Teknisia

Vol. 30, No. 1, Mei 2025, pp.54-59
E-ISSN: 2746-0185

HDPE plastic waste as a fine aggregate substitute in the production of CLC lightweight bricks: an experimental study

Taufiqurrahman Mg[1,*], Nursyamsi Nursyamsi[1], Johannes Tarigan[1], Ricky Bakara[2]

[1] Faculty of Engineering, University of North Sumatra, Indonesia
[2] Faculty of Engineering, State Polytechnic of Medan, Indonesia

Article Info
***Article history*:**
Received:
May 23, 2025
Revised:
June 12, 2025
Accepted:
June 21, 2025
Available online:
June 23, 2025

***Keywords*:**
HDPE plastic waste
CLC lightweight brick
Compressive strength
Dry unit weight
Water absorption.

Corresponding Author:
Taufiqurrahman Mg*
taufiqurrahman@students.usu.ac.id

Abstract
This study aims to examine the utilization of High-Density Polyethylene (HDPE) plastic waste as a partial substitute for fine aggregate in the manufacture of Cellular Lightweight Concrete (CLC) lightweight bricks. The method used is a laboratory experiment with variations in the addition of HDPE of 0%, 5%, 10%, and 15% to the CLC mixture. Each variation was tested to determine the compressive strength, dry unit weight, and water absorption capacity after curing for 28 days. The results showed that the addition of HDPE affected the mechanical characteristics of lightweight bricks. The compressive strength decreased with increasing HDPE percentage, where the highest value was recorded at the 0% HDPE variation of 1.16 MPa and the lowest at the 15% variation of 0.92 MPa, below the SNI 8640-2018 standard. The highest dry unit weight was achieved at a composition of 5% HDPE of 3.32 kg/m³, indicating optimal density. However, the addition of HDPE also increased water absorption, with the highest average of 25.08% at the 15% variation. Thus, the use of HDPE waste as a substitute material shows environmentally friendly potential, but needs to be optimized so as not to reduce the structural quality of CLC lightweight bricks.

Introduction

Waste is a major issue, particularly in Indonesia. The World Health Organization (WHO) defines waste as something unused, unwanted, or discarded as a result of human activity. In accordance with Law No. 18 of 2008, waste is characterized as the solid remnants resulting from everyday human activities or natural processes. The issue of waste management stems largely from the societal view that waste is merely a worthless by-product (Evita et al., 2023). A report by the World Bank indicates that global waste volume is projected to increase by 70%, from 1.3 billion tons in 2020 to 2.2 billion tons by 2025, with the largest growth occurring in developing countries (Amalia, 2021).

In Indonesia, domestic waste generation reaches 151,921 tons per day, or approximately 0.85 kg per person. Unfortunately, only 80% of the waste is collected, while the remainder pollutes the environment (Tian et al, 2013). Based on data from the National Waste Management Information System (SIPSN) under the Ministry of Environment and Forestry (KLHK), approximately 41 million tons of waste were produced in 2023 across 382 districts and cities in Indonesia. The waste was composed of various materials, including food scraps, plastics, paper, metals, and other elements. However, just

60.35% of the total waste underwent appropriate management, leaving a significant portion untreated. Plastic waste is one of the dominant components and is difficult to decompose. The Extended Producer Responsibility (EPR) program has been introduced to involve producers in managing plastic waste. Plastics, including High-Density Polyethylene (HDPE), are frequently used for food containers or bottles due to their practicality and strength. High plastic consumption leads to a significant accumulation of waste (Syarifah Ratnawati, 2020).

In the context of sustainability, HDPE plastic waste is considered to have potential as an alternative material due to its durability and recyclability into new products such as pipes or building materials (Raheem et al., 2022). Its application supports pollution reduction, resource conservation, and the advancement of a circular economy. A notable innovation includes the replacement of fine aggregate with HDPE waste in the manufacturing of Cellular Lightweight Concrete (CLC) bricks.

