Journal of Environment and Sustainable Development

Research Article https://doi.org/10.55921/TFXE9824

TOWARDS A CIRCULAR ECONOMY: COMPARATIVE EVALUATION OF ECO-PAVEMENT AND CONCRETE PAVEMENT BRICKS

Received: 29 July 2024

Accepted: 25 August 2025

Published: 30 September 2025

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Abstract

The escalating generation of solid waste poses significant threats to human health, biodiversity, and the environment, exacerbated by rapid industrialization, population growth, and economic development. This study investigates the potential of reusing solid waste materials in the production of eco-pavement bricks, comparing their sustainability with traditional concrete pavement bricks. Conducted in Bunso, Ghana, the research involved the development and assessment of eco-pavement bricks alongside commercially acquired concrete pavement bricks. The bricks' physical and mechanical properties, including dimensions, weight, water holding capacity, and compressive strength, were evaluated. Descriptive statistics and Analysis of Variance (ANOVA) were employed to analyze the data. The results indicate that eco-pavement bricks exhibit comparable performance to concrete bricks, with satisfactory water holding capacity, high compressive strength, and economic viability. The findings suggest that eco-pavement bricks are suitable for constructing walkways, pathways, and walls. This study concludes that eco-pavement bricks offer a promising approach to solid waste management, contributing to a circular economy and environmental sustainability. Adopting eco-pavement bricks can be a viable solid waste management strategy.

Keyword: Solid Waste generation; Reusing; waste recycling; Eco-pavement bricks; circular economy; environmental sustainability, biodiversity

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Introduction

Globally, the rate of solid waste generation is increasing as a result of population density, economic growth, urbanization, and industrialization which has resulted in the generation of large quantities of solid waste across various urban and rural areas. Even in Ghana, about 12,710 tons of solid waste is generated daily, with only 10% collected and disposed of at designated dumping sites (Lissah *et al.,* 2021). Pointedly, increased population growth and economic development led to increased volumes of municipal solid waste significantly and its composition (Miezah *et al*., 2015).

Most municipal wastes are usually generated from variable sources where different human activities are encountered (Abdel-Shafy & Mansour, 2018) such as industries, domestic and agricultural activities etc. Assessments conducted by Ghanaian academic institutions suggest that the country generates 0.47 kg municipal solid waste (MSW) per person per day, translating into about 4.6 million tons of MSW per year. According to Markandey (2020), organic waste account for the largest content of MSW with 61%, 14% plastics, 6% inert material, 5% paper, 3% metals, 3% glass, 1% leather and rubber, 1% textiles and 5% miscellaneous. Some of these waste materials are biodegradable hence, can be used or reprocessed into other essential products. Unfortunately, several of these waste materials cannot degrade. Therefore, the longer they persist in the environment, the more their effects accumulate and render adverse effects to human health and the environment as a whole. Subsequently, the effective and efficient management of solid waste is one of the biggest challenges local government authorities face, especially in urban setting (Firdaus & Ahimad, 2010).
Recently, most developing and developed countries are creating ways of mitigating or adapting to the undesirables changes that has occurred as a result of the rate of solid waste generation and establishing measures of reusing and recycling of various solid waste materials for other beneficial products. There is now a shift from traditional linear economy towards circular economy aimed at waste minimisation and effective use of resources. Therefore, the state of the art for sustainable, unconventional, natural, and recycled building materials should be taken into account (Kawereaki & Achal, 2020).

This research seeks to develop and compare the sustainability of pavement bricks made from waste materials against pavement bricks made from concrete. It also aim to ascertain the sustainability of the eco-pavement bricks. Additionally, it seek to reveal and publicize the benefits to the environment such as, mitigating waste build up, creation of employment, protect the environment and ensure the achievement of the Sustainable Development Goals (SDGs) 11, 12 and 13.

According to conclusions by Khan *et al*. (2021), Solid Waste Management (SWM) is a significant challenge for a society that arises local issues with global consequences. In low-income countries, over 90% of waste is often disposed at unregulated dumps or openly burned, creating serious health, safety, and environmental consequences (Solid Waste Management, The World Bank Group, 2022). As the world's population continues to grow, so does the amount of waste being produced. In 2015, the world generated 2 billion metric tons of solid waste. This number is expected to grow to 3.4 billion metric tons by 2050 (Ramakrishna, 2022).
Also, poor municipal solid waste disposal and insufficient collection practices generate serious health related problems to humans and the environment (Loboka *et al*., 2013).

Within this context, this research seeks to develop an eco-pavement brick from waste materials and assess its ability to save cost, protect the environment and ensure the achievement of environmental sustainability.

