Comparative Study Of Solar Radiation On Clay Roof Tiles And Teki Grass-Based HDPE Composite Roof Tiles

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Abstract

Along with the advancement of science and technology, various types of tiles one of them is the use of polymer composites as the main material for making tiles. Roof tiles are generally made of clay and metal. The high use of plastic in Indonesia causes high waste generation and environmental damage. Efforts to reduce the generation of plastic waste are by utilizing plastic waste into polymer composite tiles. The tile requirement is that it must be able to withstand solar heat radiation and rainwater. The purpose of this study was to determine the comparison of solar radiation values on clay tile aerial, pure HDPE tile and 20% teki grass reinforced HDPE composite tile given 5% alkaline treatment for 4 hours. The test was carried out using exposure to direct solar radiation with a tile angle of 30°. The test data was obtained on the composition of 20% teki grass, the temperature produced on the upper and lower surfaces of the tile tends to be lower than pure HDPE and the top surface of the composite tile has a difference of 0.6°C higher than clay tile but for the bottom surface has a difference of 1.3°C lower than clay tile. Based on the radiation rate of HDPE and 20% teki grass tiles have a higher value than clay tiles so that HDPE reinforced teki grass 20% of tiles can be used as alternative materials to replace clay tiles because they have good heat resistance.

Keywords: composite; hdpe; radiation rate; roof tile; teki grass

Abstrak

Seiring dengan kemajuan ilmu dan teknologi jenis genteng bermacam-macam salah satunya yaitu penggunaan komposit polimer sebagai bahan utama pembuatan genteng. Genteng pada umumnya terbuat dari tanah liat dan metal. penggunaan plastik yang tinggi di Indonesia menyebabkan terjadinya timbulan sampah yang tinggi dan terjadi kerusakan lingkungan. Upaya dalam mengurangi timbulan sampah plastik yaitu dengan memanfaatkan sampah plastik menjadi genteng komposit polimer. Syarat genteng yaitu harus mampu menahan radiasi panas matahari dan guyuran air hujan. Tujuan dari penelitian ini adalah untuk mengatahui perbandingan nilai radiasi matahari pada mataerial genteng tanah liat, genteng berbahan HDPE murni dan genteng komposit HDPE berpenguat rumput teki 20% yang diberikan perlakuan alkali 5% selama 4 jam. pengujian dilakukan dengan menggunakan paparan radiasi matahari langsung dengan sudut genteng yang digunkan sebesar 30°. Data hasil pengujian didapatkan pada komposisi rumput teki 20%, suhu yang dihasilkan pada permukaan atas dan bawah genteng cenderung lebih rendah dari HDPE murni dan permukaan atas genteng komposit tersebut memiliki selisih 0,6 lebih tinggi dari genteng tanah liat tetapi untuk permukaan bawah memiliki selisih 1,3°C lebih rendah dari genteng tanah liat. Berdasarkan laju radiasi genteng berbahan HDPE dan rumput teki 20% memiliki nilai lebih tinggi dibandingkan dengan genteng tanah liat sehingga genteng berbahan HDPE berpenguat rumput teki 20% dapat digunakan sebagai bahan alternatif pengganti genteng tanah liat karena memiliki ketahanan panas yang baik.

Kata kunci: *genteng; hdpe; komposit; laju radiasi; rumput teki*

1. Introduction

Along with the advancement of science and technology, various types of tiles are used, one of which is the use of polymer composites as the main material for making tiles. The development of composites made from natural fibers and the use of matrices derived from plastic waste are increasing, this aims to produce environmentally friendly products and achieve sustainability. The high use of plastic in Indonesia has led to the accumulation of waste and environmental damage such as flooding and soil pollution, one of the solutions to reduce the amount of waste is to maximize the use by reusing it into more useful items [1].

Polymer composite roof tiles are one of the ways to produce eco-friendly products. Composites are a combination of two or more materials to create a lighter and stronger material [2]. The advantages of composites are that they can

reduce weight, increase strength and are resistant to corrosion properties, besides that composites can be designed to comply with geometric, mechanical, chemical and structural requirements [3]. The main component in the composite is the matrix and fiber, where the matrix functions as a binder because it has ductile, binding properties, while the use of fiber functions as a reinforcement because it has elastic properties and good tensile strength [4]. In the use of fiber composites are classified into 2 types, Natural and Synthetic fiber composites [5]. In general, the microstructure of natural fibers depends on the presence of a large number of non-cellulosic components, including hemicellulose and lignin. [6,7]. While the use of matrices in composites can be divided into Metal Matrix Composite (MMC), Ceramic Matrix Composite (CMC), and Polymer Matrix Composite (PMC), these three types of matrices can be used in composites. The use of polymer matrix has a wide development due to its high specific strength and modulus as well as its low material and production cost. [8].

