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EFFECT OF ROOF INSULATION ON INDOOR THERMAL CONDITIONS AND ENERGY CONSUMPTION OF ROOM

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ABSTRACT

In this review, Buildings are identified as the largest consumers of energy in all countries.in order to develop an energy-efficient building, insulation materials are essential. The right use of insulating material in buildings not only reduces the size of the air conditioning system required but also lowers annual cost of energy. Furthermore, it helps to increase thermal comfort without the use of mechanical air conditioning, especially in summertime. Amount of energy savings achieved through thermal insulation depends on various parameter such as building type, local climate, and type of insulating material used. Expanded polystyrene (EPS), Bamboo material are used as thermal insulation material on the roof. The main objective of this paper is to reduce the indoor air temperature by providing the thermal insulation in the building.

KEYWORDS: Thermal Insulation, Energy Consumption, Thermal Comfort, Expanded Polystyrene, Bamboo.

1. INTRODUCTION

All nations are being touched by climate change, and population increase is causing a sharp rise in the amount of power needed for thermal comfort. According to estimates, the residential and construction industry consumed 36% of all energy in 2018, with global CO2 emissions responsible for 39% of that energy. It is widely recognized that the heat gain in buildings relies heavily on factors such as solar irradiance, heat exchange with the outdoor environment, and the geometry and orientation of the building. As a result, the inhabitants frequently use insulation to attain thermal comfort. In response, the scientific community is actively looking on insulation substitutes that can lower the thermal burden on buildings and cut down on the world's electricity use. Energy required to cool or heat a building is influenced by quality of thermal treatment applied to its envelope. Thermal qualities of the materials used in a building's structure, which govern their capacity to either absorb or emit solar heat, define thermal performance of a building's envelope.

Thermal insulation is a significant factor and crucial initial measure for attaining energy efficiency, particularly in envelope-load dominant buildings situated in sites with challenging climatic conditions. Insulators, referred to as thermal insulation materials, are utilized in commercial buildings to enhance the energy efficiency of the structures. They are also employed in industries to regulate the heat gain or loss in boilers and any other mechanical equipment. For a good insulation material, thermal conductivity should be very low. Several insulation alternatives are available to improve the indoor environmental building, such as rock wool, glass wool, polystyrene, polyurethane etc. In this research paper, we are going to basically focus on the two-insulation material, which are expanded polystyrene (EPS)and bamboo. Without a doubt, the roof is the most crucial component of the entire building surface. Therefore, we are installing insulation materials on the roof to mitigate the significant amount of solar radiation it receives, subsequently reducing the heat load within the building. During the summer, the horizontal roof receives the highest solar radiation and serves as the primary pathway for heat flux to enter the living space. By applying the insulation, the amount of heat flux is restricted, and indoor air temperature is improved.

Thermal insulation refers to a material or combination of materials that, when applied correctly, slow down the rate of heat flow through conduction, convection, and radiation. It effectively reduces the transfer of heat into or out of a building by providing high thermal resistance.

In other words, we can also say that the Insulating buildings involves the creation of a protective barrier, ensuring that room temperature can be maintained in accordance with specific requirements.

Thermal insulation is essential for individuals involved in construction. In today's world, there is a continuous increase in global warming, leading to drastic weather changes. This results in significant temperature variations, with some regions experiencing extreme cold while others face intense heat. To combat these adverse weather conditions, various devices have been invented, such as air conditioners and room heaters. However, these devices pose another challenge, namely high electricity consumption and harmful emissions that negatively impact the environment. Consequently, it is more prudent to construct thermally insulated homes instead of bearing substantial electricity bills. By implementing thermal insulation in buildings, people can enjoy enhanced comfort while effectively addressing environmental changes.

2. Literature Review

A thermal comfort level plays a crucial role in residential buildings. [In residential buildings, the level of thermal comfort plays a crucial role.] Numerous researchers have conducted studies to determine the comfort level in various locations and seasons. However, none of these researchers have specifically examined in Bihar state. They have utilized different insulation materials to estimate comfort level. In this chapter, a brief review of the roof insulation material is explained.

Tang et al. (2025) In this research paper the critical fire safety concerns associated with EPS external thermal insulation composite systems (ETICS). Their study evaluated expandable graphite (EG) as a flame-retardant modifier through multi-scale testing, ranging from thermogravimetric analysis to large-scale LEPIR 2 façade fire tests. The results showed that EG functions primarily as a physical intumescent, effectively reducing heat transfer and peak temperatures during fire exposure. Although char layer detachment and oxidation above 540 °C limited long-term protection, EG-modified EPS façades exhibited peak temperatures approximately 470 °C lower than untreated systems in large-scale tests. The study also highlighted the effectiveness of small-scale bench tests as a reliable screening tool for fire-retardant performance prior to large-scale evaluation.

