Prepublished copy

Nature Environment & Pollution Technology

This is a peer-reviewed prepublished version of the paper

Original Research

Eco-efficient bricks for sustainable urban plastic waste management

Yacouba Zoungranan[1*], M'Bra Ignace Christian[2], Soro Sirata Ibrahima Francis[2], Ekou Lynda[2] and Ekou Tchirioua[2]

[1] Department of Mathematics, Physics and Chemistry, University Peleforo GON COULIBALY, Korhogo, Côte d'Ivoire, (Ivory Coast)

[2] Department of Chemistry, University NANGUI ABROGOUA, Abidjan, Côte d'Ivoire (Ivory Coast)

† Corresponding author: Yacouba Zoungranan: zoungranan@gmail.com /ORCID: 0000-0003-0739-1916

Abstract: In developing countries, plastic packaging waste and the proliferation of cement plants have become real problems in terms of hygiene and public health. Common plastic packaging is produced by the petrochemical industry. It is (Ivory Coast) ,non-biodegradable and releases numerous toxic substances when heated or incinerated. In this study, building blocks were produced by incorporating waste plastic packaging (low density polyethylene) as a reinforcement in fired clay bricks. The incorporation into the raw clay matrix was carried out in proportions of 0%, 1%, 2%, 3%, 4% and 5% of plastic, corresponding respectively to brick types Bcp0, Bcp1, Bcp2, Bcp3 and Bcp4, Bcp5. The Bcp4 bricks showed optimal physical properties (water absorption rate, apparent porosity, density, and compressive strength). The introduction of 4% plastic waste into the clay increased the compressive strength, decreased the water absorption rate, and significantly reduced the apparent porosity. The influence of firing temperature (T_f), firing time (t_f) and amount of mixing water (m_{water}) was investigated on Bcp0 and Bcp4 bricks. The better plastic incorporation for the operating parameters T_f = 200 °C, mwater = 20 g and t_f =.6 h. The study shows that it is possible to have eco-efficient brick production with low energy consumption.

Key Words	Clay, Plastics waste, Bricks, Recycling
DOI	https://doi.org/10.46488/NEPT.2025.v24i03.D1742 (DOI will be active only after the final publication of the paper)
Citation of the Paper	Yacouba Zoungranan, M'Bra Ignace Christian, Soro Sirata Ibrahima Francis, Ekou Lynda and Ekou Tchirioua, 2025. Eco-efficient bricks for sustainable urban plastic waste management. *Nature Environment and Pollution Technology*, 24(3), D1742. https://doi.org/10.46488/NEPT.2025.v24i03.D1742

1. INTRODUCTION

In some African cities, such as Abidjan, the economic capital of Côte d'Ivoire, the various domestic and industrial activities that take place daily led to a proliferation of waste on the streets (Jambeck et al. 2018), especially plastic waste. This capital alone produces more than 288 tons of plastic waste every day, of which only 5% is recycled (Koumi et al. 2021). This situation is due to the country's lack of advanced technology facilities and appropriate rules and regulations on the production, use and management of plastic waste. Due to their high stability and durability, most of these plastic wastes have limited natural degradation. They take between 100 and 1,000 years to decompose (Nayanathara Thathsarani Pilapitiya and Ratnayake, 2024) . This chemical stability poses pollution problems in receiving environments, impacting human and animal health(Emadian et al. 2017; Kanellopoulos et al.

2021). In addition, strong urban demographic growth has also led to high demand for housing, and induced the development of several cement works that supply cement for making bricks for housing. Unfortunately, the day-to-day operation of these cement plants results in the release of numerous toxic substances liable to harm the environment and human health(Subashi De Silva and Hansamali, 2019; Venkatarama Reddy and Jagadish, 2003). Despite the presence of these cement plants, which are intended to facilitate access to housing, the housing crisis is a reality (N'goran et al. 2020). The bricks have a long history as a building material, from the use of clay to the incorporation of composite materials. Moulding may be followed by a bricks firing stage or also they may remain unfiring (Jiménez-García et al., 2023). Although raw clay bricks are environmentally friendly and recyclable, their physico-chemical properties may sometimes be insufficient for certain applications. In such cases, to improve the properties of the bricks, the manufacturing processes require them to be fired at very high temperatures or to use composite materials in combination with clay (Rauniyar et al., 2024). Several studies have been carried out on composite bricks made from clay and associated organic or inorganic materials. Among these studies, materials such as glass powder waste (Khan et al., 2022), rice straw (Akinyemi et al., 2022), incineration bottom ash (Adediran et al., 2024), tea waste (Hussien et al., 2024) and dolomite powder industrial waste (Kizinievič et al., 2023) have been used recently. Most of these results showed that the use of inorganic materials improved certain mechanical properties but reduced compressive strength (Ebadi-Jamkhaneh et al., 2021). This could be explained by a reduction in the vitreous phase content (Achik et al., 2020).

