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The Influence of Weather on the Performance of Laterized Concrete

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Abstract: This study examined the weathering characteristics of laterized concrete with laterite-granite fine ratio as a factor. This was done with a view of ascertaining the suitability of laterite and granite fine as substitutes to the conventional fine aggregate (sand) used in the construction industry. The weathering characteristics was examined by conditioning laterized concrete cubes to varying temperatures and alternate wetting and drying, which all represent the operating weather conditions (wet and dry seasons) in the tropics, including Nigeria. The mix proportion used was 1:2:4, the curing age of the laterized concrete was based on 28-day curing age, while the Avery Denilson Testing Machine was used in determining the compressive strength of the treated laterized concrete cubes. The result of this research showed that the compressive strength of laterized concrete with laterite-granite fine ratio variation decreases when subjected to alternate wetting and drying. It was also discovered that a laterized concrete with a laterite-granite fine ratio of between 40 and 60% conditioned to a temperature range of 75-125°C attained compressive strengths as high as 22.52 Nmm^{-2}.

Key words: Weather, effect, laterite, granite

INTRODUCTION

One of the basic infrastructural facilities that man needs for good living is shelter[1]. Man requires shelter in order to be described as living at all. Hence, shelter provision has been one of the major pre-occupations of man since the dawn of time when he lived in caves[2].

In recent times, improved knowledge of materials and the technology of construction have made it possible to construct decent buildings and even skyscrapers. However, the increasing cost of procuring these now conventional construction materials has made it impossible to meet the shelter provision requirements of the teeming population of a country such as Nigeria. Therefore, the need for a research work aimed at reviewing the use of these materials or providing/finding alternative materials, but which are relatively cheap and available cannot be overemphasized.

This effort would go a long way in alleviating the problem of shelter provision confronting the teeming Nigerian populace and apart from this, it would be another breakthrough in the world of construction. To this end, intensive investigations have been on in the South Western Nigeria to develop and establish engineering basis for the use of lateritic soils (which are abundantly available in Nigeria) as substitute of sands (fine aggregates) in construction works, most especially concreting.

In the light of this, studies that determine the proportions of concrete components that give optimum strength characteristics have been carried out[3]. Efforts have been made on how to produce laterized concretes, so that both the external and internal factors which adversely affect the durability of concrete while in service are brought to minimal. Falade[4], for instance, examined the influence of water/cement ratios and mix proportions on workability and characteristic strength of concrete containing laterite fine aggregate and discovered that water requirement increases as laterite/cement ratio increases for a given mix proportion. Meanwhile, in a previous work by Lasisi and Osunade[5] where the effect of grain size on the strength of cubes made from lateritic soils was studied, it was found out that the finer the grain sizes, the higher the compressive strength obtained. Similarly, Osunade and Babalola[6] looked into the effect of mix proportion and reinforcement size on the anchorage bond stress of laterized concrete and concluded among other things that the anchorage bond stress between a plain steel reinforcing bar and laterized concrete compares favourably with that of the ordinary concrete but higher than those of lightweight concrete. Oyekan and Balogun[7], in their findings while working on the impact resistance of plain laterized concrete, discovered that at a standard mix of 1:2:4, a water/cement ratio of 0.60 gives higher impact resistance values than those at water/cement ratios 0.65 and 0.70.

This present study, which studies the influence of weathering on the strength performance of laterized concrete, forms part of the efforts aimed at fully integrating laterized concrete for structural use in

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construction works. This was done by subjecting laterized concrete to varying temperatures and alternate wetting drying while still varying laterite-granite fine ratio as fine aggregate.

MATERIALS AND METHODS

The materials used for this experiment were;

- Lateritic soils,
- Granite (coarse and fine aggregates),
- Cement and
- Water.

The lateritic soil used was obtained from a nearby borrow pit at the Religious Centre, Obafemi Awolowo University, Ile-Ife. The material was air dried and a sample was subjected to sieve analysis using the Mechanical Sieve Shaker with sieves BS No. 4, 8, 16, 20, 40, 70, 100 and 200. The results are as shown in Table 1 and the grading curve is as shown in Fig. 1. Analysis of the results showed that the laterite used in this experiment is well graded. Also, the laterite was subjected to Atterberg Limit Tests to ascertain its suitability for the work. The results are as shown in both Table 2 and Fig. 2.

