EFFECT OF CEREAL FLOURS ON THE PROPERTIES OF CONCRETE

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NOVEMBER, 2018

Declaration

I declare that the work in the dissertation report entitled “EFFECT OFCEREAL FLOURS ON THE PROPERTIES OF CONCRETE” has been done by me in the Department of Building, under the supervision of Professor Mohammed M. Garba. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation report was previously presented for another degree at any university.

Alfa Nasirudeen Musa

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Name of Student	Signature	Date

Certification

This is to certify that this dissertation entitled "EFFECT OF CEREAL FLOURS ON THE PROPERTIES OF CONCRETE" by Alfa Nasirudeen Musa, has been duly supervised, corrected, hereby approved and meets the regulations governing the award of the Masters Degree (MSc) in Construction Technology, Department of Building, Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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Dedication

This research work is dedicated to Almighty Allah, the most Merciful and the most Gracious. Finally to my entire family member.

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Abstract

In hot weather retarding admixture are added to prolong the chemical process of hydration so that concrete remain plastic and workable for longer period of time which will gives room to high volume placements. The goal of the research is to investigate the effect of cereal flours made from maize and sorghum on the properties of concrete; this is with a view to establishing the efficacy of the selected cereals as retarder in concrete. The objectives of this research are to; determine the physical and chemical properties of cereal flour made from sorghum and maize flour, establish appropriate dosages of admixture (cereal flour) required for concrete mixes in terms of compression and tension strength, assess the effects of the cereals flour on the fresh properties of concrete, assess the effects of the cereals flour on the hardened properties of concrete. The mix used for the research was calculated using the BRE method and the water cement ratio of 0.6 was used. The mix ratio of 1:1.13:3.40 was used. Trial test was conducted with maize, sorghum, wheat and millet. The cereal was ground, sieved and added in various percentages by weight to the cement, mix and cast in a cube of 100 by 100 by100mmmould left in the mould for 24 hours then demould and immersed in water for seven days. After seven days it was tested for compressive strength, the sorghum and maizegave the highest and higher values of compressive strength respectively and therefore used for the main work. The same procedure was used for the main workthe samples used were produced in three different batches. The first sets of batches were the control samples which also served as source of comparison. The second and the third batches had various percentages of maize and sorghum flour added respectively. The curing was done by complete immersion for 1, 3, 7, 28 and 56 days for all the samples. The compressive strength and tensile strength increase from 1% to 3% dosage of the cereal flour added by weight of the cement. The compressive strength

and tensile strength increase as the age of curing increases. Sorghum flour had higher values of compression and tension strength than maize flour. The result of the water absorption test of hardened concrete for maize flour showed that at 28 days 4% and 5% dosage of maize flour added by weight of cement conform to water absorption test for hardened concrete. 1% to 3% dosage of the maize flour do not conform to water absorption test for hardened concrete, at 56 days 1% and 2% of maize flour dosage do not conform to water absorption test while 3% to 5% dosage of maize flour conform to water absorption test. For sorghum flour at 28 days 1% and 2% dosage do not conform to water absorption test for hardened concrete, 3% to 5% dosage conform to water absorption for hardened concrete. At 56 days all the specimens conform to water absorption test for hardened concrete. For the results of the abrasion resistance it was observed that the abrasion resistance decreases with increase in curing period. It was also observed that the maize flour has higher abrasion resistance than sorghum flour. The optimum compressive and tensile strength of the test specimen is achieved at 3% dosage of maize and sorghum flour added to the cement. Maize and sorghum flour delay the setting time of cement, for sorghum flour added to cement the setting time is achieved at 410 minutes while for maize is 248 minutes. Maize flour and sorghum flour are good retarding admixtures as they delay the setting time of cement.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Concrete is a very important material widely used in construction of many structures such as buildings, roads, and underground structures. It is a man-made building material that looks like stone. The word concrete is derived from the latin word concretus, meaning “to grow together”. According to Bells (2015) in 1756 British engineer John Smeaton made the first modern concrete (hydraulic cement) by adding pebbles as a coarse aggregate and mixing powdered brick into the cement.