In the traditional process, the brick kiln is heated to 1000-1500 °C, where alumina, silica and iron are converted to molten glass, which acts as a binder to ensure adhesion. It then takes several days to slowly cool the kiln and recover the bricks (Murmu and Patel, 2018). Côte d'Ivoire has several clay deposits (Bakary Soro et al. 2023; Kouakou et al. 2023) used in the manufacture of numerous ceramics (He et al. 2024) and in the construction of rural dwellings in general. The poor quality of traditional bricks has led people to turn to materials from local or imported cement works. However, these materials remain costly and even inaccessible to low-income populations. It is therefore necessary to improve the quality of traditional bricks to produce sustainable materials that are both inexpensive and environmentally friendly. Several studies have been carried out to improve the quality of fired clay bricks by adding various reinforcements, such as non-biodegradable plastic waste, to help solve plastic waste management problems (Dalkılıç and Nabikoğlu, 2017; Haque and Islam, 2021; Ikechukwu and Shabangu, 2021; Kulkarni et al. 2022; Gounden et al. 2024). The aim of the present study is to contribute to a solution for recycling plastic bags from the city of Abidjan, by incorporating them as reinforcement alongside clays in the manufacture of ecological bricks. The aim is to design composite bricks with various proportions of incorporated plastics, and to assess their physical and mechanical characteristics. In this way, local clay raw materials could be put to good use in the production of widely used building materials.

2. MATERIALS AND METHODS

2.1. Dry material preparation

Raw clay was collected from a clay pottery site (8°8'32.34" N and 5°6'21.38" W) in Katiola, a town located in central Côte d'Ivoire 393.5 km from the economic capital Abidjan. After drying, the clay was ground, and the resulting powder sieved on a sieve (Saulas, Paris, France) with an opening of 800 µm. The sieved material was stored in a jar and used as the base matrix for the ecological bricks. The plastic waste used as reinforcement is black low-density polyethylene packaging. This type of plastic is a popular household packaging material, easy to obtain due to its low cost and high capacity to hold a variety of household products. It is therefore one of the most abundant types of plastic waste to be found on the streets of Abidjan. Polyethylene bag waste was collected in residential areas, across the streets. The collected waste was thoroughly washed under running water, then dried for 48 hours at room temperature. Multiple crumbling was performed using a blender-shredder to obtain a fine plastic straw. Sieving on a sieve (Saulas, Paris, France) with an opening of 800 µm produced a homogeneous straw, as variation in dry matter particle size can affect brick properties and the repeatability of results (Kulkarni et al. 2019).

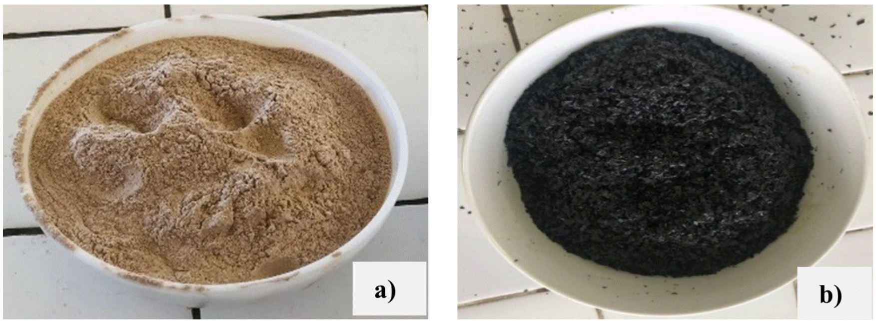

Fig. 1: Dry materials: a) clay matrix, b) plastic waste powder

2.2. Brick production

Each type of brick (Bcp0, Bcp1, Bcp2, Bcp3 and Bcp4, Bcp5) was produced using a mass M = 75 g of dry materials (mclay + mplastic) and a mass mwater of distilled water (wet material). For each brick of a given type, the mixing of dry materials is carried out by determining the corresponding mass of plastics for a proportion (0%, 1%, 2%, 3%, 4%, 5%) to always have a total mass of 75 g of dry materials.

Table 1: Composition of the dry mix

Sample	Plastic waste powder (%)	Clay (g)	Plastic waste powder (g)
Bcp0	0	75	0
Bcp1	1	74.25	0.75
Bcp2	2	73.5	1.5
Bcp3	3	72.75	2.25
Bcp4	4	72	3
Bcp5	5	71.25	3.75

For each sample, the dry mixture is prepared by means of a glass rod and then mixed with the required amount of water and kneaded. The resulting paste is poured into an 80 mm x 50 mm x 50 mm metal mould (**Fig. 2**) fitted with a removable compression plate.

Fig. 2: Moulding device

The bricks were formed using a manual mechanical press, then demoulded and dried at room temperature for 48 hours. After drying, the bricks were fired in a muffle kiln (Nabertherm GmbH, Bremen, Germany) at 200°C. In the first stage of the study, ten (10) bricks of each type (Bcp0, Bcp1, Bcp2, Bcp3 and Bcp4, Bcp5) were produced by setting the mass of mixing water at m_{water} = 15 g, the firing temperature at T_f = 200 °C and the firing time at t_f = 4 hours. This stage made it possible to select the type of dry mass mixing ratio required to obtain the type of brick with optimum characteristics (Bcp_{opt}). In the second stage of the study, the influence of the parameters firing temperature (T_f), firing time (t_f) and wet mass (m_{water}) on the physicochemical properties of Bcp_{opt} bricks was studied in comparison with Bcp0 bricks.

