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Sustainable Walling in Ondo State, Nigeria: A Cost Analysis of Conventional Versus Sand-Filled Plastic Bottle Materials

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Abstract- ***The clamor for sustainability in the construction industry is not a new development, research on alternative sustainable materials led to the discovery of waste sand-filled plastic brick as an alternative walling material. This research aimed at conducting a comparative cost analysis of using conventional material and sand-filled plastic bottles for walling in Ondo State. The paper analysed the cost of using conventional material and sand-filled plastic bottles for walling, it also compared the total cost of using both materials. The required data was collected using market survey, relevant literature and construction professionals were consulted. The collected data was analysed through the process of estimating, and the result of the estimate was used to analyse the walling cost of a prototype gate house using percentile. The results showed the total cost of walling the gate house using 225mm sandcrete blocks as ₦1,296,754.21, and that of sand-filled plastic brick as ₦864,362.49. The research suggested that up to 50.03% (₦432,391.72) of the total walling cost could be saved when sand-filled plastic bottle is used for walling the gate house. This research recommends the adoption of sand-filled plastic bottles for mass housing as a promising alternative to conventional materials and their contribution to the emission of unwanted carbon. The study recommends the establishment of supply chain for the production and distribution of sand-filled plastic bottles, like conventional walling materials.***

Index Terms- ***Sustainability, Waste sand-filled brick, Conventional material, Comparative cost analysis, Estimating***

I. INTRODUCTION

The construction industry plays a crucial role in the economic development of every nation. It contributes to the economic growth of the nation by creating employment, stimulating demand for materials, and fostering investments in infrastructure (Sanusi, 2024). The construction sector can't be overlooked because it accounts for 50% of worldwide raw material consumption (Alyaa and Dunya 2018). The activities of the construction industry have negatively impacted the environment by depleting resources, generating greenhouse gases from fossil fuel burning, and disposing of construction waste in underground landfills, which harms the environment (Li et al., 2018 and Zhang *et al*., 2022). Therefore, the construction industry is a major contributor to waste and pollution (Rubya, 2016).

In the current era, the construction trend has shifted from the conventional way of construction, and the focus is now based on green building practices, which are of utmost importance in Nigeria for promoting environmental sustainability and harnessing the potential of renewable energy systems (Anabaraonye *et al*., 2024). Sustainability is becoming more and more popular around the world and the construction industry places a high priority on the creation of sustainable buildings (Bhola, 2024). Although the initial costs of sustainable materials are often higher, their long-term financial advantages, such as reduced operational costs, energy savings, and lower maintenance expenses, make them viable investments (Abul Kashem *et al*., 2024).

Additionally, issues of waste management have attracted the attention of scholars in developed and developing countries in recent times (Mmereki, Baldwin & Li B. 2016). In Akure, the Ondo State capital, a lot of efforts have been made towards effective municipal solid waste management. This includes the establishment of the Ondo State Waste Management Authority in 1999 (Oladapo *et al*.,

2020). Plastic bottles, also known as PET, form part of this waste material. This research compared the cost difference of conventional and sustainable walling material (sand-filled bottles) in Ondo State, Nigeria.

II. LITERATURE REVIEW

The new century has brought several changes that challenge the construction industry and professionals operating within the construction industry (Ikupolati et al., 2024). The need for change and associated challenges are easily noticeable in the construction industry, especially in the design of buildings and how the designs are brought to reality (Daniel, Thorben, & Cornelia, 2024). Higher investment spending, as an example, is required because of the demand for labour and demand for building materials, which calls for recognition of the importance of sustainable development and green construction practices in the construction industry (Nik Muhammad et al., 2025). The initial costs of sustainable materials may be higher, but long-term savings in operational costs and energy efficiency make them economically viable (Yahia et al., 2024).

The use of conventional materials exhibits high embodied energy, significant greenhouse gas emissions, resource depletion, and inefficiencies, leading to increased costs and time overruns (Wickramanayake et al., 2024). The availability of these materials is influenced by various factors, which have led to a great imbalance between the availability and demand in recent years (Makanjuola and Olu-Martins 2023). There is doubt that for over 30 years, the Nigerian government have been facing several challenges in housing (Akinradewo & Adedokun, 2020). This housing challenge can be overcome through the adoption of plastic for housing when the right construction technique is employed (Pragati 2023).

The use of sand-filled bottles derived from PET bottles offers both environmental and economic advantages (Saikiaa & Britoa, 2013). One promising alternative to the use of conventional materials and their contribution to the emission of unwanted carbon is the transmission or adoption of sand-filled bottles in construction for walling, this method which involves filing plastic bottles with sand and using them for walling units, joist ceiling and concrete columns which has been proposed as cost-effective and environmentally friendly building material (Shoubi, et al., 2013). According to Makanjuola & OluMartins. (2023), these materials are readily available compared to conventional materials that require some level of processing.

III. METHODOLOGY

This study adopts a causal-comparative research approach to analyse the walling cost difference between the use of conventional 225mm sandcrete block and sand-filled plastic bottle for walling. A market survey was conducted on 225mm block, sand-filled plastic bottle and other related materials. The result was used to estimate the cost of walling a selected gate house plan with a total wall area of 67.35m2, conclusion was drawn from the walling cost. The unit cost of both walling materials was estimated as showen in the calculation below.

