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THERMAL BEHAVIOUR ASSESSMENT OF BRICK UTILIZING PLASTIC WASTE FOR ENHANCED INSULATION PROPERTIES

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ABSTRACT

Plastic waste, particularly hazardous types such as high-density polyethylene (HDPE) and Polyethylene terephthalate (PTE), is a critical problem in today's world. Recycling plastic waste to produce new materials like concrete or mortar is an effective disposal method. One such solution is adding plastic waste to bricks to create an environmentally friendly and cost-effective option to produce high-strength bricks with thermal and sound insulation properties. The study intends to investigate the feasibility of reusing plastic waste as a mixture in brick production as an eco-friendly alternative to traditional bricks. To compare the thermal performance of buildings made of plastic waste bricks and traditional bricks, the researchers digitally created four sample bricks, each containing 0%, 5%, 10%, and 15% HDPE. The thermal performance of the brick-filled plastic bottle walls was then measured on-site at a real-time recording using a chamber and tested with the thermocouples connected to a data logger - T08 software. The results showed that 10% and 15% plastic waste brick composition had higher insulation properties with the difference between internal and external air temperature average of 6°C. The lower the external air temperature with the least amount of plastic waste recorded the lowest temperature difference average of 1°C. At the external temperature of 30°C, the 0% and 5% plastic waste bricks possessed the greater internal temperature, likely due to the external air temperature flow in the box's confined space. Thus, further research and experimentation are recommended to investigate the thermal conductivity of plastic waste bricks and their correlation with the insulation properties of the material samples.

Keywords: *environment, construction, plastic waste, thermal performance*

INTRODUCTION

Over the last decade, building energy consumption has increased sharply. This surge can be attributed to several factors, including population growth, heightened indoor activity durations, amplified demand for building services, and indoor environmental quality, alongside global climate change. This pattern is evident within the United States and the European Union and in embracing a broader global context, wherein building energy surpasses over 40% of total primary energy use. Nevertheless, a substantial potential exists for conserving energy by focusing on building design, construction, and operation [1]. The transportation of building materials also plays a crucial role in their low environmental performance, so the use of local, earth-based materials should be prioritized. Predicting the thermal performance of the building envelope is essential for any eventual thermal insulation or improvement of the envelope [2]. The selection of optimal wall constructions plays a more significant role in a building's performance than a detailed energy study. The use of thermal insulation and moisture-resistant materials affects the rate of heat conduction through external walls and must be considered in building thermal analysis. According to studies by Boostani [3], using energy-efficient materials results in lower energy costs and heat exchange control in the building. The structure's direction also plays a role in thermal performance, and the appropriate orientation, courtyard shape, and shading devices can improve it. Various materials have been used for insulation in construction. A study conducted used low thermal conductivity materials such as expanded

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polystyrene (EPS) insulation and cellular concrete, as well as moderate thermal conductivity materials, which improved the insulation performance of the building [4]-[6]. PET is discussed as a possible alternative to concrete due to its lower thermal conductivity [7]-[8]. The use of textile waste in construction, such as for thermal and acoustic insulation, is highlighted as a way to reduce pollution and preserve natural resources [9]-[10]. Such materials are reported to have better thermal properties and mechanical characteristics than traditional building materials [11]. Thus, it was suggested that using waste materials in construction is an innovative concept that offers an environmentally friendly alternative to traditional building materials [12]. The research explored the viability of integrating discarded plastic bottles as a partial substitute for traditional brick, showcasing their potential to inhibit the spread of cracks subsequent to the initial block formation [13]. In addition, another study of plastic sand bricks conducted by Naveen et al. [14] discovered that it was lightweight and had a high compressive strength, making it a viable alternative to conventional clay bricks. Moreover, the low water absorption of plastic sand bricks is also noteworthy, being only 0.9%-4.5%, compared to the 15%-20% of clay bricks, making it a greater insulation building material. To the author's knowledge, much of the study was focused on the mechanical strength of the plastic waste brick rather than its insulation performance. Thus, this study aims to investigate the ratio of HDPE plastic waste to become an alternative brick material for lightweight construction that focuses on its usage as thermal insulation.

