West Africa Built Environment Research (WABER) Conference
WABER 2021 Conference, 9-11 August 2021, Accra, Ghana
Proceedings Edited by Laryea, S. and Essah, E.
ISBN 978-0-620-95367-2

EFFECT OF PETROLEUM CONTAMINATION ON PROPERTIES OF COMPRESSED STABILIZED EARTH BRICK (CSEB)

K. A. N. Sackey[1], M. M. Garba[2], O. G. Okoli [3] and D. D. Dahiru[4]
[1,2,3,4]*Department of Building, Ahmadu Bello University, Zaria, Kaduna State, Nigeria*

The Niger Delta region is the epicenter of petroleum exploration and extraction activities in Nigeria contributing to oil spills experienced in the region. Attention has been drawn to its effects on fishing and farming activities while less attention is paid to effects on soils for construction activities. This research ascertained the effect the presence of petroleum had on properties of compressed stabilized earth bricks (CSEBs) made from artificial petroleum contaminated laterite. Three sets of bricks were produced having a binder made up of rice husk ash (RHA), carbide and cement in predetermined proportions. Out of the three sets, two sets were made from laterite artificially contaminated with 2% and 3% petroleum while the third set had no contamination and acted as the control (0%). The results revealed that bricks made from petroleum contaminated laterite performed favourably on all selected tests in relation to the control at the various allotted test days respectively. It can therefore be inferred that laterite having petroleum contaminants in very minute quantities in combination with pozzolans like rice husk ash (RHA) and carbide can be used for the production of CSEBs and utilized in building construction in the Niger Delta region of Nigeria.

Keywords: compressed stabilised earth brick, laterite, petroleum, pozzolans

INTRODUCTION

In order to have an eventful existence, every living being requires a home for sanctuary and convenience in the execution of everyday activities as well as for prestige. Aminu & Ruhizal (2013) defined a home as a place for refuge, security, comfort and dignity. It is one of the three basic requirements for any individual apart from food and clothing. In the absence of shelter, his daily activities will be adversely affected (Sackey, Garba, Mamman & Adeleke 2018).

As of today, houses are constructed with numerous building materials of which concrete and steel occupy the top spots for materials used in building construction. Generally, some of these building materials are quite expensive as well as increasingly becoming scarce. Water bodies are steadily drying up from the twin effects of high temperatures caused by global warming and the increase in water

[1] kwekusackey@yahoo.com
[2] mmagajigarbaa@yahoo.com
[3] okolygody02@yahoo.com
[4] daudadahiru509@gmail.com

demands brought about by population explosion. These twin effects adversely affected the availability of sharp sand which is an important constituent of concrete. Also, the excessive demand for cement has led to the destruction of the natural features of the ground topography in areas were limestone is extracted for cement production. In addition, the gaseous discharges such as smoke and dust released from cement producing factories affects air quality and disrupts the photosynthesis processes for plants (Sackey, Garba, Mamman & Adeleke 2019). As a result of these uncontrolled extractive activities, farmlands as well as plant and animal habitats are steadily destroyed in addition to the creation of erosion and gully formations which are some of the features of man-made disasters.

Again, the blasting of rocks at quarry sites in search of coarse aggregates has its resultant effects in the form of noise pollution, injuries, destruction of properties located near such quarries in addition to the depletion of scenic sites were these rock formations are found. Many more of such activities carried out on a daily basis with the sole purpose of extracting materials for construction jobs are slowly but continously exhausting the non-renewable resources as well as destroying the ecosystem.

LITERATURE REVIEW

Petroleum contaminated soil

In the Niger Delta Region, petroleum spillage is a major source of soil contamination. As emphasized by Ayininuola (2009), he stated that the major environmental concern in the Niger Delta region is the issue of petroleum spillage. Low income earners in this region sometimes have to contend with two prominent issues; the exorbitant fees attached to most houses available for rent and the use of soil for building construction which has been accidentally contaminated from petroleum spills. Most times, in the course of the extraction process, petroleum spills onto the ground surface. In addition, accidents, negligence, faulty equipments, old and unserviceable parts of equipments, etc. contribute to the petroleum spills that often occur in the region.

Oyelowe (2015); Ezeldin & Vaccri (1996); Adeoye, Olatokunbo & Ademola (2015); Rehman, Abduljauwad & Akram (2007) asserted that spilled petroleum does not remain on the surface but seeps into the ground under the influence of gravity contaminating the soil as it moves downwards. In this way, soils far away from the point of spillage may become contaminated as a result of the horizontal movement of the spilled petroleum when it comes in contact with underground moisture.

Studies carried out revealed that the presence of these spills in some ways contributed to the improved engineering properties of the soils investigated. Researchers like Onyelowe (2015), reported that contamination of engineering soils with up to 4% petroleum was beneficial in terms of soil improvement and stabilization. Again, Al-Sanad, Eid & Isamel (1995) as cited by Obeta & Ohwoganohwo (2015) revealed that 4% petroleum contamination increased the California bearing ratio of Kuwaiti sand. Also, Otunyo (2010) as quoted by Obeta et al. (2015) affirmed that the California bearing ratio of petroleum contaminated soils were higher than the uncontaminated soils of silty clay and sandy clay soils.