CLC is a type of cellular concrete that does not use coarse aggregate and relies on foam agents to create air voids. CLC bricks are more cost-effective, easier to apply, and environmentally friendly, as they require less energy and produce lower pollution compared to red bricks (Putra et al., 2023). These bricks also offer good thermal and acoustic insulation, although their compressive strength tends to be lower. The use of foam agents significantly affects the characteristics of the bricks, including the number of voids and compressive strength (Mustapure, 2016).

The main challenge in the development of CLC bricks is maintaining strength and mechanical properties when substitute materials such as HDPE are used. Therefore, this study aims to evaluate the extent to which HDPE waste can be utilized in CLC formulations without compromising brick quality, while also promoting environmentally friendly and sustainable building material innovations

Research Methods

This study employed an experimental research method conducted at the Concrete Laboratory of the Faculty of Engineering, Universitas Sumatera Utara. The objective was to investigate the potential of High-Density Polyethylene (HDPE) plastic waste as a partial substitute for fine aggregates in the production of Cellular Lightweight Concrete (CLC) bricks. Brick specimens measuring 60 × 20 × 10 cm were prepared using a cement-to-sand ratio of 1:1.5, with HDPE substitution levels of 0%, 5%, 10%, and 15%. For each variation, three specimens were created to ensure consistency and repeatability.

Result and Discussion

Compressive Strength Testing

This test was conducted on specimens aged 28 days using a compression testing machine. The testing process involved applying a gradually increasing load onto the surface of cube specimens with dimensions of 10 cm x 10 cm x 10 cm until failure occurred. The results of the compressive strength tests are presented in the following table and graph 1

Table 1. Results of Compressive Strength Testing

Variat-ion	**Specimen Code**	**Wei-ght (Gr)**	**A (Mm^2)**	**Actual Load (N)**	**Compressive Strength (Mpa)**	**Average (Mpa)**
0% HDPE	A 0%	879	10000	13800	1.38	**1,16**
	B 0%	833	10000	10100	1.01	
	C 0%	809	10000	9700	0.97	
	D 0%	818	10000	12600	1,26	
5% HDPE	A 5%	1008	10000	10800	1,08	**1,13**
	B 5%	1016	10000	11000	1,1	
	C 5%	1026	10000	11400	1,14	
	D 5%	989	10000	12000	1,2	
10%	A 10%	947	10000	12200	1,22	**1,07**

HDPE	B 10%	905	10000	11800	1,18	
	C 10%	829	10000	8900	0.89	
	D 10%	872	10000	9900	0.99	
	A 15%	834	10000	8600	0,86	
	B 15%	763	10000	9000	0,9	
15% HDPE	C 15%	872	10000	9200	0,92	0,92
	D 15%	**822**	**10000**	**9900**	**0,99**	

Table 1 presents the effect of incorporating HDPE plastic waste on the compressive strength of CLC lightweight bricks. When no HDPE was added (0%), the average compressive strength recorded was 1.16 Mpa. However, at 5% HDPE, it decreased to 1.13 MPa; at 10% HDPE, it dropped further to 1.07 MPa; and at 15% HDPE, it declined to 0.92 MPa. These results indicate that increasing HDPE content reduces the structural integrity of the bricks, making them non-compliant with the Indonesian National Standard (SNI) 8640-2018, which requires a minimum compressive strength of 1.8 MPa.

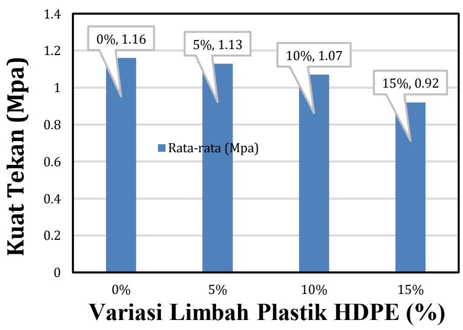

Figure 1. Compressive Strength Test Results of Lightweight Concrete Bricks

Figure 1 illustrates that the greater the amount of plastic waste added, the lower the structural strength of the lightweight bricks tends to be. While the utilization of plastic waste is beneficial in reducing environmental waste, its impact on material strength must be considered—especially in construction applications that demand high structural integrity.

