BAMBU LİFİ KATKILI BRİKETLERİN ISIL DİRENÇ ANALİZİ: DENEYSEL BİR ARAŞTIRMA

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ÖZET

Binaların mevcut konumuna bakıldığında günümüz koşullarında enerji tüketimi konusunda ciddi bir paya sahip oldukları yadsınamaz bir gerçektir. Bu tüketimin oluşmasındaki en önemli nedenlerden birisi de bina dış duvarlarının göstermiş olduğu yetersiz ısıl direnç, yetersiz ısı tutma veya yüksek ısıl geçirgenliğe sahip yapı elemanlarını tercih edilmesidir veya yalıtımsız inşa edilmesindendir. Kabukların ısıl geçirgenliğini azaltmaya yönelik birçok çalışma bulunsa da buradaki asıl amacın doğal, sürdürülebilir, yüksek verimli ve maliyeti makul ölçüde olabilecek bir yalıtım sağlamaktır. Bu amacı sağlayabilecek malzemeler arasında bambu lifleri yer almaktadır. Bambu lifleri daha çok su tutucu, esnek yapısı, hafif, düşük yoğunluğa sahip oldukları bilinse de aynı zamanda termal direnç anlamında da başarı gösterdiği ispatlanmıştır. Buradan hareketle, bu çalışmada, doğal bir lif olan bambu lifini briket harcı içerisine ağırlıkça %2 oranında ekleyerek ısıl geçiş davranışındaki iyileşmelerin kanıtlanması amaçlanmaktadır. Burada bu davranışın ne denli güç kazandırdığını ısıl direnç veri temini konusunda standartlaşmış coheating test metodolojisi uygulayarak açıklamaya gayret gösterilecektir. Bu iyileşme belirlenirken daha önceki çalışmalardan referans alınan yalıtımsız briketin değeriyle karşılaştırma yoluna gidilecektir. Buna göre, alınan veriler gösteriyor ki yalıtımsız briket toplam ısı transfer katsayısı (U-değeri) 5,5 W/mK iken %2 bambu katkılı briket numunesinin U-değeri 5.26 W/mK olarak belirlenmiştir. Bu verilerin ışığında, elde edilen iyileşme yaklaşık olarak %5 ile sınırlı kaldığı görülmektedir.

Anahtar Kelimeler: Bambu lifi, Dış duvar yalıtımı, Coheating test, U-değeri

THERMAL RESISTANCE ANALYSIS OF BAMBOO FIBRE ADDED BRIQUETTES: AN EXPERİMENTAL RESEARCH

ABSTRACT

Examining the current positioning of structures, it is indisputable that they play a significant role in the energy consumption landscape under present circumstances. The inadequacy of thermal resistance in a building's external walls, insufficient heat retention, the selection of elements with high thermal permeability, or the construction of uninsulated buildings are vital contributors to this consumption. Despite numerous efforts to diminish thermal permeability, the primary objective is to establish a natural, sustainable, highly effective, and cost-efficient insulation solution. Bamboo fibres emerge as a promising material for fulfilling this objective. Despite their known characteristics, such as a water-retaining and flexible structure, lightweight, and low density, bamboo fibres have demonstrated effectiveness in terms of thermal resistance. This study aims to validate enhancements in thermal transfer behaviour by incorporating 2% by weight of bamboo fibre, a natural fibre, into the briquette mortar. The investigation employs a standardised coheating test methodology to generate thermal resistance data, shedding light on the efficacy of this approach. Comparisons are drawn between the thermal performance of the bamboo-infused briquette mortar and an uninsulated briquette, considered as a reference from prior research. The data reveals that the total heat transfer coefficient (U-value) for the uninsulated briquette stands at 5.5 W/mK, while the U-value for the briquette with 2% bamboo content is determined as 5.26 W/mK. In light of these findings, the achieved improvement is noted to be approximately 5%.

Keywords: Bamboo fibre, External wall insulation, Coheating test, U-value

1. INTRODUCTION

In the current context, there is a persistent rise in the utilisation of non-renewable energy sources, particularly fossil fuels, to meet the escalating energy demands (Adedoyin et al., 2021). This ongoing trend contributes to global warming, with countries experiencing its effects more prominently (Lamb et al., 2021). The detrimental impacts of energy production from fossil fuels are evidenced by the escalating gas emissions, with CO_2 being just one of the harmful gases (Yoro and Daramola, 2020). Data since 2012 reveals a consistent annual increment in CO_2 levels (BP Statistical Review of World Energy, 2023). As a response, there is a quest for alternative solutions, with renewable energy sources emerging as the most viable candidates (Nijs, Tarvydas, and

