JSMBE

JOURNAL OF STRUCTURAL MONITORING AND BUILT ENVIRONMENT
e-ISSN: 2821-3432

Vol. 6 No. 1 (2026) 20-25
https://publisher.uthm.edu.my/ojs/index.php/jsmbe

Mechanical Performance Analysis of Interlocking Compressed Earth Bricks with Various Kenaf Fiber Length for Sustainable Construction Material

Noor Hannah Moideen[1], Ruzaimah Razman[1]*

[1] *Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA*

*Corresponding Author: ruzaimahr@uthm.edu.my
DOI: https://doi.org/10.30880/jsmbe.2026.06.01.003

Article Info

Received: 17 January 2026
Accepted: 21 May 2026
Available online: 30 June 2026

Keywords

Environment, green construction, mechanical performance, earth brick, kenaf reinforcement, eco-friendly building materials, material analysis

Abstract

This study examines the influence of kenaf fiber length on the mechanical properties of Interlocking Compressed Earth Bricks (ICEB). A 1:3:2 mix ratio of cement, soil, and sand with 0.75% kenaf fiber and stabilizer was used, and total KF-ICEB for this study is 54 brick were tested with 5 different kenaf fiber lengths (20mm, 30mm, 40mm, 50mm, 60 mm) to analyze their impact on strength and durability. Compressive strength results showed that all bricks did not pass the minimum requirement of 2.8 N/mm^2 for non-load-bearing applications. Flexural strength peaked at 1.91 MPa after 28 days of curing for 50 mm KF-ICEB, but the curing process revealed suboptimal hydration and bonding. Water absorption tests indicated 24.21%, exceeding the 15% baseline, indicating poor fiber distribution at 20 mm and optimal water retention at 50 mm 18.9%, closer to the control. However, uneven mixing caused clumping of fibers, which likely affected the bricks' overall quality and performance. The findings suggest the need for improved mixing methods and optimized ratios to maximize ICEB strength and durability.

1. Introduction

1.1 Background of Study

Mud is the most common natural construction material, particularly in hot, dry, and temperate climates. [1] estimated that 30–50% of the global population lives in homes built with inexpensive, locally sourced raw earth materials. These materials can be used with basic tools, low-skilled labor, and minimal technology, making them common in developing regions like Asia, Latin America, and Africa. In recent years, industrialized nations have also shown interest in earth-based materials for preserving architectural heritage and adopting eco-friendly building practices to conserve resources such as energy and raw materials [2].

Earth-based materials are environmentally friendly as their transportation has a negligible impact, and they can be recycled if no artificial binders are added. For example, producing compressed earth masonry blocks requires 15 times less energy than traditional cinderblocks [3]. Natural fibers, such as kenaf, are gaining attention due to their low cost, light weight, renewability, and eco-friendliness compared to synthetic fibers like glass. They enhance sustainability and improve the ductility, flexural strength, and tensile strength of Interlocking Compressed Earth Bricks (ICEBs) while reducing shrinkage and moisture susceptibility. ICEBs are dense bricks made from soil, water, and sometimes stabilizers. Kenaf fibers, extracted from the kenaf plant (Hibiscus cannabinus), are composed mainly of cellulose (73%), hemicelluloses (18%), and lignin (6%). These fibers improve the mechanical and thermal properties of ICEBs, such as crack resistance, flexural strength, and compression resistance [4]. However, challenges like moisture absorption and lower strength compared to synthetic fibers remain.

1.2 Structure

According to [15], Interlocking Compressed Earth Bricks (ICEBs) are a sustainable building material valued for their low environmental impact and accessibility of raw materials. However, traditional ICEBs face issues such as weak structural integrity, limited durability, and poor resistance to environmental factors. Reinforcing ICEBs with natural fibers like kenaf, known for its strength, flexibility, and eco-friendliness, has gained attention as a way to address these challenges. Despite their benefits, ICEBs have drawbacks, including low tensile strength, poor water resistance, and cracking susceptibility, which limit their use in modern construction. While synthetic materials can improve these properties, they often undermine the environmental advantages of ICEBs. As such, sustainable solutions, like using kenaf fibers, are being explored to enhance the structural integrity and durability of ICEBs without compromising their eco-friendliness. Natural fiber reinforcement has shown excellent mechanical behavior, strengthening the bond between the fiber and the brick. Studies indicate that a kenaf fiber length of around 30 mm is optimal for improving ICEB mechanical properties, as shorter fibers provide less strength. However, soaking the fibers before use can weaken the ICEBs, emphasizing the importance of proper preparation and consideration of kenaf fiber properties. Kenaf fibers have significant potential to improve ICEB sustainability and performance, but further research is needed to optimize their use. For example, compressing a soil-cement mixture in a press chamber creates denser bricks with fewer voids, increasing material strength. Understanding the relationship between kenaf fiber characteristics and ICEB performance will help maximize their effectiveness in sustainable construction [10].