EXPERIMENTAL METHODS

Sample Preparation-Plastic Waste Brick

The plastic waste brick was first made by shredding the plastic waste into small pieces with diameters ranging from 5 mm to 10 mm. The plastic waste used in this study was HDPE, derived from discarded items such as plastic bottles, milk jugs, shampoo bottles, bleach bottles, cutting boards, and other applications of HDPE plastic. The shredded plastic waste is then mixed with sand aggregates in three different ratios: 5:95, 10:90, and 15:85. A cement and sand mixture is prepared in a 1:6 ratio, followed by adding water to create a cement mortar. Table 1 provides the mixture for preparing the plastic-enhanced bricks. The aggregate and plastic waste mixture was blended with the cement mortar and thoroughly mixed. To maintain a proper experimental setup, the resulting mixture was placed to dry into a brick mould with length, width, and depth dimensions of 190, 90, and 90 mm. Figure 1 displays the sample of plastic waste bricks used in this study.

Table 1 Mixture of the HDPE plastic, sand, cement and sand in preparing the plastic-enhanced bricks

Type	HDPE plastic (kg)	River Sand (kg)	Cement (kg)
0% plastic	0	2.6240	0.4373
5% plastic	0.1312	2.4928	0.4155
10% plastic	0.2624	2.3616	0.3936
15% plastic	0.3936	2.2304	0.3717

