

Experimental Study on Partial Replacement of Cement with Coconut Shell Ash in Concrete

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Abstract: *The environmental impact of OPC is significant because its production emits large amount of CO₂. Utilization of industrial soil waste or secondary materials has been encouraged in construction field for the production of cement and concrete because it contributes for reducing the consumption of natural raw materials as resources. The volume of wastes generated in the world has increased over the years due to increase in population, socioeconomic activities and social development. One of the most attractive options of managing such wastes is to look into the possibility of waste minimization and re-use. The cost of cement used in concrete works is on the increase and unaffordable, yet the need for housing and other constructions requiring this material keeps growing with increasing population, thus the need to find alternative binding materials that can be used solely or in partial replacement of cement. Agricultural waste material, in this case, coconut shells, which is an environmental pollutant, are collected and burnt in the open air (uncontrolled combustion) for three hours and that product is incinerated in muffle furnace at 800°C for 6 hrs to produce coconut shell ash (CSA), which in turn was used as pozzolana in partial replacement of cement in concrete production. Concrete mortar cubes were produced using replacement levels of 0 and 5 percent of OPC with CSA. The Coconut Shell ash is used for the partial replacement of cement. Further, use of coconut shell ash as a value added material as in the case of binary blended cement concrete, reduces the consumption of cement. Reduction of cement usage will reduce the production of cement which in turn cut the CO₂ emissions. The time has come for the review of progress made in the field of development of binary blended cement concrete.*

Keywords: Compressive Strength, concrete, coconut shell ash, Cement

1. Introduction

Concrete is widely used as construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. Many environmental phenomena are known significantly the durability of reinforced concrete structures. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments and many other hostile conditions where other materials of construction are found to be nondurable. In the recent revision of IS: 456-2000, one of the major points discussed is the durability aspects of concrete. So the use of concrete is unavoidable. At the same time the scarcity of aggregates are also greatly increased nowadays. Utilization of industrial soil waste or secondary materials has been encouraged in construction field for the production of cement and concrete because it contributes to reducing the consumption of natural resources. They have been successfully used in the construction industry for partial or full replacement for fine and coarse aggregates. The composition of World Cement Consumption in the year 2010 is 3,313 Million Metric Tons. Among that 7.0% in India, 57.7% in China, 9.4% in Developed Countries, 25.9% in Other Emerging. The composition of Coconut Production in India in the year 2009 is 10,894,000 tonnes. Traditional areas of coconut cultivation are the states of Kerala (45.22%), Tamil Nadu (26.56%), Karnataka (10.85%) and Andhra Pradesh (8.93%).

2. Materials Used

- Ordinary Portland Cement (53 Grade)
- Fine Aggregate
- Water
- Coarse Aggregate
- Coconut Shell Ash

2.1 Cement

Cement is used right from ancient periods in construction industry. In the most general sense of the word, cement is a binder, a substance which sets and hardens independently, and can bind other materials together. The word "Cement" traces to the Romans, who used the term "opus caementicium" to describe masonry which resembled concrete and was made from crushed rock with burned lime as binder. Te volcanic ash pulverized brick additives which were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cimentum, cement and cement. Cements used in construction are characterized as hydraulic or nonhydraulic. The most important use of cement is the production of mortar and concrete – the bonding of natural or artificial aggregates to form a strong building material which is durable in the face of normal environmental effects.

2.1.1 Cement Properties and Strength Analysis

The physical properties of cement are Setting Time, Soundness, Fineness, and Strength.

Setting Time

- Cement paste setting time is affected by a number of items including: cement fineness, water-cement ratio, chemical content (especially gypsum content) and admixtures. Setting tests are used to characterize how a particular cement paste sets.
- For construction purposes, the initial set must not be too soon and the final set must not be too late.
- Initial set. Occurs when the paste begins to stiffen considerably.

- Final set. Occurs when the cement has hardened to the point at which it can sustain some load.
- Setting is mainly caused by C3A and C3S and results in temperature rise in the cement paste.
- False set :No heat is evolved in a false set and the concrete can be re-mixed without adding water
- Occurs due to the conversion of unhydrous /semihydrous gypsum to hydrous gypsum($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)
- Flash Set: is due to absence of Gypsum. Specifically used for under water repair.
- When considering cement paste strength tests, there are two items to consider:
- Cement mortar strength is not directly related to concrete strength. Strength tests are done on cement mortars (cement + water + sand) and not on cement pastes.

2.2 Sand

Sand is naturally occurring granular material composed of finely divided rock and mineral particles. The most common constituent of sand is silicon dioxide, usually in the form of Quartz. Normally fine aggregate is used as fine aggregate for preparing concrete. An individual particle in this range is termed as sand grain. These sand grains are between coarse aggregate (2mm to 64mm) and silt (0.004mm to 0.0625mm). Aggregate most of which passes 4.75mm IS sieve is used.

