PARTIAL REPLACEMENT OF CEMENT IN CONCRETE WITH ASHES OF SOME AGRICULTURAL WASTES

BY

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APPROVAL PAGE

This project have been read and found to conform to the expected requirement of the Federal University of Technology - MINNA.

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DEDICATION

This project is dedicated to the Almighty God for the opportunity and to Mercy and the children for their understanding.

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I am so grateful to the Head of Department Dr M. G. Yisa and the entire members of the staff for giving this opportunity.

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ABSTRACT

Blending cement with aluminous and siliceous base materials have been going on in Europe for the past fifty years . The sole aim is the reduction in the cost of ordinary Portland Cement.

This Project examines the effect of 40% partial replacement of ordinary Portland Cement (OPC) with ashes of agricultural wastes on:

(1) the strength of the concrete

(2) the workability of the concrete

(3) the porosity of the concrete

The experimental results showed that OPC + RHA has a slump of 130mm and compaction factor of 0.95, a compressive strength of 5.5N/mm^2 and a porosity of 12% ; OPC +GTA has a slump of 105mm, compaction factor of 0.949, Compressive strength of 3.5N/mm^2 and a porosity of 10.2% ; OPC + MCA has a slump of 80mm compaction factor of 0.9, Compressive strength of 7.5N/mm^2 and a slump of 8.0% ; OPC + BTA has a compressive strength of 5N/mm^2 and a porosity of 11%.

The analysis of variance carried out on the strength test results showed that the result are quite as the coefficient of variation is 18% and the treatment is highly significant.

The test result showed an improved workability and porosity values when compare d to acceptable values for OPC concrete.

The strength of concrete is low when compared to known strength valuesofOPC concrete stated in table 2.1.

It is concluded that the ash treatment is responsible for the high workability and

porosity. It is also responsible for the low compressive strength which can be improved through proper blending.

CHAPTER ONE

1.0 INTRODUCTION

Originally concrete was made using a mixture of only three materials; cement, aggregates and water. Later on, in order to improve some of the properties of concrete, either in the fresh or in the hardened state, very small quantities of chemical products were added to the mix. These chemicals were called admixtures.

Later still other materials in inorganic in nature were introduced into the cement mix. The original reason for using these materials were usually economic. They were cheaper than Portland cement, sometimes they exists as natural deposits (e.g Pozollonas) requiring no or little processing, some times because they were a byproduct or wastes from industrial processes (e.g fly Ash, blast furnace slag or silica fumes). A further spur to the incorporation of these supplementary material in concrete mix was given by the sharp in the cost of energy in Europe and America in the 1970s and "The cost of energy represent a major proportion of the cost of cement production" (Neville, 1996).

Yet further encouragement for the use of some of the "Supplementary" material was provided by ecological concern about opening of pits and quarries for the raw materials required for the production of Portland cement on one hand and the other hand the means of disposal of industrial wastes such as blast furnace slag, fly Ash or silica fumes. More over the manufacture of Portland cement itself is ecologically harmful in that the production of one tonne of cement results in about one tonne of CO_2 being discharged into the atmosphere.

It will be wrong to infer from the historical account that the supplementary material were introduced into concrete solely by the 'push' of their availability. Most materials also bestows various desirable properties on concrete sometimes in fresh state but more often in hardened state. So because of these reasons in very many countries, a high proportion of concrete contain one or more of these supplementary materials. It is therefore misappropriate to consider them as cement replacement materials or extenders.

In fact the appropriate nomenclature for these type of cement that can be universally accepted has been the problem. The names so far suggested are: Portland composite cement; Blended Portland cement (Neville 1996). The European approach of ENV 197-1 1992 is to use the term CEM cement which not thought to be explicit enough. The current American approach is given in ASTM C 1157-94a which covers blended hydraulic cements for both general and special application. The emphasis on the term hydraulic may conjure up a wrong image on the eyes of general users of cement.

The preceding rather lengthy discussion explains the difficulty of classifying and categorizing the different material involved.

A given cementous material may be hydraulic that is, it can undergo hydration on its own or become hydraulic only in consequence of chemical reaction with some other compounds. Yet a third group of the cementous material may be largely chemically inert but to have a catalytic effect on the hydration of other material, say, by fostering nucleation and classifying the cement paste; or to have a physical effect on the properties of fresh concrete. Materials in this category are called fillers.

1.2 Present Situation of Ceremeni Production

Perhaps at no time in its history of over hundred years has the cement industry found itself faced so suddenly with so many problems of vital importance stemming from the oil crises of 1973. A major objective of European industry naturally has been to save by any possible means some of the energy used in the cement production. This aim has been or is being steadily reached through two different courses, the effects of which are cumulative

(a) by reducing energy costs in the burning of clinker

(b) by increasing the production of composite cement.

This second approach is important to the write up. This involves replacing a proportion of clinker- high calorie consuming - by other products which are suitable and do not require further heat treatment. Such products already have been submitted to high temperature naturally e.g Pozzolanas or blast furnace slag or fly Ash.

The production of composite cement is not a new development and the concrete industry has had long experience in the use of such cement. The industrialized production of cement with slag and with fly Ash on European continent started more than fifty and twenty five years ago respectively (Dutron 1986). The natural possolanas based binders are much older. An accelerated development of composite cement has been witnessed over the past decades mainly for the three reasons:-

(1) To save energy

(2) Availability of large quantities of such constituents in many countries.

(3) Environmental protection through the realization of industrial by products combined with the preservation of land scape through reduced quarrying of the raw material used in the production of clinker.

1.3 THE PROJECT

In this project, the word 'Partial Replacement of' will be used instead of 'blended', 'mixed' or 'composite' cement. The project seeks to replace a portion of the Portland cement in concrete with the ashes of some selected agricultural wastes. The selected wastes are

(1) Rice Husk Ash (RHA)

(2) Maize Cobs Ash (MCA)

(3) Bean Thresh Ash (BTA)

(4) Guinea Corn Thresh Ash (GRA)

1.4 JUSTIFICATION OF THE PROJECT.

The project is justified because if the experiment succeeds in establishing the fact that if a portion of ordinary Portland cement is replaced with any of these material in concrete without the concrete loosing much of its structural properties such as strength, impermeability and workability, then a lot of benefit will be derived from the result such. benefits are:-

(1) Energy will be saved:- The highest index in determining the cost of cement is the cost of energy used in the production. But if a material that requires no further heat treatment replaces a portion of the cement in the construction industry, then less cement is produced, hence less energy will be required int he production.

(2) Availability of these Agricultural Wastes:- These material are available in large quantity especially during harvesting time. So instead of burning and wasting it could be put into economic use by mixing the ash with cement in the construction industry.

(3) Environmental Cleanliness through utilization of these Wastes:- The problem of wastes generated from agricultural activities will be minimized and ensuring a cleaner environment.

(4) Depletion of Vegetation through cement production: Opening of new sites for quarrying of lime stone and gypsum used for cement production will be reduced and as earlier stated, the production of one tonne of cement will lead to the

production of one tonne of CO_2. This gas is not environmentally friendly.

(5) More Food will be Produced:-

This is a long term expectation. If the farmers know that the waste will still be useful and perhaps could still be sold to builders, there will be a tendency to produce more food and thereby generate more wastes which can be sold for extra income. In a situation of this nature, the Nation will be better for it.