This implies that petroleum contaminated soils can be useful for building construction.

Compressed Earth Brick (CEB)

To adequately utilize these contaminated soils for cheap and affordable building construction especially for low income earners, compressed earth bricks (CEBs) can be made from such soils. This reduces the overdependence on concrete and its constituent materials. Adam & Agib (2001), Stulz, Mukerji, Ile & Fur (1993) as quoted by Oyelami & Van Roov (2016, p. 2) defined compressed bricks/blocks as 'masonry which are small in size having regular characteristics and produced by static or dynamic compression of earth in humid state followed by immediate demoulding'.

Guillaud, Joffroy & Odul (1985) as well as Patowary, Nath, Hussain & Kakoti (2015) affirmed that the compressed earth brick/block (CEB) is the modern outcome of molded earth known as adobe earth block. CEB normally has a high compressive strength. This is due to the high mechanical force (mechanical stabilization) applied to moist soils during the production of bricks using a press to produce maximum compaction and eliminate or reduce the presence of air pores responsible for weakness. Numerous soil types can be used for CEB production but most times, laterite is usually the preferred choice. This according to Oyelami et al. (2016) is based on the fact that laterite is well graded consisting of cohesive and cohesionless parts of a soil.

Laterite soil stabilization

Enaworu, Ugbe & Rotimi (2016) defined laterites as soils subjected to high weathering activities and composed of iron and aluminium oxides. Laterite, mostly a reddish brown soil has been utilized as a viable construction material. It is a building material that is as old as mankind. It is found in the inter tropical regions of Africa, India, South East Asia and South America were rainfall is high (Lemougna, Melo, Kamseu & Tchamba, 2011). The reddish-brown colouration is as a result of the presence of the oxide of iron which in combination with the oxides of silica and aluminium accounts for the bulk of the oxides present in laterite. The Niger Delta region has an abundant amount of laterite, some of which may have been contaminated through petroleum spills and hence, can possibly be utilized in building construction activities. Unfortunately, the utilization of laterite soils though in abundance is mostly limited to use in civil engineering works involving road construction and landfill operations (Joshua & Lawal, 2011).

To improve durability and strength of CEBs, a stabilizer such as cement is added in predetermined amount. The addition of the stabilizer results in the formation of a stronger and more durable material referred to as CSEB. A stabilizer improves both the strength and index properties of the soil making it useful for construction activities (Salahudeen & Akije, 2014 as quoted by Sadeeq, Ochepo, Salahudeen & Tijani, 2015). Other stabilizers such as pozzolans which can be substitute for cement or used partially with cement can as well help to improve soil properties. This is because studies carried out on pozzolans derived from the ashes of agricultural wastes and industrial by-products as well as from man's industrial activities such as welding has been shown to improve the strength of masonry bricks. Khalil (2017) acknowledged that many of these materials such as rice husk ash (RHA), furnace

slag, plant extracts and carbide waste are yet to be fully used in Nigeria apart from their utilization in laboratory works. Pozzolans generally are finely grounded materials and as revealed by Walker & Pavia (2011), they are rich in oxides of aluminium and silica which reacts with calcium hydroxide and moisture to create hydrated products of calcium silicate aluminium hydrate (CSAH) and calcium silicate hydrate (CSH). These hydrates are responsible for bond development. Masonry products such as CSEBs are durable, strong and very affordable and could be maximized for low cost building construction.

RESEARCH QUESTION, MATERIALS, TESTS AND METHOD

Research question

What is the effect of petroleum contamination on properties of CSEBs stabilized partially with cement, rice husk ash (RHA) and carbide.

Materials

Laterite was sourced from Dan Bazariye opposite National Animal Production Research Institute (NAPRI) in Shika, located in Giwa local government area of Kaduna State, Nigeria. The laterite was collected at a depth of 1.53m, air dried in the laboratory and sieved with a wire mesh screen aperture of 9.5mm diameter. Soil particles that passed through the 9.5mm wire mesh screen aperture were utilized in the research. Other materials used included Portland Limestone Cement (PLC) of Dangote brand which conformed to BS 12, 1996, RHA conformed to ASTMC 593:2006 specification and carbide conformed to the requirement of ASTMC 141:2005. Water satisfied the requirements of BS 3148 (1990) and the petroleum gotten from Kaduna refinery in Kaduna State served as the contaminant for the bricks.

Tests

Preliminary physical tests for the materials such as sieve analysis, percentage moisture content, atterberg and specific gravity were conducted based on the requirements of BS 1377 part 2: (1990). Proctor test (Light compaction test) according to the specifications of BS 1377 part 4: (1990) standard and bulk density test subject to BS 812 part 2: (1995) standard were undertaken. Furthermore, Free Swell Ratio (FSR) test put forward by Prakash & Sridharan (2004), Prakash, Sridharan, Prasanna & Manjunathe (2009) was carried out to determine the expansion or swell capability of the laterite.

In addition, chemical analysis to determine the mineralogical composition of oxides in the laterite, RHA and carbide using the XRF florescence spectrophotometer equipment was conducted. For the brick specimens, they were subjected to both dry and wet compressive strength tests, Abrasion, water absorption, sorptivity and ultrasonic pulse velocity (UPV) tests respectively.

