International Journal of Civil Engineering and Technology (IJCIET)
Volume 9, Issue 8, August 2018, pp. 1783–1792, Article ID: IJCIET_09_08_179
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=8
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

© **IAEME** Publication **Scopus** Indexed

AN EVALUATION OF COMPRESSIVE AND FLEXURAL PROPERTIES OF LATERITE FILLED PET BOTTLES AS A WALL CONSTRUCTION MATERIAL

Olaniyi Diran Afolayan*
Civil Engineering Department, Covenant University, Ota, Nigeria.

Abisola Mariam Salawu
Civil Engineering Department, University of Ibadan, Ibadan, Nigeria

Bamidele IbukunOlu Dahunsi
Civil Engineering Department, University of Ibadan, Ibadan, Nigeria

Abimbola Oyebola Odetoyan
Civil Engineering Department, Covenant University, Ota, Nigeria.

Akpabot, Ifiok Akpabot
Civil Engineering Department, Covenant University, Ota, Nigeria.

*Corresponding E-mail: olaniyi.afolayan@covenantuniversity.edu.ng

ABSTRACT

Today, construction industry is in need of finding indigenous, available and cost effective materials as a constituent material for construction. One of the readily available material due to its numerous advantages is polyethylene terephthalate (PET) which is commonly used for containing carbonated beverage and water bottles among others. Hence, this project access the possibility of PET bottles filled with lateritic sand for a composite wall construction system. Collected laterite was air-dried for seven days, sieved with 4.75mm BS sieve size and bagged, 90 specimen cubes were produced with clay soil samples replacing the conventional fine aggregate, sand; embedded with laterite filled PET bottles arranged horizontally, the mixes were prepared by proportioning for 10% and 15% cement stabilization and representative cubes air-dried for respective curing period . Specimens of both empty PET bottles and laterite filled PET bottles were tested at 3, 7 and 14 days for compressive strength and for 14 and 28 days for flexural strength. . Results showed that test specimen for control and stabilized specimen with 15% cement stabilization had the highest 14 days average test result in compressive strength. However, laterite filled PET bottle failed to improve flexural strength of cubes. Based on the research, it was recommended that poured clay containing 15% cement stabilization could be used for construction of *non- load bearing internal walls as it will reduce the overdependence on cement and granite usage thereby conserving the scarce natural resources as well as reducing solid waste problem posed by plastic.*

Key words: Polyethylene terephthalate; composite wall; compressive test; flexural strength test.

Cite this Article: Olaniyi Diran Afolayan, Abisola Mariam Salawu, Bamidele IbukunOlu Dahunsi, Abimbola Oyebola Odetoyan, Akpabot, Ifiok Akpabot, An Evaluation of Compressive and Flexural Properties of Laterite Filled Pet Bottles as a Wall Construction Material. *International Journal of Civil Engineering and Technology*, 9(8), 2018, pp. 1783-1792.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=8

1. INTRODUCTION

With worldwide population growth, the need of infrastructural development has also increased exponentially. In order to respond to this growth, research and countries tends to focus on adoption of indigenous and traditional materials as a constituent material in the construction process. Ofori [1] emphasized that in construction industries, cost of importing materials plays a significant role in affecting the total contract cost. Due to this price increase in construction cost, there is a growing awareness to research on the use of locally available and indigenous materials as alternative materials for construction of functional parts of low-cost houses in rural and urban centers. It is with this aim that studies carried out by [2, 3, 4, 5] emphasized that wastes used in construction processes provides a potential way of managing wastes and effectively reducing construction cost .

Worldwide, plastic consumption has increased substantially due to its numerous advantages and applications has grown substantially all over the world. According to Motjaba et al [6], PET bottles is a non-biodegradable material and challenges arise in its disposal and management. Plastics are produced from non-renewable resource, has great waste volume subsequent to its uses, takes about 300 years in nature to degrade and are considered as an environmental pollutant due to its improper disposal. Owing to these properties, recent research have attempt and succeeded in finding efficient and effective solutions for recycling and utilizing waste plastics so as to reduce its effect on the environment [7]. One of the way of effective recycling plastics, is as innovative materials for buildings and as a replacement for conventional building materials.

