EFFECTS OF CURING METHODS ON THE PROPERTIES OF HARDENED RICE HUSK ASH AND SUGARCANE BAGASSE ASH CONCRETE

By

Audu Inuwa TIAMIYU, B.Tech. (ATBU) 2006

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Declaration

I declare that the work in this thesis entitled **"Effects of Curing Methods on the Hardened Properties of Rice Husk Ash and Sugarcane Bagasse Ash Concrete**" has been carried out by me in the Department of Building, Faculty of Environmental Design, Ahmadu Bello University Zaria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

AUDU, Inuwa Tiamiyu …… ……..

Signature Date

Certification

This thesis entitled "EFFECTS OF CURING METHODS ON THE HARDENED PROPERTIES OF RICE HUSK ASH AND SUGARCANE BAGASSE ASH CONCRETE" by AUDU, Inuwa Tiamiyu meets the regulations governing the award of degree of M.sc Construction Technology of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Prof. Ibrahim K. Zubairu Chairman, Supervisory Committee	_____ Signature	_____ Date
Mal. Mamman Mas'ud Member, Supervisory Committee	_____ Signature	_____ Date
Dr. Dikko Kado Head of Building Department	_____ Signature	_____ Date
Prof. Kabir Bala Dean, School of Postgraduate Studies	_____ Signature	_____ Date

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This thesis is dedicated to the memory of my late parents, May Allah (S.W. A) Grant them Jannatul Firdaus. Amin.

ABSTRACT

Factors that affect the strength and durability of concrete include quality and quantity of cement used in a mix, grading of aggregates, shape and surface texture of aggregates, Water/cement ratio, curing methods, admixture. A lot of researches were carried out to identify the best curing method for concrete. The aim of this research work is to assess the efficiency of different curing methods for concrete produced using rice husk ash (RHA) and sugarcane bagasse (SBA) ash as partial replacement of ordinary Portland cement. The objectives were achieved by determining the effects of curing methods on specimens, and by studying the micro structure of the specimens subjected to various curing methods. RHA and SBA were sourced locally and chemical test was carried out to check their chemical properties. The RHA and SBA were used to replace the mixing cement at 5% and 20% respectively. The targeted concrete strength value was 30N/mm^2 at 28 days, which serves as the control value. 29.6 N/mm^2 and 29.0 N/mm^2 were obtained for RHA and SBA concrete respectively at 28 days under immersion method, while 29.2 N/mm^2 and 19.0 N/mm^2 were obtained for RHA and SBA under spraying method and 29.2 N/mm^2 and 20.0 N/mm^2 were obtained for RHA and SBA under polythene method. These indicated that immersion curing

method was the best curing method for both RHA and SBA specimens. The micro structure analysis also indicated that the specimens subjected to immersion curing method possessed less pores of 0.41 μm² with highest pore ratio of 287.49 μm² and less pores of 0.18 with the highest pore ratio of 257.33 μm² for RHA and SBA respectively. This contributed to higher strength of the RHA and SBA concrete specimens. Water immersion curing method is recommended as the best curing method but spraying method may appear to be more advantageous where water immersion method is difficult to achieve.

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List of Symbols and Abbreviations

%	Percentage
ASTM	American Standard for Testing Materials
BS	British Standard
cfu/ml	Colony Forming Unit per Milliliter

H_2SO_4 Sulphuric Acid

Kg Kilogram

kN Kilo Newton

M^3 Meter cube

N/mm^2 Newton per Millimeter Squared

NaOH Sodium Hydroxide

^oC Degree Centigrade

OPC Ordinary Portland Cement

RHA Rice Husk Ash

SBA Sugarcane Bagasse Ash

W/C Water Cement Ratio

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study.

Concrete is among the world's most utilized construction material. Concrete is widely used for making structures, foundations, brick/block walls, pavement, bridges/overpasses, runways, parking, structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles, etc.

Despite the advantages of concrete as a construction material, the production of cement comes at a great cost to the environment. The need for infrastructural development in both the developing and developed countries has placed a great demand on ordinary Portland cement (OPC), traditionally, the main binder in the manufacture of concrete. Concrete is a mixture of cement, water, fine aggregate (sand) and coarse aggregate (gravel or crushed rocks) in which the cement and water have hardened by a chemical reaction to bind the nearly none reacting aggregates (Peter and John, 2010).

Concrete has been used for many years in civil and construction engineering works because of its strength, durability and affordability. In the early time, a lot of problems were faced in the use of concrete such as workability, early strength and the later strength of concrete. A lot of research works have been carried out in order to overcome such problems and as such the technology of concrete production have been improved tremendously.

The two most important properties of hardened concrete are its compressive strength and durability. Compressive strength can be quantitatively measured while the durability of concrete cannot withstand some possible exceptions such as the thickness of concrete cover, it can be said that generally, factors that favor concrete strength usually benefit its durability. Factors that affect the strength and durability of concrete include quality and quantity of cement used in a

mix, grading of aggregates, shape and surface texture of aggregates, Water/cement ratio, curing method, present or otherwise of clay particles and organic matter in the mix. Other factors affecting concrete strength and durability include the use of admixtures, employment of Portland-Pozzolana and low-heat Portland cement, as well as the level of concrete compaction. In view of environmental and sustainability concerns associated with the production of cement, the use of Pozzolana to replace part of Portland cement is receiving a lot of attention.

Admixture is defined as a material, other than cement, water and aggregates that is used as an ingredient of concrete and is added to the batch immediately before or during mixing (Shetty, 2005). Producers use admixtures primarily to reduce the cost of concrete construction, to modify the properties of hardened concrete, to ensure the quality of concrete during mixing, transporting, placing and curing and to overcome certain emergencies during concrete operation.

Pozzolana are finely divided materials used in concrete in relatively large amounts and mainly used as cement replacement in order to enhance early and long term performance (Habeeb & Mahmud, 2010). The use of these materials to some extent reduces the cost of concrete production.

The American Society of Testing and Materials (ASTM, 1995) defines pozzolana as a siliceous or alumino-siliceous material that in itself possesses little or no cementitious value but that in finely divided form and in the presence of moisture will chemically react with alkali and alkaline earth hydroxides at ordinary temperatures to form or assist in forming compounds possessing cementitious properties. Some Pozzolana are natural and others are industrial by-products and both contain silica in amorphous form which react with calcium hydroxide to form more cementitious calcium silicate hydrate that contribute to the concrete strength. These materials

include volcanic ash, diatomaceous earths, condensed silica fume, pulverized fly ash, sugarcane bagasse ash and rice husk ash. This contains some form of amorphous reactive silica which may combine with lime in presence of water to form (Aitcin, 1998).

Rice husk ash (RHA), produced by the controlled burning of rice husk, and has been used as a highly reactive pozzolanic material, leading to a significant improvement on strength and durability of normal concrete. Since the end of the 1960s, extensive research has been carried out on the preparation, properties and applications of RHA in pastes, mortars and concretes and many papers and patents have been published on this subject. Although high quality RHA has been produced by many researchers under control conditions, the use of this material is still limited in many countries due to its sensitivity to burning conditions. (Sugita et al., 1997)

Researchers have found that various metal ions in the rice husk and unburned carbon influence the purity and color of the ash. Controlled burning of the husk after removing these ions with an acid leaching can produce white silica of high purity that is amorphous, reactive, and characterized by high surface area and pore volume. Acid treatment has been found to decrease the degree of crystallization of silica and carbon in rice husk reducing the sensitivity of the pozzolanic activity of the rice husk ash to burning conditions (Salas et al., 2009).

The incineration of rice husk produces high volume ash residue that could be used as a pozzolana to improve properties of concrete. When incinerated at the right temperature, RHA is primarily composed of amorphous silica (Ganesan et al., 2008). Though numerous studies have shown that RHA at low carbon content can improve physical properties of concrete, the optimum replacement level depends on the specific surface and the water/cement ratio of the concrete (Givi et al., 2010 and Ganesan et al., 2008). However, it was indicated the possible use of high carbon RHA after considerable grinding. The uses of RHA in concrete result in the growth of more calcium silicate hydrate (CSH) gels that improve the strength of concrete (Yu et al., 1999).

In addition, the filler effect of the fine RHA particles also results in improvement in mechanical properties of concrete containing RHA (Bui et al., 2005).

Sugarcane Bagasse Ash (SBA) is the pozzolana produced from the ash of an agricultural waste material obtained after squeezing out the sweet juice in sugar cane and incinerated into ash. Sugar cane is grown in the world from latitude 36.70N and 31.00S, from sea level to 1000m of latitude or little more. It is considered as essentially a tropical plant. It is a long duration crop and thus it encounters all the seasons viz; wet season, winter and summer during its lifecycle (sugarcane climate). It is produced in commercial quantities in Nigeria especially in the North and the Eastern part of the country.

Sugarcane is one of the major crops grown in over 110 countries, and its total production is over 1500 million tons (Deepchand, 1986). After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residues is obtained (Food & Agricultural Organization, 2006). The use of the sugarcane bagasse as an ash source for mineral addition into cement-based materials is subjected to two factors: the production and chemical composition of the ash. The sugarcane bagasse ash is predominantly composed of silicon dioxide, which can develop pozzolana activity depending on the characteristics of both burning and grain size. In this case, the reactivity between silica and the hydration products may improve the physical and mechanical properties of the cement-based materials.

A lot of researches have been carried out on both RHA and SBA on their pozzolanic properties and these materials are locally sourced agricultural waste readily available and are facing disposal problem. This lead to choosing the two materials to know the effects of methods of curing on the RHA and SBA concretes.

Concrete curing is one of the most important and final steps in concrete production though it is also one of the most neglected and misunderstood procedures. It is the treatment given to newly placed concrete during which it hardens so that it retains enough moisture to minimized shrinkage and resist cracking (Lambert Corporation, 1999).

Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing. Concrete that has been specified, batched, mixed, placed, and finished can still be a failure if improperly or inadequately cured. Curing should be a long term process since short period of early drying could result in potential strength gain reduction. For curing to be beneficial in concrete it should start as soon as concrete hardens since the detrimental effect of early improper curing are irreversible (ACI, 1991). In addition to increasing the strength of concrete, proper curing reduces the porosity and provides a fine pore size distribution in concrete microstructure (Alamri, 1988). Therefore, a selection of suitable curing method such as water ponding (immersion), spraying or sprinkling of water, or covering with polythene sheet material in order to produce strong and durable concrete is very necessary. However, when a certain percentage of cement is been replaced with rice husk ash (RHA) or sugarcane bagasse ash (SBA) in the concrete production, curing conditions could affect strength and concrete microstructures differently. Admixtures have shown to cause more compressive strength losses in uncured concrete specimens than normal concrete mixes (Ramez and Malhotra, 1995; Ozer and Ozkul, 2004).

The need for proper curing arises from the fact that hydration of cement can take place only in water capillaries. This is why water loss must be prevented. Furthermore, water lost internally by self-dedication has to be replaced by water from outside, i.e. ingress of water into the concrete

must take place (Neville, 2010). Thus, for complete and proper strength developments, the loss of water in concrete from evaporation should be prevented, and the water consumed in hydration should be replenished. The concrete can continuously gain strength with time provided sufficient moisture is available for the hydration of cement which can be assured only by creation of favorable conditions of temperature and humidity (James et al., 2010).

1.2 Statement of the Research Problem

The phenomenon of the widespread deterioration of concrete structures during the past two decades has become a matter of global concern. The issue of ensuring long-term durability of concrete structures has therefore assumed great importance. The hydration products extend from the surfaces of cement grains, and the volume of pore decreases due to proper curing under appropriate temperature and moisture (Safiudeen et al., 2010). Since the past decade the use of pozzolanic materials in concrete is gaining attention because of its benefits and it has been observed that concrete produced with Pozzolana as partial replacement do not go through appropriate method of curing which affect the strength and durability of the concrete (Shweta & Muneek, 1999).

Poor curing condition adversely affects the strength characteristics of pozzolanic concrete than that of ordinary Portland cement concrete (Shweta & Muneek, 1999). Much is yet to be known about the appropriate method of curing that will be suitable on pozzolana concrete and make it competitive with that of cement concrete in terms of strength and durability. For instance, for the pozzolanic activities to be explored in silica fume concrete, water is applied at the initial 7days, but it is imperative to cure the fly ash concrete for an extended period to utilize its full potential (Shweta & Muneek, 1999). Since the development of pozzolana as an admixture, a lot of

researches have been carried out on the strength and durability of pozzolana concrete, but the most common method of curing (spraying of water) is being adopted on pozzolana concrete in general, just as in normal concrete, water curing was the most effective method of curing and its produced the highest in terms of compressive strength, which same may not be suitable for pozzolana concrete in order for it to attained the required strength. Therefore, there is need to carry out research on the three conventional methods of curing (spraying of water, immersion into water and covering with polythene) to ascertain whether or not the required strength concrete will be developed on pozzolana concretes. When a specific Pozzolana is used as partial replacement of ordinary Portland cement to produce concrete, and the concretes subjected to different curing methods under the same condition, it is expected that the concretes will possess different strength due to the effects of the curing methods to the internal structure of the hardened pozzolana concrete. Therefore there is need to assess the most suitable curing method on a specific pozzolana concretes in terms of strength and pore diameter.

1.3 Justification of the Study

The results of this research provide information that helps curing of RHA and SBA concretes. The incorporation of RHA and SBA as cement replacement material can aid in cement consumption, cost of concrete production, prevent disposition challenges in the rice and sugar processing companies, which are very vital to sustainable developments. A proper curing greatly contributes to reduce the porosity and drying shrinkage of concrete, and thus to achieve high strength and greater resistance to physical and chemical attacks in aggressive environment. The hydration products extend from the surfaces of cement grains, and the volume of pores decreases due to proper curing under appropriate temperature and moisture (Safiudeen et al., 2010). Curing

of RHA and SBA concrete just as in normal concrete may not yield an effective result due to the fact that both the gel pores and capillary pores volume and pore sizes decreases with an increase in the hydration due to the formation of increased amount of hydration products. Therefore, the research could recommend a suitable curing method for RHA or SBA concretes.

1.4 Aim and Objectives

1.4.1 Aim

The aim of this research is to assess the efficiency of different curing methods for concrete produced using RHA or SBA as partial replacement of ordinary Portland cement; this is with the view to establishing the most appropriate curing method.

1.4.2 Objectives

The objectives of this research are;

i. To determine the chemical compositions of RHA and SBA.

ii. To determine the effects of various curing methods on specimens.

iii. To study the micro structure (internal structure) of specimens subjected to various curing methods.

iv. To established the best curing method for Pozzolana concrete.

1.5 Methodology

The methods adopted for the research was through literature review and laboratory works.

1.5.1 Literature review

Relevant literatures such as past researches, text books, journals, internet materials etc were reviewed to articulate the existing practice of various methods of curing to increase concrete strength using RHA and SBA as partial replacement of ordinary Portland cement.

1.5.2 Laboratory work

The ashes from RHA and SBA was produced by controlled burning using kiln. The ideal temperature used for producing RHA was 700℃, and SBA was 660°C, adopted from (Nick & Emmet, 2009) and (Alvarez & Raphael, 2012) respectively. A laboratory analysis was carried out to confirm the level of presence of silicon content and other chemical compositions in RHA and SBA. The concrete was designed according to Department of environment method (DOE method), and the optimum dosage of RHA and SBA used were 5% and 20% adopted from the work of Mauro et al., (2003) and Genesan et al., (2007).

A total of three hundred and twenty four (324) cube specimens of size 100 x 100 x 100mm were produced according to BS1881 using 0%, RHA and SBA as partial replacement of ordinary Portland cement respectively. One hundred and eight of the cubes were of control (0%), RHA concrete was also being of one hundred and eight number cubes, and SBA concrete was also being of one hundred and eight number cubes. 36 nos of control, RHA, SBA concrete specimens each at all ages were subjected to curing by spraying of water, immersion into water, and covering by polythene. The compressive strength and water absorption tests were carried out at 7, 14, 28 and 56 days according to BS 1881 ; part116; method for Determination of Compressive Strength of Concrete Cube. The percentage replacement and the relative strength development with age of concrete produced were recorded.

To achieve the third objective of the research, the microstructure of the specimens subjected to various curing methods were carried out using pore histogram obtained from scanning electron microscopy of RHA and SBA specimens at a magnification indication of 1500, at a height mark of 179mm through a backscattered detector full (BSD) in chemical engineering laboratory, Ahmadu Bello University, Zaria.

The fourth objective was achieved by comparing the results from the effects of various curing methods on the sample specimens to the results of the internal structure analysis of the same sample specimens.

1.6 Scope and Limitation of the Study

1.6.1 Scope

The research focused on the evaluation of the effects of curing methods on strength of concrete produced using 5% RHA and 20% SBA as partial replacement of ordinary Portland cement. The rice husk and sugarcane bagasse were obtained manually from local rice processing company in Wuntin Dada village of Bauchi local government of Bauchi state, and local sugar processing company in danja local government of katsina state and were burned at controlled temperatures of 700 and 660 respectively. Concrete cubes were produced and used for the test carried out which includes compressive strength test, durability, and microstructure analysis. Tables and charts were used in the analysis of the results

1.6.2. Limitation

Non availability of equipments that can be used for testing some of the durability parameters such as shrinkage, carbonation, alkaline aggregate reaction, were not available and thus were not

carried out. However the research accessed the abrasion and water absorption (of specimens) which are very important indicators of durability of concrete.

CHAPTER 2

LITERATURE REVIEW

2.1 Concrete

Concrete is an ubiquitous material and its versatility and ready availability have ensured that it has been and will continue to be of great and increasing importance for all types of construction throughout the world (Donome and Illston, 2010). Different definitions were given to concrete as a result of various researches carried out across the world. According to Harris (2006), concrete is a stone like material formed by mixing an aggregate (such as stones of irregular shape or crushed rock) with cement (which act as a binding material) and water, then allowing the mixture to dry and hardened. According to Al-Kourd and Hammad (2010), concrete was defined as a mixture of cement (11%), fine aggregate (26%), coarse aggregate (41%), water (16%) and air (6%). Furthermore, concrete was also defined by Neville (2010), as any product or mass made by the use of cementing medium, generally, this medium is the product of reaction between hydraulic cement and water.

Concrete have four major constituents which are: cement, fine aggregate, coarse aggregate and water. Any Other materials apart from those mentioned above that is added in the mix to alter the properties of the concrete are called admixtures.

2.1.1 Compositions of concrete.

2.1.1.1 Cement

The early history of cement has originated from the Egyptians who burn gypsum to obtain cementing materials. According to Shetty (2005), the investigation of L. J. Vicat led him to prepare an artificial hydraulic lime by calcining an intimate mixture of limestone and clay. This process may be regarded as the leading knowledge to the manufacture of Portland cement. The

raw materials required for the manufacture of Portland cement are calcareous materials such as lime stone or chalk, and argillaceous materials such as shale or clay (Shetty, 2005).

Portland cements are hydraulic cements, meaning they react and hardened chemically with the addition of water. Cement contains limestone, clay, cement rock and iron ore blended and heated to 1200 to 1500^0C, the resulting product "clinker" is then ground to the consistency of powder Akourd and Hammad, (2010).

Cement is a classical construction material whose use cuts across all fields of civil engineering and building construction (Neville, 2005). Ordinary Portland cement is recognized as a major construction material throughout the world.

According to Standard Specifications for Portland cement, Portland cements are classified as:

Type I: General purpose. For use when the special properties specified for any other type are not required.

Type II: For general use, more especially when moderate sulphate resistance or moderate heat of hydration is required.

Type III: For use when high early strength is desired. (Limit the C_3A content of cement to maximum 15%)

Type IV: For use when low heat of hydration is desired.

Type V: For use when high sulphate resistance is desired. (Maximum limit of 5% on C_3A)

2.1.1.2 Aggregate

Aggregates are the important constituents in concrete; they give body to the concrete, reduce shrinkage and effect economy (Shetty, 2005). Aggregates are rocklike materials used in most civil and construction engineering works. They can be classified in to two major types: coarse and fine aggregates.

i. Coarse Aggregate

According to Al-Kourd and Hammad (2010), gravels are naturally occurring or crushed.

Naturally occurring gravels are water born pieces of rock, in buried or current stream beds, they are normally rounded with smooth surfaces, other properties depends on the parent rock.

