DEVELOPMENT OF CEMENTING MATERIALS USING LOCALLY AVAILABLE RAW MATERIALS FOR BUILDING CONSTRUCTION

BY

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DEDICATION

This project is dedicated to the Almighty God and my parents Mr. & Mrs. Apata who have made it possible for me to go through this programme.

CERTIFICATION

This is to certify that this research work was carried out by **Apata, Ayodeji Oluwatoyin** of the **Department of Metallurgical and Materials Engineering** and is accepted as meeting the requirements in partial fulfillment of the award of master of Engineering (m. Eng) degree in Metallurgical and Materials Engineering.

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May the peace of God be upon the gentle soul of my late friend Bamise Olorunbe who toiled day and night to see me though but was snatched away by the cold hands of death on 13th of October, 2005. Bamise, I remember you always but I am sure we will meet at the feet of Jesus Christ one day to part no more.

I am grateful to Almighty God, the creator and custodian of knowledge for leading me successfully in all I went through while trying to achieve this academic goal.

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THE LORD IS MY STRENGTH

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

In producing cement, all the ingredients but gypsum is sourced locally. To conserve funds used in the importation of gypsum and to proffer solution to the environmental degradation posed by the dumping of rice husk in the country, this study has looked into the possibility of using locally available materials in the development of cement. In producing the cementing materials from locally available raw materials for use in building construction industry, several mixes of Pozzolana samples were prepared. Sample B comprises of Rice husk ash, fired clay and lime; Sample C comprises of Coal ash, fired clay and lime; Sample D comprises of Rice husk ash, fired clay, Coal ash and lime; Sample E comprises of Rice husk ash, fired clay, lime and 10% ordinary Portland cement. Sample A (Ordinary Portland Cement) served as the control sample. The samples were then subjected to physical and mechanical tests. The results of the Pozzolona Samples were compared with those of sample A (Control sample/ Ordinary Portland Cement). Samples B and E exhibited fineness closely related to sample A, which is an indication of increased rate of hydration. The result also showed sample A with a shrinkage value of 0.69% has higher constancy volume than pozzolona samples B, C, D and E which have shrinkage values of 3.45%, 3.45%, 3.45% and 2.76% respectively. The reduction in the shrinkage value of pozzolona sample E could be attributed to the 10% addiction of portland cement. The compressive strength of samples B, C, D and E were found to be 13.70N/mm^2, 18.00 N/mm^2, 19.75 N/mm^2 and 18.50 N/mm^2 respectively. These were lower than that of the control Sample A which was 20.25 N/mm^2. This shows that pozzolona exhibited lower strength than concrete made with Ordinary Portland Cement. However, they are higher than those obtained from sawdust concrete (Ndububa and Ndububa, 1998) and palm fruit fibre mortar (Ndububa et al, 2001). The study showed that local raw materials such as rice husk, fly ash and burnt clay can serve as alternative to cement. The study further showed that pozzolona can be adopted for simple construction work such as roofing sheets, tiles, partitions and ceiling boards.

CHAPTER ONE

1.0 INTRODUCTION

House Ownership is one of the most cherished cultural acquisitions. Unfortunately, many people are unable to own houses of their own because of the high cost of cement, which takes about 50% of the total cost of construction materials (Okpala, 1988). Limestone is abundantly available in Nigeria where nine cement factories are existing. The total installed capacity of the existing factories is about 50% of the nation's requirement while the actual combined production is less than 30% of the demand. Coupled with other factors such as the high off-shore cost elements of production arising from importation of machinery, spare parts and gypsum, cement has progressively over the last two decades become a scarce commodity for construction. The government has recently lifted tariff on imported cement, machinery and spare parts imported by existing cement manufacturers as a short-term solution (Osoba 1999). The solution to this problem is in the development of an appropriate technology that will utilize the locally available raw materials and/or improve the local procedures. Taking cognizance of the fact that rice is among Nigeria's staple food of which the husk being waste is discarded. They constitute a nuisance at this time of National Environmental clean-up exercise. Hence it is very imperative that an avenue is created through which this rice husk will be meaningfully utilized. The need for the production of alternative cementing materials, in widely dispersed location throughout Nigeria, cannot therefore be over emphasized.

1.1 Aims and Objectives of the Research

The project work- development of cementing materials using locally available raw materials for building construction is aimed at the following:

i. to produce pozzolana from its constituent materials such as rice husk ash, fly ash and burnt clay.

ii. to evaluate its cementing characteristics.

iii. to determine the suitability of pozzolana as a possible new structural element, which is safe, durable and economical when its engineering properties are compared with that of Ordinary Portland Cement (OPC). Similarity of pozzolana with any of the constituents of Ordinary Portland Cement will entail integrating it or total substitution of such constituent as the case may be, this will help in the use of locally available raw materials in cement production thereby reducing the cost of production and leading to foreign exchange earning for the country.

1.2 Theoretical Background

Cement may be defined as an adhesive substance capable of uniting fragments or masses of solid matter into a compact whole (lea, 1976).

Pozzolanas are materials containing reactive silica and/or alumina which on their own have little or no binding property, but when mixed with lime in the presence of water will set and harden like a cement (Paya et al, 2001). They are important ingredients in the production of an alternative cementing material to Ordinary Portland Cement (OPC). Fly ash, resulting from firing coal is termed pozzolana. Rice husks, burnt in open air produces amorphous ash, which is a pozzolana.

1.3 Scope of the Work

The project work shall focus on the analysis of the engineering properties of rice husks ash, coal ash and fired clay as they affect their uses as a building material. Such properties to be tested for are: loss on ignition, fineness, compressive strength, specific gravity, porosity, linear shrinkage, dry density, and water absorption. The results of these tests will express their effectiveness as cementing materials.

1.4 Expected Contribution to Knowledge

The project is expected to proffer solution to problem arising from the use of gypsum by indigenous cement industries. The study is expected to provide avenue for the use of abundant local raw materials such as rice husk, fly ash and burnt clay for the local production of cement as an alternative to Ordinary Portland Cement.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 What is Pozzolana?

Pozzolanas are usually defined as materials which, though not cementing in themselves, contain constituents which will combine with lime at ordinary temperatures in the presence of water to form stable insoluble compounds possessing cementing properties.

The Greeks and the Romans were the first civilisations known to use pozzolana. The Romans used not only crushed pottery, bricks and tiles which formed the first artificial pozzolanas but also found that some volcanic soils were excellent for producing a hydraulic mortar. Nowadays, a wide variety of siliceous or aluminous materials are used for producing pozolanas, the common materials being calcined clays, pulverised fly ash, volcanic ash and ash from agricultural residues such as rice husks. The pozzolana can be divided into two groups, natural and artificial.

2.1.1 Natural Pozzolanas

The natural pozzolanas are from the most part of volcanic origin, but include certain diatomaceous earths. The pozzolana of volcanic origin consist of glassy incoherent materials or compacted tuffs arising from the deposition of volcanic dust and ash. They may occur as does for example the Rhenish tress, in a consolidated rock –like form underlying material deposited subsequently, or in a more fragmentary and unconsolidated state, like some of the Italian pozzolans.

The volcanic pozzolanas are composed of a mixture of silicates and contain both glass and crystalline particles. The volcanic ash and dust from which they were formed has undergone rapid cooling, and in some cases has subsequently suffered considerable chemical alteration leading to the formation of zeolitic compounds.

Some analyses of volcanic ash pozzoalnas are shown in Table 2.1

TABLE 2.1: Percentage Composition of Volcanic Ash Pozzolanas

Pozolanas	Loss on Ignition	SiO_2	$A1_2O_2$	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	SO_3
Rhenish Tress	10.1	54.6	16.4	3.8	0.6	3.8	1.9	5.1	3.9	0.4
Rhenish Tress	8.5	54.8	17.2	4.4	0.6	2.3	0.9	7.0	3.8	0.1
Bavarian Tress	14.5*	57.0	10.9	5.6	0.5	6.0	2.2	1.8	1.5	0.2
Santorin Earth	4.9	63.2	13.2	4.9	1.0	4.0	2.1	3.9	2.6	0.7
Santorin Earth	3.1	65.2	12.9	6.3	-	3.2	1.9	2.6	4.2	-
Rome Segno	9.6	44.1	17.3	10.7	-	12.0	2.0	1.4	3.1	-
Segno	5.3	48.2	21.9	9.6	-	7.5	3.2	4.1	4.1	0.3
S. paolo	4.1	45.2	20.0	10.7	-	9.8	3.8	6.2	6.2	0.3
Naples: Bacoli	4.8	55.7	19.0	4.6	-	5.0	1.3	3.4	3.9	-
Biaia	4.4	59.5	19.3	3.3	-	2.1	0.2	11.3	11.3	0.2
Rmanian Tress	13.9	62.5	11.6	1.8	-	6.6	0.7	2.9	2.9	-
Crimean Tuff	11.7	70.1	10.7	1.0	-	2.5	0.3	3.7	3.7	-
U. S.A Rhyolltic	3.4	65.7	15.9	2.5	-	3.4	1.3	5.0	1.9	-
Pumicite	4.3	72.3	13.3	1.4	-	0.7	0.4	1.6	5.4	Trace

Source: (Lea, 1976)

This class of naturally occurring materials showing pozzolanic properties include the diatomaceous earths which are known by many different names and trade descriptions, and some siliceous rocks which have lost much of their basic oxides. The diatomaceous earths are composed of the siliceous skeletons of diatoms deposited from fresh or sea-water. In many cases the deposits are mixed with sand or clay.

The main constituent of diatomaceous earths is opal. This is an amorphous form of hydrous silica containing up to 10 percent water, but sub-microscopic crystals of beta-cristobalite may also be present in it (Annali, 1954).

2.1.2 Artificial Pozzolanas

The artificial pozzolanas are mainly products obtained by the heat treatment of natural materials such as clays, pulverised fuel ash, (ash from coal), shales and agricultural residues such as rice husks (Komar, 1981). Table 2.2 shows the composition of some artificial pozzolanas.