Bells (2015) also emphasized that Concrete is a material used in building construction consisting of a hard chemically inert substance known as aggregate (usually made from different types/sizes of sand and gravel) that is bonded together by cement and water. Also, Lyons (2007) maintained that concrete is a mixture of cement, aggregates and water, with any other admixtures which may be added to modify the placing and curing processes or the ultimate physical properties.

Garba (2014) described concrete as a composite material that consists essentially of a binding medium in which are embedded particles or fragments of aggregates. Concrete is a relatively new construction material when compared to earth, stone, timber and steel. However it is now the most widely used material for building and civil engineering construction. The simplest definition of concrete as suggested by Zongjin (2011) is just a constipation of filler and binder (Concrete = Filler + Binder).

Cement and water constituents of the concrete chemically react to form a binding medium (binder); this binding medium holds the aggregates (filler) together (Portland Cement Association, 2015). According to Zongjin (2011) depending on the kind of binder used, concrete can be named in different ways. For instance, if a concrete is made with non-hydraulic cement, it is called non-hydraulic cement concrete; if a concrete made of hydraulic cement, it is called hydraulic cement concrete; if a concrete is made of asphalt, it is called asphalt concrete; if a concrete is made of polymer, it is called polymer concrete.

Non-hydraulic cement cannot gain strength in water, while hydraulic cement does. (Stulz and Mukerji, 1998) The Assyrians and Babylonians used clay as a bonding substance or cement. The Egyptians used lime and gypsum cement, these are examples of non-hydraulic cement (Duggal, 2008).

Ordinary Portland cement (OPC) is the most used type of cement (Bells, 2015). According to Shetty (2005) prior to 1987, there is only one grade of OPC which was governed by IS 269 – (1989). After 1987, higher grade of cement was introduced in India. The OPC was classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS 4031part 6 – (1988). Garba (2014) opined that Portland cement is the most produced and used cement types in the construction industry. Portland cement is used in the manufacture of precast products, buildings, bridges, hydraulic engineering structures, etc. All Portland cements have the same chemical components although in varying proportions. The variations in proportion of the componentsof Portland cement determine its characteristics and type.

The major part of concrete beside the cement is the aggregate (Neville and Brooks, 2010). Aggregates include sand, crushed stone, gravel, slag, burnt shale and burnt clay. Concrete that included imbedded metal (usually steel) is called reinforced concrete or ferroconcrete (El – Reedy, 2009). According to Bells (2015) reinforced concrete was invented in 1849 by Joseph Monier who received a patent in1867. Joseph Monier was a gardener who made garden pots and tubs of concrete reinforced with an iron mesh. Reinforced concrete combines the tensile or bendable strength of metal and the compression strength of concrete to withstand heavy loads. Joseph Monier exhibited his invention at the Paris exposition of 1867, besides his pots and tubs, he promoted reinforced concrete for use in railway, pipes, floors, arches and bridges.

The properties of concrete depend on the quantities and qualities of its components. (U.S Department of Transportation, FHWA, 2015). Cement durability, strength and relatively low cost make it the backbone of building and infrastructure worldwide. Concrete as the most produced materials on earth will only be more demanded, for example, developing nations become increasingly urban, extreme weather events necessitate more durable building materials and the price of other infrastructure materials continues to rise (Portland Cement Association, 2015). The durability and other properties of concrete are highly variable and sometimes unpredictable.

However, concrete properties can be improved upon in terms of workability, water-cement ratios, setting time, segregation, pumpability, increase strength, early strength development, durability and permeability potentials and compensation of poor aggregate properties (Garba, 2014).

Introduction of admixtures in a concrete helps in improving both fresh and hardened properties of concrete (Zongjin, 2011). When admixtures are applied in a concrete it

gives a workable, well compacted, and more durable concrete which may not be possible without admixture. This is because some admixtures reduce the water content of concrete as well as the void and pores presence to give a better concrete. Strength and other properties of concrete depend on the dosage of admixtures present in the concrete (Rixomand Mailvaganam, 1999).