Crushed gravels are larger gravel particles that have been reduced in size by a crusher, which may be screened to divide in to desired size groupings.

ii. Fine Aggregate

Naturally occurring, water or wind born pieces of rock in buried or current stream beds or dunes, often rounded with smooth surfaces which may be screened to divide in to desired size groupings (Al-Kourd and Hammad, 2010). It is the aggregate most of which passes 4.75mm IS sieve and contains only so much coarser as is permitted by specification. Fine aggregates may be described as;

a. *Natural sand;* it is the aggregates resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies.
b. *Crushed stone sand;* it is the fine aggregates produced by crushing hard stones.
c. *Crushed gravel sand;* it is the fine aggregates produced by crushing natural gravel.

Effects of Aggregates on Concrete Strength:

The major characteristics of aggregates that affect both the fresh and hardened properties of concrete include shape and texture, grading, absorption, soundness, strength and stiffness and aggregate size.

The shape and texture of a coarse aggregate determine the quantity of fine aggregate required. According to Legg (1998), flaky, elongated, angular and rough particles have high voids and require more sand to fill the voids and to produce a concrete of good workability, thereby

demanding much quantity of water. The increase of water due to the poor shaped particles will greatly reduce the strength of the concrete because the water cement ratio will change significantly and the higher the water cement ratio the lower the strength of the concrete. Shape and texture of fine aggregate also have a vital effect on workability of fresh concrete, strength and durability of hardened concrete. Cubical or spherical particles have less specific area than flat and elongated particles, this result in requiring less paste and less water for workability (Shilstone, 1999). On contrary flaky and elongated particles seriously affect workability, producing harsh mixtures. For a given workability to be achieved, the flaky and elongated particles demand much water, thereby affecting the strength of the concrete.

Characteristics of concrete such as packing, density, voids content, workability, segregation and durability are affected by grading of particle size. Gotterman (1997), opined that uniformly distributed mixture generally lead to higher packing resulting in concrete with higher density and less permeability. Both coarse and fine aggregates should be uniformly graded, if fine aggregate is too coarse it will produce bleeding, segregation and harshness, but if it is too fine the demand of water will be increase thereby reducing the strength of the hardened concrete.

The properties of fresh and hardened concrete can also be affected by maximum size of aggregate. According to Washa (1998), mixtures with large maximum size of coarse aggregate tend to produce concrete with good workability; this is because of the decrease in specific surface area. Helmuth (1994), was on the view that for a given water-cement ratio, the permeability increases as the maximum size of the aggregate increases.

2.1.1.3 Water

Any water that is fit for drinking can be used in making concrete. The quality of the water used must be such that the chemical reactions which take place during the setting of cement are not impaired. Some water that is not fit for drinking may be suitable for concrete provided that they satisfy the acceptance criteria's.

Water plays an important role on strength development and durability of concrete. Curing takes place immediately after concrete placing and finishing, and involves maintenance of desired moisture and temperature conditions, both at depth and near the surface, for extended periods of time. Properly cured concrete has an adequate amount of moisture for continued hydration and development of strength, volume stability, resistance to freezing and thawing, and abrasion and scaling resistance.

Many important characteristics of concrete are influenced by the ratio (by weight) of water to cementitious materials (w/cm) used in the mixture. By reducing the amount of water, the cement paste will have higher density, which results in higher paste quality. An increase in paste quality will yield higher compressive and flexural strength, lower permeability, and increase resistance to weathering, improve the bond of concrete and reinforcement, reduce the volume change from drying and wetting, and reduce shrinkage cracking tendencies (PCA, 1988).

Reducing the water content in a concrete mixture should be done in such a way so that complete cement hydration process may take place and sufficient workability of concrete is maintained for placement and consolidation during construction. The water cement ratio needed for cement to complete its hydration process ranges from 0.22 to 0.25. The existence of additional water in the mixture is needed for ease of concrete placing and finishing (workability of concrete). Reducing

the water content in a mixture may result in a stiffer mixture, which reduces the workability and increases potential placement problems (Komatska, 1990).

2.1.1.4 Admixture

According to Shetty (2005), admixture is defined as a material, other than cement, water and aggregates that is used as an ingredient of concrete and is added to the batch immediately before or during mixing. The reasons for using admixtures as stated by Al-Kourd and Hammad (2010) are to:

a. Reduce cost of construction.
b. Achieve certain properties more effectively than by other means.
c. Ensure quality of concrete during stages of mixing, transporting, placing and curing in adverse condition.
d. Overcome certain emergencies during concreting.
e. Improve or modify some or several properties of Portland cement concrete.
f. Compensate for some deficiencies.
g. Increase workability without increasing water content or to decrease water content at the same workability.
h. Retard or accelerate the time of initial setting.
i. Create light expansion.

Admixtures are generally classified in to the following classes:

a. Air-entraining admixture.
b. Water reducing admixture.
c. Retarding admixture.
d. Accelerating admixture.

e. Super plasticizer

f. Finely divided mineral admixture.

g. Miscellaneous admixture such as workability, bonding, damp proofing, permeability reducing, grouting, gas-forming, coloring, corrosion inhibiting and pumping admixtures.

The most important factor which affects workability of a concrete is the use of admixtures. Shetty (2005), some of admixtures that greatly improve workability are plasticizers and super plasticizers.

2.1.1.5 Pozzolans

A pozzolans is a siliceous and aluminous material which , in itself, possesses little o no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties (Mehta, 1999). The broad definition of a pozzolan imparts no bearing on the origin of the material, only on its capability of reacting with calcium hydroxide and water. A quantification of this capability is comprised in the term pozzolanic activity. Pozzolana is naturally-occurring Pozzolans of volcanic origin.

2.1.2 Properties of concrete

Basically, concrete passes through three stages, from fresh state to green state and lastly to hardened state. The term fresh concrete refers to the wet mix of ingredients before they begin to cure. Concrete is said to be green when it begins to set but is not fully cured, and after it has fully cured, it is called hardened concrete. At fresh state concrete must be workable and at hardened state it must be strong and durable. Properties of concrete can be discussed according to the state of the concrete that is fresh and hardened properties of concrete.

2.1.2.2 Properties of hardened concrete

a. Strength

i. Compressive Strength

The main measure of structural quality of concrete is its compressive strength, and is one of the most important and useful properties of concrete. Compressive strength is used as a qualitative measure for other properties of hardened concrete (Shetty, 2005).

Compressive strength is usually carried out using concrete cubes; these cubes are cast in steel moulds. According to BS 1881-108(1983), the mould should be filled in three layers with at least 25 strokes. The concrete is then left in the mould for at least 24 hours, after which it will be demoulded and cured with water, until the testing day. The compressive strength of a concrete can be influenced by some factors which include the water/cement ratio, quality of raw material, coarse/fine aggregate ratio, compaction, temperature and curing.

The water cement ratio in concrete mix has an important role in the strength of concrete. The lower the water cement ratio, the higher the strength of the concrete. Basically, the low water cement ratio in concrete mix increased the concrete strength, lower the permeability, reduces drying shrinkage/cracking and increased resistance to weathering.

The quality of raw materials used in the production of concrete should be of good quality conforming to appropriate standard. The cement should be properly stored under dry condition. The aggregates used in concrete production should be free of salt, silt and clay. The water used in the concrete production should be fit for drinking and free from contaminants. These qualities directly affect the strength of the concrete.

Coarse/fine aggregate ratio also plays a great role in the strength of concrete. If the fine aggregate content is increased in concrete mix in relation to coarse aggregate, it will increase the

aggregate surface area which will in turn demand much quantity of water. The water demand will increase the water/cement ratio which will affect the compressive strength of the concrete.

Another factor that affects concrete strength is the compaction of the concrete. Improper compaction leads to trapped air in the concrete. if there is 10% of trapped air in concrete, the concrete strength will fall down in the range of 30 to 40%.

ii. Flexural Strength

Flexural strength is a measure of an unreinforced concrete beam or slab to resist failure in bending. Flexural strength is expressed as Modulus of Rupture (MR) and is determine by either third-point loading method or center point loading method.

To calculate the modulus of rupture, the position of the fracture has to be considered. According to BS 1881: Part 4: 1983, if the fracture initiates in the tension surface within the middle third of the span length, the MR is calculated as follows:

$R = {}^{1000PL}/_{bd^2}$……..2.1 (ASTM Procedure, C78)

Where:

R = Modulus of rupture

P = Maximum applied load in newtons (N)

L = Span length in (mm)

b = Average width of specimen in (mm)

d = Average depth of specimen in (mm)

And if the fracture occurs in the tension face outside of the middle third of the span length by not more than 5% of the span length, the modulus of rupture is calculated as follows:

$R = {}^{3000Pa}/_{bd^2}$……..2.2 (ASTM Procedure, C78)

`Where: a = Average distance between line of fracture and the nearest support measured on the tension surface of the beam, in (mm).

And if the fracture occurs in the tension surface outside of the middle third of the span length by more than 5% of the span length, discard the result of the test.

2.2 Micro Structure of Concrete

Concrete is a composite material whose microstructure contains random features over a wide range of length scales, from nanometers to millimeters, with each length scale presenting a new random composite with which to deal (Garboczi, 1993). In its actual uses, at the length scale of meters, concrete (always reinforced by steel) is usually considered to be a uniform material, with bulk properties like compressive strength, creep, and others. This is the usual engineering length scale.

The range of the random microstructure of concrete, from nanometers to micrometers to millimeters to meters covers nine orders of magnitude in size. It is then a large and difficult task to try to theoretically relate the microstructure and the properties of concrete. This has led to the use of computer simulations, coupled with modern experimental probes, which have provided some insight into the microstructure.

The microstructure of a material (which can be broadly classified into metallic, polymeric, ceramic and composite) can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior, wear resistance, and so on, which in turn govern the application of these materials in industrial practice. Microstructure at scales smaller than can be viewed with optical microscope is often called ultra structure or nanostructure (Kumar and Paulo, 2014)

When a polished flat sample reveals traces of its microstructure, it is normal to capture the image using microphotography. More sophisticated microstructure examination involves higher powered instruments: optical microscopy, electron microscopy, X-ray diffraction and so on, some involving preparation of the material sample (cutting, microtomy, polishing, etching, vapor-deposition etc.). The methods are known collectively as metallographic as applied to metals and alloys, and can be used in modified form for any other material, such as ceramics, glasses, composites, and polymers (Garboczi, 1993).

Two kinds of optical microscope are generally used to examine flat, polished and etched specimens, a reflection microscope and an inverted microscope. Recording the image is achieved using a digital camera working through the eyepiece.

2.3 Concrete Mix Design

Concrete mix design is the science of deciding relative proportions of ingredients of concrete, to achieve the desired properties in the most economical way (Durocrete Engineering Services, Mix Design Manual). There are various method of mix design such as IS method, DOE method, ACI method and BRMCA method.

In the IS Code method, the quantities of fine and coarse aggregate are determined by using the equation based on specific gravities of ingredients. One of the good features of IS Code method is that it incorporates the strength of cement in mix design procedure by which it is possible to effect economy in concrete mix (Shetty, 2005). According to Kumbar and Murnal, (2012), the IS code method suffers from the following limitations.

1. The method suggests 35% of sand content for zone II sand by absolute volume with a correction of +1.5% for zone I and -1.5% for zone III. These zones have wide range of variability and this correction is not sufficient to attain a cohesive mix.

2. Even though sand content is adjusted for lower water cement ratio, there is no direct adjustment for cement content. A mix in which cement content has been lowered by use of Super plasticizers may require higher sand content to improve cohesion.

3. The method gives different tables for finding contents of sand for concretes up to M35 and above M35 grade. There is sudden change in sand content from 35% to 25% in these tables when shifting from M35 grade to M40 grade concrete.

4. The method considers compaction factor as measure of workability to calculate water demand. However, the revised IS 456 (2000) has excluded compaction factor as a measure of workability.

5. The quantities of fine and coarse aggregates are calculated based on absolute volumes concept. The wet density of concrete if theoretically calculated on the basis of absolute volume concept, may not match with that actually measured.

6. The method does not include an adjustment in fine aggregate content for different workability levels.

According to Kumbar and Murnal (2012), the DOE method overcomes some limitations of IS Code method. In case of DoE method, fine aggregate content is a function of 600 micron passing fraction of sand and not the zone of sand. The 600 micron passing fraction has become known as the most critical parameter governing the cohesion and workability of concrete mix. It is well accepted that the higher the workability the greater is the fine aggregate required maintaining cohesion of mix. The water content per m^3 of concrete is recommended based on workability

requirement given in terms of slump and Vee Bee time. The method recommends different water contents for crushed and uncrushed aggregates.

Shetty (2005), recognized ACI committee 211.1 as the best method of concrete mix due to the fact that it has the advantage of simplicity, in that it applies equally well and with more or less identical procedure to rounded or angular aggregates, to regular or lightweight aggregates and to air–entraining concrete. According to Gupta (2004), ACI committee mix design is based on the following assumption:

1. Fresh concrete of a given slump and containing a reasonably well graded aggregate of given maximum size will have practically constant water content, regardless of variation in water-cement ratio and cement content which are inter-related over a considerable range of practical proportion.
2. The optimum dry rodded volume of coarse aggregate per unit volume depends on its maximum size and the fineness modulus of fine aggregates regardless of shape of particle.
3. Irrespective of methods of compaction, even after complete compaction is done a definite percentage of air remains in concrete and is inversely proportional to the maximum size of the aggregate.

2.4 Concrete Curing.

Concrete curing is one of the most important and final steps in concrete construction though it is also one of the most neglected and misunderstood procedures. It is the treatment given to newly placed concrete during the period in which it is hardening so that it retain enough moisture to immunize shrinkage and resist cracking (Lambert Corporation, 1999).

Curing is the process that is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing. Concrete that has been specified, batched, mixed, placed, and finished can still be a failure if improperly or inadequately cured. Curing should be a long term process since short period of early drying could result in potential strength gain reduction.

Adding water to Portland cement to form the water-cement paste that holds concrete together starts a chemical reaction that makes the paste into a bonding agent. This reaction, called hydration, produces a stone-like substance, the hardened cement paste. Both the rate and degree of hydration, and the resulting strength of the final concrete, depend on the curing process that follows placing and consolidating the plastic concrete.

Hydration continues indefinitely at a decreasing rate as long as the mixture contains water and the temperature conditions are favorable. Once the water is removed, hydration ceases and cannot be restarted. Curing is the period of time from consolidation to the point where the concrete reaches its design strength. During this period, you must take certain steps to keep the concrete moist and as near 73°F as practical.

The properties of concrete, such as freeze and thaw resistance, strength, water-tightness, wear resistance, and volume stability, improve with age as long as you maintain the moisture and temperature conditions favorable to continued hydration. The length of time that you must protect concrete against moisture loss depends on the type of cement used, mix proportions, required strength, size and shape of the concrete mass, weather, and future exposure conditions. The period can vary from a few days to a month or longer. For most structural use, the curing

period for cast-in-place concrete is usually 3 days to 2 weeks. This period depends on such conditions as temperature, cement type, mix proportions, and so forth. Bridge decks and other slabs exposed to weather and chemical attack usually require longer curing periods.

If curing is neglected in the early period of hydration, the quality of concrete will experience a sort of irreparable loss. An efficient curing in the early period of hydration can be compared to a good and wholesome feeding given to a new born baby.

The length of adequate curing time is dependent on the following factors:

i. Mixture proportions
ii. Specified strength
iii. Size and shape of concrete member
iv. Ambient weather conditions
v. Future exposure conditions (Kosmatka et al., 2002)

Slabs on ground (e.g. pavements, sidewalks, parking lots, driveways, floors, canal linings) and structural concrete (e.g. bridge decks, piers, columns, beams, slabs, small footings, cast-in-place walls, retaining walls) require a minimum curing period of seven days for ambient temperatures above 40 degrees Fahrenheit.(Kosmatka et al., 2002) American Concrete Institute (ACI) recommends a minimum curing period corresponding to concrete attaining 70 percent of the specified compressive strength. ACI 301 the often specified seven-day curing commonly corresponds to approximately 70 percent of the specified compressive strengths. The 70 percent strength level can be reached sooner when concrete cures at higher temperatures or when certain cement/admixture combinations are used. Similarly, longer time may be needed for different material combinations and/or lower curing temperatures.

For this reason, ACI Committee 308 recommends the following minimum curing periods. ACI 308R-2001

i. ASTM C 150 Type I cement seven days
ii. ASTM C 150 Type II cement ten days
iii. ASTM C 150 Type III cement three days
iv. ASTM C 150 Type IV or V cement 14 days
v. ASTM C 595, C 845, C 1157 cements variable

2.4.1 Main functions of curing.

2.4.1.1. Maintaining mixing water in concrete during the early hardening process**.**

i. *Ponding and immersion*

Ponding is typically used to cure flat surfaces on smaller jobs. Care should be taken to maintain curing water temperature at not more than 20 degrees Fahrenheit cooler than the concrete to prevent cracking due to thermal stresses. Immersion is mainly used in the laboratory for curing concrete test specimens.

ii. *Spraying and fogging*

Spraying and fogging are used when the ambient temperatures are well above freezing and the humidity is low. Fogging can minimize plastic shrinkage cracking until the concrete attains final set.

iii. *Saturated wet coverings*

Wet coverings saturated with water should be used after concrete has hardened enough to prevent surface damage. They should be kept constantly wet.

iv. *Left in Place Forms*

Left in place forms usually provide satisfactory protection against moisture loss for formed

concrete surfaces. The forms are usually left in place as long as the construction schedule allows. If the forms are made of wood, they should be kept moist, especially during hot, dry weather.

2.4.1.2. Reducing the loss of mixing water from the surface of the concrete

i. *Covering concrete with impervious paper or plastic sheets*

impervious paper and plastic sheets can be applied on thoroughly wetted concrete. The concrete surface should be hard enough to prevent surface damage from placement activities.

ii. *Applying membrane-forming curing compounds*

Membrane-forming curing compounds are used to retard or reduce evaporation of moisture from concrete. They can be clear or translucent and white pigmented. White-pigmented compounds are recommended for hot and sunny weather conditions to reflect solar radiation. Curing compounds should be applied immediately after final finishing. Curing compound shall comply with ASTM C309.

2.4.1.3. Accelerating strength gain using heat and additional moisture

i. *Live steam*

Live steam at atmospheric pressure and high-pressure steam in autoclaves are the two methods of steam curing. Steam temperature for live steam at atmospheric pressure should be kept at about 140 degrees Fahrenheit or less until the desired concrete strength is achieved.

ii. *Heating coils*

Heating coils are usually used as embedded elements near the surface of concrete elements. Their purpose is to protect concrete from freezing during cold weather concreting.

iii. Electrical heated forms or pads

Electrical heated forms or pads are primarily used by precast concrete producers.

iv. *Concrete blankets*

Concrete insulation blankets are used to cover and insulate concrete surfaces subjected to freezing temperatures during the curing period. The concrete should be hard enough to prevent surface damage when covering with concrete blankets.

Other forms of curing include internal moist curing with lightweight aggregates or absorbent polymer particles. For mass concrete elements (usually thicker than 3 feet), a thermal control plan is usually developed to help control thermal stresses. Additional information can be found in ACI Committee 308 report Guide to Curing Concrete.

Curing in either cold or hot weather requires additional attention. In cold weather, some of the procedures include heated enclosures, evaporation reducers, curing compounds, and insulating blankets. The temperature of fresh concrete shall be above 50 degrees Fahrenheit. The curing period for cold weather concrete is longer than the standard period due to reduced rate of strength gain. Compressive strength of concrete cured and maintained at 50 degrees Fahrenheit is expected to gain strength half as quickly as concrete cured at 73 degrees Fahrenheit. In hot weather, curing and protection are critical due to rapid moisture loss from fresh concrete. The curing actually starts before concrete is placed by wetting substrate surfaces with water. Sunscreens, windscreens, fogging, and evaporation retardants can be used for hot weather concrete placements. Since concrete strength gain in hot weather is faster, curing period may be reduced.

2.4.2 **Concrete curing methods**.

Concrete curing methods may be divided broadly into four categories:

i. Water curing

ii. Membrane curing

iii. Application of heat

iv. Miscellaneous

2.4.2.1 Water curing

This is by far the best method of curing as it satisfies all the requirements of curing, namely, promotion of hydration, elimination of shrinkage and absorption of the heat of hydration. Curing concrete with water allows controlling the evaporation of moisture from the surface and the concrete gradually produces its chemical reaction that will eventually harden the concrete. It is pointed out that even if the membrane method is adopted, it is desirable that a certain extent of water curing is done before the concrete is covered with membranes. Water curing can be done in the following ways:

i. Immersion

ii. Ponding

iii. Spraying or Fogging

iv. Wet Covering

i. *Immersion*- Immersion curing is usually done in concrete testing for curing concrete test specimens.

ii. *Ponding*- Ponding is used to cure flat surfaces on jobs or controlled areas where water could be easily ponded.

iii. *Fogging*- Fogging is used in circumstances where the temperatures are above freezing and there is low humidity.

iv. *Wet Covering*- Curing concrete with wet covering is done after concrete has hardened sufficient enough where the covering will not damage concrete's surface.

