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A REVIEW ON PHASE CHANGE MATERIALS

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ABSTRACT

In this Paper we studied briefly about phase change materials. There have been numerous studies conducted on phase change materials due to their potential applications in various fields. This term paper explores the fundamentals, properties, and applications of PCMs, focusing on their pivotal role in achieving sustainable energy practices. The paper begins by introducing the concept of phase change and delving into the principles governing the behavior of PCMs during phase transitions. It explores the various types of PCMs, including organic, inorganic, and eutectic compositions, along with their specific characteristics and phase change temperatures. In this paper we studied on various applications of phase change materials in different fields like thermal energy storage, building materials, electronics cooling, medical applications, nanotechnology and PCM composites, transportation.

Key words: Phase change materials, nanotechnology, sustainable energy.

INTRODUTION

Phase change materials (PCMs) are substances that undergo a physical change in their state (phase) from solid to liquid or liquid to gas, and vice versa, at specific temperatures or within a certain temperature range. During this phase transition, the material absorbs or releases a significant amount of latent heat without undergoing a change in its temperature. The key characteristic of PCMs is their ability to store and release thermal energy efficiently during these phase transitions. When a PCM absorbs heat, it changes from a solid to a liquid or a liquid to a gas, and during cooling, it releases the stored heat as it reverts to its original phase. This behavior allows PCMs to act as "thermal batteries," effectively managing and regulating temperature fluctuations in various applications.

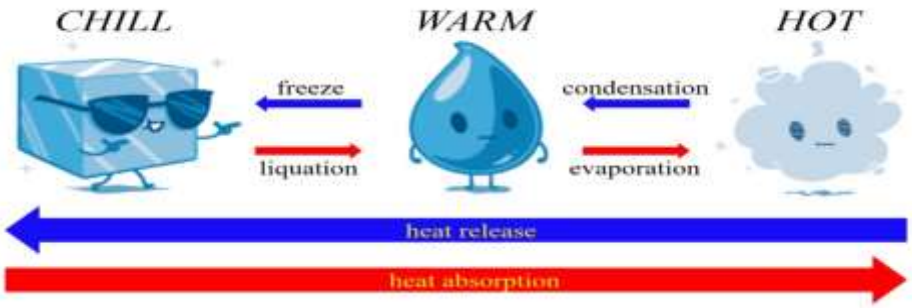

Figure 1: Energy relations of phase change materials in different phase states

PCMs have several advantages, including high energy storage capacity, isothermal behavior during phase change, and the ability to maintain a constant temperature. They find applications in industries like construction, electronics cooling, textiles, and energy storage systems. By utilizing the heat-absorbing and heat-releasing properties of PCMs, they help improve energy efficiency and thermal comfort in various processes and devices.