Soundness

- When referring to Portland cement, "soundness" refers to the ability of a hardened Cement paste to retain its volume after setting without delayed expansion. This Expansion is caused by excessive amounts of free lime (CaO) or magnesia (MgO). Most Portland cement specifications limit magnesia content and expansion.
- The cement paste should not undergo large changes in volume after it has set. However when excessive amounts of free CaO or MgO are present in the cement, these oxides can slowly hydrate and cause expansion of the hardened cement paste.
- Soundness is defined as the volume stability of the cement paste.

2.3 Coarse Aggregate

Aggregates are the most mined material in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Coarse aggregate of size 20mm is sieved and used.

Fineness

- Fineness or particle size of Portland cement affects Hydration rate and thus the rate of strength gain. The smaller the particle size, the greater the surface area-to-volume ratio, and thus, the more area available for water-cement interaction per unit volume. The effects of greater fineness on strength are generally seen during the first seven days.
- When the cement particles are coarser, hydration starts on the surface of the particles. So the coarser particles may not be completely hydrated. This causes low strength and low durability.
- For a rapid development of strength a high fineness is necessary.

2.4 Coconut Shell Ash

2.4.1 CSA Properties and Strength Analysis

Coconut shell is one of the most important natural fillers produced in tropical countries like Malaysia, Indonesia, Thailand, and Sri Lanka. Many works have been devoted to use of other natural fillers in composites in the recent past years and coconut shell filler is a potential candidate for the development of new composites because they have high strength and modulus properties along with the added advantage of high lignin content. The high lignin content makes the composites made with these filler more weather resistant and hence more suitable for application as construction materials. Coconut shell flour is also extensively used to make products like furnishing materials, rope etc. The shells also absorb less moisture due to its low cellulose content the report focuses on studying the effectiveness of coconut shell particles as a source of natural material for reinforcing epoxy resins towards their flexural properties.

Strength

- Cement paste strength is typically defined in three ways: compressive, tensile and flexural. These strengths can be affected by a number of items including: water cement ratio, cement-fine aggregate ratio, type and grading of fine aggregate, curing conditions, size and shape of specimen, loading conditions and age.

2.4.2 Coconut Shell Ash:

Many researchers have made efforts for preparing carbon black from agricultural by-products such as coconut shell apricot stones, sugarcane bagasse, nutshells, forest residues and tobacco stems. Coconut shells have little or no economic value and their disposal is not only costly but may also cause environmental problems. Coconut shell is suitable for preparing carbon black due to its excellent natural structure and low ash content. Conversion of coconut shells into activated carbons which can be used as adsorbents in water purification or the treatment of industrial and municipal effluents would add value to these agricultural commodities, help reduce the cost of waste disposal, and provide a potentially cheap alternative to existing commercial carbons.

Duration of Testing

Typically, Durations of testing are:

- 1 day (for high early strength cement)
- 3 days, 7 days, 28 days and 90 days (for monitoring strength progress)
- 28 days strength is recognized as a basis for control in most codes.

2.4.3 Carbonization of Coconut Shell Ash

Coconut shells are cheap and readily available in high quantity. Coconut shell contains about 65 – 75% volatile matter and moisture which are removed largely during the carbonization process. The carbonization process involves converting the coconut shells to char (charcoal). The charring process (making of charcoal) is known as the Pyrolysis, which is chemical decomposition of the shell by heating in the absence of oxygen. During the carbonization of coconut shells, volatiles amounting to 70% of the mass of coconut shells on dry weight basis are released to the atmosphere, yielding 30% of coconut shell mass of charcoal. The volatile released during the carbonization process is Methane, CO₂ and wide range of organic vapors. The carbonization temperature range between 400 and 850 sometimes reaches.

2.4.4 The Processing of the Coconut Shell (Carbonization)

The coconuts were procured from a nearby local temple. The coconuts were broken manually to drain out the water. The 40 coconut half shells were sun-dried for three days. Sun-drying was necessary to ease removal of the meat from the inner shells of the coconut pieces. After scraping the meat from the inner shells, the inner portions of the shells were cleaned using knives. The fibers on the outer shells were also scraped and cleaned. Emery paper was used to clean the outer shells.

The cleaned coconut shells obtained from were cut into pieces of dimensions of 1 sq.cm using hammer and were put in stainless steels containers. The containers were then kept into muffle furnace for carbonization (carbonization is the production of charred carbon from a source material. The process is generally accomplished by heating the source material usually in the absence or limited amount of air to a temperature sufficiently high to dry and volatilize substances in the carbonaceous material). The carbonization temperature selected as 600 and 800 degrees. After a soak time of 4 hours, the sample gets carbonized. As the furnace cools down, containers were taken out. The collected char was ground to form powder using a grinding machine. The powder was then sieved to a size of 2.2 μm.



