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The Use of Paraffin Wax as Phase Change Material in Building Construction

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ABSTRACT

The building sector, a major global industry, contributes to 55% of worldwide energy consumption through building operation electricity use. Phase Change Material (PCM), specifically Paraffin Wax with a melting point of 20°C to 40°C, was chosen for this study assessing its thermal properties via Differential Scanning Calorimeter (DSC). The study anticipates installing 3.3 billion room air conditioners by 2050. Peshawar's climate requires indoor air conditioning for five winter months and summer months, imposing heating and cooling loads, respectively. The study examined PCM's impact on these loads by placing it within the brick boundary wall, focusing on a 14x18x11 feet living room in Peshawar. The overall heat transfer coefficient was determined for varying PCM thicknesses. Heat loss or gain in the air-conditioned room was assessed with and without PCM in the boundary wall, emphasizing one-dimensional transfer through walls, excluding floor and roof. The analysis showed that the difference in heat flow decreased with each unit thickness of PCM, with no significant change observed after changing the thickness from 4 inches to 5 inches. The impact of increasing PCM thickness becomes less significant after a certain thickness, which is called the critical thickness. Using Paraffin wax as a 4 inch PCM could save 2,017 kWh annually and reduce carbon emissions by 778 kg CO_2 equivalent.

KEYWORDS: Thermal Energy Storage Capacity, Carbon Emissions, Annual Electricity savings, Heat Transfer

1. INTRODUCTION

Pakistan, a participant in the Paris Agreement, has committed to reducing its greenhouse gas emissions by up to 50% by 2030, aiming to limit global temperature rise below 2°C.[1]. There are numerous ways of decarbonizing or to diminish ozone depleting substance emanations, for instance, by utilizing environmentally friendly power sources, the working on modern cycle to a less carbon-escalated one and presenting energy proficiency in both the modern and private areas. One of the biggest areas worldwide is the structure area, 55% of the worldwide energy utilization happens because of power utilization in building tasks [2].

The wellsprings of emanations in structures can be divided into direct discharges and roundabout outflows. Direct discharges come from the consumption of fills like flammable gas, coal, and wood, while roundabout outflows are produced by power consumption. The majority of

Pakistan's electrical energy comes from nuclear stations, with 61% coming from warm powerplants. If indoor spaces are heated and cooled using efficient heat pumps, electricity bills may increase during peak periods. [3]**.** The study evaluates the impact of Phase Change Materials (PCM) on energy utilization in an air conditioner system by analyzing heat transfer coefficients and loss or gain of heat through boundary walls, with negligible heat transfer from floor and roof [4]. Traditional petroleum derivatives contribute to climate change and harmful pollutants. With global population growth and energy usage increasing, researchers are working on reducing petroleum derivatives, increasing energy productivity, and reducing environmental risks [5]. Any materials that will be utilized in TES (Nuclear power Stockpiling) frameworks for PCM, should have high warm conductivity and dormant intensity. They ought to be artificially steady, economical, nontoxic, and noncorrosive. [6]. Air conditioning systems are causing a global surge in energy consumption, with projections showing 3.3 billion installed by 2050. This growth is largely due to hot climates and population growth [7]. Sensible heat storage and latent heat storage are thermal energy types, with latent heat storage being particularly popular due to its ability to store thermal energy as latent heat during phase changes. [8]. Thermal energy storage (TES) enhances thermal processes and aligns energy supply with demand. Three major methods include sensible thermal energy storage, latent thermal energy storage (LTES), and thermochemical energy storage. LTES offers high capacity, compact volumes, and constant temperature, but limited thermal conductivity of PCMs challenges its performance [9].

PCMs are increasingly used in engineering applications for latent heat storage due to their high heat storage density, small volume, and moderate temperature range [10]. Industrialization improves living standards but raises environmental pollution and energy challenges. Solar energy, despite unpredictable availability, is gaining attention through thermal storage technology for high capacity and reliable phase transitions [11]. Architects, engineers, and consultants are focusing on energy-efficient buildings, emphasizing the importance of HVAC systems for thermal comfort and energy efficiency. Value-added engineering and optimization contribute to energy conservation for both buildings and HVAC systems [12]. PCMs like paraffin wax are promising in LHTES due to their low thermal conductivity. Pairing them with high-temperature metal foam creates metal foam-PCM composites (MFPCMs), enhancing heat transfer. 3D printing allows for intricate structures, extending the use of complex cell configurations [13]. This research uses a high-performance detached house model in London to demonstrate that PCMs can store more thermal energy per unit mass than conventional materials, providing improved thermal stability and reduced discomfort hours and cooling energy demands [14].

