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Research Article

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Strength of Ternary Blended Cement Composites Concrete Containing Rice Husk Ash and Laterite

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Abstract Thestrength characteristics of ternary blended cement composites made with Ordinary Portland Cement (OPC), Rice Husk Ash (RHA) and Laterite (LAT) were investigated in this work. Twenty Seven (27) concrete cubes of 150mm x 150mm x 150mm were produced at percentage OPC replacement of 0%, 15% - 85 IT [15 P] and 25% - 75 IT [25 P]. Eighteen (18) concrete cylinders of 200mm X 100mm were cast for the Splitting Tensile Strength of the mixtures at percentage replacement of 0%, 15% and 25%. The hardened samples were crushed at the end of the designated curing days of 7, 14 and 28 days for both the compressive and the tensile strength tests. The analytical aspect of this thesis used Coefficient of Variation (CoV) to examine the degree of dispersion between the compressive and splitting tensile strength.The compressive strengths of the 28 days samples for the ternary blended mix were 15.63 N/mm^2 for 15% replacement, 11.06 N/mm^2 for 25% replacement, while that of the control was 35.67 N/mm^2. The implication of the results obtained is that the maximum compressive strength for the ternary blended mix can be obtained at 15% replacement. The 28 days compressive strength for the control samples had a lower CoV which indicates that it is of a better quality in comparison to the splitting tensile strength values. That of the 85 IT [15 P] followed the same trend while 75 IT [25 P] for the splitting tensile strength had a low CoV – better quality in comparison to the compressive strength values. Apparently, the strength of the ternary blended mixture 85 IT [15 P] at 28 days is far less than that of the control mixture. Thus, it is not suitable for civil engineering or building works. The study recommended that it should be re-examined using the dry curing method for its suitability for technical purposes.

Keywords Rice husk ash; Laterite; Supplementary cementitious materials; Compressive strength test; Splitting tensile strength test

Introduction

Concrete is undoubtedly an important material in the built environment. According to Encarta Encyclopedia, it is produced from a variety of minerals which include: sand, cement, gravel or granite, and usually mixed with water and other fluids. It has found its use in almost every aspect of human endeavour and it is adjudged one of the best discoveries in human civilisation. Of all man-made construction materials in the world, concrete is the most used [1]. This fact necessitates it as a material of concern to relevant stakeholders in the built environment. However, in spite of the numerous uses of concrete, it presents some challenges that make it a deleterious material to man and his environment. The detriments associated with concrete are due largely to the composite materials that make up the hard mass. Chiefly among these composite materials is the Portland cement. The Portland cement, according to Encyclopedia Britannica, is the product obtained when limestone, shale and/ or clay is burnt and ground into powder and used as a binding material. The discharge of harmful gases and other matters in addition to the energy expended in processing and distributing cement are some of the environmental challenges encountered. Producing cement accounts for 10% rise in CO_2 production in the world [2]. Similarly, [3] mentioned the problem with Laterite as its reddish or brownish colour which may invariably result in an unwanted colouration of the blended concrete matrix. Also worthy of mentioning is the lack of publicity to most of these studies which sometimes prevents their dissemination to industries and relevant stakeholder in the built environment [4].This study will investigate the use of a combination of natural and artificial pozzolans with the aim of reducing the energy required to produce a Pozzolanic Cement which contains artificial/ natural pozzolan only. The objectives are to study the energy required to produce the pozzolans and compare same with that of OPC with a view to finding whether there is a reduction in the energy requirement.

Methodology

Materials

The concrete ingredients are:

Portland Cement (PC): The cements that were used for this study was obtained from Dangote cement company PLC Ibese plant, along Ilaro road Ibesa Ogun state and conforms to [5] and [6].

Coarse Aggregate: The granite used had a maximum aggregate size of ¾" and a minimum aggregate size of $^3/_8$". The absorption rate of the aggregate is 0.80% while its Fineness Modulus is 3.36. It conforms to [7].

Fine Aggregate: The fine aggregate used for this study was natural river sand in Ikorodu, Lagos. The sand had an absorption rate of 1.5% and Fineness Modulus of 0.78. It conforms to [7].

