM concretefloor and two with ordinary concrete floor. The only heat sourcein each chamber was the solar irradiation through the windows.

In the study, the PCM in the floor was activated by the direct sunirradiation and was well exposed. However, in practice, it wouldbe very unusual to find concrete floor without any kind of coveringsuch as wood, polyvinyl or tiles that would shelter the PCM fromdirect solar radiation. Therefore, although the research indicatedthat this technology could decrease the temperature fluctuations inthe houses, it would be very difficult to implement it on a broaderscale in practice. The proposed experimental set-up consisted oftwo identical cubicles made of concrete. One cubicle was built ofconventional concrete and one of new concrete with admixed 5%by weight of microencapsulated PCM. The obtained results revealeda decrease in temperature fluctuation in the room with PCM concreteand a shift of the temperature peak in the wall of 2 h. On theother hand, clearly distinguished how muchof the decrease of temperature fluctuation was due to the reducedthermal conductivity and how much was due to the increase ofthe heat storage capacity of the concrete with PCM. Furthermore in[8] and [9], the diurnal indoor temperature fluctuated from verylow to very high temperatures. These large temperature fluctuationswould not be acceptable by any means in real buildings, andtherefore the thermal mass of the cubicles would not be activatedto the extent as in the presented experimental set ups. Oneof the main drawbacks discovered is a severe influence ofhigh outdoor temperature peaks and solar radiation on PCM performanceduring the summer, which prevented its solidificationduring the night. As a result, PCM was not ready to undergo phasechange the next day. The main objective of work presented in was to overcome the problem and to increase the operation timeof PCM and to improve thermal comfort. To decrease high temperaturesin the investigated cubicles the special awnings wereemployed.

To conclude, the realistic potential to increase dynamic heatstorage capacity of concretes by incorporation of PCM is doubtful.Firstly, the thermal mass increase is not as high as expectedand secondly, thermal conductivity decreases significantly due toaddition of PCM to concrete. As a result, the energy from the airhas difficulty in being transported to the inside of PCM concreteconstruction within daily realistic indoor temperature variations.Moreover, maximum amount of PCM in the concrete is not higherthan 5–6% by weight (material is still workable), which means notmuch latent heat capacity can be introduced to sensible heat storagecapacity. Consequently, 5–6% by weight of PCM corresponds toapproximately 12–15% by volume of concrete, which means thatthe share of PCM in concrete is rather high and as a result, the priceof the composite would be high due to rather high price of PCM.

V.CONCLUSION

Heat storage potential of PCM technologies should always beanalyzed taking into account thermal properties and applications of PCMs/PCMcomposites but also heat transfer condition and their switching point on the surface.

Proper thermal properties of PCMs and their composites, suchas, thermal conductivity and specific heat capacity have to bedetermined as a function of temperature to correctly determined for the whole energy storagesystem.

Latent heat thermal energy storage in phase change materials offers high temperature, isothermal energystorage.

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