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CLASSIFICATION OF PHASE CHANGE MATERIALS

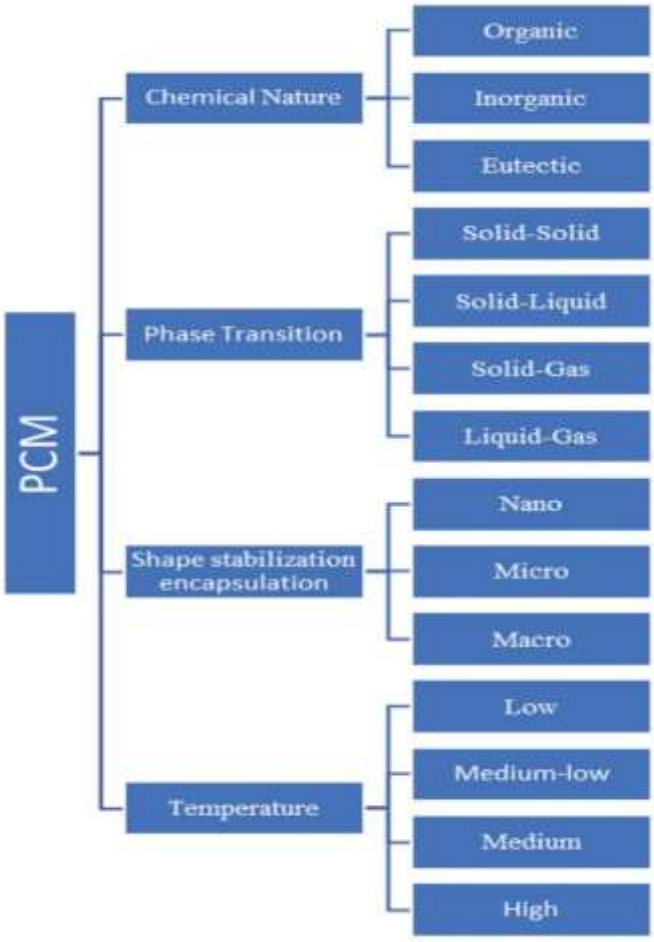

Figure 2: Classification of PCM

BASED ON CHEMICAL NATURE

Phase change materials (PCMs) can be classified based on their chemical nature into three main categories:

- Organic
- Inorganic
- Eutectic

Organic Phase Change Materials:

Organic PCMs are composed of carbon, hydrogen, and other organic elements. They are generally derived from hydrocarbons and natural substances. Examples of organic PCMs include paraffin wax, fatty acids (e.g., stearic acid), and bio-based materials like vegetable oils.

Inorganic Phase Change Materials:

Inorganic PCMs are composed of non-organic elements and compounds. They often involve salts, metals, and other inorganic substances. Examples of inorganic PCMs include salt hydrates (e.g., sodium sulfate decahydrate), metal alloys (e.g., Indium-Tin), and certain eutectic mixtures.

Eutectic phase change materials:

- Eutectic phase change materials (PCMs) are a specific type of PCM that exhibit a unique characteristic known as the eutectic point. At the eutectic point, the PCM mixture has the lowest possible melting point and remains at a constant temperature during the phase change process. This means that both the solid and liquid phases coexist at equilibrium.
- The eutectic point is achieved by combining two or more components with different melting points

in precise proportions. When these components are mixed, they form a eutectic mixture with a sharp melting point, making it ideal for various thermal management applications.

- Examples of eutectic phase change materials include Eutectic Salt Mixtures, Eutectic Metal Alloys, Eutectic Fatty Acid Mixtures, Eutectic Organic Salt Mixtures.

LITERATURE REVIEW

We studied some of the papers about phase change materials. They are explained below

Pradnya Deshpandea et.al.,[1]. In this journal he told the Phase change materials containing nanoparticles that are used to store passive latent heat are proven to be of the biggest importance to modern technology due to their extensive use in everything from home appliances to space technology. Since solar energy is the most significant renewable energy source for energy conservation in the twenty-second century, all academics are paying attention to it. Every application needs to focus on renewable energy storage as fossil fuel storage runs out and has a detrimental effect on the environment. The focus of the present paper is on diverse applications of phase transition materials and recent developments. Later, scientists are examining the phase-change materials' properties.

Jintao Huang et.al.,[2]. In this journal he told that the energy storage and renewable energy usage technologies must be created in order to improve energy efficiency. The family of energy storage materials known as phase change materials (PCMs) is one of the finest at storing and effectively exploiting renewable thermal energy. Latent heat storage (LHS) based on PCM is preferred to sensible energy storage because it has a higher storage energy density per unit volume/mass and a lower temperature differential between storing and releasing heat. But the limited thermal conductivity and high supercooling of PCMs make them less efficient as energy storage systems. This review article initially discusses the classification of phase change energy materials and the concept of phase change energy storage.

M. Mozafari et.al.,[3]. In this journal he told that heat sinks with embedded phase change materials (PCMs) are used to passively control the temperature of electronic apparatus. RT58, RT44, and n-Eicosane are used as PCMs. Aluminium fins are utilized as a thermal conductivity enhancer (TCE). While single PCM cases are analyzed independently, multiple PCM pairings are studied through their filling in various enclosures separately. Three constant heat fluxes of 1.5, 2.5, and 3.5 kW/m2 are applied to the heat sinks in order to test the thermal performance of PCMs. The transient temperature differential is brought within an acceptable range of 2.9%, and the numerical model is subsequently verified using the already available experimental data. There were found to be melting and solidification stages with high Nusselt numbers.