2. Methodology

This study was started with the preparation of kenaf fibre. The fibre that we use in this study is already treated with kenaf fibre. Then proceed with the fabrication process of composite specimen in which the treated kenaf fibre is layered in the ICEB mixture. The mixture we use is 1:3:2 for cement, soil, sand. The composite fabrication will undergo a mechanical and physical test with compressive stress and durability to evaluate performance of its mechanical properties.

The experimental approach, which included the preparation and testing of various KF-ICEB samples, provided valuable insights into the optimal fibre content and distribution for maximizing strength and durability. Mechanical testing, such as compression test and water absorption test, were crucial in quantifying the improvements brought about by the inclusion of kenaf fibres. Additionally, environmental impact analyses underscored the sustainability benefits of using renewable and biodegradable materials in brick production. Key methodological steps included the precise measurement of fibre content, mixing techniques, and controlled curing processes, all of which ensured the reliability and reproducibility of the results. The use of advanced analytical tools and statistical methods further strengthened the validity of the findings, providing a robust framework for future research in this area

3. Results and Discussion

A total of 54 specimen brick were used to study of performance a kenaf fibre used for this study is 20mm, 30mm, 40mm, 50mm, and 60mm with treated kenaf fibre. This test was conducted according to standard ASTM. The experimental specimen had been shown in figure below. This test was conducted to determine flexural strength, young modulus, stress and strain based on this study. analysis of interlocking compressed earth bricks with various kenaf fibre lengths in flexural strength.

3.1 Compressive Strength of KF-ICEB

Figure below illustrates 7-day and 28-day performance of Kenaf Fiber Interlocking Compressed Earth Bricks (KF-ICEB) for different fibre lengths, the load for 28-day load values is consistently higher than the 7-day results for most specimens, reflecting increased curing and material consolidation over time and notable improvements in the control and 50 mm fibre specimens are evident. While for strength, it follows a similar pattern, with higher 28-day values for most specimens, except for 30 mm and 60 mm fibres, where little to no improvement is seen and the control specimen consistently outperforms fibre-reinforced bricks in both time frames. Optimal performance occurs with 50 mm fibres at 28 days, which exhibits significant improvement compared to 7 days. The decline in performance for 60 mm fibres at 28 days suggests potential issues such as fibre clumping or excessive interference with the matrix as shown in Figure 1.

J. of Struct. Monit. and Built Environ. Vol. 6 No. 1 (2026) p. 20-25

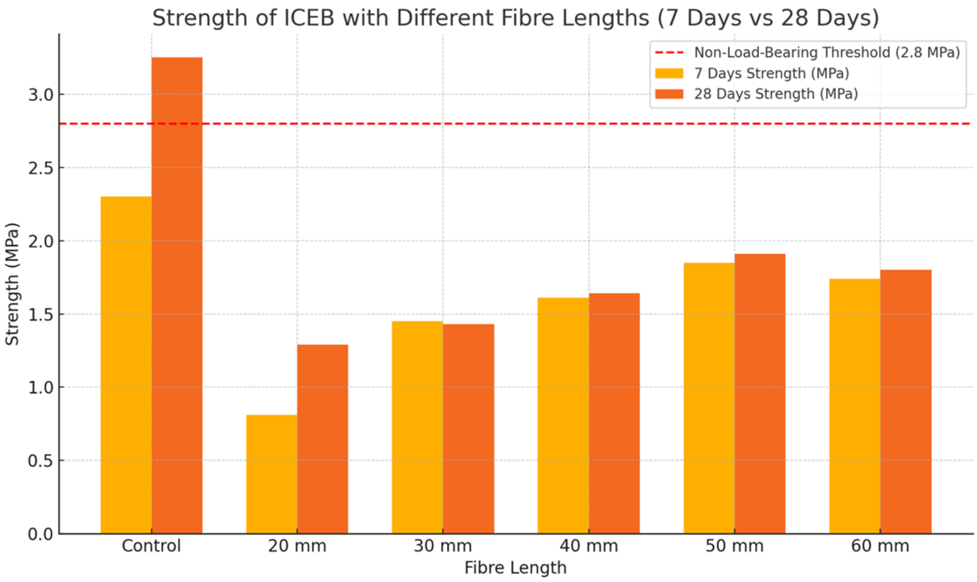

Fig. 1 *Graf KF-ICEB performance load (KN) and strength (MPa) Vs fiber length (mm) For 7 days and 28 days*