TABLE 2.2: **Percentage Composition of Some Artificial Pozzolanas**

Pozzolanas	SiO_2	$A1_2O_2$	Fe_2O_3	CaO	MgO	Na_2O and K_2o	SO_3	Loss on Ignition
Burnt clay	58.2	18.4	9.3	3.3	3.9	3.9	1.1	1.6
Burnt clay	60.2	17.7	7.6	2.7	2.5	4.2	2.5	1.3
Spent oil shale	51.7	22.4	22.2	4.3	1.1	3.6	2.1	3.2
Raw gaize	79.6	7.1	3.2	2.4	1.0	-	0.9	5.9
Raw gaize	88.0	6.4	3.3	1.2	0.8	-	trace	-
Raw molar	66.7	11.4	7.8	2.2	2.1	-		5.6
Burnt molar	70.7	12.1	8.2	2.3	2.2	-	1.4	-
Raw diatomite (U.S.A)	86.0	2.3	1.8	trace	0.6	0.4	1.5	8.3
Burnt diatomite	69.7	14.7	8.1	1.5	2.2	3.2	-	0.4
Fly-ash (U.S.A)	47.1	18.2	19.2	7.0	1.1	3.95	-	1.2
Fly-ash (British)	44.8	18.4	11.2	11.6	1.1	3.14	2.8	7.5
Fly-ash (British)	47.4	27.5	10.3	2.1	2.0	5.7	2.0	0.9
Fly-ash (British)	45.9	24.4	12.3	3.6	2.5	4.2	1.8	4.1

Source:(Lea 1976)

2.1.3 Material Used in Producing Artificial Pozzolanas

2.1.4 Rice husk and rice husk ash

Rice husk continues to remain the largest identifiable non-intensively developed agricultural commodity existing on earth. It is a typical example of naturally occurring amorphous silica deposit. The use or disposal of husk has frequently proved difficult because of the tough, woody, abrasive nature of the husk, their low nutritive properties, resistance to weathering, great bulk and high content on a world wide basis, about 80 million (20% of paddy production) tones of husk must be disposed off annually (Pillayers, 1988).

This is generally done in an unscientific manner, and if not properly utilized, will create a growing problem of space and pollution in the environment.

At controlled burning, rice husk produces an amorphous ash capable of forming a cementing material on mixing with lime. From the result of Nigeria building and road research institute Lagos, the reactive ashes are obtained when burnt in open air such as incinerator.

The predominant component of ash is silica, the reported values as compiled by Houston (1972) vary from 86.9 to 97.8% and this is responsible for its reactivity. Such a wide variation is due to various factors like variation in purity of sample and the accuracy of analytical procedures. Joseph (1982) found relatively little variation in ash composition resulting from variety or environment for eight varieties grown at three locations among 3 years. Ash recovered from the interior of large masses of buried husks, where air access is restricted is a delicate lilac pink and with adequate air supply, the ash is colourless. Increasing amounts of residual carbon cause grey to black products (Muntohar and Hantoro 2000). The composition of rice husk ash, as reported by many workers varies very widely as shown in Table 2.3.

TABLE 2.3: **Composition of Rice Husk Ash**

Investigator	Year	SiO_2	CaO	MgO	Na_2O	K_2O	Fe_2O_3	P_2O_5	Al_2O_3	MnO_3	SO_3
Beagle	1965	95.00	0.70	0.05			0.09		0.08	0.5	
Borasio	1928	94.50	0.25	0.23	0.78	1.10	TR	0.53	TR		1.13
	1929	94.23	2.27	0.12	0.39	2.22	0.53	0.24	TR		
	1930	93.95	2.28			3.15	1.01				
Fraps	1916	96.97	0.57	0.12		0.58	TR	0.5			
Garbarino	1942	90.27	0.94	0.67	0.40	1.25		0.51	TR	TR	0.33
Jones	1954	96.50	0.25	0.40	1.00	TR		0.30		TR	1.00
Thai -863	1922	95.70	2.70					0.30			

TR =TRACE **Source: (Beagle 1978)**

2.1.5 **Clay and burnt clay**

Clay is naturally, earthly, fine grained material which developed plasticity when mixed with a limited amount of water. It is composed primarily of silica, (SiO_2), Alumina (Al_2O_3) and water (H_2O), often with iron (Fe), alkalis and alkaline earth metals (Grim 1968). The composition of natural clays cover a range, one of the purest clay is china clay, principal composition-$A1_20_3$. $2SiO_2$ $2H_2O$. The clay minerals form a large component of the ceramics industry worldwide. They play a base or supportive role in foundries and in the glass, chemical, electrical and building industries.

Burnt clay is a pozzolana and is achieved by burning selected clays at temperatures ranging from 700°C to 1000°C in vertical shaft kilns. The clay may be moulded into balls or bricks.

The burnt clay if grind in a ball mill to a fine cement-like powder and mixed with fly ash and rice husk ash at suitable proportions to form a highly reactive pozzolana. (Komar 1987).

The chemical composition of burnt clay is shown in Table 2.2.

2.1.6 **Coal and coal ash**

Coal is an organic material which has a brown to black combustible rock that had its origin in the accumulation and physical and chemical attrition of vegetation, usually in swamp or moist area. Coal composed mainly of elements such as hydrogen, carbon and oxygen with small quantities of other substances like sulphur, phosphorous, moisture and volatile matter in various proportions.

Coal ash or fly ash as it is known in many countries has both pozzolanic and physical properties that enhance the performance of concrete. When Portland cement hydrates, it produces quantities of alkali calcium hydroxide (lime). Pozzolanas like fly ash react with this lime to form stable calcium silicate and aluminates hydrates. These hydrates fill the voids within the concrete, removing some of the lime and thus reducing the permeability. This process improves the strength durability, chloride and sulphate resistance of the concrete. The pozzolanic reaction occurs relatively slowly at normal temperatures enhancing strength in the longer reactive to normal portland cement concrete. (Mehta 1985)

United Kingdom Quality Ash Association (UKQAA, 2000) from her work shows that, the finer fraction of fly ash, that is, those particles that pass the 45μm sieve, act as a solid particulate plasticizer. These particles are spherical and act like ball bearing within the concrete reducing the water requirements for a given workability. A reduction in the water content lowers the permeability and increases strength and durability. In addition, the concrete is more cohesive, has a lower rate of bleeding and is less prone to segregation. (UKQAA 2000).

The advantages of using fly ash in concrete can be summarised as follows:

- Improves long term strength performance and durability
- Reduces permeability, which reduces shrinkage, creep and given greater resistance to chloride ingress and sulphate attack.
- Minimizes the risk of alkali silica reaction.

2.2 Cement

Cement may be defined as adhesive substances capable of uniting fragments or masses of solid matter to a compact whole (Lea 1976). There are two major types of cement namely: organic and inorganic cement.

The organic cements are animate in origin such as glue. The inorganic cements are composed of the earths crust and can be divided into hydraulic and non-hydraulic cement depending on the way it sets and hardens. Hydraulic cements, e.g. Portland cements are capable of setting and hardening under water whereas non-hydraulic cements, e.g lime hardens in air and cannot be used under water.

There are different types of cements used for construction, they are, Portland cements, slag cements, pozzolanic cements and high alumina cement (Jackson and Dhir 1988). All these are inorganic cements and portland cement is the most commonly used for construction and structural design of concrete (BS 1990). It is this basis, Portland cement is chosen as control for the project work. In general, Portland cement is divided into the following categories (Orchard 1976):

(a) Ordinary Portland Cement (O.P.C)

(b) Rapid hardening Portland cement.

(c) Extra rapid hardening Portland cement.

(d) Portland blast furnace cement

(e) Low heat Portland cement

(f) Sulphate-resisting Portland cement.

(g) White Portland cement

(h) Coloured Portland cement.

In America, Portland cements are divided under the America Society for Testing Materials (ASTM) standard into the following five types:

Type I- for use in general construction where the properties specified for types II, III, IV, and V are not required.

Type II- for use in general concrete construction exposed to moderate sulphate action, or where moderate heat of hydration is required.

Type III- for use when high early strength is required.

Type IV for use when low heat of hydration is required.

Type V- for use when sulphate resistance is required.

In addition, there are types IA, IIA and IIIA which are exactly the same as types I, II and III except that they have an air-entraining agent added

(Orchard, 1976). Portland cement is the resultant of pulverized clinker which consists mainly of hydraulic calcium silicate in which no further additions of components have been made after calcinations. Only water and or untreated calcium sulphate (gypsum) could be added to the clinker, though on the wish of the manufacturer, additives which does not exceed 1.0% of the materials such as Na_2O, K_2O, $CaCl_2$. (a setting time accelerator) or other elements could be added. The composition of clinker (a fixed mixture of limestone and shale or clay) is shown in the Table 2.4.

TABLE 2.4: **Composition of Clinker**

Name	Formula	Abbreviation
Dicalcium silicate	$2CaO.SiO_2$	C_2S
Tricalcium silicate	$3CaOSiO_2$	C_3S
Tri calcium Aluminates	$3CaOA1_2O_3$	C_3A
Tetra calcium alumino ferrite	$4CaO.A1_2O_3.Fe_2O_3$	C_4AF
Magnesium oxide (in free state)	MgO	MgO

Source: (Orchard, 1976)

2.2.1 The properties of compounds of clinker are discussed briefly here

(1) Dicalcium silicate (C_2S):

- (i) Imparts ultimate strength to the cement
- (ii) Offers more resistance to chemical attack
- (iii) Hardens more slowly
- (iv) Hydrates slowly

(2) Tricalcium silicate (C_3S):

- (i) Generate heat more rapidly
- (ii) Hydrates more rapidly
- (iii) Possesses less resistance to chemical attack
- (iv) Develops early strength

(3) Tricalcium alunminate (C_3A):

  (i) Weak against sulphte attack

  (ii) Reacts fast, generating a large amount of heat

  (iii) Does not contribute to develop strength

  (iv) Causes initial setting of cement.