Jiaojiao Jia et.al.,[4]. In this journal he told that prefabricated structures are now often used in residential buildings and on construction sites. Due to the high heat transmission performance of the building envelopment, prefabricated buildings have a poor internal thermal environment. By adding phase change material (PCM) to the prefabricated building envelopment, a building's interior thermal climate can be improved effectively. This study used Energy Plus software to analyze the thermal performance and energy consumption of prefabricated houses with PCM in five different climate zones. The findings showed that installing PCM within a building's wall or roof saves more energy than doing so outside, and that installing it on a structure's east or west side wall also enhances indoor air quality.

Cyril Reuben Raj et.al.,[5]. In this journal he told that the development of efficient and dependable Thermal Management (TM) systems is crucial for sustaining stability amid rising heat dissipation because modern technology relies on integrated and efficient circuitry. The research work examines the heat transfer capabilities of a novel wall-less heat sink made of highly stable Hexamethylene Diisocyanate cross-linked Polyethylene Glycol-6000 based Form-Stable Phase Change Material (FS-PCM), to ascertain whether it is appropriate for passive TM systems with chemical and thermal stability up to 1000 thermal cycles.

Min Hee Chung et.al.,[6]. In this journal he that he assessed the efficiency of thermal plates based on phase-change materials (PCMs) and manufactured of wood-plastic composites (WPCs) for lowering the urban heat island effect. The performance of thermally efficient plates comprising PCMs with two distinct albedo levels and two different melting points was evaluated. The results showed that the PCM with a melting temperature of 44 °C maintained lower surface and interior temperatures than the PCM with a melting temperature of 25 °C. A higher surface albedo also resulted in a lower surface temperature. However, despite having different melting points and the same surface albedo, PCMs performed thermally indistinguishably. By bringing down surface temperatures, PCM-based compounds can improve thermal comfort in roof finishing materials.
M. Purusothaman et.al.,[7]. In this journal he told Clearly high levels of radiation from glass windows and heat flow from the roof combine to produce the overall heat gained in a car cabin. Direct sunshine may cause closed, stopped automobiles to quickly increase in cabin temperature, endangering any children or pets left inside and perhaps resulting in property damage. After a few minutes or hours of parking in an open or exposed location, many car owners today complain that their interiors get too warm. The heat that accumulated within the car and the undesired temperature rise would cause the interior car components to deteriorate. The passengers are also affected by the inside temperature of the vehicle.
Anna Dmitruk et.al.,[8]. In this journal he told Phase change materials (PCMs) are employed in heat storage systems due to their ability to store energy in the form of latent heat of fusion. They can be used to recover surplus heat from many industrial operations. Their main drawback, which significantly limits their use, is a low thermal conductivity coefficient. This study outlined the benefits of employing metallic inserts in PCM-based heat storage devices. Investment casting methods were used to produce two distinct forms of Al-Si spatial elements: foams and honeycomb structures.
Dharmesh Pate et.al.,[9]. In this journal he told in the summer, especially on sunny days, drivers instantly feel the pain of a very high temperature after getting into a car. This is particularly valid if the car is facing the sun when it is parked in the parking lot. When using the phase change material, a large amount of cooling energy must be used to lower the temperature to a bearable level in order to preserve comfort. A stopped car facing the sun has this state-of-the-art thermostat installed to control the interior temperature. During the melting and solidification of phase-change materials, pouches along the upper inner surface of the vehicle absorb and release the energy of the heating.
Sampath Kumar et.al.,[10]. In this journal he told that the work presents a comprehensive review of phase-change materials (PCMs) and battery thermal management systems (BTMSs). PCMs are currently recognized as one of the most exciting cooling methods due to their great energy storage density. They are also more compact, simpler, and less expensive than more traditional cooling methods like forced-air cooling or liquid cooling. However, a study that will enable the researcher to recommend enhanced BTMSs is required because PCMs are used in battery applications. Due to the dearth of research in this area, the paper actually aimed to review all studies on battery applications utilizing PCMs.
Ayse Merih Sarusik et.al.,[11]. In this journal he told that the effects of the application method for microcapsules will be examined in this work, along with the characteristics of heat regulation in heat storage microencapsulated fabrics. For this objective, cotton fabrics were impregnated with PCM microcapsules using coating and impregnation methods. The presence and distribution of microcapsules on the fabric surface were studied using scanning electron microscopy (SEM). The ability of the textiles to control temperature was examined using a temperature measurement sensor and data recorder device (thermal camera). The differential scanning calorimetry (DSC) study revealed that the cotton fabric could store 2.70 J g-1 of heat energy during the melting process. Between 25.83°C and 31.04°C, fabrics coated with microcapsules began to melt.
M.S. Aludin et.al.,[12]. In this journal he told that due to its excellent thermal energy storage and thermal stability, paraffin is a Phase Change Material (PCM) that is suitable for thermal energy storage applications. Paraffin, though, has been known to flow out during melting. In this study, PCL and