Admixtures can be organic or inorganic materials added in small quantities to modify the properties of mortar in the fresh/hardened state (BS EN 998 – 1: 2010). Admixtures are substances introduced into batch of concrete, during or immediately before mixing in order to altar or improves the properties of the fresh or hardened concrete or both. According to Neil and Ravindra(1996), numerous benefits are available through the use of admixtures such as: improved quality, acceleration or retardation of setting time, coloring, greater concrete strength, increased flow for the same water - to - cement ratio, enhanced frost and sulfate resistance, improved fire resistance, cracking control, lower density, improved workability and enhanced finished concrete.

According to Okafor (2008), several compounds have been found to exhibit retarding action in concrete and their performance is covered in the British standard BS 5075: Part 1 (1982). Some of these compounds include soluble zinc, salt, borates, sugar and carbohydrate derivatives.

Cereal crops are very rich in carbohydrates, relatively cheap, produced locally in very large quantities and the production of flour from their grains does not require any complicated technology. In 2012, the top 5 cereals in the world ranked on the basis of production tonnage are maize (corn), rice (paddy), wheat, barley and sorghum. These crops are also among the top 50 agricultural commodities in the world with maize ranking second next to sugarcane. Rice (paddy) ranks third, wheat – fourth, barley –

twelfth and sorghum thirteen while millet ranks number forty – two (FAOSat, 2014). According to Chapman and Carter (1976), cereal is generally defined as a grass grown for its small edible seeds. They also explained that all cereals are angiosperms, monocots, and member of the grass family *Gramineae*.

Lantican (2001) defines cereals or grains crops as agronomic crops belonging to the grass family *Graminea* which are utilized staples; the word cereal is derived from the most important grain deity, the Roman Goddess Ceres. Baraja (2015) opted that the seed and grain are not exactly the same despite their interchangeable use. In rice, the grain consists of the brown rice and the enveloping rice hull. The brown rice is the plant's true fruit (a type of fruit called Caryopsis) and consists of a seed and the surrounding fruit wall. The fruit wall (pericarp) consists of several thin layer of tissues which are fused together and inseparable from the seed coat. In *indica* rice, the hull consists of the lemma, palea, sterile lemmas and rachilla. The grain, or kernel of corn (maize) is likewise a Caryopsis.

Okafor (2008), observed that cassava flour considerably improved the workability of the fresh concrete and delayed the setting time of cement by up to 6 hours. Cassava reduced the early strength of concrete but the long term strength will be improved. According to Otoko (2014), a small quantity of cassava powder (0.05% by weight of cement) has the potential of increasing the workability as well as the long term strength of concrete. Also Abalaka (2011) observed that the compressive strength of sugar as admixture is at peak at 0.05% of sugar concentration. He also ascertained that the maximum strength of cassava powder as admixture is at 0.05% of cassava starch concentration. For the purpose of this research the researcher intends to investigate the impact of two cereal flours namely maize and sorghum on the properties of Portland cement concrete.

1.2 Statement of Research Problem

Due to high temperature when concrete is mixed freshly the water demand for adequate workability is high, other problems associated with this high temperature are increase in concrete shrink loss, difficulties in placing concrete as a result of high rate of setting, increased tendency of plastic shrinkage cracking (Khan and Muhammad, 2004). The hot weather also has tendencies of increasing the temperature of fresh concrete resulting in lower ultimate strength and thermal cracking(Otoko, 2014). As a result of the above mentioned problems associated with fresh concrete due to hot weather retarders are introduced in producing concrete in hot climate so that concrete remain plastic during mixing, transporting, placing, compacting and finishing. These conventional retarding admixtures are rare to find thereby making search for alternative materials to be necessary.

