Suitability of Termite Clay Powder as a Partial Replacement of Cement in the Production of Lateritic Soil–Cement Brick

Abstract

An investigation was conducted to explore the possibility of partial replacement of cement with termite clay powder (TCP) in stabilizing lateritic soil-cement bricks. This was achieved through some set of objectives which include determination of chemical composition and physical properties of TCP, optimum percentage replacement of cement with TCP, compressive strength and durability test of lateritic soil-cement/TCP brick. Atomic Absorption Spectrophotometric method was used to determine the chemical composition of the powder including loss on ignition. Brick samples were produced using twin compressed earth machine and replacement levels of 0, 10, 20, 30 and 40% of cement with TCP were used with mix proportions of 1:12 and 1:18.All the brick samples were cured in water and tested for 7, 14, 21, and 28 days using compressive strength testing machine. The results obtained, however, were compared with relevant standards of compressed earth bricks. The test revealed a maximum compressive strength of 2.59 N/mm^2 and 2.09 N/mm^2 at 28 days with 10% replacement of cement with TCP for mix ratios of 1:12 and 1:18 respectively. Abrasion and moisture penetration tests were conducted on lateritic soil-cement/TCP brick samples to determine durability which showed greater resistance to mechanical erosion using wire brush at lower replacement of cement with TCP and exhibited poor resistance to moisture penetration at all levels of replacement. Considering all clay bricks made with 10% replacement level using 1:12 mix ratio with maximum compressive strength can be recommended for use in non-load bearing walls as indoor structure.

Keywords: Clay brick, durability, lateritic soil, strength, termite clay powder.

1. Introduction

The present day construction industry is under tremendous compulsion of researching and producing strong, but also durable building materials to accommodate the increasing need for shelter, devastating forces of construction and fast polluting environment (Abubakar et al., 2010). The problems besetting construction industry observed by Hashim (1992) are numerous: these include scarcity and cost of construction materials, high demand for housing, lack of promotion of the use of locally available materials.

Cement is one of the most popular conventional material for most construction works, thus, any change in its price portends significant effect on the total cost of construction. In order to reduce over dependence on conventional building materials, especially cement and also addressing the problem of 7% CO_2 emission to atmosphere (Rashid 2010), researches have been intensified on alternative materials that can be used to replace cement partially or wholly for construction purposes (Dashan and Kamang, 1991; Okoli and Zubairu, 2002; Adam and Agib, 2003). The prominent material of construction in many African countries is the laterite, and often contain some reasonable amount of clay minerals that can affect it strength and stability, hence the need for its improvement. The use of lateritic bricks (soil-cement bricks) for housing purposes has been very popular especially in the rural areas as well as in some urban centers (Abejide and Abubakar, 2002). Consequently, research efforts are now being focus on lateritic soil-cement bricks in order to improve its qualities for various construction purposes. Additives such as cement, lime, bitumen and pozzolans have been suitably tested for this purpose and encouraging results were obtained. Several other materials have also been identified to possess potentials of been used to improve the quality of lateritic bricks; prominent among them are rice husk ash, *acha* husk ash, carbide waste, timber saw dust and termite clay.

Termite clay is obtained from termite mound, while mound is a pile of earth made by termite resembling a small hill. It is made of clay whose plasticity has further been improved by the secretion from the termite while being used in building the mound (Mijinyewa et al., 2007). It is therefore a better material than the ordinary clay in terms of utilization for moulding lateritic bricks (Odumodu 1999, Mijinyewa et al., 2007) and this type of clay has been reported to perform better than ordinary clay in dam construction (Yohanna et al., 2003). The clay from the termite mound is capable of maintaining a permanent shape after moulding because of its plasticity; it is also less prone to crack when compared with ordinary clay. In addition, it has low thermal conductivity and expectedly reduced solar heat flow and temperature fluctuation within an enclosure (Mijinyewa et al., 2007).

However, there are few reports on the use of termite mound as a construction material in Nigeria where they exist in abundance and presently serve no economic benefit but if its potentials are properly tapped, it will help reduce pressure on cement, conserve the country foreign reserve and above all it will cut-down construction cost thereby making housing to be affordable to most people. TCP as an alternative building material, if properly developed, will also add advantage in promoting environmental sustainability by checking the growing problem of termite mound in the country. This study is therefore aimed at exploring the possibilities of substituting some quantity of cement with termite clay in powder form in the production of lateritic soil-cement bricks, with a view to obtaining strong and durable building material at a relatively cheaper price.

2. Experimental

2.1 Physical and Chemical Tests

Physical properties test of TCP was conducted in accordance with BS: 4550: part 3: 1978, while laterite was tested in accordance with BS 812 part 2 1975. Chemical test was carried out on the TCP using Atomic Absorption Spectrophotometric (AAS) method in other to determine its chemical composition as well as assessing its ASTM C618 requirements for its suitability as replacement material to cement in the production of laterite soil-cement bricks.