Roof tiles are an important component for roofs in the construction field. Roof tiles are generally made of clay or metal but as technology developments tile materials are increasingly varied, one of which is composite roof tiles. Fungsi utama genteng adalah untuk menahan terik matahari dan air hujan. In its use, clay roof tiles are the most widely used roof tiles because they have good strength and solar heat resistance, however, the weakness of this clay tile is that it has a heavy weight so that it adds more load to the roof structure of the house. The roof surface has the highest solar radiation exposure of about 50% to 70% of the total heat gain into the building [9]. Heat transfer is the term used to describe the flow of energy that occurs as a consequence of a change in ambient temperature [10]. Radiation heat transfer is a kind of heat transmission that doesn't include a medium or substance in the middle [11].

Research on polymer composite roof tiles has been carried out, such as research conducted by Rohman Sidik where physical and mechanical properties of the addition of polypropylene and low density polyethylene to wood plastic composite were tested. The constituent components in this composite are PP waste, LDPE, and wood powder. The results of this study are composites that use low density polyethylene matrix have higher physical and mechanical properties compared to polypropylene plastic [12]. Moreover, Yenny et al. did research on polymer composite roof tiles constructed from banana fibers. The study was carried out by combining polypropylene polymers with banana fibers using an extruder machine, with changes in composition of 10%, 20%, and 30%. The findings of this research were published in the journal Polymer Composite Roof Tiles. Based on the results of thermogravimetric analysis (TGA) testing, the objective of this study is to identify the composition that yields the best results when compared to pure polypropylene. Degradation occurred at temperatures ranging from 240 to 400^{o}C, and the sample's strength was reduced by 50% compared to that of pure polypropylene [13]. According to earlier studies that have been conducted in the past, namely the exploitation of waste plastic and glass as the primary material for the production of composite roof tiles, which have been carried out by Jalil, the objective of the study that has been carried out is to assess the flexural load strength, water absorption rate, and heat. The results of this study show a flexural strength of 6,355.31N, water absorption of 0.5% and heat absorption of 77.63% [14].

The use of natural fibers in the manufacture of composites has many advantages, not only lower costs, but the use of natural fibers also has the advantage of good mechanical properties and thermal stability so that its development is increasing [15]. The composite used in this research was created using recycled high-density polyethylene (HDPE) and teki grass (Cyperus rotundus L). Because of its abundance and accessibility, teki grass and HDPE trash are usedHDPE plastic is used because it has lightweight, strong properties and good thermal resistance, while teki grass is used because of its abundance and is often used as a weed on agricultural fields [16–18]. Therefore, research is needed on the utilization of HDPE plastic waste to produce environmentally friendly and sustainable composite materials.

This research was conducted with the aim of knowing the comparison of the heat transfer value of HDPE polymer composite roof tiles reinforced with teki grass (Cyperus rotundus L) with clay roof tiles when exposed to direct solar radiation. Heat transfer values can be obtained based on variations in the composition of HDPE and teak grass (Cyperus rotundus L) through direct solar radiation exposure testing by measuring the temperature of the upper and lower surfaces of the roof tiles.

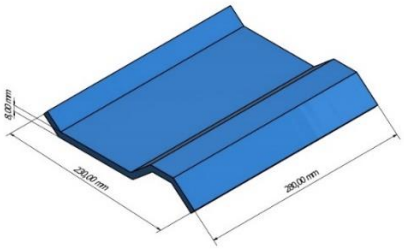
2. Research materials and methods

In this study, the research approach used was experimental, the data collection process began in November 2023 to January 2024. The materials used in this study are clay roof tiles, pure HDPE roof tiles, and roof tiles made from HDPE reinforced with 20% teff grass written as variations I, II, and III which are listed in Table 1.