3.2 Water Absorption of KF-ICEB

Based on data obtained water absorption testing, lowest water absorption due to higher density and reduced porosity in the absence of fibers and suitable for environments requiring low water permeability. Short fibers 20 mm result in the highest water absorption due to increased void content, while 30–50 mm strikes a balance, with 50 mm being the most effective in minimizing water uptake. 50 mm fibers provide the best performance in terms of water resistance, balancing reinforcement and specimen integrity. Based on the testing results shown in Figure 2 below, 50 mm fibers is recommended for optimal performance in applications where water resistance is crucial, this is to ensure consistent fiber distribution during mixing to reduce void content and improve water absorption performance and for environments with high moisture exposure, the control specimen or optimized fiber-reinforced designs with sealants might be preferable.

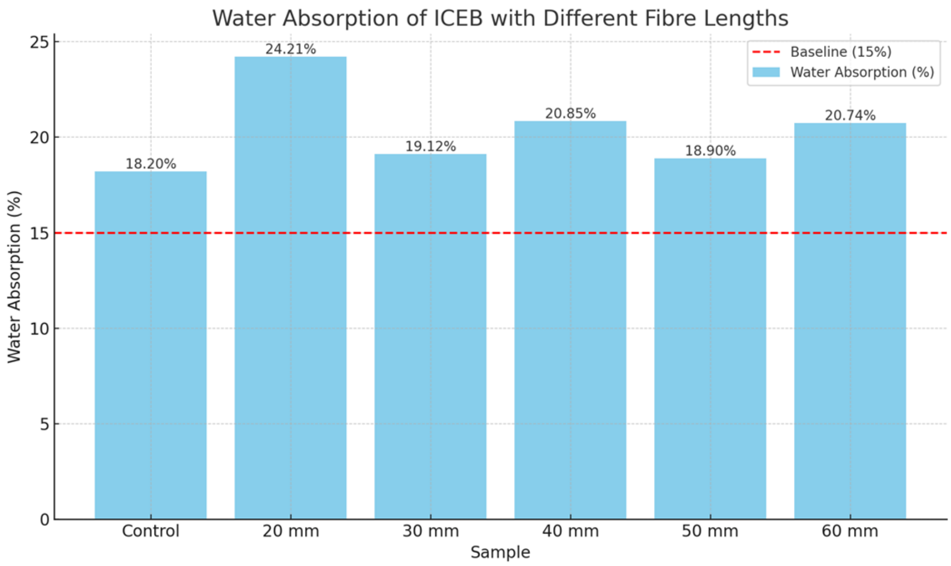

Fig. 2 *Graf water absorption vs kenaf fiber length*

4. Conclusion

The results confirmed that kenaf fiber length influences the mechanical behavior of ICEBs. The findings showed trends of both increasing and decreasing flexural strength as fiber length varied. The minimum compressive strength for load-bearing ICEBs is 5 N/mm², and all tested units exceeded this threshold, confirming their structural viability. The compressive strength of ICEBs ranged from 0.6 MPa to 12.5 MPa, depending on the percentage of stabilizers like cement or lime used. However, laboratory testing showed the flexural strength did not reach the optimal value of 3.25 MPa for 28 days of curing, likely due to insufficient moisture retention during curing, which is critical for hydration and bonding. Water absorption tests indicated that the optimal water content was 20 mm. This might be due to uneven mixing during the machine process, leading to clumps of kenaf fibers in the mixture. Additionally, a fiber length of 50 mm provided the best water absorption results. The study concluded that the optimal kenaf fiber length is critical for achieving maximum strength and durability in ICEBs. However, the tested KF-ICEB ratio of 1:3:2 (cement: soil: sand) was unsuitable for mixing with kenaf fiber. Further research is needed to identify the most appropriate mix ratio to maximize the benefits of kenaf fiber in sustainable construction applications.

Acknowledgement

This research was supported by Tun Hussien Onn University. The authors of this research would like to express their gratitude to the Faculty of Civil Engineering and Built Environment for providing the laboratory for testing.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors are responsible for the study conception, research design, data collection, data analysis, result interpretation and manuscript drafting.