1.5 THE OBJECTIVES OF THE PROJECT

The objectives of this project is to establish how

(1) The strength of the concrete

(2) Workability of the concrete and

(3) Porosity of the Concrete

are affected by the partial replacement of cement in concrete by the following individual materials:-

Rice Husk Ash (RHA)

Maize Cobs Ash (MCA)

Bean Thresh Ash (BTA)

Guinea Corn Thresh Ash (GTA)

1.6 LIMITATIONS OF THE PROJECT

The scope of this research is limited by time. We know that concrete is a complex construction material whose strength is affected by many factors. These includes the quality of the cement, fine and coarse aggregate and the quality of mixing water and ambient temperature. The effects of all these factor ideally should have been considered before considering the effects of all these replacement materials on the concrete strength. Time will not be enough to just under take these checks.

Finance is another limitation to the scope of this research. Most of the tests on concrete are destructive tests. Which means there is little or no allowance for repeated material utility. So any extension of the research to cover those other aspects earlier mentioned will require more materials and by extension more financial involvement. In effect the various other aspects are open for further investigation.

Some of the replacing agricultural waste is now being used as animal folder and so its availability for burning is not always assured such material is beans threshings. Unless production of beans is improved, the threshings will certainly be in short supply.

CHAPTER TWO

LITERATURE REVIEW

2.1 Blended Cement Concrete

Concrete in the broad sense is any product or mass made from any cementry medium. Concrete is made with several types of cement and also containing pozzalano (BROOK et al 1987). Fly ash, blast furnace slag, regulated set of additives, sulphur, admixtures, polymers, fibres and so on have at one time or the other been used in blending cement. This have given rise to various types of cement which has gotten an enhanced property in one way or the other in concrete production.

2.1.1 Pozzolanas This material have been defined by AST M 618-94 as a siliceous and aluminous material which in itself possess little or no cementous value but in a finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide at ordinary temperature to form compounds possessing cementous property.

According to Brook (1987) and Neville (1996) it will be incorrect to infer from the previous historical account that this supplementary materials were introduced into concrete solely by the push of their availability. This materials also bestows various desirable properties on concrete.

2.1.2 Fly Ash:- Fly ash known also as pulverized fuel Ash (the ash precipitated electrostatically from the exhaust gases of a coal powered station) is the most common artificial pozzolana. The American classification of fly ash will depend on the types of coal the ash originates. The one from bituminous coal is mainly siliceous and is known as flass F fly ash. It blends well with cement and produces the best of ash +cement concrete.

For any pozzolana to be used as a cement blender in concrete production ASTMC 618-94a requires 70% silica, alumna and ferric oxide taken all together and a maximum of $S0_3$, content of 5% and BS 3892 Part 1 (1993) specifies an $S0_3$ content of 2.5%.

Rice Husk Ash (RHA) have been described as a pozzolana (Neville 1984). A study carried out by D.C. Okpala (Okpala 1987) shows that at 40% partial replacement of cement in concrete by RHA and optimum strength comparable to the known standard strength can be obtained.

Mbachu and Kolawole (Mbachu et al 1998) also carried out a study on concrete made of 40% RHA and ordinary Portland cement concerning the shrinkage and modulus of elasticity. It was discovered that the result was equally comparable to the true accepted values. All those goes to show that RHA is a silicious material and hence a pozzolana.

If the RHA have produced these results, it was necessary to extend the research to other ashes of agric wastes to check its effects on the strength of the concrete so produced from this material.

2.2 Concrete Strength

Strength of concrete is commonly considered its most valuable property (Neville 1996). In considering concrete strength there are other complement properties which are equally important such as the durability and permeability which in some practical cases are considered more important. Nevertheless strength of the concrete presents the overall picture of the quality of the concrete, because strength directly relates to the structure of the hydrated cement paste. More over, the strength of concrete is almost invariably a vital element of structural design and it is specified for compliance purposes.

2.2.1 Water/Cement Ratio

In engineering, the strength of concrete at a given age and cured in water at a prescribed temperature is assumed to be dependent on two factors only:-

(I) the water/cement Ratio

(ii) the degree of compaction (Niville). When concrete is fully compacted, its strength is taken to be inversely proportional to the water/cement ratio. This relation was preceded by a rule established by (1919). He found that strength is equal to fc = $\frac{-k}{Kuw/c}$

where w/c represents the water cement ratio and $_K$ and $_K$ are empirical constants. Abrams rule although established independently is similar to a general rule formulated by Feret (1896) in that they both relates the strength of concrete to the volumes of water and cement. Feret's rule was in the form

$$fc = K\left(\frac{C}{c + w + a}\right)^2$$

where C, W, a are absolute volumetric proportion of cement, water and air respectively and K is constant.

The general form of graphical representation of strength versus water/cement ratio is as shown below in figure 2.1

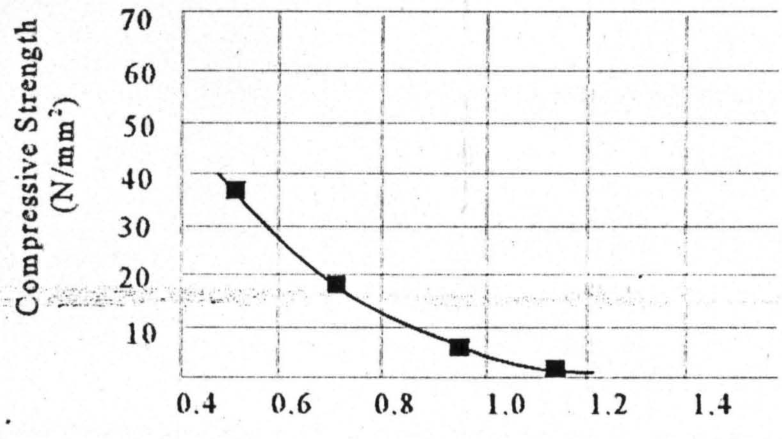


FIG. 2.1 - Compressive Strength Versus Water/Cement Ratio

From time to time, the water/cement ratio rule has been criticized as not being sufficiently fundamental. Nevertheless in practice the water cement ratio is the largest single factor in the strength of a fully compacted concrete. Perhaps the best statement of the situation is that by Gulkey (1974) which says "For a given cement and acceptable aggregate, the strength that may be developed by a workable, properly placed mixture of cement, aggregates and water (under the same mixing, curing and testing condition) is influenced by

(a) Ratio of cement to mixing water

(b) Ratio of cement to aggregate

© grading, surface texture, shape, strength and stiffness of aggregate particles

(d) Maximum size of the aggregates.

2.2.2 Curing

The water cement ratio has been identified as the only single factor that has a lot of influence on the strength of concrete. Another factor is the curing method. "In order to obtain good quality concrete, the placing of appropriate mix must be followed by curing in a suitable environment during the early stages of hardening" (Neville & Brooks (1987).

Curing is the name given to procedures use for promoting the hydration of cement and thus, the development of strength of concrete. The curing procedure being the control of the temperature and moisture movement from and into the concrete. The later not only affects strength of concrete but also the durability.

In the case of site concrete active curing nearly always cease long before the maximum possible hydration has taken place. The influence of moist curing on strength can be guaged from the figure below which was established by Price (1951) in his research on factors influencing concrete strength. The graphs are plotted for a concrete of 0.50 moisture content.