2.3. Operating parameters and their influence

The water quantity (m_{water}): For these brick series Bcp_{opt} and Bcp0, mixing was carried out with different masses m_{water} = (15 g, 20 g, 25 g and 30 g). The firing temperature was set at 500 °C for 4 hours.

The firing temperature: Bcp_{opt} and Bcp0 brick series are always considered, with m_{water} = 20 g and firing temperatures successively set at 200 °C, 300 °C, 400 °C and 500 °C for a duration of 4 h.

The firing time: The effect of time was carried out with Bcp_{opt} and Bcp0 brick series for m_{water} = 15 g. The firing time for each trial was determined by the firing temperature. The firing times for each trial were 4h, 5h and 6h. The firing temperature remained fixed at 200 °C.

2.4. Brick physicochemical characterisation

To determine the water absorption rate, the brick is dried to a constant mass (m_1), then immersed in distilled water for 24 hours. The sample is then removed, wiped with a damp cloth and weighed (m_2). Water absorption is given by equation 1:

$$Absorption\,(\%) = \frac{m_2 - m_1}{m_1} \times 100 \qquad \textbf{(1)}$$

Density is calculated after firing and cooling a mass m of brick. The dimensions of the brick are then measured with a caliper, so that the volume V is known. The density is then calculated using the following formula:

$$Density\,(t/m^3) = \frac{m}{V} \qquad \textbf{(2)}$$

To assess apparent porosity, the brick is dried to a constant mass (m1), then immersed in distilled water for 24 hours. The sample is removed, wiped with a damp cloth, and weighed to obtain a mass (m2). The volume V of the brick is given by measuring its dimensions with a caliper. Apparent porosity is calculated using the following formula:

$$Apparent\ porosity\,(\%) = \frac{m_2 - m_1}{V} \times 100 \qquad \textbf{(3)}$$

Compressive strength tests were carried out using an automatic compression machine (**Fig. 3**).

Fig. 3: Compressive strength tests with the UTEST (UTCM-6431, Ankara, Turkey) device

The breaking force causing fracture is estimated by the machine, and together with the surface area, we calculate the compressive strength using the following formula:

$$Compressive\ strength\,(MPa) = \frac{Maximum\ load\ at\ failure\,(N)}{Area\ under\ compression\,(mm^2)} \quad \textbf{(4)}$$

2. 5. Bricks composition EDS analysis

EDS analyses of the clay samples were carried out using Bruker's QUANTAX EDS microprobe with an X Flash 6/30 detector. The structural specificities of the Bcp_{opt} and Bcp0 bricks were analyzed using a Hiro SH 400 M Scanning Electron Microscope (Limonest, France).

2.6. Data processing

All calculations were performed with Microsoft office Excel 2016 Professional. Mean values and standard deviation were determined from three individual measurements.

3. RESULTS

3.1. Composition of the raw clay

Semi-quantitative EDS analysis of the clay sample enabled us to specify the composition of the clay in the study. The dispersion spectrum of the elements is shown in **figure 4** and the elemental proportions are given in **table 2**.

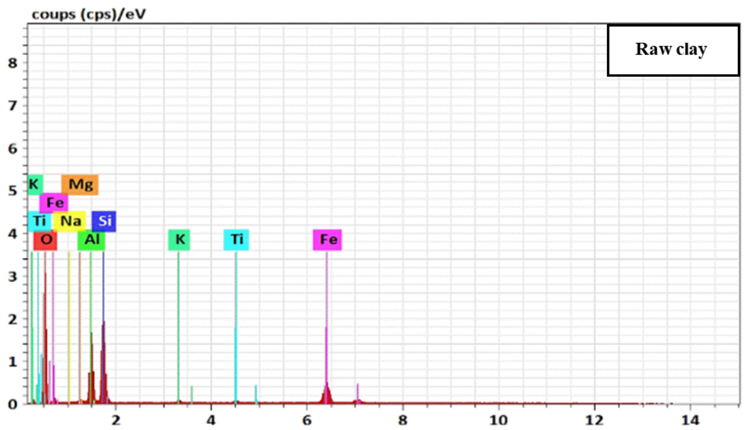

Fig. 4: Energy Dispersion Spectrum (EDS) of Raw Clay

Table 2: Elemental composition of raw clay

Elements	Normal Mass (%)	Atomic Mass (%)
O	57.32	72.36
Al	13.43	10.05
Si	17.60	12.66

Ti	0.69	0.29
Fe	9.20	3.33
Na	0.75	0.66
Mg	0.43	0.36
K	0.58	0.30
Total	100.00	100.00

The result of the semi-quantitative EDS analysis of the raw clay sample is shown in Figure 4, which presents the spectrum of the chemical elements contained in the study clay (O, Al, Si, Ti, Fe, Na, Mg, K). Table 1 shows the different mass percentages of these chemical elements. Silicon (Si) and aluminum (Al) are highly present, mainly due to the presence of chemical elements in oxide form, respectively SiO2 (silica) and Al2O3 (alumina). Alumina is a determining factor in the identification of clays. A high alumina content indicates the presence of kaolinite (Qlihaa et al., 2016). However, it is important to highlight the low presence of the chemical elements Fe, Mg, K. The presence of Ti would indicate the presence of titanium dioxide (TiO2) in the raw clay. In addition, the clay in this study is predominantly a mixture of kaolinite and illite, as observed by Kpangni et al. 2008.