Method

As seen from table 2.1, the mix proportion comprised of 4% cement, 4% RHA and 2% carbide of the dry weight of the soil. This proportion was arrived at after numerous mix proportions used in the production of the trial CSEBs were subjected to dry compressive strength test to come up with the appropriate proportion. After the trial tests, three sets of CSEBs were produced. The first set of CSEBs had 2%

petroleum contamination, the second set 3% and the third set had 0% contamination which acted as the control for the 2% and 3% contaminated CSEBs.

Table 2.1 Material proportions for petroleum contaminated 0%, 2% and 3% CSEBs

S/No	Type of test	No of brick	Mass of cement (kg)	Mass of RHA (kg)	Mass of carbide (kg)	Mass of laterite (kg)	Mass of water (kg)	Mass of petroleum (kg)	Petroleum contamination (%)
1	Dry compressive strength	20	2.4	2.4	1.2	60	15.6	0	0
		20	2.4	2.4	1.2	60	15.6	1.2	2
		20	2.4	2.4	1.2	60	15.6	1.8	3
2	Wet compressive strength	20	2.4	2.4	1.2	60	15.6	0	0
		20	2.4	2.4	1.2	60	15.6	1.2	2
		20	2.4	2.4	1.2	60	15.6	1.8	3
3	Water absorption	15	1.8	1.8	0.9	45	11.7	0	0
		15	1.8	1.8	0.9	45	11.7	0.9	2
		15	1.8	1.8	0.9	45	11.7	1.35	3
4	Abrasion	15	1.8	1.8	0.9	45	11.7	0	0
		15	1.8	1.8	0.9	45	11.7	0.9	2
		15	1.8	1.8	0.9	45	11.7	1.35	3
5	Sorptivity	15	1.8	1.8	0.9	45	11.7	0	0
		15	1.8	1.8	0.9	45	11.7	0.9	2
		15	1.8	1.8	0.9	45	11.7	1.35	3
6	Ultrasonic Pulse velocity	15	1.8	1.8	0.9	45	11.7	0	0
		15	1.8	1.8	0.9	45	11.7	0.9	2
		15	1.8	1.8	0.9	45	11.7	1.35	3

In producing the CSEBs, a calculated amount of laterite, RHA, carbide and cement were mixed thoroughly until the mixture became homogenous. Next, water was added to the mixture to initiate the chemical reaction process for the cement, pozzolan and carbide in the mix before the calculated amount of petroleum was added to those mixes that were to be contaminated. The various mixes (2%, 3% and 0% contaminated CSEBs) were then loaded on to a Nigerian Building and Road Research Institute (NBRRI) brick moulding machine which produces a press or pressure of 4N/mm2 (Ramson, 2011) for compaction. After compaction, the green bricks were extruded and taken to the curing area. Here, they were covered with plastic sheets to prevent rapid and excessive hydration from taking place. During the 28 days curing period, the bricks were watered daily by sprinkling to produce moisture for hydration as well as a warm and moist environment for curing under the polythene sheets. Five bricks for each test at an allotted test day were subjected to the outlined tests after which the averages of the 5 bricks were determined.

For the dry and wet compressive strength tests, CSEBs were crushed at 7, 28, 56 and 90 days respectively. Water absorption, sorptivity and abrasion tests were conducted at 28, 56 and 90 days. Lastly, UPV test was carried out on the bricks at 56 days and 90 days. No test was carried out on day 28 due to the late approval of the UPV equipment.



Figure 1 Petroleum contamination of stabilized soil mix



Figure 2 Compaction of contaminated stabilized soil mix



Figure 3 Extruded green bricks (CSEB)



Figure 4 CSEBs covered with blue plastic sheet during curing

Figures 1, 2. 3 and 4 show the various activities carried out to produce both the petroleum contaminated and non-contaminated CSEBs.

RESULTS AND DISCUSSION

Physical properties of laterite, RHA and Carbide

Table 3.1 Physical properties

Properties	Description		
	Laterite	RHA	Carbide
Natural moisture content (%)	15.38	-----	-----
Liquid limit (%)	38	-----	----
Plastic limit (%)	20	-----	-----
Plastic index (%)	18	------	------
AASHTO Classification system	A-2-6	------	------
Bulk density (kg/m^3)	1697	------	------
Specific gravity	2.76	2.14	2.48
Fineness modulus	3.48	-----	------
Condition of sample	Air dried	Air dried	Air dried
Colour	Reddish-brown	Greyish-white	White
Silica-Sesquioxide ratio	1.50	------	------
Free swell ratio (FSR)	1.12	------	------
Optimum moisture content (OMC %)	15.79	-----	------
Maximum dry density (MDD g/cm^3)	1.84	-----	------

From table 3.1, the natural moisture content for the laterite was 15.38% indicating a possible high bearing capacity property to withstand imposed load. Plasticity index was at 18% less than the maximum limit of 35%. This showed that the soil will not be prone to alternating swelling and shrinking when moist or dry. The soil falls under the sub-group of A-2-6 of the American Association of State Highways and Transportation Officials AASHTO M145-91 (2003) standard classification system showing the soil to be made up of sand, gravel with elastic silt fines. The bulk density and the specific gravity of the soil were 1697 kg/m3 and 2.76. These values fall within acceptable ranges for laterite soils. Also, the specific gravity of the RHA and carbide were 2.14 and 2.48 respectively. The fineness modulus was 3.48 within the range of 2.0 - 3.5 indicating that the soil was mostly made up of fine aggregates. The samples were all dried before use to prevent caking of the particles by moisture. Oxide of iron was responsible for the reddish brown colouration of the laterite while reactive amorphous silica produced the greyish-white colour of the RHA and oxide of calcium influenced the whitish colour of the carbide.