2.4.2.2 Membrane Curing

Sometimes, concrete works are carried out in places where there is acute shortage of water. The lavish application of water for water curing is not possible for reasons of economy. Curing does not mean only application of water; it means also creation of conditions for promotion of uninterrupted and progressive hydration. It is also pointed out that the quantity of water, normally mixed for making concrete is more than sufficient to hydrate the cement, provided this water is not allowed to go out from the body of concrete. For this reason, concrete could be covered with membrane which will effectively seal off the evaporation of water from concrete.

Large numbers of sealing compounds have been developed in recent years. The idea is to obtain a continuous seal over the concrete surface by means of a firm impervious film to prevent moisture in concrete from escaping by evaporation. Some of the materials, which can be used for this purpose, are bituminous compounds, polyethylene or polyester film, waterproof paper, rubber compounds etc. When waterproofing paper or polyethylene film are used as membrane, care must be taken to see that these are not punctured anywhere and also see whether adequate lapping is given at the junction and this lap is effectively sealed.

Two common types of membrane curing are:

1. Plastic Sheeting- Curing concrete with plastic sheeting requires covering all exposed areas of the concrete as soon as possible without damaging concrete finish. When plastic sheeting is used over flat surfaces, such as pavements or slabs, it should extend beyond the edges of the slab at least twice the thickness of the slab.

2. Membrane-Forming Curing Compounds- Curing compounds are chemical products usually sprayed directly over the concrete surface, and allowing it dry forming an impermeable membrane that retards the loss of moisture from the concrete.

2.4.2.3 Application of heat

The development of strength of concrete is a function of not only time but also that of temperature. When concrete is subjected to higher temperature it accelerates the hydration process resulting in faster development of strength. Concrete cannot be subjected to dry heat to accelerate the hydration process as the presence of moisture is also an essential requisite. Therefore, subjecting the concrete to higher temperature and maintaining the required wetness can be achieved by subjecting the concrete to steam curing.
A faster attainment of strength will contribute too many other advantages mentioned below. The exposure of concrete to higher temperature is done in the following manner:

i. Steam curing at ordinary pressure
ii. Steam curing at high pressure
iii. Curing by Infra-red radiation
iv. Electrical curing.

2.4.2.4 Miscellaneous Methods of Curing

Calcium chloride is used either as a surface coating or as an admixture. It has been used satisfactorily as a curing medium. Both these methods are based on the fact that calcium chloride being a salt shows affinity for moisture. The salt not only absorbs moisture from atmosphere but

also retains it at the surface. This moisture held at the surface prevents the mixing water from evaporation and thereby keeps the concrete wet for a long time to promote hydration.

Formwork prevents escaping of moisture from the concrete, particularly, in the case of beams and columns. Keeping the form work intact and sealing the joint with wax or any other sealing compound prevents the evaporation of moisture from the concrete. This procedure of promoting hydration can be considered as one of the miscellaneous methods of curing.

2.4.5 Time for curing concrete.

Many a time an engineer at site wonders, how early he should start curing by way of application of water. This problem arises, particularly, in case of hot weather concreting. In an arid region, concrete placed as a road slab or roof slab gets dried up in a very short time, say within 2 hours.

Often questions are asked whether water can be poured over the above concrete within two hours to prevent the drying. The associated problem is, if water is applied within say two hours, whether it will interfere with the water/cement ratio and cause harmful effects. In other words, question is how early water can be applied over concrete surface so that uninterrupted and continued hydration takes place, without causing interference with the water/cement ratio.

The answer is that first of all, concrete should not be allowed to dry fast in any situation. Concrete that are liable to quick drying is required to be covered with wet gunny bag or wet hessian cloth properly squeezed, so that the water does not drip and at the same time, does not allow the concrete to dry.

This condition should be maintained for 24 hours or at least till the final setting time of cement at which duration the concrete will have assumed the final volume. Even if water is poured, after this time, it is not going to interfere with the water/cement ratio.

However, the best practice is to keep the concrete under the wet gunny bag for 24 hours and then commence water curing by way of ponding or spraying. Of course, when curing compound is used immediately after bleeding water, if any, dries up, the question of when to start water curing does not arise at all.

There is a wrong concept with common builders that commencement of curing should be done only on the following day after concreting. Even on the next day they make arrangements and build bunds with mud or lean mortar to retain water. This further delays the curing. Such practice is followed for concrete road construction by municipal corporations also. It is a bad practice. It is difficult to set time frame how early water curing can be started.

It depends on, prevailing temperature, humidity, wind velocity, type of cement, fineness of cement, w/c used and size of member etc. The point to observe is that, the top surface of concrete should not be allowed to dry. Enough moisture must be present to promote hydration.

Regarding how long to cure, it is again difficult to set a limit. Since all the desirable properties of concrete are improved by curing, the curing period should be as long as practical. For general guidance, concrete must be cured till it attains about 70% of specified strength. At lower temperature curing period must be increased. Since the rate of hydration is influenced by cement composition and fineness, the curing period should be prolonged for concretes made with cements of slow strength gain characteristics.

Pozzolanic cement or concrete admixed with pozzolanic material is required to be cured for longer duration. Mass concrete, heavy footings, large piers, abutments, should be cured for at least 2 weeks. The food and agricultural organization (FAO 2006) reported that, cement blended with pozzolans would produce 65 to 95% strength of OPC concrete in 28 days. Further, it was reported that their strength normally improve with age since pozzolans react more slowly than cement due to different composition and at one year about the same strength is obtained (Bengtsson & whitker, 1986).

2.5 Pozzolana

Pozzolans are finely divided materials used in concrete in relatively large amounts and mainly used as cement replacement in order to enhance early and long term performance. The use of these materials to some extent reduces the cost of concrete production.

The American Society of Testing and Materials ASTM C618 (1992) defines pozzolan as a siliceous or alumino-siliceous material that in itself possesses little or no cementitious value but that in finely divided form and in the presence of moisture will chemically react with alkali and alkaline earth hydroxides at ordinary temperatures to form or assist in forming compounds possessing cementitious properties, ASTM (2001). Some pozzolans are natural and others are industrial by-products and both contain silica in amorphous form and that would react with calcium hydroxide (C-H) to form more cementitious calcium silicate hydrate (C-S-H) and contribute to the concrete strength. These materials include volcanic ash, diatomaceous earths, condensed silica fume, pulverized fly ash, natural pozzolan sugarcane bagasse ash and rice husk ash.

Pozzolana contains some form of amorphous reactive silica which may combine with lime in

presence of water to form C-S-H (Aitcin, 1998). Slags are the by-products of the production of the iron; slag consists mainly of calcium and alumino-silicate. Granulated blast furnace slag is the type mainly used in large scale in the cement industry. However, due to its cementitious properties and the presence of silica, slags may also possess pozzolanic activity, (Safiuddin and Zain, 2006). Adding pozzolans to concrete influence mixture proportioning, rheological behavior of fresh concrete, degree of hydration of cement paste, strength and permeability of the produced concrete (Rama, 2001).

2.5.1 Rice husk ash

The possible utilization of Rice Husk Ash (RHA) in Portland cement concrete has received attention especially in South East Asia and Pacific primarily for economic, energy and environmental considerations (Khan, 2000). Since their uses generally improve the properties of the blended cement concrete and particularly RHA has been used as a highly reactive pozzolanic material to improve the microstructure of the interfacial transition zone (ITZ) between the cement paste and the aggregate in high-performance concrete. Rice husk ash improves the properties of concrete or cement paste due to the pozzolanic reaction and its role as a micro-filler. It is often thought that the first function (pozzolanic reaction) is most important.

Rice milling generates a byproduct known as husk. This surrounds the paddy grain. During milling of paddy about 78 % of weight is received as rice, broken rice and bran and rest 22 % of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75% organic volatile matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). This RHA in turn contains around 85 % - 90 % amorphous silica (Jaturapitakkul et al., 2003, and Gambhir, 2006). So for every ton of paddy milled, about 220 kgs

(22 %) of husk is produced, and when this husk is burnt in the boilers, about 40 kgs (20 %) of RHA is generated (Mehta, 1986). India is a major rice producing country, and the husk generated during milling is mostly used as a fuel in the boilers for processing paddy, producing energy through direct combustion and / or by gasification. About 20 million tons of RHA are produced annually. It is classified as pozzolanic material according to ASTMC168 (1997 d). Hydrated (or slaked) lime is very effective in treating clays and silts.

2.5.1.2 Advantages of using rice husk ash in concrete

The use of RHA in concrete has been associated with the following essential assets:

i. Increased compressive and flexural strengths (Rodriguez, 2006)

ii. Reduced permeability (Ganesan, et al,. 2007)

iii. Increased resistance to chemical attack (Chindaprasirt, et al,. 2007)

iv. Increased durability (Coutinho, 2002)

v. Reduced effects of alkali-silica reactivity (ASR) (Nicole, et al,. 2000)

vi. Reduced shrinkage due to particle packing, makingconcrete denser (Habeeb, 2009)

vii. Enhanced workability of concrete (Habeeb and Fayyadh, 2009)

viii. Reduced heat gain through the walls of buildings (Lertsatitthanakorn, et al,. 2009)

ix. Reduced amount of super plasticizer (Sata et al,. 2007)

x. Reduced potential for efflorescence due to reduced calcium hydracids (Chindaprasirt, 2007).

2.5.2. Sugarcane bagasse ash (SBA)

Utilization of industrial and agricultural waste products in the industry has been the focus of research for economical, environmental, and technical reasons. Sugar-cane bagasse is a fibrous waste-product of the sugar refining industry, along with ethanol vapor. This waste-product

(Sugar-cane Bagasse ash) is already causing serious environmental pollution which calls for urgent ways of handling the waste.

Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons (Deepchand, 1986). After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue (FAO, 2006) is obtained, which is reused in the same industry as fuel in boilers for heat generation leaving behind 8 -10 % ash as waste known as sugarcane bagasse ash (SBA). The S BA contains high amounts of un-burnt matter, silicon, aluminum and calcium oxides (Deepchand, 1986). It is a very valuable pozzolan material if carbon free and amorphous ash could be obtained by further combustion. A few studies have been carried out on the ashes obtained directly from the industries to study pozzolanic activity and their suitability as binders, partially replacing cement (Banguant et al., 1995).

These ashes are produced under uncontrolled and non uniform burning conditions with temperatures rising above $1000^{o}C$ resulting in the crystallization of the matter (Baguant, 1995).

Recent research indicates that up to 20% of ordinary Portland cement can be replaced with well-burnt bagasse ash without any adverse effect on the desirable properties of concrete, such as, the development of high early strength, and reduced water permeability and reduced chloride penetration, all of which have a direct bearing on the durability of reinforced concrete structures (Zain, 2007), However, it has been proposed that factors such as the high temperatures and incomplete combustion that take place in the boilers, influence the reactivity of SBA. These factors affect the degree of crystalline of the silica present in the ash, and the presence of impurities, such as carbon and unburned material. Such impurities could limit the contact

between Calcium Hydroxide (CH) and reactive silica and prevent them from forming stable compounds (Alvarez et al., 2012).

In order to produce SBA with pozzolanic activity, which will give amorphous silica, low carbon content and high specific surface area, controlling the temperature of calcination is required (Martinez, 2012). Reduction of particle size of SBA by grinding also has a significant effect on the pozzolanic activity. This hypothesis has been corroborated in a recent study, where concrete containing up to 30% ground bagasse ash, showed a higher compressive strength and lower water permeability than the control concrete without ground bagasse ash, both at ages of 28 and 90 days. In another study (Alvarez et al., 2012), the replacement of cement (up to 20%) with an ultrafine, ground SBA, produced by vibrating grinding, allows for the production of high-performance concrete with the same mechanical response as the concrete prepared solely using Portland cement.

The addition of pozzolana decreases calcium hydroxides C-H formed and produces more calcium silicate hydrates (C-S-H) gel that can improve the strength and durability of concrete.

Amorphous silica that is found in some pozzolanic materials (Habeeb et al., 2009) reacts with lime more readily than those of crystalline form. The most essential assets of SBA that identifies it pozzolanic activity is the amorphous phase substance. The production of SBA can lead to the formation of approximately 60% to 70%by weight of amorphous silica. For these characteristics, SBA is an extremely reactive pozzolanic substance appropriate for use in lime-pozzolana mixes and Portland cement substances. Cement replacement by pozzolana accelerates the early hydration of tricalcium silicate (C_3S). The increase in the early hydration rate of C_3S is attributed to the high specific surface area (Feng et al., 2004)

CHAPTER 3

MATERIALS AND METHOD.

The materials used in this research were obtained from Wuntin dada village in Bauchi state and danja in Katsina state. The specimens were prepared and tested according to the relevant British Standards (BS). The compressive strength, water absorption, and abrasive strength tests were carried out in the concrete laboratory of Building Department of Ahmadu Bello University, Zaria. Chemical analysis of SBA and RHA were carried out in chemistry Department of Ahmadu Bello University, Zaria. And micro structure analysis was carried out at Chemical engineering Department of Ahmadu Bello University, Zaria,

3.1 Materials

The materials used in the study were cement, aggregates, water, sugarcane bagasse ash (SBA) and rice husk ash (RHA).

3.1.1 Cement

The cement used in the study was ordinary Portland Cement of Dangote brand because is the most widely used cement for construction in Nigeria and conform to BS 12 (1996).

3.1.2 Aggregate

The aggregates used in this research were coarse and fine aggregates. In this study single sized crushed coarse aggregate with maximum size of 20mm was used. The coarse aggregate was obtained from aggregate suppliers within Zaria town and it was in saturated surface dry condition before it was used in the mixing, and was assumed to conform to BS 812, (1996). And the fine aggregate used was also obtained from suppliers in Zaria town and it was also in saturated

surface dry condition before it was used in the mixing. The percentage passing 600μm of the fine aggregate was 40%, and also conforms to BS 812, (1996).

3.1.3 Water

The water used in the research was fresh tap water in the concrete laboratory of Building Department of Ahmadu Bello University, Zaria.

3.2 Properties of RHA and SBA

The following physical properties of RHA and SBA were investigated in the concrete laboratory of Building Department of Ahmadu Bello University, Zaria and the following results were obtained

3.2.1 Specific Gravity

The results shows that the specific gravity of RHA and SBA has an average mean of 1.55 and 1.62 respectively.

3.2.2 Physical appearance of RHA and SBA

The rice husk and sugarcane bagasse were obtained locally from rice and sugar processing company both were burned at controlled temperatures of 700°C and 660°C respectively. Sieve analysis was carried out on the two ashes. SBA is dark greenish in colour having almost the same colour with ordinary Portland cement, while RHA is light greenish in colour as shown in plate I and II. Both the SBA and RHA have no specific smell.



Plate I. Rice husk ash (RHA).

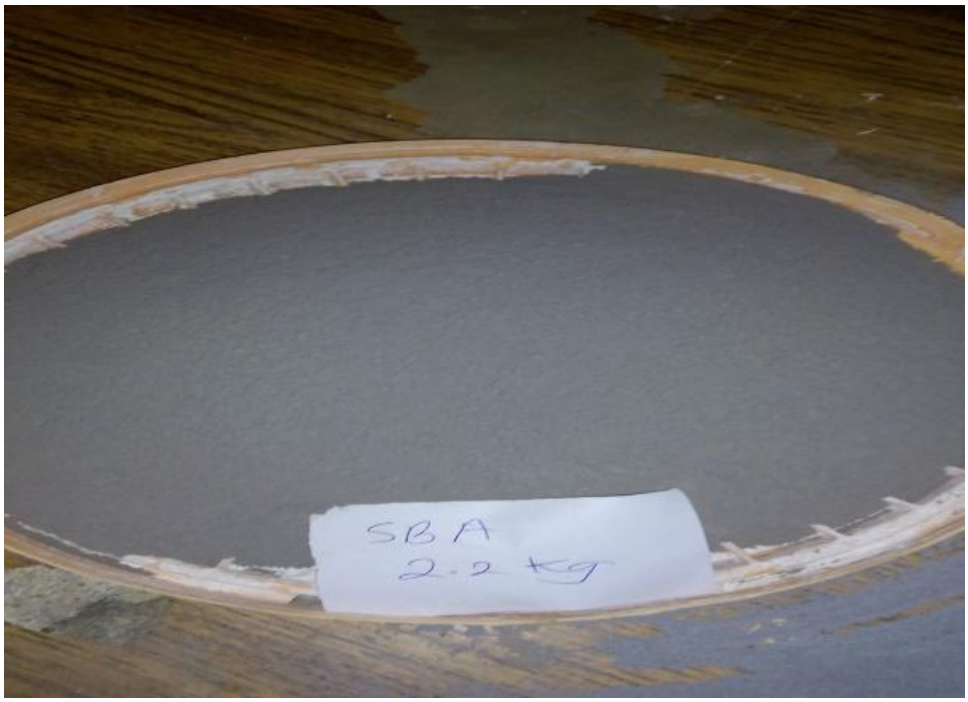


Plate II. Sugarcane bagasse ash (SBA)

3.3 Design Mixture for Concrete

A concrete of grade 30N/mm^2 at 28 days was design using the Department of Environment (DOE) Method, for both RHA and SBA concrete. The design was made for 36 cubes for 0%, 20% and 5% replacements for control, SBA concrete and RHA concrete as shown in table 3.1, table 3.2, table 3.3 respectively. The proportion of each ingredients for 36 cubes were shown in the table 3.4

Table 3.1. Concrete Mix Design for 0% replacement of OPC for 36 cubes.

Quantity	Cement (kg)	Water (kg)	Coarse aggregate (kg)	Fine aggregate (kg)
1m^3	360	240	1125	750
0.036m^3 (36 no. cubes)	12.96	8.64	40.50	27

Source: Laboratory work (2014)

Table 3.2. 20% replacement of SBA required for 36 cubes.

Quantity	Cement (kg)	SBA (kg)	Water (kg)	Coarse aggregate (kg)	Fine aggregate (kg)
1m^3	360	0.00	240	1125	750
0.036m^3 (36 no. cubes)	10.01	2.59	8.64	40.50	27

Source: Laboratory work (2014)

Table 3.3. 5% replacement of RHA required for 36 cubes.

Quantity	Cement (kg)	RHA (kg)	Water (kg)	Coarse aggregate (kg)	Fine aggregate (kg)
1m^3	360	0.00	240	1125	750
0.036m^3 (36 no. cubes)	12.31	0.65	8.64	40.50	27

Source: Laboratory work (2014)

Table 3.4. Percentage Replacement of RHA and SBA for test samples.

% Replacement	Cement (kg)	RHA (kg)	SBA (kg)
5	12.93	0.68	0.00
20	10.01	0.00	2.59

Source: Laboratory work (2014)

3.4. Specimens Identification

The concrete mixes for this research work was divided into three categories according to curing methods. SBA and RHA concrete samples produced were cured using the three curing methods namely, spraying of water, immersion into water and covering with polythene. Table 3.5 depicts the specimens' identification as used in the study.

Table 3.5. Specimen Identifications

Curing methods	RHA	SBA	Control
Spraying	SR	SS	SC
Immersion	IR	IS	IC
Polythene	PR	PS	PC

Source: Laboratory work (2014)

SC: Control specimen subjected to spraying, IC: Control specimen subjected to immersion, PC: Control specimen subjected to covering with polythene. SS: SBA specimen subjected to spraying, IS: SBA specimen subjected to immersion, PS: SBA specimen subjected to polythene, SR: RHA specimen subjected to spraying, IR: RHA specimen subjected to immersion, PR: RHA specimen subjected to covering with polythene

3.5 Laboratory Test

3.5.1 Workability test

The concrete was mixed in accordance with BS 1881; Part 108, (1983) Method for Making Test Cube from Fresh Concrete. The degree of workability of the concrete mixes for both SBA and RHA concrete was determined by slump tests as shown in plate III. The slump test was conducted in accordance with Method for Determination of Slump, BS 1881: part 102: 1983,



Plate III: Slump Test for RHA concrete

3.5.2 Moulding and compaction of concrete cubes

Cast iron moulds of 100mm x 100mm x 100mm were used to produce the concrete cubes. The moulds were oiled to allow for easy removal of concrete cubes. The concrete was placed in approximately three equal layers and each layer was rammed with 25 strokes of 50mm round ended rod.

