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Suitability Of Solar Kilned Latcrete As Partialis Extra For Block Making And Concrete Construction

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Abstract

The results of compressive strengths tests and other relevant properties of concrete obtained from laterite as replacement for sand are reported. Five replacement percentage mixtures of 20, 40, 60, 80 and 100% were considered. Concrete cubes without laterite were also produced as control. The results of the tests carried out showed that the compressive strength of laterite concrete (latcrete) increased with curing age but decreased with increase in the replacement level of sand by laterite. At 90 days all cubes with the exception of those with 80 and 100% replacement levels of sand by laterite attained the 28 days designed strength of 20N/mm^2. The rate of water absorption of laterite also decreased with increase in the replacement levels of sand by laterite, which could be attributed to the filling up of the concrete pores by the laterite fines.

1. **Introduction** Dwelling unit forms a vital requirement of man in fostering good and adequate economic and social wellbeing of the populace. Due to high cost of conventional building materials, majority of people are unable to afford comfortable place of living, hence there seem to be the trend of growing homelessness in many urban areas.

Since shelter ranks second to food in the hierarchy of human needs, this has boosted the urge to investigate and create new construction materials and improved construction methods that are relatively cheap, affordable, simple and easily available for various classes of construction in general. One of such materials is laterite. The use of laterite partial or full replacement for sharp sand in concrete production may bring down the cost of concrete production, hence the need for this work.

After the failure of various housing policies formulated by the Federal Government to contend the problems of housing due mainly to the high cost of building materials, the Federal Government decided to go into the use of locally and cheaply available material as an alternative to conventional building materials. This led to the establishment of the Nigeria Building and Road Research Institute (NBRRI) at Otta, to come up with new ideas, scientific research, technologies and materials that can bring down the cost of building houses. This subsequently led to the design and erection of prototype houses in Otta, Lagos, and Owerri by NBRRI using locally available materials which were cheap and more durable.

This work aims at highlighting the potential of tropical laterite as an alternative to sand in the production of low cost concrete for construction work. The reduction in the cost of laterite concrete compared to conventional concrete would make latcrete a feasible and viable proposition in civil engineering construction. The objective of the work had been to investigate the compressive strengths and other basic properties of latcrete which could be useful in the construction industry (engineers, technologists and all) requiring improving living conditions.

The McGraw-Hill [2] encyclopedia of science and technology describes laterite as an iron rich weathering product of (1807). The term is now used in compositional sense for weathering products composed of oxides of iron, aluminum, titanium and manganese. In this write up the considered concrete production is to be based on the cementation of laterite soil widely encountered in the eastern States of Nigeria. Laterite which is also known as "Latosol" is formed by the prolonged and severe weathering of local rocks.

And from the soil map of the world as published by the joint effort of two United Nations Agencies, Food and Agricultural Organization (F.A.O) and the United Nations Educational, Scientific and Cultural Organization (U.N.E.S.C.O), Nigerian laterite soil type falls into the international classification of “ALFISOLS” with the sub class of “Ustalf” which makes up most distribution. This laterite type tends to be strongly coloured by iron compounds and possesses to some degree characteristic and potentially useful property of hardening on exposure to air. Kaolinite is the predominant clay type in this laterite but its low specific surface and moisture retention are more than off set by the high specific surface of the colloidal silica present, giving the soil a high moisture retention capacity. Laterite soils also contain quartz, and the sesquioxide, AL_2O_3 and Fe3 O_3 in various numeral forms, and may be simply viewed as quantities of quartz together with granular aggregates of Kaolinite Clay particles weakly cemented by sesquioxide deposits. The sesquioxide are easily redeployed when the soil is worked or molded leading to the reported changes in measured properties. Laterites are acidic, low in organic matter, highly leached, usually free of soluble salts and therefore suitable for the cementation. The principal effect of cementation is to stabilize soils against internal swelling, and to enhance their compressive strength. The cementing action is produced by deposition within the pores of the soil of an insoluble binder capable of embedding soil particles in matrices cement gel. The gel matrix may be formed by hydrating the stabilizer as with Port land, or by mixing the stabilizer with some other material present, as with lime added to clay. Port land cement gel forms by the irreversible hydration of complex mixture consisting principally of calcium silicates and aluminates, creating a network of interlocking fibers of crystalline alumina silicates around cores of non reactant particles of cement. The fibrous gel, weak and amorphous at first but becoming strong and crystalline, fills the pore spaces of the soil and binds the particles together. Gel formation by port land cement is essentially independent of the composition of the soil.