Figure 1: Coconut shells and Muffle furnace



Figure 2: Coconut shell ash

2.4.5 Properties of CSA

2.4.5.1 Density Measurement

Density determination by pycnometer is a very precise method. The theoretical density of coconut shell ash using pycnometer can be obtained by the following equation:

$$\rho = [(W_2 - W_1) / \{(W_4 - W_1) - (W_3 - W_2)\}] \times \text{Density of kerosene (0.816 g/cc)}$$

where, W₁ is the weight of the empty clean and dry pycnometer, W₂ is the weight of the pycnometer containing the sample, W₄ is the weight of the pycnometer containing the kerosene, W₃ is the weight of the pycnometer containing the sample and kerosene. Using the formula, the value of density was measured.

2.4.5.2 Particle Size Analysis

The particle size and size distribution of the coconut shell ash particles has been studied by laser scattering technique (Malvern MASTER SIZER 2000, U.K.) in Metallurgical and Materials Engineering Department, NIT Rourkela. The ash particles were ultrasonically dispersed in water using sodium hexametaphosphate as dispersant.

2.4.5.3 XRD Analysis

The XRD (X-ray Diffractometer X'Pert MPD) analysis of the coconut shell ash was carried out in Metallurgical and Materials Engineering Department. Phase analysis was studied using room temperature powder X-ray diffraction (Model: PW 3040 Diffractometer, Philips, Holland) will filtered 1.54 Å α radiation. Samples (coconut shell at 6 degrees) are scanned in a continuous mode with a scanning rate of 3 degrees/min.

2.4.5.4 Micro-Hardness

Hardness is a mechanical property which represents the resistance of the material to penetration and scratching, it is measured by the distance of indentation and recovery that occurs when the indenter is pressed into the surface under constant load. Leitz micro-hardness tester was used for Hardness measurement. This tester had a diamond indenter, in the form a right pyramid with a square base and an angle 136° between opposite faces, is forced in to the material under a load ranging from 0.3 to 3 N.



Figure 3: Micro-hardness testing machine

2.4.6 Need of the Study

- Requirement of substitute for fine aggregate.
- Scarcity of fine aggregate.
- Requirement of substitute for coarse aggregate.
- To reduce the overall cost.

3. Review of Journals

3.1 Title: Potentials of Coconut Shell and Husk Ash on the Geotechnical Properties of Lateritic Soil for Road Works

Author: Olugbenga O. Amu - Corresponding Author, Opeyemi S. Owokade Senior Lecturer / Civil Engineering Dept., Obafemi Awolowo University, Ile-Ife, Nigeria, Olakanmi I. Shitan
Research Student / Civil Engineering Dept., Obafemi Awolowo University, Ile-Ife, Nigeria

Year of Publication: 2011

Merits:

- The plastic index of each sample reduces with the addition of various percentages of CSHA, indicating a reduction in swelling potential and hence an increase in strength properties.

- The samples gain higher unit weights with the addition of CSHA, the shear strengths of all samples increases respectively at 4% CSHA and that the CBR values increased gradually with increased percentages of CSHA.

Experiments:

- The lateritic soil samples were obtained from three different borrow pits meant for road construction works.
- The soil samples were obtained at average depths of 4m to obtain true representative samples of the soils used for the road construction.
- The samples were spread on different matting to facilitate air drying.
- The coconut shells and the husk were obtained from a market waste dump.
- The coconut shells and the husk were burnt separately in a metal drum. The ashes formed were allowed to cool down before sieving through 4.75mm BS sieve. The ashes were therefore stored in airtight containers to prevent moisture loss and any form of contamination.
- Preliminary tests (natural moisture content, specific gravity, particle size analysis and Atterberg's limits) were performed on the three soil samples for classification and identification purposes.
- Coconut shell and husk ash (CSHA) was added to each of the soil samples in 2, 4, 6, 8 and 10% by weight of the samples.
- The effects of the coconut shell and husk ash as stabilizing agent on the samples were thereafter determined.

3.2 Title: Experimental study on strength characteristics on M25 concrete with partial replacement of cement with fly ash and coarse aggregate with coconut shell

Author: R. Nagalakshmi

Year of Publication: 2013

Merits:

- The slump of the concrete increased as the percentage of coconut shell increases and decrease in comparison with the conventional concrete.
- The compaction factor increased as the percentage of coconut shell increases and increased in comparison with the conventional concrete.
- The specific gravity of coconut shell is low as compared to the coarse aggregate and the water absorption is high for coconut shell than coarse aggregate and hence the strength decreased in comparison with the conventional concrete.
- The slump of the concrete increased as the percentage of coconut shell increases and decrease in comparison with the conventional concrete.
- The compaction factor increased as the percentage of coconut shell increases and increased in comparison with the conventional concrete.
- The specific gravity of coconut shell is low as compared to the coarse aggregate and the water absorption is high for coconut shell than coarse aggregate and hence the

strength decreased in comparison with the conventional concrete.