According to Rossister (2014), the Silica – Sesquioxide ratio of a soil within the range of 1.33 and 2 is a true laterite hence this soil with a S-S ratio of 1.50 satisfied that requirement. The free swell ratio of this soil with a value of 1.12 can be said to have a mixture of kaolinite and montmorillonite clay components meaning the soil has a low expansivity. Lastly, 15.79% was the optimum moisture content at which the soil attained a maximum dry density of 1.84 g/cm3.

Chemical properties of laterite, RHA and Carbide

Table 3.2 Chemical constituents of laterite, RHA and carbide

Element	Concentration (wt %)		
	Laterite	RHA	Carbide
Na_2O	0.051	0.140	0.000
MgO	0.580	2.505	0.000
Al_2O_3	25.396	1.619	2.200
SiO_2	56.996	82.831	6.740
P_2O_5	0.197	7.193	0.081
SO_3	0.282	0.700	0.617
Cl	0.007	0.029	0.162
K_2O	1.825	2.111	0.120
CaO	0.211	1.497	89.435
TiO_2	1.946	0.118	0.074
Cr_2O_3	0.019	0.002	0.004
Mn_2O_3	0.081	0.268	0.007
Fe_2O_3	12.399	0.925	0.507
ZnO	0.001	0.054	0.000
SrO	0.009	0.008	0.054

From table 3.2, elements in the laterite soil that have an appreciable amount of oxides include Aluminium, Silica and Iron with corresponding percentage values of 25.39%, 56.99% and 12.39% in that order. The RHA had a very high silica content (amorphous silica) of 82.83% which is highly desirable for any pozzolanic material

to possess with regards to the reaction expected to occur with calcium oxide in the presence of water. For the carbide, the oxide of calcium with a value of 89.43% was the most prominent among all the other oxides present in the carbide.

MECHANICAL AND DURABILITY TEST RESULTS

Dry Compressive Strength

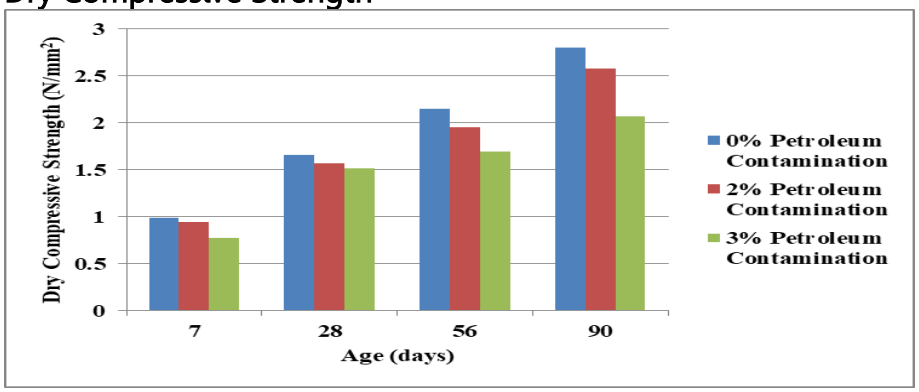


Fig 5: Dry compressive strength – age of curing relation for CSEBs

For the earliest average strength at day 7, 2% petroleum contaminated CSEBs achieved an average dry compressive strength of 0.94 N/mm2, 3%; 0.77 N/mm2 and 0%; 0.99 N/mm2. For strength at 28 days, the Nigerian Building and Road Research Institute (2006) recommended a dry compressive strength of not less than 2.0 N/mm2 at 5% cement stabilization. Average compressive strength of the bricks at 2%, 3% and 0% were however 1.57 N/mm2, 1.51 N/mm2 and 1.66 N/mm2 respectively. It was on day 56 that 0% bricks achieved the 28 days strength with an average value of 2.15 N/mm2. Furthermore, at day 90, 2% and 3% were finally able to achieve the 28 days strength with 2.58 N/mm2 and 2.07 N/mm2. The 2% and 3% bricks achieved their strength late (90 days) because the bonds that were being developed in the brick's matrix between the aggregates was from the hydration of the cementing gels slowing down due to the encapsulation activity of the petroleum contamination. However, this did not prevent the contaminated bricks from reaching the 2.0 N/mm2 28 days strength recommended. This is in line with Tremblay, Duchesne, Locat & Leroveil (2002) as quoted by Akinwumi, Booth, Diwa & Mills (2016) that petroleum contaminants found in cement stabilized soils slows down hydration but cannot prevent the development of the ultimate strength of the stabilized petroleum contaminated soils.

