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A review paper on an empirical method of solar roof tiles for thermal energy analysis applied in residential structures with phase change materials

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Abstract. The integration of solarcellsinto construction materials, such roof tiles, isgaining traction. Nevertheless, solarcells' conversion efficiencyistemperature-dependent, and a high temperaturewouldlowerit. This study examines the functionality of mortar roof tilesthat have builtinsolarcells and safety glass.
To control the temperature of the solar cells, phase modifying materials (P CM) are added to the first roof tiles at a concentration of 3% by weight.For solar roof tiles, the impact ofPhase change materials on the generation of solar-to-electrical power isassessed, and life cycle costanalysisiscarried out to determine the viabilityfrom an economicstandpoint.During six summerdays, the electricalenergy production of the solartileswith PCM appliedwas 4.1% higherthanthat of the tileswithout the component modification material. In contrast, during six winterdays, the improvementisbetween 2.2 and 4.3%. With the cost of the inverterincluded, the solar roof tileswith Phase change materials have an economicalpaybackperiod of 5.7 years. The application of Phase change materialsraises the initial cost of roof tiles by 1.2% ;nevertheless, the paybackperiodispredicted to bethreemonths shorter thanthat of the equivalentwithout PCM, given an overallimprovement in energy production of 4.1%.Whilemany countries are takingsteps to reducetheiremissions, the IEA'slatest report on global and carbonemissionsshowed an increase of 1.7 percent in emissionsyear-on-year2018 to 33.1 billion tons (IEA, 2019). Australia's 2018 increase in carbondioxideequivalentemissions of 0.7% raisesseriousconcerns about the countrysability to meetitsemissionreductioncommitmentunder the Paris Agreement (Cox, 2019).

Key words : Phase change materials, Thermal energy, Solar tiles, Roof tiles

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1 Introduction

According to the IEA report (IEA, 2019), Coal-fired power generation contributed 30% of total energy-related CO2 emissions, making it the top emitter in the power industry.However, under typical testing settings, PV cells can only convert roughly 15–24% of incident solar energy into electricity using current technology (Ma et al., 2015). Hasan et al. (2010) state that these cells also absorb the infrared portion of the sun's irradiation, which raises the panel's temperature and decreases PV conversion efficiency. According to Ma et al. (2015), for every degree Celsius that the temperature raises, the conversion efficiency could drop by 0.4–0.65%. There have been reports of similar results elsewhere (Krauter et al., 1999). Concurrently, the inside climate is impacted by the building surface's increasing temperature.

There are many roofing materials on the market. Each one has its own function and design requirements for home users. However, shingles that have the potential to generate solar energy is one of the best products available on the market for home hours. They have the potential to greatly lower energy needs. Shingles that generate solar energy are part of the category of solar energy solution commonly referred to as the building-integrated voltaic (BIPs), (Chiara Ferrari et, al. 2014). While different combinations of shingles can be used, they are limited in quantity due to commercial limitations that prevent the scaling of technology. A solar roof tile can generate up to 100 watts of power at its highest capability. The maximum power generation capacity of a single solar roof tile is about 100 watts. In hot climates, the potential of PV roof tiles increases as they can help generate more power and meet the needs of domestic customers Guillaume et, al. 2015. However, the installation must be done at a 45-degree angle to the sun’s rays to get maximum power generation. In order to minimize environmental harm and guarantee that the solar roof tiles are securely fastened together, a supporting structure must also be constructed beneath the roof tiles. Important information about the commercial viability of photovoltaic solar tiles has been revealed by earlier studies; however, for sustainable use, full information is currently unavailable. Solar tiles can clearly function well in cold climates, according to a research work by Zalamea León & Cuevas Barraza (2019); however, one of the study's limitations was that the results did not meet expectations and could not be applied to hot climates Esteban. It is clear from a different study by Carvalho et al. (2019) that environmental factors have an impact on solar roof tiles' ability to generate energy, which can ultimately have a direct impact on customer satisfaction. The demand for energy is rising quickly in tandem with the world's economies and population growth. For this reason, new technologies for energy production and storage have garnered a lot of interest lately. A new, environmentally friendly method of reducing energy consumption that able can be applied to minimize the difference between the supply and demand for energy is thermal energy storage, or TES. Latent heat storage is a preferred technique for thermoelectric storage among many other approaches (Yuan, Fan, et al 2018). It makes use of appropriate materials with a high density of energy storage and minimal temperature shift that occurs when heat is being stored and released. It has been extensively researched whether adding PCMs to building materials can rise building energy effectiveness by lowering loads related to heating and cooling. There are several thorough reviews available that discuss the various PCMs that can be added to building materials and the corresponding thermal performances, (Zhou et,al 2012). All these investigations have indicated that more investigations are required to determine the best process for incorporating PCM into building materials and then assess the materials' performance. However, research has shown that adding an appropriate quantity of PCM to building materials increases a structural element's thermal mass (Navarro, Lidia, et al 2016).