3.2. Optimal dry matter composition

The bricks were shaped progressively, increasing the amount of plastic in the total dry matter from 1% to 10% initially. Baked at 200 °C for 4 h, dislocation of the bricks was observed for proportions of 6% or more of plastic waste (**Fig. 5**). These bricks detach on cooling and can therefore not be characterized.

Fig. 5: Aspects of some types of eco-friendly bricks

The specific characteristics of the bricks obtained in the first stage of the study are shown in figure 6.

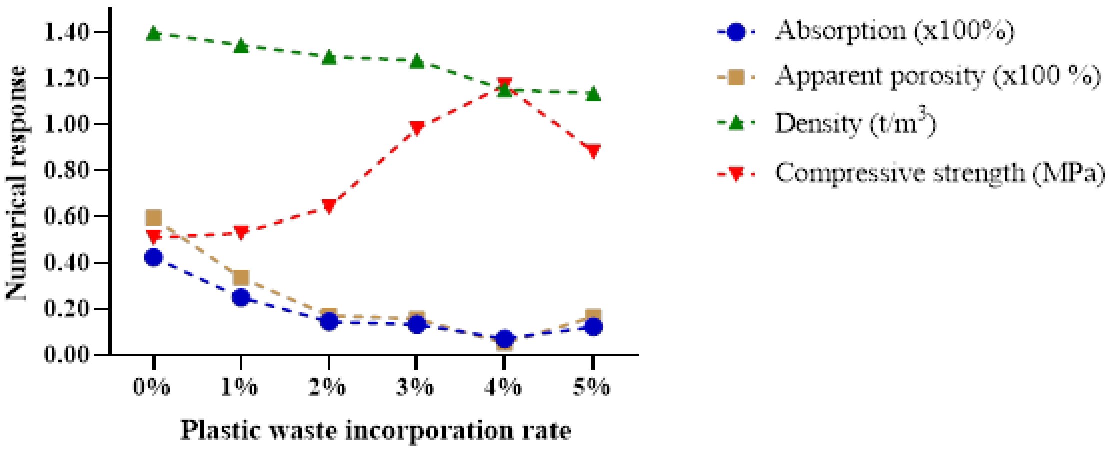

Fig. 6: Evolution of bricks characteristics, T_f = 200 ° C; m_{water} = 15 g, t_f = 4 h

Water absorption is an important characteristic for assessing the durability, thermal conductivity, and quality of a brick (Iftikhar et al. 2020). Figure 6 shows that at a firing temperature of 200 °C, the water absorption capacity of bricks decreases as the amount of plastic incorporated increases. Bcp4 bricks remain the least absorbent. The apparent porosity is positively correlated with the water absorption capacity. It decreases and reaches its lowest value also for Bcp4 bricks. The moderate addition of plastic therefore makes the bricks less porous. The density of the bricks is an important parameter in defining their field of application. Gradual addition of plastic reduces the density of bricks. The lowest density bricks are Bcp5 bricks. The incorporation of up to 4% plastic waste as dry reinforcement in the Bcp0 brick optimizes its compressive strength. Given the above, it appears that the composition of Bcp4 bricks, fired at only 200 °C, provides a significant improvement in durability and compressive strength. Scanning electron microscopy (SEM) allowed us to observe the comparative texture (**Fig.7**) of Bcp0 and Bcp4 bricks. The clay particles in Bcp0 are in the form of clusters of fine polygonal platelets (in the micrometer range), characteristic of a kaolinite (Bakary Soro et al., 2023) rather than an illite crystalline morphology. The addition of plastic waste makes the surface of Bcp4 much less glassy, but more compact and therefore less susceptible to deformation. There is also a good distribution of plastic in the porous structure of the clay in Bcp4.

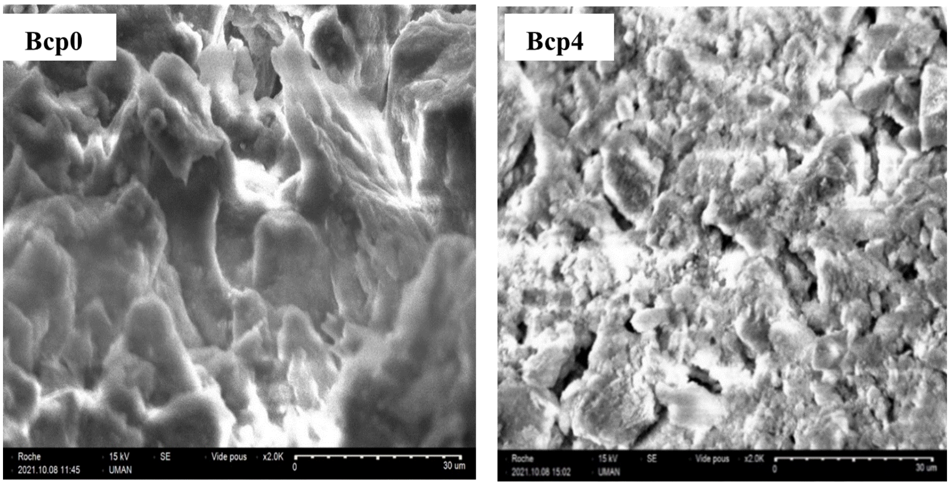

Fig. 7: SEM images comparing Bcp0 and Bcp4 bricks. T_f = 200 °C ; m_{water} = 15 g, t_f = 4 h

3.3 Effect of operating parameters

For this stage of the study, tests were carried out with Bcp0 and Bcp4 bricks.