3.5.3 Curing of specimens

The concrete cubes produced were cured using the three methods namely, spraying, immersion, and covering with polythene for 7, 14, 28 and 56 days. Plates III, IV, and V show the curing methods adopted.



Plate IV; Curing by Sprinkling of water.



Plate V; Curing by immersion in water.



PlateVI; Curing by covering with polythene.

3.5.4 Compressive strength test

The test was carried out in accordance with BS 1881: Part 116: (1983) Method for Determination of Compressive Strength of Concrete Cube. The total of 288 samples specimens of RHA and SBA of 100 x 100 x 100 was produced. Under RHA sample specimens, 48 were subjected to spraying method, 48 samples subjected to immersion method and 48 samples subjected to covering by polythene method of curing. While under SBA sample specimens, 48 were also subjected to spraying method, 48 samples subjected to immersion method and 48 samples subjected to covering by polythene method of curing. All the sample specimens were crushed at saturated surface dry condition. The crushing was carried out at 7, 14, 28 and 56 days respectively for the three methods of curing, using the hydraulic crushing machine of 1000kN capacity in the Building Department concrete laboratory. The failure load was divided by the cross-sectional area to obtain the strength.

3.5.5 Abrasion resistance test

The abrasion resistance test was carried out in accordance with African Regional Standard ARS 674: (1996). The surface of the concrete cubes was subjected to brushing by means of a wire brush. The brushing consists of one forward and backward motion per second for one minute i.e. 60 cycles. The masses of the cubes before brushing were recorded as M_1 and after brushing M_2 respectively. The mass of the detached matter i.e. $M_1 - M_2$ was recorded and the percentage weight loss of all the specimens were recorded and compared.

3.5.6 Water absorption test

Water Absorption test was carried out in accordance with Indian Standard (IS) 3495. Dry cubes were put in an oven at a temperature of 105°C to 115°C till constant mass is attained. The weight (W_1) of each cube is recorded after cooling them to room temperature. The cubes were then immersed in water for 24 hours. The specimens were then taken out of water and allow to attain surface dry, thereafter it was weighed again and recorded as W_2

The water absorption in $\% = \frac{W2-W1}{W1} \times 100$

3.5.7. Micro structure analysis.

Micro structure analysis was carried out using scanning electron microscopy to examine the flat specimen surface of hardened RHA and SBA concrete samples; the scanning was done at magnification indicator of 1500, with image voltage of 15kv, at a height mark of 179µm through a backscattered detector (BSD) full, at a ruler length of 50µm. The internal structure of RHA and SBA specimens were compared with that of control specimen under the three curing methods using pore diameter histogram obtained from the scanner.



Plate VII: Scanning electron microscopy

Chapter 4:

DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Data Presentation and Analysis

The results presented in this chapter were based on the tests carried out on the SBA and RHA concrete. The physical and chemical properties of the SBA and RHA and its composition were presented. The results for the compressive strength, water absorption, abrasion resistance tests and micro structure analysis were presented and discussed.

4.2 Physical Properties of RHA and SBA

The RHA and SBA possessed dark green in colour with average mean specific gravity of 1.55 and light green in colour with average mean specific gravity of 1.62 respectively and both have no specific smell manually.

4.2.1 Particle size distribution.

The result of particle size distribution analysis of RHA and SBA are as in table 4.1 and 4.2

Table 4.1 Sieve Analysis of Rice husk ash. (RHA)

Sieve Size	Weight retained (g)	% returned	% passing
2.36	0	0	100
1.18	0	0	100
600	34	5.8	93.2
425	41	8.3	85
300	150	30	55
212	57	11.4	43.6
150	81	16.2	27.2
63	100	20.0	7.4
Pan	35	7.4	0

Source; laboratory work, (2014)

Table 4.2 Sieve Analysis of Sugarcane bagasse ash (SBA)

Sieve Size	**Weight retained (g)**	**% returned**	**% passing**
2.36	0	0	100
600	39	6.2	92.2
425	49	8.9	89
300	170	39	59.2
212	65	12.4	51.6
150	89	17.1	34.2
63	118	28.0	8.6

Source; laboratory work, (2014)

4.3 Chemical Properties of RHA and SBA

Rice husk ash and Sugarcane bagasse were burnt under controlled temperature 700°C and 660°C respectively (Nick & Emmet, 2009), using kiln in Industrial Design Department of Ahmadu Bello University Zaria, as recommended by ASTM C618 (1992). The chemical analyses of the ashes were carried out in multi-use laboratory, Chemistry Engineering Department of Ahmadu Bello University Zaria. The analyses were clearly stated in table 4.3.

Table 4.3 Chemical Composition of RHA and SBA

Constituents	% compositions RHA	SBA
SiO_2	86.98	78.34
Al_2O_3	0.84	8.55
Fe_2O_3	0.73	3.61
CaO	1.40	2.15
MgO	0.57	0.13
SO_3	0.11	-
Na_2O	2.46	0.12
K_2O	-	3.42
P_2O_5	9.43	1.07
Loss on ignition	5.14	0.42

Source: experimental work (2014)

4.3.1 Chemical Composition of RHA and SBA

Table 3.3 shows the chemical composition of RHA and SBA. It can be observed that the percentage of the silicon dioxide (SiO_2), iron oxide (Fe_2O_3), aluminum oxide (Al_2O_3) gives a total of 88.55% and 90.50% for RHA and SBA respectively, this satisfies the requirements of the ASTM C 618 which give a minimum of 70% of the class N (raw or calcined natural pozzolana). It was also observed that RHA contains higher content of SiO_2 while cement contains higher content of CaO compared to SBA but Al_2O_3 content is higher in SBA.

4.4 Compressive Strength Test

The results of the compressive strength test based on 5% and 20% respectively for the RHA and SBA under the curing methods used were compared with that of control samples, and a control sample of 0% was produced for the purpose of comparison. The comparison was used to ascertain the extent in which the curing methods affect the strength of the hardened specimens.

The hardened specimens were demoulded after 24hours of casting. The cubes were cured under the three curing methods (spraying, immersion, and covering with polythene) and were tested for compressive strength at 7, 14, 28 and 56 days respectively. The results were shown in figure 4.1, 4.2, 4.3, and 4.4 respectively.

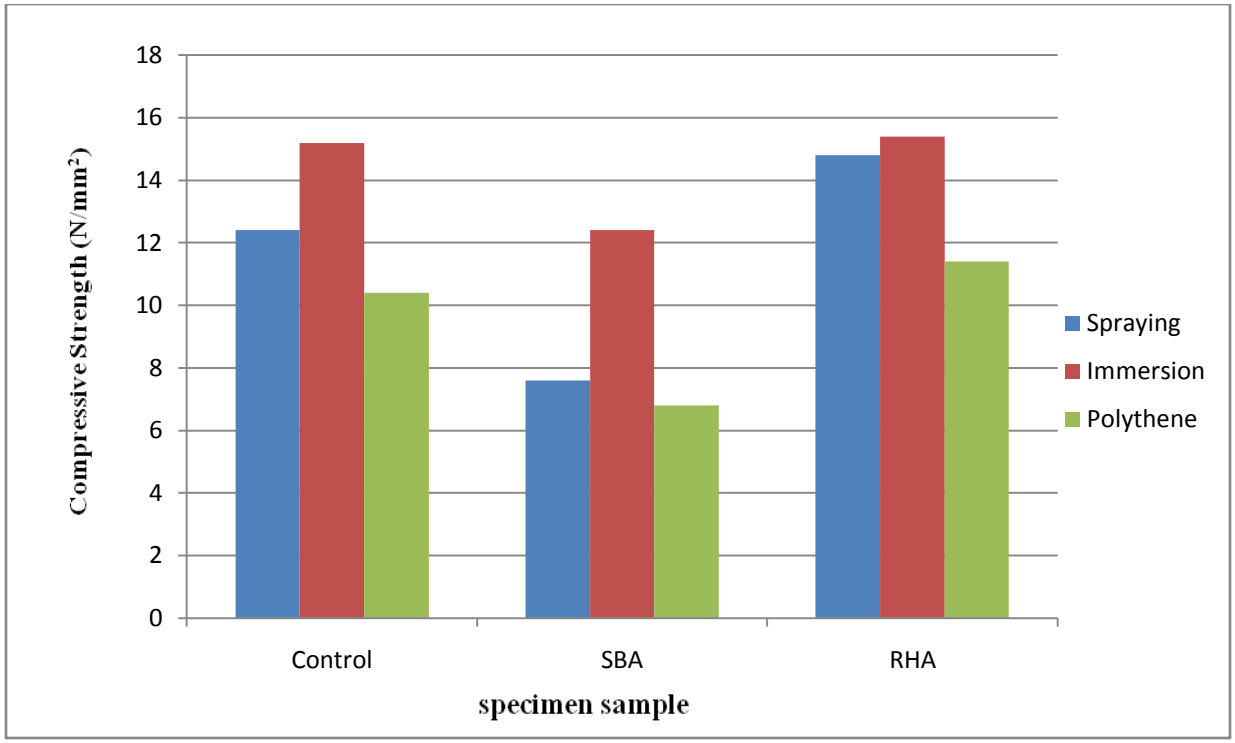


Fig. 4.1 Compressive Strength at 7 Days of curing.

The RHA specimen shows an increment in compressive strength over the control specimen under the three curing methods, with those specimens subjected to immersion curing method possessing the highest strength followed by spraying then polythene curing method, these are due to the reaction between high content of SiO_2 (86.98%) in RHA and Al_2O_3 (1.8%) and CaO (78.03%) in cement. While SBA specimen was observed to have less strength compared to the control. This may be due to the fact that the quantity of SBA present in the mix is higher than the amount required to combine with the liberated lime during the process of hydration, thus leading to excess silica leaching out and causing a deficiency in highly strength as it replaces part of the cementitious material but does not contribute to strength.

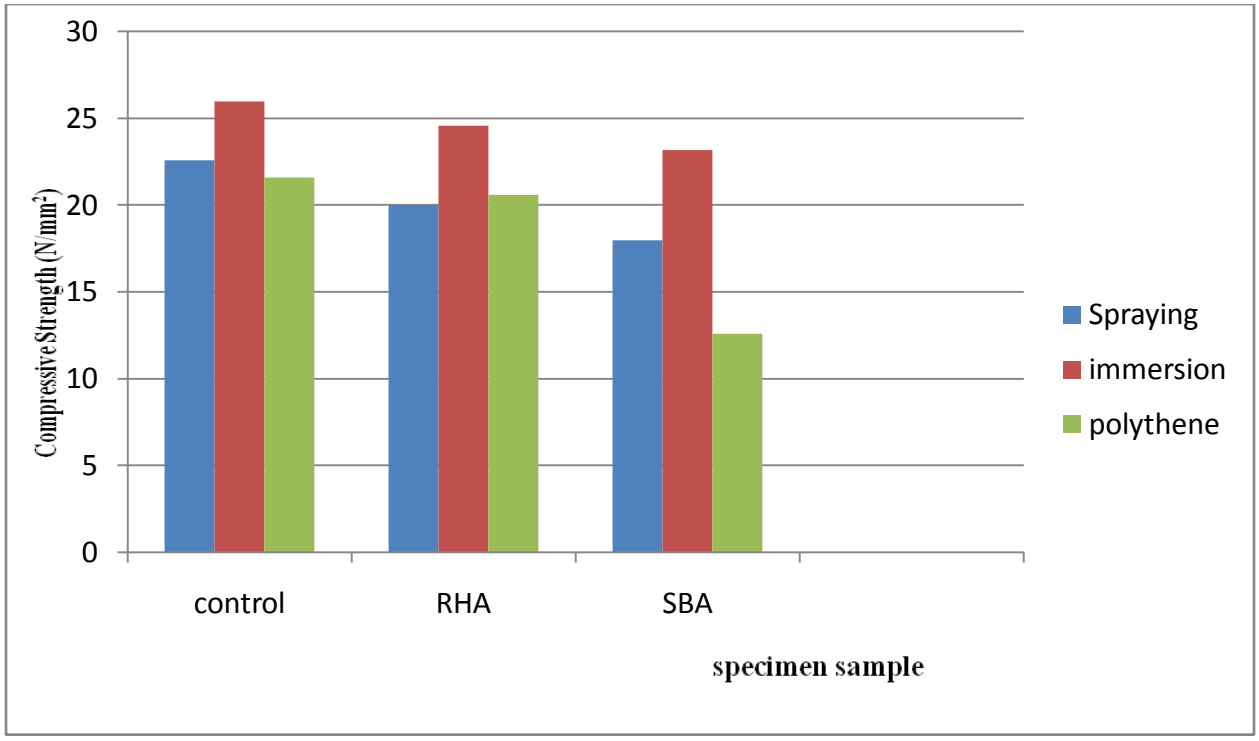


Fig. 4.2 Compressive Strength at 14 Days of curing.

The control specimen has an higher compressive strength over the test specimens (SBA and RHA) under the three curing methods, concrete containing 20% RHA posses higher compressive strength than the samples containing 5% SBA under the three curing methods used, with those subjected to immersion curing possessing the highest strength, this may be due to improved pore structure and lower porosity resulting from greater degree of cement hydration reaction without any loss of moisture from the concrete specimens. This can also be attributed to the slow hydration rate which may delay strength gain, as it reported for most Portland-pozzolan cement concrete.

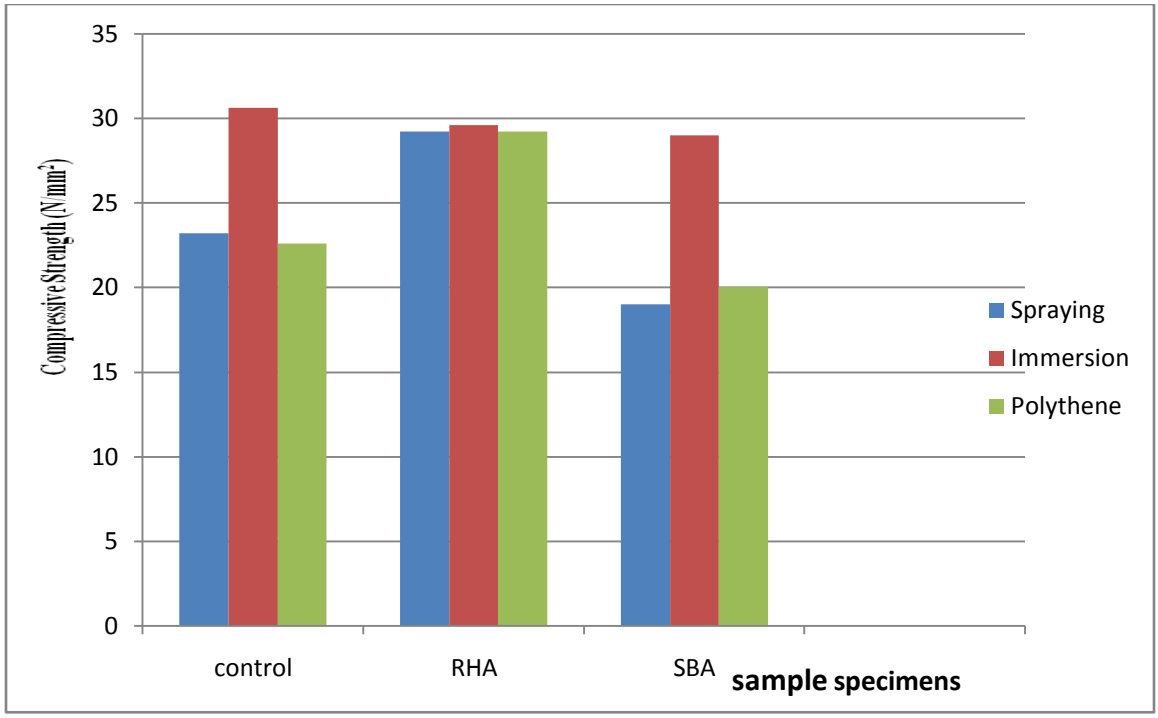


Fig. 4.3 Compressive Strength at 28 Days

The RHA specimen shows an increment in compressive strength over the control and SBA specimen under spraying and covering with polythene methods of curing at 28days, but under the immersion method, the control is slightly higher in compressive strength. This may also be due to improved pore structure and lower porosity resulting from greater degree of cement hydration reaction without any loss of moisture from the control specimens. The decrease in the total porosity of RHA specimen is attributed to the change occurring in the pore size distribution as a result of using RHA which could react with the calcium hydroxide to form C-S-H gel (Dakroury et al., 2008). Results due to the intensification mechanism of RHA blended concrete confirmed that the average pore size of concrete incorporating RHA decreased compared to that of control concrete (Sugita et al., 1997).

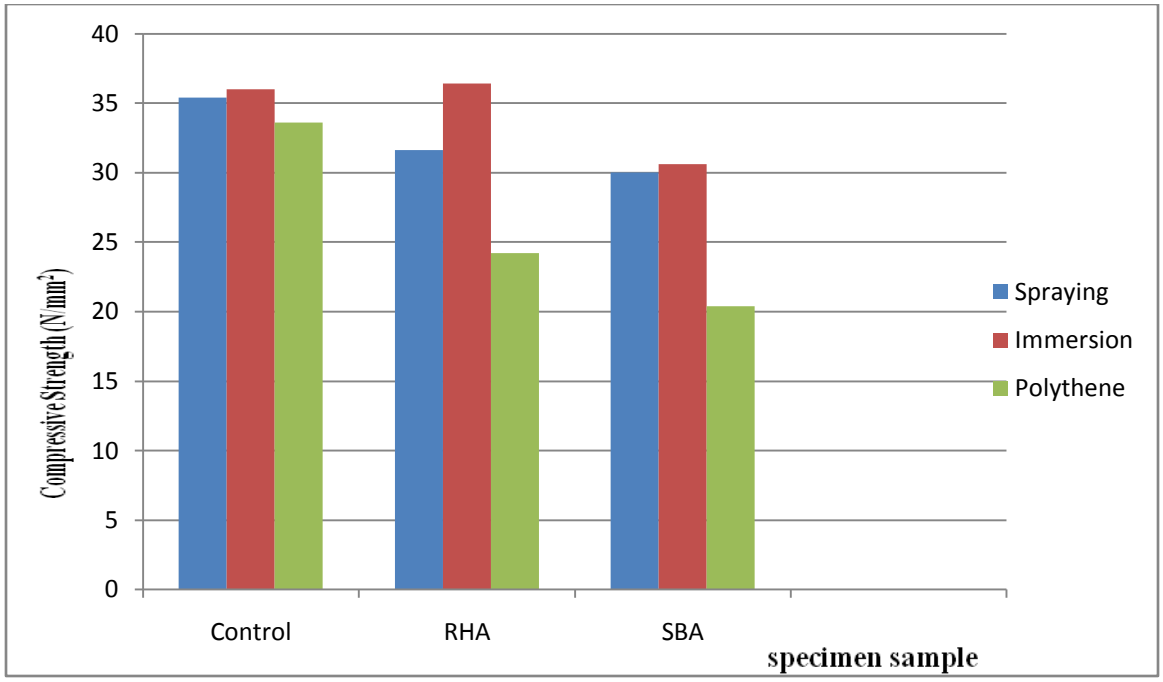


Fig. 4.4 Compressive Strength at 56 Days

The RHA specimen shows an increment in compressive strength over the control and SBA specimen under spraying method and covering with polythene methods of curing at 56days, but under the immersion method, the control is higher in compressive strength. This may also be due to improved pore structure and lower porosity resulting from greater degree of cement hydration reaction without any loss of moisture from the concrete specimens.

The increment in compressive strength of RHA specimen over control and SBA specimens under spraying and covering with polythene methods can be attributed to the pozzolanic reactions which aid the production of more calcium silicate hydrate (CSH) and calcium aluminate, thus influencing the strength.

It is concluded that RHA can provide a positive effect on the compressive strength of RHA concrete at early ages. Besides, in the long term, the compressive strength of RHA concrete produced by controlled incineration shows better performance. This was also confirmed by

Aitcin (1998), which said that adding Pozzolans would contribute to the strength enhancement at later ages only and the strength would be comparable to the OPC concrete.