Presses with higher compaction pressure can be used for petroleum contaminated soils to make bricks which will in turn lead to the contaminated bricks achieving close to the 28 days compressive strength specified by NBRRI (2006). This is because the higher the compaction pressure generated in the brick's matrix, the closer and stronger will be the bond created between the aggregates despite the presence of the petroleum contaminants in the brick's matrix. This implies that soils having petroleum content higher than 3% can be used as long as a press with a very high compaction pressure is utilized in the brick production. This agrees with Abdullah, Nagapan, Antonyova, Rasiah, Yunus & Sohu (2017) when they affirmed that an increase in compaction pressure would give rise to an increase in compressive strength of CSEBs.

Wet Compressive Strength

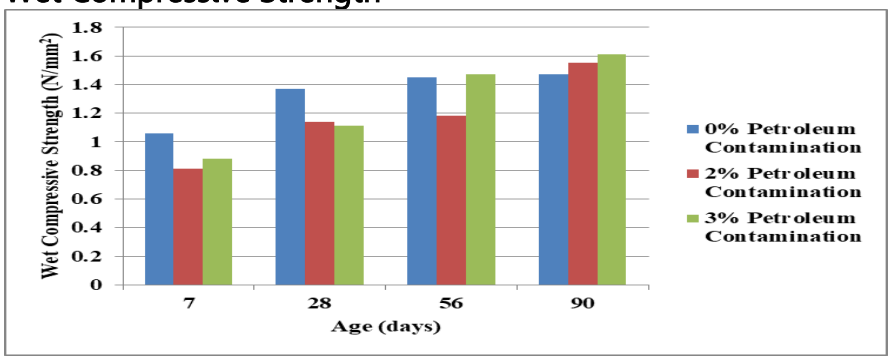


Fig 6: Wet compressive strength – age of curing relation for CSEBs

The value of 1.0N/mm2 specified by NBRRI (2006) and between the range of 0.2N/mm2 to 0.6N/mm2 also specified by National Building Code (NBC 2006) as the minimum 28 days wet compressive strength for cement stabilized bricks were satisfied by the 0% bricks (1.37N/mm2), 2% bricks (1.14N/mm2) and 3% bricks (1.11N/mm2) which were tested at 28 days. The graph showed that an increase in petroleum contamination lead to a significant increase in strength as the ages of the bricks increased. This was very much evident at 90 days when the average wet strength of the 2% bricks (1.55N/mm2) and 3% bricks (1.61N/mm2) surpassed that of the 0% bricks (1.47N/mm2).

From this, it can be deduced that the petroleum contamination hindered the ingress of moisture into the contaminated brick's matrix. This result agrees with the assertion of Onyelowe (2015) as well as with Al-Sanad et al. (1995) as quoted by Obeta et al. (2015) when they concluded from their studies that 4% petroleum contamination improved the engineering properties of soil. It also agrees with the conclusion drawn by Otunyo (2010) as cited by Obeta et al. (2015) that silty clay and sandy clay soils with petroleum contamination had higher California bearing ratio than those without petroleum contamination. The petroleum contaminants occupied available pore spaces in the brick's matrix which were not occupied by the cementing gels. For the 0% bricks, the absence of the contaminants made ingress of water into the brick's matrix easy thereby creating paths of weakness during crushing.

Abrasion

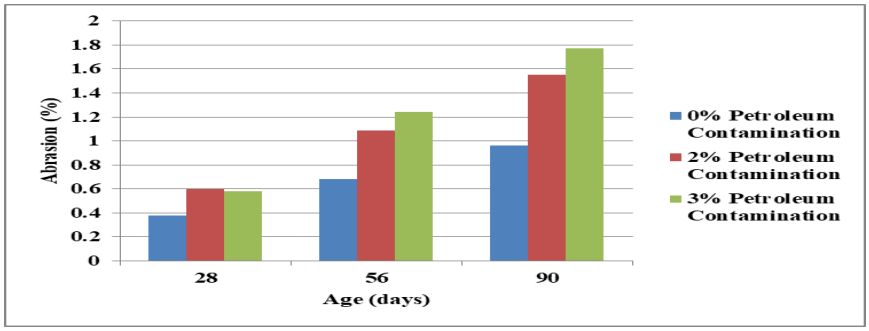


Fig 7: Abrasion – age of curing relation for CSEBs

The wearing off action was more prominent on the 2% bricks (28 days; 0.60%, 56 days; 1.09%, 90 days; 1.55%) and 3% bricks (28 days; 0.58%, 56 days; 1.24%, 90 days; 1.77%) than on the 0% bricks (28 days; 0.38%, 56 days; 0.68%, 90 days; 0.96%). The 3% bricks having the highest amount of contamination produced more wear

offs due to the influence of the petroleum contaminants in preventing the formation of some bonds between aggregates. The encapsulation of the aggregates by the petroleum contaminants lead to the cementing gels in the brick's matrix forming some weak bonds between the aggregates. Also, the electrostatic forces of attraction between the contaminants and the aggregates were not as strong as the forces that existed between the cementing gels and aggregates. As a result, the abrasive force applied were sufficient in dislodging those aggregates with weaker bonds attached to them as the bricks continued to age. The 0% bricks had the least wear off because it was difficult for the aggregates to be removed from the brick's matrix due to the absence of the petroleum contaminants which would have encapsulated the aggregates and weakened the bonds created.