Ahmed et al. (2025) In this research paper numerically demonstrated that integrating NEPCMs within a natural convection mechanism significantly enhances heat transfer and reduces the temperature of high heat-generating electronic elements.

Hu et al. (2025) In this research paper proposed a hybrid passive cooling system combining radiative cooling with latent thermal energy storage, achieving improved cooling efficiency and strong resistance to thermal shock. Improving thermal insulation performance of external walls is essential for energy-efficient buildings, especially in severe cold regions. Conventional EPS-based insulation systems are widely used but often face issues such as thermal bridging, limited mechanical strength, and poor adaptability to assembled construction methods. Recent research has focused on enhancing insulation materials through advanced composites, with graphene emerging as a promising additive due to its high strength and low thermal conductivity.

Lin et al. (2025) In this research paper developed an innovative graphene-modified EPS thermal insulation structural system for prefabricated buildings in cold regions of China. By integrating graphene into styrene polymerization and adopting modular manufacturing, the proposed system improved structural integrity and construction efficiency. Experimental results showed enhanced mechanical performance, reduced thermal conductivity (≤0.032 W/(m·K)), and a low wall heat transfer coefficient (0.164 $W/(m^2 \cdot K)$). The system achieved up to 75% energy savings, demonstrating its effectiveness for assembled building applications

Li et al. (2025) In this research paper demonstrated that a hybrid PCM–immersion cooling system, optimized using a coupled computational fluid dynamics (CFD) and artificial neural network (ANN) approach, can significantly reduce peak battery temperature and improve temperature uniformity. Their results highlight the effectiveness of integrating passive cooling materials with data-driven optimization methods for advanced battery thermal management systems.

Gokce et al. (2025) In this research paper evaluated the insulation performance of polyethylene (PE) and polyvinyl chloride (PVC) under different temperatures (22 °C and 55 °C) and currents (40 A and 60 A) using numerical simulations. The study showed that PE has higher current capacity at lower temperatures but suffers from increased Joule heating and energy loss, while PVC provides more stable insulation with lower energy dissipation. At higher temperatures and currents, PE experiences significant electrical and thermal stress, increasing the risk of overheating, whereas PVC maintains consistent performance. These findings highlight PVC's reliability under varied conditions and offer guidance for selecting optimal insulation materials in power distribution systems.

Binabid et al. (2024) In this research paper evaluated the use of vegetation at an elementary public school in Riyadh, Saudi Arabia, as a passive cooling technique. The Universal Thermal Climate Index (UTCI), mean radiant temperature (Tmrt) and air temperature (Ta) are used to study outdoor thermal comfort. Using an experimental design, eight scenarios are compared to a base model in this work. The scenarios represent various vegetation types (grass, bushes, two trees at two different heights, 5-10 m), as well as the distance between them (3.5 m and 7 m). The findings showed that Ta was lowered between (1.4-3.2)◦C, reaching a maximum reduction in August, Tmrt (7.13-64.73)◦C, where a maximum reduction was observed in October, and UTCI at (3.00-17.95)◦C in April when 10 m height trees with 3.5 m spacing between them were used. Improving the thermal performance of building envelopes through thermal insulation materials is essential for enhancing energy efficiency.

Pinchard et al. (2024) In this research paper investigated the long-term thermal conductivity and biological durability of thermal insulating mortars containing EPS, cork, and aerogel aggregates. Using accelerated ageing tests, the study showed that thermal conductivity increases over time, particularly in experimentally designed mortars, and that all materials are susceptible to biological colonization under high moisture conditions. These findings highlight the importance of long-term durability considerations when developing and applying advanced thermal insulating mortars for building refurbishment.

Erünal (2024) In this research paper investigated the thermal insulation performance of foam-extruded black EPS produced using an underwater pelletizer process. By blending general-purpose polystyrene and expandable polystyrene with carbon black or graphite powder, the study evaluated thermal conductivity, density, and glass transition temperature. The results indicated improved compatibility and insulation performance when graphite powder was combined with general-purpose polystyrene. Although the achieved thermal conductivity (0.2997 W/m·K) was higher than graphene-based EPS systems, the study demonstrated that carbon-based fillers and alternative processing routes can enhance EPS insulation properties and provide industrially viable production methods.