Table 1. Variation of Materials

Variation	Type of roof tile
I	Clay
II	HDPE Murni
III	HDPE + Rumput Teki 20%

The dimensions used in this study are the length, width, and height of the composite tile samples found in Figure 1.a. In the HDPE and teki grass composite, the fibers used were given 5% alkali treatment for 4 hours to remove lignin to strengthen fiber bonds, solar radiation testing on roof tiles was carried out with a tile angle of 30° which was carried out for one month consecutively every one hour from 10:00 AM to 16:00 PM, carried out in the open space of the Engineering Faculty building of the Veteran National Development University Jakarta. The test data resulting from the temperature of the top and bottom surfaces of the roof tiles measured using the DS18B20 sensor where the output of the measurements is in excel form. The tile testing scheme can be seen in Figure 1.b



(a)

(b)

Figure 1. (a) Dimension of Roof Tile sample, (b) Schematic of Solar Radiation Testing on Composite Roof Tile

From the results of solar radiation testing, it can be calculated for the value of radiation heat transfer using Equation (1) radiation heat rate in steady state conditions with the difference in temperature of the upper and lower surfaces of the tile. Data processing is done using Microsoft Excel. The data will be presented in the form of a graph that explains the relationship between the variables studied. Based on the graph, the results and conclusions of the study will be obtained.

$$\boldsymbol{p = \varepsilon \cdot \sigma \cdot A \cdot \Delta T^4} \qquad (1)$$

With $\boldsymbol{p}$ is the radiation heat rate (J/s), $\boldsymbol{\varepsilon}$ is the emissivity of the object,, $\boldsymbol{\sigma}$ is the Stefan-Boltzman constant $(\boldsymbol{5,67 \times 10^{-8}\ W/m^2k^4})$, $\boldsymbol{A}$ is the surface area of the object (m2), $\boldsymbol{\Delta T}$ is the temperature change (K).

3. RESULTS AND DISCUSSION

Based on the results of research that has been carried out through direct solar radiation testing, the temperature data of the upper surface and lower surface of clay tiles, HDPE composite tiles reinforced with 20% teff grass and tiles made from pure HDPE can be seen in Table 2.

Table 2. Average roof tile surface temperature (C)

Average surface temperature of tile (C)			
Time	**Average temperature of top (C)**		
	T.I	**T. II**	**T. III**
10:00	43,8	45,5	44,9
11:00	46,0	47,4	46,6
12:00	45,6	46,7	45,5
13:00	42,4	43,0	42,3
14:00	36,9	37,1	36,4
15:00	32,8	33,6	32,0
16:00	29,4	30,8	29,5
Average temperature of bottom (C)			
10:00	40,6	41,4	40,3
11:00	42,9	42,8	41,6
12:00	43,0	42,8	41,1
13:00	40,3	39,3	38,4
14:00	35,9	35,4	34,3
15:00	32,0	32,7	31,0
16:00	28,7	30,3	28,8

Table 2 shows that the results of the test obtained data on the average temperature of the upper and lower surfaces in sample I, sample II, and sample III. The temperature measurement time starts from 10:00 AM until 16:00 PM which is done every 1 hour. From the table, a graph is obtained for the difference in surface temperature distribution of each sample which can be seen in Figure 2.

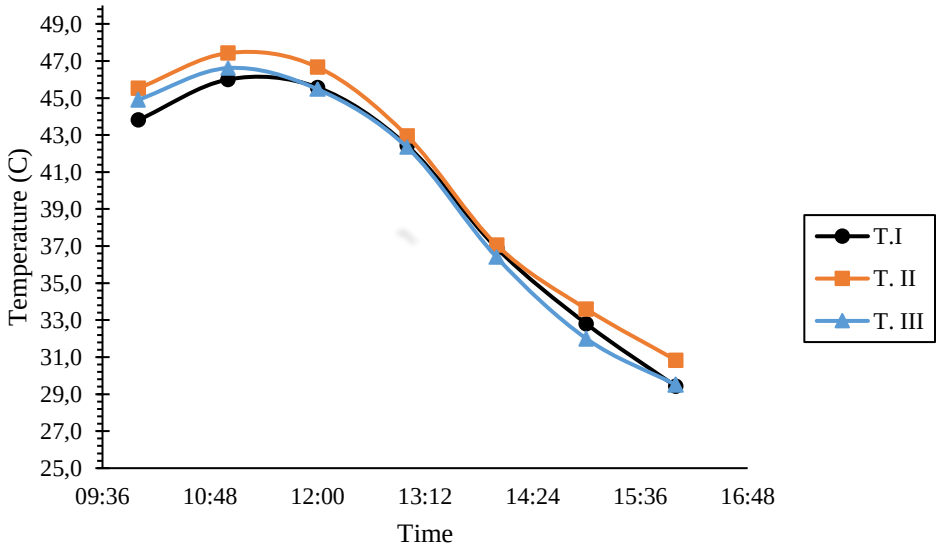


Figure 2. Temperature distribution of top surface (C)