Portable Water: The water that was used throughout the tests was a drinking water and obtained from the public supply system in Yaba College of Technology, Yaba Lagos. It appears clean and free from any visible impurities, conforming to [8].

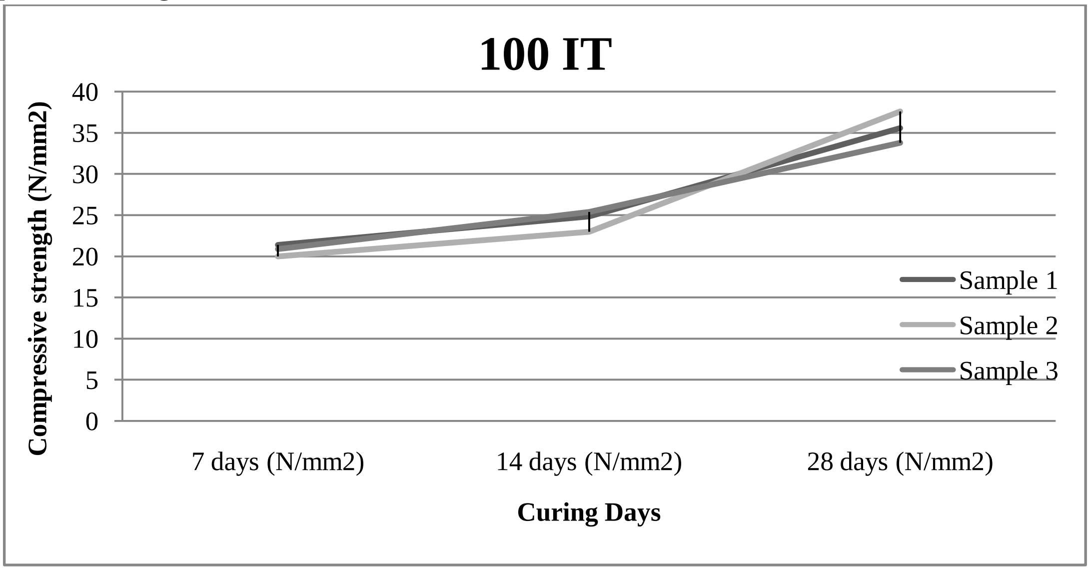
Rice Husk Ash: Rice husks are the hard coverings of rice grains which are removed from the grains during milling process. The Rice Husk used for this study was obtained from a local "Ofada" rice mill at Waasinmi in Ogun State - Nigeria. The Husk was taken from a heap and stored in a sack internally protected with polythene. The Rice Husk Ash was heated and reduced to ash in a gas kiln at about 800 ºC in the ceramics laboratory - the Federal Institute of Industrial Research, Oshodi (FIIRO). It conforms to [9].

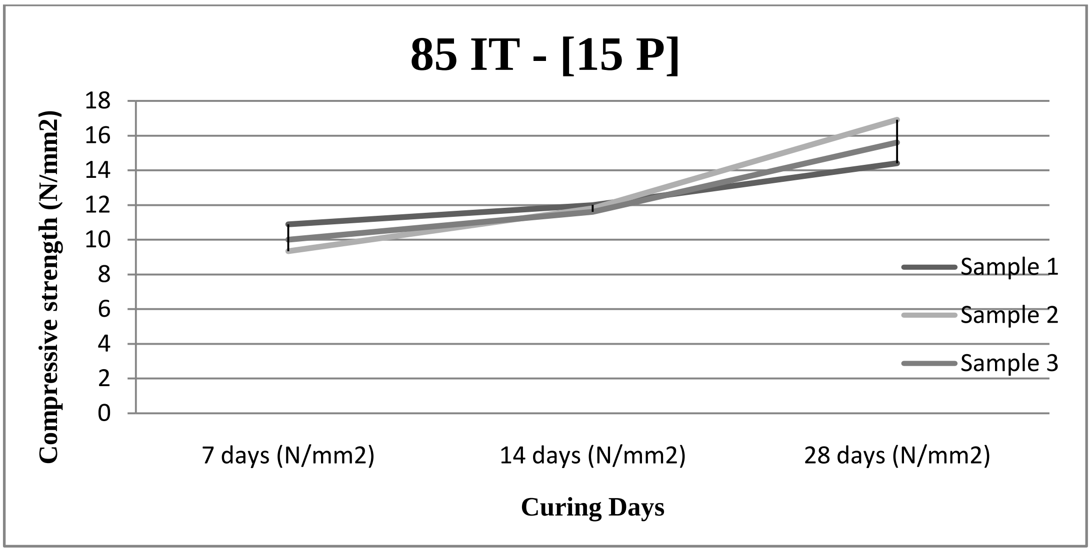
Laterite: The Laterite used for this study was taken from Ilepa, Ogun State, Nigeria. Further processing of the material was carried out at the Laboratory, Yaba College of Technology , Yaba, Lagos, Nigeria.