Effective recycling of plastic waste promotes sustainable environment through reduction of green-house effect, reduction in quantity of waste deposited in landfills and effective land use. Researches have incorporated plastic wastes as a constituent materials for different components of buildings such as walls, ceiling and roof tiles due to its sustainable potential, toughness and durability. This study is part of continuing efforts to investigate the sustainability, effectiveness and practicability of PET bottles' utilization in buildings construction. Specifically, it looks into the comparison of the compressive strength and flexural strength test of PET bottles with lateritic soils as part of a larger investigation into the properties of PET bottle wall construction system.

2. MATERIALS AND METHOD

Materials used for bottle wall masonry construction were; lateritic soil**,** PET bottles. portland cement**,** potable water, clay soil and engine oil

2.1. Specimen Preparation

PET bottles were air-dried before filling with laterite, through the use of filter funnel. Before laterite was poured into PET bottles, water was applied to laterite used in a varying measure to increase the density of PET-laterite mixture. Compaction of laterite was done with a taping rod at the rate of 20 blows per layer with 3 layers. Cubes were cast using clay mortar at a water to cement ratio of 0.30 and with a partial replacement of cement at 0%, 10% and 15% using manual mixing to bond the plastic. Laterite –filled PET bottle were diagonally arranged in a cube before casting with clay soil and cement was carried out into each cast cube. Mortar placement around laterite filled PET bottles was done after 15 minutes of mixing clay soil and cement in order to bind the bottled clay bricks together into a cube. Adoption of water/ cement ration of 0.30 is because clay particles exhibits an higher water absorption potential

2.2. Compressive Testing

Two methods for determining compressive strength of masonries was adopted. After the PET bottles were filled with lateritic soil and compacted in layers, they were weighed as shown in Fig. 1 before crushing. This was carried out using an ELE compressive testing machine (ADR TOUCH 2000). Twelve (12) number PET bottles of different water percentage content (0%, 2%, 4%, 5%, 6% and 8%) well labeled were subjected to crushing. The unit testing (single bottle test) method was carried out on fourteen (14) PET bottle units (2 empty PET bottles included), using a compressive testing machine ADR TOUCH 2000, while the brick bottle testing method was carried out on 90 number (260 x260 x160mm) cubes specimens, using ELE compressive testing machine shown in Fig. 2.

Figure 1 Showing weigh balance with PET-Laterite

Firstly, the bearing surface of the plate was cleaned to remove any loose grit. The PET bottle specimen was put in the testing machine relatively to its longitudinal axis, at the centre coinciding with the axis of the machine. Final check of the correct positioning was made, and then load was applied up to failure. The first crack that appears on the PET bottle specimen was considered as the failure point. The load at failure was recorded and divided by the sectional area of the PET bottle in contact with the platen to arrive at the compressive strength and the average compressive strength was calculated. This was done according to the specification as given in BS 1881, part 116 [8].

Figure 2 Compressive strength testing

2.3. Flexural Testing

Flexural test as shown in Fig. 3 was carried out on the cast bottle element with mould size 260 x 160 x160 in OKHARD Universal Testing Machine. The machine's maximum rest force is 600KN. The computer controlled hydraulic compression testing machine consists of load frame, oil source control cabinet, computer and printer. Test were carried out in accordance to BS 1811 [9]

Figure 3 Flexural strength testing

3. RESULTS AND DISCUSSSION

From Table 1, the natural moisture content of the laterite was 5.4% which was higher than 2.4% achieved by Aguwa [10]. The plasticity index of laterite was given as 13%. This was lower than the value of 17% achieved by Shehu [11]. It indicated that the laterite had a low plasticity (<35%) and therefore satisfies the condition specified in BS 1377 [12]. Laterite' AASHTO classification system for this laterite falls under the sub-group of A – 2 – 6 which indicates that the laterite is made up of sands, some gravel with elastic silt fines. The bulk density of the laterite was found to be 1618kg/m3. This value is close to 1460 kg/m3 obtained by Joseph *et al* [14]. Specific gravity was 2.56 as obtained by Shehu [11] but lower than 2.64 recorded by Aguwa [10] as obtained in Table 1. These three values however fell within the range specified for laterite. The fineness modulus for the laterite was 3.98 which were above the maximum value of 3.50 for fine aggregate but close to the value of 4.00 for combined aggregate. This indicates that the laterite is mostly fine aggregate with some quantity of coarse aggregate. A reddish – brown colour was observed by visual examination of the laterite sample.