Based on Figure 2 the average distribution of top surface temperature in each sample as a whole there is a difference, the highest average value of top surface temperature occurs at 11:00 AM where the highest top surface temperature is found in sample II of 47.4ºC, while the lowest top surface temperature is found in sample I of 46ºC, in sample III for the average top surface value of 46.6ºC the value is still lower than sample II. From the results of the solar radiation test, the lowest temperature occurred at 16:00 PM, where the lowest value was in sample I with a value of 29.4ºC, while the temperature in samples II and III at that time was 30.8ºC and 29.5ºC where sample III was still higher than sample I. Based on the test results that have been carried out for the distribution of the average bottom surface temperature in each sample can be seen in Figure 3.

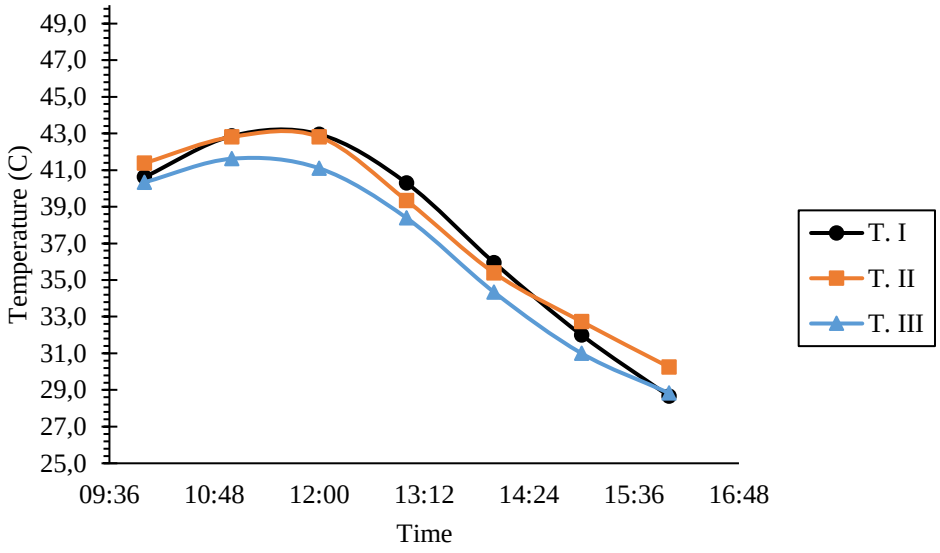


Figure 3. Temperature distribution of bottom surface

Based on Figure 3, there are differences in the average distribution of the lower surface temperature in each sample as a whole, the highest average surface temperature value occurs at 11:00 AM where the highest lower surface temperature is found in sample I of 42.9ºC, while the lowest upper surface temperature is obtained in sample III of 41.6ºC, in sample II for the average value of the lower surface of 42.8ºC, the value is still lower than sample I. From the results of the solar radiation test, the lowest temperature occurred at 16:00 PM, where the lowest value was found in sample I with a value of 28.7ºC, while for the lower surface temperature of samples II and III at that time it was 30.3ºC and 28.8ºC where sample III was lower than sample II.

The research data shows that the upper and lower surface temperatures of each sample are highest in sample II with pure HDPE composition. Meanwhile, the lowest surface temperature is found in sample I, namely clay tile. In the HDPE

polymer composite tile reinforced with 20% teki grass found in sample III for the distribution of the average temperature of the upper surface has a difference of 0.6ºC and for the lower surface 1.3ºC lower than the clay tile. Based on the difference in upper and lower surface temperatures on the tile, the radiation rate in each sample can be calculated using Equation (1) which can be seen in Table 3.

Table 3. Average roof tile radiation rate (J/s)

Sample	Time	Top temperature (C)	Bottom temperature (C)	Rate of radiation (J/s)
T. I	10:00	43,8	40,6	2,7
	11:00	46,0	42,9	2,8
	12:00	45,6	43,0	2,3
	13:00	42,4	40,3	1,9
	14:00	36,9	35,9	0,8
	15:00	32,8	32,0	0,6
	16:00	29,4	28,7	0,6
T. II	10:00	45,5	41,4	3,8
	11:00	47,4	42,8	4,4
	12:00	46,7	42,8	3,6
	13:00	43,0	39,3	3,4
	14:00	37,1	35,4	1,3
	15:00	33,6	32,7	0,5
	16:00	30,8	30,3	0,3
T. III	10:00	44,9	40,3	4,2
	11:00	46,6	41,6	4,7
	12:00	45,5	41,1	4,1
	13:00	42,3	38,4	3,7
	14:00	36,4	34,3	1,6
	15:00	32,0	31,0	0,6
	16:00	29,5	28,8	0,3

In Table 3, it can be seen that the results of the calculation of the radiation rate on each sample are in steady state. From the table, a graph is obtained for the difference in radiation rate of each sample which can be seen in Figure 4.