Materials and Methods

Study area

The study was carried out at Bunso in the Abuakwa South Municipality, Eastern Region of Ghana (Figure 1). The yearly temperature is ''29.06^{0}C'' (84.31°F) and it is 0.2% higher than Ghana's averages. Bunso lies between longitude 0.56 West and 0.15 West and latitude 6.03 North and 6.35 North and lies in the west semi-equatorial zone. Bunso receives about 117.32 millimetres (4.62 inches) of precipitation and has 242.75 rainy days (66.51%) annually, thus a double rainfall occurring in June and October.

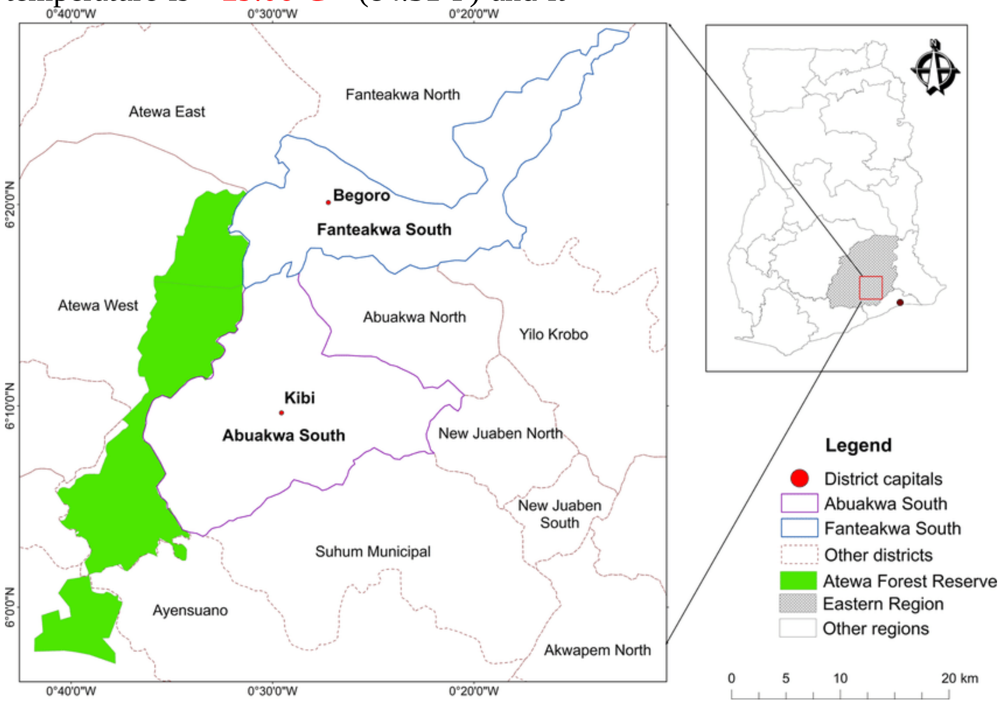

Figure 1: Map of study location (Abuakwa South Municipality of Ghana). *Aggrey et al*. (2021)

Sampling

Survey instrument and justification

Materials and equipment used in the construction of the bricks include, commercial cement, tailings, sand, pavement brick moulder, portable water, powdered coconut husk, shredded plastic, sawdust, quarry dust, Personal Protective Equipment (PPEs), weighing scale, head pan, and loading shovel.

Data collection

Construction and Design of Pavement Bricks

As stated earlier, the study was conducted at Bunso where convenient sampling was employed for the collection of the solid waste. Waste materials were collected from where they were available since due to the improper disposal of the waste materials, they are abundant in the environment everywhere. Each of the waste sample from the source of generation had their individual weights determined and recorded. The plastics were collected, washed, sun-dried and shredded into a required particle sizes. The quantity of plastic waste which was used in developing a brick size of $72cm^2$, is 40 pieces of the pure water sachet which also gives a weight of 0.2kg after shredding. During shredding, the size of the plastic is reduced to a range of 2.36–4.75 mm. This process has been shown to improve blending in concrete mixes and to minimize the loss of compressive strength. The coconut shells were collected from the environment, burnt into brickets at a certain level of temperature, watered, dried and grinded in powdered form. The sawdust were acquired from a sawmill in Nsutam, a town closer to Bunso. A pavement moulder was made according to the measurement of the same mould used in constructing the concrete pavement brick and tailings were collected from Narawa Company Limited, a mining company located in Nsuapemso. The total weight of each of the waste were determined and expressed in kilograms and the percentage of each constituent were calculated (Ansah, 2014). Waste materials were mixed together at their right proportion and with the right amount of water.

