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The Effects of Different Curing Methods on the Compressive Strength of Terracrete

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Abstract: This research evaluated the effects of different curing methods on the compressive strength of terracrete. Several tests that included sieve analysis were carried out on constituents of terracrete (granite and laterite) to determine their particle size distribution and performance criteria tests to determine compressive strength of terracrete cubes for 7 to 35 days of curing. Sand, foam-soaked, tank and open methods of curing were used and the study was carried out under controlled temperature. Sixty cubes of 100 × 100 × 100mm sized cubes were cast using a mix ratio of 1 part of cement, 1½ part of latrite, and 3 part of coarse aggregate (granite) proportioned by weight and water – cement ratio of 0.62. The result of the various compressive strengths of the cubes showed that out of the four curing methods, open method of curing was the best because the cubes gained the highest average compressive strength of 10.3N/mm^2 by the 35th day.

Keywords: Terracrete, curing, mix ratio, compressive strength.

Introduction

The need for shelter has been considered as a basic necessity for man from the beginning. It was noted that earth has been one of the major materials used in the construction of houses in Nigeria since time immemorial [1]. The quest for affordable housing coupled with the growing concern of resource deflation have been the current challenge and thus, the inclination of researchers to seek and develop new or alternative materials to facilitate mass housing delivery. This obviously calls for the search for cheap and readily available materials that can be used to solve the consequent problem of acute housing shortage for the ever-increasing population.
A cross-section of population in industrialized countries reverse to the use of earth as materials for building construction, but its use concerns mostly low-income house in developing countries [2]. Building construction basically with the use of earthen structure involves the modification of lateritic soils in its raw form. Laterite has been used in building construction for thousands years and approximately 30% of the world's present population still live in lateritic structures [3].

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Laterite is a residual deposit formed by the weathering of rocks under humid tropical conditions and consists mainly of iron and aluminium hydroxides [4]. Laterite is found extensively all over Nigeria and equally in all tropical regions of the world. The use of lateritic soils for building seems to be restricted to rural areas. This may be connected with the fact that there have not been accepted standards design parameters for the effective structural applications of laterite in laterized concrete [5].

Terracrete as defined by Olusola [6] is a mixture of laterite (as fine aggregate), granite or gravel (as coarse aggregate), cement and water in a chosen weight proportion, mixed by means that are available and equally allowed to undergo curing processes. According to ACI [7], curing is referred to as the maintenance of temperature and humidity during some definite period and it depicts the various hydrothermal reactions occurring in the high-pressure steam in addition to simple hydration. Generally, the idea of curing of whatever compound whether concrete or terracrete is to ensure that it should have the required strength to carry the load that is placed on it.

In Nigeria, over the years, the rate of building collapse has increased following the reduction of the vital components that allow the erection of proper and durable structures. It has been discovered that most players in building materials production in the country have disregard for proper curing methods [8]. Hence the results of the study are aimed at showing comparatively, the compressive strength to be attained by terracrete under different curing methods at varying curing ages.

Previous Work on Terracrete

Previous works on cement stabilized lateritic soils (terracrete) showed that its compressive strength is inversely proportional to its grain size [9]. This implies that the finer the grain size, the greater the strength. The compressive strength of terracrete is affected by delay in casting and that terracrete requires more water than concrete [10]. It was also pointed out that water – cement ratio of 0.5 is suitable for mix 1:1½:3 by weight of cement, laterite and coarse aggregate (granite) respectively

Also, Ola, et al. [11] discovered that an increase in curing period of terracrete increased its compressive strength. Osunade and Lasisi [12] found that an increase in cement content and decrease in optimum water-cement ratio of laterized concrete prisms brought an increase in the compressive strength.

Experimental Procedure

The basic materials used in this study for terracrete were laterite, granite and ordinary portland cement while foam, sand and water were used for curing. Laterite used as fine aggregate for producing terracrete was purchased in Ile-Ife, Osun state, Nigeria and the source was certainly from the abundantly available natural deposit area. Granite of 20mm size was used as coarse aggregate. Performance criteria tests and sieve analysis tests were carried out on the collected samples so as to effect compliances with the already established standards on which this work is based.