(4) Tetra calcium aluminum ferrite (C_4AF):

  (i) Poor cementing value

  (ii) Reacts slowly, generating a large amount of heat

  (iii) Comparatively inactive.

It has been observed/analyzed that most of the strength developing properties of cement are controlled by C_3S and C_2S.

Table 2.5 indicates the range of oxide composition usually found in normal portland cement.

TABLE 2.5: **Oxide Composition of Normal Portland Cement**

Oxide Ingredient	Range (%)
Lime, CaO	60-66
Silica SiO_2	19-25
Alumina $A1_2O_3$	3-8
Iron, Fe_2O_3	1-5
Magnesia, MgO	0-5
Sulphur Oxide, SO_3	1-3

Source: (Paya and Ordonez 2001)

2.2.2 Functions of ingredients of cement

The functions of various ingredients of any ordinary portland cement are given below:

1. Lime (CaO):

   - It is the major constituent of cement and its proportion needs to be maintained carefully.

- The lime in excess makes the cement unsound and causes the cement to expand and disintegrate.
- If lime is in deficiency, the strength of cement is decreased and cement sets quickly.
- If lime is in the right proportion, it makes the cement sound and strong.

2. Silica (SiO_2)
   - It is an important ingredient of cement and imparts strength to the cement due to the formation of dicalcium and tricalcium silicates.
   - Silica in excess provides greater strength to the cement but at the same time prolongs its setting time.
3. Alumina ($A1_2O_3$):
   - It imparts quick setting quality to the cement
   - It acts as a flux and lowers the clinkering temperature
   - Alumina in excess reduces the strength of cement.
4. Iron oxide (Fe_2O_3):
   - It provides colour, hardness and strength to cement.
   - It also helps the fusion of raw materials during manufacture of cement.
5. Magnesium oxide (MgO):
   - This ingredient, if present in small amount, imparts hardness and colour to the cement.
   - Magnesium oxide in excess makes the cement unsound.
6. Sulphur trioxide (SO_3):
   - If present in very small quantity, it makes the cement sound.
   - If present n excess, it causes the cement to become unsound.
7. Calcium sulphate ($CaSO_4$):
   - It is present in the form of gypsum
   - It helps in increasing the initial setting time of cement.

2.2.3 Manufacture of Portland Cement

Different types of Portland cement are manufactured to meet different physical and chemical requirements for specific purposes. However, out of these types, the type I-ordinary Portland cement is commonly used and this is used as control for the project work.

The major compounds that constitute Portland are: lime, silica, Ironoxide, alumina, and gypsum (added after burning). The production chart is shown in Figure 2.1

Portland cement is manufactured from carefully specified materials and by closely controlled process. The first step is to blend the proper proportions of limestone, marl, or other calcareous materials with clay, shale, or blast furnace slag. The mixture then is heated in a rotary kiln to temperature of approximately 1430°C to 1650°C to form a clinker. The clinker is cooled and pulverized. A small amount of gypsum is added to regulate the setting time. The pulverized product is Portland cement and can pass through a 200 –mesh sieve. It is stored in silos from which is bagged or loaded for shipment. Portland cement will retain its cementing quality indefinitely if it does not come in contact with water (White, 1981).

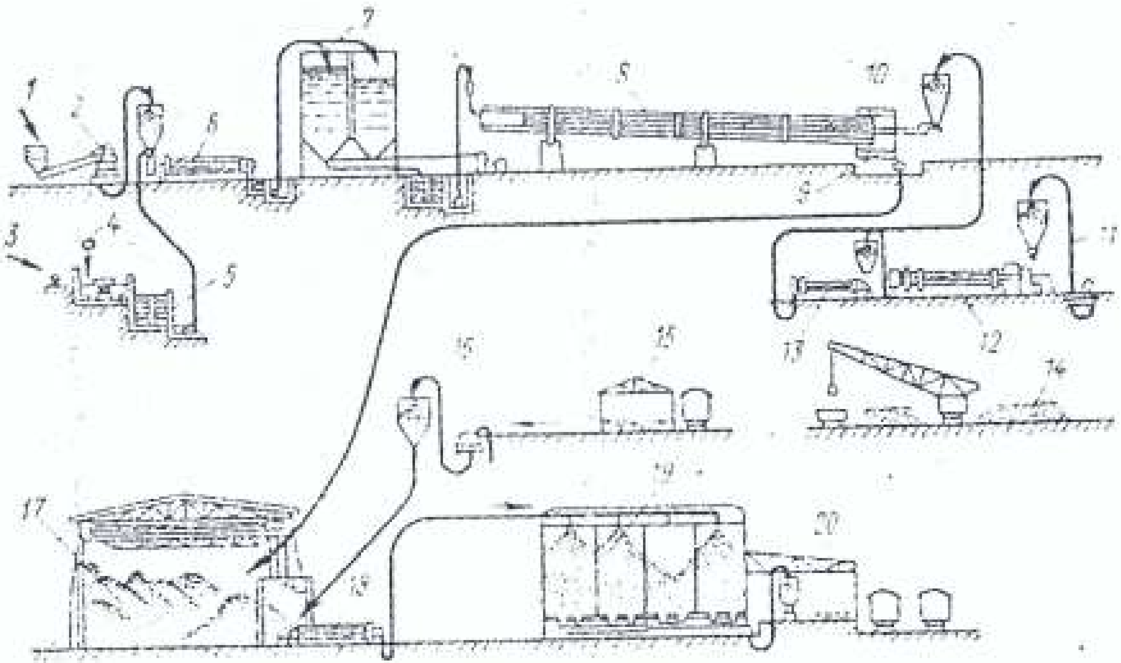


Fig. 2.1 Manufacture of portland cement by wet method

ethod

1. Supply of limestone from quarry
2. Limestone crusher
3. Supply of clay from pit
4. Supply of water
5. Clay kneading tank
6. Mill for raw materials
7. Slurry tanks
8. Rotary Kiln
9. Cooler
10. Supply of pulverized coal to furnace
11. Elevator for transporting coal from crusher to bin
12. Rotary kiln for drying coal
13. Coal mill
14. Coal storage
15. Gypsum Storage
16. Elevator for supplying gypsum from crusher to bin
17. Clinker storage
18. Ball mill
19. Cement silos
20. Cement packing

2.2.4 Setting and hardening of cement

The chemical reaction between cement and water is called hydration of cement. When cement is mixed in water (varying from 25 to 35 percent by weight), a stiff and sticky paste is formed which remains plastic for a short period. With the passage of time, the plasticity gradually disappears and the cement paste becomes stiff due to initial hydration of cement. This phenomenon by virtue of which the plastic cement changes into a solid mass is known as setting of cement. On setting, the cement binds the aggregates into a solid mass which gains strength as the time lapses, till the hydration of cement is complete. Thus, the phenomenon by virtue of which the cement paste, which is finally set, develops strength is known as hardening of cement. Table 2.6 shows the summary of properties of principal cement.

TABLE 2.6: **Summary of Properties Of Principal Cement**

Cement	Rate of strength development	Rate of heat evolution	Drying shrinkage	Resistance to cracking	Inherent resistance to chemical deterioration
Portland cements:					
Rapid-hardening	High	High	Medium	Low	Low
Normal (O.P.C)	Medium	Medium	Medium	medium	Low
low- heat	Low	Low	Somewhat Higher	high	Medium
sulphate resisting	Low to medium	Low to medium	medium	Medium	High
Cement containing					
B/f slag	Medium	Medium	Medium	Medium	Medium
Portland BF					
Super sulphate	Medium	Very low	Medium	inadequate information	High
High-Alumin					
pozzolanic	Low	Very high Low to	Medium Some what	Low high	Very high High

Source: (Komar, 1987)

2.3 Concrete

Concrete is mixture of cement, sand, gravel and water, which when placed in forms and allowed to cure, becomes hard like stone. The hardening is caused by the chemical reaction between the cement and water. The cement and water form a paste which upon hardening, binds the aggregate to a permanent mass cement is called the binding material, the gravel is called the coarse aggregate as distinguished from the fine aggregate which is sand. The mortar used in concrete is called matrix. Cement concrete when used by itself is known as mass concrete. (Rajput 2005)

2.3.1 **Material Used in Making Concrete**.

i. **Cement**

Cement is used as a binding material in the concrete required for different engineering works where strength and durability are of significant importance. For this purpose ordinary portland cement is commonly used. However, when work needs to be carried out quickly, rapid hardening cement is also used.

ii. **Aggregates**

Aggregates are materials mixed with cement and water in producing mortars and concrete. They constitute 60 to 80% of the volume of concrete, and hence are called filler materials (White 1981).

Aggregates are generally classified as follows:

- Coarse aggregate – gravel or crushed rock 5mm or larger in size.
- Fine aggregate – sand less than 5mm in size.

The criterion for a good aggregate is that, it should produce the desired properties both in fresh and hardened concrete. In testing aggregates, it is important that a truly representative sample is used.

The characteristics of the aggregates greatly influence the properties, mix proportions, workability and economy of concrete. These characteristics include abrasion resistance, resistance to freezing and good particle shape and surface texture. They should not contain materials having harmful effects such as dirt, clay, coal or organic matter.

The abrasion resistance of an aggregate is often used as index of floors and pavements. Resistance to freezing and thawing is important when the aggregates are used in exposed concrete and is related to its porosity, absorption and pore structure. If an aggregate particle absorbs so much water that insufficient pore space is available to accommodate the water expansion that occurs during freezing the concrete may be vulnerable to freezing.

Aggregate should not react chemically with cement or any other external influences. Aggregates with certain chemical constituents in some cases react with alkalis in cement. This alkalis –aggregate reaction may cause abnormal expansion and map –cracking of the concrete (white 1981).