Analysis One: Walling estimate using 225mm sandcrete block bedded and jointed in cement sand mortar of (1:6) with basic assumption of 100m2. According to Onwunsoye (2016), there are 28.8 bags of cement in 1m3, a labourer can offload 96 bags of cement a day, output of mixing machine is 20m3, and a gang can lay 80 blocks a day. The thickness of mortar between two masonry walls is 20mm (Yadav & Pal, 2023). There are 10 numbers of 225mm sandcrete blocks in 1m2 wall area

Material Cost:
(Block). There are 10 numbers of blocks in 1m2; 1100 numbers of blocks are required for 100m2, giving allowance for 10% waste; @ 1,000 per block, cost of block required = ₦1,100,000.00.

(Mortar). Using mix ratio of (1:6). Thickness of mortar between two masonry wall is 20mm; Area of block without mortar (0.450) X (0.225); Area of block with mortar (0.450 + 0.02) X (0.225 + 0.02) given the area of mortar as 0.01m2 per block; volume of mortar required (0.01 X 0.225 X 1000) = 2.25m3. Total bags of cement in 1m3 plus 10% waste @ ₦10,500 per bag = ₦332,850.00. half trip of sand (3.81m3) cost ₦ 40,000, 6m3 will cost ₦69,291.35

plus 10% waste. Unit cost of mortar plus 25% shrinkage = ₦71,810.96, for 2.25m3 cost of mortar = 2.25 x ₦71,810.96 = ₦161,574.65.

Labour Cost:
A labourer can unload and stack 96 bags of cement per day, 0.30 man day is required to unload 28.8 bags, which is the number of cement in 1m3; multiplying the 0.3 by unskilled labour cost of ₦7000 gives =₦ 2,100 as the unloading cost. Actual volume of mortar required is 2.25m3, therefore the unloading cost will be 2.25 X ₦2,100 = ₦ 4,725.00. However, the mix ratio is (1:6), the cost of unloading will be = ₦ 4,725.00 X 1/7 = ₦ 742.50, considering 10% waste.

Unloading and stacking of blocks; a labouere can unload 150nos Per Day; 7.3 Days is required for 1100 blocks @ 7000 per day, cost of unloading 7.3 X 1100 = ₦ 51,100.00.

Laying of blocks: A gang can lay 80 blocks Per Day; 12.5 Gang Day is required for 1000 blocks; the cost of laying will be (10000 + 7000) X 12.5 = ₦ 212, 500.00.

Mixer operator rate per day is = ₦10,000

Plant Cost:
A concrete mixer can mix 20m3 of concrete per day; Since the quantity of mortar required for 100m2 wall is 2.25m3, the number of days required to mix the needed concrete is 2.25/20 = 0.11 day @ ₦40,000 hiring cost per day, the cost of mixing the required concrete is 0.11 X ₦40,000 = ₦4,400

Summary	Total
Material Cost: Block = ₦1,100,000.00. Mortar 1:6 = ₦161,574.65.	₦1,261,574.65
Labour: Unloading cement = ₦742.5 Unloading Blocks = ₦51,100.00	₦274,342.50
Laying of blocks = ₦212,500.00	
Mixer Operator = ₦10,000.00	
Plant: ₦4,400	₦4,400.00
	₦1,540,317.15
Add 25% Profit and Overhead	₦385,079.29
	1,925,396.44
Cost per m² 1,925,396.44 / 100	₦19,253.96 / m²

Cost of walling gate house using 225mm sandcrete block =19,253.96 X 67.35 = ₦1,296,754.21

Analysis Two: Walling estimate using sand-filled plastic bottle bedded and jointed in clay mortar with basic assumption of 100m^2. According to Premalatha et al. (2016), an empty bottle weigh 0.02kg while a bottle filled with soil weighs 0.99kg. There are 28.8 bags of cement in 1m^3, the output of mixing machine is 20m^3 (Onwunsoye, 2016). Diameter of bottle with mortar is 90mmø while the diameter of bottle without mortar is 80mmø, and a labourer can fill 400 bottles with sand a day (Adiyat *et al*., 2015). According to Sagar (2025), a gang of skilled and unskilled labourer can lay up to 800 bottle bricks in a day, pre-filled with sand.

Material Cost:

(Bottle). 1 (50KG) sack of rice contained 114 waste plastic bottle @ ₦1,230.00; One waste bottle will cost 1230/114 = ₦11. Dimension of FUTA bottle water is 250mm x 80mmø while the diameter of bottle with mortar joint is 90mmø; Area of bottle with mortar $\prod R^2$ =3.142 X 0.045² = 0.0064m²; In 100m² we will have 100/0.0064 = 15717 bottles; 15717bottles @ ₦11 = ₦172,887.00.