References

[1] Abdullah, A. H., Nagapan, S., Antonyova, A., Rasiah, K., Yunus, R., & Sohu, S. (2017). Comparison of strength between laterite soil and clay compressed stabilized earth bricks (CSEBS). MATEC Web of Conferences, 103, 01029. https://doi.org/10.1051/matecconf/201710301029

[2] Admin. (2022). Natural Fibres - Definition, Examples, Properties, and Applications. BYJUS. https://byjus.com/chemistry/natural-fibres/

[3] Bwm. (2021). Pros & Cons Of Natural Fibres | Fibre Manufacturing. Goonvean Fibres. https://goonveanfibres.com/news-insights/news/natural-fibres-the-pros-cons/

[4] Kiron, M.I. (2021). Kenaf Fiber: Properties, Cultivation, Production, Uses and Advantages. [online] Textile Learner. Available at: https://textilelearner.net/kenaf-fiber- properties/

[5] Da Silva, T. T., Da Silveira, P. H. P. M., Ribeiro, M. P., Lemos, M. F., Da Silva, A. P., Monteiro, S. N., & Nascimento, L. F. C. (2021). Thermal and Chemical Characterization of Kenaf Fiber (Hibiscus cannabinus) Reinforced Epoxy Matrix Composites. Polymers, 13(12), 2016. https://doi.org/10.3390/polym13122016

[6] Jain, C. (2023). Water Absorption Test on Bricks: CIVIL GUIDE - a Guide for Civil Engineers. https://civilguide.in/water-absorption-test-on-bricks/

[7] Kaze, R. C., Naghizadeh, A., Tchadjie, L., Adesina, A., Djobo, J. N. Y., Nemaleu, J. G. D., Kamseu, E., Melo, U. C., & Tayeh, B. A. (2022). Lateritic soils based geopolymer materials: A review. Construction & Building Materials, 344, 128157. https://doi.org/10.1016/j.conbuildmat.2022.128157

[8] Mardoqueu. (2023, August 23). Crush testing. Biopdi. https://biopdi.com/crush-testing/

[9] Marcin. (2019, October 24). CEB Field Performance Report – Factor e Live Part 11. Open Source Ecology. https://www.opensourceecology.org/ceb-field-performance-report- factor-e-live-part-11/

[10] Laibi, A. B., Poullain, P., Leklou, N., Gomina, M., & Sohounhloué, D. K. C. (2017b). Influence of the kenaf fiber length on the mechanical and thermal properties of Compressed Earth Blocks (CEB). KSCE Journal of Civil Engineering, 22(2), 785– 793. https://doi.org/10.1007/s12205-017-1968-9

[11] Bouchefra, I., Bichri, F. Z. E., Chehouani, H., & Benhamou, B. (2022). Mechanical and thermophysical properties of compressed earth brick rienforced by raw and treated doum fibers. Construction & Building Materials, 318, 126031. https://doi.org/10.1016/j.conbuildmat.2021.126031

[12] Ibrahim, N. A., Magindran, T., Shahrin, M. I., & Yusof, N. M. (2020). Sustainable use of laterite soil as compressed cement stabilized earth block for low cost housing construction. IOP Conference Series. Materials Science and Engineering, 849, 012027. https://doi.org/10.1088/1757-899x/849/1/012027

[13] Karimah, A., Ridho, M. R., Munawar, S. S., Adi, D. S., Ismadi, Damayanti, R., Subiyanto, B., Fatriasari, W., & Fudholi, A. (2021). A review on natural fibers for development of eco-friendly bio-composite: characteristics, and utilizations. Journal of Materials Research and Technology/Journal of Materials Research and Technology, 13, 2442– 2458. https://doi.org/10.1016/j.jmrt.2021.06.014

[14] Laibi, A. B., Poullain, P., Leklou, N., Gomina, M., & Sohounhloué, D. K. C. (2017). Influence of the kenaf fiber length on the mechanical and thermal properties of Compressed Earth Blocks (CEB). KSCE Journal of Civil Engineering, 22(2), 785– 793. https://doi.org/10.1007/s12205-017-1968-9

[15] Kitchi. (2017, January 14). Are Compressed Earth Blocks the Sustainable Building Material We've Been Looking for? - EuroCert. EuroCert. https://www.eurocert.ca/2017/01/14/are-compressed-earth-blocks-the-sustainable- building-material-weve-been-looking-for/

[16] Lemougna, P. N., Melo, U. F. C., Kamseu, E., & Tchamba, A. B. (2011). Laterite Based Stabilized Products for Sustainable Building Applications in Tropical Countries: Review and Prospects for the Case of Cameroon. Sustainability, 3(1), 293–305. https://doi.org/10.3390/su3010293

[17] Madueke, C. I., Umunakwe, R., & Mbah, O. (2022). A review on the factors affecting the properties of natural fibre polymer composites. Nigerian Journal of Technology, 41(1), 55–64. https://doi.org/10.4314/njt.v41i1.9.

