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Thermal Performance of Waste Rubber Wall Panel (WRWP) as Overheat Resistance in Building Construction

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Abstract: One of the significant Malaysian building development issues would be overheating building space as the common building materials are unable to control thermal absorption in the building. Based on Malaysia Standard Department 2007 guideline, the recommended temperature for interior design environment in Malaysia should be between 23ºC and 26ºC. Because of its area located at latitude 4.2105° N and longitude 101.9758° E, Malaysia gets the sun almost every day throughout the year. A significant heat increase in Malaysian houses gets from building elements. Therefore, this situation is because the common building material cannot control the thermal absorbent into the building. Laboratory analysis was conducted to determine the feasibility of developing a low-cost building material with acceptable thermal properties. The thermal performance of the used waste rubber was investigated to produce the new insulation building material (WRWP). Waste rubber from tyre production was used in this study. 700 grams of waste rubber was mixed with 400 grams of adhesive glue for every wall panel. Installing WRWP helps to decrease 28% of indoor temperature compared to buildings without WRWP. It also helps to slow down the heat increase when the temperature outside the building increases. WRWP installation also accelerated internal temperature when the temperature outside decreases.

Keywords: Waste, rubber, thermal, insulation

1. Introduction

A global environmental issue in 21st century is climate change; it has become one of the most important and difficult issues for humanity to deal with. In this situation, Malaysia is no exception to climate change. A number of research have been carried out in order to better understand the overall temperature fluctuations in Malaysia (Tan et al., 2020; Yatim et al., 2019; Suhaila & Yusop, 2018). A study by Danial (2019) over the previous two decades, Malaysia has seen warming and precipitation abnormalities, especially in the northern half of the country. Temperature fluctuations for Malaysia vary from +0.70°C to +2.60°C, with variations in precipitation from -30% to +30% (Haliza, 2009). This temperature increase has an impact on environmental and human systems and even housing. Due to this, the extra heat that should be released into the atmosphere are retained in the building.

In addition, the location of Malaysia above the equator causes it to receive rain and heat throughout the year. This causes Malaysia to receive rain and heat throughout the year. A whole year of hot and humid weather is typical in tropical regions (Danial, 2019). Prolonged sunlight almost every day has increased the ambient temperature in Malaysia. The year 2020 is expected to be the second hottest since 1850.

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From this situation, these hot weather conditions have affected the indoor temperature of a building or housing. During the day, the inside temperature of a residential house rises dramatically, whereas the temperature drops slightly at night. This occurs when there is a temperature differential between inside and outside the building.

1.1 Modes of Heat Transfer

While most individuals desire to keep their climate comfortable, persons who live in either uncomfortable hot or cold temperature would prefer to be in a comfort level. It is occurring from an area of higher temperature to an area of lower temperature. A consequence of this is that outside heat let into the building when the temperature outside is higher than the temperature inside. Consequently, outdoor heat enters the building when the temperature outside is higher than inside the building. Outdoor air temperature is a driving force for natural ventilation, as the difference between indoor and outdoor air temperature causes the stack effect (Goodfellow and Wang, 2021). The quicker heat moves to the cooler area when has a great temperature discrepancy and makes the building's indoor temperature increase rapidly.

It is crucial to understand how heat moves across a structure. Any kind of heat may be conveyed using three different methods: conduction, convection, or radiation (The Thermal Insulation Association of Southern Africa Handbook, 2001). The mathematical expression of the different underlying physics associated with these discontinuities gives rise to three modes of heat transfer: conduction, convection, and radiation (Sidebotham, 2015).

2. Thermal insulation material

In order to prevent excessive heat absorption by the structures, a thermal insulation material is added to ensure low building temperatures. Thermal insulation materials are designed to minimise heat movement by decreasing heat conduction, convection, radiation, or all three. The most important aspect of thermal insulation is to decrease the heat transmission from outside to inside. Recent studies Wang et al., (2018) point out in a building, the thermal insulation part is very important for being able to withstand both cold and heat. The insulation of thermal contact or within the range of radiative influence reduces the transfer of heat between objects (Connor, 2019).

Therefore, the study towards thermal insulation systems for building elements has grown in recent years. The study about building insulation material may be found in Jelle et al., (2010); Schiavoni, (2016); Bakatovich, & Gaspar, (2019). There are several advantages of home insulation like add building comfort, create a cleaner home atmosphere, minimize energy costs, and positively affect the environment. To make the living environment more comfortable under adverse weather conditions, installing new insulation in the house would do the trick. As a result, the size of cooling and heating systems is decreased, as well as the amount of heat that is lost or gained in a structure Guoet al., 2019). As a result, house insulation reduces power expenditures as well as the cost of ventilation and heating.