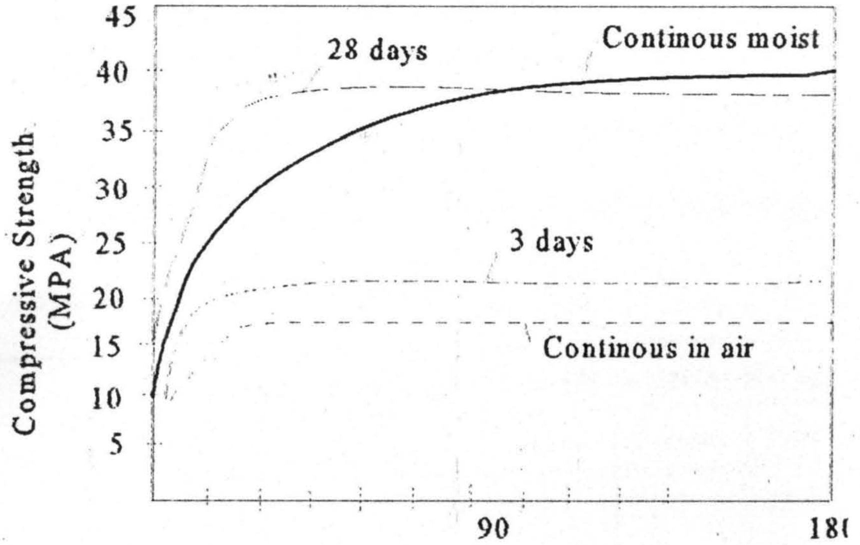


Fig. 2.2 Curing as a factor influencing concrete Strength

Tensile and compressive strength are affected in a similar manner. The Future to gain strength in consequence of adequate curing that is through loss of water by evaporation is more pronounced in thinner element and in richer mixes but less so for light weight aggregates concrete.

The necessity for curing arises from the fact that hydration of cement can take place only in water filled capillaries. This is why loss of water by evaporation from the capillaries must be prevented. Furthermore, water lost internally by self desiccation has to be replaced by water from outside ie. Ingress water into the concrete must take place. Self desiccation occurs in a sealed concrete when the water/cement ratio is less than about 0.5 because the internal relative humidity in the capillaries decreases below the minimum value necessary for hydration to take place.

"If curing is efficient, the strength of the concrete increases with age. This increase is rapid at the early age and then continues more slowly for an indefinite period" Cement and Concrete Association 1979. Concrete curing increases impermeability and

(3) Testing the Strength of a Concrete cure

(40 Testing of torsional stress can equally be made.

The compression strength test is the most common test. Nevertheless, this test must be handled by an experience technologist.

2.2.4 Compressive Strength Test Cubes

Compressive strength test for concrete with a maximum size of aggregate of up to 40mm are usually conducted on 150mm cubes. For aggregate with a nominal maximum size of 25mm or less 1200mm cubes may be used. Details of making, curing and testing are covered in part 3 and 4 of BS 1881 or in a similar publication by Cement and Concrete Association.

It is essential that the concrete in the cubes should be fully compacted. To assist in ensuring this, a 150mm cube mould should be filled in three layers and a 100mm mould in two layers using vibrator or ramming rod. The test specimen must be kept in a damp place and also it must be marked for identification. It is removed from the mould within 25 hours and care must be taken to avoid breaking the edges. Unless required for testing it should be submerged in a tank of clean water maintained at a temperature of 20 ± 2^{o}C until they are transported to testing laboratory. Specimens should arrive the laboratory in a damp condition not less than 24 hours before the test time.

2.2.5 Summary of the Testing procedure

1. The cubes should be stored in water and tested immediately on removal.
2. The bearing surface of the testing machine should be wiped clean and the cube placed in the machine in such a way that the load is applied to the faces other than the top and bottom of the cube as cast.
3. The load should be applied without shock and increases continuously at a rate of

approximately 15N/mm^2 per minute until no greater load can be sustained.

4. The compressive strength should be recorded to the nearest 0.5N/mm^2.

2.3 Workability of Concrete

2.3.1 Definition:- "A concrete which can be readily compacted is said to be workable. But to say that workability determines the ease of placement and resistance to segregation is too loose a description of this vital property of concrete" (Neville, 1996). The desired workability in any particular case would depend on the means of compaction available, likewise a workability suitable for mass concrete is not necessarily sufficient for thin inaccessible or heavily reinforced section. For these reasons workability should be described as a physical property of concrete alone without reference to the circumstances of a particular type of construction.

To obtain such a definition it is necessary to know what happens when concrete is being compacted. Whether compaction is achieved by ramming or by vibration, the process consists essentially of the elimination of entrapped air from the concrete until it has achieved a close configuration as is possible for a given mix. Glanville et al defined workability as "the amount of useful internal work necessary to produce full compaction". The ASTM C 125-93 definition of workability is somewhat more qualitative - "property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity". The AC1 definition of workability given in AC1R-90 is "That property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mix, placed, consolidated and finished". Technical literature abounds with variation of the definition of workability and consistency but they are all qualitative in nature and more reflection of a personal view point rather than of scientific precision.

2.3.2 The Need for Sufficient workability

Workability has o far been discussed merely as a property of fresh concrete. It is however also a vital property as far as the finished product is concerned because concrete must have workability such that compaction to maximum density is possible.

"The need for compaction becomes apparent from a study of the relation between the degree of compaction and the resulting strength" (Neville PP 185). It is convenient to refer to workability as a density ratio, that is the ratio of the actual density of a given concrete to the density of the same mix when fully compacted. Like wise, the ratio of the strength of the concrete if partially compacted to the strength of the concrete when fully compacted can be called strength ratio.

There is a linier relationship between the strength ratio and density ratio as shown in the Graph below.

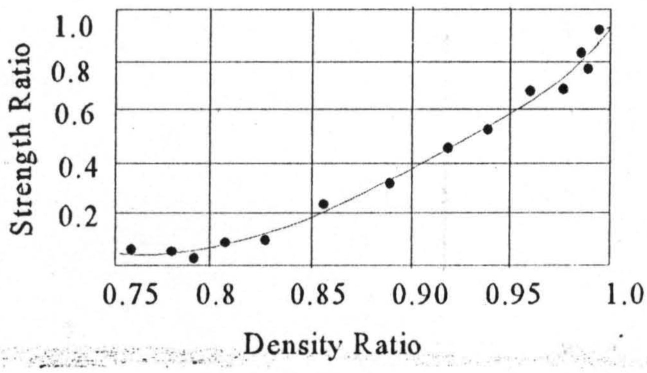


FIG. 2.3 Relation between Strength Ratio and Density Ratio

The presence of voids in concrete greatly reduces its strength, 5% of void can reduce the strength to as much as 30%. Even 2% void can result to a strength drop by 10%.

Void are in the form of bubbles of entrapped air or spaces left after excess water have been removed. The volume of the later depends primarily on the water cement ratio of the mix.

2.3.3 Factors Affecting Workability

The main factor is the water content of the mix, expressed in kilograms (or litres) of water per cubic metre of concrete. It is convenient, though approximate to assume that for a given type and grading of aggregate and workability of concrete, the water content is independent of aggregate/cement ratio or of the cement content of the mix. Based on this assumption, the mix proportion of concrete of different richness can be estimated.

If water content and the other mix proportion are fixed, workability is governed by maximum size of aggregate, its grading, shape and texture. However the grading and water/cement ratio have to be considered together as grading producing the most workable concrete for one particular value of water/cement ratio and this may not be the best for another value of the ratio. "In particular, the higher the water/cement ratio, the finer the grading required for the highest workability" (Neville, 1996). In fact for a given value of water/cement ratio, there is one value of the coarse/fine aggregate ratio that gives the highest workability.

2.3.4 Measurement of Workability

There is no acceptable test which will measure directly the workability as given by earlier state definition. Numerous attempts have been made however, to correlate workability with some easily determinable physical measurement, but none of these is fully satisfactory. Among so many method adopted to try to measure workability are

(a) Slump Test

(b) Compaction factor test - These two will be explained further. Others are

© AST M flow Test

(d) Remoulding Test

(e) Vebe Test

(f) Flow Test

(g) Ball Penetration test

(h) Nasser's K-Tester and

(I) Two Point Test

2.3.5 Slump Test

This test is used extensively in site work all over the world. The slump test does not measure the workability but useful in detecting variation in the uniformity of a mix of a given normal proportion.