Water absorption

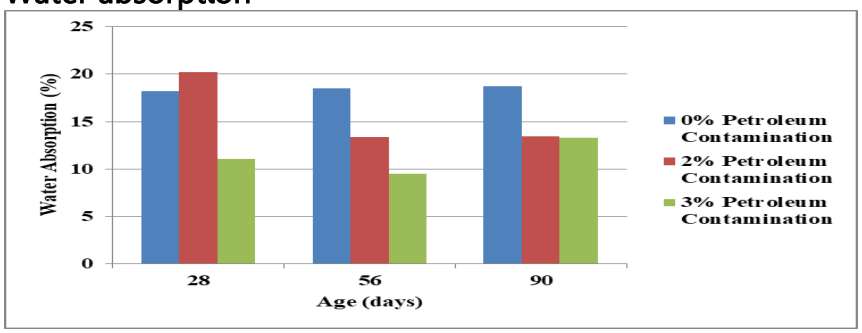


Fig 8: Water absorption – age of curing relation for CSEBs

The graph in fig 8 showed a very slow but steady increase in water absorption for the 0% bricks from 28 days (18.20%), 56 days (18.51%) to 90 days (18.72%) in that order. This probably could have been due to the high affinity of RHA for moisture. In the case of the 2% and 3% bricks, there was a drop in water absorption at 56 days (2%; 13.38%, 3%; 9.51%) from the initial average absorption values recorded at 28 days (2%; 20.23%, 3%; 11.07%) before a slight jump in average absorption was recorded at 90 days (2%; 13.46%, 3%; 13.31%). It was at this time that the water absorption of the bricks began to stabilize. The petroleum contamination sealed available air pores in the brick's matrix preventing the flow of moisture into the brick as was similarly observed during the wet compressive strength test. Also, as hydration slowed down due to the reduction in the amount of available cementing gels present in the pores, spaces not yet occupied by the gels were taken over by the contaminants which contributed immensely to the drop in water absorption.

Sorptivity

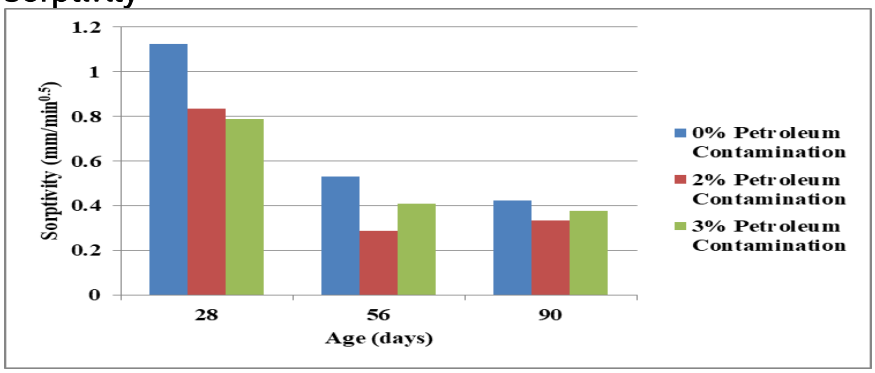


Fig 9: Sorptivity – age of curing relation for CSEBs

This test was conducted at intervals of 0, 2, 4, 8, 20, 30 and 60 minutes respectively for each brick at each allotted test day before computing the average sorptivity. At 28 days, the sorptivity test showed that 0% bricks had the highest average capillary absorption value of 1.124mm/min0.5 followed by the 2% bricks with a value of 0.835mm/min0.5 and the least being the 3% bricks with average capillary value of 0.790mm/min0.5.. The drop in capillary absorption continued all the way to 90 days for the 0% brick (0.423mm/min0.5) and 3% bricks (0.376mm/min0.5). However, there was a slight spike in capillary absorption for 2% bricks (0.335mm/min0.5) at 90 days from that recorded at 56 days (0.287mm/min0.5). Overall, all bricks recorded a considerable drop in capillary absorption despite the 0% bricks which recorded the highest average value on all test days. For the contaminated bricks, the presence of the petroleum contaminants made the ingress of water into the brick's matrix difficult.