Concrete pavement brick (CPB) consisted of two main materials which were cement and quarry dust with the ratios of 1.7: 0.9 respectively. Two kinds of Eco- pavement bricks (EPB 1 and EPB 2) were made. The EPB 1 consisted of Cement, shredded plastic, coconut husk powder, and sawdust, whereas the EPB 2 consisted of tailings, shredded plastics, coconut husk powder, and sawdust. But in all, ten (10) quantities of eco-pavement bricks were constructed, five made with 100% waste materials and the other five made with waste materials and a binding agent (cement). All the concrete mixtures which were prepared, meet the requirements specified in the standards as given by the Ghana Standard Authority (GS 1217:2018), demonstrating that concrete incorporating waste materials can be used as paving bricks and building bricks under limited conditions (Kim & Kim, 2022).

The Eco-pavement bricks made, were compared with acquired concrete bricks using dimensions, weight, cost analysis, compressive test, and water absorption as the parameters. The mechanical tests were done at the Building and Road Research Institute, located in Kumasi, Ghana.

Assessing the sustainability of the pavement bricks

The sustainability of the bricks were compared and determined using water absorption, dimensions, cost analysis, weight, and compressive strength parameters. Gencel et al. (2012) recorded that, the compressive strength is an important parameter in evaluation of paving brick quality.

Dimensions

The dimensions of each brick was determine using a tape measure and a surveying rule to measure the length , width and height of the brick and it was recorded. Length 20cm/200mm, width 10cm/100mm and height 6cm/60mm.

Weight

The weight recorded for the eco- pavement bricks were the same as that of the concrete pavement brick after a 14 day drying period which 2.6kg for all the three kinds of pavement bricks.

Cost Analysis

A cost analysis was evaluated between the cost of a concrete pavement brick and the cost of producing an eco- pavement brick. The transportation cost was used to determine the cost of producing an eco-pavement brick which revealed that, the cost of a concrete brick is 5 Ghana cedi ($0.44) whereas the cost of producing the eco-pavement brick was 2 Ghana cedi 32 pesewas ($0.21) which gives a clear indication that, eco-pavement bricks are economically viable than the concrete pavement brick.

Water Absorption

To check the water absorption of the bricks, the weight of three bricks were taken after being dried for 14 days. The brick specimen were then soaked into a head pan of 5 litres of water for 24 hours. After the 24 hours, the weight of the bricks were measured and recorded. The Water absorption (Wa) was calculated using a formula given in the Ghana Standard Authority (GSA) standard for the three brick. $W_a = \frac{m_2 - m_1}{m_1} \times 100$ where m1 refers to the initial weight of the brick in grams before being submerged in water and m2 refers to the weight obtained after 24hours submerging of the brick.

Compressive strength test

Nine specimen of bricks were sent to the Building and Road Research Institute (BRRI- Kumasi) to conduct the compressive strength test of the bricks. Out of the 9, each of the 3 bricks (CPB, EPB 1 and EPB 2) had three replicates which were used to conduct the test by placing the surface area of each brick towards an upward direction to the testing machine. Each brick was tested three times using their replicates, this was done to ensure accuracy. A two – way analysis of variance was used to ascertain the differences between the numbers of times at which each bricks were tested.

Data analysis

The data was analyzed and summarized using Microsoft Excel 2016 package and with descriptive statistics in Statistical Package for the Social Sciences (SPSS). Analysis of Variance (ANOVA) were used to ascertain the significant differences in the different treatments of the brick strengths in SPSS.

Results

Waste generation in Bunso

Composition of Solid Waste in Bunso

The types of solid wastes generated in Bunso during the study include plastic, natural organic material, metals, and glass. Out of the total amount of waste generated over the study period, 75% were plastic waste, 15% were organic waste, 3% were glass; and metals and others were 2% and 5% respectively.

Impacts of improper disposal of solid waste

Ninety-six (96%) of the respondents indicated that they are aware of the effects of the improper disposal of solid waste whereas the remaining 4% said they are not aware of the effects.

