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Assessment of Influence Calcined Black Cotton Soil on the Fresh Properties and Tensile Strength of Concrete (A Case Study of Black Coting Clay Calcined at 700^{O}C)

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Abstract: *Supplementary cementing materials (SCM) have become an integral part of high strength and high performance concrete mix design. These may be naturally occurring materials, some of the commonly used supplementary cementing materials super plasticizer. It is being used very commonly as pozzolanic material in mortar and concrete, and has exhibited considerable influence in enhancing the mechanical and durability properties of mortar and concrete. The use of black cotton soil as partial replacement of cement 10% in concrete. Properties reported in this research be situated the fresh mortar/concrete properties, mechanical and durability properties. Best on the analysis show the higher percentage of black cotton soil less strength obtain, compare to 0% of cement. The regression graph shows negative value Correlations to control.*

Keywords: *Clay, Supplementary Cementing Materials and Strength.*

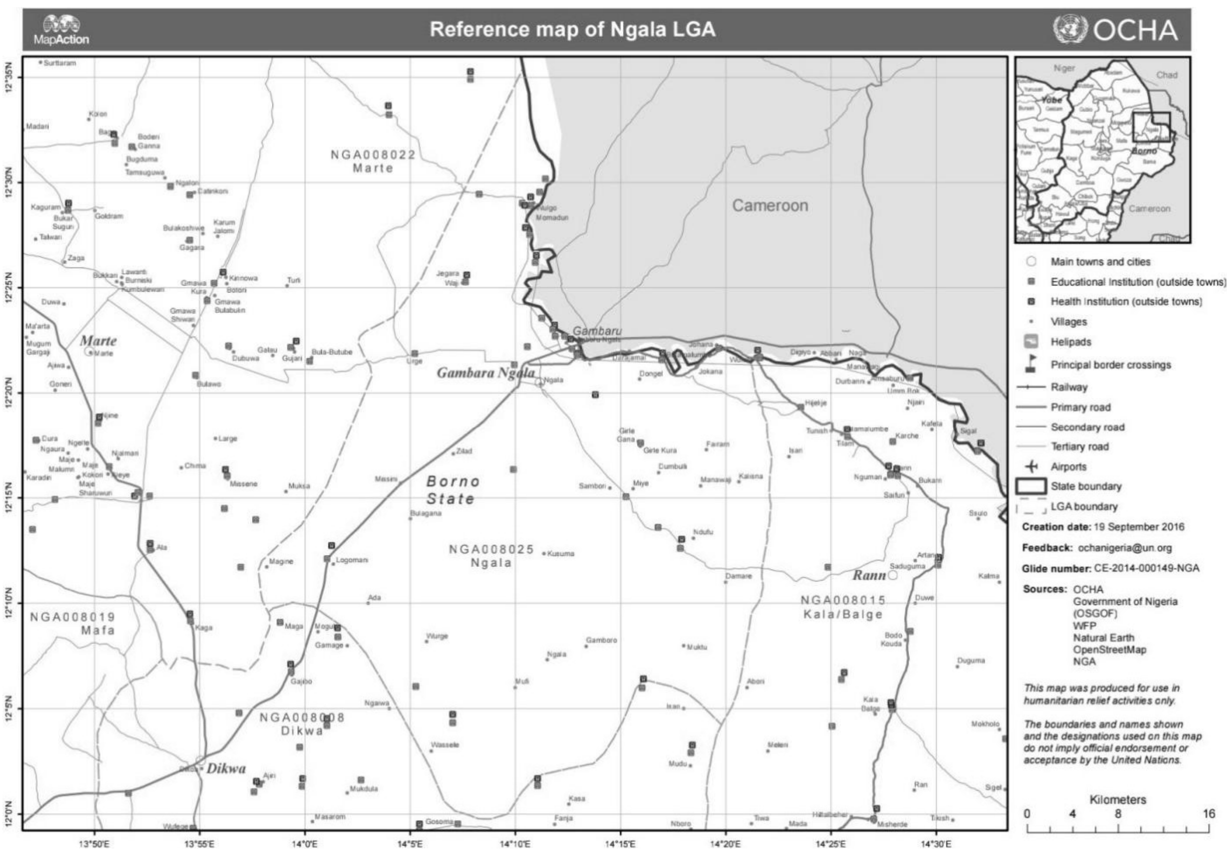
INTRODUCTION

Concrete is the most consumed material in the world after water. Cement is the most expensive and energy intensive ingredients of concrete. For each ton of cement, there is between 0.5 and 1 ton of carbon dioxide emitted into the atmosphere (Rubenstein, 2012). In order to reduce the unit, cost of concrete and the energy required for its production, the use of waste materials, industrial by products, and innovative materials is becoming necessary. Using waste materials to replace cement will reduce the amounts of materials sent to landfill and the amount of cement used in concrete (Baalbaki, 2003, 2005). Pozzolanic materials are silica or silica-alumina based materials and can be incorporated in concrete as partial substitution of cement. Provided that proper curing is employed, these materials can react with the products of cement hydration to produce additional gels which would contribute to strength enhancement and durability. These materials can be waste, industrial by-products or natural materials. Pozzolanic materials include fly ash (Baalbaki and Blondin, 1994), silica fume, and ground granulated blast furnace slag.

Other materials such as calcined clays are also pozzolanic materials but require energy to produce as they are not either waste or industrial byproducts.

METHODOLOGY