The particle shape and surface texture of an aggregate influence the properties of fresh concrete more than they do on hardened concrete. Rough textured or flat and elongated particle require more cement paste to produce workable concrete than is required by rounded or cubical aggregates.

Coarse aggregate particles should be cubical in shape and free of excessive amount of flat and elongated pieces. Long silvers of aggregate pieces should be avoided or at least limited to 15% by weight of the total aggregate. This is also important in fine aggregate, since sand made by crushing stone often consists of angular particles. (Zhang and Malhotra 1996).

Hard and durable aggregates are best suited for use in concrete. Aggregates that are soft, flaky and slow rapid wear when exposed to the weather generally are unsatisfactory. Weak, friable or laminated aggregates are undesirable (White 1981).

iii. **Water and Water-Cement Ratio**

As stated earlier, dirty aggregates reduce the quality of concrete. As a matter of fact, water is used to wash such aggregates off dirt.

Water is also used in concrete and mortar mixes. This causes the hydration of cement. Excess water of hydration demands more aggregates to produce a workable and economical mixture. Of the total volume of concrete, water comprises 21% (2 to 42 US gallons per cubic yard).

In engineering practice, the strength of concrete at a prescribed temperature is assumed to depend primarily on two factors, the water-cement ratio and the degree of compaction. Water-cement ratio is the ratio of water to cement and is expressed as the ratio of the weight or volume of water to the weight or volume of cement in concrete mixture.

Water to be used for mixing mortar or concrete must not contain dissolved substances which affect the setting time unduly or retard the hardening. In general, the only impurities in natural water that are likely to be objectionable are dissolve salts and the permissible limits of these are quite wide.

Acid water with pH value less than 3.0 may create handling problems and should be avoided, though mixing water which contain hydrochloric, sulphuric, and other common inorganic acid in concentrations as high as 10,000 ppm generally have no adverse effect on concrete strength (Lea, 1976).

2.3.2 **Mix Proportion**

Generally, mix proportion can be defined as a statement of quantity of the component materials of concrete in ratio to each other. Such information are used to give the designer of a structure and concrete mixer what quality of cement, fine and coarse aggregate are to be added together to achieve a specific strength economically and under favourable conditions of concrete production. Such statements are usually of the form X: Y: Z where X is a ratio of cement in the mix, Y is that of fine aggregate and Z is the coarse aggregate. Common mix proportion are:

1:9 - Cement to all-aggregates for mass concrete foundations.

1:2:4- Cement to fine aggregate to coarse aggregate for lintels and floors.

1:$1^1/_2$:3-Cement to fine aggregate to coarse aggregate for narrow reinforced concrete beams and columns.

1:6- Cement to fine aggregate for cement mortar.

The water cement ratio is always 0.6 (Lea, 1976). For this project work the mix proportion will be 1: $1^4/_5$: 6 by Weight which is equivalent to 1:2:4 by volume.

2.3.3 Curing of Concrete

Curing can be defined as the procedure used in promoting the hydration of cement in concrete (Neville, 1981). ASTM in its publication defines curing as keeping the concrete moist and warm enough that the hydration of its cement content may continue.

In general, curing comprises the application of heat and/ or the preservation of moisture within the concrete. The application of heat speeds up the chemical reaction and consequently the rate of hardening of the concrete. It can be imagined that preventing the escape of moisture from the concrete enable the previous unwanted minute particles of cement to participate in the cementing action. If heat is applied to accelerate the hardening of the concrete, it is therefore important not to expel the water held within the concrete.

The temperature at which concrete is cured has an important bearing on the development of its strength with time. The rate at which concrete made with Ordinary Portland Cement increases with increase in concrete temperature at early ages, although at later ages the concrete made and cured at lower temperatures show a somewhat higher strength (Jackson and Dhir, 1988).

2.4 Properties of Cementitous Materials

The properties of cementitous materials dictate their fields of application. As a matter of fact, the strength, durability and efficiency of buildings and installations are achieved only when the properties of the materials are correctly evaluated.

These properties can generally be sub headed under physical, chemical, and mechanical properties.

2.4.1 Physical Properties

These includes the characteristics of materials relating to weight, density, the permeability to liquids, gases, heat and radioactive rays as well as their resistance to aggressive environment.

2.4.2 Chemical Properties

These include the characteristics of materials relating to their resistance to acids, alkalis, and salt solutions which may initiate exchange reactions in the materials and cause their failure.

2.4.3 Mechanical Properties

These include the characteristics of materials relating to its ability to resist compression, tension, impact indentation, creep, abrasion and other forces. The strength developed by a cement either when tested in a mortar or a concrete is dependent on many factors such as the grading of the sand or aggregate, the proportion of water used, the degree of mixing, the temperature and humidity of the atmosphere in which its conducted, the method by which the material is placed in the moulds, the curing conditions, the method of testing and the age at which tests are carried out (Lea, 1976).

2.5 TESTS ON THE PHYSICAL PROPERTIES OF CEMENT

2.5.1 Fineness

Several methods are available for measuring the fineness of cement, for example BS 4550, part 3 prescribes a permeability method which is a measure of the resistance of a layer of cement to the passage of air, for this project work, sieve method was used.

The reaction between the water and the cement starts on the surface of the cement particles and in consequence the greater the surface area of a given volume of cement the greater the hydration. It follows that for a given composition, fine cement will develop strength and generate heat quickly than coarse cement.

2.5.2 Linear Shrinkage

This is defined as percentage moisture content of a substance (soil) at a point where it suffers no further decrease in volume on drying. Linear shrinkage can be determined according to BS 1377. (1975) by using a mould size 14cm x 3cm. the soil-water mixture shall be placed in the mould and the mould shall then be gently jarred to remove any air pockets in the mixture. The soil shall then level off along the top of mould with palette knife. The mould shall then be placed in the oven for drying, the mould shall remain in the oven until shrinkage was largely ceased. The mould and soil shall then be cooled and the mean length of the soil bar measured.

The percentage linear shrinkage can be calculated from the following expressions:

$$\%\text{linear shrinkage} = 1 - \frac{\text{length of oven dry sample}}{\text{Initial length of sample}} \times 100 \qquad \text{..........2.1}$$

$$= 1 - \frac{\text{length of oven dry sample}}{14} \times 100 \qquad \text{...........2.2}$$

2.5.3 **Dry Density**

Density is the mass per unit volume of a material. The density of cement samples can be obtained by using a rectangular container with a known volume, beam balance, and smooth edge metal. The samples must be first dried in the oven, then the mass of the rectangular container must be measured and filled with cement sample and weighed with beam balance. The dry density can be calculated as follows:

Volume of container (cm^3) $= L \times b \times h$

Container weight (g) $= m_1$

Container + cement (g) $= m_2$

Cement weight (g) $= (m_2 - m_1)$

$$\text{Dry density } (g/cm^3) = \frac{(m_2 - m_1)}{\text{Volume of container}} \qquad \ldots\ldots 2.3$$

2.5.4 **Specific Gravity**

Specific gravity of a material can be defined as the weight of a certain volume of material per unit weight of an equal volume of water (Smith, 1975). The specific gravity of the sample was determined using pyconometer method in accordance with BS 1377. (1975).

The expression for the specific gravity was derived from the following:

m_1 = mass of empty dry bottle.

m_2 = mass of bottle + dry sample.

m_3 = mass of bottle + sample + distilled water.

m_4 = mass of bottle + distilled water only.

$$\text{Specific gravity} = \frac{m_2 - m_1}{(m_4 - m_1) - (m_3 - m_2)} \qquad \ldots\ldots 2.4$$

2.5.5 Porosity

Porosity can be defined as the percentage pore space within a given volume. Total or absolute porosity is a measure of the total void volume and is the excess of bulk volume over grain volume. It is usually determined as the excess of grain density (the same as specific density) over dry density per unit of specific density and can be obtained from the following expression:

$$\text{Porosity} = 1 - \frac{\text{dry density}}{\text{specific gravity}} \times 100 \quad \ldots\ldots\ldots\ldots 2.5$$

(Neville, 1981)

2.6 Test of Concrete

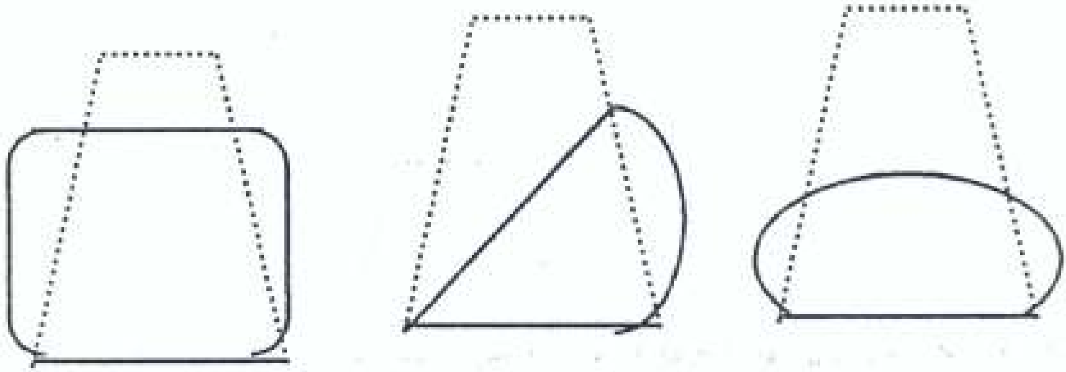
2.6.1 Workability

Workability implies the ease with which a concrete mix can be handled from the mixer to its finally compacted shape. The strength of concrete of a given mix proportion is seriously affected by the degree of its compaction, it is vital, therefore, that the consistence of the mix be such that the concrete can be transported, placed, and finished sufficiently easily and without segregation. A concrete satisfying these conditions is said to be workable (Neville, 1993).

