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Closed Cell Elastomeric Foam Insulated Zinc Roof

Azween Irma Zainal[1*], Wan Asrul Asmi Wan Ishak[2]

[1] Kolej Komuniti Rembau, Negeri Sembilan, Malaysia
[2] Civil Engineering Department, Polytechnic Port Dickson, Negeri Sembilan, Malaysia

*Corresponding Author: azween@kkrembau.edu.my

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Abstract: *The thermal and acoustic inefficiencies of zinc roofing present significant challenges to residential comfort, particularly in rural Malaysia, where cost considerations favour its widespread use. The high thermal conductivity of zinc roofs is a source of excessive heat transfer into the home, and those zinc roofs also generate noise from rainfall. The aims of these studies are to determine the heat absorption difference between zinc roofs . Data was collected by directly measuring indoor temperatures and noise levels before and after insulation as part of the research. Between 1:00 pm and 2:00 pm, temperature readings were recorded; meanwhile, during rainfall at different time intervals, the noise measurements were taken. Results show that prior to insulation, under a zinc roof, the average temperature indoors was 46.6°C and after insulation with the closed cell elastomeric foam insulation, the average temperature was reduced down to 39.3°C. The reduction was similar; noise levels before insulation were 83.0dBA, and post insulation was 79.0dBA. Finally, these findings show a notable decrease in indoor temperatures of 8.6°C and noise levels up to 4.0dBA, resulting in improved residential comfort. Adopting closed-cell elastomeric foam insulation has economic and environmental benefits in addition to immediate thermal and acoustic benefits. The insulation layer also improves the duration of zinc roofs, whether it is coated with alkaline zinc masonry paint or by applying zinc-milled flat sheets, by preventing corrosion and structural deterioration. This work outlines the feasibility of using closed-cell elastomeric foam as an affordable insulation material in the tropical region for zinc roofing. It indicates that policies and homeowners should include such insulation solutions in affordable housing strategies.*

Keywords: Zinc roofing, closed-cell elastomeric foam, thermal insulation, noise, temperature

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1. Introduction

Residential comfort in Malaysia's tropical climate with high temperatures and high humidity is challenging. Some of the homes require efficient roofing solutions to maintain a stable indoor environment due to the constant exposure to sunlight and unpredictable weather patterns. Zinc roofing is inexpensive and available in rural areas and so is used there. Yet, despite its cost advantages, zinc roofs do retain some negative aspects such as high heat absorption and the generation of high noise during rainfall. The problems are uncomfortable for residents, especially those inhabiting homes without air conditioning, or extra insulation (Kaamin, Ab Rahman, Suwandi, Kesot, & Razzaq, 2013).

The problem with the zinc roof lying in the absorption and passing on of the heat. Zinc roofs cause immense rise in internal temperature when solar radiation is at its peak in the afternoon.

Unlike other roofing materials that have natural insulation capabilities, zinc does not have the ability to maintain the indoors at a temperature that is comfortable enough (Abdelrady, Abdelhafez, & Ragab, 2021). From this situation, dependence on cooling by means of electric fans and air conditioning is enormously strengthened, and accordingly the use of energy increases as well as household expenditures. Additionally, the dangers to the environment, arising from the excessive use of energy, are especially in connection with carbon emissions and depletion of the natural resources (Ezzati, Mohammadi, & Fard, n.d.).

Apart from being thermal inefficient, zinc roofs generate no less noise pollution, especially during heavy rainfall. Zinc has a metallic nature that amplifies the sound of raindrops and makes it disruptive to the home. The problem is compounded by the fact that this noise is especially disruptive at night when it interferes with some residents' sleep. Long term excessive noise levels can affect the welfare of the residents, in the following ways: concentration, productivity and the general quality of life. The additional risk of excess heat and the pollution by noise convey the necessity for an effective insulation that improves the performance of the zinc roof (Hens, Janssens, & Zheng, 2003).

1.1 Problem Statement

In rural areas due to the fact that zinc roofing is affordable and easy to install, it is widely used. Although the economic advantages of zinc roofs are clear, thermal regulation as well as noise pollution control is an issue. It is one of the key issues of excessive heat absorption. Being a highly conductive metal, Zinc transfers heat directly into the indoor environment, resulting in high-temperature increases, particularly during the middle of the day. This causes discomfort to residents, who have to resort to cooling through air conditioning and electric fans, further raising electricity consumption and costs of an already energy-intensive household (Yuliani, Hardiman, Setyowati, Setyaningsih, & Winarto, 2021).