Table 1 Result of Physical Test on Laterite

Properties	Value
Natural Moisture content (%)	5.4
Liquid limit (%)	37
Plastic limit (%)	24
Plastic index (%)	13
AASHTO classification system	A-2-6
Bulk density	1618kg /m3
Specific gravity	2.56
Fineness modulus	3.98
Condition of sample	Air –dried
Colour	Reddish – brown

(Source: Laboratory work)

3.1. Compressive Strength

Sulymon et al [13] stated that there exists a relationship between moisture content and compressive strength and this is expanded by Table 2 and Fig. 4 showing the relationship between moisture content and the compressive strength test of laterite filled PET bottles. At 4%, the optimum moisture content was attained having an average compressive strength of 25.65KN.

Table 2 Compressive strength test result on laterite filled PET bottles

Percentage of water (%)	Average compressive strength (KN)
0	23.4
2	18.8
4	25.65
5	17.9
6	15.25
8	14.5

(Source: Laboratory work)

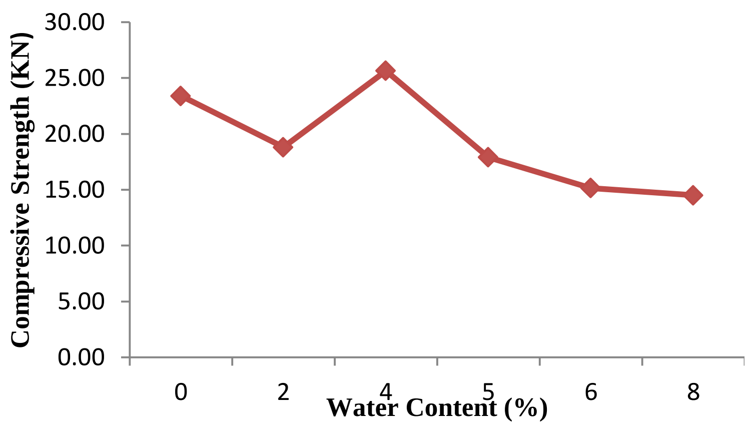

Figure 4 Relationship between compressive strength and moisture content

It was observed as shown in table 3 and 4 that the compressive strength of test clay cubes all had an increase in strength with a corresponding increase in curing time. No test was conducted for cubes with 0% cement content on day 14 as they were still weak. This was due to the fact that the aggregates which are mostly fine aggregate and in the absence of cement, took longer periods to absorb moisture and harden. The longer period it took for the 0% cubes to harden is as a result of the water present in its pores. Also, the massive shrinkage which leads to a reduced cube dimension eliminated a lot of air pores which increased the density of the cubes. This was as a result of the binding properties of the clay particles which have angular or non-rounded shapes. They formed flakes that stuck together when the desired amount of water was added thus, enabling them produce the highest compressive strength [15].

The clay content caused strong cohesion and massive shrinkage. This shows that clay has some cementing material that can bind particles together. The small quantity of coarse aggregate contributed to the cubes (0%, 10% and 15%) not having a very high compressive strength as coarse aggregate are known to improve mechanical strength. Cubes with 10% and 15% cement content had a steady increase in average compressive strength with 15% cement content showing a higher value as the curing period increases. At day 7, 10% cement cubes recorded an average compressive strength of 0.66N/mm^2 and 0.67N/mm^2 at 14 days respectively. This showed that there was a reduction of strength for the 10% cement cubes which is in tandem with the work of Olofinnade et.al. [16]. However, that was not the case for 15% cement cubes as it continued to record higher average compressive strength as the days went by. No recording was available for cubes with 0% cement content due to their weak state as at the time of crushing (14days).