The hydration of various components, which is temperature dependent, proceeds at different rates. Tricalcium aluminate cures almost instantaneously at 20°C and is responsible for early strength gains, which tricalcium silicates takes several hours at the same temperature and is more important in controlling the final strength of the cement. A further important property of port land cement is that it releases some limes in the course of hydration during curing, and that this lime is able to react and form additional cementation bonds.

Laterite soil is commonly stabilized by cement, lime or a mixture of the two. The initial production in Nigeria should however be based on cement since it is locally available and cement mix produces about 2 to 3 times the strength of an equivalent lime mix. Cement stabilizing process is not much affected by small variation in soil composition; hence an additional suitability of soil-cement mixes for investigation of production problems.

2. **Materials and Method Cement** The cement used for this work was the Eagle brand of port land cement manufactured by the Eastern Bulkcem Company limited in Port-Harcourt, Rivers State of Nigeria. The cement has a specific gravity of 3.5. The initial, final setting time and soundness of the cement are 53mins, 90mins, and 0.50mm respectively.

Aggregates. The fine aggregates used in this work were sharp river sand and laterite soil. They were obtained from the Otamiri soil deposit at the Federal University of Technology, Owerri (F.U.T.O). The sand complied with the requirement of BS882:1983. The specific gravity was 2.26. The laterite soil specific gravity was 2.51. The grain size distribution of the particles are shown in tables 5 & 6 and plotted in figure 1

Coarse Aggregate. The coarse aggregate was obtained from local suppliers. The aggregate had a specific gravity of 2.63 and the aggregate impact and crushing values of13.0% and 22.1% respectively.

Water. The water used for the test work as specified in the BS 3148 was potable and free from waste matters.

Preparation of Specimen /Testing

Mix Design. The concrete mix design was based on the minimum strength of 20N/mm^2 at 28 days as specified by the BS standard.

Casting of Cubes. The sand, coarse aggregates, laterite and cement were collected together in a mixing pan and uniformly mixed. Water was then added to the mix and the entire content in the pall was thoroughly mixed repeatedly to obtain a homogenous mix. Then the fresh concrete mix was placed inside a cubical metallic mould of dimension 150mm x 150mm x 150mm which was greased before the placement. The concrete content was compacted with a metallic compacting tool to eliminate air voids and left under laboratory condition for 24 hours before curing in a water tank for 3, 7, 14, 21, 28 and 90 days. From this tank the specimens were obtained for the various tests to be conducted.

Three cubes were cast for each replacement level of sharp sand by laterite, and a total of six replacement levels of 0%, 20%, 40%, 60%, 80% and 100% were made. A total of 90 cubes were casted for the entire test.

Compressive Strength Test The compressive specimens were cubes of dimension 150mm x 150mm x 150mm. The three cubes for each replacement levels were tested for 3, 7, 14, 21, 28 and 90 days. The compressive strength was calculated using the formula.

$$\delta_c = P/A$$

Where,

δ_c = Compressive Strength (N/mm^2)

P = Load applied on cubes [Newton (N)]

A = Cross sectional area of cubes [millimeters square (mm^2)]

The test was conducted according to [6] BS 1881: part 5:1983. Testing was by an electric motorized standard compression machine (Cat 70-C0019/2). The results are presented in table 5-10

Grain Size Distribution Test: The grain size distribution of the sharp sand and laterite soil was carried out based on [5] BS 1881. The tests were carried out on an arranged number of sieves of various sizes to determine the distribution of the various grain sizes of the fine aggregates. The results are shown in table 5 and 6.