The granite (coarse and fine aggregates) used was obtained from the Religious Centre, Obafemi Awolowo University Campus, where a construction work was going on. The cement used for this experiment was the Ordinary Portland Cement produced by the West African Portland Cement Company. This conformed to the[8] requirements. Apart from this, it is the one widely used in the construction industry and it is also readily available. Tap water obtained from the Agricultural Nursery beside Civil Engineering building was used in carrying out the experiment. The water cement ratio used for the project was based on the optimum water-cement ratio given by Ogundeko[9], that is;

$$Y = -0.94 + 3.85X$$

Where Y = Laterite - Cement ratio
X = Water- Cement ratio

Batching of materials was done by weight. The semi automatic scale at the 20 kg range available in the Civil Engineering Structures Laboratory was used. The manual method of mixing, using shovels and trowels, was employed. The mix ratio used was 1:2:4. The granite fine-laterite ratios used as fine aggregate were 0, 20, 40, 60, 80 and 100%. This was to ascertain the range of combination that will give the optimum compressive strength. The mixing was done such that the dry components were mixed until a satisfactory uniform colour was obtained. The desired water was added gradually to the mixed dry components and thorough mixing was done to give a workable concrete. The procedures for casting the test specimens were done in accordance with[10,11] for each of the cubes. The moulds (150×150×150) mm^3 available in the Civil Engineering Structures Laboratory were used in casting the cubes. Fourteen replicates were made for each laterite- granite ratio variation. The curing of cubes was based on 28 day curing age. The curing was done using the curing tank available in the Civil Engineering Structures Laboratory.

Three of the fourteen replicates of the cured cubes for each laterite-granite ratio variation of 0, 20, 40, 60, 80 and 100%, respectively were subjected to temperatures of 25, 75, 125 and 175°C, respectively for two h using the ovens in the Agricultural Engineering Department Laboratory.

The increment in temperature of 50°C was employed to allow for the coverage of a wide range within the limited time available. The temperature started with 25°C to condition the specimens to room temperature. For example, it implies that 3 of the 14 replicates of 0% laterite-

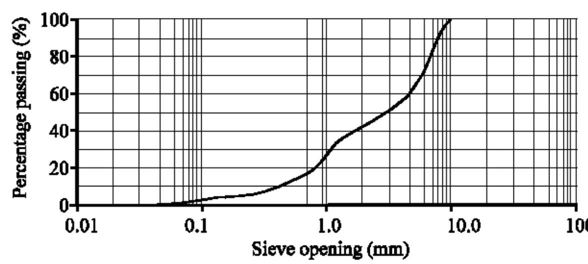

Fig. 1: Grading curve for the lateritic soil

Table 1:Results of sieve analysis of laterite

Sieve No.	Sieve opening	Weight of sieve (g)	Weight of sieve+soil (g)	Weight of soil retained (g)	Retained (%)	Passing (%)
4	4.760	466.32	793.35	327.03	33.50	67.50
8	2.360	426.81	650.93	224.12	22.27	45.23
16	1.180	396.41	541.46	145.05	14.41	30.82
20	0.850	375.01	431.11	56.10	5.57	25.25
40	0.425	340.17	474.25	134.08	13.32	11.93
70	0.212	314.04	385.17	71.13	7.06	4.87
100	0.150	303.25	311.48	8.23	0.80	4.07
200	0.075	297.03	314.19	17.16	1.69	2.38
Rec. Pan	-	268.03	292.22	24.19	2.38	-

Type of soil: Laterite, Total weight: 1007 g

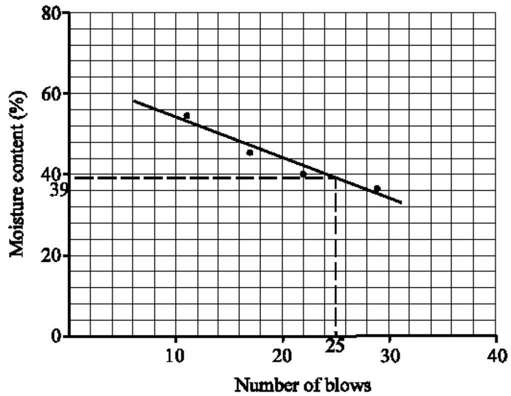

Fig. 2: Determination of Liquid Limit (LL) and Plasticity Index (PI)