Dry Density

In this research, the outcomes of the dry density assessment for lightweight concrete bricks measuring 20 cm × 20 cm × 10 cm after a 28-day curing period are displayed in the subsequent table and diagram.

Table 2. Oven-Dry Density Test Results

Variation	Test Object Code	Dry Oven Content Weight (Kg/m2)	Average Oven Dry Fill Weight (Kg/m3)
0 %	A 5%	2.96	3.03
	B 5%	3.10	
	C 5%	3.02	
5 %	A 10%	3.36	3.32
	B 10%	3.29	
	C 10%	3.32	
10 %	A 10%	3.30	3.17
	B 10%	3.05	
	C 10%	3.17	
15 %	A 15%	3.12	3.09
	B 15%	3.06	
	C 15%	**3.09**	

Table 2. shows that the addition of HDPE plastic waste in the production of CLC lightweight concrete bricks affects the dry density. The 0% HDPE variation has an average dry density of 3.03 kg/m³, which increases to 3.32 kg/m³ at the 5% HDPE level. A slight decrease is observed at the 10% HDPE level, with an average of 3.17 kg/m³, and the 15% variation records an average of 3.09 kg/m³.

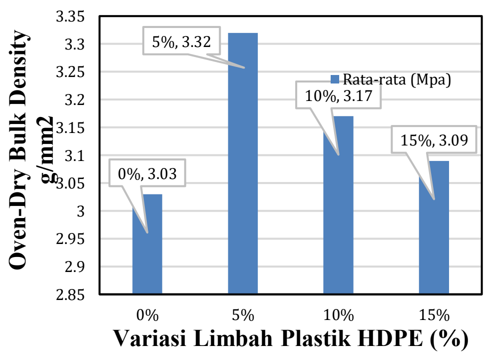

Figure 2. Oven-Dry Density Graph of Lightweight Concrete Bricks

The data presented in Figure 2 show that incorporating 5% HDPE plastic waste results in the highest oven-dry density, implying the brick achieves its most compact and durable structure at this proportion. Conversely, adding HDPE beyond 5% leads to a decrease in density, suggesting that excessive amounts of plastic waste may compromise the bricks' compactness and overall strength. Therefore, the optimal HDPE waste composition for achieving the best oven-dry density is at the 5% level.

Water Absorption

In this study, the water absorption test results for lightweight bricks cut to dimensions of 20 cm × 20 cm × 10 cm are presented following oven-drying at 110ºC for approximately 24 hours, then immersion for another 24 hours. The results are shown in the following table and graph.

Table 3. Water Absorption Test Results of Lightweight

Variat-ion	Sample Code	Oven-Dry Density (Kg/m³)	Saturated Density (Kg/m³)	Water Absor-ption	Average Water Absorption (%)
	A 5%	2.96	3.70	24.83	
0 %	B 5%	3.1	3.88	25.16	**21.85 %**
	C 5%	3.02	3.49	15.56	
	A 10%	3.36	4.20	25.00	
5 %	B 10%	3.29	4.12	25.08	**21.92 %**
	C 10%	3.25	3.76	15.69	
	A 10%	3.3	4.12	24.85	
10 %	B 10%	3.05	3.81	24.92	**24.62 %**
	C 10%	3.07	3.81	24.10	
	A 15%	3.12	3.90	24.84	
15 %	B 15%	3.06	3.82	24.84	**25.08 %**
	C 15%	**3.09**	**3.88**	**25.57**	

Table 3 shows that the addition of HDPE plastic waste increases the water absorption capacity of CLC lightweight bricks. The 0% HDPE variation has an average water absorption of 21.85%, increasing slightly to 21.92% for 5% HDPE. The 10% variation increases to 24.62%, and the 15% variation further rises to 25.08%. These results suggest that HDPE contributes to the bricks' ability to absorb water, which has implications for their performance and durability. However, based on the SNI 8640-2018 standard, the water absorption levels of these bricks remain within acceptable limits, as they are still relatively below 25%.