Aggregates were sieved to remove unwanted substances. Granite got from the source was crushed to smaller particles to an average size of 20mm with the use of hand hammer. The laterite collected for the purpose of this work was air-dried in the laboratory by spreading it to reduce its water content to the natural water content of the soil. Sample grading was done in order to determine the proportion of various sizes of particles in the aggregates in order that uniformity can be established with the specified standard.

The sieve analysis of granite sample was carried out using sieve apparatus of large sizes while that of laterite sample was carried out with smaller sieves sizes. Mix proportion of 1 part of cement, 1.5 part of laterite and 3 part of coarse aggregate (granite) was used. Batching was carried out by weight. The optimum water cement/ratio for workable mixes were determined using the expression [13]:

$$Y = -0.9 + 3.85 X \quad (1)$$

Where:
Y = laterite / cement ratio
X = water / cement ratio

From the ratio of 1:1½:3, the laterite-cement ratio is 1.5

$Y = -0.9 + 3.85 x$

$1.5 = - 0.9 + 3.85 x$

$x = 0.62$

This implies that water-cement ratio used for this study was 0.62. Wooden mould of standard size 100 × 100 × 100mm was used and initially lubricated with oil before placing terracrete mix into the mould to allow for easy removal of cubes in order to prevent damage of the terracrete cubes. Casting was carried out after the fresh terracrete was placed into the moulds using hand trowel. The moulds were partially filled and compacted using the tampering rod before finally filling the mould to the top level and later compacted.

A total of 60 cubes were cast. The cubes were removed from the moulds the second day of casting and later subjected to specified methods of curing.

Water Curing (Tank Method): Cubes of terracrete were placed in a tank filled with potable water cited in an enclosed area to keep it at room temperature.

Foam-soaked Curing (Foam Method): Cubes were covered with soaked foam (carpet underlay) and were kept wet in order to prevent premature hardening and cracking. The cubes were placed in an enclosed area to keep it at room temperature.

Sand Curing (Sand Method): Cubes were covered with sand and the process was equally carried out in an enclosed area to keep it at room temperature.

Open Curing (Open Method): The cubes were cured three times a day with the use of hand to pour water on the surfaces of the cubes.

Five compressive strength testing periods:- 7th, 14th, 21th, 28th and 35th day were used for the cured terracrete cubes samples. Three cubes from each curing process and age were tested for their compressive strength using a compressive strength testing machine operated electronically and the average compressive strength computed.

Results and Discussions

Sieve Analysis

The results of the sieve analyses of granite and laterite specimen were shown in Tables 1 and 2 respectively.

Table 1. Sieve analysis of granite sample

Sieve Opening (mm)	Weight of Sieve (g)	Weight of Sieve & Sample (g)	Weight of Sample Retained (g)	% Retained	% Cummulative Retained	% Passing
20.00	1550	1600	50	1.25	1.25	98.75
14.00	1500	2400	900	22.50	23.75	76.25
10.00	1500	3150	1650	41.25	65.00	35.00
6.30	1550	2400	850	21.25	86.25	13.75
5.00	1550	1650	100	2.50	88.75	11.25
3.35	1400	1500	100	2.50	91.25	8.75
Pan	1500	1850	350	8.75	100.00	-

Table 2. Sieve analysis of laterite sample

Sieve (mm)	Weight of Sieve (g)	Weight of Sieve & Sample (g)	Weight of Sample Retained (g)	% Retained	% Cummulative Retained	% Passing
2.36	435	500	65	4.46	4.46	95.54
1.18	396	675	279	19.16	23.62	76.38
0.85	374	555	181	12.43	36.05	63.98
0.60	355	580	225	15.45	52.50	48.5
0.425	340	590	200	17.17	69.67	31.13
0.300	320	495	175	12.07	81.74	19.31
0.212	314	435	121	8.31	90.05	11.00
0.150	305	370	65	4.46	94.51	6.94
0.075	295	375	80	5.31	99.82	1.03
0.063	290	290	0	0	99.82	1.03
Pan	260	275	15	1.03	100.00	0

From the result obtained, the 10.00 mm sieve retained 1.65 kg of 4.00 kg of granite used. This shows that the granite used was majorly less then 14.00 mm in diameter but greater than 10.00 mm in diameter. It also represents 41.25% of the total weight retained. From the particle size distribution curve (Figure 1) of the granite, it was interpreted that the finess modulus of granite sample used was 3.56. It has a co-efficient of uniformity (Cu) of 1.60 that is less than four [13]. The value shows that the granite samples are uniformly graded. The co-efficient of curvature (Cc) is 1.16 and it falls within the acceptable range of about two [13]. The effective size of thee granite is 6.82 mm in diameter.