1.1 Heat Transfer in Envelopes Enhanced with PCM

High degrees of thermal insulation, cutting-edge ventilation, radiation barriers, and latent Heat Storage components are common features of contemporary, dynamically working roofs and attiques that improve thermal performance in a range of environmental circumstances. Today's roof designer consider a number of important design aspects such as the PCM-enhanced goods' thickness, density, and heat-storageability., as well as the optical properties of the material used for the roof's surface and the potential location of radiant barriers.

The amount of PCM employed, its physical characteristics, the local environment, and the structure's design all affect how much the thermal behavior benefits attributed to PCM-enhanced building envelopes increase. Therefore, in order to assess the potential energy advantages of PCMs, a thorough numerical evaluation of the impacts on energy and temperature in buildings are essential. Presently, their are number of numerical models available to capture the specifics of the heat transfer mechanism, which were created for PCM-enhanced envelopes thermal simulations at the system scale. None the less ;simpler techniques are also some times chosen since the ymay produce PCM performance estimations quickly.

2 PCM

A Phase change materialis a material that is utilized to achieve latent heat storage. At phase transition, this material has the ability to release and store enough energy to beused for both heating and cooling. In P Phase change materials, the change from solid to liquid, and vice versa, occursoften. It can be separated into four categories :Nowadays, nanoparticle mixed Inorganic phase-change materials that undergo phase shift, organic materials that change phases, and a combination of inorganic and organic molécules known as eutectic Phase change materials are also utilized as the key components shown in figure no.1 (Kutaet.al; 2016).

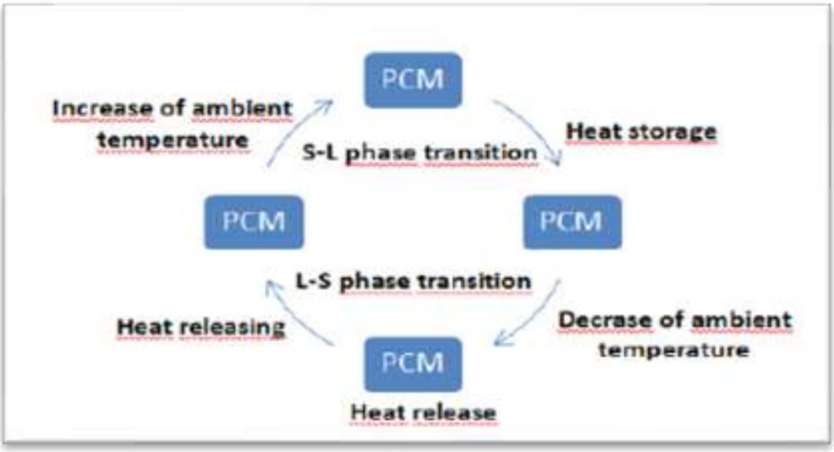

Fig. 1. Phase change transition

2.1 Classification of PCM

Phase-change materials can be categorized in a variety of ways. The most common method of grading transitions is from solid to liquid, solid to solid, gas-to-liquid, and solid to gas. Chemical composition is a significant factor in another significant classification type (B. Zalba et.ai; 2003). It is significant because the kind of composition has an important impact regarding the characteristics of phase change materials. Following is a classification based on the type of chemical composition: eutectics, inorganic, and organic.