Amongst the other major shortcomings of zinc roofing, it tends to generate too much noise during rainfall. Raindrops dropping on the metallic surface make loud noises, preventing sleep, concentration, and daily activities. Especially difficult in such conditions of heavy rain, this problem makes indoor environments uncomfortable to stay in and also harm the overall health of the residents.

Furthermore, such rainfall is detrimental to zinc roofs as they get rusted and corroded gradually. In the long term, it makes them less durable and pushes up the maintenance costs. The insulation solution must address these issues as heat transfer must be minimized, noise pollution should be reduced, and the lifespan of zinc roofs should be increased.

1.2 Objectives

The ultimate aim of this study is to find an efficient solution towards the issues surrounding zinc roofing in residential buildings. The objective of the study is to evaluate the response of closed-cell elastomeric foam insulation to the problem of excessive heat absorption, noise pollution, and life of the material. Thus, the research aims to show a cost effective sustainable way to boost residential comfort predominantly in rural areas where zinc roofing is used. To evaluate the performance of the closed-cell elastomeric foam insulation on the reduction of indoor temperatures, one of the major objectives is defined. This study seeks to find out how much insulation can reduce temperature fluctuations in houses when zinc roofs absorb and transfer heat directly into them. These findings can provide the basis for determining whether such a solution could provide a more stable and comfortable indoor environment with less dependence on artificial cooling.

One aim is to determine noise reduction due to closed-cell elastomeric foam insulation. This study aims to investigate whether the interior sound insulation material can substantially reduce the noise levels reflected by the roofing, and thus enhance indoor acoustic conditions. The research will quantify to what degree the material increases residential comfort by conducting sound level measurements before and after insulation.

Furthermore, this study will examine the long-term benefits of the recycled closed-cell elastomeric foam when roofing with zinc. Zinc roofing has the problem of corrosion and rust which causes frequent repairs and high maintenance costs. The research aims to exploit the protective properties of the insulation, to determine whether it could lengthen the life of a zinc roof, and thereby cut the maintenance overhead. This study proposes these objectives to contribute to practical and sustainable roofing solutions to increase the residential living conditions in tropical climates.

2. Literature Review

Zinc Roofing: Benefits and Challenges

In terms of affordability, availability, and ease of installation, zinc roofing is highly favoured and widely used in residential and commercial buildings. Zinc is lightweight and hence; less demanding for structural support than other roofing materials like tiles, concrete or asphalt shingles, which reduces construction costs. In addition, zinc is a highly recyclable material as well, a good choice in terms of the environment. Its malleability allows shape to be given to various designs; therefore, it is suitable for architectural applications that do not include standard roofing solutions (Kindangen, 2024).

However, despite such advantages, zinc roofing is too easily prone to many drawbacks (Zhang et al., 2021). The high thermal conductivity is one of the main concerns in terms of the fact that it absorbs excessive heat. Zinc is a metal that conducts heat very quickly and increases indoor temperature by a large amount in strong solar radiation areas (Rostami Tapeh Esmaeil, 2023). Zinc roofs are commonly found on homes, and while they are attractive, they can be unbearably hot at midday, making the need for additional cooling by fans or air conditioning, often by means of fossil fuel burning machines, an added energy consuming and very costly addition (Kindangen, Rogi, Gosal, & Mandey, 2024).

Zinc roofing tends to be quite noisy during rainfall which is another major problem. Raindrops, making contact with the metal surface, produce loud, disruptive noise that is painful and can disrupt sleep, communication, and the overall indoor climate noise (Jay et al., 2021). The problem is especially acute in places where there is frequent heavy rain. Zinc roofs are unlike tile roofs, which naturally dampen noise, or concrete roofs, which amplify sound, which makes it difficult for occupants to live in a peaceful indoor environment (Hosseinpour, Katbab, & Ohadi, 2022a).