paraffin were dissolved in chloroform at varied mass percent compositions, and the combination was subsequently purified using precipitation techniques. To conduct the leakage test, the composite samples were placed on a set of four-layer filter sheets and heated to 90°C for one hour. The addition of PCL to the paraffin phase dramatically reduced the bulk percentage of leakage. The PCL polymer matrix in the composites may have trapped the paraffin molecules during the melting process, keeping them from leaking.

Jifen Wanga. B et.al.,[13]. In this journal he told that heat storage nanocomposites made of paraffin wax (PW) and multi-walled carbon nanotubes (MWNTs) have been created, and their thermal properties have been investigated. Results from differential scanning calorimetry (DSC) showed that the melting point of a nanocomposite reduced in contrast to the base material as the mass fraction of MWNTs, w, was raised. When MWNTs were added, the latent heat capacity fell. The enhancement ratios in the thermal conductivities of nanocomposites increase both in the liquid and solid states when w increases when compared to pure PW. For the composite with a mass percentage of 2.0%, the thermal conductivity enhancement ratios are 35.0% for the solid state and 40.0% for the liquid state, respectively.

Prufungsanstalt et.al.,[14]. In this journal he told Building roof structures made of membrane materials have a relatively low thermal insulation capacity when compared to typical building materials. Phase change chemicals are employed to improve the insulating capabilities of the membrane materials. Phase change materials absorb energy while being heated if the phase transition happens. Otherwise, this energy can be released into the environment in the phase change range during a reverse cooling process. The insulation effect of the Phase Change Material is temperature and time dependent and produces a novel sort of insulation that is substantially different from the insulation properties of any other material.

Siddique A. Khateeba et.al.,[15]. In this journal he told that the Li-ion battery that was tested in the lab for this study was designed to be utilized in electric scooters. This experimental effort looked at four different ways to dissipate heat: (1) using natural convection cooling, (2) using an aluminum foam heat transfer matrix, (3) using phase change material (PCM), and (4) combining aluminum foam with PCM. The PCM is used to reduce the temperature rise of the Li-ion cells and to distribute heat uniformly across the battery module. This is abundantly supported based on the experimental findings presented in this research.

Nadezhda S et.al.,[16]. In this journal he told that the behavior of phase change materials in an electronic cabinet housing an energy-generating component is numerically studied in the current work. With the aim of enhancing heat removal, a complex finned heat sink with an overall width of 10 cm and fins with a difficult shape and a width of 0.33 cm and a height of 5 cm was developed. Because fatty acids have a melting point of 46 C, they have been considered to be phase transition materials. The two-dimensional issue under examination was developed using non-primitive variables.