2.2 Production of Brick Specimen

The component materials comprising laterite, cement and TCP were measured and mixed thoroughly in the desired mix proportion of 1:12 and 1:18. These mix ratios were obtained from the trail tests where higher and lower strength values of 2.47N/mm^2 and 1.77N/mm^2 were obtained from the mix ratios at 28 days hydration respectively. Absolute volume method of calculation was used to determine the quantities of materials for the two mix ratios. Tables 1 and 2 shows the quantities of materials required for each mix ratio used for production of test specimens.

Table 1: Brick Making Materials for Mix Ratio 1:12

Replacement levels (%)	*Laterite (kg)*	*Water Required (kg)*	*Water used (kg)*	*Cement (kg)*	*TCP (kg)*
0	*72.65*	*4.13*	*6.20*	*4.72*	*0,00*
10			*6.60*	*4.25*	*0.47*
20			*6.60*	*3.78*	*0.94*
30			*6.75*	*3.30*	*1.42*
40			*6.80*	*2.83*	*1.89*

Table 2: Brick Making Material for Mix Ratio 1:18

Replacement levels (%)	*Laterite (kg)*	*Water Required (kg)*	*Water used (kg)*	*Cement (kg)*	*TCP (kg)*
0	*109*	*4.13*	*7.90*	*4.72*	*0.00*
10			*7.90*	*4.25*	*0.47*
20			*8.20*	*3.78*	*0.94*
30			*8.20*	*3.30*	*1.42*
40			*8.30*	*2.83*	*1.89*

Replacement levels of 0, 10, 20, 30 and 40% of TCP with cement were used in stabilizing the laterite sample. Twin brick pressing machine of brick size 100 mm x110 mm x 230 mm was used for the production of brick specimen. A Total of 180 bricks were produced for the two mix ratios for the purpose of the research. Samples were cured and tested at 7, 14, 21 and 28 days hydration periods. Four bricks were tested for each hydration period and for each replacement levels for different mix ratios using compressive strength testing machine.

2.3 Durability Tests on Cement/ TCP Stabilized Brick

Durability tests were carried out on the Cement/TCP brick samples in order to further determine their suitability as construction material. Abrasive strength test using wire brush and moisture penetration test using Capillary Absorption Method was used as described by African Regional Standard for Compressed Earth Bricks (2000).

3. Results and Discussion

3.1 Physical and Chemical Properties of Termite Clay Powder & Laterite

The physical properties of termite clay powder (TCP) and laterite are presented in Table 3. It can be seen that the moisture content of 15% in the TCP corresponding to maximum dry density of 1.70 kg/m^3 is within the minimum value specified by NBRRI (Nigerian Building and Road Research Institute) of 12%, but the maximum dry density was lower than 1.78 kg/m^3 as obtained by Olaoye and Anigbogu (2000). The specific gravity of 2.47 was obtained on TCP sample, though this was higher than 1.42 an observed by the same authors, and lower than 3.15 for that of cement. The plasticity index of TCP was, however, found to be 10%, which indicates that TCP has low plasticity (< 35%) according to BS: 1377 (1975).

While field observation reveals the colour of the laterite sample to be Reddish-Brown, which means that the sample contain excess of iron and aluminum during lateralization (Osinubi and katte, 1997). The result of particle size distribution on laterite sample revealed 52% of the particle to fall within the medium sand region, while silt and coarse particles were in the region of 24% each. According to Okoli and Zubairu (2002) an optimum grading is the one in which the proportion of large and small grains are well balanced leaving no gap and having sufficient clay fraction to facilitate cohesion. Thus, the sample of laterite used can conveniently be classified as uniform or well graded with particles ranging between 2.0mm - 63μm as suggested by Smith (1994).

Table 3: Physical Properties of Termite Clay Powder (TCP) and Laterite

Properties	*TCP*	*Laterite*
Moisture content (%)	*15*	*19*
Liquid limit (%)	*30*	*26*
Plastic limit (%)	*20*	*9*
Plasticity index (%)	*10*	*17*
Fineness modulus	*1.66*	*-*
Specific gravity	*2.47*	*2.56*
Maximum dry density (kg/m³)	*1.7*	*1.60*
Colour	*Reddish-brown*	*Reddish-brown*

The plasticity index of laterite was found to be 17%, indicating that the laterites samples can be described as having low plasticity (<35%) according to BS: 1377 (1975). This indicates that the laterite sample has good cohesion and hence can be able to receive proper compaction to enhance strength and durability characteristics .The laterite has a maximum dry density of 1.60 kg/m^3, though this was found to be lower than 1.75 kg/m^3 but higher specific gravity of 2.56 was obtained on laterite sample when compared with 2.40 (Osinubi, 1995). Both values however, were within the range specified for lateritic materials.