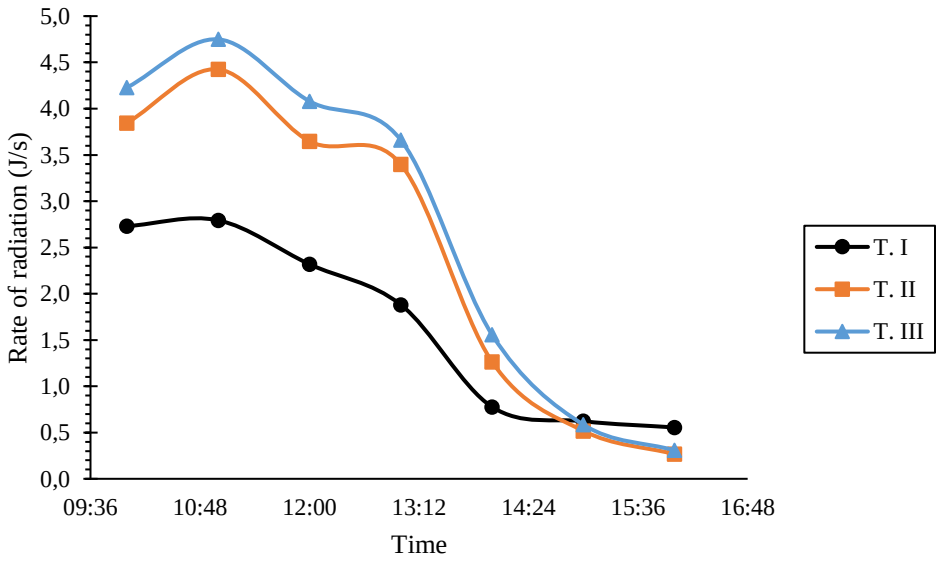


Figure 4. Radiation rate of tile (J/s)

Based on Figure 4, there is a difference in radiation rate in each sample, the highest radiation rate value occurs at 11:00 AM where the highest radiation rate is found in sample III of 4.7J/s, while the lowest radiation rate is obtained in sample I of 2.8J/s, in sample II for radiation rate value occurs at 4.4J/s, the value is still lower than sample III. From the results of these calculations for the lowest radiation rate value occurs at 16:00 PM, where the lowest rate is found in samples II and III with a value of 0.3J/s, while the radiation rate in sample I occurs at 0.6J/s where the value is still higher than samples II and III. From the results of these calculations for the lowest radiation rate value occurs at 16:00 PM, where the lowest rate is found in samples II and III with a value of 0.3J/s, while the radiation rate in sample I occurs at

0.6J/s where the value is still higher than samples II and III. Based on the solar production curve, the maximum point is at lunch, which is 11:00 AM [20]. The results of direct solar radiation research on clay roof tiles, pure HDPE polymer composite roof tiles, and HDPE polymer composite roof tiles reinforced with 20% teff grass, the highest radiation rate occurs at 11:00 AM with the largest radiation rate value found in HDPE composite roof tiles reinforced with 20% teff grass while the smallest is found in clay roof tiles.

4. Conclusion

Based on the results of thermal testing, it can be concluded that the composition of HDPE and 20% teki grass samples has a significant effect on the absorption of the upper and lower surfaces of the roof tiles when exposed to direct solar radiation. Thus, in the composition with 20% teak grass, the resulting temperature on the top and bottom surfaces of the tile tends to be lower than pure HDPE and the top surface of the composite tile has a difference of 0.6^{o}C higher than clay tile but for the bottom surface has a difference of 1.3^{o}C lower than clay tile. Based on the radiation rate, tiles made from HDPE and 20% teki grass have a higher value than clay roof tiles so that tiles made from HDPE reinforced with 20% teki grass can be used as an alternative material to replace clay roof tiles because it has good heat resistance.

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