3.3.1. Firing temperature

The effects of increasing the temperature to 400°C and 500°C were not compared due to the dislocation of the Bcp4 bricks at these temperatures. The results of the temperature effect are shown in figure 8.

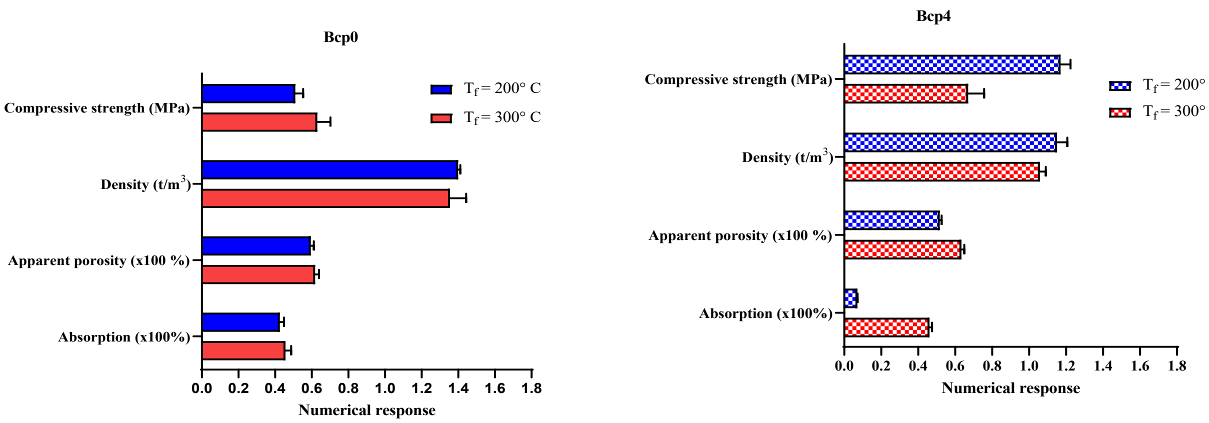

Fig. 8: Effect of firing temperature on the characteristics of Bcp0 and Bcp4 bricks; m_{water} = 15 g, t_f = 4 h

As the temperature increases from 200°C to 300°C, there is an increase in water absorption capacity, porosity, and a slight increase in density. On the other hand, a decrease in the compressive strength of the material is observed.

3.3.2. Effect of firing time

The results of firing at T_f = 200 °C at various times are shown in figure 9.

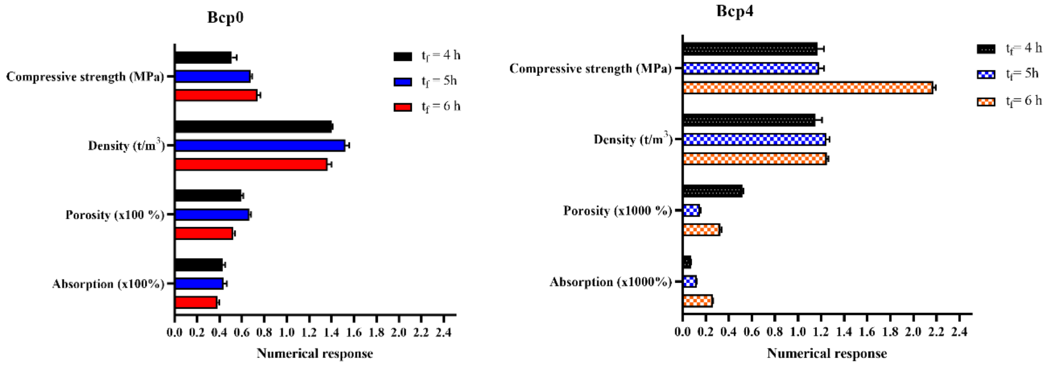

Fig. 9: Effect of firing time on the characteristics of Bcp0 and Bcp4 bricks; m_{water} = 15 g, T_f = 200 °C
Firing for 6 hours improves compressive strength and density. The bricks become slightly denser and more resistant to compression.

3.3.4. Effect of wet mass

Above m_{water} = 25 g, wet matter acts as a limiting factor for brick shaping at the compaction stage. For example, the production of bricks Bcp4 at m_{water} = 30 g resulted in a deformed brick (**Fig. 8)** due to material leakage during compaction. The same moulding difficulties were observed with Bcp0 from m_{water} = 25 g.