- 20% of cement replaced with fly ash and 10%, 20%, 30% of coarse aggregate replaced with coconut shell resulted that the compressive strength is reduced when compared with the conventional concrete.
- The compressive strength of the concrete reduced with increasing percentage of the coconut shell replacement.
- The cube compressive strength of concrete at the age of 7 days resulted in marginal reduction with 10% and 20% replacement of coarse aggregate with coconut shell.
- The Split Tensile strength at 7days was reduced by 8% with 20% replacement of fly ash and the 10% replacement of coarse aggregate with coconut shell when compared with conventional concrete.
- The strength of concrete decreased as the percentage of replacement of the conventional material increased
- The reduction in compression strength is less in comparison with the split tensile strength with the replacement of conventional material.

Experiments:

- The mix proportion for M25 is 1: 1.18: 2.86 and W/C ratio of 0.44 was casted.
- In general, fly ash is used at about 15-25% of the cement content.

Workability Test:

- **Slump cone test:**
 - ✓ The apparatus used for conducting the slump test consists of slump cone.
 - ✓ The internal surface of the mould is thoroughly cleaned and free from moisture and adherence of any old set concrete before commencing the test.
 - ✓ Concrete is placed in the mould and is removed for slump value.
- **Compaction factor test:**
 - ✓ It consists of a rigid frame that supports two conical hoppers vertically aligned above each other and mounted above a cylinder.
 - ✓ The top hopper is filled with concrete but not compacted.
 - ✓ The door on the bottom of the top hopper is opened and the concrete is allowed to drop into the lower hopper.
 - ✓ Once all of the concrete has fallen from the top hopper, the door on the lower hopper is opened to allow the concrete to fall to the bottom cylinder.
 - ✓ This mass is compared to the mass of fully compacted concrete in the same cylinder achieved with hand rodding or vibration.
 - ✓ The compaction factor is defined as the ratio of the mass of the concrete compacted in the compaction factor apparatus to the mass of the fully compacted concrete.

Tests for Concrete:

- Test for Compressive strength of concrete cubes: To calculate the compressive strength of concrete cubes the

universal testing machine (UTM) having capacity of 300tonne was used.

- Test for Split tensile strength of concrete cylinders: The universal testing machine (UTM) having capacity of 150tonne was used for the splitting tensile strength of the concrete cylinders.
- Test for Flexural strength of concrete beams:
- The transverse bending test is most frequently employed, in which a rod specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique.

These tests were carried out at the age of 7 days, 14 days, 28 days and 56 days.

3.3 Title: Experimental assessment on coconut shells as aggregate in concrete

Author: Daniel Yaw Osei
Department of Civil Engineering Cape Coast Polytechnic, Cape Coast, Ghana

Year of Publication: 2013

Merits:

- Increase in percentage replacements by coconut shells reduced the strength and density of concrete.
- With the exception of complete replacement, 20%, 30%, 40%, and 50% replacement of crushed granite by coconut shells can be used in producing lightweight
- Concrete 18.5% replacement of crushed granite with coconut shells can be used to produce structural concrete per the requirements of concrete.
- Coconut shells can be used as partial replacement of crushed granite or other conventional aggregates in reinforced concrete construction.
- Further studies should be carried out to ascertain the possibility of using coconut shell concrete as a structural material.
- Durability studies on coconut shell concrete should be carried out to assess its behaviour in aggressive environments.
- Developing countries like Ghana should encourage the use of agricultural wastes in construction as an environmental protection and cost reduction measure.

Experiments:

- A concrete mix of ratio of 1:2:4 by volume, with a water cement ratio of 0.6 was used as control, to which the properties of all other mixes were compared.
- Coconut shells were used to replace 20%, 30% 40%, and 50% and 100% of the granite by volume. In an experimental investigation, [9] found out that replacement of granite with palm kernel shells by volume produced a better performance concrete than replacement by weight.
- Six different mixes were batched and 12 specimens of each mix were produced.
- After casting, the moulds were covered with plastic sheets to prevent water loss through evaporation. After

24 hours, the cubes were demoulded and immersed in a curing tank to cure for strength gain.

- The curing process is beneficial to hydration of cement, while improving the physical and mechanical properties of concrete.
- On each day of testing, the specimens were removed from the tank and placed in the open air for about two hours. The compressive strength of the concrete specimen was determined by crushing after determination of density. The results for the density and compressive strengths are the average of three tests.