Compressive strength test was done on the control for poured clay cube without PET bottles and it was observed that it recorded higher values of average compressive strength with 3, 7 and 14 days recording 0.77N/mm^2, 0.84N/mm^2, 0.88N/mm^2 respectively for 10% and 1.08N/mm^2, 1.17N/mm^2, 1.41N/mm^2 for 15% as shown in Fig. 3. An increase in compressive strength was observed for the entire unreinforced cube tested. 15% cement cube had a higher strength on both day 3, 7 and day 14 recording 0.65N/mm^2, 0.69N/mm^2 and 0.75N/mm^2 respectively. This showed that stabilizing agents are necessary for strength development.

3.2. Flexural Strength

An increase in flexural strength was observed for all test cubes with laterite filled PET bottles tested. Fifteen percent cement cubes had a higher strength on both day 14 and day 28 recording 0.89N/mm^2 and 0.91N/mm^2 as shown in Table 5. This showed that stabilizing agents are necessary for strength development. An increase in flexural strength was also observed for all specimens with laterite filled PET bottle as was in the case of the cubes without laterite filled PET bottles (Control) as shown in Table 6. Fifteen percent cement cubes still recorded the higher strength between the two cement specimen (10% and 15%). It was assumed that with the inclusion of the PET bottles, there would be a large increase in strength. But comparing both the cubes with laterite filled PET bottles and the cubes without laterite filled PET bottles, they had almost the same result but with cube specimen without laterite filled PET bottles posting better readings as shown in table 5 and 6. This showed that PET bottles arranged in the cubes failed to improve the flexural strength of the PET bottle reinforced cubes, it indicated that there was anchorage failure implying no bonding between the PET bottles and the poured clay [16].

Table 3 Compressive strength of cubes at various cement percentages reinforced with PET bottles

Sample Shape	Designation	Cement Content (%)	Curing Duration (days)	Cross-sectional Area (mm2)	Failure KN	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm2)
Cube	A_1	10%	3	67,600	44.3	0.66	
	B_1	10%	3	67,600	41.8	0.62	0.62
	C_1	10%	3	67,600	40.1	0.59	
	A_2	10%	7	67,600	42.6	0.63	
	B_2	10%	7	67,600	46.2	0.68	0.66
	C_2	10%	7	67,600	45.7	0.68	
	A_3	10%	14	67,600	50.9	0.75	
	B_3	10%	14	67,600	41.4	0.61	0.67
	C_3	10%	14	67,600	43.5	0.64	
Cube	A_1	15%	3	67,600	46.2	0.68	
	B_1	15%	3	67,600	43.5	0.64	0.65
	C_1	15%	3	67,600	42.9	0.63	
	A_2	15%	7	67,600	44.7	0.66	
	B_2	15%	7	67,600	48.8	0.72	0.69
	C_2	15%	7	67,600	47.4	0.7	
	A_3	15%	14	67,600	51.1	0.76	
	B_3	15%	14	67,600	50.6	0.75	0.75
	C_3	15%	14	67,600	50.2	0.74	

Table 4 Compressive strength of cubes at various cement percentages unreinforced (Control)

Sample Shape	Designation	Cement Content (%)	Curing Duration (days)	Cross-sectional Area (mm2)	Failure KN	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm2)
Cube	A_1	10%	3	67,600	51.1	0.76	
	B_1	10%	3	67,600	54.6	0.81	0.77
	C_1	10%	3	67,600	50.3	0.74	
	A_2	10%	7	67,600	58.2	0.86	
	B_2	10%	7	67,600	55.9	0.83	0.84
	C_2	10%	7	67,600	57.1	0.84	
	A_3	10%	14	67,600	60.1	0.89	
	B_3	10%	14	67,600	58.6	0.87	0.88
	C_3	10%	14	67,600	59.7	0.88	
Cube	A_1	15%	3	67,600	70.5	1.04	
	B_1	15%	3	67,600	74.3	1.10	1.09
	C_1	15%	3	67,600	75.7	1.12	
	A_2	15%	7	67,600	80.4	1.19	
	B_2	15%	7	67,600	79.8	1.18	1.17
	C_2	15%	7	67,600	77.6	1.15	
	A_3	15%	14	67,600	96.2	1.42	
	B_3	15%	14	67,600	95	1.41	1.41
	C_3	15%	14	67,600	94.9	1.40	