Mix Designs: Concrete mix M 30 of a standard mix ratio of 1:2:3 (blended cement: sand: granite) was used for the concrete. Batching was by weight and a constant water/cement ratio of 0.6 was adopted throughout the research. Manual mixing was used and mixing was done on a concrete surface adjacent the College Laboratory [10]. The ternary blended cement mixture [6] (P65) (P35) was a combination of 75% - 85% [5], 15% - 25% Pozzolan (Rice Husk Ash and Laterite). The mixture used a mix of Type I cement with 65% RHA and 35% LAT as SCMs additions. The SCMs were first mixed together for a homogenous mix. The mixture of the SCMs was then added to the Portland cement and blended for homogeneity before mixing thoroughly with the fine aggregate and the coarse aggregate mix simultaneously at the standard proportions. Water was then added gradually and the whole mix was mixed for homogeneity. The workability of the newly mixed concrete was measured by slump test. Twenty seven (27) cubes of 150mm X 150mm x 150mm and eighteen (18) cylinders of 200mm X 100mm were made. Nine (9) cubes were made with OPC and aggregates for the control mix representing three (3) samples for 7 days, 14 days and 28 days of curing; nine (9) cubes for 15% replacement for OPC with SCMs representing 7 days, 14 days and 28 days of curing; also, nine (9) cubes for 25% replacement for OPC with SCMs representing 7 days, 14 days and 28 days of curing. All the cast samples were cured in water. In the same vein, six (6) cylinders were made with 100% OPC for the control mix representing two (2) samples for 7 days, 14 days and 28 days of curing; six (6) cylinders for 15% replacement for OPC with SCMs representing 7 days, 14 days and 28 days of curing; also, six (6) cylinders for 25% replacement for OPC with SCMs representing 7 days, 14 days and 28 days of curing [10]. The control samples and the samples from the ternary blended concrete were tested for performance properties and comparison at the College Laboratory. This research focuses on the technical properties of the fresh concrete and gain in strength of the hardened concrete specimen. The workability as stated earlier was determined using the slump test according to [11]. Compressive strength was tested according to [12]. The Splitting Tensile Strength was carried out according to [13]. The compressive and splitting tensile strengths of each sample for the different percentage replacements of the SCMs at 0%, 15% and 25% are cured for periods of 7, 14 and 28 days. The specimens were tested using the compression testing machine.