Fig. 10: Material loss during compaction of Bcp4 at m_{water} = 30 g

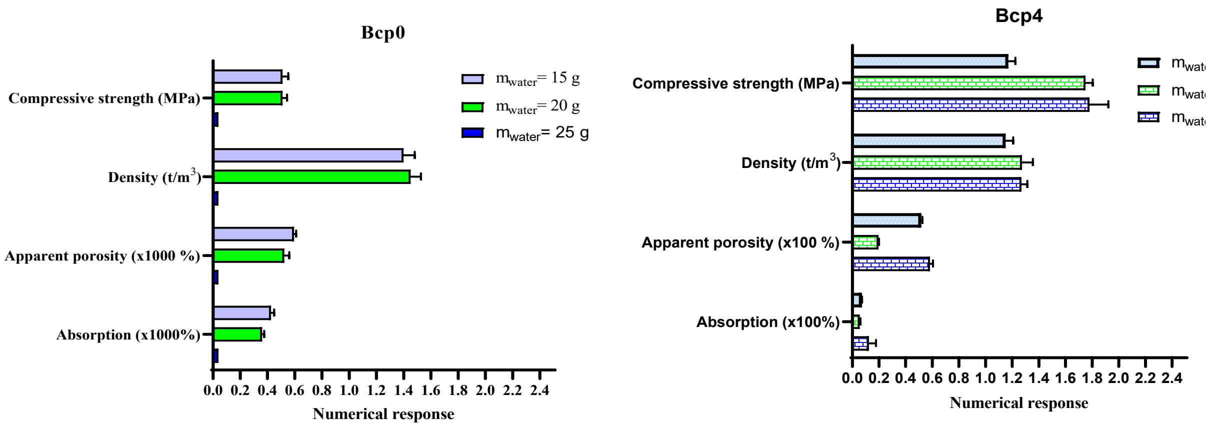

Fig. 11: Effect of wet mass on the characteristics of Bcp0 and Bcp4 bricks; T_f= 200 °C, t_f= 4
The amount of wet matter influences the characteristics of the bricks produced. For the Bcp4 brick type, as the amount of moisture increases, the compressive strength and porosity increase. This increase in porosity leads to an increase in water absorption capacity. This could be a limiting factor in the durability of the bricks. However, at m_{water} = 20 g the compressive strength is improved. This amount of m_{water} = 20 g also improves the physicochemical and mechanical properties of Bcp0 bricks.

4. DISCUSSIONS

Composite bricks were developed by dispersing plastic (polyethylene) in clay. The results of the composite bricks obtained present much better brick characteristics compared to bricks elaborated with raw clay alone. A study of the influence of the dry matter mixing ratio revealed that moderate incorporation of polyethylene improved the quality of composite bricks, especially their compressive strength. The study revealed that compressive strength was highest at 4% plastic. Moderate increases in plastic content (up to 5%) lower density and porosity, significantly reducing the water absorption capacity of composite bricks. The experimental study by (Ebadi-Jamkhaneh et al., 2021) on the mechanical properties of fired clay bricks incorporated with plastic waste had shown that the addition of 3% fine polyethylene plastic particles can include the fired clay brick as a load bearing brick. Another study by (Hussien et al., 2024) on the tea waste additive effects on the physical and mechanical properties of unfired clay bricks also showed that samples containing 2.5% and 5% of the additive gave better compressive strength results. The present study also showed that increasing the firing temperature to 300 °C increased density and lowered compressive strength. There was also an increase in the water absorption and porosity of composite bricks. This result could be due to the behavior of polyethylene. Polyethylene melts at 85 °C and degrades at 274 °C (Wahane et al. 2023). Thus, at temperatures below 300 °C and above its melting point, it remains in the liquid state, enabling it to adhere better to the clay and close the pores of the clay material. Above the degradation temperature of polyethylene, the liquid shrinks to form pellets, creating voids in the clay material. This shrinkage phenomenon is likely to explain the increase in porosity and absorption leading to a reduction in the strength of composites. As water absorption capacity is recognized as an indicator of durability and porosity (Vasić et al. 2020), a temperature of 200 °C is more suitable for firing clay-polyethylene composite bricks. A low absorption capacity and high density could reduce brick permeability and resistance to certain climatic conditions (Vasić et al. 2020). The increase in porosity linked to the plastic additive improves thermal conductivity (Hussien et al., 2024) and makes it possible to obtain lightweight insulating bricks. As for the effect of firing time, it shows that it is after 6 hours of firing that resistance and density are high. Finally, a study of the effect of wet mass shows that maximum compressive strength values are obtained at 20 g.

5. CONCLUSION

Conventional bricks made from high temperature clay require a high consumption of energy and clay raw materials. In this study, clay-plastic composite bricks were developed using different proportions of polyethylene plastic waste. The Bcp4 bricks exhibited optimum physical and mechanical properties at only 200°C, with a 15 g water mixture and a cooking time of 4 hours. This is equivalent to an incorporation rate of 4% of the mass of the brick. The effects of operating parameters such as baking temperature, amount of wet material and baking time were investigated. The optimum baking time for bricks was found to be 6 hours per 20 g of wet mass and a cooking temperature of 200°C. The results show that the incorporation of plastic waste into the bricks can lead to a significant improvement in the performance of the bricks. Bricks produced under the conditions revealed by the study could be an alternative means of reducing polyethylene plastic waste. This suggests positive prospects for solutions in the construction industry.