Table 2: Liquid and plastic limit result

	LL	LL	LL	LL	PL	PL	PL
No. of Blows	11	17	22	29			
Tin No.	AA	AB	AC	AD	AE	AF	AG
Wet Soil + Tin	26	22	25	30	18	11	10
Dry Soil + Tin	20	17	21	26	17	10	9
Weight of tin	9	6	11	15	14	6	6
Weight of water	6	5	4	4	1	1	1
Weight of dry soil	11	11	10	11	3	4	3
Moisture content	54.54	45.45	40.00	36.36	33.33	25.00	33.33

granite ratio were subjected to a temperature of 25°C for 2 h. Also, another 3 replicates were subjected to 75°C for 2 h. The temperature treatment continued in this trend for each of the laterite-granite ratio variations. The temperature was applied to subject the specimens to the dry season which operates in the tropics.

The remaining two of the 14 replicates of the cured cubes were subjected to alternate wetting and drying. This was done such that replicates were first dried at 50°C for 2 h (because in recent times the highest temperature recorded in Nigeria was 46, 50°C was thus used to give allowance for any possible increment) and then immersed in water at room temperature for 1 h. These were repeated in three cycles, making use of the drying oven available in the Agricultural Engineering Department Laboratory. The alternative wetting and drying was done to subject the specimens to factors of weathering (i.e. rainy and dry seasons) that are operating in the tropics.

After each cube had been subjected to the desired conditions, their crushing loads were determined using the Avery-Denilson Testing Machine Testing Machine available in the Agricultural Engineering Department Laboratory. Prior to crushing, the cubes were weighed to facilitate the determination of densities.

RESULTS

The observed crushing loads of the cubes are as shown in Table 2-9 for laterite-granite fine ratio variation of 0, 20, 40, 60, 80 and 100% and alternate wetting and drying respectively. The observed values are temperature, volume, effective area, weight and crushing load of each cube which had been subjected to desired conditions. The concrete mix used was 1:2:4, while the curing age was 28 days.

The analyses are as represented in Table 2 to 9 under column headings average weight, density, average crushing load and compressive strength. The relationship between the compressive strength of cubes (treated cubes) and characteristics such as temperature, laterite-granite fine ratio variation and alternate wetting and drying are as shown in Fig. 3-5.

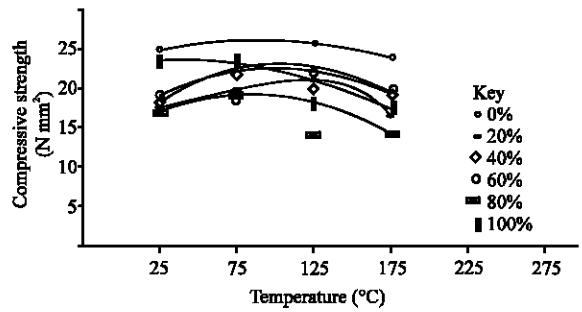

Fig. 3: Effect of temperature variation on the compressive strenth of laterized concrete

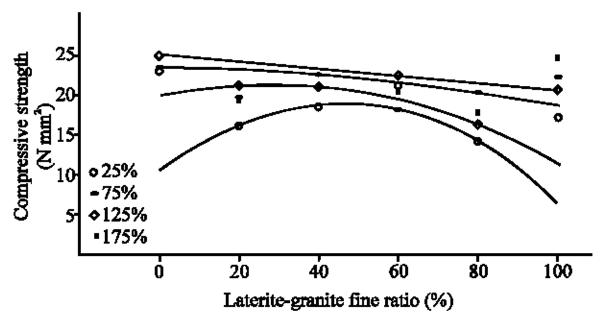

Fig. 4: Effect of Laterite-Granite fine ratio variation on the compressive strengh of laterized concrete

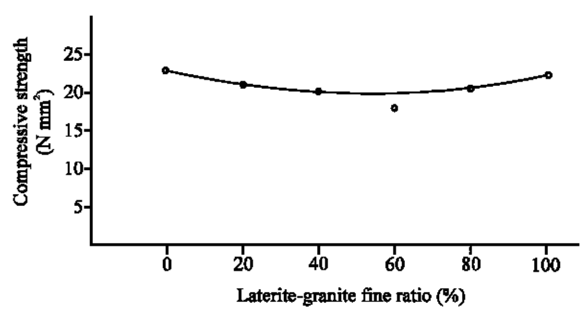

Fig. 5: Effect of alternate wetting and drying on lthe compressive strength of laterized concrete