Table 5 Flexural strength for 10% and 15% Reinforced cubes

Sample Shape	Designation	Cement Content (%)	Curing Duration (days)	L(mm)	B(mm)	D(mm)	P(KN)	Flexural Strength (N/mm2)	Average Flexural Strength (N/mm2)
Cube	A_2	10%	14	650	200	200	10.3	0.84	
	B_2	10%	14	650	200	200	10.15	0.82	0.84
	C_2	10%	14	650	200	200	10.45	0.85	
	A_3	10%	28	650	200	200	10.1	0.82	
	B_3	10%	28	650	200	200	9.85	0.8	0.85
	C_3	10%	28	650	200	200	11.4	0.85	
Cube	A_2	15%	14	650	200	200	10.8	0.88	
	B_2	15%	14	650	200	200	10.94	0.89	0.89
	C_2	15%	14	650	200	200	11.05	0.9	
	A_3	15%	28	650	200	200	10.5	0.85	
	B_3	15%	28	650	200	200	11.6	0.94	0.90
	C_3	15%	28	650	200	200	11.1	0.91	

Table 6 Flexural strength for 10% and 15% PET bottles Unreinforced Cubes.

Sample Shape	Designation	Cement Content (%)	Curing Duration (days)	L(mm)	B(mm)	D(mm)	P(KN)	Flexural Strength (N/mm2)	Average Flexural Strength (N/mm2)
Cube	A_2	10%	14	650	200	200	13.52	1.09	
	B_2	10%	14	650	200	200	14.6	1.18	1.17
	C_2	10%	14	650	200	200	15.43	1.25	
	A_3	10%	28	650	200	200	12.8	1.04	
	B_3	10%	28	650	200	200	15.05	1.22	1.11
	C_3	10%	28	650	200	200	13.14	1.07	
Cube	A_2	15%	14	650	200	200	15.65	1.27	
	B_2	15%	14	650	200	200	16.9	1.37	1.31
	C_2	15%	14	650	200	200	15.85	1.29	
	A_3	15%	28	650	200	200	16.95	1.38	
	B_3	15%	28	650	200	200	16.45	1.34	1.36
	C_3	15%	28	650	200	200	16.8	1.37	

4. CONCLUSIONS

The lateritic soil was well graded and identified to be an A – 2 – 6 soil based on AASHTO classification system. The physical and mechanical properties of the laterite were satisfied. At 14 days, specimen with 15% cement content gave highest average compressive strength (non reinforced PET bottle) recording 1.41N/mm2, however, 0% cement content (control) was still soft during test at 14 days. The average compressive strength of the 15% cement cubes (reinforced with PET bottle) at 14 days was satisfactory recording a value of 0.75N/mm2. The strength could still increase with increase in curing time. PET bottles failed to improve the compressive strength of the cubes at all cement percentages due to poor bonding with the slurry.

However, if it can be improved in some way, the compressive strength may increase. The low compressive strength values recorded for all cement percentages (unreinforced cubes) indicates the inability to be used as a structural member for construction but suitable for members in compression e.g. walls Flexural test result showed that cubes (10% and 15%) without PET bottle reinforcement recording 1.31N/mm2 and 1.36N/mm2 respectively performed better than cubes (10% and 15%) having the PET bottle reinforcement recording 0.89N/mm2 and 0.91N/mm2. Anchorage failure of the PET bottle was a contributory factor to the poor performance of PET bottle reinforced poured clay cubes.

