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Utilization of Calcined Lateritic Soil as Partial Replacement of Cement on Concrete Strength

A.T. John, R.G. Damini and I. S. Akosubo

Abstract— Utilization of concrete in almost every civil engineering applications has continued to place a high demand on constituent concrete materials. This work is part of a study investigating the structural characteristics of concrete using calcined lateritic soil as a partial substitute for conventional cement. Concrete samples cubes were produced using different contents of calcined lateritic soil. The quantity of calcined lateritic soil was varied from 0-20% at intervals of 5% for three different temperatures, 200^0C, 400^0C and 600^0C. The cube specimens were cured for a period of 7, 14, 21 and 28days and tested in the research laboratory for compressive strength. Results obtained from the investigation showed that the targeted compressive strength of concrete 20.0N/mm^2 at 28 days was achieved for all specimens (0 – 20%) cement replacement for 400^0C calcination temperature. The targeted compressive concrete strength of 20N/mm^2 at 28 days was also achieved for concrete cubes samples with 0, 5, 10 and 20% cement replacement with calcined lateritic soil for 400^0C and 600^0C calcination temperature while that for 15% replacement was a little lower. The predominant soil type collected from the site is A7 and OL by AASTHO and USC system soil classification respectively. Base on the findings, it is recommended that the use of calcined lateritic soil as partial replacement of conventional cement by weight should be embraced and not be frightened for the making of concrete during construction. The calcined lateritic soil can be used in concrete mixes as cement with 5% to 20% replacement for 200^0C and 400^0C respectively.

Index Terms— Lateritic soil, Partial Replacement, Concrete Strength, Calcined,

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1 Introduction

I. Introduction

One of the factors that affect construction industry is the high cost of cement, using a binder, in the production of concrete and his related construction materials such as mortar, concrete blocks have led to pursuit for substitute. Apart from the cost implication, the production process of cement produces significant quantities of carbon emissions. The production of one ton of Portland cement emits approximately one ton of CO_2 in the atmosphere (Vipul and Pawan, [10]), which harms the ecology and the future of living things. Investigation on a substitute to cement has so far concentrated on the partial replacement of conventional cement with pozzolans. Arthanari et al. [1] defined Pozzolans as siliceous material, which by itself holds no cementitious properties but in processed way and finely divided form, react in the existence of water with lime, to form compounds of low solubility having cementitious properties. Utilization of concrete in the construction industry have set a high requirement for its constituents' materials, consequently, the demand to study into other environmentally friendly constituents to boost sustainability. Lateritic soil had been used in building development for a decade. The use of these richly locally accessible materials, when calcined to replace cement in the production of concrete, would reduce a significant amount of carbon emissions. In Nigeria, laterite soil has been an important material used for building (Osunade, [8]). Laterite soil has also been utilized as aggregate in some parts of the world (Kamaruzaman and Muthasamy, 2013).

A. T. John is with the Department of Civil Engineering, Niger Delta University, Wilberforce Island, Nigeria
R.G. Damini is with the Department of Civil Engineering, Federal University, Otuoke, Nigeria
I. S. Akosubo is with the Department of Civil Engineering, *Nigeria Maritime* University, *Okerenkoko*, Nigeria

Lasisi, et al. [6] stated that the durability of lateralized mortars and concrete can be improved by the low permeability features of laterite. Efe and Salau [5] study on the influence of high temperature on altered concrete, they stated that conventional concrete cannot survive considerable load above 250°C while lateralized concrete consist 25% laterite in the fine aggregate can withstand higher load with the increase in days and at temperature about 500°C. They attained compressive strength up to 30.44N/mm^2 for concrete with 25% laterite and 75% sand at 500°C. They also noticed that there is economic saving if lateralized concrete is used in areas of high temperature about 500°C. Laterite was utilized as a sand substitute in concrete by (Udeoyo, et al., [9]) and their study showed an enhancement in workability as the proportion of laterite increased in the concrete. At higher replacement of sand by laterite, the concrete considerably became more workable.

Balogun and Adepegba [2] made a statement that provided the percentage of laterite does not exceed 50, the mix percentage appropriate for structural utilization of lateralised concrete is 1:1½:3 with a water-cement ratio of 0.65.

This paper is aimed at investigating calcined lateritic soil as partial replacement of conventional cement on compressive strength of *c*oncrete.

II. Experimental Programme

A. Materials

Cement

Portland Limestone Cement (Grade 42.5) meeting the requirement of EN 197-1 [3] was used in the casting of the 150mm x 150mm x 150mm concrete cube specimens.

Fine Aggregate

The fine aggregate exploited was river sand at Tombia, an outskirt of Yenagoa. The maximum particle size was 4.75mm. It conformed to B.S. 882; 1992.

lateritic soil

The lateritic soil used for this investigation was the source from Abudu in Orhionwo Local Government Area, Edo State, Nigeria.

