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Evaluation of the Compressive Strength of Lateritic Bricks, Produced with Termite Clay Powder as Partial Replacement of Cement: A Case Study of Bekwarra, Cross-River State

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Abstract
The use of termite clay powder as a partial replacement for cement in the production of laterite bricks is a promising approach to reducing the cost and environmental impact of building materials production, particularly cement in Nigeria. The study used different proportions of termite clay powder as a partial replacement for cement in the production of laterite bricks. The bricks were tested for compressive strength in accordance with standard methods. Results from the test revealed the compressive strength of laterite bricks produced with termite clay powder as a partial replacement for cement varied depending on the proportion of termite clay powder used, with replacement levels of 0%, 10%, 20%, 30%, 40% and 50%. The compressive strength of the bricks increased as the proportion of termite clay powder increased up to a certain point. Beyond that point, the compressive strength decreased. The compressive strength of the bricks after a 7days hydration period was found to be of value 0.68N/mm^2 with a 28days value of 2.81N/mm^2, corresponding to a 0% cement replacement level, which is a level free from termite clay powder. The optimum compressive strength of the bricks with proportions of termite clay powder was found to be of value 2.51N/mm^2 for a 28days hydration period, corresponding to a 10% cement replacement level. Therefore, it was affirmed that the suitable replacement level of cement with termite clay powder for the laterite brick production be kept at 10%, as further increase in termite clay powder content decreased the strength of the laterite bricks.

Keywords: Compressive Strength, Cement, Laterite Bricks, Termite Clay Powder, Partial Replacement

1. Introduction

The major Engineering construction material employed worldwide in construction activities is essentially the ordinary Portland cement. Ordinary Portland cement is a binder that has proven to be a very useful and reliable material in construction works for a long while. Consequent upon this, its price has had a very significant effect on the total cost of construction. In Nigeria, the price of cement is seen to readily increase due to somewhat monopoly in the cement industry. This need not be allowed to go on unabated, more so for the obvious fact that comfortable and affordable accommodation has been a huge challenge for the ever-increasing population of the country, Nigeria. It would be a good development to make efforts at seeing that this situation is arrested, and building cost, brought within the reach of the common man. In doing this, researches have been intensified on alternative building materials that can be used to replace cement partially or wholly for construction purposes [1].

Aside cement, laterite is also a predominant material used in building construction over time in most African countries. Laterite bricks are commonly used in Nigeria for building construction. The production of laterite bricks involves the use of cement as a binding material. The use of cement, however, has been associated with environmental issues such as carbon dioxide emissions and the depletion of natural resources. To address these issues, there has been a growing interest in the use of alternative materials for cement in the production of laterite bricks. One such material is termite clay powder, which has been found to possess cementitious properties. In this work, the compressive strength of laterite bricks produced with termite clay powder as a partial replacement for cement was examined. This is aimed at obtaining bricks of reliable strength, stability and durability that could be used in the construction of buildings that would be affordable to a greater percentage of the Nigerian people.

Termite clay powder is a by-product of termite activity. Termites are known to produce soil aggregates that are rich in clay minerals. These aggregates have been found to possess cementitious properties, making them a potential alternative to cement in the production of laterite bricks. The use of termite clay powder as a partial replacement for cement has been studied in several countries, including Nigeria.

More so, studies have shown that termite clay powder is a waste material that is readily available in Nigeria and has been shown to have pozzolanic properties and can be employed as a partial replacement for cement to improve the compressive strength of laterite bricks [4].

An investigation on the assessment of termite clay powder as a partial replacement for cement in laterite bricks produced in Idah, Kogi state, Nigeria was conducted. The study used four different mix ratios of laterite soil and termite clay powder, with cement content ranging from 0% to 40%. The compressive strength of the bricks was determined at 7, 14, 21 and 28 days. The results showed that the compressive strength of the bricks increased with increasing cement and termite clay powder content. The highest compressive strength of 2.20 N/mm2 was obtained for a 10% cement replacement [4].