Several methods can be used to measure workability, for example, slump test, compacting factor test and verbs test, but slump test will be discussed.

2.6.2 Slump Test

A 300mm high concrete cone with open base of 200mm diameter and smaller opening of 100mm diameter at the top prepared under standard conditions is allowed to subside and the slump or reduction in height of cone taken be measure of workability. The cone is filled with freshly mixed concrete in three equal layers, each being tamped 25 times with a tamping rod. When the cone has been filled and leveled off, it is lifted carefully. The amount of slump is then measured which is the decrease in the height of the centre of the slumped concrete. The three types of slump usually observed are true slump, shear slump, and collapse slump, these are shown in Fig 2.2 The true slump is the accepted slump showing that the concrete is workable. Table 2.7 shows the degree of workability.



True slump shear slump collapse slump

Fig : 2.2 kind of slumps

TABLE 2.7: **Degree of Workability**

Degree of workability	Very low	Low	Medium	High
Slump (mm)	0-25	25-50	50-100	100-175

Source: (Neville 1981)

2.6.3 **Compressive Strength**

The compressive strength of concrete can be defined as the maximum load per unit area it can carry. The higher the load, the more useful the concrete as a structural element all things beings equal. The compressive strength of a concrete can be determined by the use of control Milano Haly universal testing described in BS 1881, part 116. Also, a hydraulic compressive strength machine can be used. Figure 2.3 illustrates the compressive strength test and Table 2.8 shows the typical values of compressive strength for different types of lightweight concrete

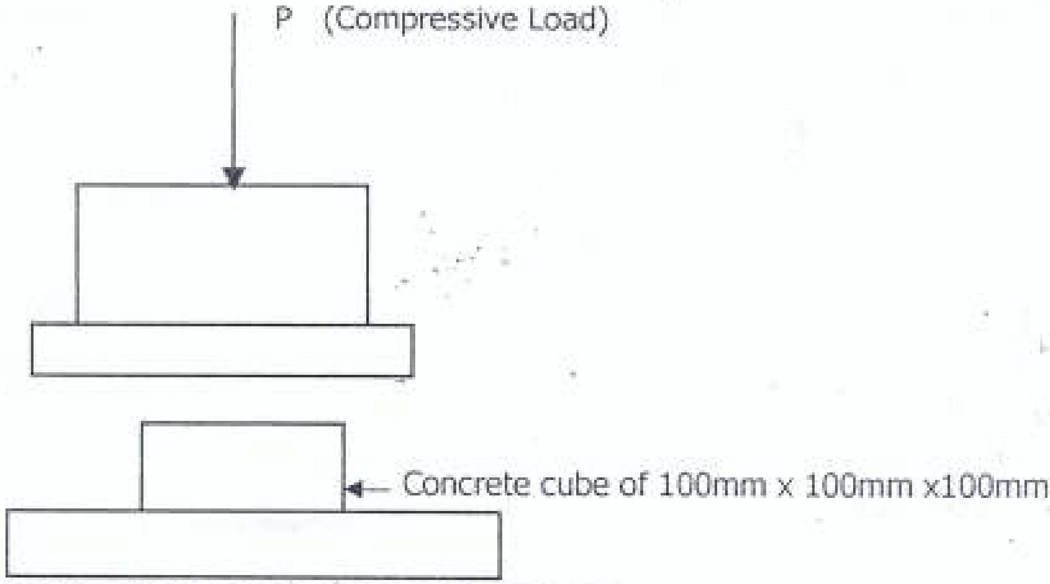


Fig 2.3 compressive load on concrete cube.

$$\sigma = \frac{p}{b \times d} \qquad \text{.................... 2.6}$$

σ = compressive strength N/mm ^{2}

p = compressive load in kN

b = breadth of the cube in mm.

d = length of cube in mm

TABLE 2.8: Typical Values of Compressive Strength for Different Types of Lightweight Concrete

Type of concrete	Aggregate	Density of concrete (Kg/m^3)	Compressive strength of 28 days aged cubes
Aerate concrete		400 – 800	1.4 – 4.9
Partially compacted light Weight aggregate concrete	Pumice	720 – 1120	1.4 – 4.9
	Foamed slag	960 – 1520	1.4 – 5.6
	Sintered pulverized – fuel ash	1120 – 1280	2.8 – 7.0
	Expanded clay or shale	960 – 1200	5.6 – 8.4
	Clinker	1040 – 1520	2.1 – 7.0
Structural light weight aggregate concrete	Pumice	1040 – 1600	10.5 – 21.0
	Foamed slag	1380 – 2080*	10.5 – 42.0
	Sintered pulverized – fuel ash	1360 – 1760*	14.0 – 42.0
	Expanded clay or shale	1360 – 1840*	14.0 – 42.0
Dense concrete	Gravel	2240	28.0

*These denser concretes are obtained by replacing some lightweight fines by natural sand.

Source: Department of environment, Britain: Overseas Building Notes No. 152, Manufacture and Application of Light weight concrete, 1973.

2.6.4 **Density of Concrete**

Density of concrete is the weight of the concrete per unit volume of the mould used for casting.

2.6.5 **Dynamic Modulus of Elasticity.**

In some cases it is desirable to determine the progressive change in the strength of a concrete specimen, such an investigation can be made using a large number of compression test specimens, a batch of them being tested at suitable time intervals. It is clear, however, that it would be preferable to observe the variation in the quality of the same specimen over the entire duration of the investigation.

To this end, advantage can be taken of the general relation between strength of concrete and its dynamic modulus of elasticity. The relation between the dynamic modulus of elasticity of concrete E_d and its strength F_{cu} can be derived from the British code of practice for the structural use of concrete CP 110: 1972 It can be stated as:

$E_d = 7.6\ F_{cu}^{\ 0.33} + 14.$ 2.7

Where E_d is in kN/mm^2 and F_{cu} in N/mm^2

2.6.6 **Water Absorption Capacity**

The water absorption capacity is determined by measuring the increase in weight of dried sample when immersed in water (the surface water being removed). The ratio of the increase in weight to the weight of the dry sample, expressed as a percentage, is termed absorption.

CHAPTER THREE

3.0 EXPERIMENTAL TECHNIQUES

3.1 Materials and Preparation

i. **Rice Husk**

This was sourced from a local rice mill shop located in Idah, Kogi State. The rice husk was burnt in open air to ash and sieved through 0.1mm grade.

ii. **Coal**

This was obtained from Okaba mine, located in Kogi State. The coal was first completely burnt in open air to ash. Ashes obtained were collected and sieved through 0.1mm grade.

iii. **Kaolin Clay**

This was collected from a deposit at Iyoloko, Idah, Kogi state. The clay was first dried in sun, then ground to fine size before burning at 1000^0C.

iv. **Ordinary Portland Cement (O.P.C)**

The Dangote cement brand was purchased from a local cement vendor.

v. **Silica Sand**

This was sourced from a local deposit around Idah, Kogi state. The sand was graded in accordance with British standards (BS 1377) 1975.

vi. **Gravel Sand**

This was sourced from a local deposit around Idah, Kogi State.

Vii **Lime**

This was purchased from a local vendor.

3.2. Experimental Procedure

3.2.1 Preparation of Pozzolana

The pozzolana cement samples were prepared by mixing various raw materials in various proportions and designated as B,C,D, and E.

Typical compositions of the mixes are given in Table 3.1 below:

Table 3.1: **Composition of the mixes**

SAMPLE	COMPOSITION
A	Ordinary Portland Cement (O.P.C)
B	Rice husk Ash/fired clay/lime in ratio 2:1 (Pozzolana: lime)
C	Coal Ash/Fired clay/lime in ratio 2:1
D	Rice husk Ash/fired clay/ coal Ash/lime in ratio 2:1
E	Rice Husk Ash/fired clay/coal Ash/lime/10% O.P.C

3.2.2 Preparation of Test Samples

Two different categories of samples were prepared. The first category is composed of cement and graded sand while the second category is composed of cement, sand and gravel to make concrete.

In each case, samples were thoroughly mixed prior to addition of water. On addition of water, the slurry obtained was cast into moulds of 100mm cubes as shown in Plate 1 and allowed to dry for 24 hours. On demoulding, the samples were cured by forming a pond over the concrete after it has set (Plate 2). The mixes were specified by volume rather than by weight because the bulk relative densities are not in the same order due to different size of grains. The water cement ratio range was 0.4 to 1.2 as recommended in earlier work (Paramasivan and Loke, 1978).

An average value of 0.65 was adopted in order to produce sufficient workabilities. It was expected that the pozzolanas will absorb much of the water.

3.3 Analysis of Cement And Pozzonlana Samples

The cement and pozzolana samples were subjected to chemical analysis using the Atomic Absorption Spectrophotometer (AAS). The results obtained is shown in Table 4.2

3.4 Testing Procedure

(i) Loss On Ignition:

50g of dry sample was measured and heated to 700^{0}C in a furnace and the loss on ignition was calculated for the sample using the relation.

$$\%\ \text{Loss On Ignition} = \frac{(50 - W_1)\ 100}{50} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

where W_1 is the mass of heated sample.

ii) Fineness Test:

Fineness test was carried out by sieving the samples for 15 minutes using 0.1mm mesh. The percentage of the residue by mass was determined

iii) Linear Shrinkage Test:

Linear shrinkage was determined according to B.S. 1377, 1975 method by using a mould of size 14cm x 3cm. The sample was mixed with water to form a paste. The paste was placed in the mould and levelled off along the top of the mould with palette knife. The mould was placed in the oven for drying. The percentage linear shrinkage was calculated from equation 2.2.

iv) Dry Density:

The density of sample was obtained by using a rectangular container with a known volume. The rectangular container was measured and filled with cement sample, which was levelled off along the top of the container and weighed with beam balance. The dry density was calculated using equation 2.3.

v) Specific Gravity:

The specific gravity of the samples was determined using pyconometer method in accordance with B.S. 1877. 1975. The specific gravity was derived from equation 2.4.

vi) Porosity:

Porosity of the samples was obtained from equation 2.5.