4.5. Abrasion Resistance Test on Concrete Cubes.

The results of the abrasion test on the concrete cubes subjected to different curing conditions are shown in fig. 4.5 4.6, 4.7 for the control, RHA and SBA concrete sample respectively.

Details are presented in appendix, tables B-2 and B-3.

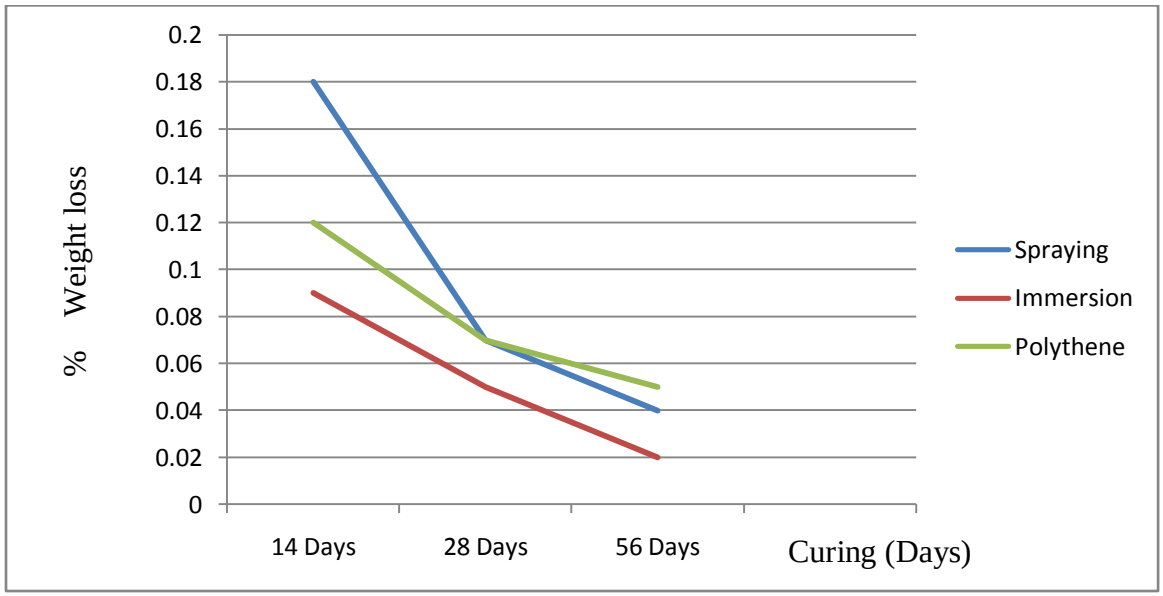


Fig4.5. Abrasion resistance test for control specimens.

The average percentage weight loss of all the samples in all the curing methods at all ages of test was recorded. At 14 days, the samples under spraying and polythene have the percentage weight loss of 0.18% and 0.12% respectively, while the sample under immersion possessed the lowest percentage weight loss of 0.09%. At 28 days, the highest percentage weight loss of 0.07% was recorded for samples under both spraying and polyethene, while samples under immersion possessed the lowest percentage weight loss of 0.05%. At 56 days, the highest percentage weight loss of 0.05% was also recorded on the samples under polythene, followed by 0.04% for the sample under spraying, while the lowest percentage weight loss of 0.02% was recorded for the

sample under immersion. This showed that the abrasion resistance of the concrete increased with the increase in maturity age. Concrete subjected to immersion have the highest abrasion resistance compared to those under spraying and covering with polythene.

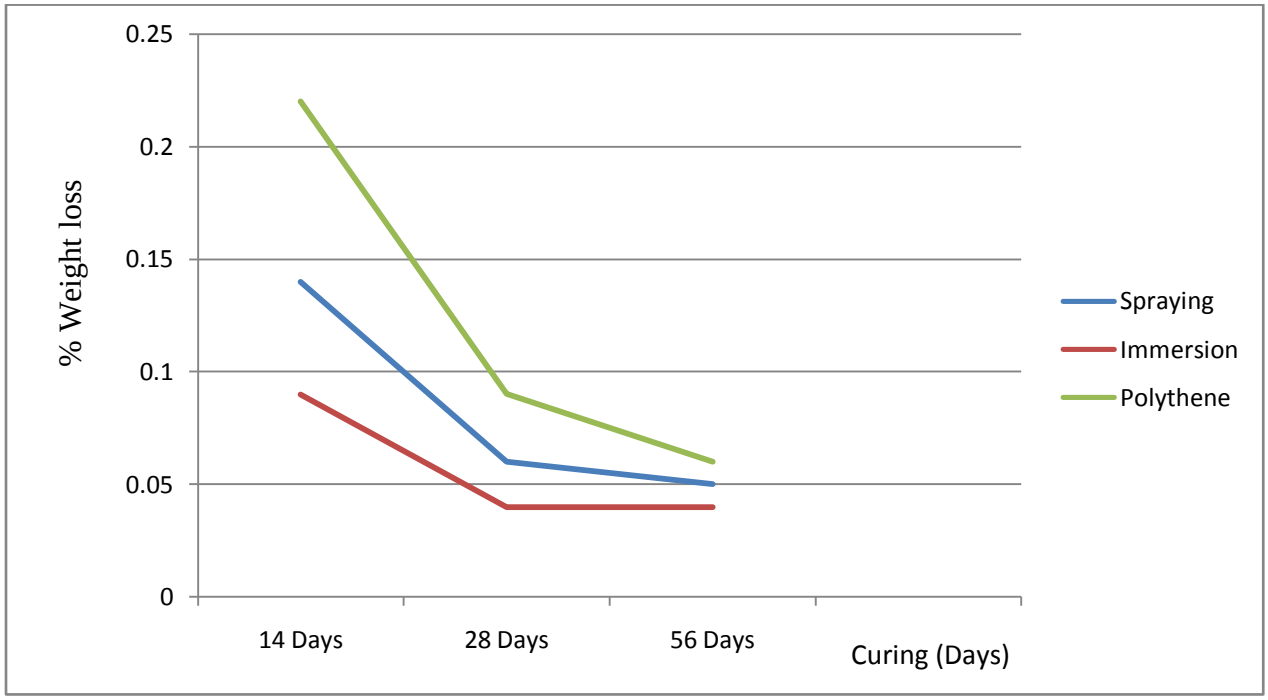


Fig.4.6 Abrasion resistance test for RHA concrete.

The average percentage weight loss of all the samples in all the curing methods at all ages of test was recorded. At 14 days, the samples under immersion possessed the lowest percentage weight loss of 0.09%. Sample under spraying also possessed percentage weight loss of 0.14%, while sample under polythene possessed the highest percentage weight loss of 0.22%. At 28 days, the sample under immersion possessed the lowest percentage weight loss of 0.04% followed by samples under spraying with percentage weight loss of 0.06%. While sample under polythene possessed the highest percentage weight loss of 0.09%. At 56 days, the highest percentage weight loss of 0.06% was recorded under polythene, followed by 0.05% under spraying, while the lowest percentage weight loss of 0.04% was recorded for the samples under immersion. The abrasion resistance of RHA concrete specimens also increased with the increase in maturity age.

This showed that the RHA specimen subjected to immersion have the highest abrasion resistance compared to those under spraying and covering with polythene. This can be attributed to sufficient moisture and suitable vapour pressure which are maintained to continue the hydration of cement.

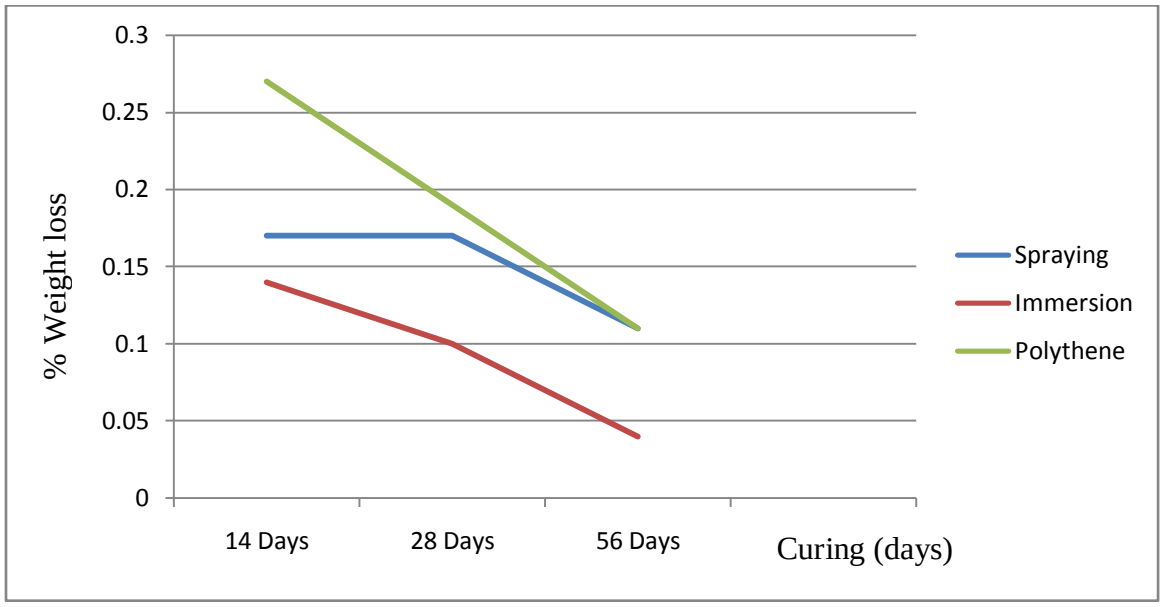


Fig 4.7 Abrasion Tests Results of SBA specimens

The average percentage weight loss of all the samples in all the curing methods at all ages of test was recorded. At 14 days, the samples under immersion possessed the lowest percentage weight loss of 0.14%. Sample under spraying also possessed percentage weight loss of 0.14%, while sample under polythene possessed the highest percentage weight loss of 0.27%. At 28 days, the sample under immersion possessed the lowest percentage waste loss of 0.10% followed by sample under spraying with percentage weight loss of 0.17%. While sample under polythene possessed the highest percentage weight loss of 0.19%. At 56 days, both sample specimens under spraying and polythene possessed the same percentage weight loss of 0.11%, while the specimen under immersion possessed the lowest percentage weight loss of 0.04%. The abrasion resistance of SBA concrete specimens also increased with the increase in maturity age. This showed that

the SBA concrete subjected to immersion also have the highest abrasion resistance compared to those under spraying and covering with polythene.

4.6. Water Absorption Test on Sample Specimens.

The results of the water absorption test on the concrete cubes subjected to different curing conditions are shown in fig 4.8, 4.9, for RHA and SBA concrete respectively. Details are presented in appendix, tables C-1 and C-2.

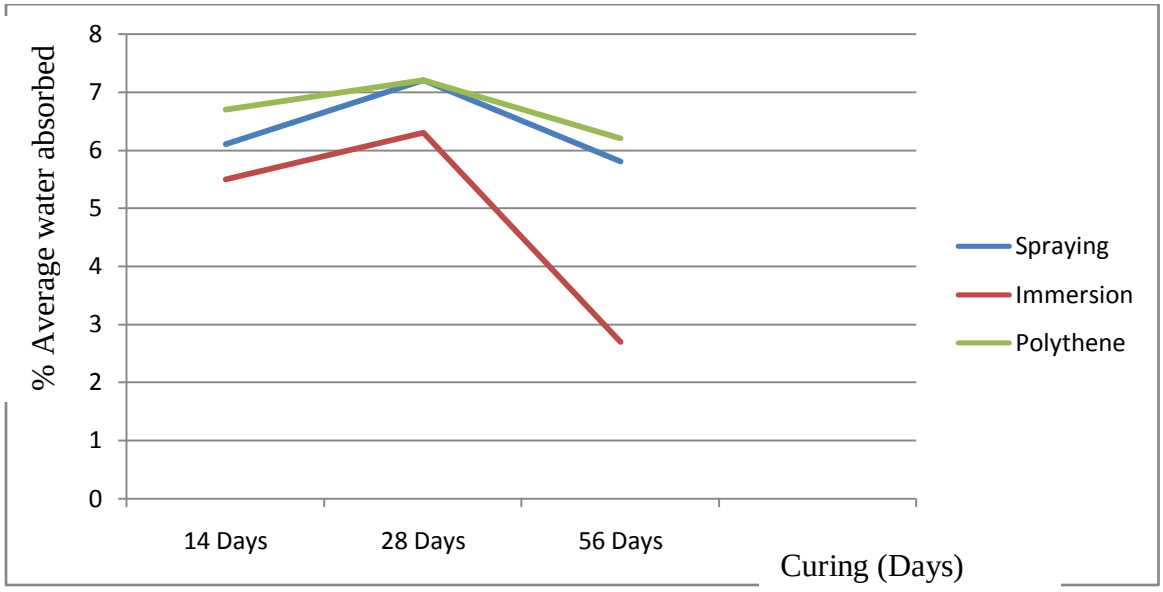


Fig.4.8. Water absorption test on RHA specimens.

The average percentage weight loss of all the samples in all the curing methods at all ages of test was recorded. At 14days, the specimen under Polythene was observed with the highest percentage water absorption of 6.7%, followed by the specimen under spraying with 6.1%, while specimen under immersion possessed the lowest of 5.5%.At 28days, specimens under both spraying and polythene possessed the same percentage water absorption of 7.2%, while specimens under immersion possessed the lowest of 6.3%. At 56days, specimen under polythene possessed the highest percentage water absorption of 6.2%, followed by the specimen under spraying with 5.8%, while specimen under immersion possessed the lowest of 2.7%. The water

absorption of RHA concrete specimens decreased with the increase in maturity age. This showed that RHA concrete subjected to immersion have lower water absorption at 56days,

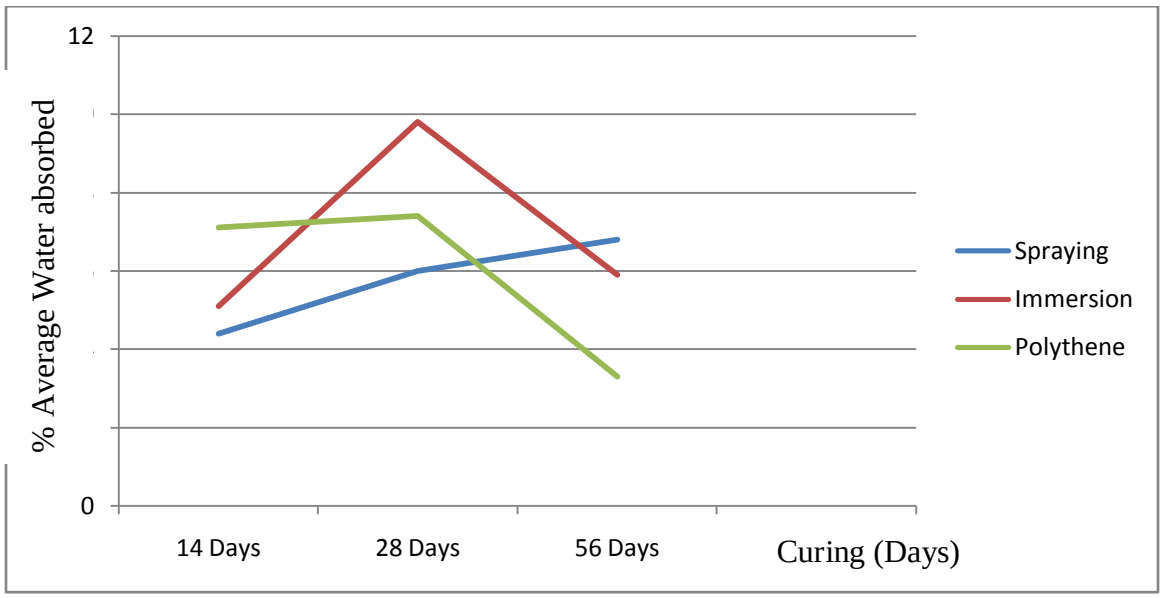


Fig 4.9. Water absorption test on SBA concrete.

The average percentage weight loss of all the samples in all the curing methods at all ages of test was recorded. At 14days, the specimen under spraying was observed with the lowest percentage water absorption of 4.4%, followed by the specimen under immersion with 5.1%, while specimen under polythene possessed the highest of 7.1%. At 28days, specimen under spraying possessed the percentage water absorption of 6.0%, followed by the specimen under polythene with 7.4%, while specimen under immersion possessed the highest of 9.8%. At 56days, specimen under spraying possessed the percentage water absorption of 6.8%, followed by the specimen under immersion with 5.9%, while specimen under polythene possessed the lowest of 3.3%. This showed that SBA concrete subjected to covering with polythene have a lower water absorption at 56days, while SBA concrete subjected to immersion have the higher rate of water absorption at 28days.

In conclusion, RHA and SBA samples subjected to covering with polythene have a lower water absorption as the maturity age increases. One of the main sources of contamination of concrete in

structures is water absorption which influences durability of the concrete and also has the risk of alkali aggregate reactions. The incorporation of pozzolan such as RHA and SBA reduces the average pore size and results in a less permeable paste. It was observed that the incorporation of RHA in the composites could cause an extensive pore refinement in the matrix and in the interface layer, thereby decreasing water permeability. The radial expansion of Portland cement hydration products in pozzolanic particles would have a pore modification effect therefore reduces the interconnectedness among pores.

4.7. Micro Structure on Sample Specimens.

The type, amount, size, shape, and the distribution of various phases present in the concrete solid constitutes are scanned out. In order to find the link between the various caring methods adopted and the microstructure of the specimens. The scanning electron microscopy (SEM) was adopted to observe the internal structure of the RHA and SBA specimens under the three different curing methods.

The detail of results of pore diameter histogram and Fibremetric image of internal structure of control, RHA and SBA specimens subjected to spraying, immersion, and covering with polythene curing methods were shown in fig 4.10 and plate 8, fig 4.11 and plate 9, fig 4.12 and plate 10 for control specimens. Fig 4.13 and plate 11, fig 4.14 and plate 12, fig 4.15 and plate 13 for RHA specimens. Fig 4.15 and plate 14, fig 4.17 and plate 15, fig 4.18 and plate 16 for SBA specimens respectively. The summary of pore histogram of control, RHA, SBA under the three curing methods were classified using low, average and high categories of pore sizes and were presented in tables 4.1, 4.2, and 4.3 respectively.