Ultrasonic pulse velocity

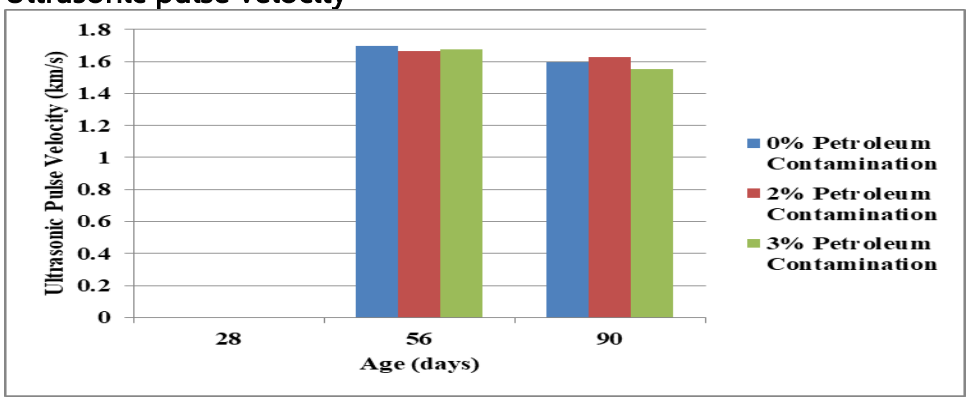


Fig 10: Ultrasonic pulse velocity – age of curing relation for CSEBs

No test was conducted at 28 days hence, the zero value seen on the graph. At day 56, average UPV values recorded for 0%, 2% and 3% bricks were 1.700km/s, 1.668km/s and 1.678km/s respectively. At 90 days, a slight drop in average UPV values for 0% (1.596km/s), 2% (1.627km/s) and 3% (1.553km/s) bricks were recorded. This test signified that the presence of the petroleum contamination did not have any significant effect on the UPV of the contaminated bricks (2% and 3%) when compared to the uncontaminated bricks (0%). The low values revealed the presence of an appreciable amount of air pores which might be present in the brick's matrix. This implies that a higher compaction pressure more than the pressure used in the production of the bricks (4N/mm2) would be necessary so as to have higher UPV values.

CONCLUSIONS

Laterite containing petroleum contaminant can be used in the production of CSEBs. Bricks made from petroleum contaminated laterite (2% and 3%) performed favourably and even surpassed the performance of the uncontaminated bricks (0%) especially during the water related tests. This shows that the petroleum contaminated bricks have the potential to perform optimally than the uncontaminated bricks in a moist environment such as the Niger Delta region of Nigeria where petroleum contaminated laterite is found. The dry compressive strength gains of the petroleum contaminated bricks were slow when compared with the uncontaminated bricks. However, the contaminated bricks were able to

achieve their ultimate 28 days strength but at a later day. Higher compaction pressures for the production of CSEBs with higher petroleum contamination therefore shows promising possibilities for petroleum contaminated laterite.

REFERENCES

AASHTO M145-91 (2003). Standard specification for classification of soils and soil-aggregate mixtures for highway construction purposes. American Association of State Highways and Transportation Officials. Washington D.C., U.S.A.

Abdullah, A., Nagapan, S., Antonyova, A., Rasiah, K., Yunus, R., & Sohu, S. (2017). Strength and absorption rate of compressed stabilized earth bricks (CSEBs) due to different mixture ratios and degree of compaction. MATEC Web of Conferences, no. 103, pp. 1-8

Adam, E. A. & Agib, A. R. A. (2001). Compressed stabilized earth block manufacture in Sudan. United Nations Educational, Scientific and Cultural Organization. 7 Place de Fontenoy, 75352 Paris 07 SP, France.

Adeoye, O., Olatokumbo, O., & Ademola, A. (2015). Effect of crude oil contamination on the index properties, strength and permeability of laterite soil. New York Science Journal. vol. 8, no. 10, pp. 82-86.

Akinwumi, I. I., Booth, C. A., Diwa, D., & Mills, P. (2016). Cement stabilization of crude oil contaminated soil. Proceedings of the ICE-Geotechnical Engineering, vol. 169, no. 4, pp. 336-345.

Al-Sanad, H. A., Eid., W. K., & Isamel, N. F. (1995). Geotechnical properties of oil contaminated Kuwaiti sand. Journal of Geotechnical Engineering, vol. 121, no. 5, pp. 407-412.

Aminu, G. W., & Ruhizal, R. (2013). Housing policies and programmes in Nigeria: A review of the concept and implementation. Business management dynamics, vol. 3, no. 2, pp. 60-68.

ASTM C 141: 05. Standard specification for hydraulic hydrated lime for structural purposes. American Society for Testing and Materials International, 100 Barr Harbour Drive, PO Box C700, West Conshohocken, PA, 19428-2959, USA.

ASTM C 593: 06. Standard specification for fly ash and other pozzolans for use with lime for soil stabilization. American Society for Testing and Materials International, 100 Barr Harbour Drive, PO Box C700, West Conshohocken, PA, 19428-2959, USA.

Ayininuola, G. M. (2009). Influence of diesel oil and bitumen on compressive strength of concrete. Journal of Civil Engineering (IEB), vol. 37, no. 1, pp. 65-71.

BS 12. (1996). Specification for Portland Cement. British Standard Institution, London, UK.

BS 1377: Part 2 (1990). Methods of tests for soils for civil engineering purposes. British Standard Institution, London, UK.

BS 1377: Part 4 (1990). Methods of test for soils for civil engineering purposes. Compaction - related tests. British Standard Institution, London, UK.

BS 3148. (1990). Standard for quality of mixing water. British Standard Institution, London, UK.

BS 812: Part 2 (1995). Testing aggregate. Methods for determination of bulk density. British Standard Institution, London, UK.

BS EN 12390: Part 3 (2009). Testing hardened concrete. Compressive strength of test specimens. British Standard Institution, London, UK.

Enaworu, E., Ugbe, F. C. & Rotimi, O. J. (2016). The geochemistry and geotechnical (compaction) analysis of laterite soils: A case study of Okpanam Area. AshEse Journal of Engineering. Vol. 2, no. 3, pp. 75-82.