Results & Discussions

Compressive Strength





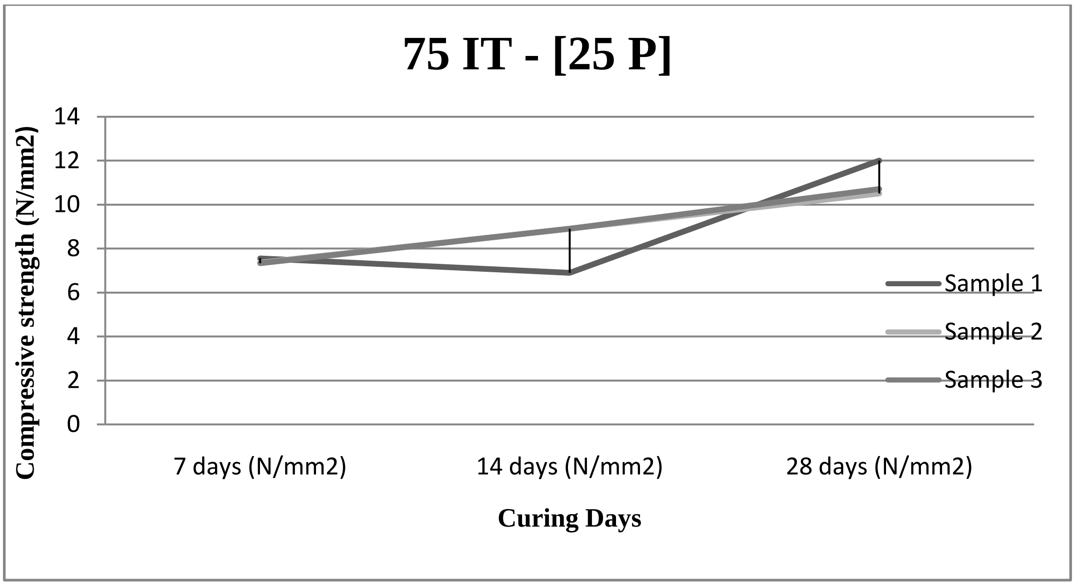
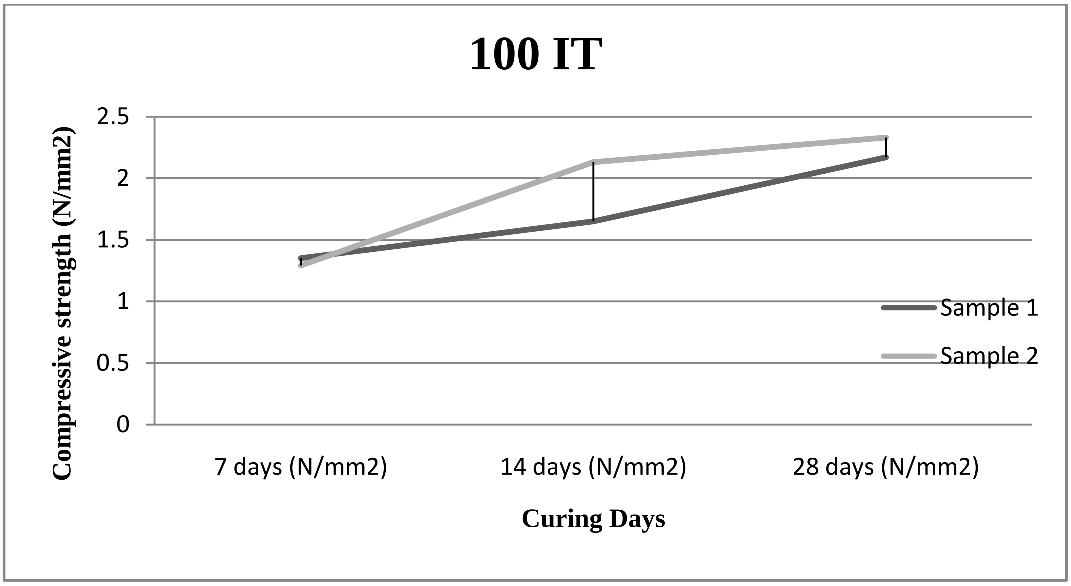
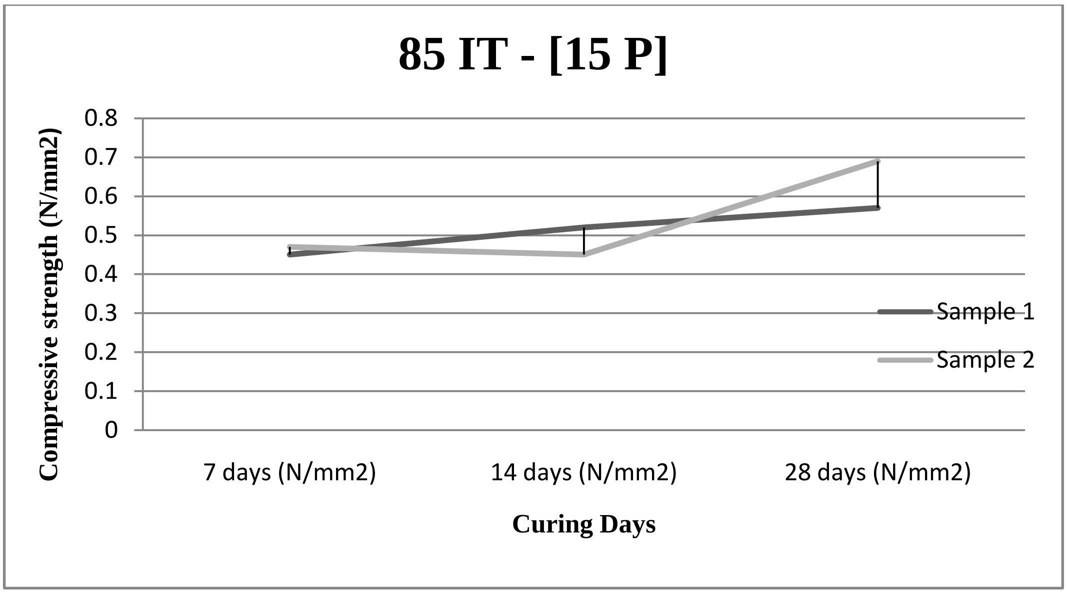