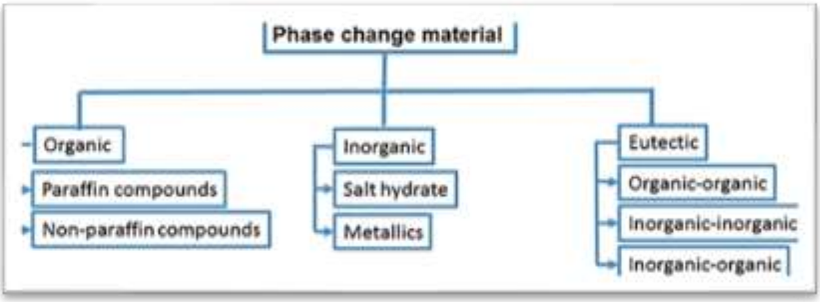

Fig. 2. Showing Classification of Phase change material

2.2.1Organic Phase change materials:

Among the most widely used PCM types nowadays are organic PCMs, which are separated into two groups: non-paraffin and paraffin. Paraffinisamong the PCMsthat are most frequently utilized in TES system operations. At the necessary temperature ranges, paraffins can be utilized singly or in combination. Among the organic compounds are alcohols, fattyacids, glycols, and esters component sused to make non-paraffin compounds. Fattyacids have drawn the greatest attention among organic and nonparaffin PCM types due to their many advantageous qualities, which include their constant form, cost-effectiveness, and lack of requirement for further encapsulation. Bio-based PCMs are also present in non-paraffinorganic PCMs.

2.2.2 Inorganic Phase change materials:

Compared to organic PCMs, inorganic PCMs are substantially less expensive and non-flammable. Inorganic PCMs contain metals, salts, metalalloys, and salt hydrates. When calculating salt hydrates, the conventional formula is ABnH2O, where n is the number of water molecules in the salt mixture. Sincesalt and salt hydrates are plentiful in saltlakes and the ocean, theircostisonly one percent of that of paraffin.Compared to organics, inorganic phase transition materials are far more conducive to commercialization due to theirreasonablecost and non-flammableproperties. Salt hydrates have significantlygreater promise thanorganic phase transition materials for batterytemperature control systems. On the other hand, the application of inorganic phase transition materials in batteryheat management systems has not receivedmuch attention.

2.2.3 Eusthetic phase change materials:

Only two types of eutectics are currently in widespread usage, despite the factthat there are three varieties: organic-inorganic phase change materials and organic-organic phase change materials .Different real-world needs can be satisfied by using different compounding strategies.

In order to createorganic complex phase change materials with the preferred melting point and latent heat storage that meet everyday practical needs, it is common practice to blend two or more organic phase change materials (PCMs) by melting and mixing them at different phase change temperatures. The synthesis of eutectic poly fatty acids from concentrated fatty acids, the creation of binarye utectic compounds from fatty acids and fatty alcohols, and the coupling of fatty acids with paraffins for binary PCM are a few examples of eutectic PCM generation reported in the literature.

3 Phase change materials: their uses in building cooling applications

Applications for PCMs can be found in both new construction and retro fitting existing structures Jelle, B. P et al. (2017). The targeted usefulness, melting range, and inclusion approa chdefine the PCM system's operating mode. Hybrid systems, which use PCM for both the heating and cooling, are possible uses for this technology. There are passive and active categories for each mode. Between active and passive systems, there are differences in the driving force used to charge and discharge the store, according to J. Heier et al.(2015While passive storagejust relies on the temperature difference between the store and its surroundings, active storage makes use of pumps or fans.

4 Result and Discussion

Based on PCM research, the thermal parameters it may be summed up as follows: Organic PCMs have a melting point that varies from 21°C to 57°C, whereas that of inorganic PCMs ranges from 22°C to 33°C. The K value varies from 0.143 to 0.54 for eutectic PCMs, 0.54 to 1.09 for inorganic PCMs, and 0.2 to 0.34 for organic PCMs. All PCMs have a heat of fusion of 160–260 kJ/kg.

5 Conclusion

The reviewed articles were shown, together with a study of their thermal performance. An overview of the PCM sutilized in each area of the program, along with the corresponding, 1. Thermophysical characteristics and methods of encapsulation are demonstrated. It was shown that: 2.Phase change materials workf unction as heat-resistant materials, ensuring the thermal ease of use of residents. 3. PCMs have been shown to be effective in reducing energy consumption in cooling applications, including ceilings in the passive category and HVAC in the active one. 4. Many commercially available PCMs are made from organic substances like paraffin; however, bio-based, inorganic, and eutectic mixes cause less danger. 5. Wheninvestigating new cooling system applications with many assumptions, the accuracy of the results decreases.6. Optimization studies and economic analysis require special attention, as some literature fails to mention them.

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