Overall, the results suggest that polyethylene plastic waste can be reused to produce environmentally friendly bricks, which could significantly reduce plastic waste in the environment. These composites are promising for use as durable bricks for walls, paving and other construction applications. However, it would be necessary in future studies to expand the type of plastic waste and increase the mechanical characterisation tests.

Author Contributions:

Y.Z: Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing original draft, review and editing, Visualization. **M.I.C**: Software, Formal analysis, Writing original draft, Visualization. **S.S.I.F**: Investigation, Visualization. **E.L**: Conceptualization, Project administration, Methodology, Formal analysis. **E.T.**: Methodology, Supervision, Validation. All authors have read and agreed to the published version of the manuscript." Authorship should be restricted to individuals who have made significant contributions to the research.

Funding: This research received no external funding

Conflicts of Interest: The authors declare no conflicts of interest

REFERENCES

1. Achik, M., Benmoussa, H., Oulmekki, A., Ijjaali, M., El Moudden, N., Touache, A., Álvaro, G.G., Rivera, F.G., Infantes-Molina, A., Eliche-Quesada, D., Kizinievic, O., 2020. Evaluation of technological properties of fired clay bricks containing pyrrhotite ash. Constr Build Mater 269, 121312. https://doi.org/10.1016/j.conbuildmat.2020.121312
2. Adediran, A., Kikky, S. M., Adhikary, S. K., Ducman, V., Perumal, P., 2024. Upcycling municipal solid waste incineration bottom ash in clay-bonded bricks. Ceramics International. https://doi.org/10.1016/j.ceramint.2024.12.324
3. Akinyemi, B. A., Mami, O., Adewumi, J. R., 2022. Utilisation of treated rice straw waste fibre as reinforcement in gypsum–cement unfired clay bricks. *Innovative Infrastructure Solutions*, *7*(5), 308. https://doi.org/10.1007/s41062-022-00911-y
4. Bakary Soro, S., Coulibaly, M., Paul Gauly, L., Dri, S. R., Sanou, A., Trokourey, A. (2023). Characterization of Clay Materials from Côte d'Ivoire: Possible Application for the Electrochemical Analysis. Journal of Materials Science Research 12(1), 51. https://doi.org/10.5539/jmsr.v12n1p51
5. Dalkılıç, N., Nabikoğlu, A., 2017. Traditional manufacturing of clay brick used in the historical buildings of Diyarbakir (Turkey). Frontiers of Architectural Research 6, 346–359. https://doi.org/10.1016/j.foar.2017.06.003
6. Ebadi-Jamkhaneh, M., Ahmadi, M., Kontoni, D.-P. N., 2021. Experimental study of the mechanical properties of burnt clay bricks incorporated with plastic and steel waste materials. IOP Conference Series: Earth and Environmental Science *899*(1), 012042. https://doi.org/10.1088/1755-1315/899/1/012042
7. Emadian, S.M., Onay, T.T., Demirel, B., 2017. Biodegradation of bioplastics in natural environments. Waste Management. https://doi.org/10.1016/j.wasman.2016.10.006
8. Gounden, K., Mwangi, F. M., Mohan, T. P., Kanny, K., 2024. Improving the performance properties of plastic-sand bricks with Kaolin Clay. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-024-05788-8
9. Haque, Md.S., Islam, S., 2021. Effectiveness of waste plastic bottles as construction material in Rohingya displacement camps. Clean Eng Technol 3, 100110. https://doi.org/10.1016/j.clet.2021.100110
10. He, I. L., Atheba, G. P., Gbassi, G. K., 2024. Food Study of Ceramic Objects from Artisanal Pottery in the City of Katiola in Côte d'Ivoire. Food and Nutrition Sciences 15(11), 1033–1042. https://doi.org/10.4236/fns.2024.1511066
11. Hussien, A., Zubaidi, R. Al, Jannat, N., Ghanim, A., Maksoud, A., Al-Shammaa, A., 2024. The effects of tea waste additive on the physical and mechanical characteristics of structural unfired clay bricks. Alexandria Engineering Journal *101*, 282–294. https://doi.org/10.1016/j.aej.2024.05.090
12. Iftikhar, S., Rashid, K., Ul Haq, E., Zafar, I., Alqahtani, F.K., Iqbal Khan, M., 2020. Synthesis and characterization of sustainable geopolymer green clay bricks: An alternative to burnt clay brick. Constr Build Mater 259, 119659. https://doi.org/10.1016/j.conbuildmat.2020.119659
13. Ikechukwu, A.F., Shabangu, C., 2021. Strength and durability performance of masonry bricks produced with crushed glass and melted PET plastics. Case Studies in Construction Materials 14, e00542. https://doi.org/10.1016/j.cscm.2021.e00542
14. Jambeck, J., Hardesty, B.D., Brooks, A.L., Friend, T., Teleki, K., Fabres, J., Beaudoin, Y., Bamba, A., Francis, J., Ribbink, A.J., Baleta, T., Bouwman, H., Knox, J., Wilcox, C., 2018. Challenges and emerging solutions to the land-based plastic waste issue in Africa. Mar Policy 96, 256–263. https://doi.org/10.1016/j.marpol.2017.10.041
15. Jiménez-García, E. de J., Arellano-Vazquez, D.A., Titotto, S., Vilchis-Nestor, A.R., Mayorga, M., Romero-Salazar, L., Arteaga-Arcos, J.C., 2023. A low environmental impact admixture for the elaboration of unfired clay building bricks. Constr Build Mater 407, 133470. https://doi.org/10.1016/j.conbuildmat.2023.133470