5. CONTRIBUTION TO KNOWLEDGE

Utilizing waste plastic bottles as a constituent building materials can have substantial effects on total embodied energy of buildings by reducing green-house effect associated with CO_2 emission arising from production and hydration of cement. It has been established that poured clay construction is a new innovation. Also, it was established that PET bottle failed to improve the compressive strength of reinforced poured clay cube. The research also showed that poured clay is lightweight in nature. A small quantity of cement is required for stabilization in poured clay.

6. FUNDING

This research was funded by no organization but the publishing by Covenant University Centre for Research Innovations and Discovery (CUCRID).

REFERENCES

[1] Ofori, G (1993) Research in construction industry development at the crossroads. Construction Management and Economics, 11, 175-185

[2] Shi, C., & Zheng, K. (2007). A review on the use of waste glasses in the production of cement and concrete. Resources, Conservation and Recycling, 52, 234-247.doi:10.1016/j.resconrec.2007.01.013

[3] Jani, Y., & Hogland, W. (2014). Waste glass in the production of cement and concrete – A review. Journal Environmental Chemical Engineering, 2, 1767–1775.

[4] Akinwumi, I. I., Awoyera, P. O., Olofinnade, O. M., Busari, A. A., & Okotie, M. (2016). Rice husk as a concrete constituent: Workability, water absorption and strength of the concrete. Asian Journal of Civil Engineering, 17, 887–898.

[5] Olofinnade, O. M., Ede, A. N., & Ndambuki, J. M. (2017). Sustainable green environment through utilization of waste soda-lime glass for production of concrete. Journal of Material and Environmental Sciences, 8 ,1139–1152

[6] Mojtaba Valinejad Shoubi, Masoud Valinejad Shoubi, Azin Shakiba Barough (2013) Investigating the Application of Plastic Bottle as a Sustainable Material in the Building Construction. International Journal of Science, Engineering and Technology Research Volume 2,January 2013, pp: 28-34

[7] Sanisah S. (2013) Sustaining Sustainability," Palaver: Sense and Sustainability" in Proceedings international Journal of Advances in Engineering & Technology, (IJAET) Malaysian Town Plan Journal. Volume 01, pp: 60-70. 2013.

[8] BS1881 - 116: (1983). Testing Concrete - Method for determination of compressive strength. British Standard Institution, London, England, UK.

[9] BS1881 - 4: (1970). Testing Concrete - Method for determination of flexural strength. British Standard Institution, London, England, UK.

[10] Aguwa J Isiwu. *Study of Compressive Strengths of Laterite-Cement Mixesas a Building Material AU J.T. 13(2) 114-120 (Oct. 2009)*

[11] Shehu, I. A. (2010). Suitability of Termite Clay Powder as a Partial Replacement of Cement in Laterite Soil. (Unpublished master's thesis) Ahmadu Bello University, Zaria.

[12] BS 1377. (1975). Methods of test for soils for civil engineering purposes. British Standard Institution, London, England, UK.

[13] Nurain Sulymon, Olatokunbo Ofuyatan, Olowofoyeku Adeoye, Simon Olawale, Ayobami, Busari , Gideon Bamigboye, Joshua Jolayemi. Engineering Properties Of Concrete Made From Gravels Obtained In South-Western Nigeria. Cogent Engineering (2017), 4: doi.org/10.1080/23311916.2017.1295793

[14] Joseph O Ukpata, Maurice E Ephraim and Godwin A Akeke (2012), "Compressive strength of concrete using lateritic sand and quarry dust as fine aggregate", *ARPN Journal of Engineering and Applied Sciences,* Vol. 7, No. 1, ISSN 1819-6608.

[15] Amana Ocholi, Manasseh Joel. Effect of Variation in Temperature on Some Properties of Cement Stabilized Lateritic Interlocking Bricks. International Journal of Engineering and Technology Volume 4 No. 1, January, 2014

[16] Olofinnade Oluwarotimi M., Anthony N. Ede, Julius M. Ndambuki, Ben U. Ngene, Isaac I. Akinwumi and Olatokunbo Ofuyatan. Strength and microstructure of eco-concrete produced using waste glass as partial and complete replacement for sand. Cogent Engineering (2018), 5: 1483860