Strength Characteristics of Concrete Beams with Cement Partially Replaced by Uncalcined Soldier-Ant Mound Clay

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ABSTRACT
Various researchers in the recent past have investigated the pozzolanic properties of many waste materials like fly ash, electric arc furnace slag (a by-product of steel production), ground broken bottles, ashes produced from various agricultural waste such as palm oil waste, rice-husk ash, wheat straw ash, etc. No research findings have been reported on uncalcined soldier-ant mound clay (SAMC) as a pozzolana. It is therefore the aim and objective of this work to consider uncalcined soldier-ant mound clay as pozzolana. Eighty-four (84) beam specimens were cast, with seventy-two having cement replaced with soldier-ant mound clay varying from 5% to 30% at 5% interval. A concrete mix ratio of 1:2:4 (Cement/SAMC: sand: granite) with 0.65 water/cement ratio was adopted for this investigation. Results indicate that the addition of SAMC in the mix produced concrete of lower density than normal concrete; increases the initial and final setting time of cement with increased workability. The density as well as the flexural strength of concrete decreased with increase in SAMC content. However, 5% SAMC content in the mix is considered optimum for improved structural performance when compared with normal concrete.

Keywords: Concrete slabs, Soldier-Ant Mound Clay, Density, Flexural strength, Crack pattern.

1.0 INTRODUCTION

Pozzolanic materials are siliceous or siliceous and aluminous materials, which in themselves have little or no cementation value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration, at ordinary temperature to form compounds, possessing cementations properties.

According to Mehta and Aitan (1990), the small particles of pozzolana are less reactive than Portland cement but when dispersed in paste they generate a large number of nucleation sites for the precipitation of hydrocarbon products. Therefore, the mechanism makes the paste more homogeneous and dense, because of the pozzolanic reactions between the amorphous silica of the minerals added and the calcium hydroxide produced by the cement hydration reactions. The physical effect of the fine grains allows denser packing within the cement and reduces the wall effect in the transition zone between the paste and the aggregates.

Math (1997) reported that the utilization of fly ash is 70% in Australia, 4% in UK, and 4% in cement manufacturing in France. Fly ash is extensively used in concrete as an admixture in order to reduce cost of cement. Salau (1997) studied the effect of partial replacement of Ordinary Portland Cement (OPC) with pulverized Electric Arc Furnace (EAF) slag and concluded that up to 30% of Ordinary Portland Cement could be replaced with pulverized EAF slag without impairing the eventual strength of the OPC and recommended its use where reduced heat of hydration in the early life of concrete is essential. Stoitchkov *et al* (1996) presented the results on the physical and mechanical properties of cement mortars and concretes containing the active mineral “Pozzolit” admixture. They observed that the behaviour of the admixture is similar to that of micropelletized silica fume and that cement with "pozzolit" admixture exhibits strength 20 – 30% higher than those in reference samples as well as lower gas permeability and increased content of pores of smaller radius.

Bin Alam *et al* (2006) carried out a study on the utilization of fly ash generated from Barapuker power plant and reported that the fly ash is used as an admixture with Shah special cement in 5%, 10% and 15% proportion. Results show that 10% replacement level was optimum as almost no loss of strength in the mixes was recorded.

Oyekan and Kamiyo (2008) studied the effects of rich husk ash (RHA) on some engineering properties of concrete blocks and cement and concluded that the addition of RHA in the mix produced sandcrete of lower density and compressive strength. However, RHA had fairly significant effect on the compressive strength of the concrete cube specimens, increasing the latter by nearly 17% (at 28 days) and at 5% RHA content.

Al-Rawas *et al* (2001) investigated lateritic clays from five sites in Northern Oman, subjecting them to extensive programme of testing involving chemical, mineralogical, thermal and physical analysis and concluded that the total content of silica, alumina and iron oxide together with the burning temperature and duration of burning have significant effects on the physical properties of the pozzolans. Elinwa (2004) investigated calcined soldier-ant (termite) mound clay (CSAMC) as cement replacement in cement mortar and concrete. Results of the study show that CSAMC, as pozzolana, can reduce the heat of hydration of cement by about 17% when 40% cement is replaced with it. It also accelerates the setting time of concrete.