The importance of the use of retarder for producing concrete in hot climate cannot be over emphasis as set retarding concrete admixtures delay the chemical reaction that takes place when concrete starts the setting process (Mihai and Rosca, 2008). Retarders as admixture in concrete a lot of initial setting problem could be solved. The main problem associated with conventional retarder is that they are imported and expensive (Alibaba, 2017), thereby affecting the overall cost of producing concrete and these makes their usage low in construction practices in Nigeria.

The production of Conventional retarding admixtures involves industrial processes which emit carbon monoxide to the atmosphere thereby affecting the ecosystem. The research intends to use cereal flour (maize and sorghum) as conventional retarding admixture in concrete.

1.3 Justification of the Study

Cereal crops are widely available in the world and can be afforded by everyone which will not affect the cost of the project. Cereals are carbohydrates which could be good retarders. Retarders have the properties of slowing down the chemical process of hydration so that concrete remains plastic and workable for longer time than concrete without retarder (Shetty, 2005). The slowing down of heat of hydration will leads to reduction in thermal cracks.

Using cereal flour will avail more opportunities for the farmers in terms of increase in income from the sale or yield from their farms, this will also create more job opportunities that will increase the standard of living.

Concrete containing organic admixture is used for good performance and for ecological and economic reasons. The most common organic admixtures are sugar and carbohydrate derivatives (cassava and cereal).

1.4 Aim and Objectives

1.4.1 Aim

The study aims at investigating the effect of cereal flours made from maize and sorghum on the properties of concrete; this is with a view to establishing the efficacy of the selected cereals as retarders in concrete.

1.4.2 Objectives

The objectives of this research are to;

(i) Determine the physical and chemical properties of cereal flours made from sorghum and maize flour.

(ii) Establish appropriate dosages of admixture (cereal flour) required for concrete mixes.

(iii) Assessthe effects of the cereal flour on the fresh properties of concrete.

(iv) Assess the effects of the cereal flour on the hardened properties of concrete.

1.5 Scope and Limitations

1.5.1 Scope

Theresearch assessed the properties of cereal flour and its effects on the setting time of cement and properties of concrete.The major properties of concrete evaluated were compressive strength, tensile strength, water absorption and abrasion resistance. The cereal flours used are maize flours and sorghum flours. Tests such as soundness test, setting time test and slump test was carried out on fresh concrete.Cost analysis of retarders was not carried out in this research.

1.5.2 Limitations

Tests such as flexural strength, creeps and shrinkage were not conducted, due to unavailability of machines and equipment.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Concrete

Concrete is a construction material made by mixing cement paste (Portland cement and water) and aggregate (sand and stone). The cement-paste is the "glue" which binds the particles in the aggregate together (Malhotra, 2000). (Shetty, 2005) stated that the strength of cement-paste depends on the relative proportion of water and cement, a more dilute paste been weaker. They further stated that concrete hardens through chemical reaction between water and cement without the need for air. The relative proportion of cement-paste and aggregates affects the strength, a high proportion of the paste making stronger concrete.

Mehta, (2002) stated that in the United States, the annual production of over 500 million tons of concrete implies about two tons for each man, woman and child. Such volumes require vast amounts of natural resources for aggregate and cement production. Malhotra, (2000) stated that CO_2 is known to be a greenhouse gas that contributes to global warming, and the cement industry alone generates about 7% of it. Strength is gained gradually, depending on the speed of the chemical reaction. It is important to note that high strength and high performance of concrete are not synonymous. Materials are mixed in specific proportions to obtain the required strength. Strength of mix is specified as M5, M10, M15, M20, M25, M30 etc, where M signifies Mix and 5, 10, 15 etc. as their strength in Kn/m^2. In United States, concrete strength is specified in PSI which is Pounds per Square Inch. Strength is gained gradually depending on the speed of chemical reaction. It is important to note that high strength and high performances of concrete are not synonymous. The high strength concrete is based on compression strength measured at a given age.