This research was carried out from Black Cotton clay soil type found at Ngala local government area of Borno State of Nigeria, adjacent to the border with Cameroon. It is situated in the east central area of the state. It is not far from the Chard Basin, which has been a structural depression since the tertiary period. It has vast fertile lands of Black cotton clay soil types, where crops like wheat, rice and vegetable are grown under irrigated conditions.



Materials

In making any type of concrete, selection of appropriate types of materials is very important as all the properties depends on them. The following materials were used and as explained below.

Cement

In this research study, the Ordinary Portland Cement (OPC) was used and that is equivalent to ASTM Type 1. The use of OPC was in compliance with the limits of the British Standard BS 12:1996. OPC is the most common cement used in general concrete construction when there is no exposure to sulphates in the soil or groundwater. Initial setting time of OPC is faster than PPC (Portland Pozzolana Cement), so it is recommending in projects where props are to be removed early. It is easy to handle as compared to PPC. Its initial strength is higher than PPC. Curing period of OPC is less than PPC and curing cost reduces. Hence it is recommended where curing cost prohibitive. OPC is environmentally friendly and economical. Therefore, the study uses Ordinary Portland Cement OPC and was obtained from cement vendors in Nigeria.

Aggregate

Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Coarse aggregates are any particles greater than 0.19 inch, but generally range between 3/8 and 1.5 inches in diameter. River aggregates was used.

Gravel

Gravel is a loose aggregation of rock fragments. Gravel is classified by particle size range and includes size classes from granule- to boulder-sized fragments. It is categorized into granular gravel (2 to 4 mm or 0.079 to 0.157 in) and pebble gravel (4 to 64 mm or 0.2 to 2.5 in). ISO 14688 grades gravels as fine, medium, and coarse with ranges 2 mm to 6.3 mm to 20 mm to 63 mm. One cubic metre of gravel typically weighs about 1,800 kg (or a cubic yard weighs about 3,000 pounds). It was obtained from vendors.

Water

Water is the key ingredient, which when mixed with cement, forms a paste that binds the aggregate together. The water causes the hardening of concrete through a process called hydration. The role of water is important because the water to cement ratio is the most critical factor in the production of "perfect" concrete. Therefore, the study was used tap water throughout.

Experimental Procedure

Workability Test

The workability of the fresh concrete mix was determined by the slump test. Fresh concrete was placed into a slump cone in three layers and compacted with a tamping rod to ensure all air pockets were removed. The slump cone was removed and the slump height was determined by measuring the difference between the cone height and the fresh mix.