Ezeldin, H. S., & Vaccari, D. A. (1996). Organic emissions from petroleum contaminated soil fixed in concrete. Journal of Soil Contamination, vol. 5, no. 1, pp. 35-52.

Guillaud, H., Joffroy, T., & Odul, P. (1985). Compressed Earth Block: Manual of Design and Construction, Volume II. A Publication of the Deutsches Zentrum fur Entwicklungstechnologien – GATE in: Deutsche Gesellschaft Fur Technische Zusammenarbeit (GTZ) GmbH in Coordination with BASIN.

Joshua, O., & Lawal, P. O. (2011). Cost Optimization of Sandcrete Blocks through Partial Replacement of Sand with Lateritic Soil. Epistemics in Science, Engineering and Technology, vol. 1, no. 3, pp. 89-94

Khalil, I. M. (2017). Performance based evaluation of cassava starch and makuba matrix for the stabilization of compressed earth brick. Unpublished Doctoral Thesis, Department of Building, Ahmadu Bello University.

Lemougna, P. N., Melo, U. F. C., Kamseu, E., & Tchamba, A. B. (2011). Laterite based stabilized products for sustainable building application in tropical countries: Review and prospects for the case of Cameroon. Sustainability. Vol. 3, pp. 293-305.

National Building Code. (NBC 2006). Building Regulations. Ohio : Lexis Nexis Butterworths.

Nigeria Building and Road Research Institute (NBRRI 2006). NBRRI interlocking block making machine. NBRRI Newsletter, vol. 1, no. 1, pp. 15–17.

Obeta, I, N., & Ohwoganohwo, J. (2015). Application of used engine oil in soil - cement stabilization. Nigerian Journal of Technology (NIJOTECH), vol. 34, no. 1, pp. 104-108.

Onyelowe, K. C. (2015). Pure crude oil contamination on Amaoba lateritic soil. EJGE, vol. 20, no. 3, pp. 1129-1142.

Otunyo, A. W. (2010). Reduction of the shear strength of soils in the NigerDelta area of Nigeria due to crudeoil production. Nigerian Journal of Technology, vol. 29, no. 2, pp.130-140.

Oyelami, C. A., & Van Rooy, J. L. (2016). A review of the use of lateritic soils in the construction/development of sustainable housing in Africa: A geological perspective. Journal of African Earth Sciences, vol. 119, pp. 1-12.

Patowary, B. N., Nath, N., Hussain, I., & Kakoti, H. J. (2015) Study of compressed stabilized earth block. International Journal of Scientific and Research Publication. Vol. 5, no. 6, pp. 1-4

Prakash, K., & Sridharan, A. (2004). Free swell ratio and clay mineralogy of fine-grained soils. Geotechnical Testing Journal, vol. 27, no. 2, pp. 220-225.

Prakash, K., Sridharan, A., Prasanna, H. S. & Manjunatha, K. (2009). Identification of soil clay mineralogy by free swell ratio method. IGC, Guntur, India. pp. 27-30.

Ramson, P. P. (2011). The effect of varying range of soil grain sizes on cassava starch stabilized compressed earth. Unpublished Bachelor of Science Project, Department of Building, Faculty of Environmental Design, Ahmadu Bello University, Zaria, Nigeria.

Rehman, H. U., Abduljauwad, S. N., & Akram, T. (2007). Geotechnical behaviour of oil-contaminated fine grained soils. Electronic Journal of Geotechnical Engineering (EJGE). Pp. 1-12.

Rossiter, D. G. (2004). Digital soil resource inventories: Status and prospects. Soil use and Management, vol. 20, no. 3, pp. 296-301.

Sackey, K. A. N., Garba, M. M., Mamman, M. & Adeleke, B. K. (2018). Assessing the flexural strength of stabilized poured laterite beams reinforced with three strand polypropylene rope. Environ. Journal of Environmental Studies, vol. 4, no. 6, pp. 13-23.

Sackey, K. A. N., Garba, M. M., Mamman, M. & Adeleke, B. K. (2019). Strength properties of cement stabilized poured laterite. SetJet. Journal of Environmental Technology, vol. 1, no. 1, pp. 29-36.

Sadeeq, J. A., Ochepo, J., Salahudeen, A. B., Tijjani, S. T. (2015). Effect of bagasse ash on lime stabilized laterite soil. Jordan Journal of Civil Engineering. vol. 9, no. 2, pp. 203-213.

Salahudeen, A. B., & Akije, I. (2014). Stabilization of highway expansive soils with high loss on ignitions content kiln dust. Nigerian Journal of Technology (NIJOTECH), vol. 33, no. 2, pp. 141-148.

Stulz, R., Mukerji, K., Ile, S. K. & Fur, A. T. (1993). Appropriate building materials: A catalogue of potential building solutions, SKAT, Intermediate Technology Publishing, Gallen (London).

Tremblay, H., Duchesne, J., Locat, J. & Leroveil, S. (2002). Influence of the nature of organic compounds on fine soil stabilization with cement. Canadian Geotechnical Journal, vol. 39, pp. 535-546.

Walker, R. & Pavia, S. (2011). Physical properties and reactivity of pozzolans and their influence on the properties of lime-pozzolans paste. Materials and Structures. Vol. 44, pp. 1139-1150.