OPTIMIZING ENERGY PERFORMANCE OF BUILDINGS IN PAKISTAN USING BIM

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Abstract- An unprecedented increase in global and national energy demand has arisen due to the rapid development of infrastructures and population growth. The residential sectors consume the major share of energy resources, up to 22% of the world's total energy consumption. In Pakistan, the residential sector consumes an average of 45% of the nation's energy resources. To address this issue and mitigate the escalating demand, the optimization of energy resources is required. The Phase Change Material (PCM) has been approved as a vital source for enhancing energy usage worldwide. In PCM, the material can store and release energy as it undergoes the transition stage. Utilizing the PCM in the building envelope, particularly in Peshawar, with distinct heating and cooling requirements, makes it possible to reduce energy consumption substantially. Extensive analysis reveals that PCM A25H exhibits the highest performance, achieving an impressive energy efficiency of 8.82%. To further investigate the impact of PCM thickness and its strategic placement within walls and roofs. The analysis outcomes demonstrate that applying a 40mm PCM coating on the interior side of building walls and roofs in Peshawar can significantly reduce energy consumption.

Keywords- Energy Performance. BIM, Phase Change Material, Energy Model

1 Introduction

In recent years, it has been observed that the development of infrastructures has increased exponentially, which results in more energy consumption of valuable resources. Pakistan is an underdeveloped country with very limited energy resources, and the residential sector is the major source of energy consumption. In the last two decades, the usage and optimization of energy resources in Pakistan have not been done properly as the world is moving towards sustainable infrastructure development and maximum utilization of available natural resources to decrease energy resource usage [1]. Building Information Modeling (BIM) has emerged with the immense potential to revolutionize building design, construction, and operation using Phase Change Materials (PCM). Therefore, extensive studies are required to provide the roadmap for future residential constructions in Pakistan, understand the applications of PCM in Pakistan, and optimize energy performance [2].

Concerns about the dependability of the energy supply are growing due to the expansion of the population and industrialization. Based on UN estimates, assuming the growth rate remains constant at 1.07% starting from 2020, with a population of 7.8 billion, the global population is projected to reach 9.7 billion by the conclusion of 2050 [3]. Similarly, it is expected that there would be a 19% rise in the worldwide energy consumption by the conclusion of 2040. With the rapid growth of the world's population, there is a corresponding increase in people's reliance on equipment and appliances for their comfort and mobility. Consequently, this exacerbates the issue of global warming. These factors are contributing to the global increase in energy consumption [4]. Given the rising energy demand in Pakistan, there has been a noticeable increase in the disparity between energy supply and demand. Therefore, it is crucial to implement necessary measures to address the energy crisis. To ensure rigorous adherence to construction regulations for thermal efficiency in buildings, the most widely used method is to augment the insulation thickness. The lightweight façade option, sometimes known as

curtain walls, has experienced an increase in popularity due to limited space constraints. Lightweight construction has benefits such as accelerated construction timeframes, more design flexibility, and cost-effectiveness [5]. Given these conditions, there is a growing interest in thermal energy storage devices that can conserve energy in buildings. Phase change materials (PCMs) with latent heat storage capabilities have attracted considerable study. These phase change materials (PCMs) have a high thermal energy storage capacity and are efficient at retaining heat. [6] Through the process of absorbing heat throughout the daylight and subsequently releasing it during cooler periods. PCMs play a crucial role in managing temperature management within buildings, leading to substantial reductions in energy consumption. Several energy-saving rules have been created, including Pakistan's building codes established in 2013 [7]. However, these codes are not being enforced in the construction of residential buildings, which are still being built using old materials. To achieve energy efficiency, it is necessary to consider strategies for low-carbon buildings and techniques for net-zero energy buildings [8]. The PCM method has demonstrated superior outcomes due to its specific temperature needs. PCM can be controlled by the utilization of fans and natural air circulation during the summer, leading to a reduction in the need for supplementary cooling devices and resulting in lower temperatures in walls and rooms.
To successfully integrate Phase Change Materials (PCM) into buildings, several key elements must be considered. These include the specific type of PCM to be used, the prevailing local temperature conditions, the weight restrictions, and the most suitable sites for installation. Although PCMs have potential applications in both active and passive building energy systems, there is a lack of research on incorporating PCMs into building envelopes in Pakistan. Hence, it is imperative to conduct more extensive research that considers numerous design components and the varied climatic conditions prevalent in different cities of Pakistan. These investigations will offer useful insights into the possible advantages of PCM integration in the Pakistani environment.

2 Research Methodology

The study evaluates the impact of incorporating phase change material (PCM) into a building's structure to improve insulation. For improved insulation, PCM was added, double-pane windows were used, and the window-to-wall ratio was decreased. The study uses variable energy models to predict the behavior of PCM during charging and discharging, considering their volatile nature. Autodesk Revit (Student Version) software is used for modelling, while the Insight Building performance analysis program performs dynamic energy modelling and heat transfer calculations [10]. The models integrate internal loads, including occupants, machinery, and lighting, allowing comprehensive evaluations of power and energy use. The Figure 1 shows the 3D view of a proposed building. This tool is crucial for architects, engineers, and designers to optimize energy efficiency and minimize environmental impact in building design and operation.