Specific Gravity of Ordinary Portland cement Determination

Weighed a clean and dried specific gravity bottle with its stopper (W_1). Was placed a sample of cement up to half of the flask (about 50g) and was weighted with its stopper (W_2). Add kerosene to cement in flask till it is about half full. Mix thoroughly with glass rod to remove entrapped air. Continue stirring and add more kerosene till it was flushed with the graduated mark. Dry the outside and weigh (W_3). Empty the flask, clean it and refill with clean kerosene and flush with the graduated, also dry the outside and weigh (W_4).

$$\textbf{Cement Specific Gravity} = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4) \times 0.79}$$

Where:

W_1 = Weight of empty flask
W_2 = Weight of empty flask + Cement
W_3 = Weight of empty flask+ Cement + Kerosene
W_4 = Weight of empty flask+ Kerosene
0.79 = Specific Gravity of Kerosene

Specific Gravity of Aggregate Determination

Determined and recorded the weight of the empty clean and dried pycnometer, W_P. Then place 120g of a dried aggregate sample in the pycnometer. Also, determined and recorded the weight of the pycnometer containing the dried aggregate, W_{PS}. Added distill water to fill about half to three-fourth of the pycnometer. Soak the sample for 10 minutes. Applied a partial vacuum to the contents for 10 minutes longer, to remove the entrapped air. Stop the vacuum and carefully removed the vacuum line from pycnometer. Filled the pycnometer with distil (water to the mark), clean the exterior surface of the pycnometer with a clean, dried cloth. Determine the weight of the pycnometer and contents, W_B. Empty the pycnometer and cleaned it. Then fill it with distill water only (to the mark). Clean the exterior surface of the pycnometer with a clean, dried cloth. Determine the weight of the pycnometer and distil water, WA. Empty the pycnometer and cleaned it.

$$\text{Specific Gravity}, G_S = \frac{W_0}{W_0 + (W_A - W_B)}$$

Where:

W_0 = weight of sample of oven-dry soil, g = W_{PS} - W_P
W_A = weight of pycnometer filled with water
W_B = weight of pycnometer filled with water and soil

Grain Size Analysis of Aggregate

Grain size analysis is the determination of the size grain of particles present in a soil. It is expressed as a percentage of the total dry weight. Two methods are generally used to find particle size distribution of soil: (1) Sieve analysis. (2) Hydrometer analysis. The sieve analysis is generally applied to the soil fraction larger than 75 µm (retaining on the No. 200 Sieve). Grains smaller than 75 µm (0.075 mm) are sorted by using sedimentation process (hydrometer analysis). Therefore, the study is adopting sieve analysis method instead of hydrometer method.

Sieve Analysis Procedure

Oven dry the aggregate sample, allowed it to cooled. Then take 431g of oven dried soil. Weigh each sieve and a pan to be used W_O (then made sure each sieve is cleaned before weighing it, by using a brush to removed grains stuck in mesh openings). Arrange the stack of sieves so that the largest mesh opening is at the top and the smallest is at the bottom and attach the pan at the bottom of the sieve stack. Pour the dried sample on the top sieves. Add a cover plate (to avoid dust and lost particles while shaking). Place the stack of sieves in the mechanical shaker and shake for 10 minutes. Removed the stack of sieves from the shaker, and measured the weight of each sieve and the pan with the soil retained on them W_F. Subtract the weights obtained in step (2) from those of step (6) to give the weight of soil retained on each sieve. Their sum will be compared to the initial sample weight; both ensured to be within about 1%. Because if the difference is greater than 1%, too much material will have lost, and weighing and/or sieving should be repeated $/W_F – W_O/ >1\%$.

Preparation of Concrete and Test Specimens

In this study, the mix was designed according to British method and the mix proportion (cement: sand: stone chips) is equal to 1:2:4 and the water cement ratio (w/c) was equal to 0.5. The casting and testing process was briefly discussed below.