Mohammad Ghalambaz et.al.,[17]. In this journal he told free convection heat transfer of a solution of nano-encapsulated phase change materials (NEPCMs) in an inclined porous cavity was simulated and discussed. The core of the nano-shell layers that surround the phase change materials store and release a large amount of energy during melting and solidification along the hot and cold walls. The governing equations are provided and transformed into a non-dimensional form prior to being solved using the finite element method. Simulated results are extensively verified. The effects of the fusion temperature and the Stefan number on the distributions of streamlines, isotherms, and the heat capacity ratio, as well as the characteristics of heat transport, are then investigated at different angles of the cavity's inclination.

Ammar A et.al.,[18]. In this journal he told Latent heat thermal energy storage is advantageous for the thermal control of heat transfer systems, fluctuating thermal loads, and the growth of renewable systems. In a compact space, a latent heat thermal energy storage (LHTES) device has the ability to store and release a lot of heat. However, the main issue with LHTES technology is how badly they transport heat. Most LHTES are unable to rapidly absorb or release the required energy because of

their poor thermal reaction times. Therefore, using metal foams, extended wavy surfaces, and nano additives to enhance the heat transfer properties of LHTES is a potential approach. The current investigation's goal is to analyze how wavy tubes affect a composite phase-change material.
Xiaohu yang et.al.,[19]. In this journal he told the current numerical methods to calculate the transient free onetion along the elted path and the eat transfer in the cavities with various aspect ratios are presented. The visualization test is set up to allow for the measurement of internal temperature distribution and the solid-state interface. Iulation results are analyzed in terms of the strealine and blood pressure response to temperature, as well as the blood sugar level and blood flow efficiency.
Yongcun Zhou et.al.,[20]. In this journal he told Due to its exceptional qualities, including high latent heat storage capacity, suitable solid-liquid phase change temperature, thermal dependability, and low cost, PCMs have attracted increased attention. The classification, traits, and evaluation standards of organic/composite PCMs are systematically illustrated in this article, along with an introduction to some common preparation techniques, including in-situ polymerization, interfacial polymerization, spray drying, porous material adsorption, sol-gel, melt-impregnated and mixing, electrospinning, vacuum infiltration, and ultrasonic method.
Xiao Chen et.al.,[21]. In this journal he told Pure PCMs' limited potential to be used and developed because to their poor electrical, thermal, and photo absorption properties. Versatile carbon materials have been given more consideration as supporting materials to build shape-stabilized composite PCMs in order to address these shortcomings and increase the utilization efficiency of thermal energy. Despite several analyses of carbon-based composite PCMs that focus on improving thermal conductivity, a thorough analysis of carbon-based composite PCMs is lacking.
Mohammad Ghalambaz et.al.,[22]. In this journal he told Phase change materials (PCMs)-metal foam enclosed between two annuli is studied for conjugate flow and heat transfer. At the inner surface of annuli, a pulse heat load is used, while convection cooling is applied to the outer surface. The phase change is modeled using the enthalpy-porosity technique, and the Darcy-Brinkman model is used to account for natural convection in the porous medium. The finite element method is used to convert the governing equations into a non-dimensional form and solve them. The governing equations in the non-dimensional form are solved using the finite element method. The phase change interface is captured by an automatic grid adaption method.
Mohammad Ghalambaz et.al.,[23]. In this journal he told A suspension of Nano Encapsulated Phase Change Materials (NEPCMs) in an enclosure is explored for its free convective flow and heat transfer. Phase Change Material (PCM) serves as the core of NEPCM particles, which are shell-core structured. The enclosure is a square chamber with differentially heated isothermal vertical walls and insulated top and bottom walls. Inside the cavity, the NEPCM particles move through natural convection. The PCM cores go through a phase change from solid to liquid, absorbing part of the ambient heat as latent heat in the hot zone and releasing it as solidification in the cold region. Partially differential equations are used to introduce the governing equations for the conservation of mass, flow, and heat in the NEPCM suspension.
AFIF HASAN et.al.,[24]. In this journal he told preliminary research into the potential of palmitic acid as a phase change material (PCM) for energy storage has been conducted. Transition periods and temperature ranges, the spread of the solid-liquid boundary, and the features of the heat flow rate of the used circular tube storage system were all included in the parametric research of phase transition. The findings of the experiment demonstrated that the melting front moves both radially and axially. The melting process is significantly influenced by the convective heat transfer that occurs in the liquid phase. Additionally, the simple conduction model is inadequate for describing the melting process.
Umberto Berard et.al.,[25]. In this journal he told that the literature demonstrates many approaches to including PCMs in the building envelope. The usage of PCMs as an additive or replacement material in common concrete mixtures for building applications is the main topic of this review. The best PCMs for incorporating into concrete mixtures, according to the literature, are organic paraffin and non-