A study carried out on experimental investigation of the compressive strength of laterite bricks produced with termite clay as partial replacement for cement concluded that the compressive strength of laterite bricks increased by up to 48% when 10% termite clay powder was used as a partial replacement for cement. Similarly, another study conducted on the evaluation of the strength properties of laterite bricks produced with termite hill soil found that the compressive strength of laterite bricks increased by up to 27% when 5% termite clay powder was used as a partial replacement for cement [6] and [7].

1.1 Justification of the Study

Cement, one of the basic materials used in construction of buildings has far gone beyond the reach of the common man, due to its high and ever-increasing cost. More so, being the main binder in the production of the most frequently used Sand-Crete blocks required in construction of buildings, its use is indispensable. This has been responsible for the severe shortfall in the availability of befitting accommodation for the increasing population of the Nigerian citizenry. It is hoped that this could be abated by resorting to the use of bricks, as well as an achievement of further cost reduction by partially replacing the quantity of cement used in production of these lateritic bricks with termite clay powder.

1.2 Study Objectives

1. To examine the effect of Termite Clay Powder on the strength of lateritic soil bricks.
2. To examine the effect of cement on the strength of lateritic soil bricks.
3. To investigate the possibility of using Termite Clay Powder in partially replacing the cement content of the materials used in the production of lateritic soil bricks.
4. To justify the effect of the use of Termite Clay Powder in brick production on the cost of brick building.

2. Methodology

Samples of lateritic soil materials were collected from Bekwarra local Government Area of Cross River State. Termite clay materials were also collected from anthills located within the same area and further transported to the laboratory in Cross-River State University of Technology. The clay materials were air dried for 24 hours before processing. The bigger lumps were crushed and broken down into smaller particle sizes. The Termite clay materials were further sieved and grinded into finer particles. Considering the number of experiments that were required to be carried out, a total of 200 bricks were moulded after clay has been mixed with water, tempered and thoroughly worked into a plastic state.

2.1 Soil Classification Procedures

The lateritic soil and the TCP which are clearly distinct materials were subjected to laboratory testing procedures to establish various index properties of the materials and also classify them based on the notable systems of soil classification. Hence, tests such as the Natural Moisture Content Test, Specific Gravity Test, Atterberg Limit test and Particle Size Distribution Test were carried out on the materials in accordance with empirical methods as stipulated in the British Standard of Testing Civil Engineering Materials, BS 1377 [2]. The results generated from conducting these tests, further enabled for the classification of the lateritic soil and the TCP. The American Association of State Highway and Transport Officials (AASHTO) classification system as well as the Unified Soil Classification System (USCS) were both employed to delineate the materials into different soil groups based on its characteristics. The summary of the test results is outlined in Table 1.

Table 1: Properties of the Lateritic Soil and Termite Clay Powder

S. No	Properties	Results	
		Lateritic soil	**TCP**
1	Colour	Reddish Brown	Darkish Brown
2	% Passing N0 200 Sieve	36	35.8
3	Liquid limit (%)	28	24
4	Plastic limit (%)	9	11.1
5	Plasticity index (%)	19	12.9
6	Linear shrinkage (%)	8	9
7	Specific gravity	2.7	2.4
8	AASHTO Classification	A-2-6	A-2-6
9	Unified Soil Classification	SC (Clayey Sand)	SC (Clayey Sand)