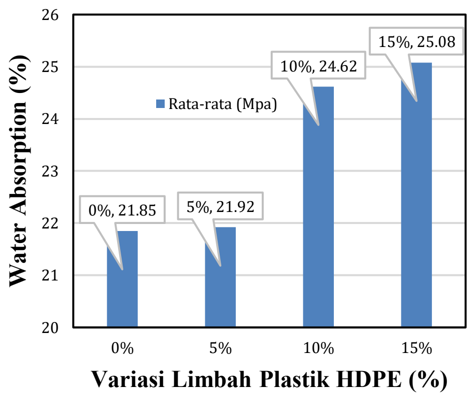

Figure 3. Water Absorption Graph of Lightweight Concrete Bricks

The data in Figure 3 show that although the initial addition of HDPE plastic waste may slightly reduce water absorption, higher proportions tend to increase the bricks' water absorption. This may indicate that plastic waste contributes to the porosity of the material, thus increasing its water retention capacity. Nevertheless, this also has implications for the mechanical strength and durability of the bricks, which should be carefully considered in construction applications.

Conclusions

This study evaluates the potential of HDPE plastic waste as a substitute for fine aggregate in the manufacture of CLC (Cellular Lightweight Concrete) lightweight bricks. The test results show that the addition of HDPE has an impact on the compressive strength, dry density, and water absorption of the bricks. The addition of HDPE up to 15% causes a decrease in compressive strength from 1.16 MPa (0% HDPE) to 0.92 MPa (15% HDPE), which does not meet the minimum standard of SNI 8640-2018 of 1.8 MPa. In terms of density, bricks with 5% HDPE show the highest value (3.32 kg/m³), indicating the densest and most stable structure. However, increasing HDPE by more than 5% actually decreases the density, which affects the strength and density of the bricks. The water absorption test shows that all variations remain within the range of 15–25%, indicating that the addition of HDPE does not significantly increase the porosity of the bricks. In conclusion, although the use of HDPE waste in small amounts (maximum 5%) can increase the density of bricks without drastically reducing the quality, use above this threshold is not recommended because it has a negative impact on mechanical strength. This study supports the use of plastic waste for sustainable construction, but a careful approach in its proportions is needed so as not to compromise building quality standards.

References

Al-Hadithi, A. I., Almawla, S. A., & Mohammed, M. K. (2023). Fresh, mechanical and impact properties of self-compacting lightweight concrete containing waste PET fibers. Innovative Infrastructure Solutions, 8(10), 1–24. https://doi.org/10.1007/s41062-023-01223-5

Amalia, F., & Putri, M. K. (2021). Analisis Pengelolaan Sampah Anorganik Di Sukawinatan Kota Palembang. Jurnal Swarnabhumi, 6(2), 134–142. Link PDF

Amran, Y. H. M., Farzadnia, N., & Ali, A. A. A. (2015). Properties and applications of foamed concrete: a review. Construction and Building Materials, 101, 990–1005. https://doi.org/10.1016/j.conbuildmat.2015.10.112

Belmokaddem, M., Mahi, A., Senhadji, Y., & Pekmezci, B. Y. (2020). Mechanical and physical properties and morphology of concrete containing plastic waste as aggregate. Construction and Building Materials, 257, 119559. https://doi.org/10.1016/j.conbuildmat.2020.119559

Bhosale, A., Zade, N. P., Sarkar, P., & Davis, R. (2020). Mechanical and physical properties of cellular lightweight concrete block masonry. Construction and Building Materials, 248, 118621. https://doi.org/10.1016/j.conbuildmat.2020.118621

Evita, Pasongli, H., Salam, R., & Marthinu, E. (2023). Analisis Hubungan antara Pengetahuan dan Sikap Peduli. Growth Dan Manajemen Lingkungan, 13(1), 31–43.