Toleikyte, 2021). However, the surge in the global population leads to a concurrent uptick in energy consumption, fostering a continued reliance on fossil fuels (Okoh and Okpanachi, 2023). It is crucial to recognise that more than just increasing renewable energy sources may be necessary as a standalone solution for reducing CO_2 emissions. The expanding global population directly correlates with a heightened focus on the building sector (Zhong et al., 2021; Omer, 2008). This surge results in increased energy consumption as people seek comfort, striving to maintain optimal temperatures in both summer and winter (De Dear and Schiller Brager, 2001; Taylor, Brown and Rim, 2021). Addressing the escalating energy costs in the building sector necessitates implementing measures to boost renewable energy sources (Al Naimat and Liang, 2023). Notably, the building sector currently accounts for 40% of global energy consumption (Cuce, Cuce and Alvur, 2023; Christopher et al., 2023; Cuce, 2017). Examining the overall condition of buildings reveals that external walls (40%) and windows (30%) are the primary areas where heat transfer is most intense (Uygunoğlu, Özgüven and Çalış, 2016). The data indicates that the external walls of buildings have the least thermal resistance. Consequently, a substantial alteration in the external wall envelope of buildings or reinforcement efforts for existing structures is imperative. This is crucial not only for ensuring comfort for building occupants and reducing energy expenses but, most significantly, for minimising adverse environmental effects. Numerous researchers have conducted extensive studies on innovative methods and materials such as aerogel (Cuce et al., 2014; Cuce et al., 2024), XPS (Ozel, 2011; Li, Peng and Liu, 2020), EPS (Al-Yasiri and Szabo, 2023), insulation plaster (Cuce et al., 2023), which is considered a future trend (Pedroso et al., 2023), VIP (Jeon et al., 2016), and glass wool (Braulio-Gonzalo and Bovea, 2017). Their collective findings affirm substantial energy savings resulting from these studies.

In Turkey, particularly in Anatolia, the construction of houses using briquettes is prevalent, given its positive attributes like durability against fire (Phonphuak and Thiansem, 2012). Additionally, research on briquettes indicates a thermal conduction coefficient of 0.8 W/m/K, necessitating certain measures to enhance thermal resistance (Çuhadaroğlu, 2005). In this reinforcement process, it is essential for the solutions to be environmentally friendly, cost-effective, possess a low transmission coefficient, be aesthetically pleasing, and be highly feasible. In the pursuit of achieving these goals, researchers have explored the utilisation of waste materials or naturally occurring plant resources for insulation, adding an environmentally conscious dimension to their

studies (Çuhadaroğlu, 2005; Majumder et al., 2021; Corinaldesi, Donnini and Nardinocchi, 2015; Huang, Xu and Wang, 2023; Erkmen and Sari, 2023; Quan et al., 2023).

Addressing thermal insulation in buildings, whether old or new, is a crucial concern. While developed countries exhibit higher sensitivity and ongoing implementation of solutions, achieving a more impactful outcome at a lower cost may require significant efforts. Despite numerous innovative approaches in this domain, there is a limited focus on the thermal use of bamboo fibre in buildings, despite the extensive mechanical studies conducted by researchers. In this study, samples were created by incorporating 2% bamboo fibre by weight in addition to the standard briquette composition, aiming to assess their contribution to thermal resistance. The study follows an experimental approach, utilising the coheating test method as the experimental methodology. The inner part of the designed hot box is configured with an electric heater to create a heat transfer environment to the sample, while the outer part is controlled by air conditioning. Thermocouples measure temperatures on the inner and outer surfaces of the sample, and a sensitive sensor gauges the heat flux. The objective is to develop a cost-effective yet efficient insulated briquette by substituting bamboo fibre as an alternative to traditional briquettes.

2. Material and Method

2.1. Material

In this study, bamboo, the focal point of the research, is employed with the aim of providing insulation. The findings reveal that bamboo is a versatile, sturdy plant with high strength and partial fire resistance. Its fibrous structure aligns with the general principles of insulation, indicating its potential for thermal insulation. The process begins by subjecting the acquired bamboo to multiple passes through a grinder, transforming it into a fibrous structure. Subsequently, the cement, fine aggregate, and coarse aggregate, intended for briquette casting, are separated by sieving them into appropriate sizes. Each component is meticulously weighed based on pre-established data, placed into a bowl, and blended by gradually adding water. The weights are outlined in **Table 2.1**. Specifically, the weight of bamboo fibre is set at 100 g, constituting 2% of the total weight. After thorough homogenous mixing, the mould is prepared within the briquette mould using a vibration machine to ensure a robust bond at every point. The prepared moulds are then removed from the mould and leave in the open air to obtain the final sample.