3.4 Title: Properties of Concrete with Coconut Shells as Aggregate Replacement

Author: Amarnath Yerramalaa Ramachandrudu

Year of Publication: 2012

Merits:

- Addition of CS decreases workability and addition of fly ash either as cement replacement or aggregate replacement increases workability of CS concrete. Increase in CS percentage decreased densities of the concretes.
- With CS percentage increase the 7 day strength gain also increased with corresponding 28 day curing strength. However, the overall strength decreased with CS replacement when compared to control concrete. Furthermore, fly ash as cement replacement had negative influence when compared to corresponding CS concrete and fly ash as aggregate replacement had similar performance as that of corresponding CS replaced concrete.
- Similar to compressive strength, the split tensile strength also decreased with increase in CS replacement. Furthermore, for 28 days of curing addition of fly ash as cement replacement reduced overall split tensile strength of CS concrete and fly ash addition as aggregate replacement showed no major difference with corresponding CS replaced concrete (M4).
- The results demonstrated that, irrespective of CS percentage replacement there was good relationship between compressive strength and split tensile strength. The equation proposed by Raphael, 1984 [19] for normal concrete was over predicting at lower strengths for CS concretes.
- Increase in CS replacement permeable voids also increased. With 10% CS replacement the permeable were 30 percent higher than control concrete. Similarly, the permeable voids were 88 percent higher than control concrete for 20% CS replacement. Addition of fly ash as cement replacement increased permeable voids with corresponding CS concrete (M4). However, addition of fly ash as aggregate replacement reduced permeable voids.
- The absorption characteristics show that the initial 30 min absorption values for all the concretes were lower than limits commonly associated with good quality concrete [21]. The maximum absorption was 2.3% for the concrete having 20% CS and 25% fly ash as cement replacement. Fly ash as cement replacement increased

water absorption and fly ash as aggregate replacement did not show any marked difference with corresponding CS replaced concrete.

- Sorptivity of the concretes was higher than control concrete for all CS concretes. The maximum sorption was 0.18mm/s^{0.5} for the concrete having 20% CS and 25% fly ash as cement replacement. Similar to absorption, fly ash as cement replacement increased sorption and fly ash as aggregate replacement did not show any marked difference with corresponding CS replaced concrete.

Experiments:

- Normal aggregate, that is, crushed blue granite of maximum size 20 mm was used as coarse aggregate. Well graded river sand passing through 4.75 mm was used as fine aggregate. The specific gravities of coarse and fine aggregates were 2.65 and 2.63 respectively.
- Coconut shells which were already broken into two pieces were collected from local temple; air dried for five days approximately at the temperature of 25 to 30°C; removed fibre and husk on dried shells; further broken the shells into small chips manually using hammer and sieved through 12mm sieve.
- The material passed through 12mm sieve was used to replace coarse aggregate with CS. The material retained on 12mm sieve was discarded. Water absorption of the CS was 8% and specific gravity at saturated surface dry condition of the material was found as 1.33.
- Coarse aggregate was then replaced with CS in 10 (M2), 15 (M3), 20 (M4) percentages to study effect of CS replacement. Furthermore, a mix with both CS and fly ash (M5) was also employed, in which, 20% of CS was replaced with aggregate and 25% of fly ash was replaced with cement.
- M6 mix contained 20% of coconut shells and 5% of fly ash both replaced with aggregate. Free water to cementitious ratio was maintained constant at 0.6 for all concrete mixes.
- Extra water was added in the mixes depending on the CS replacement to compensate water absorption of the CS particles.
- The concretes were mixed in a planetary mixer of 100 l capacity. The mixing time kept to about 3 to 4 min. Mixing of the materials was in a sequence: (i) portion of design water poured into mixture drum; (ii) cement gently placed; and (iii) aggregate and CS was spread over the cement and started mixing.
- During mixing, the remaining design water was poured into the mix for thorough mix of concretes. Specimens were then prepared and left for 24 hours. The specimens were demoulded after 24 hours and immersed in normal water for curing until the test age.
- The main objective of the present investigation was to study the performance of CS concretes in terms of strength and transport properties with normal water curing and with no chemical admixtures in the mixes.
- Performance of the concretes was assessed through: compressive strength, split tensile strength, water absorption and sorption. The specimens were tested for compression and split tensile strengths at 1, 7 and 28

days. The strengths were obtained by considering the average of two replicate specimens.

- However, if the variation of any individual value from the average was greater than 10 %, a third specimen was tested. Absorption and sorption tests were conducted at 28 days of curing. These tests were also conducted on two replicate specimens and the average values were reported.