Mixing of Concrete

The amount of cement, sand, stone chips and water was calculated. According to the estimation, 10% of the amount of cement was replaced with kaolin by weight. The amount of sand was given as twice of cement by weight and stone chips also be fourth times of cement by weight and water was given as half of cement by weight. Then the sand, cement and stone chips was mixed properly. After proper mixing of sand, cement and stone chips, half of total amount of water was added to the mix. Then all the materials were mixed properly.

Experimental Specimens

Types of Specimen	Size	Mix Ratio	Water Cement Ratio	Curing Ages (Days)	Total No. of Specimens	
					Non-heated (control)	Heated
Short Beam	150mmX300mm	1:2:4	0.5	14,28,56	9	9
Total required Short Beam					**18**	

Heating of Sample with elevated temperature

An electric muffle furnace with a maximum operating temperature of 1200°C was used to heat the Black Cotton Clay at 700^0C. The furnace was capable of maintaining constant temperature with ± 1°C accuracy. An inbuilt thermocouple in the furnace enables its temperature to be recorded throughout the test. The internal dimensions of the furnace are 180 × 180 × 300 (deep) mm. At the time of placing the specimens inside the furnace, the furnace was at the room temperature. The furnace temperature was set with the help of digital temperature controller attached to the furnace power supply with feed-back temperature for a thermocouple located in the furnace. The furnace was completely closed during the heating and cooling cycles except for two 10 mm diameter holes for the release of fumes and these was used for placing thermocouples in the furnace. The furnace will then have switched off and the specimens were allowed to cool down for 24 hours inside the furnace. The specimens were then taken out from the furnace and were allowed to cool to the atmospheric temperature.

Concrete Placement and Compaction

In this process, the inner surfaces of the moulds were lubricated with Mobil oil which facilitates the removal of the moulds. After that, the moulds were placed in a perfect place and then the concrete mix was placed into the moulds. Here concrete was placed in three layers. And compaction was also being done in three layers. Each layer was compacted by 25 blows by temping rod. After completion of placement and compaction, the specimens were expose to air for hardening.

Curing of Specimens

The specimens were removed from moulds after 24 hours; All the specimens were carefully cured by the clean water available in the laboratory. The specimens were cured for 7, 14, 28 and 56 days at room temperature as required in this study.

3.3.11 Concrete Water Absorption Test Methods

Water absorption coefficient method was adopted to determine the water absorption rate of the produced concrete specimens. According to Parrott, (1992) the rate at which water is absorbed into concrete can provide useful information related to the pore structure, permeation characteristics and durability of the concrete surface zone that is penetrated. Basheer et al. (2001) studied the relationship between different water absorption indices and other concrete corrosion factors using water absorption approach. The specimens, with 50mm x 50mm x 50mm concrete cube will be oven dried and, after cooling, put in partial immersion in water or saturated salt solution, in closed containers. According Nolan, (1996), the process depends on following factors; surface energy, surface tension and capillarity.

The water absorption coefficient test approach employed in this research is related to that outlined in EN ISO 15148: -2002. It is significant that the specimens have the same initial moisture content. In this project, the following procedure was adopted to ensure this condition. 75mmX75mmX1000mmconcrete Beams was cured for 7, 14, 28 and 56 days, followed by drying at 105˚C in the oven for a further 1 day and allow to cool at test condition until the weight of each specimen stabilized to within 0.1% of its total mass, when measured over 24 hours as adopted by YEN, (2007).

Water absorption was measured by weighing the specimen initial weight on an electronic balance then the measurement was continuing at time intervals of 30 min, 60 min, and 90 min. weighing will be conducted immediately to reduce evaporation from the sample.