Microstructure analysis results on control specimens

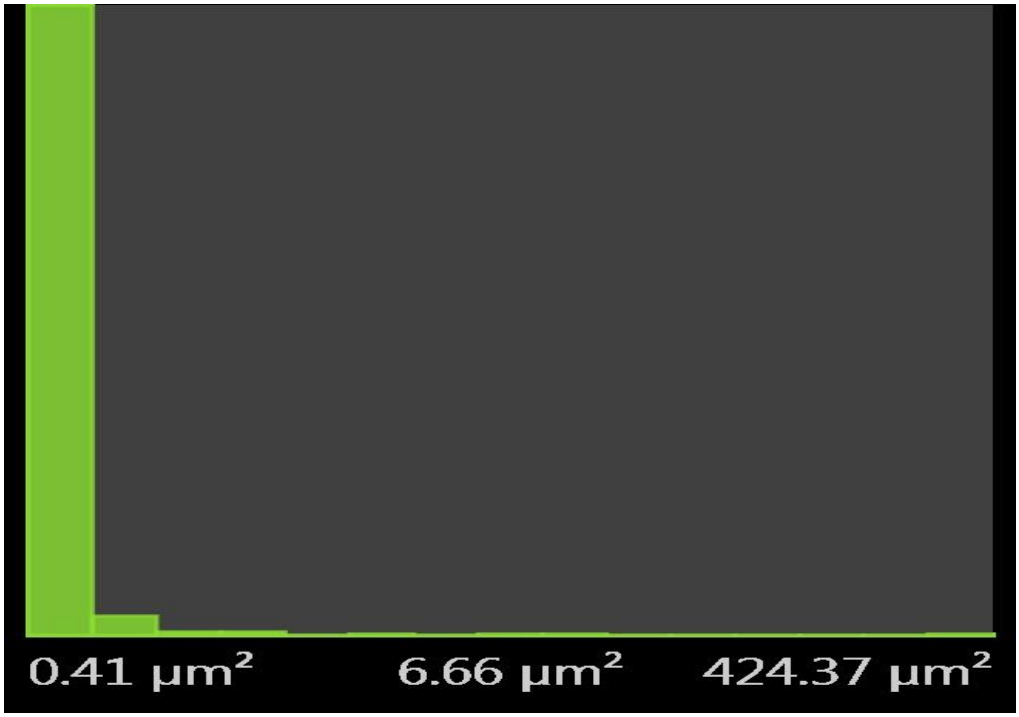


Fig. 4.10: Pore histogram of spraying control (SC) specimen

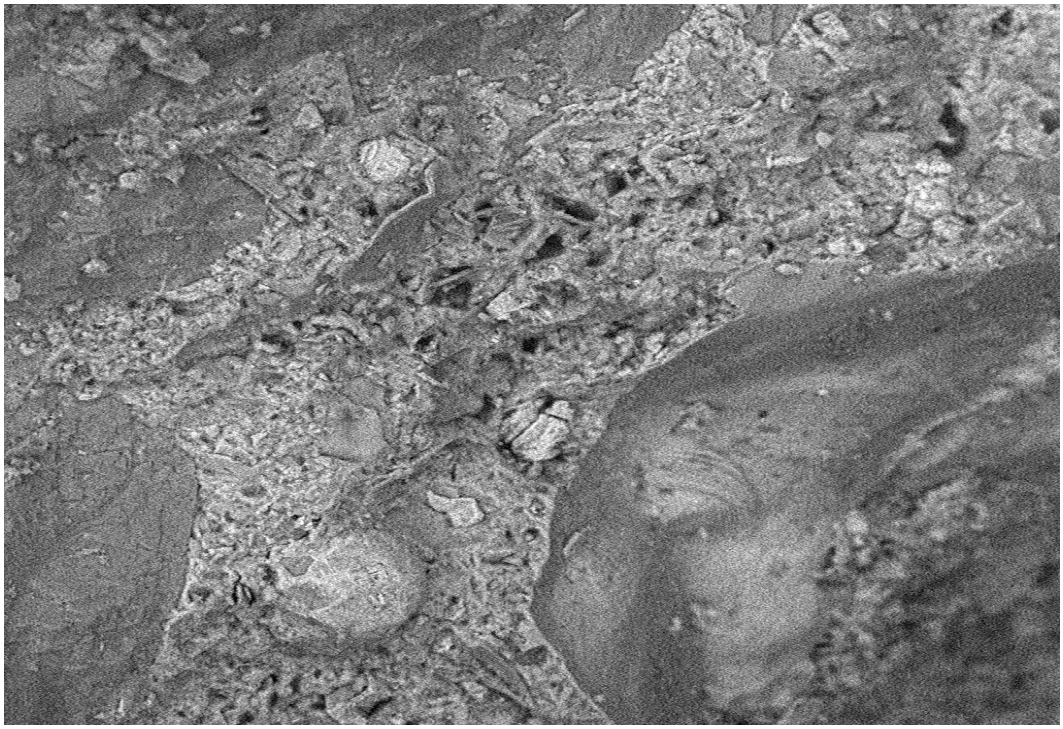


Plate VIII: Fibremetric image of spraying control (SC) specimen

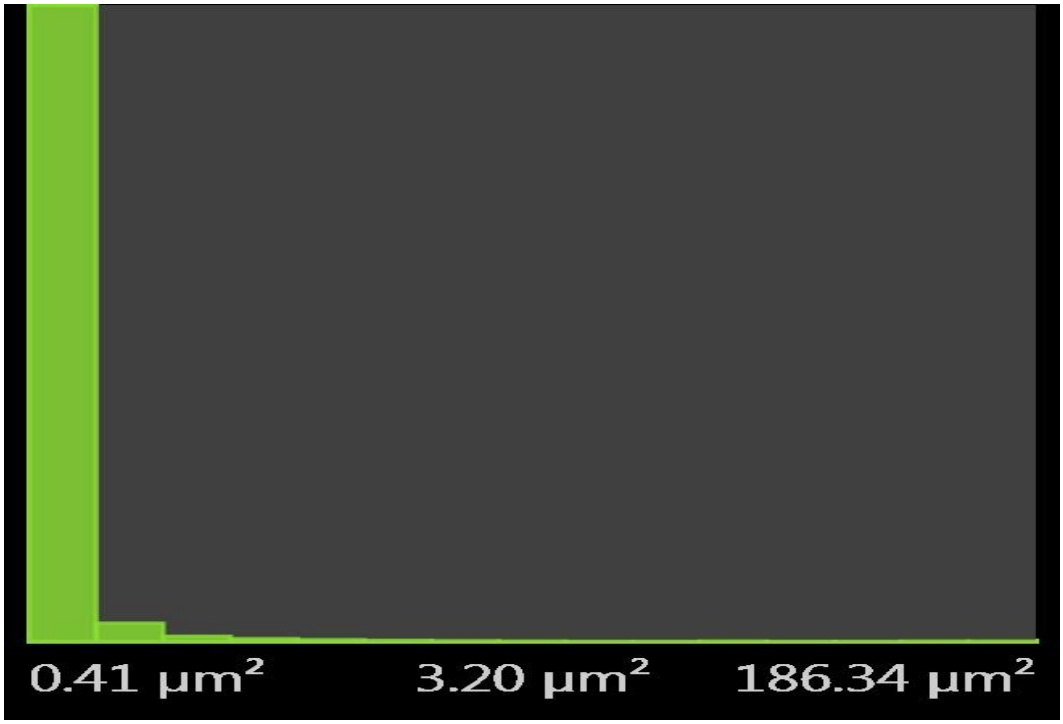


Fig 4.11: Pore histogram of immersion control (IC) specimen

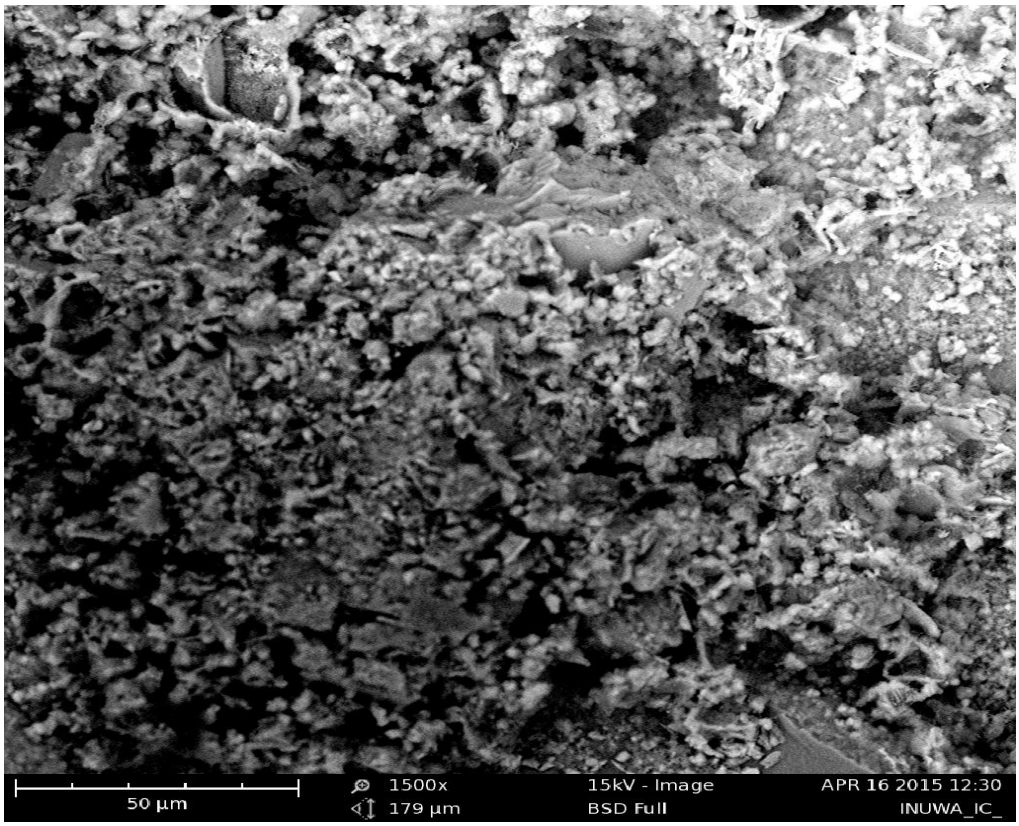


Plate IX: Fibremetric image of Immersion control (IC) specimen

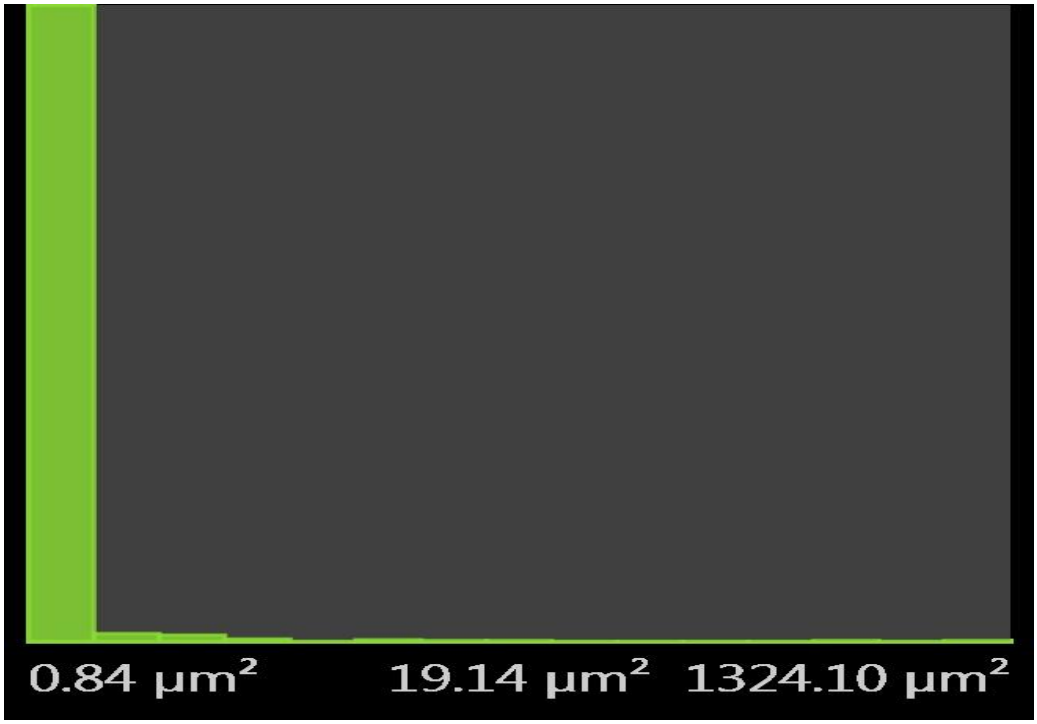


Fig. 4.12: Pore histogram of Polythene control (PC) specimen

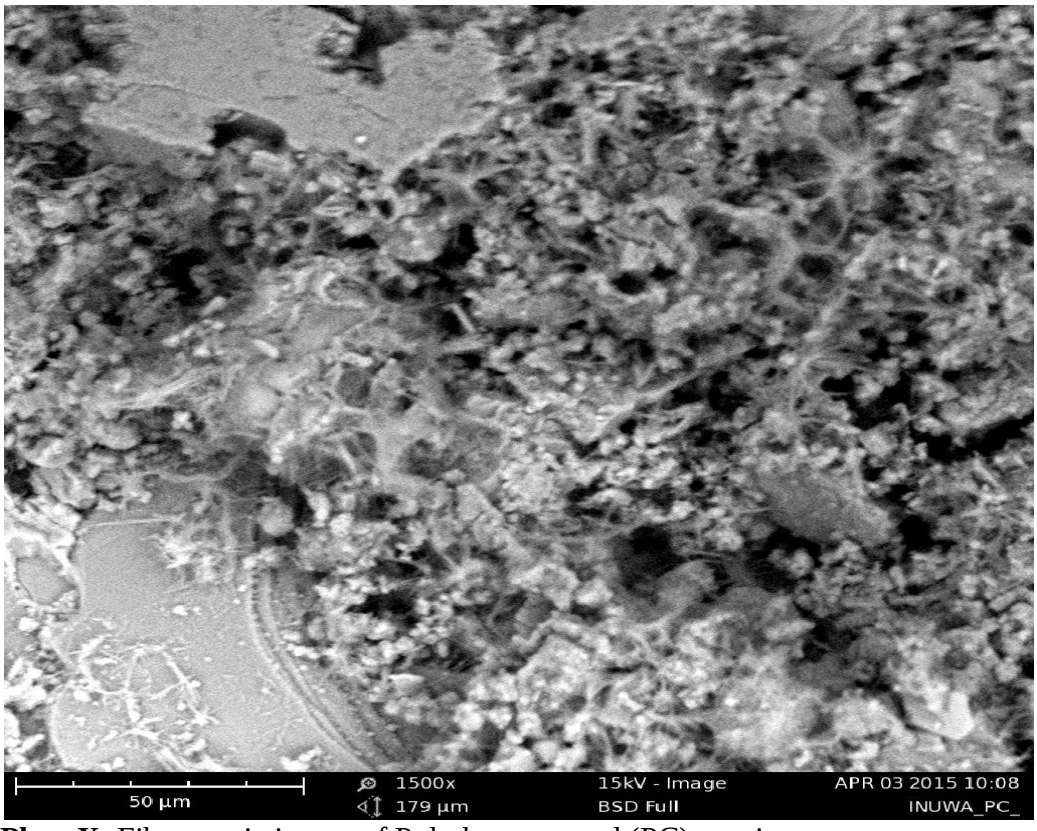


Plate X: Fibremetric image of Polythene control (PC) specimen

Table 4.4 Classification of pore sizes for control specimens.

Curing methods	low (μm²)	average (μm²)	high (μm²)
Spraying (SC)	0.41	6.66	424.37
Immersion (IC)	0.41	3.20	186.34
Polythene (PC)	0.84	19.14	1324.10

The summary of the pore sizes classification above shows that the control specimen subjected to immersion curing method possessed less pores with the lowest, average, and high of 0.41 μm², 6.66μm², and 424.37μm² respectively, compared to those subjected to spraying and polythene curing methods. This can be attributed to the greater degree of cement hydration reaction without any loss moisture from the sample specimens.