Figure 1: 3D view of Proposed Building

2.1 Phase Change Materials (PCMs)

The research aim is to assess several Phase Change Materials (PCMs) and determine the best appropriate PCM for the climatic conditions in Peshawar. The choice of PCM is determined by the standard room temperatures (18–25°C) often observed in residential properties in Pakistan. Previous research has thoroughly examined these Phase Change Materials (PCMs) and demonstrated their potential to enhance the energy efficiency of buildings. Table 1 displays the essential attributes of the chosen PCM. To evaluate the efficiency of each Phase Change Material (PCM) in terms of the building's yearly energy consumption, they are separately integrated into the building's structure. The study attempts to identify the most efficient phase change material (PCM) for minimizing energy usage in buildings by analyzing the energy performance of several PCMs.

Table 1 Property of Phase Change Material

Material Name	**(Melting, freezing Temp (℃)**	**Freezing Temperature (℃)**	**Density (kg/m³)**	**Thermal conductivity (W/m.K)**	**Specific Heat (KJ/KG.K)**
RT21HC	21	20	825	0.2	2
RT22HC	22	20	730	0.2	2
RT25HC	25	22	825	0.2	2
SP25E2	25	24	1450	0.5	2
A25H	25	25	810	0.18	2.15
M182/Q21	24	21	235	0.11	1.97

2.2 Energy Model of Building

Building performance analysis often begins with designing a conceptual model in Revit, which can be transformed into an energy model that can be analyzed in Insight. Figure 2 shows the energy model of the building. This model can be adjusted to suit unique requirements and project constraints. The energy model's generation and forecasting precision depend on energy choices. Users can fine-tune the model's behavior to fit their specific requirements. Adding more specific data, such as material parameters and thermal space properties, improves the model's accuracy. This allows for a more comprehensive evaluation of the building's energy performance and better decisions regarding sustainability and energy efficiency solutions. Insight helps identify desired outcomes and identify areas for improvement. With sustainability goals like the 2030 Challenge and Net Zero, Insight is a vital tool for achieving sustainability goals.

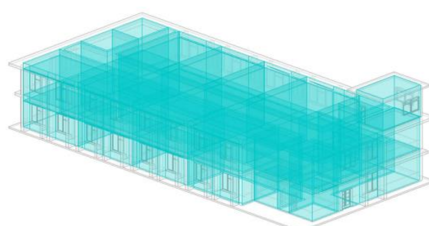

Figure 2: Energy Model of Building

2.3 Optimal Energy Reduction Option

The initial window-to-wall ratio in the study was 58%. The ratio was subsequently decreased to 30% and 20% to improve energy efficiency. Application of various phase change materials (PCMs) and evaluation of changes in energy usage resulted in analysis. The observed effects of these modifications and the integration of PCMs on energy performance are depicted in the accompanying. The studies showed that the PCM A25H is the most efficient for energy savings after extensive examination. This PCM choice produced a noteworthy 8.84% annual total energy reduction. The choice of PCM A25H as the best option highlights its potential for significant energy savings and underlines its suitability for boosting building energy efficiency. Table 2 shows the comparison between all three conditions

Table 2 Annual Consumption of Heating and Cooling with Different Condition

CM	Heating Condition			Cooling Condition		
	Existing Condition (kw-h)	PCM with 30% Win/wall (kw-h)	PCM with 20% Win/wall (kw-h)	Existing Condition (kw-h)	PCM with 30% Win/wall (kw-h)	PCM with 20% Win/wall (kw-h)
RT21HC	175582.7059	174912.4523	174437.3841	618868.27775	620665.0964	619655.4664
RT22HC	175595.308	175770.8576	174444.4178	618880.2934	625558.7976	619669.8269
RT25HC	175570.69	174899.8503	17663.4866	62008.86255	620648.6844	617895.2814
SP25E2	175796.3	175348.2491	174885.1967	619880.34	626159.5933	625319.0654
A25H	175436.4635	174752.4335	174266.8176	618051.4883	619840.3943	618810.2494
M180	175716.3464	175051.9542	174575.4206	619283.8523	621112.6159	620128.4832

3 Conclusion and Recommendations

The study suggests that Pakistan's growing population and urbanisation may lead to an energy crisis. To address this, a guide for designing energy-efficient residential buildings in Peshawar is presented, focusing on the use of Phase Change Materials (PCMs). Simulations using DOE-2 algorithms and Revit Insight were conducted on six PCMs, double-pane windows, and reduced window-to-wall ratios. The findings show that using A25H with a 20% window-to-wall ratio and double-pane windows can reduce heating and cooling energy consumption by up to 8.84%. Further research is needed to assess the effects of PCM features on heat transport and transition temperature. The feasibility and financial sustainability of incorporating PCM technology in construction projects need to be evaluated.

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