All the results obtained for the physical properties are shown in Table 4.3

(vii) Compressive Strength Test:

A hydraulic compression machine was used to crush 100mm specimen cube to determine compressive strength. The test was carried out in accordance with British standard specifications (BS 1881). The sample was crushed at seven days interval and the compressive strength values obtained were given in Table 4.4 and Figure 4.2 respectively.

(viii) Dynamic Modules of Elasticity Test:

The dynamic modulus of elasticity of the sample was determined using equation 2.7.

The dynamic modulus of elasticity of the samples was determined at seven days interval and the values obtained are shown in Table 4.5 and Figure 4.3 respectively.

(ix) **Water Absorption Test:**

The water absorption tests was conducted by weighing specimen cube before and after soaking in watei for 28 days. The ratio between the difference in weight was taken as the water absorption. The values obtained are given in Table 4.6 and Figure 4.4 respectively

Plate 1 showing some of the cubes produced

Plate 2 showing cube samples during curing

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

An Investigation has been carried out on the production of pozzolana as cementing materials for use in the building construction. The pozzolana cement samples were prepared from various mixes of rice hush ash, fly ash, burnt clay and lime. The cement so produced was used to make cement mortar and concrete cubes. Measurements were taken of their physical and mechanical properties. The result obtained are given in Table 4.1-4.6 and presented in Figure 4.1 - 4.4.

TABLE 4.1: Results of sieve Analysis (grading) for the fine aggregate used in the mix proportions

BS sieve size (mm)	Mass Retained (g)	% Retained	Cumulative % passing	Cumulative % Retained
5.00	15.80	0.99	99.01	0.99
4.00	41.60	2.60	96.41	3.59
2.00	199.60	12.48	83.93	16.07
1.00	502.50	31.41	52.52	47.48
0.80	198.50	12.41	40.11	59.89
0.20	560.30	35.02	5.09	94.91
0.06	51.40	3.21	1.89	98.12
Pan	30.30	1.89	0.00	100.00
	1600			

TABLE: 4.2: Chemical Composition of O.P.C and Pozzolana Samples

SAMPLE	A	B	C	D	E
SiO_2	22.00	48.49	35.49	42.69	40.62
Al_2O_3	5.50	6.05	13.12	8.29	8.01
Fe_2O_3	3.30	3.03	7.73	5.55	5.30
CaO	64.20	35.14	36.52	36.00	38.81
Na_2O	0.64	1.90	1.37	1.76	1.65
K_2O	0.72	2.17	1.41	1.22	1.42

TABLE 4.3: Summary of Physical Properties of The Samples

SAMPLE	A	B	C	D	E
% Loss On Ignition	4	10	4	10	5
Fineness % Retained in 0.1mm Sieve	2.33	2.67	3.33	3.67	2.67
% Linear Shrinkage	0.69	3.45	3.345	3.345	2.76
Dry Density (g/cm^3)	2.09	1.22	1.22	1.11	1.12
Specific Gravity	3.05	2.42	2.42	2.34	2.36
% Porosity	31.48	49.59	50.41	52.56	52.54

TABLE 4.4: Results of Compression Tests on Concrete Samples of 1:2:4 Mix Ratio

Sample cube of No.	Age of cube (days)	Mass of cube (g)	Cube density g/cm^3	Crushing load (KN)	Compressive strength (N/mm^2)
A_1	7	2342.00	2.34	93.00	9.30
B_1		1965.00	1.97	76.50	7.65
C_1		2160.00	2.16	136.50	13.65
D_1		2262.00	2.26	162.50	16.25
E_1		2558.00	2.56	63.50	6.35
A_2	14	2370.00	2.37	138.50	13.85
B_2		1987.50	1.99	92.00	9.20
C_2		2182.50	2.18	143.50	14.35
D_2		2285.00	2.29	172.50	17.25
E_2		2580.00	2.58	115.50	11.55
A_3	21	2401.00	2.40	177.00	17.70
B_3		2017.50	2.02	122.50	12.25
C_3		2210.00	2.21	162.50	16.25
D_3		2315.00	2.32	186.50	18.65
E_3		2603.00	2.60	165.00	16.50
A_4	28	2405.00	2.41	202.50	20.25
B_4		2025.00	2.03	137.50	13.70
C_4		2220.00	2.22	180.00	18.00
D_4		2322.00	2.32	197.50	19.75
E_4		2615.00	2.62	185.00	18.50

TABLE 4.5: Results of Dynamic Modulus of Elasticity of The Concrete Samples

Sample cube Ref. No	Age of cube (days)	Dynamic Modulus of Elasticity (KN/mm^3)
A_1	7	29.86
B_1		28.87
C_1		32.01
D_1		33.07
E_1		27.99
A_2	14	32.09
B_2		29.81
C_2		32.31
D_2		33.45
E_2		31.02
A_3	21	33.62
B_3		31.27
C_3		33.07
D_3		33.96
E_3		33.16
A_4	28	34.51
B_4		32.05
C_4		33.73
D_4		34.34
E_4		33.91

TABLE 4.6: Results of Water Absorption Tests on Concrete Samples

Sample cube Ref No.	Age of cube (days)	Initial Mass (g)	Average mass after curing (g)	Density of concrete (g/cm^3)	Water absorption capacity (%)
A_1		2300.00	2342.00	2.34	1.83
B_1		1900.00	1965.00	1.97	3.42
C_1	7	2100.00	2160.00	2.16	2.86
D_1		2200.00	2262.00	2.26	2.81
E_1		2500.00	2558.00	2.56	2.32
A_2		2300.00	2370.00	2.34	3.04
B_2		1900.00	1987.00	1.99	4.60
C_2	14	2100.00	2182.00	2.18	3.92
D_2		2200.00	2285.00	2.28	3.86
E_2		2500.00	2580.00	2.58	3.20
A_3		2300.00	2401.00	2.40	4.39
B_3		1900.00	2071.50	2.02	6.15
C_3	21	2100.00	2210.00	2.10	5.23
D_3		2200.00	2315.00	2.32	5.22
E_3		2500.00	2603.00	2.60	4.12
A_4		2300.00	2405.00	2.41	4.56
B_4		1900.00	2025.00	2.03	6.57
C_4	28	2100.00	2220.00	2.22	5.72
D_4		2200.00	2322.00	2.32	5.55
E_4		2500.00	2615.00	2.62	4.61