2. MATERIALS AND METHODOLOGY

2.1 Material:

Following material is used for this study.

2.1.1 Paraffin Wax:

Paraffin wax, weighing 10mg, was obtained from a local market with a temperature range of 20-40 ºC. A list of Phase Change Materials (PCMs) was prepared based on operational temperatures and market availability. Paraffin wax was tested for thermal conductivity, melting temperature, specific heat capacity, and thermal diffusivity.

2.2.1 Methods:

This case study examines the impact of a 14 feet x 18 feet x 11 feet living room in Peshawar on multiple rooms within a house or multiple city houses. The American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) recommends indoor temperatures of 22°C for winter and 23°C for summer, with a relative humidity level of less than 60%. In Peshawar city, air conditioning is required during the winter months (November- March) and the summer months (May-September). If efficient heat pumps are used, peak electricity bills may occur during these months.

Thermal analysis tests were conducted to understand the relationship between temperature and phase change materials' properties, focusing on dimensions, mass, phase, and mechanical behavior. Two methods were used to analyze material specimens.. These techniques were

- Thermal gravimetric analysis (TGA)
- Differential Scanning Calorimetry (DSC)

By using the above techniques the results of Paraffin Wax in temperature range from 19 ºC-50 ºC for thermal conductivity, thermal diffusivity, specific heat, specific heat, enthalpy, thermal effusivity were calculated. A customized Excel analysis tool was created to evaluate heat transfer coefficients and loss or gain of heat by airconditioned rooms. The analysis focused on one-dimensional heat transfer through boundary walls, with floor and roof heat transfer considered negligible.

3. RESUTLS AND DISCUSSION

3.1 Paraffin wax (1 cm thick):

By using paraffin wax(1-inch) as PCM, annual electricity savings of 1,017 kWh/year, 23,397PKR/Year can be achieved, reducing the carbon footprint by 392 kgCO2 equivalent.

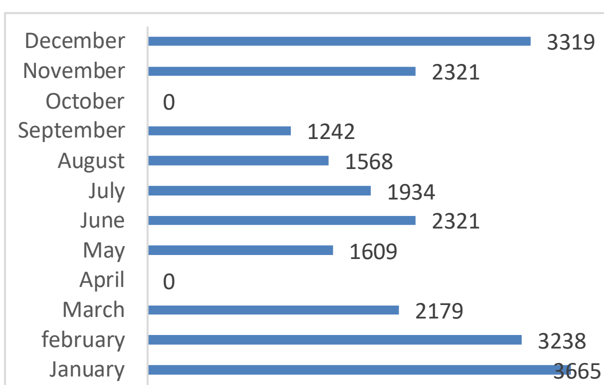

Figure 1: Impact of Paraffin wax (1 inch thickness)on monthly electricity cost(PKR)

3.2 Paraffin Wax (2 cm thick):

By using paraffin wax(2-inch) as PCM, annual electricity savings of 1,529 kWh/year, 23,397PKR/Year can be achieved(assuming 1kWh=23PKR), reducing the carbon footprint by 590 $kgCO_2$ equivalent.

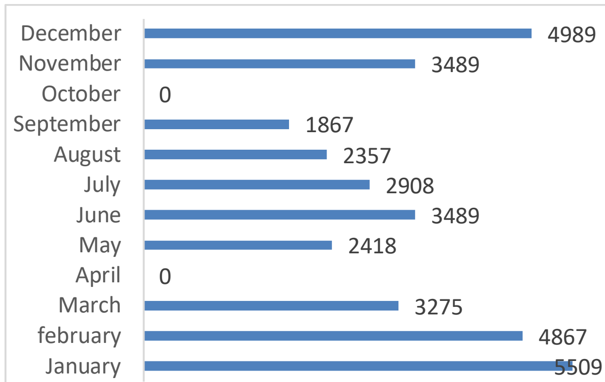

Figure 2: Impact of Paraffin wax (2 inch thickness) on monthly electricity cost (PKR)

3.3 Paraffin Wax (3 cm thick):

By using paraffin wax(3-inch) as PCM, annual electricity savings of 1,818 kWh/year, 41,820 PKR/Year can be achieved, reducing the carbon footprint by 701 $kgCO_2$ equivalent.