3.5 Title: Coconut Husk Ash as a Partial Replacement of Cement in Sandcrete Block Production

Author: Oyelade, Olumide Akintoye
Civil Engineering and Environmental Department,
University of Lagos Nigeria

Year of Publication: 2011

Merits:

The compressive strength of the ordinary Portland cement /coconut husk ash sandcrete blocks generally decreases as the percentage of coconut husk ash content increases

Experiments:

Oyekan (2008) carried out work on the use of sawdust and sugar as admixtures in sandcrete blocks production. He discovered that sawdust as an air entraining agents has no appreciable effect on the compressive strength of blocks. **The result on the use of sugar showed that sugar had a significant effect on the compressive strength of the blocks increasing it by 17% at 28 days.**

Nimityongskul and Daladar (1995) conducted an experiment to develop new kinds of pozzolana from other agricultural wastes apart from rice husk and rice straw. The study investigated the use of coconut husk, corn cob and peanut shell ash as cement replacement materials. A series of tests were performed to determine the chemical composition of coconut husk ash, corn cob ash and peanut shell ash which are referred to as CHA, CCA and PSA respectively. The mechanical properties of paste and mortar containing different percentages of ash replacement were investigated. Experimental results revealed that coconut husk ash and corn cob ash cannot be utilized as pozzolana while peanut shell ash is classified as Class C pozzolana according to ASTM Standards.

Oyekan (2007) investigated the strength characteristics of sandcrete blocks in which crushed waste glass is partially replaced with cement in sandcrete block production. Crushed waste glass was discovered to have significant effect on the compressive strength of sandcrete blocks. At a mix proportion of 1:6 the compressive strength of the 450mm x 150mm x 225mm blocks (at 28 days) increased by 39% over the control value and by nearly 74% over the control value for the 450mm x 225mm x 225mm blocks.

3.6 Title: Stabilization of Poor Lateritic Soils with Coconut Husk Ash

Author: J.R. Oluremi, S. I. Adedokun, and O. M. Osuolale

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Ladoke Akintola University of Technology, PMB 4000, Ogbomosho, Nigeria

Year of Publication: 2012

Merits:

- The addition of coconut husk ash increases the plastic limit but reduces the plasticity index of the lateritic soil.
- California bearing ratio of the poor lateritic soil also increases continuously with the addition of coconut husk ash.
- Coconut husk ash increases the California bearing ratio and can therefore be used to improve soils with low CBR values.

Experiments:

The poor lateritic soil was wet washed on sieve 425 μ m. The retained sample was weighed and kept in the oven for 24hours at a regulated temperature of 1050C. The samples were then broken into smaller fragments, care being taken not to reduce the sizes of the individual particles.

The coconut husk was dried and burnt in a controlled environment until it completely turned to ashes. The product called coconut husk ash was mixed in 0%, 2%, 4%, 6%, 8% and 10% by mass of the soil sample with the oven-dried samples of poor lateritic soil.

Particle size analysis test, Atterberg limit test, British Standard (BS) compaction test, and California bearing were carried out on each of the natural and stabilized samples. In addition, chemical compositions of the Coconut husk ash were analyzed.

This reveals that the coconut husk ash contains large percentage of K₂O (62.43%) follows by SiO₂ (17.9%), which corroborate the fact that coconut husk ash is a pozzolanic material.

3.7 Title: Assessing the Mechanical Performance of Ternary Blended Cement Concrete Incorporating Periwinkle Shell and Bamboo Leaf Ashes

Author: Akaninyene A. Umoh, Olasunkanmi Olabode Femi - Building Department, Faculty of Environmental Studies, University of Uyo, Uyo, Akwa Ibom State, Nigeria.

Alake Olaniyi, Adewumi J. Babafemi - Building Department, Faculty of Environmental Design and Management, Obafemi Awolowo University, Ile-Ife, Nigeria.

Year of Publication: 2013

Merits:

- The Periwinkle shell ash has the highest chemical content of CaO while Bamboo leaf ash predominantly content SiO₂ thereby making the two mineral admixtures a complementary cementing materials suitable for ternary blended cement concrete.
- The relationship between tensile splitting strength and compressive strength of the combined mixes of ternary blended cement concrete had a higher value, n of 0.873, which is greater than 0.75 for most normal weight concrete.
- The correlation coefficient, R lies between 0.916 and 0.985 indicating a very strong linear relationship between tensile splitting strength and compressive strength of ternary blended cement concrete.