Coarse Aggregate

Coarse aggregate with particle size greater than 4.75mm and maximum size of 12.5mm is used. It conformed to B.S. 882; 1992.

Water

Water-free from septicity was used in the mixing of the concrete specimen as specified by BS 3148:[4]

B. Method

Lateritic soil

The sourced Lateritic soil samples were sundried for 3 to 4 hours to eliminate moisture content, and calcined (burnt at control temperature) in a furnace with temperatures of 200^0C, 400^0C, and 600^0C respectively. The calcined (burnt) soil samples were pounded after cooling using mortal and pistol after which the burnt samples were sieved through sieve No 50, the percentage passing through the sieve would have the required degree of cement.

Mix proportion

Batching by weight was adopted in this research. A mix ratio of 1:2:4 (cement: fines: coarse aggregate) was studied with a water/cement proportion of 0.5. A concrete mould of 150x150x150mm was used for the production of the concrete cubes. The mould was coupled before casting of the concrete and lubricated as it should be for easy removal of hardened concrete cubes.

Fresh Concrete Test

Slump test was conducted to measure the workability of fresh reference concrete and concrete containing calcined lateritic soil.

Compressive Strength Test

One hundred and fifty-six cubes specimens of size 150 mm × 150 mm × 150 mm were cast for this research, twelve for reference (0%) and forty-four cubes specimens for each percentage (5%, 10%,15%, and 20%) for three different temperatures (200^0C 400^0C and 600^0C) of calcined lateritic soil. The moulds were cast with fresh concrete in three layers and each layer was tamped 25 times with a tamping rod. The prepared cubes were given 24 hours to set before demolding and stored in water (curing phase) to increase the strength of concrete, eliminate shrinkage, and absorb the heat of hydration until the age of test. Before testing, specimens were air-dried for 30 minutes to1 hour. Cubes were cured for 7, 14, 21 and 28 days. The crushing strength of the concrete samples is estimated by dividing the failure load attained by the cross-sectional area of the concrete sample. The cubes were tested 7, 14, 21 and 28 days.

III. Results and Discussion

A. Results

Table I: Slump Values of 200^0C Calcined Lateritic Soil used as Partial Replacement.

Replacement	W/C Ratio	Slum (mm)
Control (0%)	0.5	70
5%	0.5	20
10%	0.5	27
15%	0.5	33
20%	0.5	40

Table II: Slump Values of 400^0C Calcined Lateritic Soil used as Partial Replacement.

Replacement	W/C Ratio	Slum (mm)
Control (0%)	0.5	70
5%	0.5	24
10%	0.5	33
15%	0.5	23
20%	0.5	27

Table III: Slump Values of 600^0C Calcined Lateritic Soil used as Partial Replacement.

Replacement	W/C Ratio	Slum (mm)
Control (0%)	0.5	70
5%	0.5	34
10%	0.5	35
15%	0.5	52
20%	0.5	32

Table IV: Compressive Strength of 200^0C Calcined lateritic soil as Replacement for 7, 14, 21 and 28 days

Percentage Replacement	7 Days (N/mm^2)	14 Days (N/mm^2)	21 Days (N/mm^2)	28 Days (N/mm^2)
Control (0%)	16	18.89	20.44	23.85
5%	19.6	19.6	21.0	23.3
10%	16.0	19.3	19.1	20.0

15%	**17.5**	**13.7**	**18.0**	**19.3**
20%	**17.6**	**14.4**	**18.2**	**20.0**

Table V: Compressive Strength of 400^{0}C Calcined lateritic soil as Replacement for 7, 14, 21 and 28 days

Percentage Replacement	7 Days (N/mm^2)	14 Days (N/mm^2)	21 Days (N/mm^2)	28 Days (N/mm^2)
Control (%)	**16**	**18.89**	**20.44**	**23.85**
5%	**16.1**	**17.6**	**20.9**	**23.3**
10%	**15.6**	**16.6**	**17.9**	**20.4**
15%	**16.0**	**18.1**	**19.5**	**20.3**
20%	**15.9**	**20.3**	**18.8**	**21.4**

Table VI. Compressive Strength of 600^{0}C Calcined lateritic soil as Replacement for 7, 14, 21 and 28 days

Percentage Replacement	7 Days (N/mm^2)	14 Days (N/mm^2)	21 Days (N/mm^2)	28 Days (N/mm^2)
Control (%)	**16**	**18.89**	**20.44**	**23.85**
5%	**19.6**	**14.2**	**20.7**	**21.0**
10%	**15.1**	**20.4**	**19.8**	**21.8**
15%	**14.1**	**20.4**	**18.7**	**18.0**
20%	**17.3**	**20.0**	**14.4**	**20.2**

