Studying The Role of Phase Change Materials in Improving the Thermal Performance Efficiency of Adaptive Building Envelopes

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Abstract:

In the context of unsustainable approaches, buildings are increasingly dependent on mechanical systems to ensure quality requirements of thermal indoor environment, which causes the need for more energy as well as rising the associated greenhouse gas emissions rates. This requires increased awareness towards energy conservation and reduction of energy consumption in conjunction with enhancing buildings sustainability. In this regard, we find that the building envelope plays a crucial role in reducing energy consumption; as well as its role in raising the performance of buildings as the regulating mediator in the reciprocal relationship between the internal and external environment, especially when applying appropriate technical solutions and energy-saving materials within the structure of the envelope, which enhances the concept of passive adaptation to the simultaneous environmental changes. So, Improving the efficiency of energy performance during the operational phases of the building envelope is a vigorous area of research; Organizations and responsible authorities are always seeking to come up with advanced technologies based on renewable energy sources in order to reduce buildings' dependence on fossil fuels and provide cooling and/or heating energy requirements, as well as improve indoor thermal comfort in a more sustainable and cost-effective manner.

In this regard, Thermal Energy Storage Systems (TES) are discussed as one of the most effective advanced technologies in managing the thermal performance of the building envelope with a particular focus on studying the role of Phase Change Materials (PCMs) in raising the efficiency of the building's thermal performance. This study sheds light on the importance of applying

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phase-changing materials in the building envelope and its role in activating the principle of thermal adaptation to daily fluctuations. by discussing the nature of that category of materials, their types, and their distinctive properties in addition to studying its main working principle, then studying criteria for choosing the most appropriate. focusing on current studies and future scenarios for these materials to monitor their thermal behavior and examine their role in raising the efficiency of the building envelopes performance. The main results indicated that the phase change materials have a significant effect on reducing the cooling/heating load, saving energy and gaining thermal comfort.

Keywords:

Phase change Materials (**PCMs**) - Thermal Energy Storage Systems (**TESSs**) - Thermal indoor environment quality (Thermal Comfort) - Adaptive Building Envelopes – Passive Cooling - Energy Saving.

Introduction:

The continuing increase in energy consumption in buildings is one of the most pressing issues worldwide. At the global level, the percentage of energy consumed to provide thermal comfort (heating and cooling) reaches 40% and 61% of the total energy demand in commercial and residential buildings, respectively [1]. According to the International Energy Agency (IEA), the building sector is most responsible for the rising total energy consumption worldwide (Figure 1). By the year 2050 AD, it is expected that the energy consumed for heating and cooling in buildings will increase by up to 12% and 37%, respectively [2]. United Nations reports mentioned during the year 2050 AD the possibility of a significant increase in population growth, with 75% of them concentrated in cities and urban areas, which will result in an increase in energy demand by about 50%, as well as a tripling of the demand for cooling buildings compared to 2010 AD. Which requires designing cities within an environmental framework that enhances the principles of sustainability.[3]

The building envelope plays a major and effective role in controlling energy and controlling heating and/or cooling loads to meet the thermal comfort requirements of the residents of the building spaces in the short term, in addition to its effective role in reducing energy consumption and carbon dioxide emissions into the atmosphere in the long term [3].]

Therefore, the building envelope represents the protective shield from successive climate changes, and it is also an effective element in managing the building’s performance from an energy perspective efficiently. This is a matter for which many responsible international bodies and organizations have moved towards introducing a new generation of building envelopes that are characterized by their ability to adapt to respond dynamically to the variables of the surrounding environment with the aim of mitigating the climate, reducing carbon dioxide and achieving energy efficiency. This is confirmed by reports from the International Energy Agency (IEA) that most of the investments and expenditures of the building sector have been directed to renovating existing building envelopes and creating responsive envelopes that are more compatible and adaptable to external environmental stimuli.

Research problem:

The problem of the research study lies in the following:

• The greatest reliance in providing internal thermal environmental quality requirements on active mechanical systems that consume more energy, and the inability of buildings with their traditional designs to achieve internal thermal stability.

• Knowledge deficiency about the application of latent thermal energy storage technologies in adaptive building envelopes.

Therefore, the problem of the study can be formulated in the following question: What is the role of advanced technologies based on storing latent thermal energy (phase change materials) in improving the thermal performance of the building from the perspective of energy conservation, and what is the extent of their impact on reducing cooling and/or heating loads to ensure comfort? Thermal?

Research Importance:

The importance of the research lies in shedding light on the role of thermal energy storage technologies in managing the thermal performance of the building envelope with a methodology that is more compatible and compatible with the environment within a sustainable environmental framework.

Research Aims:

The research study aims to do the following:

• Study the role of advanced technologies based on renewable solar energy sources (thermal energy storage systems) in improving the thermal performance of the building.

• Monitoring and evaluating the thermal behavior of phase change materials integrated into the various elements of the building envelope according to what was stated in previous literature, to determine the effectiveness of their application from an energy saving perspective (and the effectiveness of their application in reducing cooling and/or heating loads).

Research hypothesis:

The research study verifies the validity of the hypothesis which states that: Applying latent thermal energy storage systems by integrating phase change materials into building envelope elements leads to improving the thermal performance of the building, which enhances energy savings from the perspective of reducing cooling and/or heating loads.

Research Methodology:

The research study follows the descriptive survey and descriptive analytical approach to verify the validity of the study hypothesis by analyzing a group of previous and current studies that included the integration of phase-change materials within the structure of the various cover elements, in order to monitor and evaluate the thermal behavior of this category of materials. In order to verify its optimal effectiveness in reducing cooling and/or heating loads, and thus saving or conserving energy.

Recommendations:

The research study recommends to designers the importance of effective communication with scientific research centers specialized in the field of materials science, as well as the necessity of joining the materials design table as key participants within the scientific work team with the aim of bringing about a radical transformation in the field of materials science, as materials science transforms from a field that explains materials to a field Materials are designed to have properties that suit the design and performance requirements stipulated by the designer and to achieve the desired applied functions, which results in the generation of new synthetic and synthesis concepts in the field of advanced materials science. It also recommends the following:

• The need for responsible organizations and institutions to adopt solutions and applications of passive cooling in national projects, in addition to appealing to research bodies about the importance of intensive research work to advance this category of materials in order to improve its applications and widespread spread.

• Pushing the wheel of scientific research towards creating advanced materials that increase the efficiency of the thermal performance of building envelopes within the framework of the concept of passive adaptation in order to achieve environmental compatibility with current and future variables.

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