paraffins because they have melting points that are suitable for human comfort, a high heat capacity, little volume change during phase transitions.
Agnieszka Jachura et.al.,[26]. In this journal he told this study examines the prototype tube-vacuum solar collector's whole life cycle to determine its environmental impact. The use of a phase change material as a heat-storing substance that was inserted within the collector's tubes-vacuum was the creative aspect of the approach. Paraffin was the PCM used in this investigation. Three stages were included inside the system boundaries: production, operation (use phase), and disposal. Using Sima Pro, an ecological life cycle assessment was performed.
Adil A.M. Omara et.al.,[27]. In this journal he told there are several ways to include PCMs into air conditioning systems, which are outlined. Additionally, the impacts of PCM geometry, flow, and heat transfer properties on the efficiency of air conditioning systems are explored, as well as the prospective application of PCMs to boost these systems' energy efficiency and performance coefficient. We cover current research on the thermodynamic (energy and exergy), financial, and environmental advantages of PCM integration in air conditioning systems.
Mohammad Davoud Heidar et.al.,[28]. In this journal he told that the life cycle assessment (LCA) method is an effective tool for environmental management. A complete LCA, especially in the early stages of a product's design, takes too much time and data to be carried out by industrial enterprises during their production and consumption processes. Therefore, there is a growing need for less complicated methodologies that don't require a lot of data or time to show a company's potential for resource efficiency. The purpose of this study is to test the robustness of streamlined LCA (SLCA) tools and procedures in the case study of a wood-based PCM panel in order to determine whether they are appropriate for usage in the building material sector.
Kunjie Yuan et.al.,[29]. In this journal he told These materials have a tremendous amount of potential for the creation of cutting-edge renewable energy infrastructure because they can reversibly store a significant amount of thermal energy during the isothermal phase transition. In order to control the thermal charging and discharging rate of PCMs and increase heat-utilization efficiency, thermal conductivity is essential.
S. A. M. Mehryan et.al.,[30]. In this journal he told that the quality of a product depends on a metal or polymer melting evenly. Convection fluxes influence heat transmission during melting, which leads to an uneven melting process. Lorentz and Kelvin forces can be used to control flow and heat transfer in the presence of a magnetic field. The goal of the current study is to examine how the presence of two magnetic sources affects the flow of melting and heat transfer in a hollow.
Madeeha Khan et.al.,[31]. In this journal he told Pakistan's residential sector is one of the country's biggest energy consumers. Pakistan is on the verge of an energy crisis due to its fossil fuel-dependent electricity producing system and a growing energy supply-demand gap. As a result, Pakistan needs to take serious measures to improve the energy efficiency of residential buildings. The objective of the current study is to numerically evaluate how adding Phase Change Materials (PCM) to the building envelopes of five major Pakistani cities with various climates might improve the energy performance of residential structures.
Afshin Marani et.al.,[32]. In this journal he told Many academics are interested in the use of phase change materials (PCMs) in the fabrication of concrete building components. The thermal performance of PCM-integrated wall specimens is investigated parametrically in this paper using a novel reduced-scale experiment that takes into account two types of concrete, two types of PCM, and various concrete and PCM layer thicknesses. To assess each PCM's performance under various temperature settings, three different ambient temperature profiles of a summer day in three separate cities were taken into account as the outside ambient temperature.
Amal Louanate et.al.,[33]. In this journal he told Six climate-representative regions of Morocco were chosen for a thorough investigation of the PCM enhanced-walls model: El Jadida, Fez, Marrakesh, Ifrane, and Errachidia. To examine the thermal behavior and energy performance of a residential building integrated with four different PCMs in further detail, numerical simulations were performed.