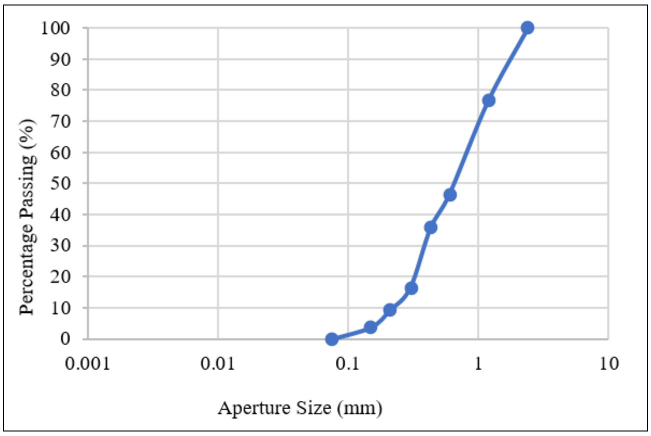

Fig 1: Particle Size Distribution Curve of TCP

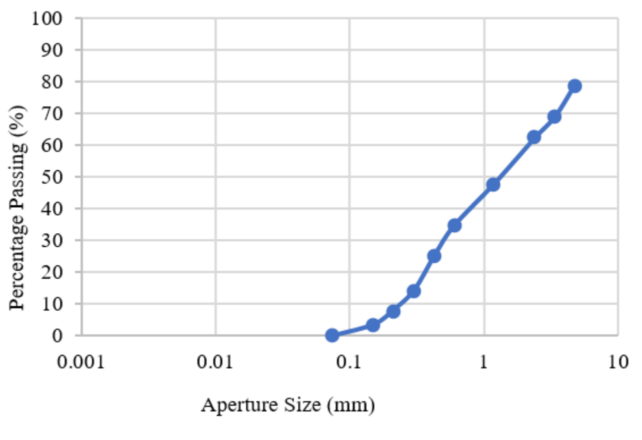

Fig 2: Particle Size Distribution Curve of the Laterite

2.2 Batching and Brick Moulding Procedures

The materials involved in the mix includes; lateritic soil, termite clay powder, cement and water. Absolute weight method of calculation produced the quantities of material for the mix ratio. The bricks were moulded with mix ratio of 1:12, having various percentage replacement of cement ranging from 0-50% at 10% intervals. A total of 48 bricks were produced from the mix at the above stated replacement levels having 2 bricks from each of the hydration period of 7, 14, 21 and 28 days. The quantity of the mix constituents, outlining the various weights of individual constituents are presented in Table 2.

2.3 Compressive Strength Test on the Lateritic Bricks

Compressive strength is an important factor in determining the quality of bricks. In Nigeria, the minimum compressive strength required for laterite bricks is 1.75 N/mm2 [12]. The compressive strength of laterite bricks is readily influenced by various factors, such as the quality of the laterite soil, the proportion of additives used, and the method of production.

Sequel to the moulding and production of the bricks, the bricks were fired, cured and subjected to strength test using the compressive strength testing machine. Again, the compressive strength test is basically an empirical procedure undertaken to ascertain the strength of a solid mass. It involves subjecting the brick sample to a compressive force or a crushing intensity. The strength test of the bricks was conducted after each hydration period.

The crushing affords a basis for comparing the quality of bricks relative to the induced stress. Samples were placed in the compression testing machine, positioned between the stationary and movable plates of the machine. The load was applied at a uniform rate till failure. The failure load which is displayed on a gauge, was recorded. The ratio of the average load to the cross-sectional area gave the compressive strength. Mathematically, it is given as;

$$\text{Compressive Strength} = \frac{Average\ Load}{Cross-sectonal\ Area}$$

Furthermore, after obtaining the compressive strength of the bricks, a graph of compressive strength plotted against each hydration period (number of days) was obtained for each cement replacement levels. The graph displays a variation in strength of the bricks relative to the hydration period. Hence, the strength of the bricks is correlated with the hydration period, with longer hydration period producing higher strength bricks. The compressive strength test was carried out in accordance with BS 1377 [2].

Table 2: Mix Quantities for Bricks Production

Replacement Levels (%)	Laterite (kg)	Water required (kg)	Water used (kg)	Cement (kg)	TCP (kg)
0	24.0	0.60	0.60	2.00	0.00
10	24.0	0.60	0.54	1.80	0.20
20	24.0	0.60	0.48	1.60	0.40
30	24.0	0.60	0.42	1.40	0.60
40	24.0	0.60	0.36	1.20	0.80
50	24.0	0.60	0.30	1.00	1.00

3. Results and Discussion

The study considers the use of TCP in partial replacement of cement for the production of laterite bricks. The produced bricks having being subjected to compressive strength test gave a higher strength value of 2.43N/mm2 for 28days hydration period relative to a 0% cement replacement level, while a 50% cement replacement level for a 28day hydration period gave the lowest strength value of 1.80N/mm2.