According to 38% (57) of the respondents, air pollution is the highest effect of improper disposal of solid waste. 37% also said health impacts followed by 11 % (17) soil degradation, 11% (16) water contamination and the others with 3% (5) **(Figure 2).**

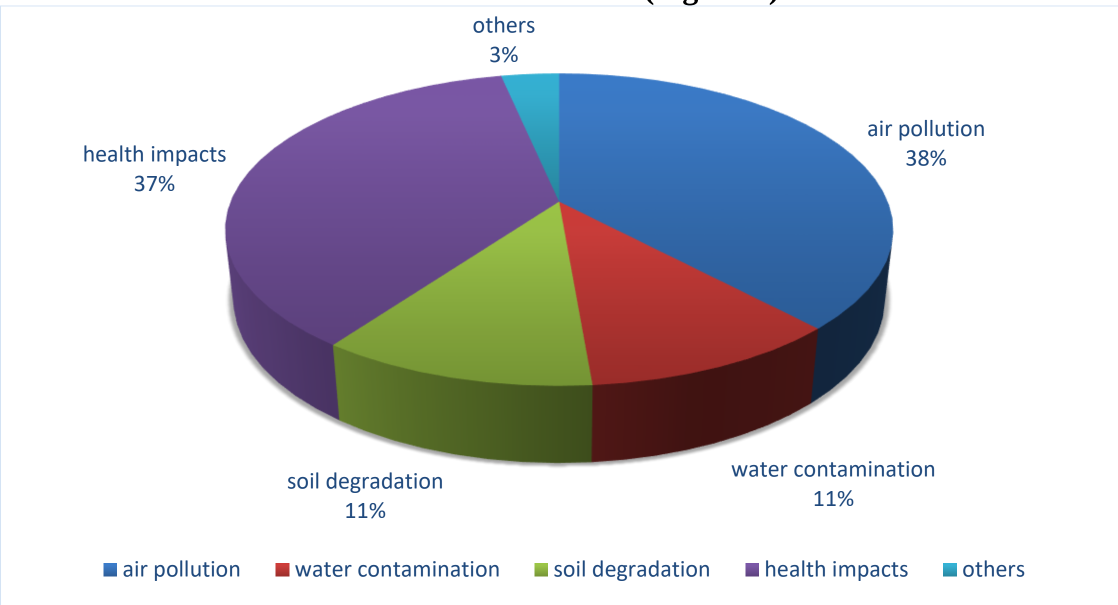

Figure 2: Composition of the effects of improper disposal of solid waste at Bunso

Waste Minimisation

Out of the total responses, 79% of the respondent answered that, they have being provided with and information on solid waste management methods and 21% said otherwise.

According to (66) of the respondents, recycling was indicated as the kind of solid waste management method they have been provided with. Thirty-seven (37) also indicated that, composting is the most known solid waste management method followed by source reduction and reusing with (27) and (20) respectively.

Constructed and Designed Pavement Bricks

Bricks are a large and important part of the building and construction industry. Bricks have been used as masonry units due to the strength and durability they provide in structural applications. (Murmu and Patel, 2018). According to Al-mansour *et al*., (2019), Concrete bricks are another type of conventional brick made of Ordinary Portland Cement (OPC), water, aggregates and additives. The generation of high volumes of waste is both an environmental and economic challenge. It has become unsustainable to manage this waste. Thus, recycling of waste into valuable products has become part of the sustainable development goals for many countries. (Makgabutlane *et al*., 2022). The utilization of waste in construction materials does not only reduces pollution but also the number of natural aggregates used, which are responsible for environmental degradation and the depletion of natural resources. Zero-cement products known as alkali-activated bricks have been developed as sustainable construction materials. These products utilize waste such as rice husk, fly ash, bottom ash, cement kiln dust, blast furnace slag and mine tailings limited conditions (Kim & Kim, 2022).

At the end of the study, ten (10) eco-pavement bricks were constructed, five made with 100% waste materials which are denoted as Eco-Pavement Brick One (EPB 1) and another five made with waste materials and a binding agent (cement) denoted as Eco-Pavement Brick Two (EPB 2), additional five bricks were acquired which were the concrete bricks, and are denoted as Concrete Pavement Brick (CPB) **(Figure 3)**. Thus, in all fifteen pavement bricks were available for the study. **(Table 1)** gives a summarized information about the characteristics of the pavement bricks. The total waste materials summed up to 2.6kg, 2.6kg and 2.6kg for CPB, EPB 1 and EPB 2 respectively. The composites makes up the total weight of each brick

Concrete Pavement Brick (CPB)

Eco-Pavement Brick (EPB 1)

Eco-Pavement Brick (EPB 2)

Figure 3: Constructed eco-pavement bricks and an acquired concrete brick.

Table 1: Summarised characteristics of the pavement bricks.

Specimen type (Prism)	Thickness (mm)	Compressive Strength (MPa)		Brick size(cm^3)	Weight (kg)	Water Absorption (Wa)	Cost of production (GH¢)
CPB	100	19.81	413.30	72	2.6	9	5
EPB 1	100	25.46	531.33	72	2.6	16	2.32
EPB 2	100	22.91	477.99	72	2.6	11	2.32

Sustainability of the pavement bricks

Dimensions

The pavement bricks takes the shape of a prism, and to calculate the brick size with such shape, the surface area is needed which includes the height, width and length. Hence, per the dimensions given the brick size is $72m^3$.