Table 2.1. Measurements used in this study

Material	Fibre content rate	2%
	Cement	2380 g
	Water	2270 ml
	Fine Aggregate	5088 g
	Coarse Aggregate	1278.5 g
	Fibre	100 g

2.2. Coheating Test

If it is needed to define the coheating test briefly, it is a standardised method that allows heat transfer by creating a certain temperature difference in the internal and external environment of the object to be measured and determines the total heat transfer coefficient with the measurements taken during this process. Crucially, the temperature difference should be set at a minimum of 10°C, with the internal temperature selected as 25°C, representing the standard for human comfort. Creating this temperature difference involves providing the indoor environment with a heat source and using air conditioning or outdoor air for the external environment. A fan may be necessary for adequate air circulation in practical indoor air scenarios. Additionally, a sensitive instrument should be employed for accurate results in heat flux measurement. The combination of heat flux data and the created temperature difference allows the total heat transfer coefficient to be determined. It is worth noting that this method is typically more suitable for winter conditions, as it assumes the indoor air to be 25°C, and the outdoor air should appropriate a temperature difference of at least 10°C. The coheating test can be conducted both in a laboratory setting and in a real-world environment. In this study, a hot box is devised to establish a coheating artificial test environment. Leaving an area suitable for the briquette's size raises the internal environment's temperature using a heater. Additionally, laboratory cooling is achieved using air conditioning. Heat flux data is collected by placing a sensitive sensor on the inner surface of the briquette sample, and internal temperature measurements are obtained using a thermocouple. Only a thermocouple is positioned on the external surface, and data collection continues until the system reaches equilibrium. It is crucial to minimise leakage during this process.

3. Results and discussion

The commonly available briquette in construction markets is identified, through experimental tests, to have a thermal conductivity of 0.8 W/m/K. The data derived from the coheating test, employed to validate the accuracy of this study, indicates a thermal conductivity of 0.82 W/m/K for the

briquette. Consequently, upon comparing these figures, a marginal difference of 2.5% is observed. This variance can be deemed reasonable, attributed to factors such as the authentic nature of the experimental data and variations in material aggregates. To illustrate the proximity of the obtained values graphically, Figure 2.1 provides a more visually explanatory representation in this context.