The findings demonstrated that the local weather conditions, HVAC system characteristics, PCM layer thickness, and location had a significant impact on the effectiveness and selection of PCMs. Additionally, the optimal PCM resulting in the lowest annual energy usage was selected with respect to each climate zone.
Almas Sheriyev et.al.,[34]. In this journal he told This study intends to examine the thermal efficiency of PCM and PCM in combination with nocturnal mechanical (MV) and natural (NV) ventilation in a residential building situated in eight cities in climate zone (Af) of tropical rainforest. Numerical simulations were used to complete the research, and a special methodology for choosing the PCM melting temperature based on the thermal comfort limitations was developed.
Alireza Riahi et.al.,[35]. In this journal he told on the hottest days of five cities with various climates—Tehran, Ramsar Hamedan, Bushehr, and Ahvaz—the experimental integration of a vapor compression cycle and a phase change material (PCM) storage tank was assessed. Two distinct test chambers and a controller system are used to establish the temperature conditions for interior (evaporator) and outdoor (condenser, compressor, etc.) air conditioning devices. Two scenarios have been used to examine the desired system. The system is evaluated for both the standard air conditioning (AC) system (without a PCM) and the AC + PCM unit in each scenario.
Sahand Rahemipoor et.al.,[36]. In this journal he told that the introduction of 3D printing, traditional construction has been completely transformed, allowing for the quick and affordable production of intricate structures. However, there are still issues that need to be resolved in order to effectively include useful additives into 3D printed construction materials. Here, we outline a simple and green strategy for encouraging environmentally friendly structures while lowering energy usage.
Qudama Al-Yasir et.al.,[37]. In this journal he told in order to give structures the necessary energy and thermal comfort performance, the building envelope is a crucial component. Recent studies that concentrate on novel strategies and methodologies have incorporated improvement solutions in this area. With a special emphasis on phase change materials (PCMs), the primary approaches used in this field are explored to find contemporary and efficient methods.
Qudama Al-Yasir et.al.,[38]. In this journal he told that the experimental research is done on the thermal behavior of a PCM-enhanced thermally inefficient building envelope. In order to achieve this, two identical rooms—one filled with PCM (the PCM room) and the other without (the reference room)—are constructed and tested in Al Amarah, an extremely hot city in Iraq. To construct the PCM room, previously studied factors are taken into account, such as the ideal location and thickness of the PCM layer in the roof and the best-performing PCM capsules embedded concrete bricks.
C. Guardia et.al.,[39]. In this journal he told Under the current thermal standards, the poor thermal performance of many housing units constructed between 1940 and 1980 results in a low energy efficiency. These facades need to be updated in order to meet requirements for comfort and energy efficiency. Although this approach does not take into account thermal inertia, External Thermal Insulation Composite System (ETICS) are frequently utilized to boost thermal insulation.
M. Frigione et.al.,[40]. In this journal he told a Phase Change Material (PCM) for mortars by incorporating through the ‘‘form-stable method” a thermoplastic low-melting polymer (PEG 1000) into a porous inert substrate (i.e., Lecce Stone), obtained as residue from processing stone, is reported. The viscosity of pure PEG at different temperatures was first assessed to identify an appropriate processing temperature to introduce fluid PEG into the pores of the stone. A complete (chemical, thermal and morphological) characterization was performed on the developed PCM composites, varying the impregnation times.

CONCLUSION

This term paper highlights the significant role of Phase Change Materials in advancing sustainable energy technologies. We considered all the phase change materials on their performance and we have to conclude that the organic Phase change materials are best phase change materials for cooling applications where paraffin wax derived from organic materials (hydro carbons) have a high latent

heat of fusion, making them efficient in absorbing and releasing large amounts of energy during phase transitions. By studying these all the journals we have to know that the efficiency of a PCM depends on the specific application and the operating conditions. Each PCM has its advantages and limitations, and the choice of PCM should be based on the particular requirements of the intended use. Research and development in this field continue to explore new materials and formulations with even higher efficiency and performance.

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