Experiments:

- Periwinkle shells and bamboo leaves were obtained and taken to the laboratory where they were spread in an open space for 12-14 days.
- The periwinkle shells and dried bamboo leaves were calcined, each material separately, in a furnace to a temperature of 600 degree Celsius for 20 minutes.
- The cement constituent was subsequently replaced with percentage combination of periwinkle shell ash and bamboo leaf ash.
- The cement, PSA, and BLA were measured and mixed together until a uniform colour was obtained.
- The blended mix was spread on already measured fine aggregate placed on an impermeable flat form and mixed thoroughly before the coarse aggregate and water were added.
- Workability test was conducted on the fresh concrete with the aid of slump cone apparatus and the value obtained range between 0-25mm.
- After casting they were covered with wet woolen bags and stored in a place not exposed to direct sunlight for a day; de-moulded and immersed in water curing tanks until their testing ages.
- The concrete specimens were tested for compressive strength and tensile splitting strength in a compression testing machine

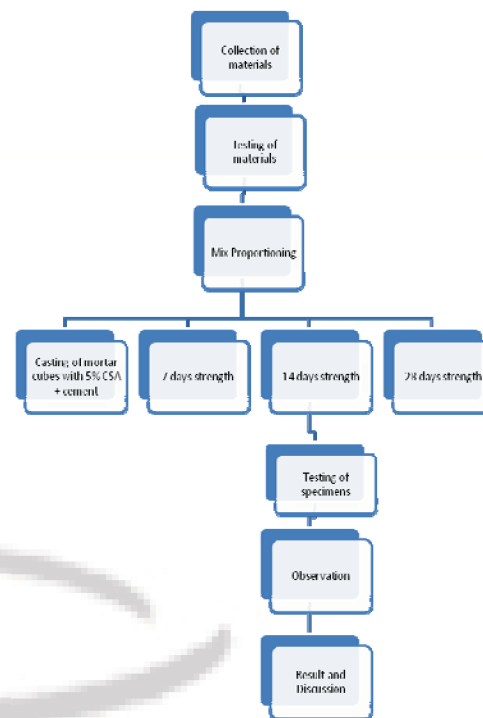
4. Methodology

Figure 4: Flow chart of the Experimental Work

5. Tests Conducted

The following tests were conducted to study the effect of coconut shell ash as cement for concrete.

- Sieve analysis
- Specific gravity for coarse aggregate
- Specific gravity for fine aggregate
- Slump test
- Vee bee Consistometer test
- Compressive strength test

5.1 Sieve Analysis Test for Fine Aggregates

The name given to the operation of dividing a sample of aggregate into various fraction each consisting of particles of the same size. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation.

The aggregate used for making concrete are normally of the maximum size 80mm, 40mm, 20mm, 10mm, 4.75mm, 2.36mm, 600micron, 300micron, 150micron and 75micron.

In the IS and AST standards, the sieve sizes are given in times of the number of openings per inch is equal to the square of the number of sieves. In the IS460-1962, the sieves are designed by size of the aperture in mm.

6. Coconut Shell Ash as Partial Replacement of OPC in Concrete Production

The high cost of construction materials like cement and reinforcement bars has lead to increased cost of construction. This coupled with the pollution associated with cement

production, has necessitated a search for an alternative binder which can be used solely or in partial replacement of cement in concrete production. More, so disposal of agricultural waste materials such as rice husk, ground nut husk, corn cob and coconut shell have constituted an environmental challenge, hence the need to convert them into useful materials to minimize their negative effect on the environment. Research indicates that most materials that are in rich amorphous silica can be used in partial replacement of cement. It has also been established that amorphous silica found in some pozzolanic materials react with lime more readily than those of crystalline form. Use of such pozzolanas can lead to increased compressive and flexural strengths. The American Society of testing materials (ASTM) defines pozzolans as siliceous or aluminous materials which possess little or no cementitious properties but will, in the presence of moisture, react with lime $[\text{Ca}(\text{OH})_2]$ at ordinary temperature to form a compound with pozzolanic properties. Examples of pozzolans include class C fly ash which contains more than 10% CaO, blast furnace slag and silica fumes. ASTM C 618 – 78 specifies that any pozzolana that will be used as a cement binder in concrete requires a minimum of 70% silica, alumina and ferric oxides. BS 3892:1965 parts 1&2 specify maximum loss on ignition of 12%, maximum MgO content of 4% and SO_3 of 2.5% respectively.

The aim of this study is to determine the suitability of coconut shell ash for use in partial replacement of cement in concrete production. The objectives include ascertaining the optimum replacement level of Portland cement with CSA that will still give required compressive strength as well as compare the setting times of OPC paste with OPC-CSA paste at various replacement levels.

7. Materials and Methods

The materials used during the study include:

Coconut shell: This was obtained in hostel of Kamaraj College of Engineering & Technology, Tamilnadu, India.
Cement: Dalmia cement, a brand of OPC available locally in Tamilnadu was used. The oxide composition is presented in table 1.