Other than thermal and noise concerns, zinc roofs are susceptible to corrosion, especially in humid or coastal areas. Rust and structural degradation is caused by prolonged exposure to moisture and fluctuating weather conditions (Arumugam, Ramalingam, & Vellaichamy, 2022). This wastes over time and reduces the durability of the roof thus may require frequent maintenance and the cost of replacement. Zinc roofing is also often covered by protective coatings and insulation materials to extend the lifespan of zinc roofing and to improve its performance (Hosseinpour, Katbab, & Ohadi, 2022b).

Closed-Cell Elastomeric Foam Insulation

High performance insulation, closed cell elastomeric foam is highly thermal resistant and equally noisy. This is dense and moisture resistant foam making effective heat transfer prevention and minimizing temperature fluctuations within buildings (D'Agostino, Parker, Melià, & Dotelli, 2022). Closed-cell elastomeric foam, when applied to roofing systems, serves as a thermal barrier that inhibits the passage of heat, as well as contributes to a steadier indoor climate (Tariku, Shang, & Molleti, 2023).

Closed-cell elastomeric foam offers great benefit in that it resists moisture penetration. This foam, unlike traditional insulation material, will not absorb the water and gradually will deteriorate (Kindangen, 2024). The other insulation materials suffer from the fact that they become wet quickly in humid climates and would be destroyed in extreme conditions, making it particularly suitable for such use as mentioned earlier. Closed-cell elastomeric foam also helps protect the structural integrity of roofs by preventing the build-up of condensation, preventing potential mild growth and corrosion (Okokpujie et al., 2022). Closed-cell elastomeric foam is well known for its soundproofing over thermal insulation. The dense composition of foam helps absorb sound waves in order to reduce noise wave transmission from external sources like rainfall, traffic and industrial activity (Zheng, Carmeliet, Hens, & Bogaerts, 2020).

It can reduce indoor noise levels dramatically, increasing the residential comfort, if applied to zinc roofs. Specifically, in those places where noise pollution is an issue again and again, this helps occupant enjoy a quiet and peaceful living condition (Wang, Huang, & Yang, 2022). In addition, closed cell elastomeric foam has a long life and low maintenance. Installed once, it continues to insulate and reduce noise, without the need for regular replacement or repair. It is also environmentally friendly because its energy efficient properties contribute to having lower cooling costs by not needing air conditioning as often as possible leading to a similar cost effective property (Du, Hong, Gu, Li, & Wang, 2023).

Noise Pollution and Its Impact

Among urban and rural environments, noise pollution is a major issue as high noise levels ruin the well-being as well as the productivity of people subjected to such high noises. Particularly for residential noise pollution, it can cause psychological and physiological effects which affect the quality of sleep, stress levels and the general state of mental health. High noise levels can irritate and also shake focus, and in more extreme cases may even lead to cardiovascular problems (Bourikas, Gauthier, Khor Song En, & Xiong, 2021).

For zinc roofing homeowners, noise pollution is one of the major drawbacks in particular during heavy rain. The raindrops impact on the metallic surface of the roof gets amplified and results in loud and continuous noise inside the home. This makes residents behind enemy lines, disrupting household activities, including sleep and communication, demoralizing life for residents. Unlike most other roofing materials that naturally dampen or direct sound, zinc roofing does not (Aimar, Orgéas, Du Roscoat, Bailly, & Sentis, 2023).The use of closed cell elastomeric foam as a sound proofing material has been shown to reduce the amount of indoor noise disturbance. Elastomeric foam absorbs sound waves and dampens vibrations, reducing the transmission of external noise and thus making the indoor environment quieter (Hafez et al., 2023).

However, the effectiveness of this insulation material depends on thickness, density and how it is applied. Because foam can be closed-cell, properly installed, and provides a good noise barrier, it is a suitable solution in residential buildings with zinc roofs (Zheng, Janssens, Carmeliet, Bogaerts, & Hens, 2004).

Noise pollution also is a concern in industrial as well as commercial settings, apart from the residential use. High noise workplaces can mean decreased productivity along with increased stress on employees. By adopting such noise dampening materials in building construction, the working environment can be more comfortable, more so for businesses and for individuals (Dong, Kong, Mousavi, Rismanchi, & Yap, 2023). The addition of technical checks to enhance the energy efficiency and acoustic performance, usually through the installation of closed cell elastomeric foam are also possible (Lau & Choi, 2021).