2.1.1 Concrete Properties

2.1.1.1 Fresh Concrete

Shetty, (2005) defined fresh concrete or plastic concrete as a freshly mixed material which can be moulded in to shape. The relative quantities of cement, aggregates and water mixed together, control the properties of concrete in the wet state as well as in the hardened state. The behaviour of green or fresh concrete from mixing up to compaction depends mainly on the property called "workability of concrete". Workability of concrete is a term which consists of the following four partial properties of concrete namely, Mixability, Transportability, Mould ability and Compactibility. Workability represents the amount of work which is to be done to compact the concrete in a given mould. The desired workability for a particular mix depends upon the type of compaction adopted and the complicated nature of reinforcement used in reinforced concrete. A workable mix should not segregate. Some of the factors which affect workability according to Shetty, (2005) include Water content, Size of aggregates, Surface texture of aggregate, Use of admixtures, Mix proportions, Shape of aggregates and Grading of aggregates. There are five tests widely used for the determination of the fresh concrete workability: Slump test, Compacting factor test, Vee-bee consistometer test and Flow test (Neville *et al.,* 2010)

More specifically, slump test measures the consistency of the concrete in that specific batch. This test is performed to check the consistency of freshly made concrete. Consistency is a term very closely related to workability. It is a term which describes the state of fresh concrete. It refers to the ease with which the concrete flows. It is used to indicate the degree of wetness. Workability of concrete is mainly affected by consistency i.e wetter mixes will be more workable than drier mixes but concrete of the same consistency may vary in workability (ASTM C1170, 2008). It is also to determine

consistency between individual batches. It is divided into true slump, shear slump and collapse slump.

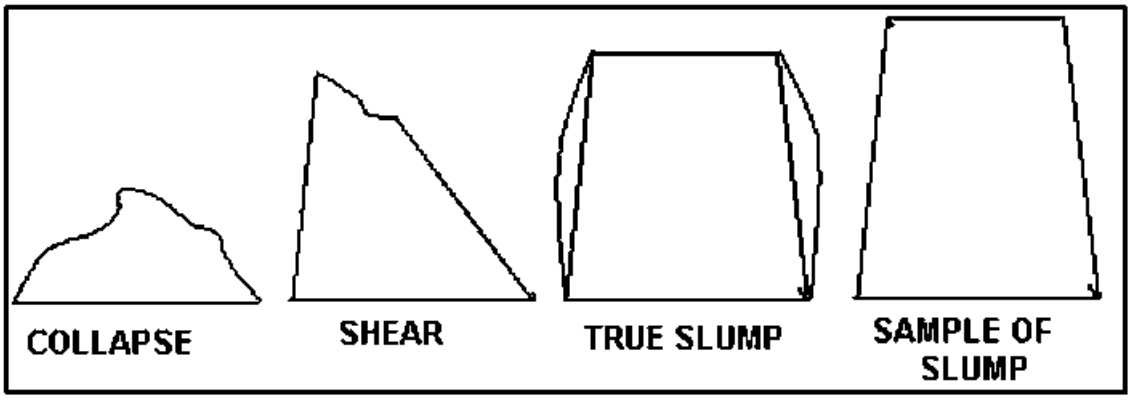


Figure 2.1: Types of Slump (Source: Neville, 1995).

Table 2.1: standard values of workability, slump and compacting factor of concretes with 20mm or 40mm maximum size of aggregate

Degree of workability	Slump (mm)	Compaction Factor
Very low	0 – 25	0.78
Low	25 – 50	0.85
Medium	25 – 100	0.92
High	100 – 175	0.95

Source: (ASTM: C143 and B.S: 1882 part 2).

Setting time test

Shetty, (2005) stated that an arbitrary division has been made for the setting time of cement as initial setting time and final setting time. It is difficult to draw a rigid line between these two arbitrary divisions. Initial setting time is regarded as the time elapsed between the moments that the water is added to the cement, to the time that the paste starts losing its plasticity. The final setting time is the time elapsed between the moment

the water is added to the cement and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure. The time interval for which the cement products remain in a plastic condition is known as initial setting time. A minimum of 30minutes is giving for mixing and handling operation. The constituents and fineness of cement is maintained in such a way that the concrete remains in plastic condition for certain minimum of time. Once the concrete is placed in the final condition, compacted and finished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damage from external destructive agents. The time should not be more than 10 hours which is referred to as the final setting time.