The test is prescribed by ASTMC 143-90 and BS 1881 Part 102 1983. The mould for the slump test is a frustun of a lone 300mm high. It is placed on a smooth surface with the smaller opening at the top and filled with concrete in three layers. Each layer is tamped 25 times with a standard 16mm diameter steel rounded at the end. The top surface is struck off and firmly held to the base during the entire operation. This is facilitated by a handle or foot rest brazed to the mould. Immediately after filling, the cone is slowly lifted and the unsupported concrete will now slump-hence the name of the test. The decrease in height of the slumped concrete is called slump and it is measured to the nearest 5mm.

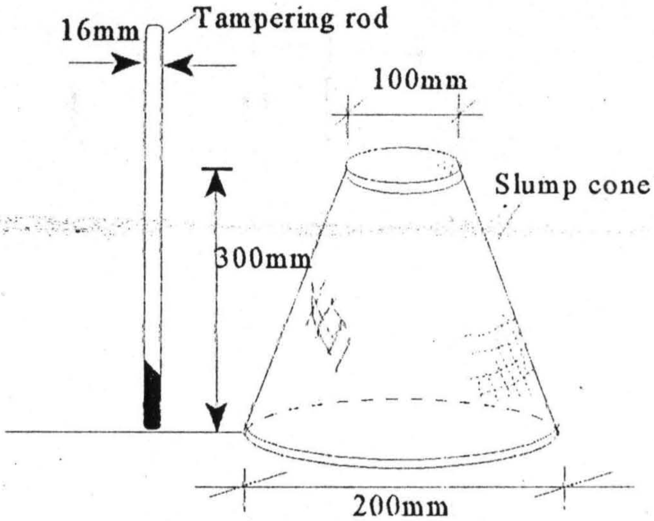
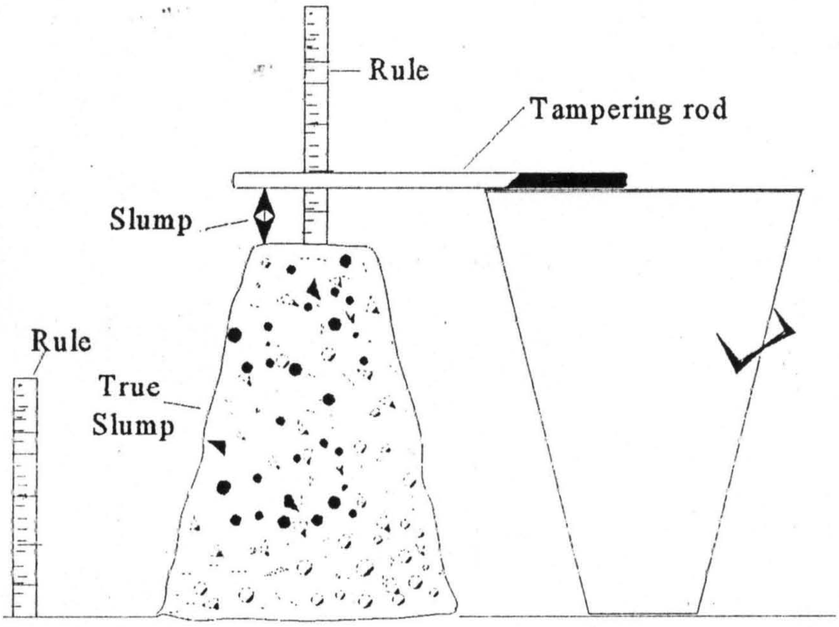
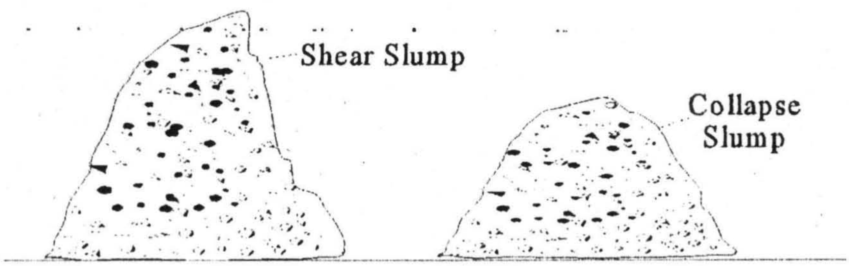


Fig. 2.4 SLUMP TEST APPARATUS



SLUMP TEST

"If instead of slumping evenly all round in a true slump one half of the cone slides down an inclined plane, a shear slump is said to have taken place" (Obande1993)



Mixes of stiff consistency have zero slump, so that in the rather dry range, no variation can be detected between mixes of different workability.

Table 2.2 Description of workability and magnitude of slump (Neville 1996)

Description of Workability	Slump (mm)
No slump	0
Very low	5-10
Low	15-30
Medium	35-75
High	80-155
Very High	160-Collapse.

2.3.6 Compaction Factor Test

The degree of compaction called the compaction factor is measured by the density ratio that is the ratio of the density actually achieved in the test to the density of the same concrete fully compacted (Neville 1991). The compaction factor test is prescribed in BS 1881 Part 103 1993 and ACI 12113-75 1992 and it is appropriate for concrete with aggregate up to 40mm.

The apparatus consists essentially of two hoppers each in the shape of a frustrum of a cone and one cylinder, the three being above one another. They have hinged doors at the bottom. All inside surfaces are polished to reduce friction.

To carry out the test, the upper hopper is filled with concrete, this being placed gently so that at this stage no work is done on the concrete to produce compaction. The bottom door of the hopper is then released and the concrete FIG 2.5 falls into the lower hopper.

This is smaller than the upper one and is therefore filled to over flowing. The bottom door of the lower hoper is then released and the concrete falls into the cylinder. Excess concrete is cut by two floats slide across the top of the mould and the wet mass of the

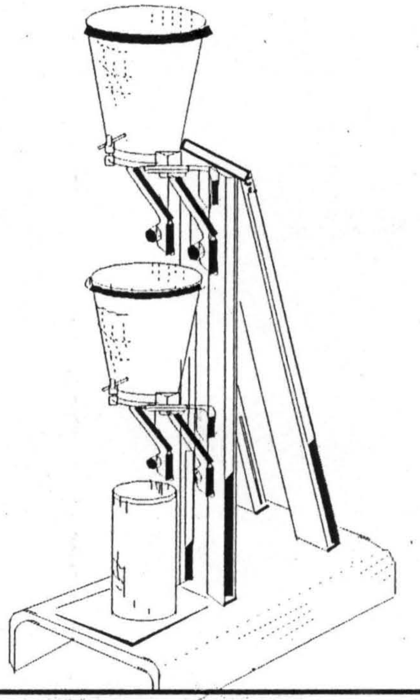


Fig. 2.5

Compaction Factor Apparatus

concrete in the known volume of the cylinder is determined. The density then calculates and this density is divided by the density of a fully compacted concrete is defined as the compaction factor. The later density is obtained by filling the cylinder with concrete in four layers, tamped or vibrated

Table 2.3: Description of workability and compaction factor (Neville PP 192).

Description of workability	Compaction Factor
Very low	0.78
Low	0.84
Medium	0.93
High	0.96

Unlike slump test variation in the workability of dry concrete are reflected in large change in the compaction factor that is the test is more sensitive at low workability end of the scale that at high workability.