Figure 1: Variation of compressive strength against curing days for sample 1, sample 2 and sample 3

As presented from figure 1 of the control mix and ternary blends indicated that the compressive strength of the 85 IT [15 P] was greater than that of the 75 IT [25 P]. However both demonstrated a significantly low strength development at the curing ages of 7 days, 14 days and 28 days when compared to samples from the control mix. The low but gradual increase in strength can be attributed largely to the manual mixing method adopted and the curing by immersion process used. In addition, the strength development may be due to the combined increase in proportion of CaO and SiO_2 which have been proven to be responsible for strength gain in concrete mix. The percentage increase of the 85 IT [15 P] in comparison to the 75 IT [25 P] was 73.6%, 69.8% and 70.8% while its percentage decrease in comparison to the control mix was 48.4%, 48.3% and 43.8% respectively. In contrast, the decrease in percentage of the 75 IT [25 P] in comparison to the 100 IT [25 P] was 35.6%, 33.7% and 31.0% respectively at curing ages of 7, 14 and 28 days. Hence, the optimum strength of the ternary blended mixture for this study was obtained at 15% replacement at 7, 14 and 28 days curing.

Splitting tensile strength





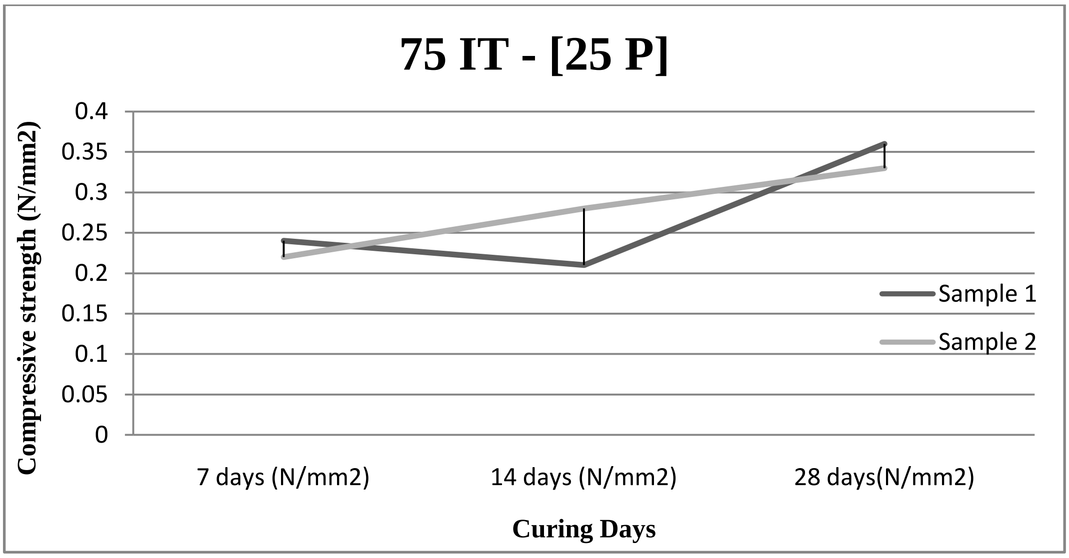


Figure 2: Variation of compressive strength against curing days for sample 1 and sample 2

As presented from figure 2 that the splitting tensile strength results of the 85 IT [15 P] was greater than that of the 75 IT [25 P]. Also, they had low strength development at the curing ages of 7 days, 14 days and 28 days in comparison to the control mixture. The gradual percentage increment of the 85 IT [15 P] when compared to the 75 IT [25 P] was 50%, 50.5% and 54.8% while its percentage decrease in comparison to 100 IT was 34.8%, 25.7% and 28% respectively. For the 75 IT [25 P], the percentage decrease in comparison to 100 IT was 17.4%, 13% and 15.3% respectively at curing ages of 7, 14 and 28 days. Also, the maximum splitting tensile strength of the ternary blended mixture was obtained at 15% replacement at 7, 14 and 28 days [14].

Statistical Analysis

This study used Coefficient of Variation (CoV) to analyse the data obtained from the compressive strength and the splitting tensile strength test. The CoV values are presented in the tables below:

Table 1: CoV for compressive strength (N/mm^2)

	7 Days	14 Days	28 Days
100 IT	0.0279	0.0422	0.0435
85 IT [15 P]	0.0635	0.0138	0.0653
75 IT [25 P]	0.0137	0.115	0.0601