Weight

The calculated weight of the concrete pavement brick (CPB) was 2.6kg (2600.0g). The eco-pavement bricks EPB 1 and EPB 2 had calculated weights same as the CPB of 2.6kg (2600.0g) and 2.6kg (2600.0g) respectively.

Cost analysis

In **(Table 2),** a cost analysis was evaluated between the cost of a concrete pavement brick and the cost of producing an eco-pavement brick. The transportation cost was used to determine the cost of producing an eco-pavement brick which revealed that, the cost of a concrete brick is 5 Ghana cedi ($0.44) whereas the cost of producing the eco- pavement brick was 2 Ghana cedi 32 pesewas ($0.21). Cost of producing one brick= 116 /50 = **GH¢2.32**.

Table 2: Calculations of the cost of producing an Eco-pavement brick.

Materials	Transportation cost (GH¢)	Quantities	Weight (kg)	Number of bricks being estimated
Sawdust	10	$^1/_2$ Sack	6.9	23
Coconut husk powder	10	$^1/_2$ Sack	6.7	23
Plastics	null	500 pieces	2.5	25
Cement	15	I bag of cement	50	30
Tailings	15	1head pan	25	15
	Total=50			Total=116

Water Absorption (Wa)

Ghana Standard Authority, (2018) in their pavement standards provide a formula or an equation for calculating the water absorption $W_a = \frac{m_2 - m_1}{m_1} \times 100.$ As stated earlier, before the calculations were done, all the kilogram units were converted into grams.

According to the calculations done and as presented in **(Table 3)**, the water absorption for the three brick specimen were 9%. 16% and 11% for CPB, EPB 1 and EPB 2 respectively. The water absorption of bricks determined in accordance with clause 6.6 in the standard state that, it should not exceed 10%. But EPB 1and EPB 2 failed the test by achieving more than 10% as stated in the standard. Only the CPB gave out a good and accepted results.

The samples in total 3 were submerged in water as required by the Ghana Standard Authority standard in clause 6.6. The specimens were weighed completely dry on the electronic scale with the following absorption percentages: 9% for CPB, 16% for EPB 1 and 11% for EPB 2. According to the aforementioned standard, the absorption percentage should not be greater than 10% for concrete pavers. As the samples are made of waste materials, cement and tailings, these paver did not show excellent results for this variable except CPB.

Table 3: Information on the processes of water absorption for each pavement brick.

Bricks	Drying days	Weight before immersion (kg)	Duration of soaking (hours)	Amount of water used (litres)	Weight after 24hr. of immersion (kg)	Total water holding capacity (%)
CPB	14	2.6	24	5	2.9	9
EPB 1	14	2.6	24	5	3.0	16
EPB 2	14	2.6	24	5	2.7	11

Compressive Strength Test

From the compressive strength test results, EPBI (25.4642MPa) and EPB2 (22.9078MPa) attained the highest compressive strength followed by CPB (19.8075) which served as the control specimen during the study. All the nine bricks had the same thickness of 100mm. The maximum load of the bricks were recorded and an average was calculated which resulted in CPB (413.3029kN), EPB 1 (531.3318kN) and EPB 2 (477.9941kN).the means of the nine bricks were recorded and subjected to Analysis of Variance (ANOVA) to statistically test if there are any significant differences between the means of the bricks. The strength mean levels obtained are presented in the mean table **(Table 4)** and a visual interpretation presented in **(Figure 4).**