Noise pollution is a general problem that affects millions of people in the world. Long term and practical solutions of reducing indoor noise disturbances are achieved through the integration of soundproofing material in roofing systems especially in zinc roofs (Tao, Ren, Zhang, & Peijs, 2021). Insulation of residential and commercial buildings reduces the noise flow through walls, floors and roofs and thins the sound pressure wave coming from outside to the building's surfaces, thus improving the acoustic balance of buildings and improving the well-being of building occupants while also promoting the building's sustainability and comfort (Couret & Párraga, 2022).

3. Methodology

This work evaluates the efficacy of closed-cell elastomeric foam insulation on improving the thermal and acoustic performance of zinc roofing. The methodology consists in a systematic treatment of data collection, analysis and evaluation. These include identifying the research problem, selecting the appropriate materials and equipment for measuring, collecting data through measuring and analysing results to measure the effect of insulation on a temperature and noise level (da Costa, Silva, Maciel, Cusi, Maquera, & Haddad, 2023).

An experimental research design of the study including measuring of temperature and noise levels before and after application of closed-cell elastomeric foam insulation to zinc roofs is followed. The significant advantage of this method is the direct comparison with the insulation material to assess how much it affects indoor thermal and acoustic conditions.

There are two major measurements taken in the data collection process: indoor temperature, noise levels. Indoor temperature readings are done before and after installation and these are then measured. Peak hours recorded temperature is at 1:00 PM to 2:00 PM that is when heat absorption is at its highest. Accurate temperature readings are obtained with the use of an infrared thermometer. Noise Level Measurement: Noise level measurements are taken at different periods of rainfall. Measurement of decibel level at different times of the day and night is done with a sound level meter. Inspectors read how well the material reduces noise before and after the insulation.

Certain materials and equipment are used in order to efficiently conduct this study. Underneath the Zinc roof, this material was applied to evaluate its insulation properties for thermal and acoustic purposes. Indoor Temperature Variations before and after insulation can be measured with the use of an Infrared Thermometer. Sound Level Meter (SLM) was used to measure noise levels during rainfall in order to ascertain sound proofing amalgamation effectiveness. Insulation material: Required for every insulation job to ensure a proper use. Ladders and Safety Gear: Required for safe installation of insulation on the roof.

The accuracy of the results may be affected by some limitations. These temperature and noise measurements can be influenced by environmental factors such as fluctuation in weather conditions, the change in rainfall intensity and change of sunlight exposure. Thickness and quality of material as well as insulation effectiveness may also depend on it. Several other insulation materials can be further tested in the future to determine better insulation materials with varying application techniques that will improve zinc roofing performance efficiently.

4. Results and Discussions

Insulation is analysed with respect to the recorded data for temperature and noise in order to determine its effectiveness of a reduction. The decrease in heat absorption and the amount by which noise level drops are assessed. Findings are in the form of tables and graphs, using data visualization techniques as bellows.

Table 1: Temperature Measurements Before and After Insulation

Day /Time (PM)	Temperature Before (°C)	Temperature After (°C)	Differences (°C)
Day 1 (1:00 - 2:00pm)	46.4	38.9	-7.5
Day 2 (1:00 - 2:00pm)	45.1	39.6	-9.4
Day 3 (1:00 - 2:00pm)	48.3	39.3	-9.0
Average	46.6	39.3	-8.6