Table 3: Compressive strength and density of laterized concrete at 0% laterite-granite fine ratio

Temperature (°C)	Replicate	Weight (kg)	Average weight (kg)	Volume (m^3)	Density (KN/m^3)	Crushing load (KN)	Average crushing load(KN)	Effective area (mm^2)	Compressive strength (N/mm^2)
25	1	7.60	7.73	0.15^3	22.01	560	563.33	150^2	25.04
	2	7.73				550			
	3	7.86				580			
75	1	7.37	7.69	0.15^3	21.91	480	526.67	150^2	23.41
	2	7.85				540			
	2	7.85				560			
125	1	7.71	7.77	0.15^3	22.01	550	583.33	150^2	25.93
	2	7.69				590			
	3	7.92				611			
175	1	8.09	7.74	0.15^3	22.06	550	543.33	150^2	24.15
	2	7.22				510			
	3	7.92				570			

Table 4: Compressive strength and density of laterized concrete at 20% laterite-granite fine ratio

Temperature (°C)	Replicate	Weight (kg)	Average weight (kg)	Volume (m^3)	Density (KN/m^3)	Crushing load (KN)	Average crushing load(KN)	Effective area (mm^2)	Compressive strength (N/mm^2)
25	1	7.70	7.60	0.15^3	21.64	350	420	150^2	18.67
	2	7.48				390			
	3	7.61				520			
75	1	7.41	7.36	0.15^3	20.96	460	443.33	150^2	19.70
	2	7.51				490			
	2	7.15				380			`
125	1	7.42	7.43	0.15^3	21.91	460	476.67	150^2	21.19
	2	7.31				520			
	3	7.55				450			
175	1	7.03	7.29	0.15^3	20.77	310	366.67	150^2	16.30
	2	7.27				390			
	3	7.57				400			

Table 5: Compressive strength and density of laterized concrete at 40% laterite-granite fine ratio

Temperature (°C)	Replicate	Weight (kg)	Average weight (kg)	Volume (m^3)	Density (KN/m^3)	Crushing load (KN)	Average crushing load(KN)	Effective area (mm^2)	Compressive strength (N/mm^2)
25	1	8.10	7.85	0.15^3	22.37	370	410	150^2	18.22
	2	7.84				350			
	3	7.60				510			
75	1	8.14	7.97	0.15^3	22.71	550	506.67	150^2	22.52
	2	7.52				440			
	2	8.26				530			
125	1	8.73	8.15	0.15^3	23.22	520	453.33	150^2	20.15
	2	8.36				490			
	3	7.37				350			
175	1	7.72	7.84	0.15^3	22.34	400	440	150^2	19.56
	2	7.52				430			
	3	8.27				490			

Table 6: Compressive strength and density of laterized concrete at 60% laterite-granite fine ratio

Temperature (°C)	Replicate	Weight (kg)	Average weight (kg)	Volume (m^3)	Density (KN/m^3)	Crushing load (KN)	Average crushing load(KN)	Effective area (mm^2)	Compressive strength (N/mm^2)
25	1	7.71	7.60	0.15^3	21.88	430	453.33	150^2	20.15
	2	7.68				450			
	3	7.65				480			
75	1	7.79	7.71	0.15^3	21.97	360	430	150^2	19.11
	2	7.57				460			
	2	7.77				470			
125	1	7.76	7.78	0.15^3	22.17	530	503.33	150^2	22.37
	2	7.76				470			
	3	7.84				510			
175	1	7.86	7.89	0.15^3	22.48	500	460	150^2	20.44
	2	7.45				400			
	3	8.07				480			

Table 7: Compressive strength and density of laterized concrete at 80% laterite-granite fine ratio

Temperature (°C)	Replicate	Weight (kg)	Average weight (kg)	Volume (m^3)	Density (KN/m^3)	Crushing load (KN)	Average crushing load(KN)	Effective area (mm^2)	Compressive strength (N/mm^2)
25	1	8.03	8.03	0.15^3	22.59	490	400	150^2	17.78
	2	7.99	7.99			330			
	3	7.77	7.77			380			
75	1	8.01	8.01	0.15^3	22.48	530	456.67	150^2	20.30
	2	7.86	7.86			410			
	2	7.80	7.80			430			
125	1	7.90	7.90	0.15^3	22.62	400	346.67	150^2	15.41
	2	7.87	7.87			350			
	3	8.05	8.05			290			
175	1	7.89	7.89	0.15^3	23.08	260	343.33	150^2	15.2
	2	8.21	8.21			440			
	3	8.21	8.21			330			