Microstructure analysis results on RHA specimens

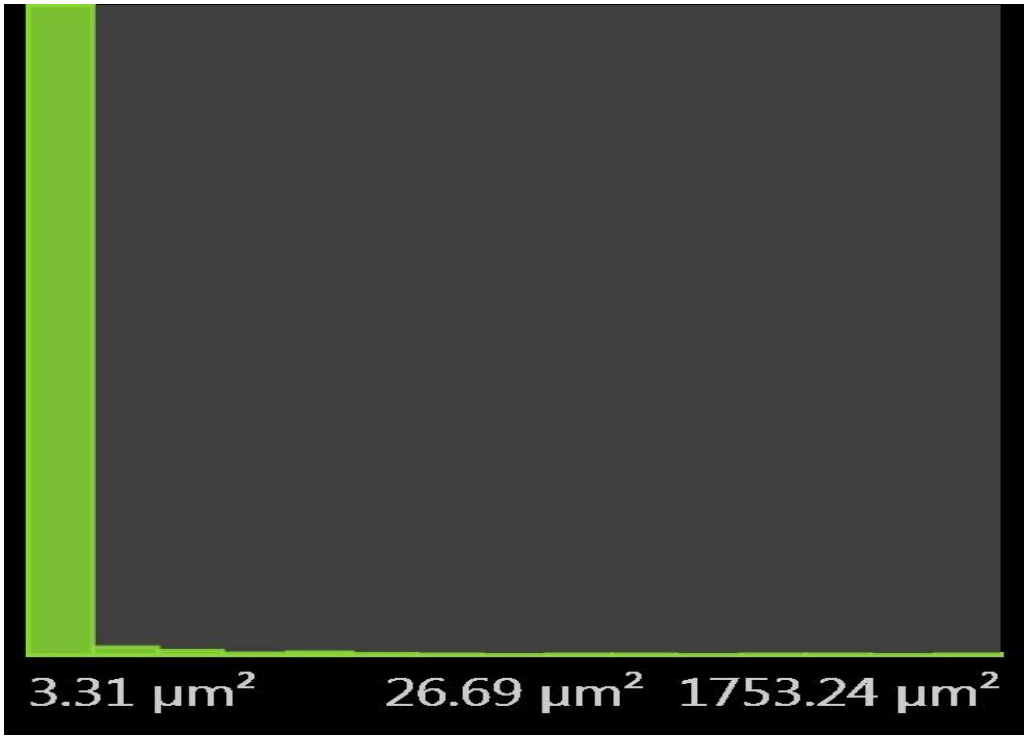


Fig 4.13: Pore Histogram of Spraying RHA (SR) specimen

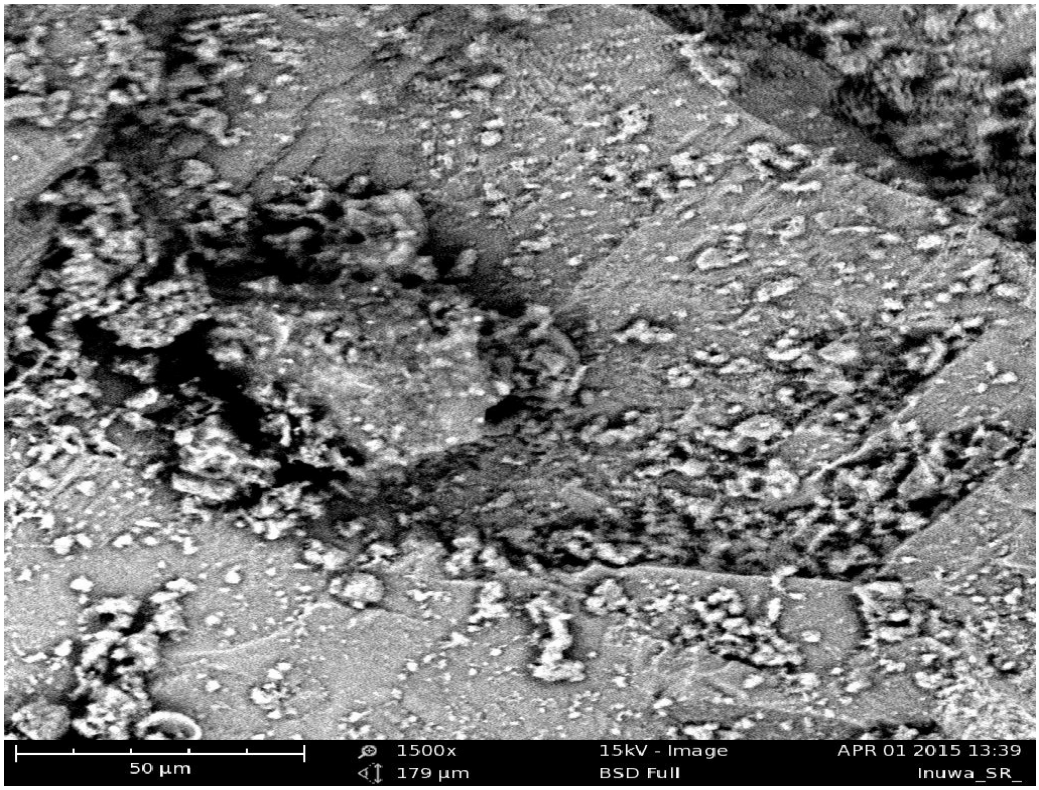


Plate 11: Fibremetric image of Spraying RHA (SR) specimen

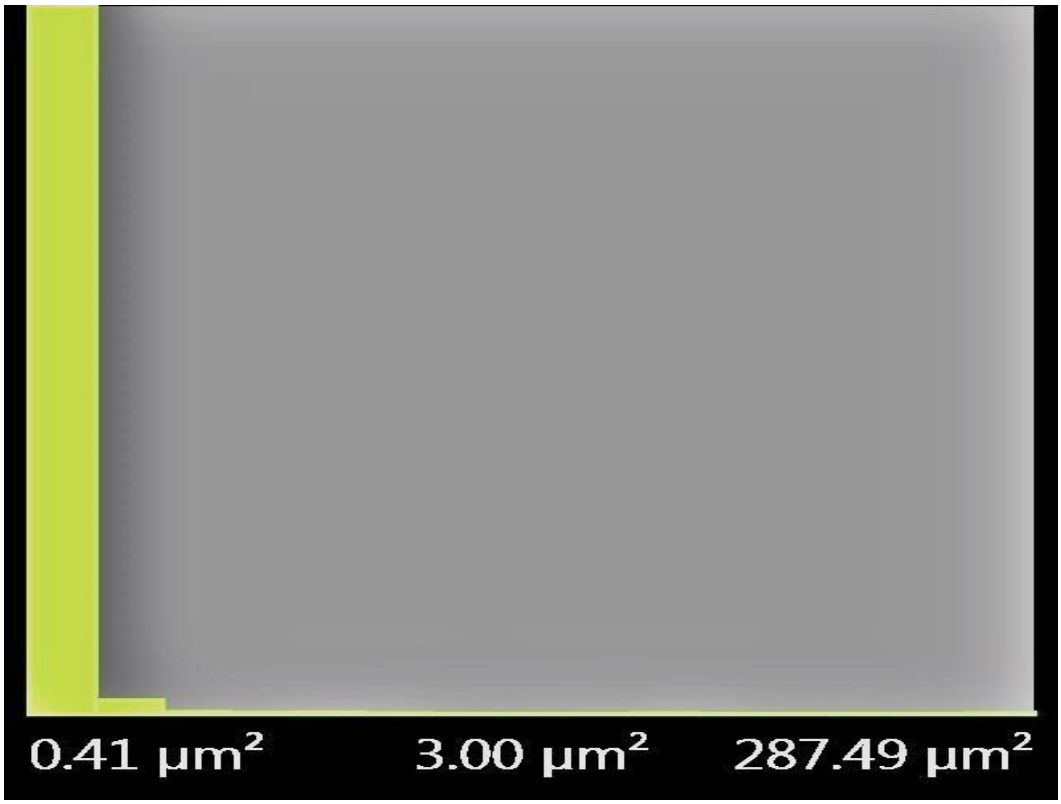


Fig 4.14: Pore histogram of Immersion RHA (IR) specimen

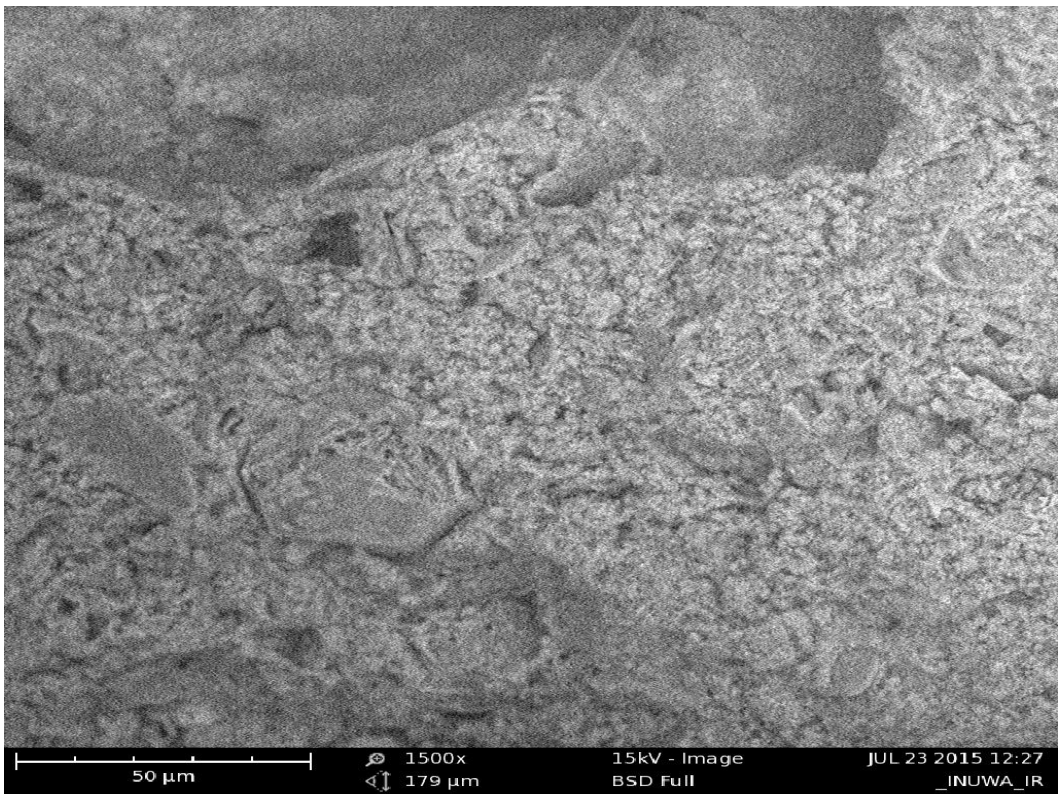


Plate 12: Fibremetric image of Immersion RHA (IR) specimen

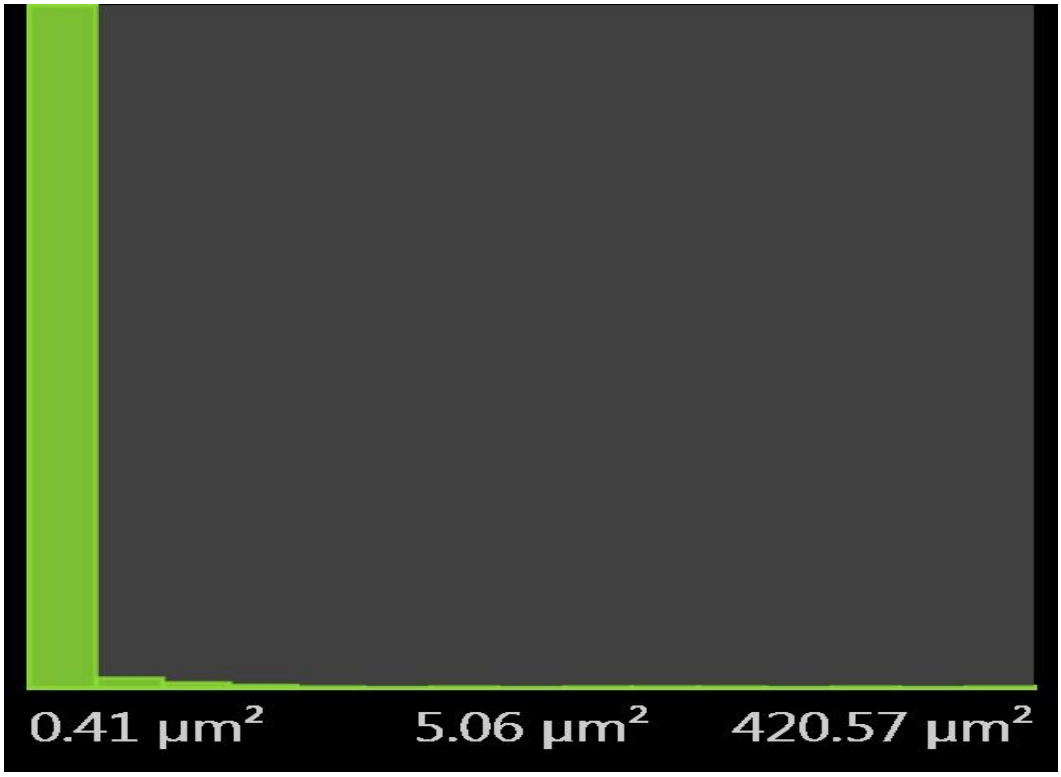


Fig. 4.15: Pore Histogram of Polythene RHA (PR) specimen

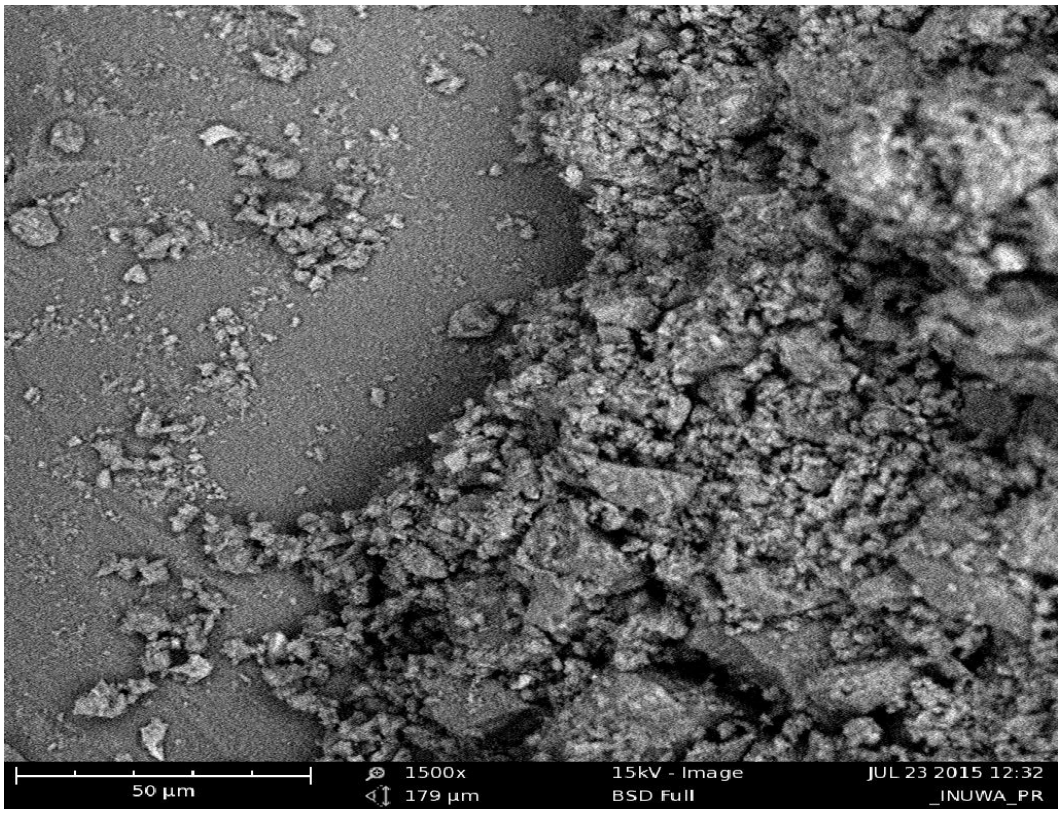


Plate 13: Fibremetric image of Polythene RHA (PR) specimen

Table 4.5 Classifications of pore sizes for RHA sample specimens.

Curing methods	low (µm²)	average (µm²)	high (µm²)
Spraying (SC)	3.31	26.69	1753.24
Immersion (IC)	0.41	3.00	287.49
Polythene (PC)	0.41	5.06	420.57

The summary of the pore sizes classification of RHA specimens showed that specimens subjected to immersion method of curing possessed less pores with the lowest, average, and high of 0.41µm², 3.00 µm², and 287.49 µm² respectively, compared to those under spraying and polythene methods of curing. This was also due to greater degree of cement hydration reaction without any loss from the sample specimens.