Table VII: Soil Classification

TEST NO	PSD (%)			ATTERBERG LIMIT		USC SYSTEM	AASHTO CLASSIFICATION
	SIEVE NO 10	SIEVE NO 10	SIEVE NO 10	LL	PI		
1	99	72.0	49.2	44.2	17.5	OL	A-7
2	92	72.3	39.3	38.5	18.7	CL	A-6
3	94	89	64.7	45.8	15.5	OL	A-7

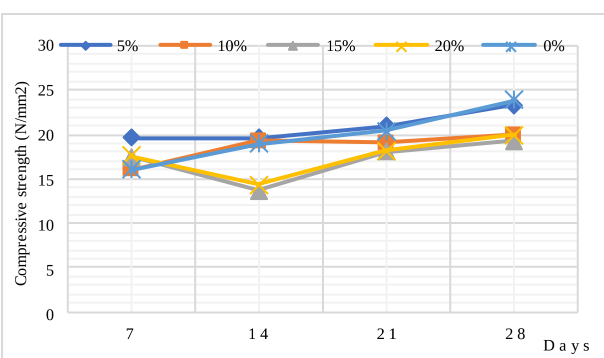

Fig. 1. Compressive Strength against days for 0% ,5% ,10%, 15%, and 20% cement replacement at calcination temperature of 200^{0}C

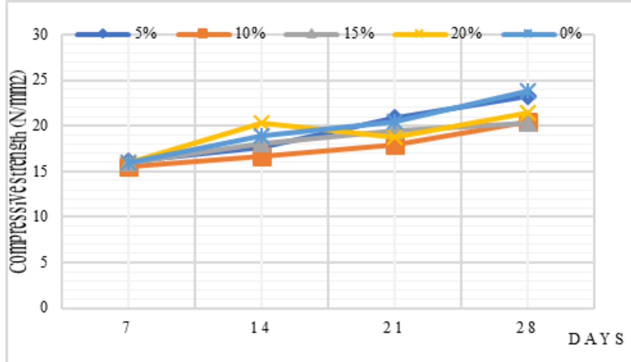

Fig. 2. Compressive Strength against days for 0% ,5% ,10%, 15%, and 20% cement replacement at calcination temperature of 400^{0}C

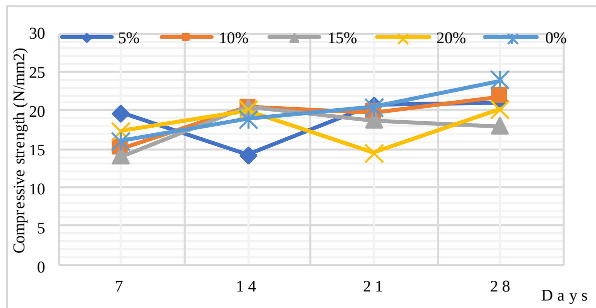

Fig. 3. Compressive Strength against days for 0% ,5% ,10%, 15%, and 20% cement replacement at calcination temperature of 600^{0}C

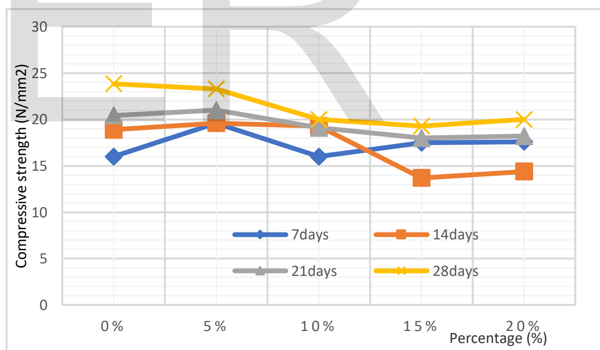

Fig. 4. Compressive Strength against percentage replacement for 7, 14, 21and 28days at a calcination temperature of 200^{0}C

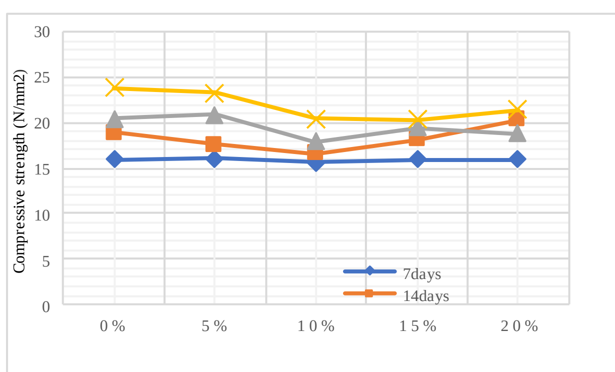

Fig. 5. Compressive Strength against percentage replacement for 7, 14, 21and 28days at a calcination temperature of 400^{0}C