Table 8: Compressive strength and density of laterized concrete at 100% laterite-granite fine ratio

Temperature (°C)	Replicate	Weight (kg)	Average weight (kg)	Volume (m^3)	Density (KN/m^3)	Crushing load (KN)	Average crushing load(KN)	Effective area (mm^2)	Compressive strength (N/mm2)
25	1	8.10	8.21	0.15^3	22.39	520	556.67	150^2	24.74
	2	8.33				620			
	3	8.20				530			
75	1	8.49	8.08	0.15^3	23.02	530	526.67	150^2	23.41
	2	7.98				460			
	2	7.77				590			
125	1	7.98	8.07	0.15^3	22.99	480	443.33	150^2	19.70
	2	8.29				380			
	3	7.94				470			
175	1	7.57	7.74	0.15^3	22.05	400	390	150^2	17.33
	2	7.15				440			
	3	8.31				330			

Table 9: Compressive strength and density of laterized concrete subjected to alternate wetting and drying

Ratio variation (%)	Replicate	Weight (kg)		Average weight (kg)		Volume (m^3)	Density (KN/m^3)		Crushing load (KN)	Average crushing load(KN)	Effective area (mm^2)	Compressive strength (N/mm^2)
		Initial	Final	Initial	Final		Initial	Final				
0	1	7.75	7.80	7.81	7.86	0.15^3	22.25	22.39	550	515	150^2	22.89
	2	7.87	7.91						480			
20	1	7.32	7.35	7.46	7.56	0.15^3	21.25	21.54	460	470	150^2	20.89
	2	7.60	7.64						480			
40	1	7.70	7.75	7.61	7.65	0.15^3	21.68	21.80	470	455	150^2	20.22
	2	7.51	7.55						440			
60	1	7.51	7.53	7.53	7.55	0.15^3	21.45	21.51	390	405	150^2	18.00
	2	7.54	7.56						420			
80	1	7.68	7.71	7.53	7.56	0.15^3	21.45	21.54	540	460	150^2	20.44
	2	7.39	7.41						380			
100	1	7.92	7.94	8.08	8.10	0.15^3	23.02	23.08	530	500	150^2	22.22
	2	8.23	8.25						470			

Figure 3 examines the effect of temperature variation on the compressive strength of laterized concrete with laterite-granite fine ratio variation also as factor. Figure 4 determines the effect of laterite- granite fine ratio variation on the compressive strength of the concrete at various temperature treatments.

Figure 5 examines the effect of alternate wetting and drying on the compressive strength of laterized concrete at varying laterite-granite fine ratio, the figure also compares the compressive strength at the varying laterite-granite fine ratio for alternate wetting and drying with the maximum compressive strengths attained for each percentage laterite- granite fine ratio variation.

The compressive strength of each cube was obtained using the formula:

$$\text{Compressive Strength} = \frac{\text{Crushing Load } (N/mm^2)}{\text{Effective Area}}$$

While the density of each cube was obtained from the expression:

$$\text{Density} = \frac{\text{Mass (KN/m}^3)}{\text{Volume}}$$

Where, mass (KN) = $\frac{\text{Weight in Kg}}{104}$ (For the Civil Engineering Laboratory, 1N = 104g).

RESULTS AND DISCUSSION

Considering the effect of temperature on the compressive strength of laterized concrete, Figure 3 shows that for some of the laterized concrete cubes, i.e., those with laterite-granite fine ratio of 0, 20, 40, 60 and 80% with concrete mix of 1:2:4 at a curing age of 28 days, temperature had an appreciable impact on the compressive strength of the laterized concrete from 25-125°C. For example, for 0% laterite-granite fine ratio, the compressive strength increases from 25.04 N/mm^2 to 25.93 N/mm^2 3.55% increase for a temperature range of 25-75°C unlike that at 100% laterite-granite fine ratio in which the compressive strength decreases from 24.74 N/mm^2 to 17.33 N/mm^2 29.95% decrease for a temperature range of 25-175°C.

A further increase in temperature from 125 to 175°C and above causes a decrease in the compressive strength of the laterized concrete cubes. For example, for 20% laterite-granite fine ratio, compressive strength decreases from 21.19 N/mm^2 to 16.30 N/mm^2 23.07% decrease for temperature range of 125-175°C, for 60% laterite-granite fine ratio, compressive strength decreases from 22.37 N/mm^2 to 20.44 N/mm^2 for temperature range of 125-175°C.