2.40 Porosity

It has been shown from various research and discussions that the strength of concrete is fundamentally a function of the volume of voids in it. The relation between strength and total volume of void was found to be a unique problem of most construction materials not only concrete. Brittle materials in which water leaves behind pores, for example plastic the strength is a direct function of its void content. The graph in Fig. 2.6.1 shows how the strength of various materials are affected by the percentage porosity

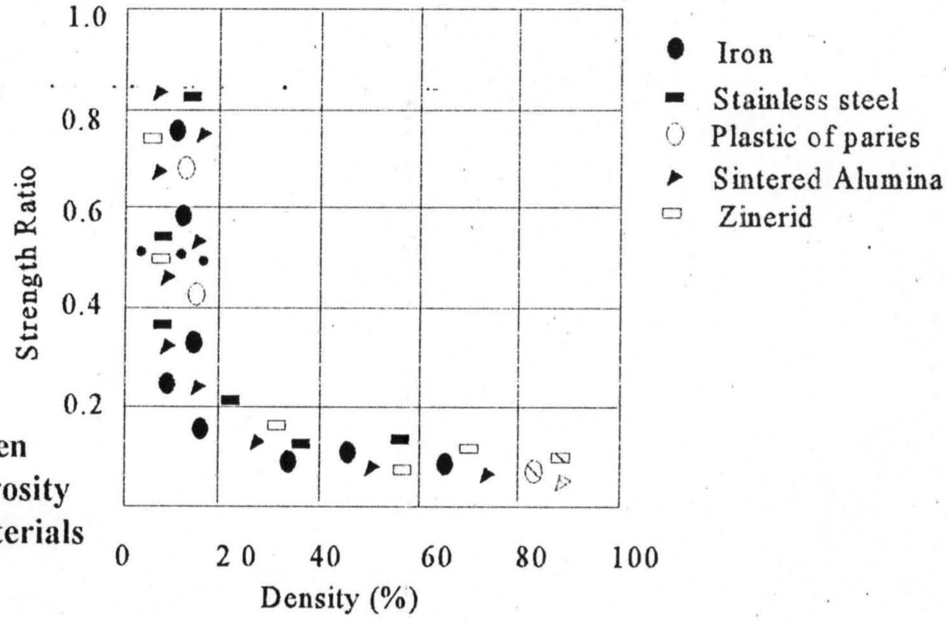


Fig. 2.6
Relation between stregth and porosity of different materials

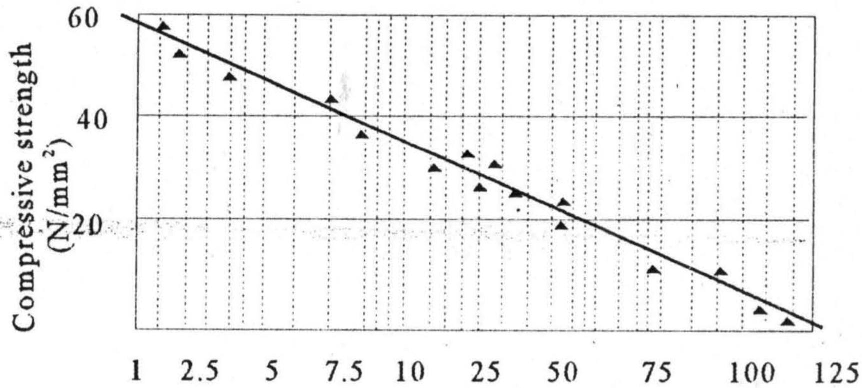


Fig. 2.7

"strictly speaking strength of concrete is influenced by the volume of all voids in concrete, entrapped air, capillary pore, gel pores and entrained air if present" (Neville).

On a linear-Log graph the influence of void on relative strength can be shown to be linear as in fig 2.3.2 below and for a log-log graph, it is parabolic.

There is no doubt that Fig. 2.6 relation between strength porosity of different materials (Neville PP 279) porosity which is defined as total volume of the overall volume of pores larger than gel pores expressed as a percentage of the overall volume of the hydrated cement paste is primarily factor influencing the strength of the cement paste.

Rossler and Odler (1984) in their research on porosity of concrete prescribed a linear relationship between strength and porosity within the range of porosity of 5% and 18%.. They show in their studies that effects of pores smaller than some in diameter was negligible. Consequently in addition to total porosity the effect of pore size distribution on strength must be considered. Generally at a given porosity smaller pores lead to a higher strength of the cement paste.

Neville (1996) is of the opinion that the dependence of strength of hydrated cement paste on its porosity and on pore size distribution is fundamental, research papers occasionally consider a relation between strength and the gypsum content of the cement. But this is the out come of the fact that the typsum content affects the progress of hydration of cement and thus the pore distribution within the hydrated cement paste. The problem is how ever complicated by the factor that different method of determining porosity do not always yield the same value. The main reason for this is that the process porosinetry measurement especially if it involves removal of addition of water affects the structure of the hydrated cement paste.

2.4.1 Total Voids In Concrete

In this section Neville and Brooks (1987) tried to state the formula for the determination of total porosity in concrete by considering a concrete having a mix proportion of cement, fine aggregate and coarse aggregates of C, Af, Ac by mass, a water cement ratio by mass of W/c and a volume of entrapped air a. The total volume of voids in concrete Vc is given by

$$V = Vgw + Vcw + Vcc + a \quad (1)$$

But the volume of gel water Vgw is given as

$$Vgw = 0.190\ Ch \quad (2)$$

$$Vcc + Vcw = \left(\frac{W}{C} - 0.36h\right) C \quad (3)$$

and by substituting (2) and (3) in (1)

$$Vv = \left[\frac{W}{C} - 0.17h\right] c + a \quad (4)$$

Now the total volume of concrete

$$V = \frac{C}{3.15} + \frac{Af}{Pf} + \frac{AC}{Pc} + W + a \quad (5)$$

Where Pf and Pc are specific gravity of fine and

and coarse aggregates.

The concrete porosity P can be derived from equation (4) and (5)

$$P = \frac{Vv}{V} = \frac{W/c - 0.17h + a/c}{0.317 + \frac{1A_f}{\rho_f c} + \frac{1Ac}{\rho_c c} + \frac{W}{c} + \frac{a}{c}}$$

Where W/c = Water/Cement ratio

h = degree of hydration

c = Mass of Cement

W = Mass of water

Ac = Mass of Coarse aggregate

Af = Mass of fine aggregate

ρ_c and ρ_f are the specific gravity of coarse and fine aggregates.

Efforts will be made to determine the porosity using this expression.

CHAPTER THREE

MATERIALS AND METHODS

3.10 Ash Production

The ashes produced from the selected Agricultural wastes used for this research was by burning these wastes in a metal incinerator in open air with a normal burning temperature. Using ordinary burning method is necessary if the result of this research is going to be of benefit to the ordinary people. The burnt ashes was sieved through a British Standard sieve (75 micron). The portion passing the sieve is reported to have the required degree of fineness which is 0.063mm and below (Okpala 1987) while the residue was thrown away.

Chemical analysis of these ashes to determine their siliceous or albuminous content level was not carried. But since Rice Husk Ash (RHA) have been described as pozzolana that is silicious material (Neville 1984). The other materials which are equally agricultural waste has some similarities to the RHA and they are equally available in abundance.

3.20 Specimen Preparation

Since the research is essentially a laboratory work concrete specimens were prepared. The partial replacement of cement by 40% of the ashes of these agricultural wastes was done by weight. The reason for the replacement by weight is obvious. The 1:2:4 mix design which is one part cement, two parts fine aggregate and four part coarse aggregate is a weight proportion.

The quantity of concrete required for each replacement was considered from the point of view of the quantity required for the slump tests. From the weight of this, the weight of the material separates is determined. After the slump test, compaction factor test is performed using the same concrete mix, and finally this concrete is cast into cubes. On the whole 32 cubes (100mm x 100mm x 100m) were cast for the strength test. These comprises eight cubes for each of the replacing materials.

3.30 TESTS

3.3.1 Workability Tests

For each of the mix the slump test were carried. The same concrete mix was used to carry out the compaction factor test and findings were recorded.