Workability of Fresh Concrete The workability of concrete mix determined using slump and compaction factor tests. The test was carried out on each percentage replacement level of 0, 20, 40, 60, 80 and 100. The test was performed according to [8]BS 1881: part 2:1970. The results are shown in table 1

Water Absorption Test The water absorption test was carried out using cube specimens of various replacement levels. The specimens were immersed in water for twenty four (24) hours. The percentage water absorption was computed as a percentage difference of the weight of specimens before and after immersion in water. This test was conducted according to BS 1881: part 122: 1983. The results are presented in table 4.

3. Results and discussion

Fresh properties of latcrete

Workability The workability of laterite concrete (latcrete) was determined by the slump and compaction factor tests.

Slump Test. The slump test was carried out on all fresh mixes. The slump was insensitive at 0% replacement level of sharp sand by laterite and increased with increase in the replacement level. The result is shown in the table 1 below:

Table 1 – Slump Test Result

Combination		
% Sand	% Laterite	Slump (mm)
100	0	0
80	20	10
60	40	17
40	60	22
20	80	30
0	100	38

Compacting Factor Test: The compacting factor test was carried out on each of the replacement level of 0, 20, 40, 60, 80 and 100% of sharp sand by laterite. The compacting factor results were approximately constant at a value of 0.80. The results are presented in table 2 below:

Table 2 – Compaction Factor Test Results

Combination		
% Sand	% Laterite	Compacting Factor
100	0	0.79
80	20	0.79
60	40	0.80
40	60	0.80
20	80	0.82
0	100	0.82

Compressive Strength Of Lateritic Concrete

The compressive strength of the test cubes obtained at the various percentage replacement levels of sharp sand by laterite is shown in table 3. The results indicate that the strength increased with age and decreased with increased replacement levels. The result shows that the minimum specified strength of 20N/mm^2 (20mpa) at 28 days were attained at 0% to 20% replacement levels of the 14 days curing and 0% to 40 % for the 21 and 28 days, then 0% to 60% for the 90 days curing durations while the values for the strength of 80% and 100% replacement levels were slightly lower than the required design strength. The 3 days and 7 days strength was below the designed strength of 20N/mm^2. Fig 1 shows the curves of the compressive strength versus percentage laterite content

TABLE 3 – COMPRESSIVE STRENGTH OF LATERITIC CONCRETE

Combination		Compressive Strength (N/mm^2)					
% Sand	% Laterite	3 Days	7 Days	14 Days	21 Days	28 Days	90 Days
100	0	16.30±0.01	17.47±0.05	20.68±0.02	21.13±0.03	22.14±0.02	24.46±0.01
80	20	16.05±0.06	17.26±0.03	20.60±0.0	21.36±0.03	21.73±0.05	23.82±0.05
60	40	15.90±0.03	16.37±0.03	18.99±0.02	20.48±0.03	21.46±0.05	22.90±0.01
40	60	15.52±0.02	15.90±0.02	17.53±0.03	19.72±0.05	19.72±0.02	22.16±0.02
20	80	13.67±0.02	14.99±0.02	15.51±0.05	17.26±0.06	18.05±0.02	19.32±0.02
0	100	9.72±0.02	11.04±0.03	12.79±0.02	14.77±0.07	15.48±0.07	17.20±0.03