From the result obtained in Table 2, it can be seen that lateritic soil is retained mostly by the 1.18 mm sieve, which implies that the particle sizes range between 2.36 mm and above 1.18 mm. This is closely followed by 0.425 mm granite particle sizes less than 0.600 mm. They represent 19.16% and 17.17% respectively of the total weight of the laterite used.

From the particle size distribution curve (Figure 2) of the laterite, it was interpreted that the finess modules of lateritic soil was 6.45. It has a co-efficient of uniformity of 8.75 that is higher than six, which means that the soil is well graded and such would allow for proper workability.

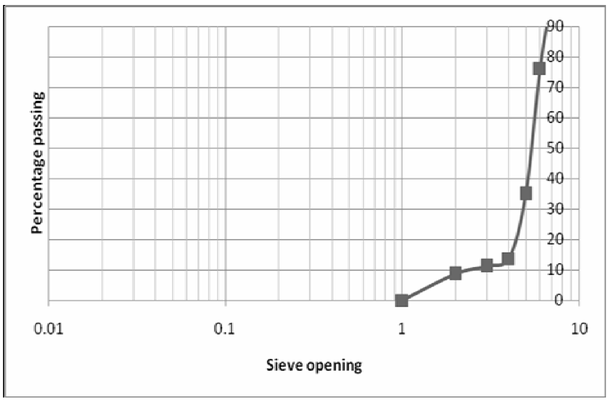

Figure 1. Sieve analysis of granite sample

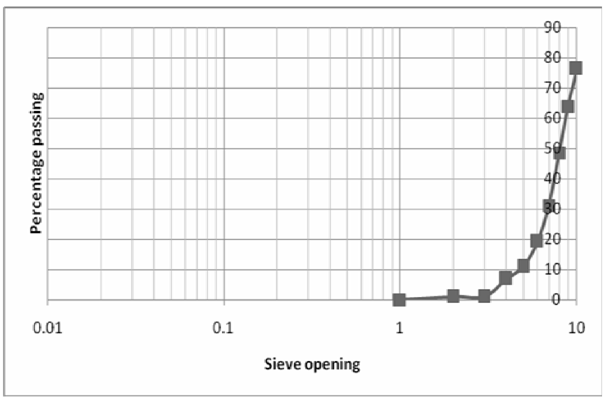

Figure 2. Sieve analysis of laterite.

Table 3. Compressive strength of terracrete cubes under different curing methods

	Curing Method															
	Tank Method				Damp sand Method				Foam-soaked Method				Open Method			
Curing period (Days)	Specimen No	Failure load (kN)	Average failure load (kN)	Average compressive stress N/mm^2	Specimen No	Failure load (kN)	Average failure load (kN)	Average compressive stress N/mm^2	Specimen No	Failure load (kN)	Average failure load (kN)	Average compressive stress N/mm^2	Specimen No	Failure load (kN)	Average failure load (kN)	Average compressive stress N/mm^2
7	1	50	48	4.8	1	53	51	5.1	1	55	53	5.3	1	59	62	6.2
	2	46			2	50			2	53			2	63		
	3	55			3	50			3	51			3	64		
14	1	56	54	5.4	1	61	59	5.9	1	63	60	6.0	1	7	76	7.6
	2	51			2	59			2	60			2	75		
	3	55			3	57			3	57			3	74		
21	1	70	66	6.6	1	72	68	6.8	1	70	71	7.1	1	88	86	8.6
	2	65			2	67			2	73			2	87		
	3	63			3	65			3	70			3	83		
28	1	78	75	7.5	1	82	79	7.9	1	86	82	8.2	1	93	94	9.4
	2	74			2	78			2	87			2	97		
	3	73			3	77			3	79			3	92		
35	1	80	81	81	1	87	84	8.4	1	90	88	8.8	1	110	103	10.3
	2	84			2	86			2	83			2	100		
	3	79			3	79			3	71			3	99		

Compressive Strength of Terracrete

The results of the compressive strength of terracrete cubes under different curing methods are shown in Table 3 and Figure 3 respectively.

