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Porous Ceramic Roof Insulation in Malaysia's Construction Industry: A Review

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Abstract

Nowadays, Malaysia's construction industry has risen to become one of the country's fastest-growing industries. The application of green building is becoming more popular towards increasing the use of sustainable products in the construction industry. Nevertheless, due to rapid construction and low sustainable products for buildings, problems related to thermal comfort could indeed arise which may cause people stress and irritation. As a result, the objectives of this paper are to identify the issues, problems, concepts, and needs of Porous Ceramic Roof Insulation. In order to do so, extensive literature reviews conducted via various databases (i.e., Scopus, Web of Science, and Scopus) were explored. The findings have revealed that Porous Ceramic Roof Insulation has the potential to be marketed due to its great benefits (i.e., roof cooling, water absorption, solar absorption, and heat absorption within the building). Thus, it is anticipated that the study of Porous Ceramic Roof Insulation would improve the building's well-being while increasing thermal comfort.

Keywords: Porous Ceramic Roof Insulation, Literature Reviews, Thermal Comfort

Introduction

Of late the heating, ventilation, and air conditioning (HVAC) systems have become the main consumers of energy in buildings (Damiati et al., 2016). Over the past ten years, the use of HVAC in developing countries with hot and humid climates has risen tremendously. This is due to the fact that heat extremes caused by global climate change has caused difficulty and discomfort for people (i.e., working inside the building & outdoors and doing physical activities). Consequently, the goal of thermal comfort is to improve people's productivity while improving their safety and health. Thermal comfort is critical for buildings, particularly in tropical climates where intensive cooling capacity is required. The function of buildings themselves is to provide a comfortable indoor environment for occupants (Hamzah et al., 2018). When the objectives cannot be achieved, thermal discomfort happens and results in reducing the occupants' performance and reducing their emotions (Grassi et al., 2022).

Cool materials used in buildings has become one of the solutions to mitigate building overheating. Building overheating boosts both cooling loads and peak electricity consumption, which in turn fosters global and local warming. Whereas building insulation is

a crucial factor in achieving thermal comfort for occupants during cold winters and warm summers. Insulation happens to be a material that is used to reduce heat loss or heat gain and decreases the energy demands of the heating and cooling systems. Better insulation in buildings bring additional benefits in energy savings, resulting in lower energy bills and protecting the environment by reducing carbon dioxide emissions (Kumar & Suman, 2013). While, thermal insulation is an opaque element (i.e., roof insulation) that becomes a major component of a building envelope retrofit strategy. The function of roof insulation is to insulate the building against heat inflow from the outside during the day (Kumar & Suman, 2013). In the construction market industry, there are various materials used as roof insulations (i.e., ceramic wool, rock wool, perlite concrete) that functions to control the high temperature in the roof and building as well. Nevertheless, these roof insulation materials (i.e., ceramic wool, rock wool, perlite concrete) face numerous problems (i.e., sun exposure, corroding due to excessive weather, and unsafety) to their occupants. Thus, Porous ceramic roof insulation is introduced in this study to improve thermal comfort in buildings as well as to reduce hazardous materials in the building thus resulting in a safer environment. Accordingly, this study aims (i) to identify the issues, problems, concepts, and needs of Porous Ceramic Roof Insulation in the Malaysian construction industry.

Problem Statement

Thermal comfort has recently become a critical issue for modern brick and concrete houses, particularly in urban areas where houses are very close to each other and trees are scarce to shade the houses. Achieving thermal comfort inside the building does not only benefit the occupant's health but also allows occupants to be comfortable and are able to function effectively (Leng et al., 2019). As a result, good roof insulation is required to enhance comfort of a space by having good thermal comfort in a building.

In Malaysia, roof insulation is not widely used by developers due to the cause of additional cost spent by the homebuyers. However, it differs from other countries (i.e., western) where the installation of roof insulation will improve the company's branding and reputation. Furthermore, roof insulation is currently facing problems in terms of material selection, installation procedures, and influence of thermal comfort in the building. As such, the roof insulation is frequently exposed to over-heated roof systems. It can cause blisters on its surface which is caused by trapped moisture or air beneath the layers of roofing. Since the outdoor temperature continues to rise, the pressure in these patches forces the moisture to expand. Furthermore, hazardous material gassing (i.e., toxic, flammable, corrosive, reactive, and oxidizing gas) may result from weather conditions and cause corrosion in the roof structure. The gassing of hazardous materials also causes climate change due to trapped heat, respiratory disease from smog, and air pollution. Following thereon, poor installation and workmanship may result in leaks problems. If unskilled workers do not install the roof insulation properly, leakage will likely happen. The drastic poor installation and workmanship will increase roof problems and reduce the life expectancy of roof insulation as well. Further, improper roof insulation also causes poor ventilation. As a result, the R-value (i.e., the measure of resistance to heat flow through a material thickness) will decrease and raise the temperature and humidity which causes heat stress as well as harm towards human health (Damiati et al., 2016: Leng et al., 2019).