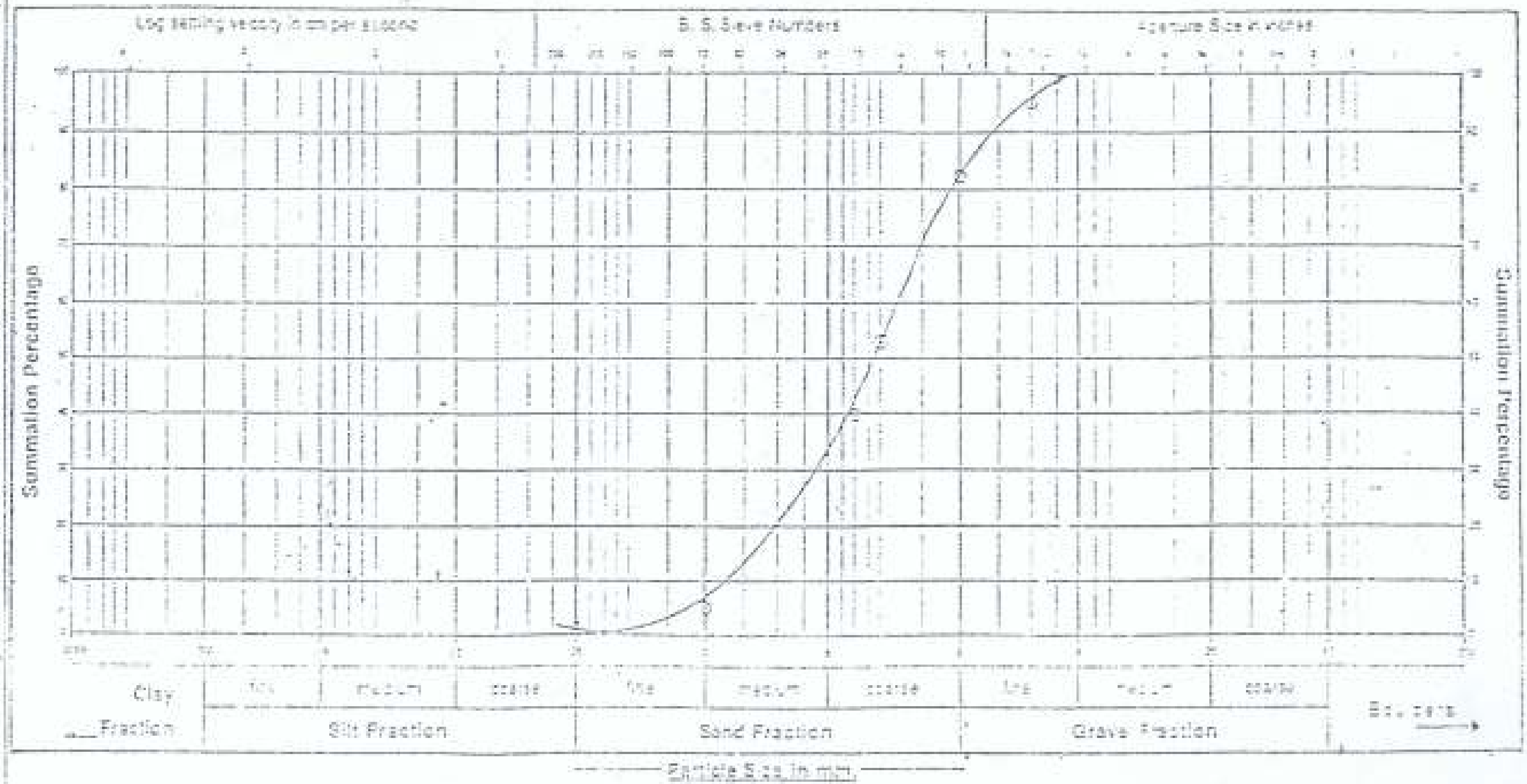


Fig. 4.1 Grading Curve for fine Aggregates

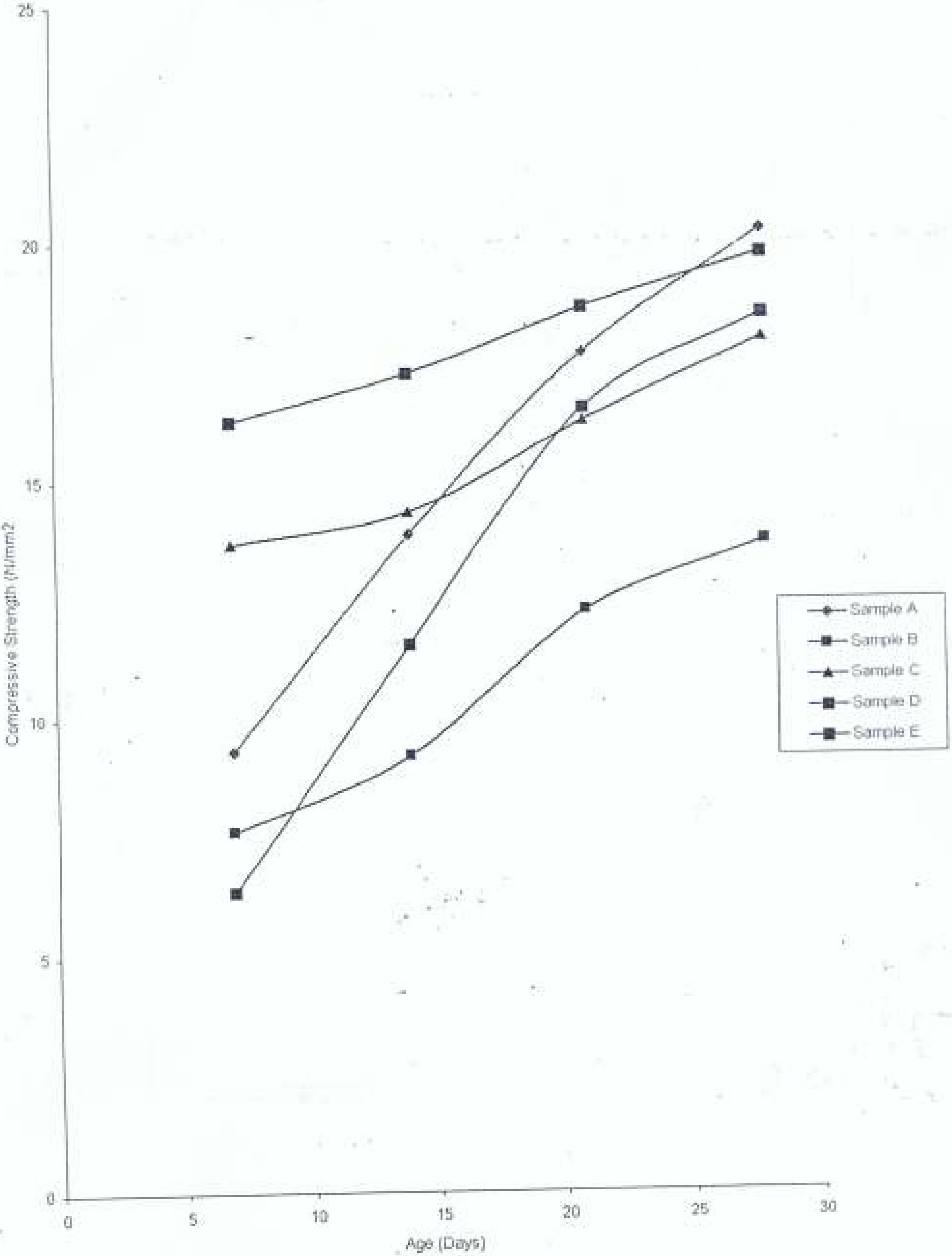


Fig. 4.2: Compressive Strength Curves For Various Samples

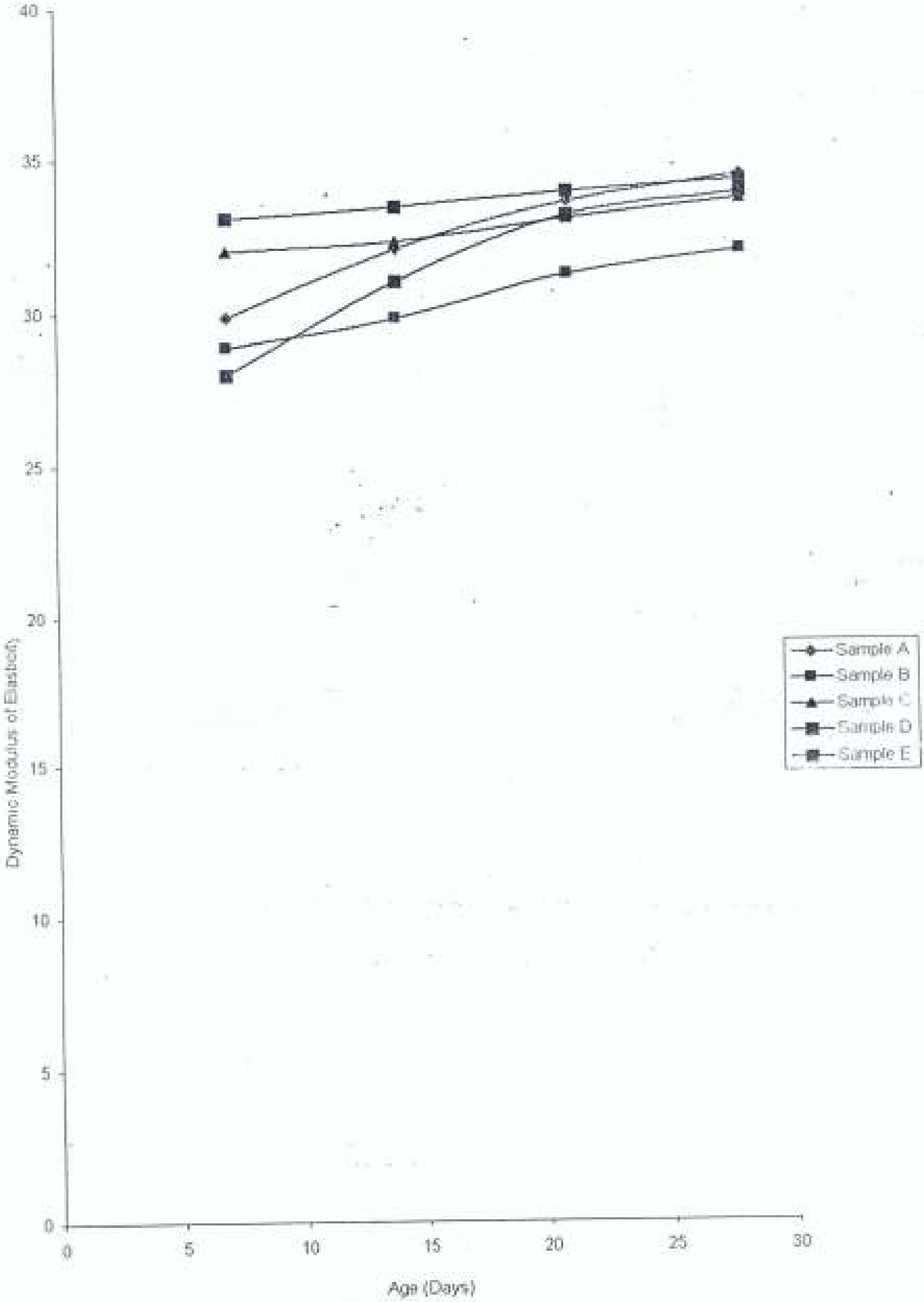


Fig. 4.3: Dynamic Modulus of Elasticity Curves of Various Samples

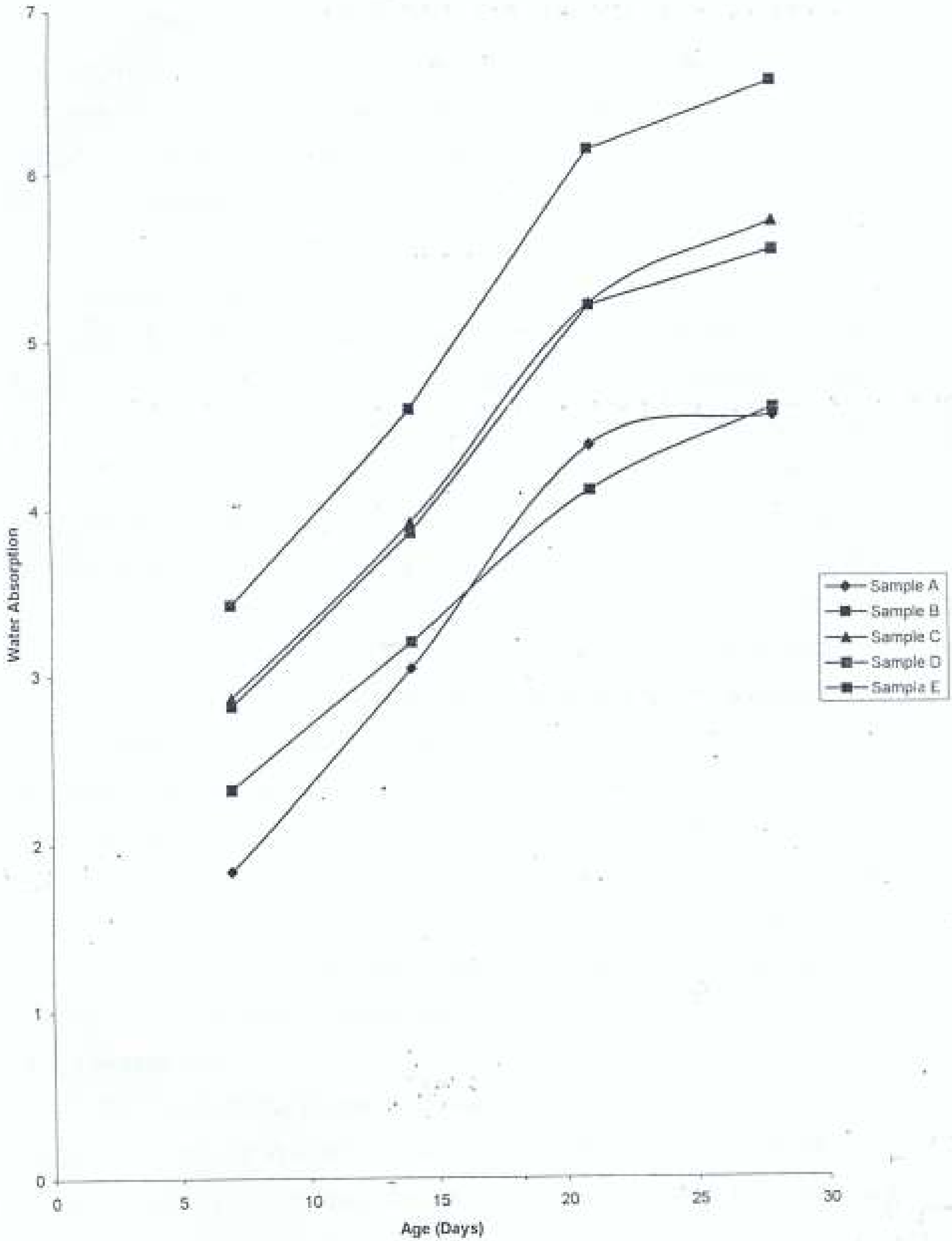


Fig. 4.4: Water Absorption Capacity Curves For the Various Samples

4.2 DISCUSSION

4.2.1 Loss On Ignition

The losses on ignition values were determined for samples A,B,C,D and E (Table 4.3). It can be seen that samples A and C have lower values (4%) than samples B and D (10%) and E (5%). The reason for these lower values is that samples A and C initially contained less volatile matters, which were burnt off during calcinations.

4.2.2 Fineness Test

The result of fineness test in Table 4.3 shows that samples A (2.33%), B, (2.67%) and E (2.67%) are closely related in term of increased rate of hydration which leads to high strength and heat generation, while samples C (3.33%) and D (3.67%) shows decreases in rate of hydration. Grim (1968) observed that the reduction of the clinker to a very fine state of division by grinding is usually considered to increase its value as a cementing material in two ways. In the first place, a fine powder is able to coat the surfaces of grains of sand more completely than a coarse one. In the second place, the reaction between cement and water takes place only at the surface of the solid particles, further action being hindered by the accumulation of the products of the reaction coating the unattached materials. Hence, the more finely ground a cement, and the greater the surface exposed in proportion to its mass, the more rapid is the rate of hydration and the greater is the proportion of the cement which react. Also the amount of bleeding decrease with fineness of the samples, but required more water for workability which can result in an increase in dry shrinkage.

4.2.3 Shrinkage

The result of the percentage linear shrinkage (Table 4.3) shows that sample A (Ordinary Portland Cement) with shrinkage value of 0.69% has higher constancy of volume than the pozzolana (samples B,C,D,) with shrinkage value of 3.45% each. This is likely due to the place of pozzolana as an organic vegetable aggregate as compared to Ordinary Portland Cement (O.P.C.) Sample E has lesser value (2.76%) than other pozzolana probably due to 10% Ordinary Portland Cement (O.P.C.) added to it.

The cement gel undergoes an inward shrinkage during which existing voids are increased in size or new ones formed, and contemporaneously the whole structure suffers a small contraction in its outward dimensions. This contraction of the outward form of the mass is rather less than the inner shrinkage, thus accounting for a small contraction in its outward dimensions. It must be noted that when set cement or concrete loses water the change in volume is only a small fraction of the volume of the water lost. This may be due to the restraints set up by the non-shrinking bodies present, for example, the aggregate and unhydrated cement grains and by elastic forces in the gel itself.

4.2.4 Dry Density and Specific Gravity

The results of dry density and specific gravities as given in Table 4.3 shows that sample D has least values (1.11 g/cm^3 and 2.34 respectively) compared to other samples. While that of Ordinary Portland Cement (O.P.C.) are 2.09 g/cm^3 and 3.05 respectively. It implies that the replacement of Ordinary Portland Cement (O.P.C.) with pozzolana by weight will result in greater volume of the cementitious materials in the mix.

4.2.5 Porosity

The percentage porosity of the samples investigated (Table 4.3) shows that sample A (Ordinary Portland Cement) with value 31.48% has lowest permeability (to air and water) compared to pozzolanas. Pores are small cells in a material filled with air or water. Pores may be open or closed, fine and coarse. Fine closed pores filled with air are good heat insulation properties. Structures, which are required to be very strong or impervious are built from denser materials, whereas walls of buildings are generally made of substantial porous materials which possess good heat insulation properties.

4.2.6 Compressive Strength

In Table 4.4 and Figure 4.2, the average compressive strengths for the samples, B,C,D. and E aged for 28 days are 13.70N/mm^2, 18N/mm^2, 19.75N/mm^2 and 18.50N/mm^2 respectively. The values are found to be lower than those of sample A (Ordinary Portland Cement) whose compressive strength is 20.25N/mm^2. However, they are higher than those obtained from sawdust concrete (Ndububa and Ndububa, 1998), and palm fruit fibre mortar (Ndububa et al 2001). According to the Nigerian Standard Organization (NSO. NIS, 1975), the specified strength for sandcrete block is 3.5N/mm^2. Comparison of the strengths of pozzolana concrete samples B,C,D and E with the standard specification shown in Table 4.8, it can be seen that the values obtained are far higher. Thus pozzolana can safely be used in replacement for Ordinary Portland Cement.