Table 2: CoV for splitting tensile strength (N/mm^2)

	7 Days	14 Days	28 Days
100 IT	0.0227	0.126	0.0356
85 IT [15 P]	0.0217	0.0816	0.0952
75 IT [25 P]	0.0435	0.16	0.0571

Explanation of CO_2 intensities: For this study, a total of about 53 kg was expended in casting all the test specimens. Approximately 40 kg was used to cast the cubic samples while about 13 kg was used to cast the cylindrical samples. These values represent about 20% reduction of OPC in the cylindrical samples and approximately 16% of OPC in the cubic samples. Reports from environmental scientists show that the amount of CO_2 generated by the production of RHA and LAT are practically zero. To decrease permeability, pozzolanic materials such as Rice Husk Ash & Laterite are used optimally in concreting. When strength gain is guaranteed and permeability is reduced, the durability of the concrete is assured. The implication of this is the drastic reduction in the overall cost of maintaining the structure(s) during its service year.

Conclusions

From this study, the strength characteristics of concrete was investigated with the following conclusions:

i. The extremely slow rate of strength development, the [85 IT] mixture had the tendency to outperform the control mix in later strength development.

ii. The overall costs of ternary blended cement mixtures may be lowered when the start-up cost is reduced and the durability is improved. Factors such as the type of supplementary cementitious materials adopted and the nearness of the work site significantly influence the start-up cost. Using low cost SCMs like RHA and LAT in concrete mixtures and improving the durability of the mixtures will help to lower the start-up cost and reduce the amount of 'cementitious materials to be used'.

iii. That using Ternary blended cement concrete mixtures lowers the intensity of carbon dioxide generated in the built environment.

iv. The outcome of the statistical analysis indicated that the values of the compressive strength do not vary significantly from those of the splitting tensile strength.

v. Increasing the amount of RHA significantly improved the colour of the ternary blended mixtures.

Recommendations

i. Different mix ratios and percentage replacements should be tried for the proportioning of the SCMs and substitution with OPC.

ii. Dry curing method should be adopted and examined for possible speedy strength development.

iii. The two materials chosen for this thesis should be tried with the newly discovered 'Living Building Materials (LBMs).

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