Javaid et al. (2024) Investigated rice straw waste boards focusing primarily on thermal insulation performance and material processing. Their work examined the effects of water and alkali pre-treatments on lignocellulosic straw combined with different polymer matrices (PE, PLA, and epoxy). Among these, epoxy-based composites exhibited superior interfacial bonding and uniform straw dispersion. Microstructural analyses (FTIR, XRD, EDS) confirmed that pre-treatment significantly modified straw morphology, leading to improved thermal performance. Using the guarded hot plate method, the minimum thermal conductivity achieved was approximately 0.023 $W\ m^{-1}\ K^{-1}$, comparable to conventional expanded polystyrene (EPS), indicating strong potential for RS boards as low-carbon insulation materials

Pal et al. (2023) Evaluated thermal comfort all year in various climatic zones using an online as well as offline questionnaire. The questionnaire assessed how ventilation, moisture, and temperature affected thermal comfort. Over the course of the autumn, spring, and monsoon seasons, 2702 valid surveys were collected from respondents in various locations.

The survey also showed that summertime discomfort is a problem for people in Chhattisgarh, with Raipur people reporting higher levels of discomfort as people in other regions.

Hung Anh et al. (2021). Depending on the material, the main variables significantly affecting thermal conductivity coefficient are temperature, moisture content & bulk density. Thermal performance is also affected by other elements like as thickness, airflow velocity, pressure, and age. Most of the time, the relationship between thermal conductivity and temperature is linearly rising. Both organic and inorganic materials' thermal conductivity is significantly influenced by their moisture content. key variable in determining thermal conductivity is bulk density, which exhibits opposite tendencies for conventional and organic materials, respectively, with a linear decline for conventional materials & a nonlinear variation.

Muhieldeen et al. (2020) Developed a prototype of a wooden room and analyzed the temperature distribution inside and outside the room by using glass wool as roof insulation in different layers. As the insulation layer was increased throughout the experiment, the temperature within the room dropped. To assess how well each glass wool insulation thickness reduced the temperature within the wooden room model, different thicknesses of insulation were utilized. Transversely sliced bamboo layers are used as a natural thermal insulator in a revolutionary roof slab insulation system that was introduced by

Chandra et al. (2019) In this research paper to minimize the negative environmental impacts associated with artificial insulation materials. The study determined that an optimal insulation layer thickness of 25 mm resulted in 53% reduction in heat within building. In a case study conducted by

Saiefeddine (2019) In this research paper thermal performance of bamboo as a roofing material was investigated. The results indicated that bamboo exhibited favourable thermal properties. The room insulated with bamboo showed a 4℃ lower indoor temperature compared to the one without bamboo insulation, thereby providing a more comfortable humidity level. The comparative experiment conclusively demonstrated the excellent insulation capabilities of bamboo. The intermittent heating operation for six typical insulating walls was examined by

Meng et al. (2018) In this research paper the findings demonstrate that the foamed concrete wall & inner insulation wall had the highest thermal response rates, making them best options for intermittent heating operation. On the other hand, self-insulating concrete walls and outside insulation are both comparatively bad options.

Singha & Borah (2017) In this research paper reported that bamboo possesses supplementary attributes like easy processability, exceptional strength, high elasticity, and resistance to abrasion. Consequently, due to its diverse properties, its rapid growth, adaptability of most climatic condition, bamboo emerges as a viable alternative as roof insulation material.

Perminder et al. (2016) In this research paper reported that Bamboo has become recognized as a contemporary engineering material, with recent research demonstrating its notable antibacterial properties.

Kulatunga, (2015) In this research paper has reported about the development of sustainable roofing material. The roofing material primarily prioritizes safety, building aesthetics, lightweight design, durability, and minimal environmental impact. Roofing plays a crucial role in maintaining the thermal envelope, shielding the building from extreme temperatures. This research gives an idea of constructing bamboo roof covering by addressing the environmental and social benefits.

Chel et al. (2009).**)** In this research paper Brick & adobe vaults make up the building's structure. To arrive at the governing equation for the inside air, the equations for overall heat transmission to the building were deduced. The Range-Kutta numerical approach was then used to resolve this equation. Calculating the building's potential for annual energy savings both before and after adding earth-to-air heat exchanger was another aspect of research.

3. Research Objective

- To evaluate the room air temperature by an experimental model.
- To evaluate the relative humidity experimentally for different insulating material.
- Compare & analyse the obtained results for room, wall and roof.
- Obtain the Energy consumption for different insulating building material.

4. Research Gap

- Comparison of an insulation material such as Bamboo & EPS have not been reported yet.
- Comparison of the Energy Consumption of these insulation materials have not been reported yet.
- Performance of these insulating materials have based on climatic condition.

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