Various researchers in the recent past have investigated the pozzolanic properties of many waste materials like fly ash, electric arc furnace slag (a by-product of steel production), ground broken bottles, ashes produced from various agricultural waste such as palm oil waste, rice-husk ash, wheat straw ash, etc. No research findings have been reported on uncalcined soldier-ant mound clay as a pozzolana. It is therefore the aim and objective of this work to consider uncalcined soldier-ant mound clay as pozzolana.

2.0 MATERIALS AND EXPERIMENTAL PROCEDURE

The soldier-ant mound material used was collected from a heap of termite mound at the lagoon front area of the University of Lagos. The outer clay was scraped off as this has for long been exposed to ambient atmospheric conditions which may adversely hinder objective assessment of the chemical composition of the material. The inner clay was milled into fine powdered form and the particles that passed through sieve 212μm were used. Figure 2 shows the particle size distribution of the fine and coarse aggregates as well as cement and the termitaria clay. The results of the preliminary tests, carried out on the aggregates are shown in Table 2.

The mix proportion of 1:2:4 (cement/SAMC: sand: granite chippings) by weight with water cement ratio of 0.65 was adopted for this investigation. The proportion of grinded soldier-ant mound of the total cement content was varied from 5% to 30% in steps of 5% in the mixes. A total of eighty-four (84) cubes of 150 x 150 x 150mm as well as eighty-four (84) beams of size 150 x 150 x 770 were cast and tested. The specimens were tested in accordance with BS 1881. Figure 1 shows the typical loading arrangement of a test beam specimen.

3.0 RESULTS AND DISCUSSION

3.1 Chemical Analysis of Uncalcined Soldier-Ant Mound Clay

The chemical analysis of the grinded soldier-ant mound clay and Ordinary Portland Cement used in this investigation is presented in Table 1 below. These compounds in SAMC have no cementitious values but in finely grinded form and in the presence of moisture, chemically react with calcium hydroxide compounds which have cementitious properties. The Silica (SiO_2) content of SAMC is 61.50% which exceeds the recommended value, according to ASTM C618 by 40%. Also, the total content of SiO_2, Al_2O_3 and Fe_2O_3 in the SAMC is in excess of the recommended 70%. The CaO is within the recommended limit of 10%. From the results obtained, the constituent materials of SAMC conformed to requirements of ASTM C618; hence the material is a good pozzolana as it exhibits good pozzolanic properties.