Also, from the table below it is seen that the compressive strength of the lateritic bricks declines upon increase in the percentage replacement of cement. In view of the fact that the experiment is carried out on the investigation of partial replacement of cement with TCP, it is obvious that the result obtained from 50% replacement level is far from acceptable. It is therefore preferred that the optimum compressive strength obtainable from any of the other levels of replacement be considered.

Table 3: 0% Replacement Level

Hydration period (days)	Brick number	Weight of brick (g)	Dial reading (N)	Area of bricks (mm^2)	Volume of brick mould (cm^3)	Density (g/cm^3)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
7	1	11200	30000	47250	6142.5	1.82	0.63	0.68
	2	11800	34000	47250	6142.5	1.92	0.72	
14	1	10600	100000	47250	6142.5	1.73	2.11	2.16
	2	10800	104000	47250	6142.5	1.76	2.20	
21	1	11000	108000	47250	6142.5	1.79	2.29	2.27
	2	11000	106000	47250	6142.5	1.79	2.24	
28	1	11400	135000	47250	6142.5	1.86	2.86	2.81
	2	11000	130000	47250	6142.5	1.79	2.75	

Table 4: 10% Replacement Level

Hydration period (days)	Brick number	Weight of brick (g)	Dial reading (N)	Area of bricks (mm^2)	Volume of brick mould (cm^3)	Density (g/cm^3)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
7	1	10800	30000	47250	6142.5	1.76	0.63	0.66
	2	11000	32000	47250	6142.5	1.79	0.68	
14	1	11000	98000	47250	6142.5	1.79	2.07	2.07
	2	11200	98000	47250	6142.5	1.82	2.07	
21	1	10800	100000	47250	6142.5	1.76	2.11	2.14
	2	11000	102000	47250	6142.5	1.79	2.16	
28	1	11000	118000	47250	6142.5	1.79	2.50	2.51
	2	11000	119000	47250	6142.5	1.79	2.51	

Table 5: 20% Replacement Level

Hydration period (days)	Brick number	Weight of brick (g)	Dial reading (N)	Area of bricks (mm^2)	Volume of brick mould (cm^3)	Density (g/cm^3)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
7	1	10800	26000	47250	6142.5	1.76	0.56	0.57
	2	11000	28000	47250	6142.5	1.79	0.59	
14	1	11400	94000	47250	6142.5	1.86	1.99	2.01
	2	11000	96000	47250	6142.5	1.79	2.03	
21	1	11000	100000	47250	6142.5	1.79	2.11	2.07
	2	10800	96000	47250	6142.5	1.76	2.03	
28	1	11200	98000	47250	6142.5	1.82	2.07	2.12
	2	11000	102000	47250	6142.5	1.79	2.16	

Table 6: 30% Replacement Level

Hydration period (days)	Brick number	Weight of brick (g)	Dial reading (N)	Area of bricks (mm^2)	Volume of brick mould (cm^3)	Density (g/cm^3)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
7	1	11000	25000	47250	6142.5	1.99	0.58	0.54
	2	11800	23000	47250	6142.5	1.76	0.49	
14	1	11000	90000	47250	6142.5	1.79	1.90	1.93
	2	10800	92000	47250	6142.5	1.76	1.95	
21	1	10600	92000	47250	6142.5	1.73	1.95	2.00
	2	11000	96000	47250	6142.5	1.79	2.03	
28	1	11000	96000	47250	6142.5	1.79	2.03	2.05
	2	10800	98000	47250	6142.5	1.76	2.07	

Table 7: 40% Replacement Level

Hydration period (days)	Brick number	Weight of brick (g)	Dial reading (N)	Area of bricks (mm^2)	Volume of brick mould (cm^3)	Density (g/cm^3)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
7	1	11000	22000	47250	6142.5	1.79	0.47	0.45
	2	11800	20000	47250	6142.5	1.76	0.42	
14	1	11000	86000	47250	6142.5	1.79	1.82	1.84
	2	11200	88000	47250	6142.5	1.82	1.86	
21	1	10600	90000	47250	6142.5	1.73	1.90	1.90
	2	11400	90000	47250	6142.5	1.86	1.90	
28	1	10800	92000	47250	6142.5	1.76	1.95	1.99
	2	10600	96000	47250	6142.5	1.73	2.03	