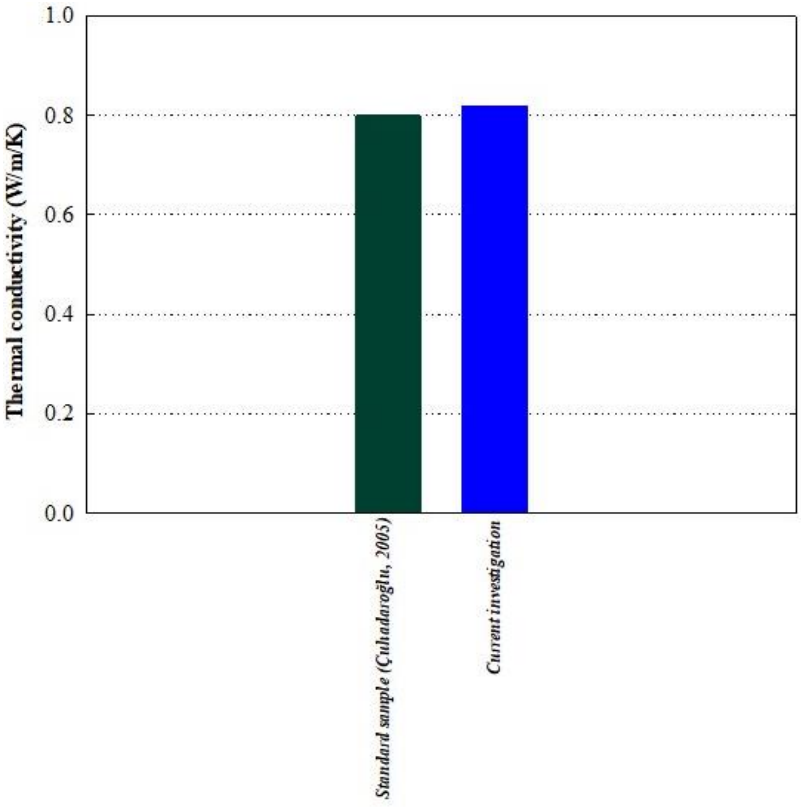


Figure 2.1. Confirmation of coheating test method results

Figure 2.2 depicts a graph presenting the data obtained from the 10-hour coheating test. The x-axis represents time, the left side of the y-axis indicates the temperature axis based on internal and external temperatures, and the right side symbolises the range of heat flux values. The indoor and outdoor temperature difference averaged around 10°C, meeting the coheating test criteria. However, analysis of the heat flux values, obtained with the sensor's sensitivity and by dividing the temperature difference by approximately 10, suggests an average U-value of 5.26 W/m^{2}K. This reveals that the value of 5.5 W/m^{2}K obtained through a similar procedure for standard briquettes is slightly higher. Although this variation appears small, it demonstrates the potential impact on the monthly or annual unit energy cost for building occupants.

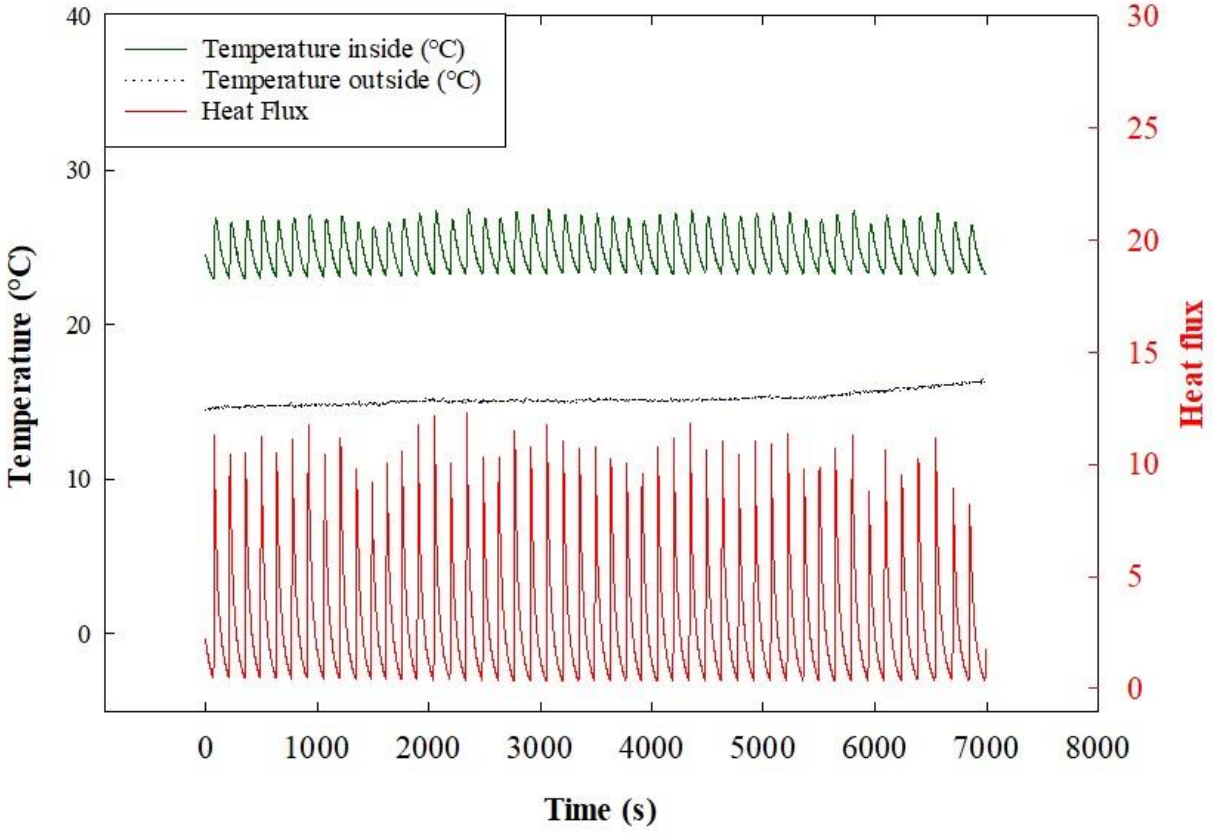


Figure 2.2. Measured internal and external temperatures along with heat flux values

4. Conclusion

- The thermal conductivity coefficient value obtained from the study for the traditional briquette is 0.82 W/m/K, and the corresponding U-value is 5.5 W/m^{2}K.
- On the other hand, the U-value determined from the briquette sample incorporating bamboo fibre is measured as 5.26 W/m^{2}K using the coheating test methodology.
- It is observed that bamboo, the primary focus of the study, provides protection against a 5% thermal transition even when added in very small quantities to the briquette mortar.

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