Table 4: A mean table showing results from the Analysis of Variance

Category	LS means	Groups
CPB	19.43	A
EPB 2	22.91.	A
EPB 1	25.46	A
LSD	9.79	

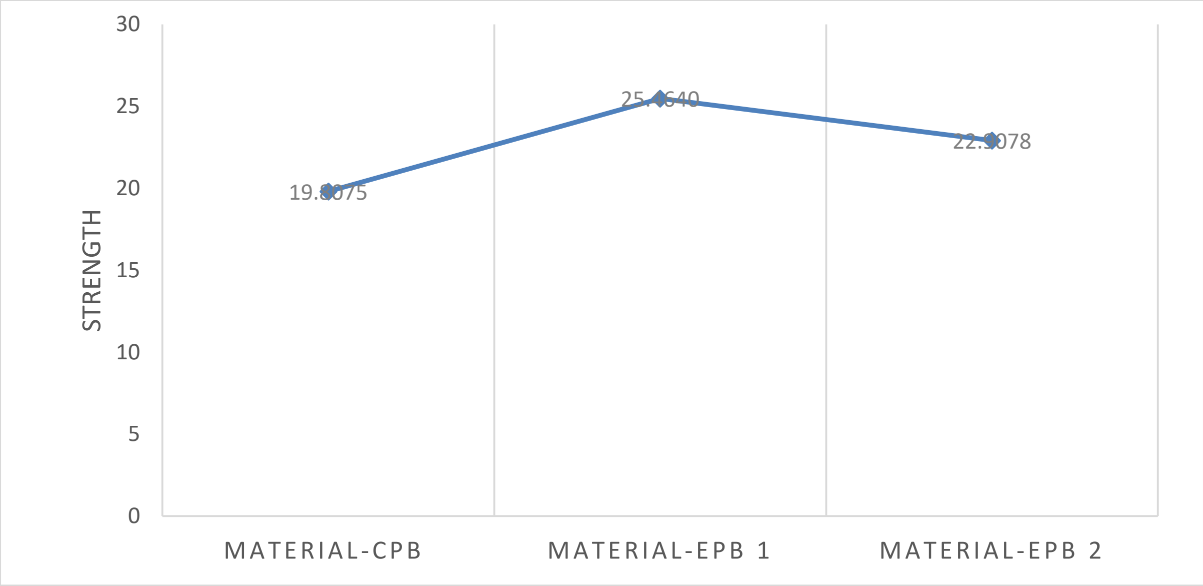

Figure 4: A visual interpretation of the mean table.

Discussion

Solid Waste, disposal, effects and Management

Observations in literature showed that, increased population growth and economic development led to increased volumes of municipal solid waste significantly and its composition (Miezah *et al*., 2015). Organics wastes account for the largest content of MSW with 61%, 14% plastics, 6% inert material, 5% paper, 3% metals, 3% glass, 1% leather and rubber, 1% textiles and 5% miscellaneous. (Markandey, 2020). From the survey it was revealed that solid wastes generated in Bunso were mostly plastics and organic waste. The large volume of plastic wastes implies that there is a strong resource potential for reusing and recycling. The conventional landfill, incineration, composting, and ways of handling solid wastes are common as mature technologies for waste disposal (Hannan *et al*, 2018). Most developing countries that suffer from sever environmental pollution problems are caused by the large quantities of solid waste. (Al-Khatib & Martini, 2010), and from the study air pollution recorded the highest percentage among the effects of improper waste disposal. However, from the study source reduction and reusing are being practiced in the waste management chain likewise the organic wastes which are being used for compost on farmlands of some household heads. Traditionally, the most commonly used technologies for the treatment of the organic fraction of MSW is composting. Solid waste segregation depends mainly on the public awareness and the active participation which attest to the fact from the replies of the study respondents.

Utilization of solid waste as composites for Eco-pavement bricks

The incorporation of waste materials in construction composites can compromise some of the brick properties (Delva *et al*., 2018). The utilization of waste in construction materials do not only reduces pollution but also reduces the rate of exploiting our natural aggregates, which are responsible for environmental degradation and the depletion of natural resources. The study reveals that, the quantity of plastic waste needed as part of the additives to make an eco-pavement brick is 0.2 kg which is equivalent to the waste generation rates across Ghana irrespective of the socioeconomic considerations ranged from 0.2 to 0.8 kg/person/day (UNEP, 2013).

Nationally, waste generation rate was 0.47 kg/person/day a Middle class area and 0.27 kg/person/day for a low class socioeconomic area all in the Kumasi metropolis in Ghana. (Zikali *et al*., 2022). Gaisie & Owusu-Ansah (2022) obtained similar generation rates data among the different socioeconomic class areas in Accra. The average per capita per day generation were 0.29 kg organic, 0.02 kg paper, 0.06 kg plastic and 0.004–0.01 kg for metal, glass, textile or leather and rubber. (Gaisie & Owusu-Ansah, 2022).
More than 50% of the global production of coconut is processed into dried coconuts (Rogers *et al.*, 2012). Coconut shell is one of the most vital natural fillers produced (Leman *et al*., 2017), Coconut shells have shown great potential to be used as admixtures in the production of concrete due to its excellent properties. It has been revealed that the utilization of coconut husk showed considerable enhancement in strength development (Hasan *et al.*, 2016). According to Subramanian *et al*. (2015), several studies have analysed the suitability of wood ash as a partial cement replacement material in the production of structural grade concrete and self-compacting concrete for applications in building construction. Shreekant *et al*. (2016) in his study used cement, jelly dust, baby jelly and iron ore tailings for making blocks. An experimental study carried out by Gayana & Ram Chander (2018) on iron-ore tailing based interlocking paver blocks, which gives the properties of interlocking concrete block pavers mixed with iron ore tailings as a partial replacement for cement.