2.1 Insulation Material

In the market, slab or block insulation, roof and loft insulation, blanket insulation, wall insulation, flat roof insulating materials, floor insulation, sheets with reflective finishes, lightweight materials, wall panel insulation materials, and attic insulation materials are offered. Natural rubber, expanded polystyrene, cork board, aerogel or other nano-porous material, cellular glass, cellulose fibre, dense rock wool, woven fabric waste, cotton, agro waste, and wood fibres other materials are used to create these materials. The reuse of various types of agricultural wastes or industrial wastes as thermal insulation materials can make a significant contribution to sustainability.

The 3R (Reduce, Recycle, Reuse) concept was suggested by the architects and aims to reduce the usage of non-renewable energies and materials to conserve energy and reduce environmental effects. Furthermore, the most cost-effective method is to reuse waste materials without changing the composition of the material, which can reduce energy consumption during the thermal insulation material's manufacturing process.

The research community has made significant efforts to identify alternative renewable building materials and minimal technologies that result in more sustainable and economical construction that meets today's comfort requirements (Usman et al., 2012). From an environmental standpoint, developing and implementing innovative, efficient technology and goods with improved manufacturing process parameters is important to reduce energy use and the use of raw materials (Vasilache, 2010). Thermal quality enhancement in buildings by thermal insulation is critical for sustainable development (Diakaki et al., 2008; Galvin, 2010; Lopes et al., 2005). Standard insulation materials, on the other hand, such as extended polystyrene, mineral wool, and polyurethane foam, are inefficient and expensive (Monahan & Powell, 2010). To reduce this situation, the selection of materials that reduce energy consumption is very important.

2.2 Waste Rubber as Abundant Material

The amount of rubbish produced on daily basis by Malaysians has increased by 100.75%. It increased to 38,142 tonnes in 2018 compared to 19,000 tonnes in 2005 (Muhammad, 2010). This figure does not include industrial solid waste. Each industrial production process will produce a lot of solid waste, which is very hard to manage. This solid waste has harmed the ecosystem, as well as threatened animals, plants, and even human lives. This solid waste is very difficult to dispose of and takes a long time to decompose or be destroyed. Occasionally, some of these wastes are unable to be disposed of at all.

One of the industries that produce solid waste that is difficult to dispose of is the tire processing factory. The number of tire manufacturing plants in Malaysia is expanding, while the creation of solid waste or waste rubber as a result of this manufacturing process is also expanding. This waste rubber will no longer be used by the factory, and it will be disposed of.

One of the most critical concerns in waste rubber management is the high cost of solid waste management in terms of transmission from garbage to the disposal location and the disposal technique used. These wastes are classified as difficult-to-decompose wastes and are frequently disposed of by incineration. Air pollution will result from the burning of this waste rubber since black smoke, and carbon dioxide will be emitted into the atmosphere.

2.3 Rubber as Insulation Material

Rubber, either natural or synthetic form has been used as an isulator since 1870. Rubber is well-known for their elasticity, water resistance, and electrical insulation. The electrons are firmly connected in rubber molecules and normally need much energy to separate them. Rubber is an excellent insulator since it does not conduct heat and slows down electrons. The purpose of an insulator is to halt or slow the flow of electrons through the material. Since rubber does not have free electrons that can quickly move and cause the electrons to prevent thermal transfer into the building element. Ultimately, it makes it a better insulator.

Waste rubber from tyre production (WRTP) used as thermal insulation material is investigated in this research work. Recently, few studies have been done on the rubberized thermal insulation properties. In developing the composites for heat isolation, the use of devulcanized waste rubber tyres (Hittini et al., 2010) Evaluated the assessment of thermal insulation and mechanical qualities of waste composite/natural rubber (Abdel Kader et al., 2011). In addition, (Hu et al., 2020) investigated the co-pyrolysis of real-world plastic and tires waste in terms of thermal behaviour, kinetics, and gas evolution characteristics. Investigate the effects of proportion and particle size of rubber gradation on thermal, mechanical and acoustic characteristics of plastics using rubber mortars (Herrero et al., 2013). Investigates through experimental and modelling methods, to study the cement composite combine with waste rubber in thermal conductivity contact (Benazzouk et al., 2008). All these studies showed rubber decreased thermal absorption and can act as thermal insulation material.

3. WRWP Materials

Waste rubber wall panel (WRWP) are created by combining two materials which are waste rubber from tyre production as shown in Fig. 1 and liquid glue shown in Fig. 2. These waste rubber, taken from the factory are readily available in bullet chip form. So, it can reduce the cost the material processing and labour to prepare the waste material in bullet form. These waste rubber that are abundantly found in the factory would normally be disposed at the landfills. This method of disposal can cause environmental pollution. The chemical in the waste rubber is also the same as the old tyres, which cannot be disposed forever. In this study, Dunlop contact adhesive glue was chosen to mix with the waste rubber as the bonding material as it dries quickly and easier to manage (see Fig.2). This adhesive is readily accessible at a reasonable price, lowering the cost of WRWP processing.