2.1.1.2 Hardened Concrete

It is a poor thermal insulator, but has high thermal capacity. It is not flammable and has good fire resistance, but reduces strength at high temperatures. A concrete made with ordinary Portland cement has low resistance to acids and sulphates but high resistance to alkalis (Shetty, 2005). The compressive strength depends on the proportions of the ingredients, i.e. cement-water ratio and the cement aggregate ratio. Concrete as earlier stated is a widely used construction material for various types of structures due to its structural stability and strength. El – Reedy, (2009) discovered that concrete has relatively high compressive strength, but significantly lower tensile strength, and as such is usually reinforced with materials that are strong in tension (often steel). El – Reedy (2009), further stated that the elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develop. He concluded by saying concrete has a very low coefficient of thermal expansion, and as it matures concrete shrinks. Therefore, all concrete structures will crack to some extent, due to shrinkage and tension. Concrete which is subjected to long-duration forces is prone to creep.

Compressive strength

It can be measured by plotting applied force against deformation in a testing machine. Some material fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures. According to El – Reedy (2009), the compressive strength of concrete is used as the most basic and important material property when reinforced concrete structures are designed. It has become a problem to use this value, however, because the control specimen sizes and shapes may be different from country to country. The ultimate strength of concrete is influenced by the water-cement ratio (w/cm), the design constituents, and the mixing, placement and curing methods employed. They further stated that if all things being equal, concrete with a lower water-cement ratio make a stronger concrete than that with a higher ratio. Shetty (2005) stated that the ultimate compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. It is obtained experimentally by means of compressive test. The apparatus used for this experiment is the same as that used in a tensile test. However, rather than applying a uniaxial tensile load, a uniaxial compressive load is applied. As can be imagined, the specimen (usually cylindrical) is shortened as well as spread laterally.

Tensile strength

Tensile strength is not the same as compressive strength and the values can be quite different. Some materials will break sharply, without plastic deformation, in what is called brittle failure. Others, which are more ductile, including most metals, will experience some plastic deformation and possibly necking before fracture (El – Reedy,2009). The Ultimate Tensile Strength (UTS) is usually found by performing a tensile test and recording the engineering stress versus strain. The highest point of the

stress-strain curve is the UTS. It is an intensive property; therefore its value does not depend on the size of the test specimen. However, it is dependent on other factors, such as the preparation of the specimen, the presence or otherwise of surface defects, and the temperature of the test environment and material (El – Reedy, 2009). Tensile strengths are rarely used in the design of ductile members, but they are important in brittle members. They are listed as common materials such as alloys, composite materials, ceramics, plastics, and wood. Tensile strength is defined as a stress, which is measured as force per unit area. For some non-homogeneous materials (or for assembled components) it can be reported just as a force or as a force per unit width. In the SI system, the unit is the Pascal (Pa) (or a multiple thereof, often mega Pascal (MPa), using the mega- prefix); or, equivalently to Pascal, newton per square meter (N/m^2) (Neil et al., 1996). A customary unit is pounds-force per square inch (lbf/in^2 or psi), or kilo-pounds per square inch (ksi, or sometimes kpsi), which is equal to 1000 psi; kilo-pounds per square inch are commonly used for convenience when measuring tensile strengths (Neil et al., 2009).