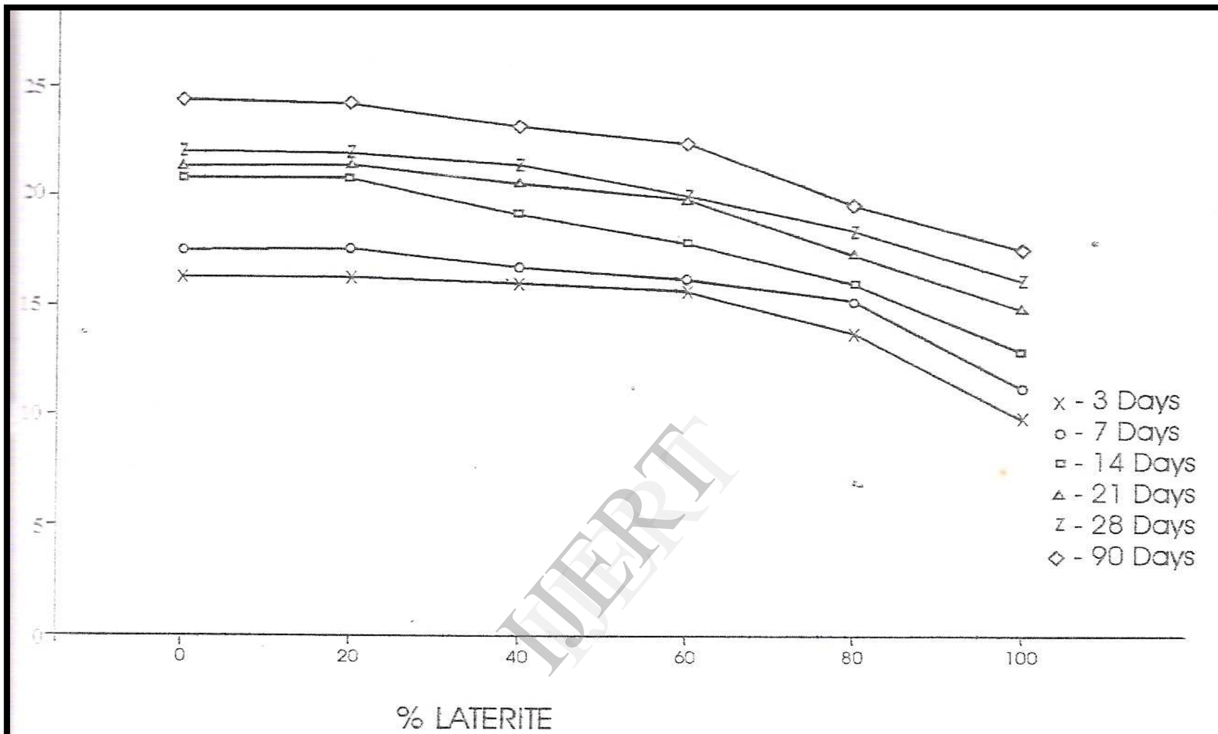

Fig. 1: CURVES OF COMPRESSIVE STRENGTH VS PERCENTAGE LATERITE

Water absorption

Table 4 Shows the results of the water absorption test. From the result it could be observed that the rate of water absorption of the specimens decreased as the replacement levels of sharp sand by laterite increases. It means that the highest replacement level has a low rate of water absorption.

TABLE 4 Water Absorption Test Result

S/n	Combination		Dry Weight (gm)	Wet weight (gm)	Water Absorption (gm)	Percentage Water Absorption %
	% Sand	% Laterite				
1	100	0	7909	8011	102	1.29
2	80	20	7716	7794	778	1.01
3	60	40	7650	7712	62	0.81
4	40	60	7686	7741	57	0.74
5	20	80	7669	7720	51	0.67
6	0	100	7469	7509	40	0.54

4. Conclusion and Recommendations

Conclusion Based on the results of the laboratory test of concrete cubes produced using laterite as a partial replacement for sharp sand, the following conclusions could be drawn:

(1) The compressive strength of concrete cubes increased with age but decreased with increase in replacement level of sharp sand by laterite.

(2) All the lateritic concrete did attain the designed strength with the exception of those with 80% and 100% replacement levels of sharp sand by laterite.