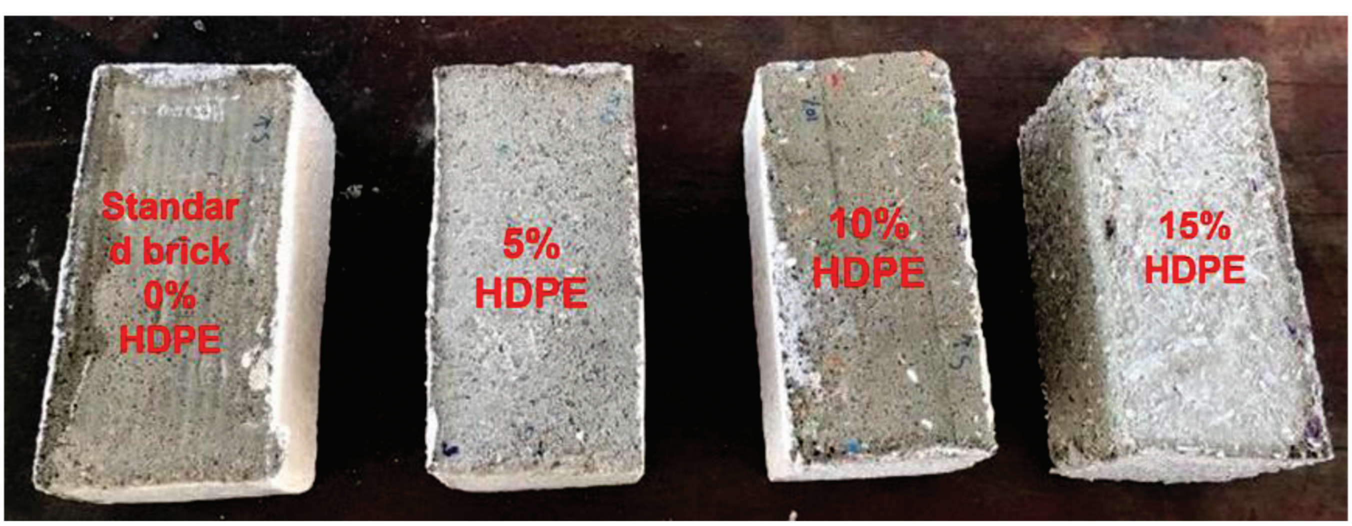

Figure 1 The sample material of the plastic waste brick

Thermal Measurement

Preparations were made for thermal measurements after creating four material samples. The thermal measurements were conducted using a thermal chamber model adopted in the study conducted by Arsandrie et al. [8]. The chamber model was created to represent a room measuring 0.55 m x 0.35 m in size. The chamber was made of pine wood panel with a thickness of approximately 0.02 m to withstand the influence of external temperature conditions. For this study, the external temperature was maintained at 30, 33, 35, 37 and 40°C, adhering to the weather climate in Malaysia, recorded with the maximum at 40°C [15]. An opening with a width equal to that of the sample materials was made for the placement of the samples to be tested. This experiment used a conditioned chamber to investigate the difference between the internal and external air temperatures. Several thermocouples were attached to the chamber and connected to a data logger with TC08 software for real-time recording. This study used eight thermocouples, six placed inside the chamber and two outside. The study was carried out in triplicate to ensure accurate and consistent results. Figure 2 illustrates the experimental setup for the chamber and the point of the thermocouple placed.

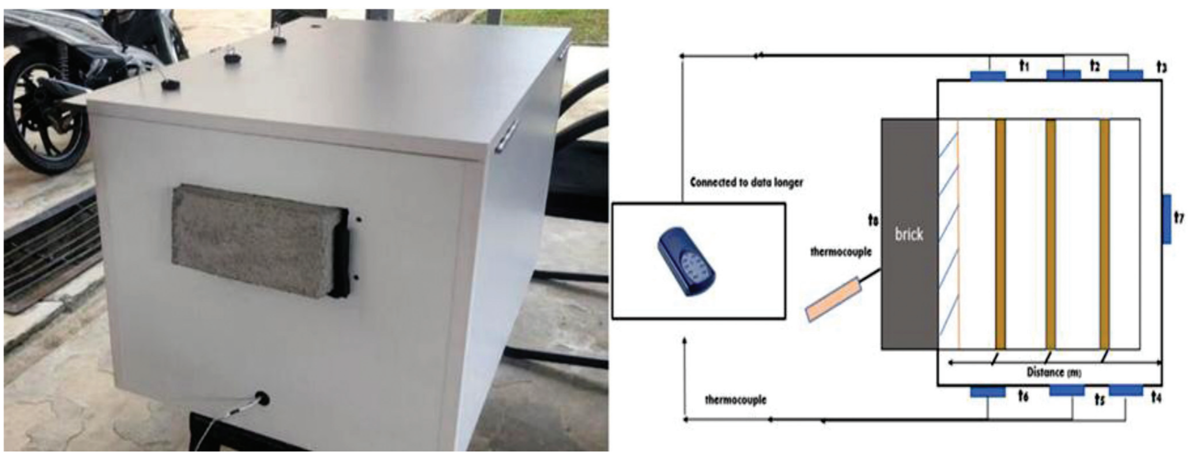

Figure 2 The sample plastic waste brick with the temperature measurement points using the thermocouples for data recording

RESULTS AND DISCUSSION

The result of the thermal measurements is shown in Table 2. This table showed a better performance where the internal air temperature was significantly lower and maintained an average of 33°C than that of the external air temperature. Nonetheless, the thermal performance measurement for each brick sample is presented in Figure 3. The thermal measurements revealed significant temperature variations as the external temperature increased to 40°C. The average difference between the internal and external temperature was only 1.89°C. The studies also showed that utilizing the brick of 10% and 15% plastic bottles provided excellent thermal performance at 40°C, with differences at 6.45°C and 6.94, respectively. Furthermore, the external temperature is 33°C for both 10% and 15% plastic, and the temperature reduces to 32°C and 30°C, respectively. The lowest difference in air temperature between internal and external temperature was observed in the 0% and 5% mixture. These compositions, in contrast, increased the internal air temperature by up to an average of 2°C. This study indicates that an increase in the HDPE percentage, which is capable of maintaining the internal temperature, proves the tendency of HDPE to be used as insulation for building construction. This study is aligned with the other researchers on the potential of the HDPE as an insulation material for buildings [16]-[17]. Moreover, the higher the external temperature, the lower the internal temperature using plastic waste brick as the construction material. It is accepted that brick samples containing 10% and 15% HDPE perform better than others with the lowest difference temperature value. Thus, from this observation, it can be concluded that HDPE is a thermoplastic polymer known for its versatility and excellent insulating properties. It was also noted that the polymer's repeating units were responsible for trapping air bubbles, thus inhibiting the flow of heat energy through it. The external temperature at