Fig. 1 - Waste Rubber from Tyre Production

Fig. 2 - Dunlop contact adhesive glue

3.1 WRWP Making Process

Thermal tests were conducted based on the study's objective to determine how much indoor thermals reduces after the installation of WRWP as wall insulation material and the pattern of temperature rise and fall when the outdoor temperature changes. Experimental work was constructed with brick walls using a 3.00 ft x 3.00 ft house model was constructed with the brick wall and cement plaster. The thickness of the brick wall is a half brick wall. Fig. 3 shows the house model for this test.

Fig. 3 - House Model

Figure 4 shows the waste rubber wall panel (WRWP) designed in square form 1.00ft x 1.00 ft with a maximum thickness of 0.13ft. Every wall panel contains 700 grams of waste rubber mixed with 400 grams of glue. This WRWP was produced follow the step below:

- Waste rubber and glue were blended into a mixture with the 1:1.75 (Glue: waste rubber).
- The combined mixture rubber was placed in the oiled coated steel mould designed in an attractive shape like in Fig. 5.
- This design will make this WRWP more attractive to use as an interior wall finishes.
- Then it is pressed by placing a weight on the mould cover for 3 hours to ensure the rubber can stick firmly to each other.
- Next, the WRWP is removed and left to dry for 24 hours. WRWP was installed on the wall of the house model with the same glue such in Fig. 6.

Fig. 4 - Waste Rubber Wall Panel (WRWP)

Fig. 5 - Steel Formwork

Fig. 6 - WRWP installation

3.2 WRWP Thermal Test

The temperature and thermal conductivity of the wall without the WRWP are both measured using a single heat flow meter and surface temperatures sensors. This example is shown in Fig. 7. Another flowmeter was placed outside the model to determine the outside temperature (see Fig. 8).

Temperature readings were taken inside and outside the house model, every two hours from 7.00 am until 9.00 pm. After installing WRWP, the indoor and outdoor temperature of the house model were recorded every two hours again from 7.00 am until 9.00 pm. The record data were compared between the temperature inside and outside the house model.

Fig. 7 - Heat Flowmeter and Surface Temperatures Sensors

Fig. 8 - Outside Heat Flowmeter

4. Result

Table 1 showed the test result of the inside and outside building temperature before WRWP installation, while Table 2 showed the building temperature after WRWP installation. Both tables also show Δt based on temperature differences.

$$\Delta t = T\ hot - T\ cold \qquad (1)$$

Table 1. and Table 2. showed the maximum Δt value for building without WRWP is 2.9 °C at 1.00 pm while building with WRWP is 3.8°C at 3.00 pm. It shows the temperature inside the building with WRWP is lower than the thermal building without WRWP.

Table 1 - Temperature data without WRWP installation

Time	**Without WRWP (°C)**		
	Outside Temperature	**Inside Temperature**	**Δt value**
7.00 am	26.3	28.1	1.8
9.00 am	29.1	27.7	1.4
11.00 am	32.4	30.4	2
1.00 pm	33.8	30.9	2.9
3.00 pm	35.2	33.7	1.5
5.00 pm	34.1	33.1	1.0
7.00 pm	30.1	30.5	0.4
9.00 pm	28.8	29.7	0.9

Table 1 - Temperature data with WRWP installation

Time	**With WRWP (°C)**		
	Outside Temperature	Inside Temperature	Δt value
7.00 am	26.9	27.5	0.6
9.00 am	28.3	26.7	1.6

11.00 am	31.7	28.9	2.8
1.00 pm	33.9	30.2	3.7
3.00 pm	35.7	31.9	3.8
5.00 pm	33.2	30.7	2.5
7.00 pm	30.1	29.7	0.4
9.00 pm	29.4	30.1	0.7

5. Discussion

Fig. 9 and Fig. 10 showed the graph of the data analysis from Table 1 and Table 2; both figures show the line shape of the difference between outside with indoor temperature for both situations. The line for Inside temperature for the house model without WRWP is unstable, and we can see the distance between the line inside temperature and the outside temperature is close. While the line for Inside temperature for the house model without WRWP is unstable, and we can see the distance between the line inside temperature and the outside temperature is close.

The line for inside temperature for the house model with WRWP installation is stable, and the distance between the line inside temperature and the outside temperature is a little far. The result proved the installation WRWP can reduce heat transmittance into the building.