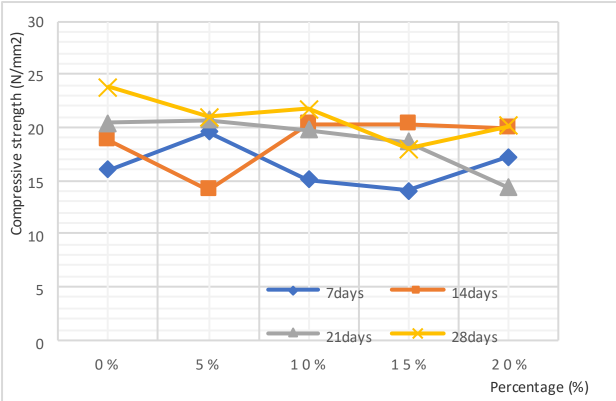

Fig. 6. Compressive Strength against percentage replacement for 7, 14, 21and 28days at a calcination temperature of 600^0C

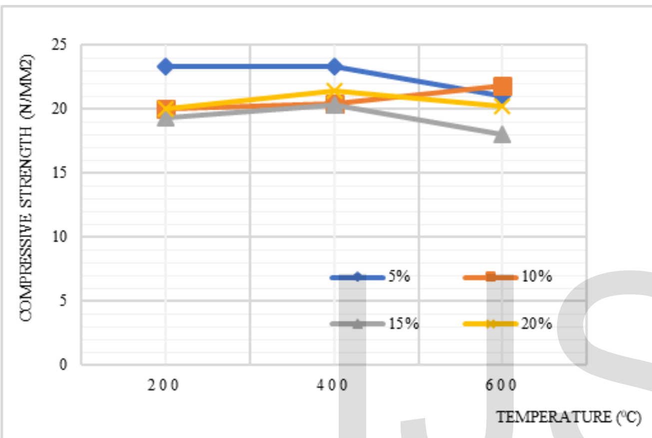

Fig. 7. Compressive Strength against calcination temperature at 28days

B. Discussion

For compressive strength test cube specimens was prepared without replacement. Compressive strengths of calcined lateritic soil concrete (0–20% replacement) at different days are shown in Table I – VI and Figure 1 - 7. Targeted compressive concrete strength of 20N/mm^2 at 28 days was attained for all specimens up to 0– 20% replacement of cement for 400^0C calcination temperature while that for 15% for 200^0C and 600^0C replacement was slightly lower. The results showed that the compressive strength at age 28 days of concrete with 5% of 200^0C and 400^0C calcined lateritic soil replacement of cement exhibits a compressive strength (23.3N/mm^2). This is about 2.3% reduction when compared with concrete strength of 0% replacement (23.85 N/mm^2). For 5% of 600^0C calcined lateritic soil replacement compressive strength shows a reduction of up to 12% of concrete strength of 0% replacement. For 10% cement replacement, the compressive strength decreased about 17.8%, 14.5%, and 8.6% from the original strength for 200^0C, 400^0C and 600^0C respectively. For 15% cement replacement, the compressive strength decreased about 16.6%, 14.9%, and 24.5% of the original strength for 200^0C, 400^0C and 600^0C respectively. For 20% cement replacement, the compressive strength decreased about 16.6%, 10.3%, and 14.9% of 0% cement replacement for 200^0C, 400^0C and 600^0C respectively.

Soil Classification

From Table 7.0 the predominant soil type collected from the site is A7 and OL by AASTHO and USC system soil classification respectively.

IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

This research was conducted to evaluate the effect of calcined lateritic soil as partial replacement of cement on the compressive strength of concrete. The following conclusions drawn are based on the result of the investigation:

i. Target compressive concrete strength of 20N/mm^2 at 28 days was attained for all specimens up to 0 – 20% replacement of cement with calcined lateritic soil for 400^0C calcination temperature.

ii. Target compressive concrete strength of 20N/mm^2 at 28 days was achieved for specimens with 0, 5, 10 and 20% replacement of cement with calcined lateritic soil for 400^0C and 600^0C calcination temperature while that for 15% replacement was a little lower.

iii. Calcined lateritic soil can be used as a replacement of cement for a percentage up to 20%

iv. The predominant soil type collected from the site is A7 and OL by AASTHO and USC system soil classification respectively.

B. RECOMMENDATION

Based on the conclusions from this study, the following recommendations are made:

i. The use of calcined lateritic soil as partial replacement of cement should be embraced and not be frightened for the production of concrete during construction.

ii. The calcined lateritic soil can be used in concrete mixes as cement with 5% to 20% for 200^0C and 400^0C respectively.

iii. further research on durability and chemical composition aspects of calcined lateritic soil replaced concrete is essential to recommend this material for sustainable concrete practice.

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