Table 8: 50% Replacement Level

Hydration period (days)	Brick number	Weight of brick (g)	Dial reading (N)	Area of bricks (mm^2)	Volume of brick mould (cm^3)	Density (g/cm^3)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
7	1	10800	18000	47250	6142.5	1.76	0.38	0.40
	2	11400	20000	47250	6142.5	1.86	0.42	
14	1	11000	70000	47250	6142.5	1.79	1.48	1.57
	2	10800	78000	47250	6142.5	1.76	1.65	
21	1	10600	84000	47250	6142.5	1.73	1.78	1.74
	2	10400	80000	47250	6142.5	1.69	1.69	
28	1	10800	86000	47250	6142.5	1.76	1.82	1.80
	2	11000	84000	47250	6142.5	1.79	1.78	

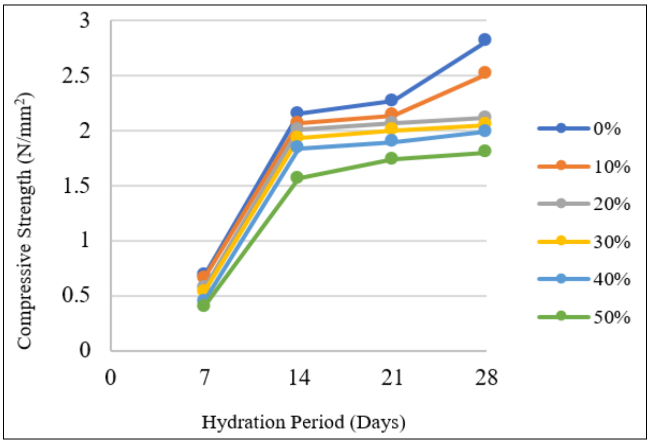

Fig 3: Compressive Strength Graph at Different Cement

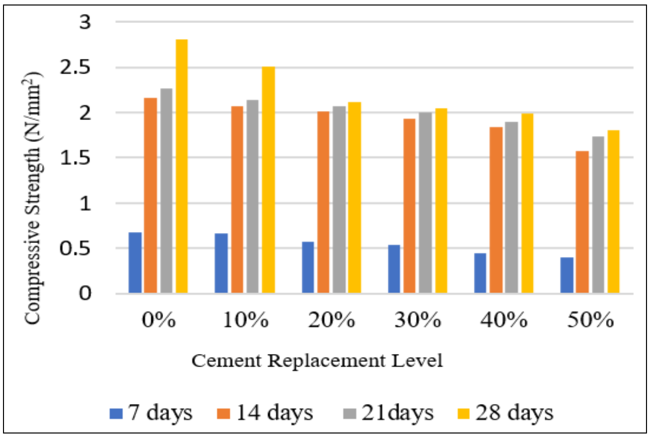

Fig 4: Variation in Compressive Strength of the Bricks Replacement Levels

4. Conclusion

The effect of TCP as partial replacement of cement in the production of laterite soil cement bricks has been investigated. The compressive strength test of different levels of replacing cement with TCP, for 7, 14, 21 and 28 days hydration period was carried out on the bricks pressed out of a Hydrafoam machine. The following conclusionss were drawn based on the results:

1. The TCP can be used as partial replacement of cement with a minimal replacement level in the production of laterite soil cement bricks.
2. The TCP is a pozzolona, as it possesses cementitious properties.
3. The compressive strength of 10% replacement of cement with TCP produced an optimum strength of 2.51N/mm2 after 28 days curing.
4. The 10% replacement is the most suitable replacement level.
5. Generally, it was confirmed that the higher the curing age, the better the strength of the bricks pressed with the materials in all the replacement levels, as the 28 days curing produced the highest strength in each of the levels.

Table 9: Nomenclature

AASHTO	American Association of State Highway and Transport Officials
BS	British Standards
TCP	Termite Clay Powder
USCS	Unified Soil Classification System

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