16. Kanellopoulos, P.G., Verouti, E., Chrysochou, E., Koukoulakis, K., Bakeas, E., 2021. Primary and secondary organic aerosol in an urban/industrial site: Sources, health implications and the role of plastic enriched waste burning. Journal of Environmental Sciences 99, 222–238. https://doi.org/10.1016/j.jes.2020.06.012
17. Khan, F. A., Shehzad, Y., Zaman, S., 2022. Sustainable production of clay bricks with a varying quantity of waste glass powder. *Innovative Infrastructure Solutions 7*(6), 363. https://doi.org/10.1007/s41062-022-00967-w
18. Kizinievič, O., Gencel, O., Kizinievič, V., Sutcu, M., Skamat, J., 2023. Recycling of dolomite powder in clay bricks: Effects on characteristics and gas release. Construction and Building Materials 404, 133217. https://doi.org/10.1016/j.conbuildmat.2023.133217
19. Kouakou, L.P.M.-S., Karidioula, D., Manouan, M.R.W., Pohan, A.G.L., Cissé, G., Konan, L.K., Andji-Yapi, J.Y., 2023. Use of two clays from Côte d'Ivoire for the adsorption of methyl red from aqueous medium. Chem Phys Lett 810, 140183. https://doi.org/10.1016/j.cplett.2022.140183
20. Koumi, A.R., Ouattara-Soro, F.S., Quéré, Y., Louault, Y., Yayo N'Cho, A.J., Coulibaly, S., Yao, K.M., Atsé, B.C., Sankare, Y., Cecchi, P., 2021. Les déchets plastiques dans l'océan au cœur de l'Aquathon d'Abidjan, Côte d'Ivoire. Natures Sciences Sociétés 29, 458–468. https://doi.org/10.1051/nss/2022004
21. Kpangni, E.B., Andji, Y.Y.J., Adouby, K., Oyetola, S., Kra, G., Yvon, J., 2008. Mineralogy of Clay Raw Materials from Cote d`ivoire: Case of the Deposit from Katiola. Journal of Applied Sciences 8, 871–875. https://doi.org/10.3923/jas.2008.871.875
22. Kulkarni, P., Ravekar, V., Rama Rao, P., Waigokar, S., Hingankar, S., 2022. Recycling of waste HDPE and PP plastic in preparation of plastic brick and its mechanical properties. Cleaner Materials 5, 100113. https://doi.org/10.1016/j.clema.2022.100113
23. Kulkarni, V. V., Golder, A.K., Ghosh, P.K., 2019. Production of composite clay bricks: A value-added solution to hazardous sludge through effective heavy metal fixation. Constr Build Mater 201, 391–400. https://doi.org/10.1016/j.conbuildmat.2018.12.187
24. Murmu, A.L., Patel, A., 2018. Towards sustainable bricks production: An overview. Constr Build Mater 165, 112–125. https://doi.org/10.1016/j.conbuildmat.2018.01.038
25. Nayanathara Thathsarani Pilapitiya, P.G.C., Ratnayake, A.S., 2024. The world of plastic waste: A review. Cleaner Materials 11, 100220. https://doi.org/10.1016/j.clema.2024.100220
26. N'goran, A., Fofana, M., Akindès, F., 2020. Redéployer l'État par le marché : la politique des logements sociaux en Côte d'Ivoire. Critique internationale N° 89, 75–93. https://doi.org/10.3917/crii.089.0078
27. Qlihaa, A., Dhimni, S., Melrhaka, F., Hajjaji, N., Srhiri, A., 2016. Caractérisation physico-chimique d'une argile Marocaine [Physico-chemical characterization of a morrocan clay]. Journal of Materials and Environne 7, 1741–1750.
28. Subashi De Silva, G.H.M.J., Hansamali, E., 2019. Eco-friendly fired clay bricks incorporated with porcelain ceramic sludge. Constr Build Mater 228, 116754. https://doi.org/10.1016/j.conbuildmat.2019.116754
29. Rauniyar, A., Nakrani, R. K., Narpala, S. R., Nehaun, Arun, S., 2024. An evaluation of the use of plastic waste in the manufacture of plastic bricks. Discover Civil Engineering 1(1), 43. https://doi.org/10.1007/s44290-024-00045-3
30. Vasić, M. V., Pezo, L.L., Radojević, Z., 2020. Optimization of adobe clay bricks based on the raw material properties (mathematical analysis). Constr Build Mater 244, 118342. https://doi.org/10.1016/j.conbuildmat.2020.118342
31. Venkatarama Reddy, B.V., Jagadish, K.S., 2003. Embodied energy of common and alternative building materials and technologies. Energy Build 35, 129–137. https://doi.org/10.1016/S0378-7788(01)00141-4
32. Wahane, A., Dwivedi, S., Bajaj, D., 2023. Effect in mechanical and physical properties of bricks due to addition of waste polyethylene terephthalate. Mater Today Proc 74, 916–922. https://doi.org/10.1016/j.matpr.2022.11.293