Water: Portable water from the Department of Civil Engineering, Kamaraj College of Engineering & Technology and was used both for the mixing of concrete as well as in curing of the cubes. The coconut shell was sun dried for 48 hours to remove moisture from it. It was then subjected to uncontrolled combustion using open air burning for 3 hours and allowed to cool for about 12 hours. The burnt ash was collected and sieved through a IS sieve (75 microns). The resulting ash, which has the required fineness, was collected for use. The oxide composition of the ash was determined and the result is shown in table 1. Using a mix design ratio of 1:2:4 and water binder ratio of 0.5, a total of 54 concrete cubes of size 150mmx150mmx150mm were cast using varying OPC-CSA ratio of 100:0, 90:10, 85:15, 80:20, 75:25 and 70:30 respectively, i.e., 9 cubes per % replacement. The cubes were cured and crushed after 7, 14, 28 days respectively and strength results are presented in table 4.

8. Test Results

Table 1 shows the oxide composition of CSA and OPC respectively, while table 2 is the result of average setting times for various OPC-CSA mixes. Table 3 is the result of density and compressive strength test at 7, 14 and 28 days respectively and table 4 give the pozzolanic activity index of various mixes at 7, 14 and 28 days respectively.

9. Discussion of Results

Tables 1 show the oxide composition of CSA and OPC respectively. From table1, CSA contains 37.97% SiO_2 , 24.12% Al_2O_3 and 15.48% Fe_2O_3 . This gives 77.57% of $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$ which is in line with ASTM C 618-78 requirement of 70% minimum for pozzolana. The LOI of 11.94 and SO_3 of 0.71 all falls within agreeable limits. Table 2 shows the average setting times of the various OPC-CSA combinations. Table 2 depicts the various percentage replacements. The setting times increases with increase in the amount of coconut shell ash. The initial setting time increases from 1 hour 5 minutes at 0% replacement to 3 hours 26 minutes at 30% replacement while the final setting time increases from 1 hour 26 minutes at 0% replacement to 4 hours 22 minutes at 30% replacement. However, BS12 (1978) recommends initial and final setting times to be not more than 45 minutes and 10 hours respectively for which the CSA/OPC pastes passes in final setting time. From table 4, it can be seen that the average density decrease with percentage replacement from 2525.5Kg/m³ for OPC to 2314Kg/m³ at 30% replacement. This is expected, since the density of cement is higher than that of the CSA. Table 3 shows the pozzolanic activity index at various OPC-CSA replacement levels and age. The index decreases with increasing percentage replacement of OPC with CSA. There is a decrease of the pozzolanic activity index with increased curing age at 15% and 30% replacement but no discernable trend is observed with increase in curing age at 10,20 and 25% replacement levels. From Table 3, we notice a decrease in pozzolanic activity with increasing percentage replacement, which is expected, since the strength decrease with increasing percentage replacement of OPC with CSA. The compressive strength decreases with increase in percentage replacement of OPC with CSA. The 7 days strength decreases from 13.78N/mm² for OPC to 6.43N/mm² for 30% replacement with CSA. The strength after 28 days curing decreases from 34.22N/mm² for OPC to 13.11 N/mm² 30% replacement with CSA. The optimal 28 days strength for OPC-CSA mix is recorded at 10% replacement (31.78N/mm²).

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Table 1: Composition of Cementitious substances

Oxide	Percentage concentration (%)	
	CSA	OPC
SiO ₂	37.97	20.7
Al ₂ O ₃	24.12	5.75
Fe ₂ O ₃	15.48	2.5
CaO	4.98	64
MgO	1.89	1
MnO	0.81	0.2
Na ₂ O	0.95	0.6
K ₂ O	0.83	0.15
P ₂ O ₅	0.32	0.05
SO ₃	0.71	2.75
LOI	11.94	2.3

Table 2: Setting Time

% replacement	Initial setting time (mins)	Final setting time (mins)
0	65	83
10	253	330
15	275	375
20	289	401
25	305	425
30	326	442

Table 3: Pozzolanic activity index

%replacement	Pozzolanic activity index		
	7 days	14 days	28 days
0	0	0	0
10	90.35	93.3	92.87
15	80.62	70.12	67.88
20	62.84	66.1	57.8
25	48.4	48.41	48.71
30	46.81	46.07	37.31

Table 4: Compressive Strength of mortar cubes

% replacement	Curing age(days)	Average density (Kg/m ³)	Average strength (N/mm ²)
0 percent	7	2525.5	13.78
	14	2522	18.82
	28	2514	34.22
10 percent	7	2504.5	12.89
	14	2517.5	17.56
	28	2514.5	31.78
15 percent	7	2471.5	11.11
	14	2475	14.89
	28	2456	23.23
20 percent	7	2450.5	8.66

	14	2427.5	12.44
	28	2388	19.78
25 percent	7	2357	6.67
	14	2338.5	9.11
	28	2340.5	16.67
30 percent	7	2314	6.45
	14	2322.5	8.67
	28	2543	13.11

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