The sustainability of Eco-pavement bricks against the Concrete pavement brick

Per this study, pavement bricks with wastes and cement (EPB 1) had the highest water absorption, this depicts that the waste materials create pore spaces within the brick which easily allow the flow of water into it hence, retains more moisture content. The water absorption of quality bricks should be less than 20 % after 24 hr. of immersion in water (Wahid et al, 2015). Thus, in this case all the three bricks pass the test of water absorption as bricks were immersed for 24hours and the results are 9%, 16% and 11%. Nevertheless, per the GSA standard, only the CPB passed the test and gave an excellent results while the other two samples failed the test. As it can be evidenced, the use of this raw material would generate a great benefit for the environment, as well as provide direct and indirect jobs.

Furthermore, after the compressive strength test, the bricks with plastic waste turned out to be the ones with the highest compressive strength. It was then advised that, the eco-pavement bricks can be used for unload bearing structures like; corridor pathway, walkways, walls etc.

Arbili *et al*., (2022) concluded that, the use of iron ore tailing from 5 % to 15 % has shown increase in the compressive strength of the concrete compared to normal concrete. Whereas, addition of iron ore tailings from 15 % to 25 % has resulted in lower compressive strength compared to that of conventional concrete. (Arbili *et al*., 2022). Thus in the case of the study, EPB 1 and EPB 2 had a compressive strength between 20MPa to 23MPa with 14 days curing.

Conclusions and recommendations

It was estimated in the study that solid wastes generated in Bunso were mostly plastics and organic waste which implies that there is a strong resource potential for reusing, recycling and composting. The practice of improper solid waste disposal leads to high levels of air pollution and the most practiced solid waste management methods are recycling and composting. Generally, it is concluded that, Eco-pavement bricks can be made with coconut husk powder, sawdust, cement and plastic waste. It was revealed that, the quantity of plastic waste needed as part of the additives to make an eco-pavement brick is 0.2 kg which is equivalent to the waste generation rates across Ghana irrespective of the socioeconomic considerations ranged from 0.2 to 0.8 kg/person/day (UNEP, 2013). Dimension of the bricks (concrete and eco-pavement) were 20cm×10cm×6cm giving a brick size of $72cm^3$. The Concrete pavement brick and the two eco-pavement bricks had the same weight of 2.6kg, which can be concluded that all the three kinds of bricks had same weight. Per the Ghana Standard Authority, only the concrete pavement brick obtained an acceptable percentage for the water absorption, hence the eco-pavements failed but in some research, these two would have been considered as providing good water absorption level yet in these instances, the pavement bricks can still be used for constructing walkways, corridors and pedestrian pathways.

Moreover, pre the compressive strength test, the category of pavement bricks with plastic waste expressed higher strength levels and maximum load limits whereas the concrete pavements which were the control rather expressed lower compressive strength levels as well as the maximum loading limits. It is concluded that the eco-pavement bricks should be used for unload bearing structures like; corridor pathway, walkways, walls since they have same dimensions, weight, higher compressive and higher water absorption rate. Since the survey recorded 95% of the total respondents who consider Eco-Pavement brick as an initiative of solid waste management, it can be concluded that individuals are ready to take up this initiative of managing their solid waste.
Further studies should be done to investigate the impacts of using tailings as a binding agent in place of cement. Other factors such as durability, abrasion resistance, tensile and flexile strength tests, etc. should be tested to determine the sustainability of an Eco-pavement brick. This initiative should be practiced by individuals and households to help ensure effective reuse of plastic waste. Further studies should be done to investigate the factors that account for the relatively high strength recorded for the eco-pavement bricks, compared to the concrete pavement brick.

Acknowledgements
The authors are grateful to the Andoh Family, UCAES management and staff, members of Alliance for Environmental Intervention and Leaders of F. D. Walker Child and Youth Development Centre who contributed in diverse ways to make this project a success.

Compliance with ethical standards
Competing interest statement: authors declare that they have no conflicting interest.
Human and animal rights: Humans and animals were not used as objects of this study by authors.

References
Abdel-Shafy, H. I., & Mansour, M. S. (2018). Solid waste issue: Sources, composition, disposal, recycling, and valorization. Egyptian journal of petroleum, 27(4), 1275-1290.