3.3.2 Strength Test

The cubes were air dried for each test after wet curing for the number of days required for the compression test. Crushing of the cubes took place on the 7th, 14th, 21st and 28th day wet curing. This is necessary to establish the rate of hydration of the cement and the rate of strength gain.

3.3.3 Porosity Calculation

The most important factor in determining porosity is the specific gravity. This factor was determined for the fine and coarse aggregate. The specific gravity for Ordinary Portland Cement (OPC) is 3.15 but when partially replaced by the ashes of these agricultural wastes there was a drop in the specific gravity and the measured values are presented in table 3.4 below.

3.4 Measurement

Weight of concrete required for the slump test, compaction factor test and casting of cubes = 22.76kg

For 1:2:4 mix 1 part by weight (Cement + Ash)

= 1/7 x 22.76 = 3.25kg

Wt of Ash = 40% x 3.25 = 1.3kg

Cement = 60% x 3.25 = 1.95kg

Wt of fine aggregate = 2/7 x 22.76 = 6.5kg

Wt of coarse aggregate = 4/7 x 22.76 = 13kg

Table 3.1: Table showing Weights of Material

CEMENT		Fine Aggregate	Coarse Aggregate
ASH	CEMENT		
1.3kg	1.95kg	6.5kg	13kg

These weights were used in all the mix proportion. These are constant weight for the experiment. The weight of water constitutes the major variation. Each mixture exhibited the capacity to absorb water at different levels. Hence, the variation in the effects on workability, strength and porosity.

A different weight of 19.2kg was used to determine weight proportion in the case of Beams. Thresh Ash (BTA). The ash realised from burning the bean thresh available weighed only 1.10kg and so not enough to carry out the slump and compaction factor tests but it was enough to cast the eight cubes required for the strength test.

Table 3.2: Weight of Water used for each concrete mix.

OPC + RHA	OPC + GTA	OPC + MCA	OPC + BTA
3.3kg	2.8kg	2.20kg	1.10kg

3.5 The specific gravity of the different materials used in the mix was determine using the ratio method; that the ratio of the density of the material to the density of water. The results were recorded in the table below.

Table 3.3: Specific gravity of materials

Coarse Aggregate	Fine Aggregate	OPC+RHA	OPC+GTA	OPC+MCA	OPC+BTA
2.70	2.60	2.80	2.85	2.92	2.96

As have been stated earlier, OPC + BTA has a total weight of 1/7 x 19.2 = 2.74kg

Ash = 40% x 2.74 = 1.10kg

Cement = 60% x 2.74 = 1.64kg

Fine Aggregate = 2/7 x 19.2 = 5.43kg

Coarse Aggregate = 4/7 x 19.2 = 1.0.97kg

Before carrying out the compression strength each cube was weighed. This was necessary to see if there is any change in weight due to water entrainment into the concrete. So the following weights as shown in the table below as recorded.

Table 3.4: Weights of Concrete Cubes before Crushing.

PERIOD	**Weights (kg)**			
	OPC + RHA Concrete	OPC + GTA Concrete	OPC+MCA Concrete	OPC+BTA Concrete
7 days	2.42	2.48	2.56	2.46
14 "	2.43	2.50	2.58	2.48
21 "	2.44	2.50	2.58	2.50
28 "	2.45	2.52	2.58	2.50

For the strength tests two cubes were crushed for each of the material combination and the average of the compression strength taken. In most case these two results are usually the same.

3.6 Porosity Computation

The degree of hydration (h) for 14 days average wet curing period is 70% (Powers 1959). According to the prescription of American Concrete Institute - ACI 211.1-84 the following table is presented to guide the determination of the percentage of air entrapped in concrete paste.

Table 3.5: percentage of air entrapped in a concrete Paste.

(ACI 211.1-84)

Aggregate Size	10mm	12.5	20	25	40	50	70	150
% air	3	2.5	2	1.5	1.0	0.5	0.3	0.2

The average size of the aggregate used for casting the cubes is about 20mm size. So the percentage of entrapped air is 2%.

The volume of the air entrapped in the concrete paste is found using the expression

$$V = \frac{C}{3.15} + \frac{Af}{\rho_f} + \frac{Ac}{\rho_c} + \underline{W} + a$$

This expression was rearranged to give

$$\frac{a}{V} = \frac{a}{\frac{C}{3.15} + \frac{Af}{\rho_f} + \frac{Ac}{\rho_c} + \frac{W}{C} + a}$$

Where C = Weight of cement

3.15 = Specific gravity of Cement.

Af = Weight of fine Aggregate

ρ_f = Specific gravity of fine aggregate

Ac = Weight Coarse Aggregate

ρ_c = Specific gravity of coarse aggregate

a = Volume of air entrapped.

In this research, the weight of cement means the weight of cement + the weight Ash and instead of using 3.15 as the specific gravity, the values stated in table 3.3 will be used.

For a 1: 2: 4 mix

OPC + RHA W/C = 1.15 - See table 3.6 below

Table 3.6: Water/Cement Ratio as Calculated

Material	OPC+RHA	OPC+GRA	OPC+MCA	OPC+BTA
W/C Ratio	1.15	0.977	0.77	0.89

The specific gravity stated in table 3.3 is used.

$$\frac{a}{V} = \frac{a}{\frac{1}{2.80} + \frac{2}{2.60} + \frac{4}{2.90} + \frac{4}{2.70} + 1.15 + a} = \frac{2}{100}$$

$$= \frac{a}{0.36 + 0.77 + 1.48 + 1.15 + a} = \frac{2}{100}$$

100 a = 2a + 7.52

98a = 7.52 ∴ A = 0.076mm^3.

This volume will be used throughout as the volume of air in the mix

<u>Porosity (OPC + RHA)</u>

Mass of Cement (OPC + RHA) = 3.25kg

Specific gravity = 2.8

Mass of fine aggregate (Af) = 6.5kg

Specific gravity of fine Aggregate 2.60

Mass of coarse Aggregate Ac = 13kg

Specific gravity of coarse Aggregate = 2.70

$$P = \frac{\frac{W}{C} - 0.17h + \frac{a}{C}}{0.317 + \frac{A_f}{\rho_f} + \frac{A_c}{\rho_c} + \frac{W}{C} + \frac{a}{C}}$$

Where h is the degree of hydration put at 70%

$$P = \frac{1.5 - 0.17 \times 0.7 + (0.076/3.25)}{0.317 + \frac{6.5}{2.6} + \frac{13.}{2.7} + 1.15 + \frac{0.076}{3.25}}$$

$$= \frac{1.054384615}{0.317 + 2.5 + 4.81 + 1.15 + 0.023} = \frac{1.05}{8.8} = 0.12 \times 100$$

$$= \underline{12\%}$$

<u>OPC + GTA</u>

W/C = 0.977

$$P = \frac{0.977 - 0.17 \times 0.7 + 0.076/3.25}{0.317 + \frac{6.5}{2.6} + \frac{13.01}{2.7} + 0.977 + \frac{0.076}{3.25}}$$

$$= \frac{0.977 - 0.119 + 0.023}{0.317 + 2.5 + 4.8 + 0.977 + 0.023} = \underline{10.2\%}$$

<u>OPC+MCA</u>

W/C = 0.77

$$\text{Porosity(P)} = \frac{0.77 - 0.17 \times 0.7 + 0.023}{0.317 + 2.5 + 4.81 + 0.77 + 0.023}$$

$$= \underline{8\%}$$

<u>OPC + BTA</u> W/C = 0.89

Weight of Cement (OPC + BTA) = 2.74kg

Weight of fine aggregate = 5.43kg

Weight of coarse aggregate = 10.79kg.

$$P = \frac{0.89 - 0.17 \times 0.7 + 0.076/2.74}{0.317 + \frac{5.43}{2.60} + \frac{10.79}{2.70} + 0.89 + \frac{0.076}{2.74}}$$

$$= \frac{0.89 - 0.119 + 0.028}{0.317 + 2.088 + 3.996 + 0.89 + 0.028}$$

$$= 11\%$$

4.4 Analysis of Variance of the Strength Test Results

The most critical test carried out is the strength. To check for the reliability of this result I decided to carry out the analysis of variance. The coefficient of variation and F-test result will help draw a reasonable conclusion as to the validity of the result.