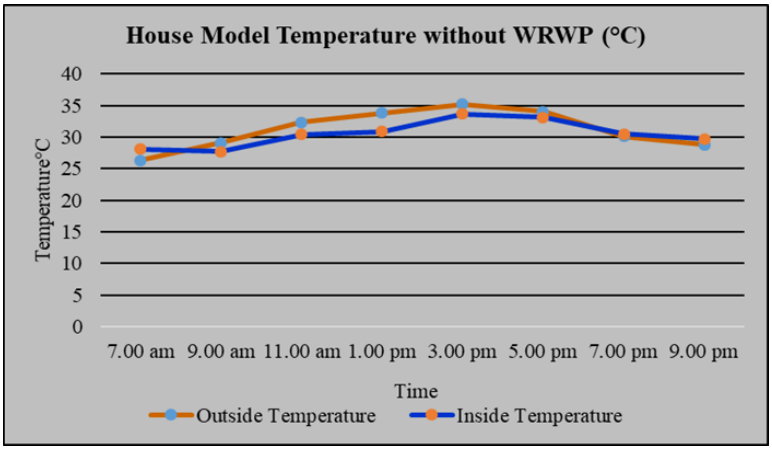

Fig. 9 – House Model Temperature Without WRWP

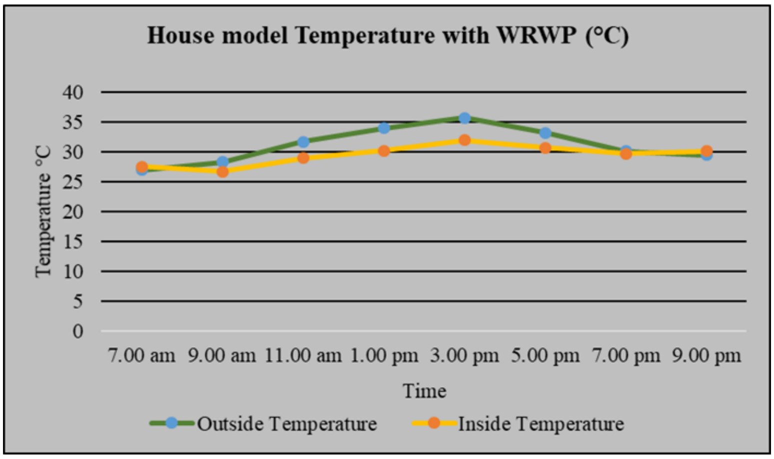

Fig. 10 – House Model Temperature With WRWP

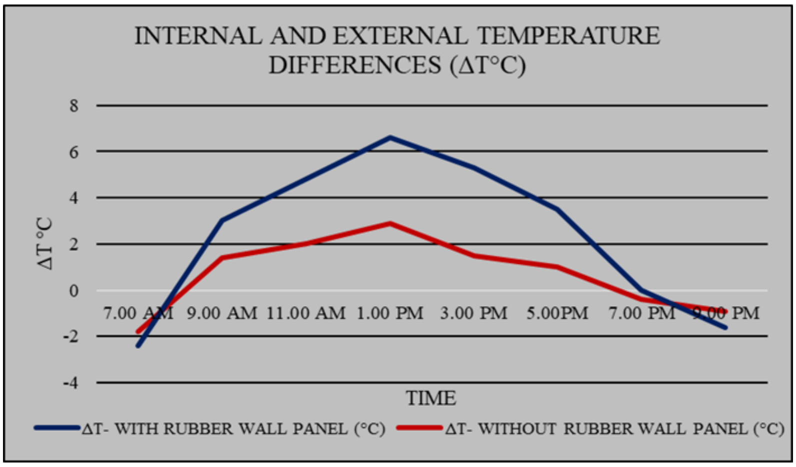

Fig. 11 – Δt value for wall with WRWP and without WRWP

The data in Fig. 11. shows that Δt value of the house model with WRWP gradually absorbed heat during hot temperature compared to the house model without WRWP. It can see that Δt value from 7.00 am until 1.00 pm was slowly increased for the building with WRWP compared to the building without WRWP.

The graph also showed the Δt value for building with WRWP has a rapid temperature drop in the evening compared to building without WRWP. It is because WRWP was rapidly released heat during cool temperatures. It is because waste rubber is the thermal insulation material that can reduce thermal absorption into the building. It is also can release heat quickly during the cool temperature.

6. Conclusion

The waste rubber from tyre production as a WRWP is a good alternative to reduce heat from the outside of the building transmitted into the building. Besides, it also can slow down the absorption of heat into the building when the weather outside is hot and also release heat out of the building quickly when the weather outside is cold. The process of producing it uses low cost due to use the abundant material and also already in bullet chip form. Reuse of this material also can reduce environmental pollution cause of reducing the dumping of these waste rubber at landfills.

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