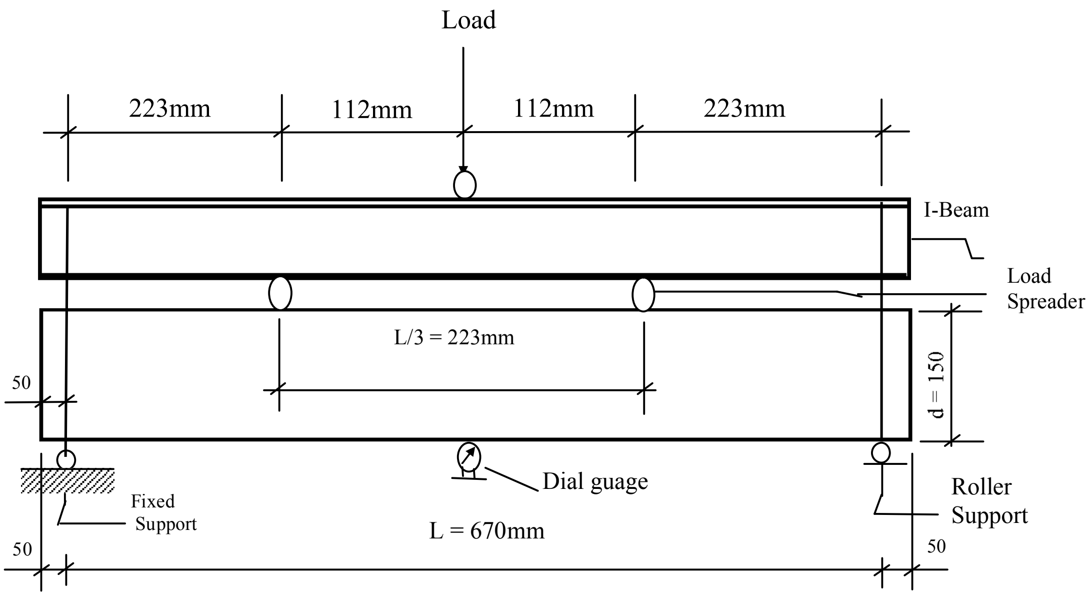

Figure 1: Typical Beam and Loading arrangement

Table 1. Chemical Analysis of Uncalcined Soldier-Ant Mound and Cement

Chemical Composition	Uncalcined Soldier-Ant Mound %	Ordinary Portland Cement %
Silica (SiO_2)	61.50	20.90
Calcium Oxide (CaO)	2.02	64.60
Sodium Oxide (Na_2O)	0.26	0.17
Ferrous Oxide (Fe_2O_3)	16.19	4.72
Potassium Oxide (K_2O)	0.60	0.41
Aluminium Oxide (Al_2O_3)	29.20	5.20
Sulphate (SO_3)	0.44	1.46
Magnesium Oxide (MgO)	0.69	2.00
Loss of Ignition (LOI)	7.76	1.13
Lime Saturated Factor (LSF)	0.79	-

3.2 Physical Properties and Sieve Analysis.

The particle size distribution curves of the aggregates, cement and SAMC are shown in Figure 2. There is hardly a distinct difference in the cement and SAMC used in this investigation. The cement and SAMC recorded bulk density values of 1475.0 and 1073 kg/m_3 respectively, indicating that the SAMC was 27% lighter than cement. The specific gravity of the sand, granite, cement and SAMC were 2.65, 2.69, 3.15 and 2.60 respectively. It is observed that the specific gravity of the cement was

26% higher than that of the SAMC, which is an indication that the inclusion of SAMC in concrete mixes will result in lighter product.

Table 2: Some Physical Properties of Aggregates, Cement and SAMC

	Sand	Granite	Cement	SAMC
Shape Index	-	0.15	-	-
Fineness Modulus	2.51	-	-	-
Fines content (% passing through 0.063 sieve)	0.14	-	40.2	15.0
Flakiness Index (%)	-	8	-	10
Bulk Density (kg/m^3)	1280.0	1547	1475	1073
Moisture Content (%)	0.46	-	-	0.38
Los Angeles Abrasion (%)	-	26	-	-
Uniformity coefficient	1.34	1.07	-	-
Void Ratio	0.4	0.37	-	-

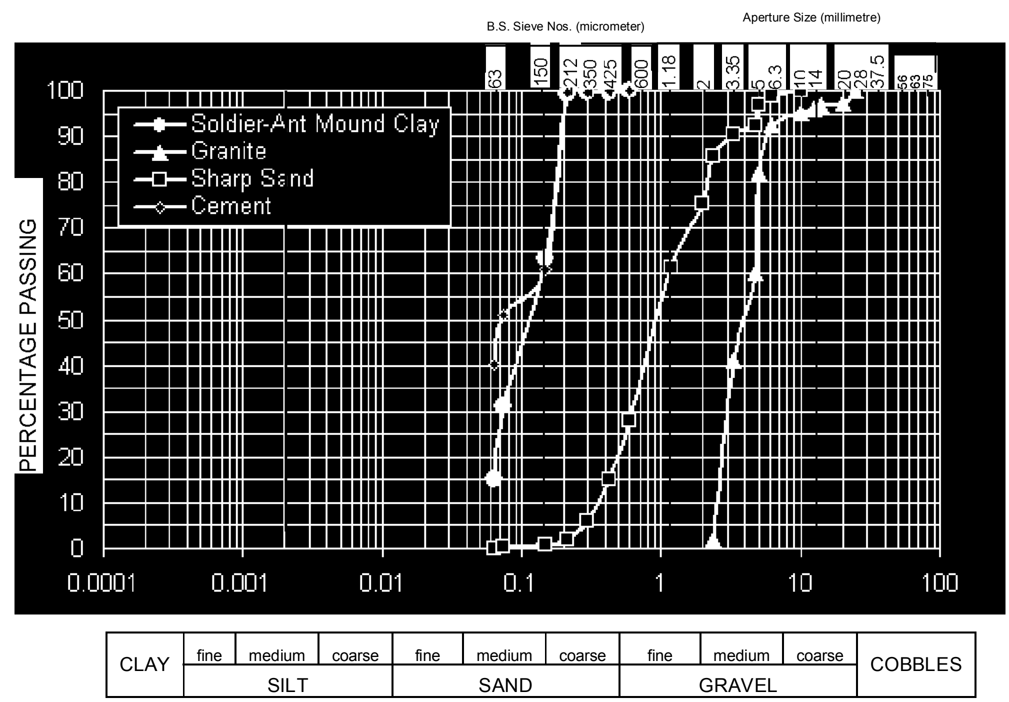

Figure 2: Particle Size Distribution Curves of Aggregates, Cement and SAMC

The pozzolanic activity index (PAI) was determined and found to be 76%. This exceeds the minimum requirement of 70%