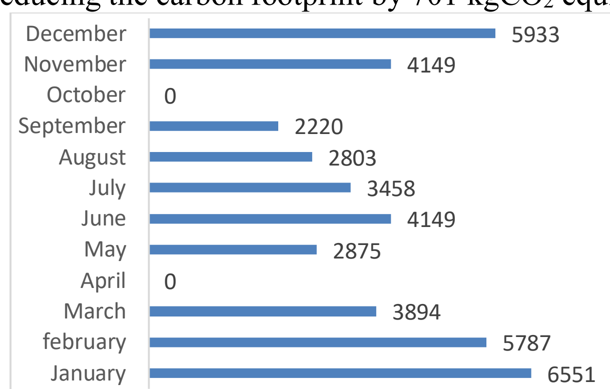

Figure 3: Impact of Paraffin wax (3 inch thickness) on monthly electricity cost (PKR)

3.4 Paraffin Wax (4 cm thick):

By using paraffin wax(4-inch) as PCM, annual electricity savings of 2,017 kWh/year, 46,383 PKR/Year can be achieved, reducing the carbon footprint by 778 $kgCO_2$ equivalent.

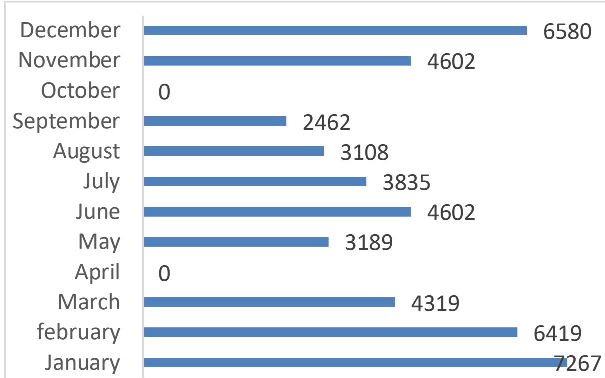

Figure 4: Impact of Paraffin wax (4 inch thickness) on monthly electricity cost (PKR)

3.5 Paraffin wax (5 cm thick):

By using paraffin wax(5-inch) as PCM, annual electricity savings of 2,152 kWh/year, 49,491 PKR/Year can be achieved, reducing the carbon footprint by 830 $kgCO_2$ equivalent.

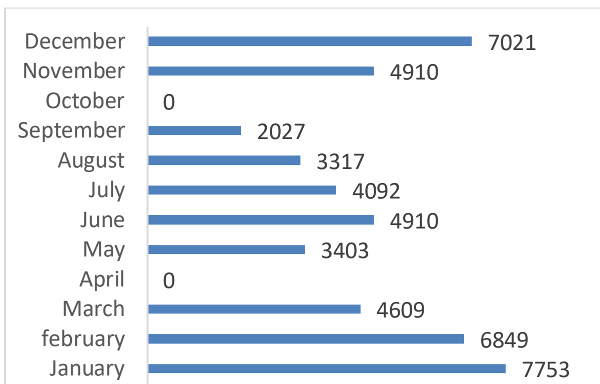

Figure 5: Impact of Paraffin wax as PCM (5 inch thickness) on monthly electricity cost (PKR)

4. CONCLUSIONS:

This research indicated that the installation of paraffin wax in building has significant effects on temperature flow and ultimately on economy. It was observed that increasing the thickness decreased the total cost of electricity by curbing the heat flow.

The temperature flow decreased with increasing the thickness of paraffin wax until no notable change was recorded by increasing PCM thickness from 4 cm to 5 cm. Hence it is concluded that 4 cm is critical thickness for PCMs.

By using paraffin wax

- (1-inch) as PCM, annual electricity savings of 1,017 kWh/year, 23,397PKR/Year can be achieved, reducing the carbon footprint by 392 $kgCO_2$ equivalent.

- (2-inch) as PCM, annual electricity savings of 1,529 kWh/year, 23,397PKR/Year can be achieved(assuming 1kWh=23PKR), reducing the carbon footprint by 590 $kgCO_2$ equivalent.

- (3-inch) as PCM, annual electricity savings of 1,818 kWh/year, 41,820 PKR/Year can be achieved, reducing the carbon footprint by 701 $kgCO_2$ equivalent.
- (4-inch) as PCM, annual electricity savings of 2,017 kWh/year, 46,383 PKR/Year can be achieved, reducing the carbon footprint by 778 $kgCO_2$ equivalent.
- (5-inch) as PCM, annual electricity savings of 2,152 kWh/year, 49,491 PKR/Year can be achieved, reducing the carbon footprint by 830 $kgCO_2$ equivalent.

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