[18] Millogo, Y., Aubert, J. E., Hamard, E., & Morel, J. C. (2015). How Properties of Kenaf Fibers from Burkina Faso Contribute to the Reinforcement of Earth Blocks. Materials, 8(5), 2332–2345. https://doi.org/10.3390/ma8052332

[19] Priji, E. M., Chockalingam, D. M., Venkatakrishnaiah, D. R., & Dayakar, P. P. (2020, January 28). *Advantage of laterite over clay in the manufacture of compressed stabilized earth bricks (CSEBs)*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3526847

[20] Paul, S., Islam, M. S., & Elahi, T. E. (2022). Comparative effectiveness of fibers in enhancing engineering properties of Earth as a building Material: A review. *Construction & Building Materials*, *332*, 127366. https://doi.org/10.1016/j.conbuildmat.2022.127366

[21] Pickering, K., Efendy, M. A., & Le, T. (2016). A review of recent developments in natural fibre composites and their mechanical performance. Composites. Part a, Applied Science and Manufacturing, 83, 98–112. https://doi.org/10.1016/j.compositesa.2015.08.038

[22] Sathishkumar, T., Navaneethakrishnan, P., Shankar, S., Rajasekar, R., & Rajini, N. (2013). Characterization of natural fiber and composites – A review. Journal of Reinforced Plastics and Composites, 32(19), 1457–1476. https://doi.org/10.1177/0731684413495322

[23] Vinod, A., Sanjay, Suchart, S., & Jyotishkumar, P. (2020). Renewable and sustainable biobased materials: An assessment on biofibers, biofilms, biopolymers and biocomposites. Journal of Cleaner Production, 258, 120978. https://doi.org/10.1016/j.jclepro.2020.120978

[24] Turco, C., Paula, A. C., Teixeira, E. R., & Mateus, R. (2021). Optimisation of Compressed Earth Blocks (CEBs) using natural origin materials: A systematic literature review. Construction & Building Materials, 309, 125140. https://doi.org/10.1016/j.conbuildmat.2021.125140

[25] Conway, A. (2023, August 7). Compressed Earth Blocks. Vale Das Lobas. https://www.valedaslobas.com/compressed-earth-blocks/

[26] The Raw Materials of Compressed Earth Block - Block&Brick Making Machine Supplier LONTTO. (n.d.). Block&Brick Making Machine Supplier - LONTTO. https://www.block-machine.net/the-raw-materials-of-compressed-earth-block/

[27] Wasselynck, G., Trichet, D., Ramdane, B., & Fouldagar, J. (2010). Interaction Between Electromagnetic Field and CFRP Materials: A New Multiscale Homogenization Approach. IEEE Transactions on Magnetics, 46(8), 3277–3280. https://doi.org/10.1109/tmag.2010.2045359

[28] Astm.org. https://www.astm.org/standards/c67

[29] Laursen, P. T., Herskedal, N. A., Jansen, D. C., & Qu, B. (2013). Out-of-plane structural response of interlocking compressed earth block walls. Materials and Structures, 48(1-2), 321–336. https://doi.org/10.1617/s11527-013-0186-2

[30] Abdullah, A. H., Nagapan, S., Antonyova, A., Rasiah, K., Yunus, R., & Sohu, S. (2017).

[31] Comparison of Strength Between Laterite Soil and Clay Compressed Stabilized Earth Bricks (CSEBs). MATEC Web of Conferences, 103, 01029. https://doi.org/10.1051/matecconf/201710301029

[32] Al-Fakih, A., Mohammed, B. S., Nuruddin, F., & Nikbakht, E. (2018). Development of Interlocking Masonry Bricks and its' Structural Behaviour: A Review Paper. IOP Conference Series: Earth and Environmental Science, 140, 012127. https://doi.org/10.1088/1755-1315/140/1/012127

[33] Senthilkumar, P., Senthilkumar, R., & Marichelvam, B. (2008). Influence of Fiber Length on Mechanical Properties of Kenaf fiber Epoxy Composites. International Journal of Advances in Engineering and Management (IJAEM), 2(11), 37.https://doi.org/10.35629/5252-02113741

[34] Tezara, C., et al. "Factors That Affect the Mechanical Properties of Kenaf Fiber Reinforced Polymer: A Review." Journal of Mechanical Engineering and Sciences, vol. 10, no. 2, 2016, pp. 2159–2175, journal.ump.edu.my/jmes/article/view/8050, https://doi.org/10.15282/jmes.10.2.2016.19.0203.

[35] Saari, S, et al. "Strength Properties of Interlocking Compressed Earth Brick Units." AIP Conference Proceedings, 1 Jan. 2017, https://doi.org/10.1063/1.5005648. Accessed 21 Apr. 2024.