Table 4.4: Data table

Treatment	Replication				Total Treatment	Treatment Mean
RHA	4	5	5.2	5.5	19.7	4.93
GTA	2.5	3.0	3.3	3.5	12.3	3.075
MCA	5	7.5	7.5	7.5	27.5	6.875
BTA	3	4	4.5	5	16.5	4.125
Grand Total (G)					76	

Grand mean (G.M) 4.75

The research is purely a laboratory experiment and so Completely Randomised Design Method was used in the analysis of Variance.

Correction Factor (C.F) = $\frac{G^2}{H} = \frac{76^2}{16} = 361$

Total Sum of Square = $\sum_{2=1}^{n} X_1^2 - CF$

$= (4^2 + 5^2 + 5.2^2 + 5.5^2 + 2.5^2 + 3^2 + 3.3^2 + 3.5^2 + 5^2 + 7.5^2 + 7.5^2 + 7.5^2 + 3^2 + 4^2 + 4.5^2 + 5^2) - 361$

$= 39.64$

Treatment Sum of Square = $\frac{\sum_{1}^{t} T_i^2}{r}$ - CF

$$= \frac{19.7^2 + 12.3^2 + 27.5^2 + 16.5^2 - 361}{4}$$

$$= \underline{30.97}$$

Error Sum of Square = Total Sum of Square - Treatment S.S

$$= 39.64 - 30.97$$
$$= \underline{8.67}$$

Mean Square Values

Treatment M.S = $\frac{\text{Treatment S.S}}{t-1} = \frac{39.64}{3} = \underline{13.21}$

Error M.S. = $\frac{\text{Error S.S}}{t(r-1)} = \frac{8.67}{4 \times 3} = \underline{0.7225}$

Compute F Value

$$F = \frac{\text{treatment M.S}}{\text{Error M.S}} = \frac{13.21}{0.7225} = 18.28$$

Tabular F Value = $\frac{\text{Treatment d.f}}{\text{Error d.f}}$

$$= \frac{3}{12}$$

f1 = 3, f2 = 12

At 5% level of significance, F = 3.26

At 1% level of significance F = 5.41

The computed F Value is greater than the tabular F Value even at 1% level of significance. The treatment on the cement is highly significant.

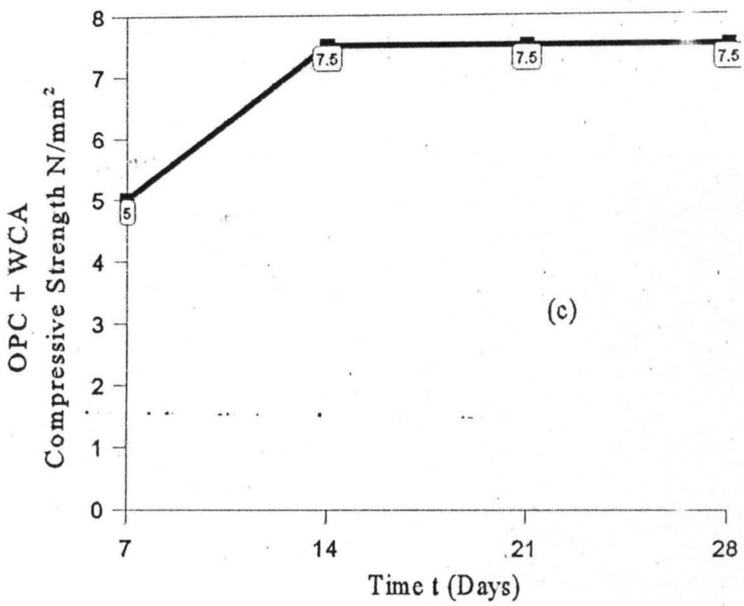
Coefficient of Variation = $\frac{\sqrt{\text{Error M.S}}}{4.75} \times 100$

= 18%

18% Coefficient of variation is low enough to make the research result more reliable.

Table 4.5 - Analysis of variance (ANOVA) Table.

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	Computed F	Tabular F 5%	1%
Treatment	3	30.97	13.21	18.28	3.26	5.4
Experiment Error	12	8.67	0.7225			
Total	15	39.64		CV = 18%		



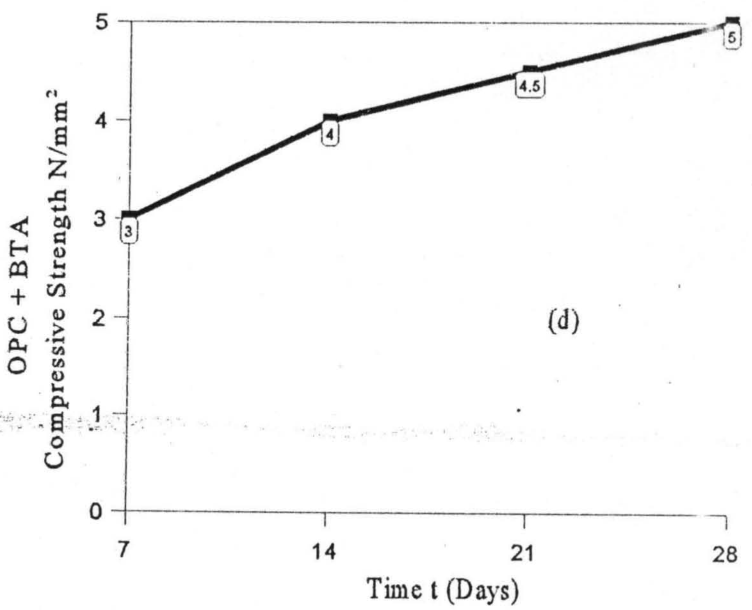


Fig. 4.1 - Graphical representation of the rate of hydration

4.6 Discussion of the Results

The results of the experiment has clearly show that no material is actually useless. What is required is the know how to convert it to useful items. In fact some of the result were quite unpredictable.

4.6.1 Slump and Compaction Factor Test Result

The results of these experiments are quite comparable to the acceptable values stated in tables 2.2 and 2.3. The slump test values in table 2.2, 105 is said to indicate high workability. All the slump values from the result only the one of OPC+MCA which is 80mm is said to fall within the medium range.

In table 2.3 a compaction factor of 0.96 is said to indicate high workability, the experimental result in table 4.1, all compaction factor is up 0.90 and above. All these falls in the range of high workability. It can easily be deduced that blending cement with these ashes improves its workability.

4.6.2 Strength Test Result

As have been stated earlier, strength is the most important of all concrete properties. This research efforts were made to see that this all important property is enhanced in the OPC + Ash concrete. From table 2.1, a grade 20 concrete of 1:2:A mix design without any blending of the cement should have acquired a strength of 13.5N/mm^2 within the first seven days of wet curing. So that within 28 days a strength of 20N/mm^2 should have been attained.

However by looking at table 4.2 it might seem discouraging to notice that the highest strength of 7.5N/mm^2 attained by OPC + MCA after 28 wet curing is no where near the 20N/mm^2. It must be borne in mind that by partially replacing cement in concrete with these ashes, we are not trying to do away with cement but how to reduce its cost in the total construction cost and to reduce the adverse environmental effects of cement production. Again we are trying to reduce the environmental nuisance of these agric wastes by converting to a useful material for construction of houses. So the "low" strength recorded should not be a deterrent.