Kumar (1991) has observed that strength properties for pozzolana can be enhanced with more ageing and time if extended beyond 28 days. Practically, strength is affected by the following factors; Grading of the sand or aggregate, proportion of water used, degree of mixing, the curing conditions, temperature and humidity of the atmosphere in which it is conducted, method of testing and the age at which tests are carried out.

4.2.7 Dynamic Modulus of Elasticity

The results of the dynamic modulus of elasticity with hydration period for up to the age of 28 days for all concrete samples are presented in Table 4.5 and in Figure 4.3. The results, just as in the case of compressive strength indicate that the modulus of elasticity increase with age and that for a given hydration period, concrete made with Ordinary Portland Cement (O.P.C.) exhibited higher modulus of elasticity than concrete made with pozzolanas.

4.2.8 Water Absorption Capacity

The higher value of water absorption capacity for the pozzolanas at the same age with that of Ordinary Portland Cement (O.P.C.) concrete is attributed to their higher porosity (Table 4.6 and Figure 4.4). The concrete made with 10% O.P.C. (sample E) has lower water absorption capacity value compared with samples B, C, and D but higher than that of Ordinary Portland Cement (O.P.C.) concrete. On the average the results are less than 7.0% which is the maximum water absorption specified for building boards by American Society for Testing and Materials (ASTM, 1974). Water absorption of building materials is governed by the volume of the pores, their shape and size. It is also influenced by the nature of materials and their water retaining properties. Saturation with water increases volume but strength decreases because the links between the particles are broken by the penetrating molecules of water.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Investigations were carried out to determine the properties of pozzolana as cementitious materials for use in building industries. Several mixes of pozzolana cement were made and subjected to various qualitative tests. The following findings were made;

i) Samples B and E were found to exhibit fineness closely related to sample A (Ordinary Portland Cement). This is an indication of increased rate of hydration and in effect high strength and heat generation. On the other hand, samples C and D have less fineness and in effect decrease rate of hydration.

ii) Sample E (pozzolana plus 10% Ordinary Portland Cement) was found to have least shrinkage value compared with other pozzolanas. It implies that sample E may cause less distress in concrete in which they have been used. While samples B,C,D, may show progressive cracking, which may later accentuated by frost action if the concrete is exposed to the weather.

iii) The higher value of water absorption capacity for the pozzolanas at the same age with Ordinary Portland Cement is attributed to their higher porosity. On the average, the results are less than 7% which is the maximum water absorption specified for building boards (ASTM, 1974).

iv) The study showed that pozzolanas can be adopted for simple construction work such as roofing sheets, tiles, partitions and ceiling boards.

v) The investigation also shows that pozzolanas hold some promise for use as load bearing structural material in low-cost rural housing and in low-income urban housing projects particularly in bungalows and single storey buildings. This is due to the relatively high compressive strength over sandcrete blocks and earth brick. (Udububa, 1996).

5.2 Recommendations

Based on the results obtained form the research work, the following recommendations are suggested:

i) With high cost of building materials, pozzolanas can be used in replacing part of Ordinary Portland Cement (O.P.C.) to reduce cost especially in low-cost housing schemes.

ii) Investment in the small medium scale industries for the production of construction materials such as burnt clay bricks, roofing sheets, and sanitaryware locally, should be encouraged by the Federal Government. This can be done through granting of soft loans and little or no tariff on the finished products.

iii) Massive financial support should be given to research and development of local construction materials. For example, the building and road research institute should be encouraged to go into full scale production either directly in partnership with local firms of some of the materials that have been thoroughly researched and proved to be viable.

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