Table 4 summarises the chemical composition of termite clay powder. The result shows the combined percentage of SiO_2, Al_2O_3 and Fe_2O_3 to be 86.34%, which satisfies the ASTM requirement of pozzolanic materials of minimum of 70%. MgO composition was found to be 2.65% which is less than 4% maximum requirement, while CaO and SO_3 composition are 4.06% and 1.80% respectively and are within the recommended range of ASTM C6I8-78. The loss on ignition showed the extent of carbonation in sample of TCP during the test, the value obtained was 5.10% which is less than 7% maximum required for pozzolan. It means that most of the sample where absorbed by the system and the sample contains very little carbon. Although the value obtained was higher when compared with value of 3.3% obtained by Dashan and Kamang (1999) for RHA/OPC concrete and was equally lower than 43.57% obtained by Al-Khalaf and Yousif (1984) for RHA concrete and as such the pozzolan (TCP) is more effective compared to those obtained in RHA/OPC and RHA concrete.

Table 4: Chemical Composition of Termite Clay Powder (TCP)

Properties	*Quantities (%)*
CaO	*4.06*
SiO_2	*52.02*
Al_2O_3	*27.72*
Fe_2O_3	*6.60*
MgO	*2.65*
SO_3	*1.80*
Loss on Ignition	*5.10*

The setting time of cement/TCP paste for various replacement levels are illustrated in Table 5. Results presented in Table 5 showed a prolonged setting time with increase in TCP content in the paste. The initial setting time of the cement paste was 1 hour 43 minutes, while the final setting time was 2 hours 15 minutes. The initial and final setting times of the paste at certain replacement level of cement with TCP were found to be longer than that of cement paste alone. But the time was found to be in compliance with BS 4550: Part 3 (1978) and ASTM C451-89 stipulation.

Table 5: Initial and Final Setting Time of Cement / TCP Paste

Replacement Level (%)	*Cement Quantity (gm)*	*TCP Quantity (gm)*	*Initial setting time (min)*	*Final Setting time (min)*
0	*400*	*0*	*103*	*135*
10	*360*	*40*	*110*	*147*
20	*320*	*80*	*120*	*150*
30	*280*	*120*	*128*	*150*
40	*240*	*160*	*140*	*168*

Table 6 shows the results of soundness test on cement / TCP paste. No change in volume was observed at 0% and 10% replacement of cement with TCP. But as the percentage of replacement increased, a gradual increase in volume of the test specimen was recorded. The highest expansion of 1.10mm was recorded at 40% replacement level, and this value is less than the maximum value of 10mm as stipulated in BS 4550: Part 3 (1978).

Table 6: Soundness Test of Cement / TCP Paste

Replacement Level (%)	*Initial circumference (mm)*	*Final circumference (mm)*	*Expansion (mm)*
0	*28.5*	*28.5*	*0*
	29.0	*29.0*	*0*
10	*28.9*	*28.9*	*0*
	31.5	*31.5*	*0*
20	*29.0*	*29.3*	*0.3*
	27.3	*27.3*	*0.3*
30	*27.3*	*27.9*	*0.6*
	28.3	*28.9*	*0.6*
40	*28.6*	*29.0*	*1.0*
	28.0	*29.1*	*1.1*

3.2 Compressive Strength of Cement/TCP Brick

The development of compressive strength of cement/TCP bricks test for both mixes (1:12 and 1:18) is shown Figure 1 and 2. The results generally showed an increase in compressive strength with an increase in hydration period for all samples, whereas an increase in strength was observed at certain percentage replacement of cement with TCP in both mix ratios. The analysis of result illustrated in Figure 1 and 2 showed that bricks made with the mix ratio of 1:12 developed higher strength at all levels of replacement, and all the samples of 1:12 mix ratio developed 65% of their 28 days strength in 7 days.