Methodology

The research method in this study focuses on literature reviews from past research. Sources such as journal articles and conference proceedings gathered from three main databases (i.e., Scopus, Web of Science, and Science Direct) have been used as a literature review for this study. These journal articles and conference proceedings were drawn from international and local publications, particularly in Malaysia towards obtaining updated information regarding porous ceramic roof insulation.

Global and Malaysian Roof Insulation Scenario

Every year, insulating the building's roof helps in saving a lot of money. Insulation saves energy by limiting the internal temperature of the building. Insulation lowers the amount of energy required to operate the building. Roof insulation has been used in all buildings around the world to achieve the goal of maximizing comfort in the building. Roof insulation requirements differ depending on the climate of the building and the country. As a result, there are numerous types of roof insulation around the world. As such, glass wool insulation has been used for many years as a popular thermal roof insulation material. The manufacturing process has significantly improved the durability and itchiness of glass wool. Glass wool is made from recycled glass that when melted in a furnace and then spun into fibers in a spinner, forms millions of tiny air pockets by the glass wool fibers which will trap air (Mendoza et al., 2021). Because of the trapped air, glass wool is considered a poor heat conductor, which is a critical necessity for efficient insulation. Glass wool, a soft material, is one of the most efficient and eco-friendly insulation materials in the market. The excellent thermal properties will assist a building in saving energy and reducing its environmental impact. Particularly, China and India are projected to record the fastest growth in glass wool insulation demand (Zhao et al., 2018).

In Malaysia, there are numerous roof insulations available in the market such as PU foam, aluminum foil, stone wool, and cellulose insulation. One of the popular materials is Polyurethane Foam or known as PU Foam. PU foam has been categorized as a modern and highly recommended insulation for buildings because of its effectiveness. It attains even the smallest gaps when sprayed onto the surface which brings permanent and damage resistance to a building, enhancing thermal comfort and lowering heating costs (Kuranska et al., 2022). PU Foam also has a long lifespan, providing a building with a lifespan of up to 20 years. PU Foam is also a good insulator since heat energy cannot pass through it due to the small air bubbles trapped inside it (Yanilmaz et al., 2012). In addition, PU Foam does not harm people and the environment around it, and most importantly, it is cheap and has been the primary choice for contractors in Malaysia. However, several guidelines must be followed to ensure that the function of roof insulation can be fully utilized. Roof insulation protects the building and its occupants from weather's effects. Roof insulation systems must be sufficiently assured and meet applicable standards. Roof insulation systems must be designed in accordance with international standards. An uninsulated flat roof, for example, has a U-Value of about 1.5 W/m^2k. When it comes to insulation, a value of 0.25 W/m^2k or less is required. To accomplish this, the roof should be insulated with insulation boards of approximately 150mm in thickness (LABC, 2002). Another example is warm roof insulation. To achieve a U-Value of 0.20 W/m^2, 120mm of rigid foam or 200mm of mineral wool or natural insulation will be required. To achieve incredible levels of $0.13W/m^2$, 300mm of mineral wool or 180mm of rigid foam will be required (Asia, 2012). In Malaysia, the Malaysian Standard has been used to standardize

the use and functionality of roof insulations. The Malaysian Standard is entitled "*Energy efficiency and use of renewable energy for residential buildings – Code of practice*".

Concept of Porous Ceramic Roof Insulation

Porous ceramic roof insulation is selected for this study as an alternative for roof insulations. The inspiration for the design comes from the cool roof concept (Figure 1). The cool roof concept may enhance thermal comfort in buildings while also providing an impact on the environment by reducing the use of devices in cooling down the temperature inside the building. Generally, by implementing various approaches such as reflective paint, sheet coverings, or highly reflective tiles, the cool roof system is a roofing system that can deliver high reflectance and high thermal emittance (Kolokotroni et al., 2018). In line with the goals of Green Building, which is to reduce the impact of buildings on human health and the environment during construction, the selection of porous ceramic roof insulation is clearly well suited for this purpose.