(3) The workability of fresh laterite concrete measured in terms of slump showed that the workability increased with increase in the replacement level of sand by laterite while the compaction factor test showed that the workability was quasi stable within the investigation levels with a compaction factor value of 0.80.

(4) The water absorption decreased with increased replacement levels of sharp sand by laterite.

Recommendation. According to the findings in this work, it is seen that laterite concrete if cured for 90 days, as against the 28 days could be taken as *partialis extra* replacement for sand in construction and block making.

2. It was observed that replacement level should not exceed 60%(sixty percent) so as not to compromise with strength as more of the replacement levels attained the designed strength at the 90 days curing age.

3 Further tests such as shrinkage and durability tests could be conducted on laterite concrete to ascertain its long term performance and suitability as concrete material.

4. Additive could be used to enhance the workability of resulting concrete mixture. This could be raw gypsum and alumina slag.

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Table 5 Grain Size Analysis of Laterite

Sieve size (mm)	**Mass retained (g)**	**Mass passing (g)**	**Cumulative mass retained (g)**	**Percentage passing %**
5.60				
3.35				100
2.00	16.7	16.7	2.8	97.2
1.18	37.0	53.7	9.0	91.2
600ụm	98.7	152.4	25.4	74.0
425ụm	149.7	302.1	50.3	49.7
300ụm	87.0	389.1	64.8	35.2
212ụm	80.0	469.1	78.0	22.0
150ụm	60.7	529.8	84.9	15.1
63ụm	50.2	580.1	96.6	3.4
Receiver Pan	20.0	600.0	100	
Total	**600.0**			

Table 6 Proportion of Concrete Constituent by Weight

		Weight Of Constituents				
Combination			Fine Aggregate			
% Sand	% Laterite	Cement (kg)	Sand (kg)	Laterite (kg)	Coarse Aggregate (kg)	Water (kg)
100	0	21.166	42.37	0.000	78.47	11.856
80	20	21.166	33.896	8.474	78.47	11.856
60	40	21.166	25.422	16.948	78.47	11.856
40	60	21.166	16.948	25.422	78.47	11.856
20	80	21.166	8.474	33.896	78.47	11.856
0	100	21.166	0.000	42.37	78.47	11.856

Table7 Concrete Mix Design

S/n	Item	Calculation of result/ specification	Remarks
1.	**Minimum strength at 28 days**	**20 N/mm^2 (20Mpa)**	**Specified**
2.	**Margin**	**7 N/mm^2 (7Mpa)**	**Specified**
3.	**Mean Strength**	**F mean = f min + Margin = 20+7 = 27 N/mm^2 (27Mpa)**	
4.	**Cement type**	**Ordinary Portland Cement (Eagle Cement)**	**Specified**
5.	**Maximum size of aggregate**	**38 minimum**	**Sieve test**
6.	**Aggregate used**	**1. (a) Fine aggregate – sharp sand (b) Fine aggregate – Laterite (As partial replacement for sand 2. Coarse aggregate – local gravel**	**Specified**
7.	**Specific gravity of aggregates**	**1. Coarse aggregate – 2.66 2. Fine aggregate (sand) – 2.60 3. Fine aggregate (laterite) – 2.51**	**Laboratory results**
8.	**Percentage fine passing 60mm sieve**	**35.0**	**Sieve test**
9.	**Water to cement ratio**	**0.56**	**Specified**

10.	Water content	185 kg/m^3	Calculation
11.	Density of concrete	2400 kg/m^3	Specified
12.	Cement content	330 kg/m^3	Calculation
13.	Total aggregate content	1885 kg/m^3	Calculation
14.	Fine aggregate content	660 kg/m^3	Calculation
15.	Coarse aggregate content	1225 kg/m^3	Calculation
16.	Mix proportion	Cement : Fine agg.: Coarse agg.: Water 330 : 660 : 1225 : 185 1 : 2.0 : 3.71 : 0.56 1 : 2 : 4 : 0.56	