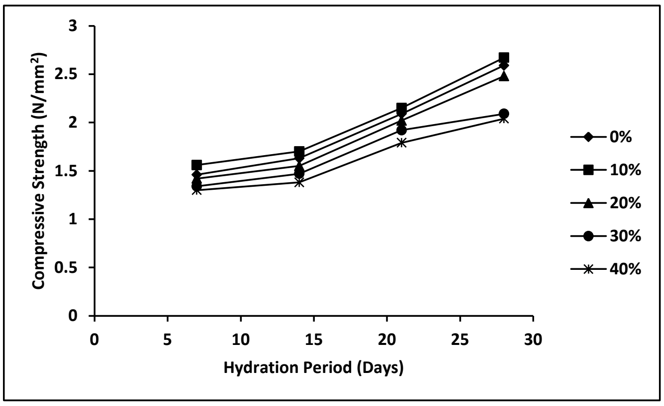

Figure 1: Compressive Strength of Cement/TCP Bricks, ratio 1:12

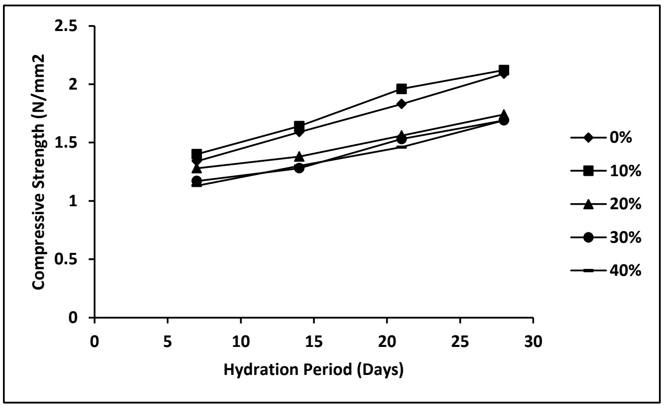

Figure 2: Compressive Strength of Cement/TCP Bricks, ratio 1:18

However, the samples of 1:18 mix ratios developed about 60% of their 28 days strength in 7 days. This means the cement/TCP bricks developed most part of their 28 days compressive strength at an early stage. Considering the level of replacement level, the 10% replacement of TCP with cement in both mix ratios exhibited the best performance. This suggests that the compressive strength of lateritic soil-cement bricks stabilized with 10% TCP develops higher strength when compared with that of conventional cement stabilized bricks.

3.3 Durability of Cement/TCP Brick

The durability of cement/TCP brick was measured using Abrasive Coefficient and Capillary Absorption Test, the results of which are presented in Figure 3 and 4 respectively.

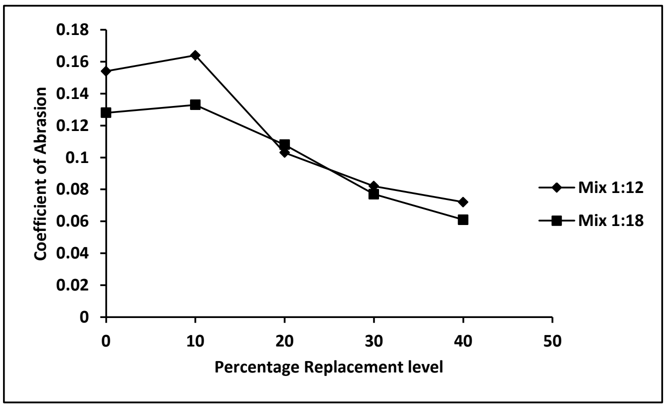

Figure 3: Abrasion Coefficient of Bricks

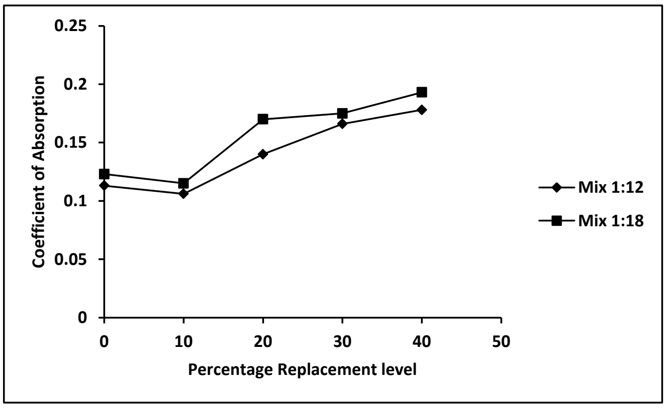

Figure 4: Water Absorption Coefficient of Bricks

The results on abrasion test showed cement / TCP bricks to have comparable durability of the cement laterite bricks. From abrasion coefficient graph for the two mix ratios, it was observed that the resistance of the bricks was higher at 10% replacement of cement with TCP when compared to that with 0% replacement. However, as the replacement level increased the resistance of the bricks to wear reduced significantly.

The capillary absorption test data, illustrated in Figure 4, reveals that the coefficient of absorption of TCP brick, generally increased with the increase in the amount of replacement level. Like that in compressive strength the 1:12 mix, however, performed better than 1:18 mix. Interestingly, bricks made with 10% replacement level in both the mixes appeared to achieve the best performance although the difference of the absorption values for 0% and 10% was found to be very small.

4.0 Conclusion

From the research findings it can be concluded that termite clay powder (TCP) can be used as partial replacement of cement in stabilization of lateritic soils for the production of lateritic soil-cement bricks. The most suitable replacement level of cement with TCP was found to be 10%. Brick samples produced using mix ratio of 1:12 developed relatively higher compressive strength than those produced with 1:18 for all replacement levels which can, therefore, be recommended for use in the construction of non-load bearing walls in indoor structures.

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