Determination of Split Cylinder Test

Split cylinder test used to estimate the tensile strength of concrete. Cylinder concrete specimen of 150 mm diameter and 300 mm length are placed in the apparatus, as shown a compressive load is applied uniformly until the concrete split. A metal strip is placed above the concrete specimen to ensure a uniform distribution of the compressive load to the concrete sample. The compressive load at the time of splitting is measured and recorded. Tensile strength of concrete can be calculated using the following equation:

$$Ft = (2P)/(\pi * D * L)$$

Where:
P is the compressive load at the failure
D is the diameter of the specimen
L is the length of the specimen

Figure 1: Sample for the tensile strength test

RESULTS AND DISCUSSION

Result: Physical Properties of Aggregate

	Coarse Aggregate	Fine aggregate
Specific gravity	2.73	2.51
Crushing Value	18%	
Clay lumps	Nil	Nil
Moisture Content	3.20%	Nil
Fineness Modulus	3.77%	
Absorption	1.22%	

Physical Properties of Cement

Specific gravity	3.53
Minimum strength at 7days	32.5N/mm2
Maximum strength at 28days	47.8N/mm2
Initial setting time	45mins
Final setting time	153mins

Laboratory Results of Tensile Strength

S/N	Curing Ages (days)	Control Sample (Mpa)	Tensile Strength (Mpa) with 10% Black Cotton Clay Replacement
1	14	7.37	7.23
2	28	7.75	7.84

Test: Two-Sample Assuming Unequal Variances

	Contro l	***Strength (BC-700-10%)***
Mean	7.56	7.535
Variance	0.07	0.19
Observations	2	2
Hypothesized Mean Difference	0	
Df	2	
t Stat	0.07	
P(T<=t) one-tail	0.48	
t Critical one-tail	2.92	
P(T<=t) two-tail	0.95	
t Critical two-tail	4.30	

There is no significant difference between 10%Calcined Black Cotton replacement and the control sample. Therefore, the 10% replacement is almost the same with the control sample.

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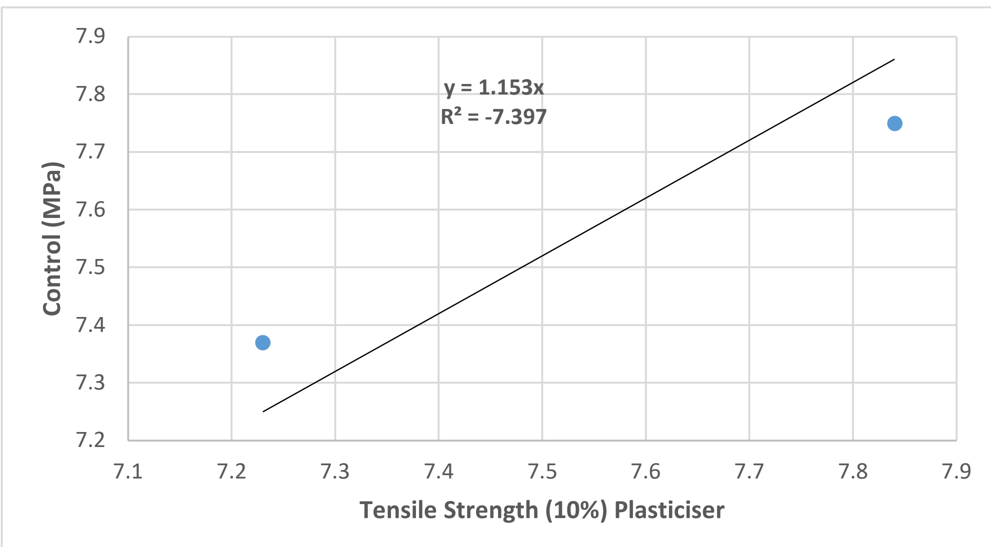

Regression Analysis for control and 10% Black cottonReplacement Sample
The graph shows that, there is negative correlation of -7.397 or –ve 7.397% which means, the increase in Black Cotton percentage may lead to the decrease in tensile strength.

CONCLUSION AND RECOMMENDATION

Conclusion

Based on the analysis, the following conclusions were drawn:

1. The t – test shows that, there is no significant difference between the control sample and the 10% Black Cotton replaced sample with cement in terms of tensile strength.
2. The regression graph indicates negative correlation between the control and the experimented sample. This shows that, the higher the Black Cotton replacement, the lower the tensile strength.

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