The coefficients of curvature of the sand and granite aggregates as shown in Table 2 are 1.34 and 1.071 respectively. It showed that the sand and granite particles were reasonably well graded aggregate materials in this experiment. The granite aggregate recorded a shape index value of 0.15. The moisture content, determined in accordance to BS 1377 – part 2. The other parameters measured are presented in the table.

3.3 Effects of SAMC on the Setting Time of cement.

The results indicate that the addition of SAMC considerably advanced the initial and final setting time of cement based pastes. The SAMC particles in the pastes act as agents to promote nucleation and prompt accelerated hydration mechanism. The acceleration of the setting time of cement pastes could have been caused by the increasing volume of hydration compounds as well as the reduction of distances between individual particles as a result of the presence of SAMC particles in the matrix. The close network so formed by the SAMC particles act as barrier to limit the plastic flow capability of the mixes; hence accelerated setting time is enhanced.

As the percentage substitution of cement with SAMC increases, the initial and final setting time advanced (decreased). At 30% substitution level, the initial setting time reduced by 84.6% while the final setting time advanced by 30.19%. With these results, it could be opined that SAMC is a very effective cement setting time accelerator.

3.4 Densities and Compressive Strengths of Concrete with SAMC

Table 4 shows the values of densities for cubes and beam specimens with different contents of SAMC.

Table 4: Physical Characteristics of concrete mixes with different percentages of SAMC in Cement

% SAMC in Cement	Slump (mm)	Setting Time (minutes)		Average Density (kg/m^3) (Days)		Average Cube Strength (N/mm^2) (Days)	
		Initial	Final	7	28	7	28
0	50	26	212	2367	2376	20.37	26.81
5	53	20	196	2343	2349	19.19	26.00
10	59	12	189	2339	2345	15.93	24.59
15	64	9	172	2329	2338	13.78	19.93
20	68	7	166	2322	2331	10.52	15.63
25	73	6	152	2320	2324	6.37	11.56
30	79	4	148	2309	2315	2.89	9.19

This same trend in mean density and average cube strength was observed for 21- and 28-day curing ages. These results showed that the moisture content and moisture absorption tendency of the specimens increased with curing age, thus resulting into increase in weight and density of test specimens with age. The gain in density from the fresh state at cast to hardened, well water-cured state decreased with increasing SAMC content, and could have reduced the bond between cement and aggregate particles and the nature of interface between the aggregate and cement. The variance in specific gravity of cement (3.15) and SAMC (2.60) is also responsible for the reduction in the density of concrete produced, as the percentage of SMC content in the mix increased.

3.5 Effects of SAMC on Compressive Strength

Figure 3 and Table 4 show the compressive strength with variation of SAMC content in cement and curing age.