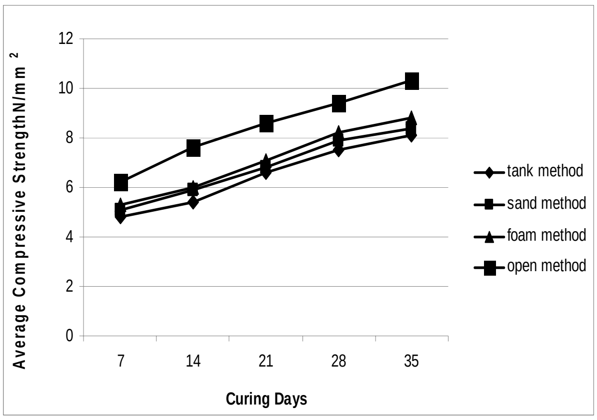

Figure 3. Compressive strength of terracrete cubes under different curing methods.

From the results obtained, it was observed that at 28 day curing period with the maintenance of room temperature to avert rapid evaporation of moisture, the open method of curing produced cubes with the highest compressive strength. Equally, for the 35th day compressive strength, and according to Olawole et al (1996) that the longer the curing period, the higher the compressive strength. This has been supported by the result gotten from the crushing of the cubes. In comparison, the result shows that open method of curing at 35th day had an increased compressive strength of 0.90 N/mm^2 as against 9.40 N/mm^2 that it had on 28th day of curing. Sand method of curing gained the least addition compressive strength of 0.50 N/mm^2 as against 7.90 N/mm^2 that it had on 28th day of curing.

The result showed that open method of curing had higher compressive strength at 35th day (10.30 N/mm^2) than at 28th day (8.80 N/mm^2). It is noticeable that despite an increase in the average compressive strength of the 35 days terracrete cubes (10.30 N/mm^2) compared with 28 days curing period (8.80 N/mm^2) , the level of average strength gained is significantly more than the levels of strength of other curing methods at either 35 or 28 day curing period.

In this research, since room temperature was maintained, the moisture applied to the open system was enough to allow it achieve a high compressive strength in comparison to others. Taking into consideration that when the moisture presence is much, the faster the hydration and thus, the quicker the gain of compressive strength. But in as much as this is true, the excessiveness of water could have an effect on the compressive strength.

Laterite is a water-retaining material and thus, the presence of excess water leads to shear when load is applied. In comparing the level of retention of water by sand and foam; sand being a porous material allows water to percolate, and with consistent presence of moisture which is the case of tank method of curing, led to results that are low because the moisture is still given off as vapour due to the higher temperature presence in its location.

In the case of foam-soaked mode of curing, when moisture is applied, it settles on the surface of the foam and gently sips through its tiny pores to the surfaces of the cubes. The rate of seepage is lower than that of sand because of its neatly closed pores, but still, a sufficient amount of moisture sips through it. The decrease in the average compressive strength in this case is higher than that of sand because of the retention of moisture on the surface by the foam and the exposure to temperature was high enough to lead to evaporation.

Conclusion and Recommendations

The preliminary test carried out on the samples used during the course of this study shows:
(1) The open method of curing is the most suitable method under the said conditions.
(2) When the temperature was controlled, small quantity of water was required for curing terracrete.
(3) Curing water must be free of substances that can attack or stain the hardened concrete, particularly when terracrete with good appearance is required.
(4) The open method which is the most effective in gaining the compressive strength was found to be the most economical because of free access to water that may be free of impurities.

From the foregoing, the following recommendations have been made based on the findings of this study:-
(1) The professionals in the field of construction should embrace the use of terracrete because it is cheaper than concrete and bleeding is not common in it as in concrete and consequently, small amount of water is required for its curing provided temperature is controlled.
(2) The following precautions should be taken when casting terracrete in hot weather.
   (i) Aggregates and equipment for handling terracrete should be in a covered space to reduce the negative effects of heat from the sun.
   (ii) Curing of terracrete should commence as soon as the casting is finished in hot weather.
   (iii) The terracrete surfaces should be protected from free circulation of drying air.

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