Abrasion

Abrasion can be intentionally imposed in a controlled process using an abrasive. Grynko, (2012) stated that abrasion can be an undesirable effect of exposure to normal use or exposure to the elements. The resistance of materials and structures to abrasion can be measured by a variety of test methods. These often use a specified abrasive or other controlled means of abrasion. Under the conditions of the test, the results can be reported or can be compared to items which are subjected to similar tests. Such standardized measurements can produce two quantities: abrasion rate and normalized abrasion rate (also called abrasion resistance index) (Grynko, 2012). The former is the amount of mass lost per 1000 cycles of abrasion. The latter is the ratio of former with

the known abrasion rate for some specific reference material. One type of instrument used to get the quantities abrasion rate and normalized abrasion rate, is the abrasion scrub tester. This instrument is made up of a mechanical arm, liquid pump, and programmable electronics. The machine draws the mechanical arm with attached brush (or sandpaper, sponge, etc.) over the surface of the material that is being tested. The operator sets a pre-programmed number of passes for a repeatable and controlled result. The liquid pump can provide detergent or other liquids to the mechanical arm during testing to simulate washing and other normal uses. The use of proper lubricants can help control abrasion in some instances. Some items can be covered with an abrasion resistant material. Controlling the cause of abrasion is sometimes an option.

Water absorption

ASTM C 140 (2017) Water Absorption test for hardened concrete states that, the test procedure involves drying a specimen to a constant weight, weighing it, immersing it in water for specified amount of time, and weighing it again. The increase in weight as a percentage of the original weight is expressed as its absorption (in percent). The average absorption of the test samples shall not be greater than 5% with no individual unit greater than 7%.

ASTM C1585-13 classifies factors affecting water absorption of a concrete surface as follows:*(a)* concrete mixture proportions; *(b)* the presence of chemical admixtures and supplementary cementitious materials; *(c)* the composition and physical characteristics of the cementitious component and of the aggregates; *(d)* the entrained air content; *(e)* the type and duration of curing; *(f)* the degree of hydration or age; *(g)* the presence of micro cracks; *(h)* the presence of surface treatments such as sealers or form oil; and *(i)* placement method including consolidation and finishing. Water absorption is also strongly affected by the moisture condition of the concrete at the time of testing.

2.1.2 Materials for Concrete

2.1.2.1 Cement

Cement, the major component of concrete was defined by BS EN 197-1(2011) as the inorganic constituent that is mixed with water to produce paste. Cement undergoes process of hydration to attain its hardened state and required durability. The two major constituent of cement are calcium and silicon (Newman and Choo, 2003). Anhydrous silicate and aluminate reacts chemically with water which makes cement paste to harden and gain its strength (Newman et al., 2003). In developing countries, production of cement increase by 4% annually due to increase in construction (World Business Council for Sustainability, 2007).

It very important to note that concrete durability is related to compressive strength. Compressive strength of a concrete depends of the hydration process, higher compressive strength values are obtained when complete process of hydration takes place due chemical reaction of water and cement. The chemical composition cement is as shown in Table 2.2;

Table 2.2: Chemical Composition of Cement

Chemical Name	Chemical Formula	Notation	Percent by Weight
Tricalcium Silicate	$3Cao.Sio_2$	C_3S	50
Dicalcium Silicate	$2Cao.Sio_2$	C_2S	25
Tricalcium Aluminate	$3Cao.Al_2O_3$	C_3A	12
Tetracalcium Aluminoferrite	$4Cao.Al_2O_3.Fe_2O_3$	C_4AF	8
Gypsum	$CaSO_4.H_2O$	CSH_2	3.5

(Source: Portland Cement Association, 2015)

2.1.2.2Aggregates

Gambhir (2004) argued that aggregate gives greater stability in concrete because of their ability to reduce cracking and shrinkage when used in a concrete. It is important to know that aggregate occupies about 75% of the total volume of concrete (Meddah, Zitouni and Belaabes 2010).

Coarse Aggregate

In construction, Less than 5mm sizes of sand and crushed stone are normally referred to as fine aggregate whereas coarse aggregates are formed by mixtures of gravel and crushed stone with sizes between 9.5mm and 37.5mm.

Alexander and Mindess (2005) opined that strength, workability and ability to offer resistance to environmental attack, are few among factors that choice of aggregate can influence and as such they are the most durable constituents of concrete. Therefore, durability of concrete depends on the properties of aggregates used in that concrete.