Aggrey, J. J., et al (2021). Using participatory spatial tools to unravel community perceptions of land-use dynamics in a mine-expanding landscape in Ghana. Environmental Management, 68, 720-737.

Al-Khatib, M. I., & Al-Martini, S. (2019). Predicting the rheology of self-consolidating concrete under hot weather. Proceedings of the Institution of Civil Engineers-Construction Materials, 172(5), 235-245.

Al-Mansour, A., et al (2019). Green concrete: By-products utilization and advanced approaches. Sustainability, 11(19), 5145.

Ansah, B. (2014). Characterization of municipal solid waste in three selected communities in the Tarkwa Township of Tarkwa Nsuaem Municipality in Ghana (Doctoral dissertation).

Arbili, M. (2022). Concrete made with iron ore tailings as a fine aggregate: A step towards sustainable concrete. Materials, 15(18), 6236. (2022). Household solid waste handling practices and recycling value for integrated solid waste management in a developing city in Zimbabwe. Scientific African, 16, e01150

Delva, L., et al. (2018). On the role of flame retardants in mechanical recycling of solid plastic waste. Waste management, 82, 198-206.

Firdaus, G., & Ahmad, A. (2010). Management of urban solid waste pollution in developing countries.

Gaisie, E., et al. (2022). Gender and household resilience to flooding in informal settlements in Accra, Ghana. Journal of Environmental Planning and Management, 65(8), 1390-1413.

Gayana, B. C., & Ram Chandar, K. (2018). Sustainable use of mine waste and tailings with suitable admixture as aggregates in concrete pavements-A review.

Gencel, O., et al (2012). Properties of concrete paving bricks made with waste marble. Journal of cleaner production, 21(1), 62-70.

Ghana Standards (GS 1217:2018) Building and Construction Materials- Concrete Paving Blocks.

Hannan, M. A., et al (2018). Capacitated vehicle-routing problem model for scheduled solid waste collection and route optimization using PSO algorithm. Waste management, 71, 31-41.

Hasan, M., et al. (2016). Study on physicochemical properties of edible oils available in Bangladeshi local market. Archives of Current Research International, 6(1), 1-6.

Kawereaki, S., et al. (2020). The utilization of agricultural waste as agro-cement in concrete: A review. Sustainability, 12(17), 6971.

Kim, J., & Kim, N. (2022). Recycling Waste Paver Blocks in the Manufacture of New Concrete Paver Blocks and Building Bricks. Applied Sciences, 12(21), 10970.

Leman, A. S., et al. (2017, November). Properties of concrete containing coconut shell powder (CSP) as a filler. In IOP Conference Series: Materials Science and Engineering (Vol. 271, No. 1, p. 012006). IOP Publishing.

Lissah, S. Y., et al (2021). Managing urban solid waste in Ghana: Perspectives and experiences of municipal waste company managers and supervisors in an urban municipality. PloS one, 16(3), e0248392. https://doi.org/10.1371/journal.pone.0248392

Loboka, M. K., et al (2013). Municipal solid waste management practices and fecal coliform water contamination in the cities of the developing countries: The case of Juba, South Sudan. International Journal of Environmental Sciences, 3(5), 1614-1624.

Makgabutlane, B., et al (2022). Plastic-fly ash waste composites reinforced with carbon nanotubes for sustainable building and construction applications: A review. Results in Chemistry, 4, 100405.

Markandey, K. (2020). Solid waste management: a case study of Hyderabad. Governing Council of the Indian Geographical Society, 1.

Miezah, K., et al (2015). Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana. Waste management, 46, 15-27

Murmu, A. L., & Patel, A. (2018). Towards sustainable bricks production: An overview. Construction and building materials, 165, 112-125.

Ramakrishna, S. (2022). Guest editorial: Materials for a sustainable future. Drying

Rogers, P. P., et al. (2012). An introduction to sustainable development. Routledge.Technology, 40(14), 2815-2816.

Shreekant, R. L., et al. (2016). Utilisation of mine waste in the construction industry–a critical review. International Journal of Earth Sciences and Engineering, 9(01), 182-195.

Solid Waste Management, the World Bank Group, 2022.

Subramanian, P., et al. (2015). Wood ash as an effective raw material for concrete bricks. International journal of research in engineering and technology, 4(2), 2319-1163.

United Nations Environment Programme, 2013.

Wahid, S. A. et al. (2015). Utilization of plastic bottle waste in sand bricks. Journal of Basic and Applied Scientific Research, 5(1), 35-44.

Zikali, N. M., et al. (2022). Household solid waste handling practices and recycling value for integrated solid waste management in a developing city in Zimbabwe. Scientific African, 16, e01150.