Examining the effect of laterite-granite ratio variation on the compressive strength of laterized concrete, Figure 4 shows that for suitable temperature observed during the course of this research work such as 75-125°C, the laterized concrete cubes show an increase in compressive strength for laterite-granite fine ratio of 20, 40, 60 and 100%, respectively. For example, the 60% laterite-granite fine ratio shows an increase in compressive strength from 19.11N/mm^2 to 22.37 N/mm^2 17.05% increase for temperature range of 75-125°C. Also, for 20% laterite-granite fine ratio, the compressive strength increases from 19.70N/mm^2 to 21.19N/mm^2 7.05% increase for temperature range of 75-125°C.

From Fig. 4 also, it could be deduced that the optimum compressive strength could be gotten from laterite-granite ratio between 40-60% at a temperature range of 75 and 125°C. This is evident in that no compressive strength was as high as those obtained within the ranges i.e., for 40-60% at 75-125°C, compressive strength range is 19.22 N/mm^2-22.52 N/mm^2.

Furthermore, looking at the effect of alternate wetting and drying on the compressive strength of laterized concrete, a comparism of the compressive strength of a 40% laterite- granite fine ratio of a laterized concrete subjected to alternate wetting and drying 20.22 N/mm^2 with the compressive strength of also a 40% laterite-granite fine ratio of a laterized concrete at temperature of 75°C 22.52 N/mm^2 shows that there was a decrease in strength by 9.01% when subjected to alternate wetting and drying. Also, comparing the compressive strength of a 60% laterite-granite fine ratio laterized concrete at temperature of 125°C 22.37% also shows that the strength decreases by 19.53% when the same ratio was subjected to alternate wetting and drying i.e., 18.00 N/mm^2.

CONCLUSION

The conclusions arrived at, at the end of this research work are as follows:

For laterized concrete mix 1:2:4 and curing age at 28 days, with laterite- granite fine ratio variation as a factor, from 0-80% had reasonably high compressive strengths for temperature applications up to 125°C (e.g., for 0%, compressive strength obtained was between 25.04 N/mm^2 and 25.93 N/mm^2 for temperature range of 25-125°C, also 20%, compressive strength obtained was between 18.67 N/mm^2 and 21.19 N/mm^2 for a temperature range of 25-125°C). The reason for this could be due to some other inherent salts present in the laterite which may experience a breakdown in their internal structure when subjected to temperatures above 125°C, thus leading to a reduction in the compressive strength of the laterized concrete, on the other hand, the increase in compressive strength for 0-80% at temperature range of 25-125°C could be due to a gradual build up in the bond of the inherent salts present in the laterite which thus lead to a high bearing capacity of the laterized concrete;

When the same laterized concrete is subjected to alternate wetting and drying, compressive strengths were as low as 18.00 N/mm^2. It implies that laterized concrete depreciates with time under the prevailing conditions (rainy and dry season) in the tropic;

Optimum compressive strengths could be obtained between 40-60% laterite-granite fine ratio at temperature of 75-125°C. For example, compressive strengths within this range were as high as 22.52 N/mm^2. The reason might be due to the fact that the ratio of laterite-granite is 1:1. Granite is impermeable and has a high density, but with large diameter of fines. Whereas, the size of laterite is smaller, thus rendering the concrete practically voidless,

d. Laterized concrete would have a gain in weight when it comes in contact with water. For example, at 0% laterite-granite fine ratio, the weight prior to immersion was 7.81 kg while the weight after immersion was 7.86 kg gain in weight of about 0.64%. This could be due to water absorbing properties of laterized concrete for laterite's finess.

Future works on weathering characteristics of laterized concrete with laterite- granite fine ratio variation as a factor should focus on ascertaining the effect of continuous alternate wetting and drying on the compressive strength of laterized concrete or perhaps, since weathering is a continuous gradual process, efforts should be made to subject laterized concrete with desired factors, to operating weathering conditions (i.e., wet and dry seasons) prevailing in the tropics for a minimum of three years and thus the compressive strength is examined whether it depreciates with the continuous impact of weathering. Also, the effect of different concrete mix such as 1:1½:3 and 1:3:6 on the compressive strength of laterized concrete with laterite- granite fine ratio variation as factor should as well be investigated.

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