(Filling Bottle) An empty Bottle weighs 0.02kg, while a bottle filled with sand weighs 0.99kg. Therefore, sand required for filling a bottle is 0.99-0.02=0.97kg, 15717 Bottles will require 15717 X 0.97 = 15245.49kg. In 1m³, we have 28.8 bags and a bag weigh 50kg; In 1m³ = 50 x 28.8 = 1450kg; Volume of sand required for filling the bottles 15245.49/1450 = 10.51m³; If 3.81 m³ (Half trip) cost ₦40,000; the cost of required sand will be (40,000 X 10.51)/3.81 = ₦110,341.21.

(String) say 50 bundles @ ₦500 = ₦25,000.00

(Mortar) Area of bottle with mortar $\prod R^2$ =3.142 X 0.045² = 0.0064m² - Area of bottle without mortar $\prod R^2$ =3.142 X 0.04² = 0.0014m^2; Volume of wall thickness 0.225 x Area of mortar 0.0014 x Number of Bottles 10526 =5.5m^3; Half trip of clay (3.81m^3) =

₦50,000.00, therefore 5.5m^3 plus 25% shrinkage will cost = ₦90,233.10.

Labour Cost

(Filling Bottle) A labourer can fill 400 bottles per day; Number of days required will be 15717/400=39 days; Cost of filling 39 x 7000 = ₦ 273,000.00

(Laying of plastic brick) Gang can lay 800 bottle bricks per day on average; days required will be 15717/800 = 19.65 days; Cost of laying will be (10000 + 7000) X 19.65 = ₦ 334,050.00

(Operator) Mixer operator rate per day is = ₦10,000

Plant Cost

A concrete mixer can mix 20m^3 of concrete per day; Since the quantity of mortar required for 100m^2 wall is 5.5m^3, the number of days required to mix the needed concrete is 5.5/20 = 0.28 days @ ₦40,000 hiring cost per day, the cost of mixing the required concrete is 0.28 X ₦40,000 = ₦11,200

Summary	Total
Material Cost: Bottle = ₦172,887.00; Sand = ₦110,341.21; String = ₦25,000.00, Mortar 1:6 = ₦90,233.10.	₦398,461.31
Labour: Filling Bottle = ₦273,000.00; Laying Plastic Brick = ₦334,050.00; Mixer Operator = ₦10,000.00	₦617,050.00
Plant: ₦11,200	₦11,200.00
	₦1,026,711.31
Add 25% Profit and Overhead	₦256,677.83
	1,283,389.14
Cost per m² 1,283,389.14 / 100	₦12,833.89 / m²

Cost of walling gate house using plastic bottle brick =12,833.89 X 67.35 = ₦864,362.49

IV. DISCUSSION OF FINDINGS

The result of the analysis shows the total material cost for sandcrete block as ₦1,261,574.68, as against that of waste sand-filled plastic bottle, which is ₦398,461.31, the difference in material cost is ₦863,113.34. This suggested that about 46% of material cost could be saved when waste plastic brick is used in placement of the conventional 225mm sandcrete block.

However, comparing the labour cost indicated that the cost of labour for sand-filled plastic brick (₦617,050.00) is higher than that of conventional 225mm block wall (₦274,342.5). The difference arises due to the fact that the coverage area of the conventional 225mm block wall is greater than that of sand-filled plastic bottle, there for more labour is required for laying the plastic bottle and filling the bottles with sand.

The analysis also showed the plant cost for sand-filled plastic bottle (₦11,200) as higher than that of sancdcere block wall (₦4,400). The difference in cost results from the volume of mortar that is required for laying the plastic brick, since the bricks are in smaller units, more mortar is required compared to sandcrete block wall. This finding is in agreement with Yahia et al., (2024) who said sustainable construction may be high initially.

When all cost headings, such as material cost, plant cost and labour cost, was summed up and 25% profit and overhead was added, the cost per meter square (Cost/m2) for both walling materials was aggregated to ₦19,253.96 for 225mm sandcrete block and that of sand filled plastic bottle bedded and jointed with clay mortar came to ₦12,833.89 this suggested sand-filled plastic bottle as been cheaper when all cost headings are put into consideration.

Comparing the overall cost of walling the gate house, it will cost ₦1,296,754.21 when sandcrete block is used, compared to using sand-filled plastic bottle with an overall walling cost of ₦864,362.49. This analysis suggested that 50.03% (₦432,391.72) of walling cost could be saved if the gate house wall is constructed using sand-filled plastic bottles with clay mortar compared to using sandcrete block. This finding also conforms with that of Saikiaa & Britoa, (2013), where he stated that sand-filled bottles offer both environmental and economic advantages. These materials are also readily available Makanjuola & OluMartins. (2023).

V. CONCLUSION AND RECOMMENDATION

In conclusion, this research on sustainable walling which was achieved through the process of estimation implore Ondo state government in particular and Nigeria government in general, to adopt the use of sand-filled plastic bottles for mass housing, as this is a promising alternative to the use of conventional materials and their contribution to the emission of unwanted carbon Local production and supply chain should be developed for the production and distribution of sand-filled plastic brick, like conventional 225mm sandcrete block, this will help reduce the housing challenge faced by the general public in Ondo state and Nigeria.

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