Microstructure analysis results on SBA specimens

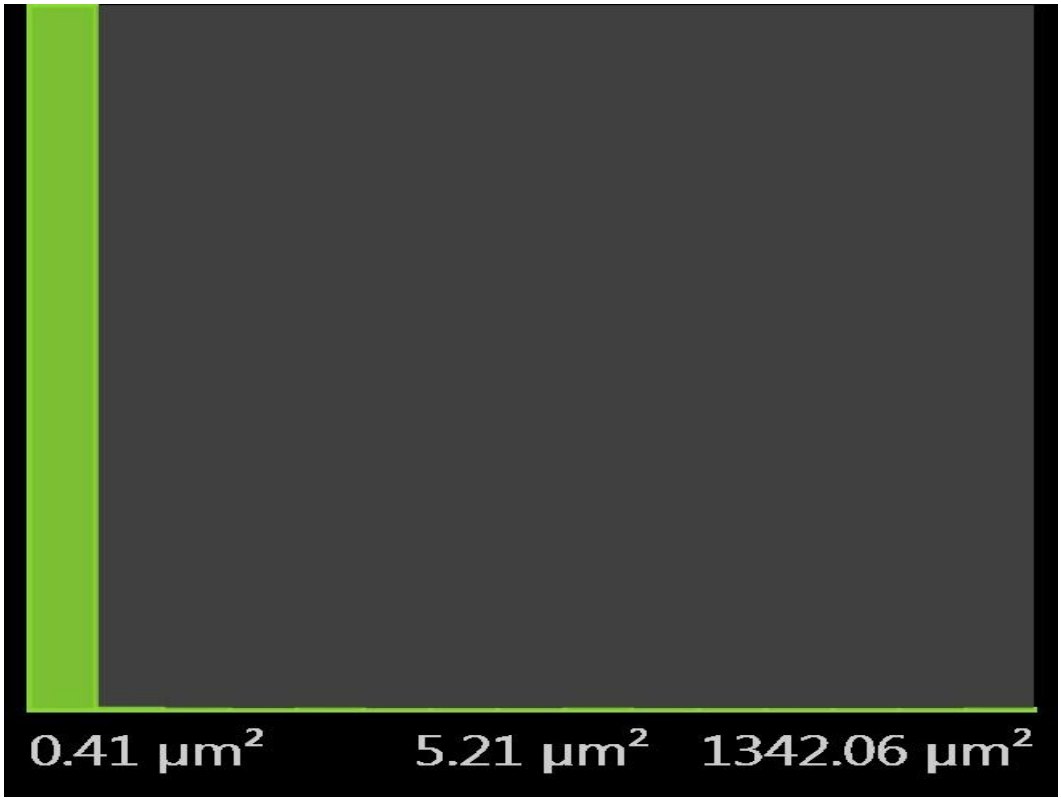


Fig. 4.16: Pore histogram of Spraying SBA (SS) specimen

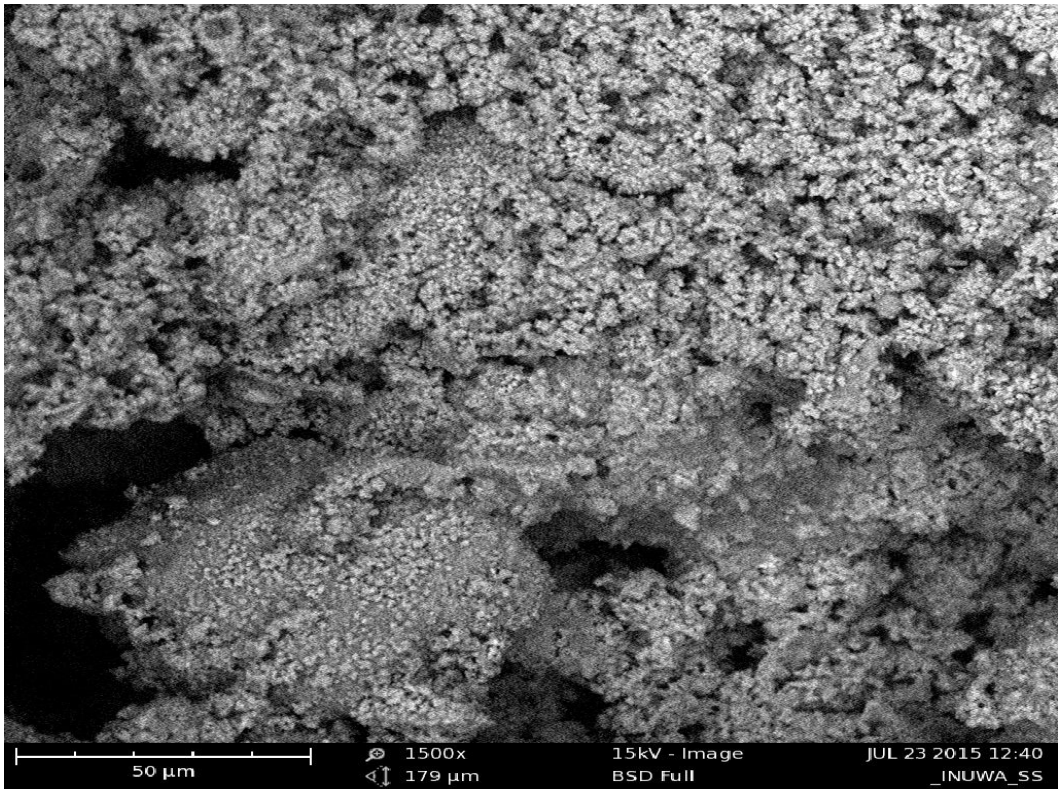


Plate 14: Fibremetric image of Spraying SBA (SS) specimen

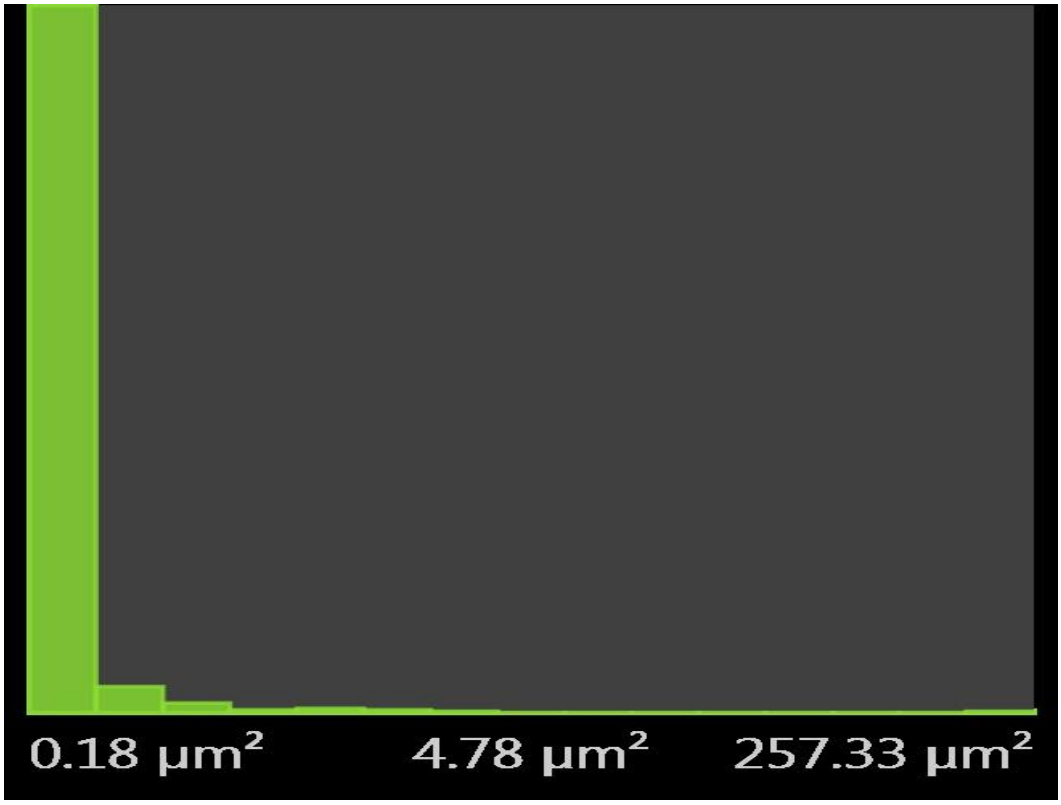


Fig. 4.17: Pore histogram of Immersion SBA (IS) specimen

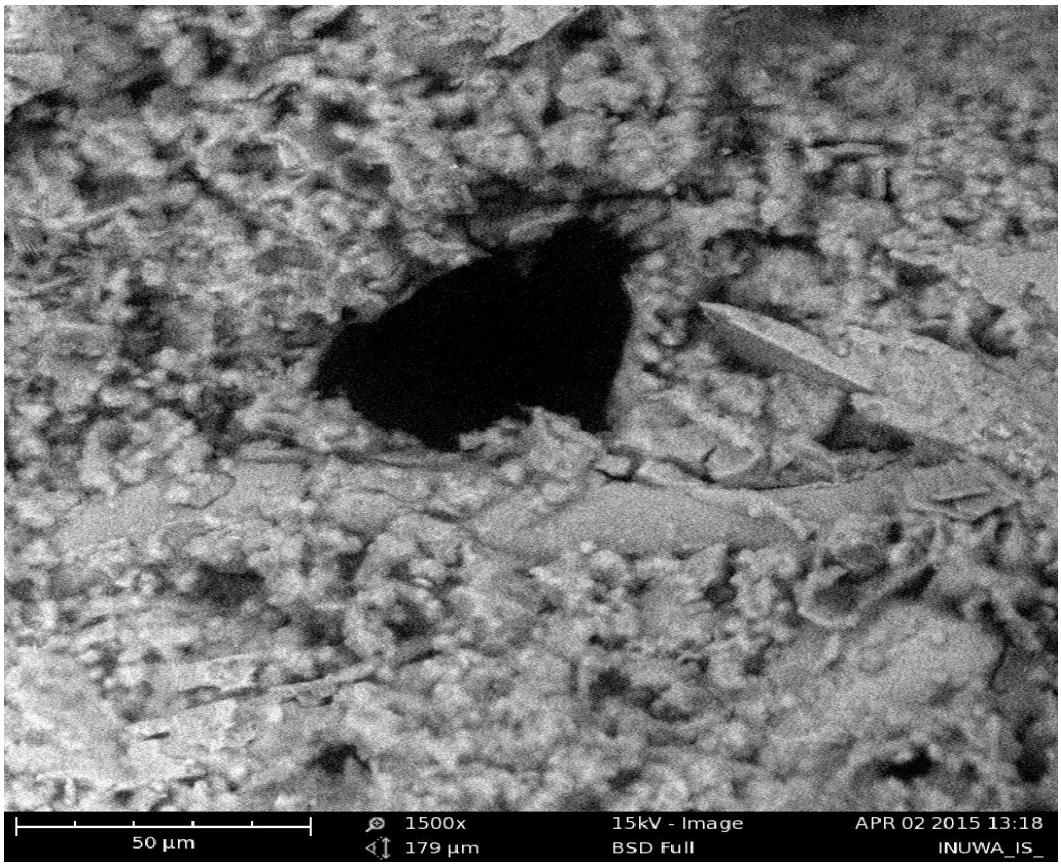


Plate 15: Fibremetric image of Immersion SBA (IS) specimen

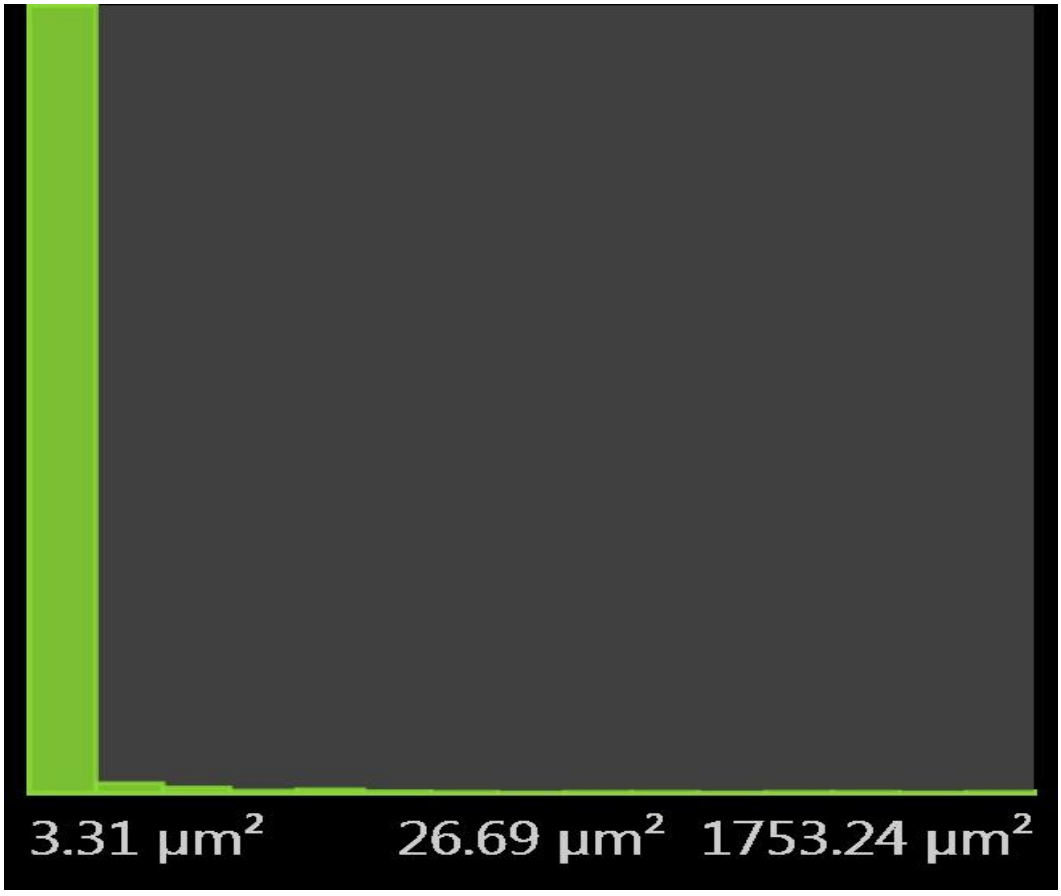


Fig. 4.18: Pore histogram of Polythene SBA (PS) specimen

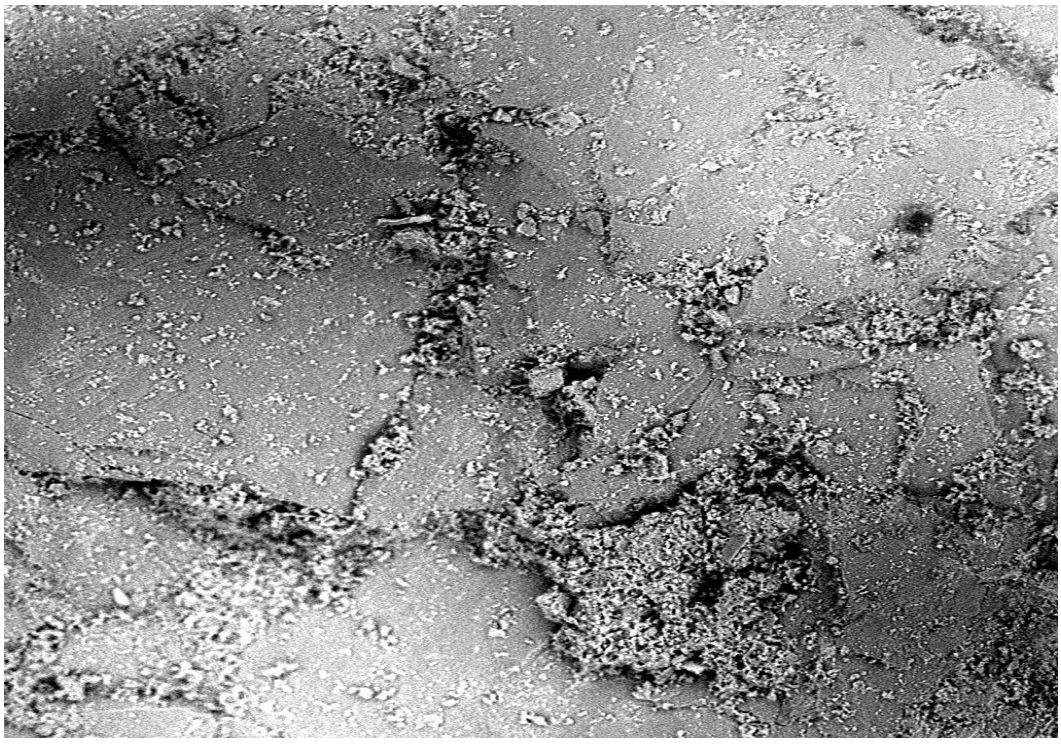


Plate 16: Fibremetric image of Polythene SBA

Table 4.6 Classifications of pore sizes for SBA sample specimens.

Curing methods	low (μm²)	average (μm²)	high (μm²)
Spraying (SC)	0.41	5.21	1342.06
Immersion (IC)	0.18	4.78	257.33
Polythene (PC)	3.31	26.69	1753.24

The summary of the pore sizes classification of SBA specimens showed that specimens subjected to immersion method of curing still possessed less pores with the lowest, average, and high of 0.18μm², 4.78 μm², and 257.33 μm² respectively, compared to those under spraying and polythene methods of curing. This was also due to greater degree of cement hydration reaction without any loss from the sample specimens.

It can be concluded from the above that the microstructure of RHA and SBA sample specimens under immersion curing method is obviously different from those specimens under polythene and spraying curing methods. This was due to the fact that both gel pores and capillary pores volume and pore size decrease with an increase in the hydration due to the formation of increased amount of hydration products. According to Kristic and Erickson (1997), it is well accepted that mechanical and elastic properties of solids are adversely affected by the presence of pores or voids in the materials. This leads to improved microstructure of the concrete samples subjected to immersion method of curing.

Chapter 5:
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings.

i. It was observed that the total content of SiO_2, Al_2O_3 and Fe_2O_3 was 88.55% and 90.50% in RHA and SBA respectively, these met the requirement of 70% minimum recommendation by ASTM C618 (1992).

ii. The specific gravity for RHA and SBA has an average mean of 1.55 and 1.62 respectively.

iii. The RHA samples subjected to immersion method of curing produced concrete with highest strength of 15.4kN/mm^2, 24.6kN/mm^2, 29.6kN/mm^2 and 36.4kN/mm^2 at 7, 14, 28 and 56 days respectively.

iv. The SBA samples subjected to immersion method of curing produced concrete with highest strength of 12.4kN/mm^2, 23.2kN/mm^2, 29.0kN/mm^2 and 30.6kN/mm^2 at 7, 14, 28 and 56 days respectively.

v. The result of abrasion resistance test indicates that the RHA specimens subjected to immersion curing method posses the lowest percentage of weight loss of 0.09, 0.04, and 0.04 at 14, 28, and 56 days respectively.

vi. The result of abrasion resistance test indicates that the SBA specimens subjected to immersion curing method posses the lowest percentage of weight loss of 0.14, 0.10, and 0.04 at 14, 28, and 56 days respectively.

vii. The water absorption test indicate that the RHA specimens subjected to immersion curing method possessed the lowest percentage water absorption of 5.5, 6.3, and 2.7

viii. at 14, 28, and 56 days respectively.

ix. The micro structure analysis results indicate that the RHA specimens subjected to immersion curing method possess less average pores sizes of 3.00 μm^2.

x. The micro structure analysis results indicate that the SBA specimens subjected to immersion curing method also possess less average pores sizes of 4.78 μm^2.

5.2 Conclusions

The following conclusions are drawn from the research work;

1. The RHA with 90.50% and SBA with 88.55% used possess the main requirement of Pozzolana of 70% minimum recommendation by ASTM C618 (1992).
2. Curing by immersion in water proved to be the most suitable curing method for RHA and SBA specimens, because it posses higher strength compare to spraying and polythene methods of curing
3. The micro structure analysis also proved that spraying method of curing may be use where immersion method seems to be difficult.

5.3 Recommendations

Based on the result from the research work, the following recommendations were made;

1. RHA and SBA concrete can be used as partial replacement to cement in the production of concrete.
2. Immersion curing method is recommended in order to achieve good hardened concrete properties.
3. On construction site were immersion curing method may be difficult, spraying method of curing can be adopted instead of polythene method.

5.4 Contribution to knowledge

1. Immersion method of curing is the best curing method for RHA and SBA concretes.
2. It has been confirm that microstructure analysis can be used to determine the strength of concrete in terms of pore diameter.
3. The use of RHA and SBA as replacements of cement reduces the needs for cement for production of concrete.

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Appendix A: Table showing compressive strength test on sample specimens.

Table A-1: Compressive strength test at 7 days

Description	Curing Methods	Mass (Kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Max. load (kN)	Strength kN/mm^2	Average Strength kN/mm^2
Control	Spraying	2.28	2280	2280	122	12.2	12.4
		2.28	2280		112	11.2	
		2.28	2280		136	13.6	
	Immersion	2.38	2380	2407	108	10.8	15.2
		2.45	2450		170	17.0	
		2.39	2390		180	18.0	
	Polythene	2.27	2270	2257	88	8.8	10.4
		2.25	2250		96	9.6	
		2.25	2250		136	13.6	
RHA	Spraying	2.20	2200	2213	122	12.2	14.8
		2.22	2220		176	17.6	
		2.22	2220		146	14.6	
	Immersion	2.36	2360	2347	210	21.0	15.4
		2.32	2320		148	14.8	
		2.36	2360		106	10.6	
	Polythene	2.18	2180	2207	120	12.0	11.4
		2.20	2200		100	10.0	
		2.24	2240		120	12.0	
SBA	Spraying	2.22	2220	2227	80	8.0	7.6
		2.24	2240		86	8.6	
		2.22	2220		60	6.0	
	Immersion	2.24	2240	2260	104	10.4	12.4
		2.26	2260		156	15.6	
		2.28	2280		112	11.2	
	Polythene	2.08	2080	2250	60	6.0	6.8
		2.30	2300		60	6.0	
		2.37	2370		82	8.2	

Source: Laboratory Work (2014)

Table A-2: Compressive strength test at 14 days

Description	Curing Methods	Mass (Kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Max. load (kN)	Strength kN/mm^2	Average Strength kN/mm^2
Control	Spraying	2.13	2130	2276	200	20.0	22.6
		2.42	2420		220	22.0	
		2.28	2280		260	26.0	
	Immersion	2.40	2400	2406	280	28.0	26.0
		2.32	2320		240	24.0	
		2.50	2500		260	26.0	
	Polythene	2.32	2320	2300	210	21.0	21.6
		2.34	2340		240	24.0	
		2.24	2240		200	20.0	
RHA	Spraying	2.30	2300	2326	200	20.0	20.0
		2.40	2400		180	18.0	
		2.28	2280		220	22.0	
	Immersion	2.33	2330	2320	280	28.0	24.6
		2.39	2390		200	20.0	
		2.24	2240		260	26.0	
	Polythene	2.16	2160	2176	240	24.0	20.6
		2.14	2140		180	18.0	
		2.23	2230		200	20.0	
SBA	Spraying	2.09	2090	2156	200	20.0	18.0
		2.14	2140		160	16.0	
		2.18	2180		180	18.0	
	Immersion	2.34	2340	2400	220	22.0	23.2
		2.37	2370		260	26.0	
		2.49	2490		220	22.0	
	Polythene	2.08	2080	2183	100	10.0	12.6
		2.19	2190		160	16.0	
		2.28	2280		120	12.0	

Source: Laboratory Work (2014)

Table A-3: Compressive strength test at 28 days

Description	Curing Methods	Mass (Kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Max. load (kN)	Strength kN/mm^2	Average Strength kN/mm^2
Control	Spraying	2.26	2260	2300	210	21.0	23.2
		2.32	2320		250	25.0	
		2.32	2320		120	12.0	
	Immersion	2.38	2380	2380	320	32.0	30.6
		2.40	2400		280	28.0	
		2.36	2360		320	32.0	
	Polythene	2.26	2260	2273	210	21.0	22.6
		2.24	2240		250	25.0	
		2.32	2320		220	22.0	
RHA	Spraying	2.42	2420	2413	320	32.0	29.2
		2.40	2400		210	21.0	
		2.42	2420		350	35.0	
	Immersion	2.52	2520	2380	208	20.8	29.6
		2.32	2320		320	32.0	
		2.30	2300		360	36.0	
	Polythene	2.32	2320	2340	260	26.0	29.2
		2.36	2360		330	33.0	
		2.34	2340		280	28.0	
SBA	Spraying	2.38	2380	2340	270	27.0	19.0
		2.34	2340		200	20.0	
		2.30	2300		200	20.0	
	Immersion	2.36	2360	2403	280	28.0	29.0
		2.40	2400		330	33.0	
		2.54	2540		260	26.0	
	Polythene	2.28	2280	2326	220	22.0	20.0
		2.36	2360		190	19.0	
		2.34	2340		190	19.0	

Source: Laboratory Work (2014)

Table A-4: Compressive strength test at 56 days

Description	Curing Methods	Mass (Kg)	Density (Kg/m^3)	Average Density (Kg/m^3)	Max. load (kN)	Strength kN/mm^2	Average Strength kN/mm^2
Control	Spraying	2.24	2240	2290	320	32.0	35.4
		2.42	2420		380	38.0	
		2.21	2210		360	36.0	
	Immersion	2.24	2240	2290	360	36.0	36.0
		2.42	2420		400	40.0	
		2.21	2210		340	34.0	
	Polythene	2.41	2410	2283	370	37.0	33.6
		2.26	2260		340	34.0	
		2.18	2180		300	30.0	
RHA	Spraying	2.52	2520	2453	340	34.0	31.6
		2.42	2420		290	29.0	
		2.42	2420		320	32.0	
	Immersion	2.30	2300	2387	380	38.0	36.4
		2.46	2460		370	37.0	
		2.40	2400		340	34.0	
	Polythene	2.15	2150	2237	220	22.0	24.0
		2.28	2280		250	25.0	
		2.28	2280		250	25.0	
SBA	Spraying	2.34	2340	2360	270	27.0	30.0
		2.34	2340		320	32.0	
		2.40	2400		270	27.0	
	Immersion	2.36	2360	2420	300	30.0	30.4
		2.50	2500		310	31.0	
		2.40	2400		296	29.6	
	Polythene	2.32	2320	2287	200	20.0	20.4
		2.32	2320		200	20.0	
		2.22	2220		210	21.0	

Source: Laboratory Work (2014)

Appendix B: Table Showing Abrasion Test.

Table B-1: Abrasion Resistance Test for 0% replacement Concrete (control).

Age of Test	Curing methods	Average Weight (g)	Average New Weight (g)	Weight Loss (g)	% Weight Loss (%)
	Spraying	2138	2134	4.3	0.18
14 Days	Immersion	2236	2233	2.0	0.09
	Polythene	2138	2134	2.6	0.12
	Spraying	2264	2262	1.6	0.07
	Immersion	2199	2198	1.0	0.05
28 Days	Polythene	2138	2153	2.3	0.07
	Spraying	2236	2235	1.0	0.04
	Immersion	2138	2138	0.3	0.02
56 Days	Polythene	2203	2202	1.0	0.05

Source: Laboratory Work (2014)

Table B-2: Abrasion Resistance Test for RHA Concrete.

Age of Test	Curing methods	Average Weight (g)	Average New Weight (g)	Weight Loss (g)	% Weight Loss (%)
	Spraying	2288	2285	3.3	0.14
	Immersion	2306	2304	2.0	0.09
14 Days	Polythene	2318	2246	4.6	0.22
	Spraying	2277	2276	1.3	0.06
	Immersion	2322	2321	1.0	0.04
28 Days	Polythene	2246	2244	2.0	0.09
	Spraying	2282	2280	1.3	0.05
	Immersion	2328	2327	1.0	0.04
56 Days	Polythene	2259	2257	1.6	0.06

Source: Laboratory Work (2014)

Table B-3: Abrasion Resistance Test for SBA Samples.

Age of Test	Curing methods	Average Weight (g)	Average New Weight (g)	Weight Loss (g)	% Weight Loss (%)
14 Days	Spraying	2220	2217	2.7	0.17
	Immersion	2327	2324	3.3	0.14
	Polythene	2319	2313	6.3	0.27
28 Days	Spraying	2289	2283	4.0	0.17
	Immersion	2307	2305	2.3	0.10
	Polythene	2267	2265	4.3	0.19
56 Days	Spraying	2240	2237	2.3	0.11
	Immersion	2244	2243	1.0	0.04
	Polythene	2313	2311	2.3	0.11

Source: Laboratory Work (2014)

Appendix C; Table showing water absorption test.

Table C-1: Water Absorption Tests Results on RHA Specimens

Age of Test	Curing methods	Average Weight (W1)(g)	Average Drying Weight (W2)(g)	W2-W1 (g)	% Average Water (%)
14 Days	Spraying	2169	2313	132	6.1
	Immersion	2170	2298	123	5.5
	Polythene	2216	2365	151	6.7
28 Days	Spraying	2100	2251	154.3	7.2
	Immersion	2076	2209	131.7	6.3
	Polythene	2100	2251	154.3	7.2
56 Days	Spraying	2117	2238	121	5.8
	Immersion	2089	2143	56	2.7
	Polythene	2243	2382	139	6.2

Source: Laboratory Work (2014)

Table C-2: Water Absorption Tests Results of SBA Concrete

Age of Test	Curing methods	Average Weight (W1)(g)	Average Drying Weight (W2)(g)	W2-W1 (g)	% Average Water (%)
	Spraying	2128	2221	93	4.4
	Immersion	2273	2389	116	5.1
14 Days	Polythene	2147	2300	153	7.1
	Spraying	2069	2193	124	6.0
	Immersion	2042	2241	199	9.8
28 Days	Polythene	2076	2229	153	7.4
	Spraying	2105	2249	144	6.8
	Immersion	2120	2246	126	5.9
56 Days	Polythene	2130	2062	68	3.3

Source: Laboratory Work (2014)