30°C could gain more heat due to increased internal temperature compared to the standard brick and the 5% plastic waste brick. These are probably due to the flow of the external air temperature in the confined space of the thermal chamber box, resulting in a drastic increase in the internal air temperature. Furthermore, it is observed that at an external temperature of 33°C, both 0% and 5% plastic compositions exhibit a similar average temperature of approximately 33.15°C, with a marginal increase of 0.15°C. In this scenario, both internal temperatures indicate a heat gain, likely attributed to the heat flow within the confined space, contributing to this phenomenon. It is also suggested that future research conducted on thermal conductivity should be done to gain a more comprehensive understanding of the insulation properties of these materials. Figure 3 displays the visual presentation of these results.

Table 2 Variations of the temperatures measured at external temperatures of 30°C, 33°C, 35°C, 37°C and 40°C

		Internal temperature (°)		
Type of brick	External temperature (°)	Min	Max	Average
	30	34.15	34.32	34.23
	33	32.28	33.98	33.13
0% plastic	35	33.02	34.90	34.02
	37	35.11	36.87	35.99
	40	36.07	39.11	37.59
	30	32.22	33.13	32.00
	33	33.05	34.25	33.18
5% plastic	35	32.09	34.12	33.11
	37	33.14	36.08	34.61
	40	33.58	37.21	35.40
	30	29.43	29.65	30.00
	33	31.77	33.68	32.07
10% plastic	35	31.77	33.70	32.73
	37	32.34	34.23	33.29
	40	32.11	34.99	33.55
	30	29.47	30.34	29.91
	33	29.31	30.65	30.00
15% plastic	35	30.41	33.20	31.81
	37	30.90	34.08	32.49
	40	31.24	34.88	33.06

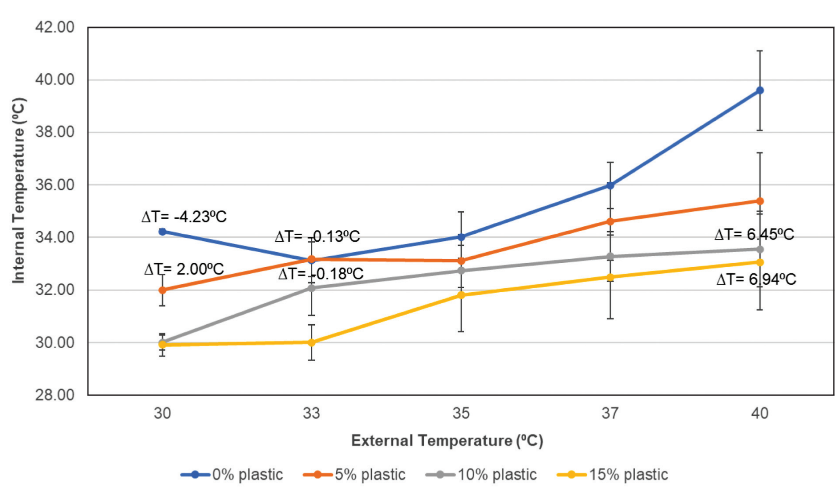

Figure 3 Temperature variation of the internal temperature based on different percentages of the plastic waste

CONCLUSION

The results of this experiment have shown a promising potential for using plastic bottles in light construction for thermal cases. It has been proven that it can aid in insulating the temperature in hot weather. The conclusion drawn from this study is that a more significant number of plastic waste additives produce brick samples with improved thermal properties. The highest temperature difference of 7°C was recorded when the external temperature reached 40°C. The plastic waste brick samples containing 15% and 10% HDPE waste plastic additives were found to have the best composition in improving thermal properties for insulating construction. However, it should be noted that the relative humidity was higher when using plastic, and future research could consider incorporating treatments to achieve different results.

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