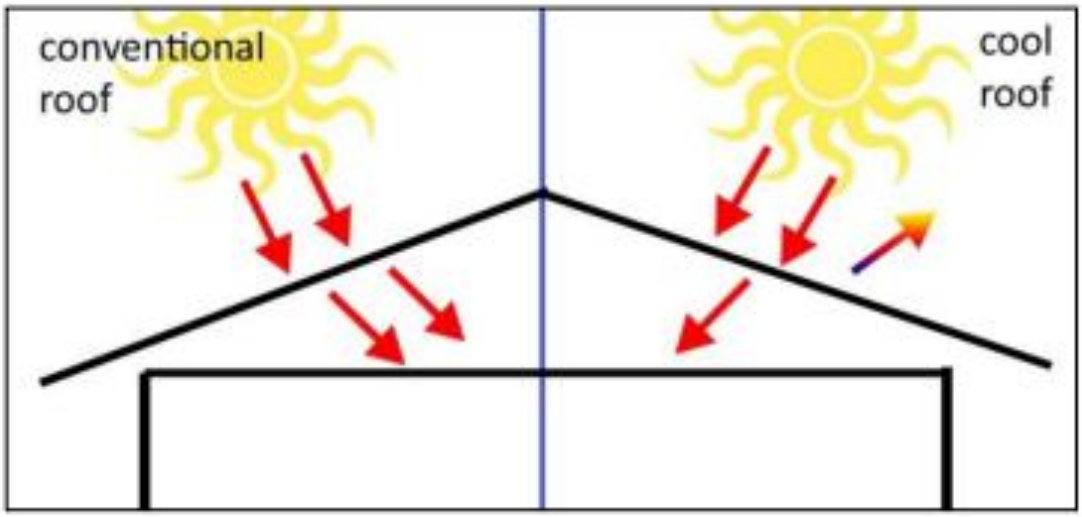

Figure 1: Cool roof concept
Source: (Masatlioglu, 2020)

The porous ceramic roof insulation is made up of waste resources and porous materials (i.e., ceramics) as the main ingredients. Porous building materials are one of the passive strategies used for building energy conservation (Zhang et al., 2018). The passive cooling material can act as ambient cooling sinks to reduce rising building temperatures caused by heat sources, straightforward solar absorption, or heat absorption within the building without consuming energy (Tao et al., 2020). According to Kato et al (2008), Porous ceramics have several benefits compared to normal ceramics. As such, porous ceramics are more lightweight and have high machinability, water absorption, and heat insulation. Whereas normal ceramics (i.e., tiles) are dense, heavy, and have low machinability. Nevertheless, they discovered that water absorption and retention depend on the pores of the ceramics. As such, the properties will have deteriorated if the pore size is large or is too high in porosity and will better perform in small pores.

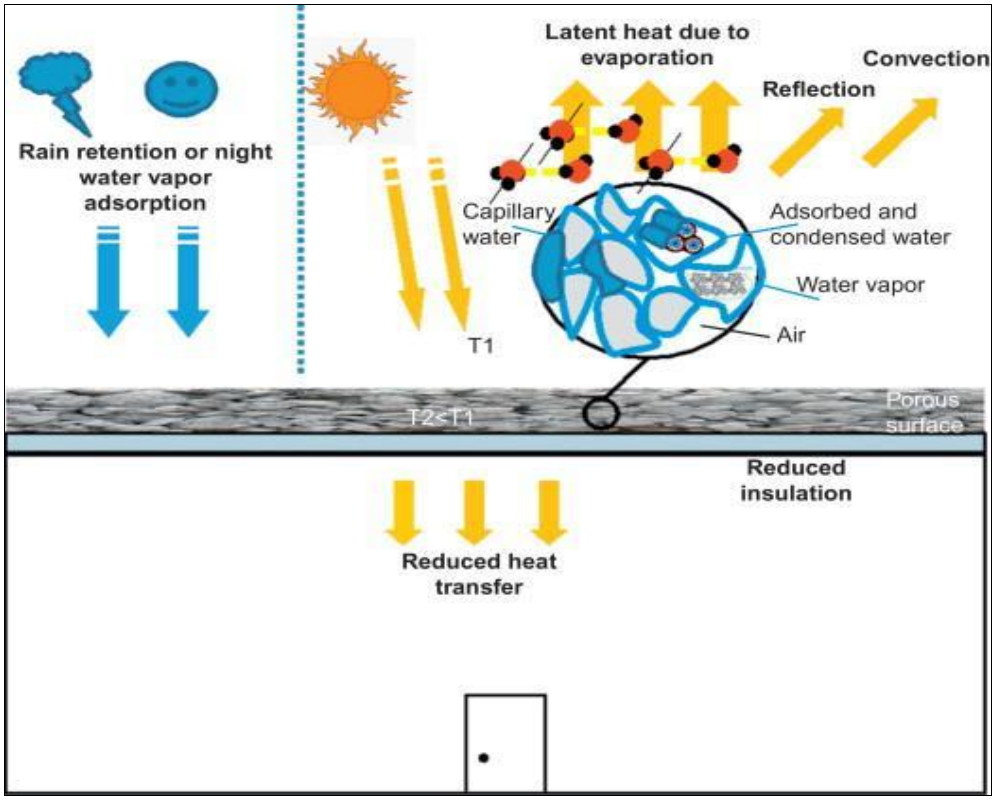

Figure 2: The porous material's cooling effect
Source: (Carbonari et al., 2015)