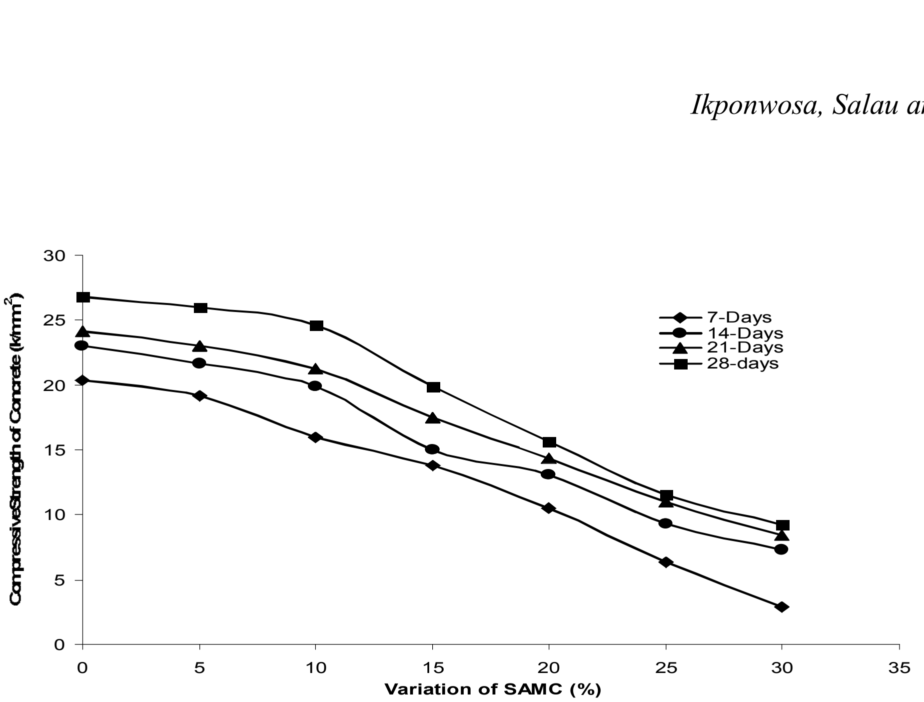

Figure 3. Variation of Strength with Percentage SAMC

All tested specimens and load cases for different percentages of SAMC showed increases in load bearing capacities as curing age increased. Also, with increase in percentage content of SAMC, compressive strengths of specimens reduced almost linearly. Up to 20% substitution of Cement with SAMC at 5% interval, the strength varied between 31.62 and 48.57% when compared with control. For 25 and 30% substitution levels, the percentage difference in strengths was 81.48 and 217.99%. This is an indication that substitution of cement with SAMC beyond 20% level is not recommended for production of concrete structural components.

3.6 Effect of Percentage of SAMC on Flexural Strength of Concrete Beams

Figure 7 presents the relationship between flexural strength and curing age for test specimens with various percentages of Soldier-ant mound clay (SAMC).

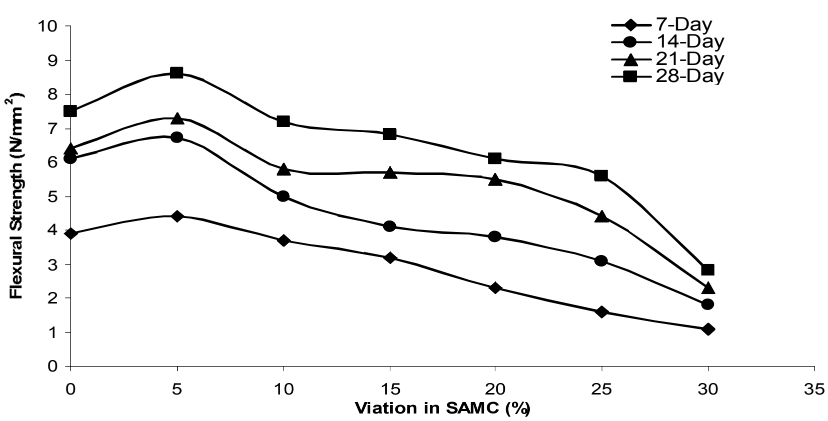

Figure 4. variation of Flexural Strength With Percentage SAMC

For test beam specimens, as curing age increase from 7 t0 28 days, a gradual decrease in flexural strength was observed as the percentage of SAMC content increases. The maximum value of flexural strength attained were 4.4, 6.7, 7.3 and 8.6 N/mm^2 for 7-, 14-, 21- and 28-day curing ages respectively, suggesting that the substitution of cement with Soldier-Ants Mound Clay should be limited to 5%.

4.0 CONCLUSIONS AND RECOMMENDATION

The results of the experiments carried out on Soldier-Ants Mound Clay as partial replacement for cement in concrete show that:

(i) The results of chemical analysis of SAMC indicate that all the chemical compounds contents conformed to the requirements of American Society for Testing and Materials Specifications for Pozzolanas (ASTM-C618 92a).

(ii) With the addition of SAMC, the setting time of the paste is accelerated. This shows that SAMC is an accelerator and will be effective for cold weather concreting and where early removal of formwork is required. The workability of the mix also increased as Solider-Ant Mound Clay (SAMC) content increased.

(iii) Generally, the densities and compressive strengths of concrete containing SAMC decreased as the percentage of SAMC content increased in the mix.

(iv) The flexural strength of concrete containing 5% of SAMC content is higher than that of reference concrete mix. This shows that concrete containing 5% SAMC content can be used for structural element such as beams.

(v) The optimum replacement level for SAMC content in concrete beam production is about 5%.

It is recommended that effect of ageing should be considered on the pozzolanic effect of SAMC.

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