Jones, M. R., & McCarthy, A. (2005). Behaviour and assessment of foamed concrete for construction applications. Cement and Concrete Composites, 27(9–10), 845–853. https://doi.org/10.1016/j.cemconcomp.2005.03.017

Kearsley, E. P., & Wainwright, P. J. (2001). Porosity and permeability of foamed concrete. Cement and Concrete Research, 31(5), 805–812. https://doi.org/10.1016/S0008-8846(01)00490-2

Kumar, P., Singh, R., & Sharma, A. (2021). Classification and performance evaluation of lightweight, normal weight, and heavyweight concrete: A review. Construction and Building Materials, 273, 121815. https://doi.org/10.1016/j.conbuildmat.2020.121815

Limami, H., Manssouri, I., Cherkaoui, K., Saadaoui, M., & Khaldoun, A. (2020). Thermal performance of unfired lightweight clay bricks with HDPE & PET waste plastics additives. Journal of Building Engineering, 30(November 2019), 101251. https://doi.org/10.1016/j.jobe.2020.101251

Lv, X. Sen, Cao, W. X., Yio, M., Ji, W. Y., Lu, J. X., She, W., & Poon, C. S. (2024). High-performance lightweight foam concrete enabled by compositing ultra-stable hydrophobic aqueous foam. Cement and Concrete Composites. https://doi.org/10.1016/j.cemconcomp.2024.105675

Manaf, I. A., Marsi, N., Genesan, V., Yusrianto, E., Shariff, H. H., Adnan, S. H., Awang, M., Ali, R., & Jamir, M. R. M. (2021). Compressive strength, sound absorption coefficient (SAC) and water absorption analysis of HDPE plastic waste reinforced polystyrene and Portland cement for lightweight concrete (LWC). Journal of Physics: Conference Series, 2051(1). https://doi.org/10.1088/1742-6596/2051/1/012043

Mustapure, N. (2016). A Study on Cellular Lightweight Concrete Blocks. International Journal of Research in Engineering and Technology, 188–191.

Muthusubramanian, B., Neelamegam, P., Ramar, V., & Suresh, V. (2023). Assessing the embodied carbon and energy required for manufacturing sustainable concrete blocks using plastic pollution as a fiber. Environmental Science and Pollution Research, 30(49), 107533–107548. https://doi.org/10.1007/s11356-023-29933-4

Narayanan, N., & Ramamurthy, K. (2000). Structure and properties of aerated concrete: a review. Cement and Concrete Composites, 22(5), 321–329. https://doi.org/10.1016/S0958-9465(00)00016-0

Putra, F. C., Tamrin, A., & Rahmawati, K. (2023). Pengaruh Penggantian Sebagian Agregat Halus dengan Limbah Plastik Terhadap Berat Jenis, Kuat Tekan dan Nilai Ekonomis pada Bata Ringan. Indonesian Journal Of Civil Engineering Education, 9(2), 74. https://doi.org/10.20961/ijcee.v9i2.83608

Putrilan, M., Harahap, S., & Nursyamsi, N. (2024). The Evaluation of the Use PET and HDPE Plastic Waste. 03(01), 49–57.

Raheem, A., Azam, A., Arooj, A., Razzaq, A., Sohail, M. I., & Zulfiqar, B. (2022). Recycling and utilization of high-density polyethylene (HDPE) waste: A comprehensive review. Journal of Environmental Management, 301, 113821. https://doi.org/10.1016/j.jenvman.2021.113821

Tian, H., Gao, J., Hao, J., Lu, L., Zhu, C., & Qiu, P. (2013). Atmospheric pollution problems and control proposals associated with solid waste management in China: a review. Journal of Hazardous Materials, 252, 142-154.