Figure 2 shows the porous materials' cooling effect caused by the porous material characteristics and contributes to the flow conditions of the coolant. It shows that the Porous Ceramic Roof Insulation provides a cooling effect in a building. It aids the building to become cooler and provides energy efficiency by requiring less energy for air conditioning. As a result, it provides a positive impact on a safer environment by lowering greenhouse gas emissions (Carbonari et al., 2015).

Needs of Porous Ceramic Roof Insulation in the Malaysian construction industry

The introduction of porous ceramic roof insulation can be competitive and cost-effective in the market due to their insulation efficiency and lower density. According to the United Nations' Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), published in February 2022, the Earth needs to avoid serious consequences of rising temperatures and increasingly extreme weather. According to IPCC reports, South-East Asia, which includes Malaysia, is one of the world's most vulnerable regions to excessive climate events (Ehsan et al., 2022). The Porous Ceramic Roof Insulation can help reduce the production of hydrofluorocarbons (HFCs). This is due to the presence of hydrofluorocarbons, which are potent greenhouse gases found in air conditioners and refrigerators (HFCs). Furthermore, a non-combustible gas known as freon is evaporated repeatedly to help produce cool air throughout the air conditioning system. Both HFCs and freon can cause breathing difficulties, fluid build-up in the lungs, and organ damage. To reduce heat penetration into the building, Marangoni et al (2017) used a porous layer with low thermal conductivity on ceramic tiles. This layer reduces the thermal conductivity of the tile, which has thermal insulation properties for building use. According to Marangoni et al (2017), the

porosity layer should be tailored to have sufficient mechanical strength as well as a low thermal conductivity value. While Rashidi et al (2018) revealed that the surface of a ceramic exposed to sunlight changes heat with its surroundings for convention and radiation.

In contrast, the Rockwool roof insulation is commonly used as roof insulation in the Malaysian Construction industry due to its benefits and advantages. Nevertheless, Rockwool roof insulation has several flaws which can be countered by the porous ceramic roof insulation. As such the Rockwool roof insulation that has heavy properties and causes difficulty during delivery, is easy to cause rashes due to the stone fibers ingrained and the performance only depends on its thickness. While the Porous Ceramic Roof Insulation was designed to provide high-quality and be environmentally friendly to ensure that occupants in the building have good thermal comfort. Apart from having good roof insulation, the Porous Ceramic Roof Insulation will reduce the amount of freon gas emitted by HVAC systems which causes air pollution. It appears to ensure the safety and comfort of the occupants of the building. Thus, to ensure that the Porous Ceramic Roof Insulation is accessible to customers, various strategies should be taken by construction players in the Malaysian Construction Industry. As such, Porous Ceramic Roof Insulation will use indirect sales platforms, which will involve various intermediaries before the product reaches the users. In addition, it will help e-commerce marketing via official websites which will be easier to manage, to control the orders and also to ensure financial stability. In addition, the awareness of using Porous Ceramic Roof Insulation among construction players in the Malaysian Construction Industry can also be spread using social media platforms (i.e., Facebook and Instagram). As a result, these strategies will enhance the development of porous ceramic roof insulation in Malaysia, increase thermal comfort in the building by reducing the use of mechanical devices (i.e., HVAC and fan) and contribute to a greener environment.

Conclusion

This paper identifies the issues, problems concepts, and needs of Porous Ceramic Roof Insulation in the Malaysian Construction Industry. From the review, the following conclusion can be made: -

- The existing roof insulation in Malaysia faces problems related to material selection, and installation procedures and contributes to thermal discomfort in the building.
- Cool materials used in the building become one alternative to mitigate the building overheating.
- The Porous Ceramic Roof Insulation is viable in the Malaysian construction industry due to its great potential impact. These include roof cooling, water absorption, solar absorption, and heat absorption within the building without consuming energy.

Thus, further research should be emphasized on the application and effectiveness of porous ceramic roof insulation for selected buildings in Malaysia. While, the evaluation of other aspects such as durability, cost, and maintenance also requires further research.

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