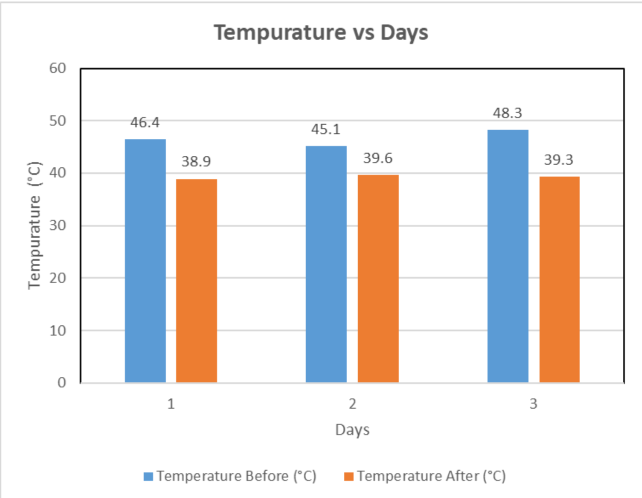

Figure 1: Graph of Temperature Versus Day

The results have been measured for 1 hour between 1.00pm to 2.00pm for 3 days during the afternoon. From the results in Table 1, the temperature recorded before installation of the closed-cell elastomeric to the zinc roof shows that the temperatures are between 46.4°C for the first day, 45.1°C for the second day and 48.3°C for the third day. This shows that the temperature at the zinc roof recorded very high for the third day. After the installation of the closed-cell elastomeric to the zinc roof, it shows that the temperature decreased from 46.4°C to 38.9°C for the first day with a difference of 7.5°C for the first day. For the second day of the measurement by using the thermometer, it has recorded that the temperature is 45.1°C decreased to 39.6°C with a 9.4°C reduction after the installation of the insulation. For the third day of installation, the temperature decreased around 9°C from 48.3°C to 39.4°C. The average of the temperature is 46.6°C before installation of insulation and the average of temperature after insulation is 39.3°C which leads to average reduction of 8.6° C. From these results, it can be concluded that the closed-cell elastomeric foam zinc roof does decrease the temperature after installation.

Table 2: Noise Level Measurements Before and After Insulation

Day (during rain)	Noise Level Before (dBA)	Noise Level After (dBA)	Differences (dBA)
Day 1	84.7	79.8	4.9
Day 2	80.5	77.3	3.2
Day 3	83.7	79.9	3.8
Average	83.0	79.0	4.0

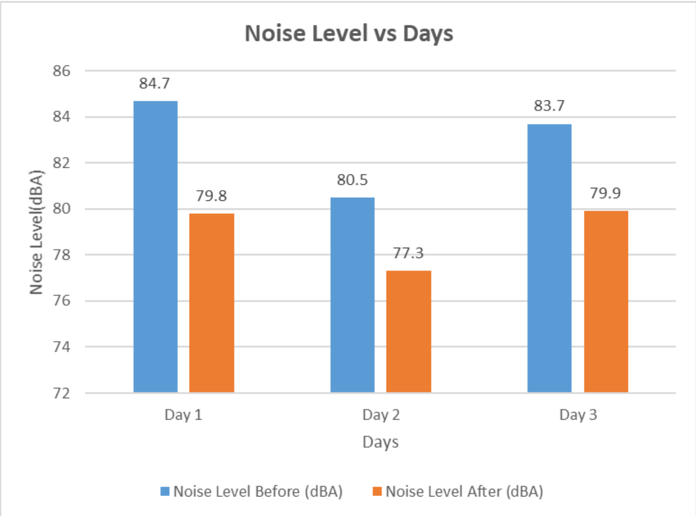

Figure 2: Graph of Noise Versus Day

Table 2 shows the noise level measurement before and after the installation of the closed-cell elastomeric to the zinc roof. The measurements were taken by using the sound meter level during heavy rain for three days. From these results, the measurement of the noise level reduced to 79.8dBA from 84.7dBA with the difference 4.9dBA for day 1 and for day 2 the noise level reduced 3.2dBA from 81.5dBA to 77.3dBA. For the third day, the noise level was reduced to 3.8dBA from 83.7dBA to 79.9dBA. The insulation reduced levels of noise up to 4.9dBA, significantly improving the indoor acoustic comfort. From these results, the average for the noise level is 83.0dBA before the installation of the closed-cell elastomeric to the zinc roof while after the insulation the average of noise reduced to 79dBA with average reduction difference is 4.0dBA. The relevance of these results with previous research stressing sound dampening properties of closed cell elastomeric foam is also supported.

5. Conclusion

This research shows how closed cell elastomeric foam insulation can serve to overcome the chief restrictions of zinc roofing. This solution reduces indoor temperatures and noise pollution in a cost effective, sustainable, and efficient manner as an alternative to the means of improving residential comfort in a tropical climate. Future research may investigate additional sustainable roofing materials and affordability to further improve the viability of viable sustainable roofing solutions.

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