The question that might agitate the minds of readers of this research will be "Is this strength of 7.5 N/mm^2 of any structural value". In the area of flexural loading I will suggest that we must be careful in recommending this strength. But we have structures of mass concrete work, purely compressive member work and light load bearing elements. These strength can be recommended and this will mean a very high saving in terms of cost of construction.

Never the less, a further research should be carried out with these ashes but this time the percentage of the cement to be replaced by the ash may be reduced from 40% to say 20% or vary the percentage replacement from between 20% to 50% to determine the actual percentage replacement that will give the optimum strength. I do not agree with the research method where every ash must replace cement by 40%, it has to be varied.

If the result of the research is anything to go by the OPC + MCA concrete recorded the highest strength value of $7.5W/mm^2$, Lowest porosity 8% but low compaction factor 0.9 (Tables 4.2, 4.1, 4.3). By this result it will be noticed that blending of these ashes is necessary. All these will certainly improve the strength and other needed and equally important properties of the concrete.

To further actualise the usefulness of these OPC + Ash Concrete, Studies must be carried out in the area of bonding between this concrete and any reinforcement. OPC Concrete is known to have good bonding with reinforcement. So checks must be carried out to see if this is the case with OPC + Ash Concrete.

The long term check to be carried out is the durability of these OPC + Ash Concrete. This may involve test for resistance to abrasion and how long it takes for the concrete to start disintegrating. This check will enable the structural engineers to actually predict the live span of any structure constructed using OPC + Ash Concrete.

There are so many other checks and investigation to be carried out to really decie what will be the extent of application of this material. In a paper published by the faculty of Environmental Science, Mbachu and Kolawole carried a research on the Shrinkage and Elastic Modulus of OPC + RHA Concrete (Mbachu et al 1998). In the paper the two scholars were able to establish the fact that within aggregate sizes and shape, the shrinkage and elastic modulus of OPC + RHA concrete is quite comparable to that of the normal OPC Concrete.

4.6.3 <u>Result of Porosity Calculation</u>

From table 4.3, the highest porosity is recorded in the case of OPC + RHA. As earlier stated and indicated in the graph sketch in Fig. 2.6 that the higher the porosity, the lower the strength of concrete. In this statement there is no upper or lower limit. In fact if zero porosity can be achieved it will be good for the strength of materials. Porosity is a basic problem of many materials not only concrete. In some construction jobs where the concrete is required to be highly impermeable, the calculated porosity might be treated as high. On the whole the porosity values recorded in this research is quite low as to be accepted for ordinary concrete works.

Since porosity is an important factor that effects concrete strength, further checks must be carried out on porosity of OPC + Ash concrete.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY: In summary, the slump and compaction test result from this research is quite comparable or even better than the existing values. If the result are examined properly, it will be noticed that the fineness of the ash have contributed to this good result. The ash serves as a filler and so there was better aggregation of the cement particles and so ease of placement is improved which slump and compaction factor tests sets to establish.

The strength test result at a glance may seem low when compared with the recorded values of OPC concrete. There is nothing to loose if this results can be improved and our construction needs adjusted to meet with this values. We have everything to loose if we just discard the result and continue to import or produce cement the way we are currently doing. Our main of objective in going into this research is to reduce cost of construction and save the environment from pollution of cement production. These objective must be pursued to its logical conclusion.

The OPC + Ash concrete can be useful in area of mass concrete work, light load bearing elements and purely compressive members.

There quite a number of areas which we have to investigate in order to make the result structurally useful, for example the bonding of the OPC + Ash concrete to reinforcement, establish shear stress capability of this concrete and its torsional strength values.

The porosity calculation equally provides excellent result which are comparable to the existing values. But I suggest that conclusion can not now be drawn that. OPC +

Ash concrete has low porosity until further investigation has been reached especially in the area of aggregates.

5.2 Conclusion

From the research result it can be concluded that the ash form a filler between the cement and aggregate particles thereby bringing the particles closer and this have improved the workability.

The ash presence is the mix brought the cement particles closer to the water of hydration and so the rate of hydration increased rapidly. This is noticed in case of OPC + MCA where by before the 14th day wet curing, hydration was complete at 7.5N/mm^2 strength. This strength never changes until the 28th day. In Ordinary Portland Cement (OPC) concrete, it is usually assumed that hydration is never complete until after one year (See Table 2.1). This rapid hardening capability without any reduction in gypsium content is an advantage especially in wet concreting.

The result of the porosity calculation which we have noticed to be very encouraging may not be unconnected with the presence of the ashes in the concrete. The filling of inter particle gaps, by the ash water permeability is reduced. Thereby reducing the porosity.

By the improvement of workability and Porosity due to the presence of the ash in the concrete, it will appear high strength have been sacrificed, but I feel convinced that a balance can be struck in the quantity of ash replacing cement with improved strength without any sacrifice in the improved workability and porosity.

5.3 Recommendation

Since this my little effort could produce this fantastic result, I am recommending that:

(1) The research on the OPC + Ash concrete should be pursued further than mere seminar paper presentation material to an extent that production of blended cement with these ashes of agricultural wastes will be actualised since there is enormous gain from this.

(2) All research work on ash and concrete must be coordinated so that notes will be taken on what has been established. This will enable us build a library of knowledge on blended cement in Nigerias. I know we are not doing anything new when we talk about blended cement but our own blending is with the ashes of agricultural waste. Others blend with fly ash, blast furnace slag etc.

(3) If the research result is adopted, Nigeria Society of Engineers must be prepared to establish a national standard code guiding the use of Agricultural Wastes Ash blended cement in construction industry.

(4) The Building Society of Nigeria must be encouraged to build prototype houses using this cement. This will facilitate its adoption in the country.

(5) Federal Government should be sensitised to take note of these research going on in various universities and other tertiary institution as it relate to construction materials as this may be formular required to jump start the housing for all programme.

(6) When eventually this cement is in production, we have to embrace it and use it. Our environment and finances will be better for it. A mud stabilized with cement in the ratio of 1:6 have been recommended by the Building Society of Nigeria and the strength is a mere $1.8N/mm^2$ (Shehu 1998). Ordinary mud house did not kill our parents. Even the "reinforced concrete" houses have killed more people than mud houses ever did. So the low strength of OPC + Ash concrete in this research should discourage us. This can be improved.

REFERENCES

(1) Neville, A.M. (1996) "Properties of Concrete"
Addison Wesley Longman Limited
London.

(2) Frohnsdorff, G. 91984) "Blended Cement"
ASTM STP 897 Pg 62.

(3) Power, T.C. Copeland L.E., MANN, H.M. (1959) "Capillary Continuity or Discontinuity in Cement Paste".
Portland Association Research and Development Laboratories
No. 2 Pg 38-48 (MAY).

(4) Brook, J. J. and A.M. Neville (1987) "Concrete Technology" Long Man Publication.

(5) Okpalla D.C. (1987) "Rice Husk Ash as a Partial Replacement of Cement in Concrete". The Nigeria Society of Engineers Annual Conference Proceeding, Port Harcourt (Nor).

(6) Price, W. H. (1951) "Factors Influencing Concrete Strength ACI Vol. 47 Pg 417-432 (Feb).

(7) Code of Practice (CP) 110 (1972).
"Structural Use of Concrete
British Standard Institution.

(8) Obande, M.O. 91993) "Briddying and Concreting"
Longman Group U.K. Ltd.

(9) Cement and Concrete Association (1979).

"Concrete Practice"

Wexham Spring: London.