Fine Aggregate

This concrete constituent is also referred to as fine aggregate, fine aggregate suitable for concrete mixing should be free from clay and any chemical or physical pollution, the role of fine aggregate in concrete is to fill the spaces between coarse aggregates so as to help in providing cohesion to the concrete (Alilou and Teshnelab 2010). Same Authors added that proportion of fine aggregate in a concrete is one of many factors that can influence it strength and durability.

PERFORMANCE OF AGGREGATES IN A CONCRETE

Size, shape, and texture of aggregates are the parameters of aggregate the influence the compressive strength of a concrete (Alexander*et al.*, 2003). Similar suggestion was also made by Neville (1995); he pointed out shape, grade, and size properties of aggregate as factors upon which concrete performance depends. The compressive strength of

concrete is also affected by the content of aggregate present in that particular concrete. Meddah et al (2010) asserted that when the content of coarse aggregate in a concrete is increased the compressive strength expected from that concrete will also increase.

2.1.2.3Water

Water is a very important constituent of concrete, water as a constituent of concrete serves as the inter-particles lubrication between the cements particles. Content, source, and quality of water can influence the compressive strength of a concrete. Therefore, it is believed that water used in concrete must be pure and free from any impurities. Lamond and Pielert (2006) stated that water plays a great role on strength and durability of a concrete. Therefore, water with impurities is not suitable to be used in a mixing of concrete as it will affect its strength and performance.

EFFECT OF WATER IMPURITIES ON CONCRETE DURABILITY

The effect of water impurities on concrete durability cannot be over emphasized; mechanical properties of concrete are affected if water used in mixing of concrete is impure (Lamond and Pielert, 2006). According to The Constructor (2014), quantity and quality of water can influence the strength and durability of concrete. Alilou*et al.,* (2010) opined that the roles of water in concrete mixing are to help in chemical composition of cement so as to facilitate the hydration process and help in producing fluent and workable concrete.

However, the British Standard BS EN 1008 (2002) have made a provision for the type of water suitable to be used for concrete mixing. Therefore, for a concrete to produce its required strength and durability, water used during mixing of such concrete should be free from impurities.

2.2 Admixtures

Admixtures are chemicals or minerals added to concrete mixes either during the mixing phase or at the job site to achieve the desired effects. Admixtures are vital constituents of concrete which improve and enhance the properties and performance of the concrete in its fresh and hardened state. Introduction of a very small quantity of admixture into concrete can alter or transform its properties.

There are several definitions of admixtures given by different researchers, some of which are “additional constituents of concrete other than cement, aggregate or water introduced into concrete mix prior to or in the process of mixing (Kosmartka ,Kerkhoff and Panarese2003)”. Another definition of admixture as offered by ASTM C494/C494M (2017), “Admixture is a material other than water, aggregates, hydraulic cement and fibers that is used as an ingredient of concrete or mortar and is added to the batch immediately before and during mixing”. Shetty, (2005) defined Admixture 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. Admixtures are used to impact or modify the properties of hydraulic Portland cement concrete. They also improve the durability and quality of concrete.

According to Neville,(1995) when admixtures are introduced into concrete, it should not exceed 5% of the mass of cement but the percentage could be greater than when dealing with a concrete meant for special cases.

Admixtures are added in order to reduce the water content in a mixture or to slow the setting rate of the concrete while retaining the flowing properties of a concrete mixture. Admixtures are used to modify the properties of concrete or mortar to make them more suitable to work with by hand or for other purposes such as saving mechanical energy.

According to Rizvi, (2008) the application of admixture offers various benefits to concrete. Such benefits include; reduction of water/cement ratio, improves workability, improves acceleration and retardation of setting time. Aignesberger and Kem, (1981) opined that 20% of content of water can be reduced by the presence of superplaticizers admixture to produce a concrete with better durability.

Rizvi, (2008) further asserted that admixtures can be grouped into chemical and minerals. Mineral admixtures are fly ash and silicate fumes, these agents are added to concrete in order to improve resistance to thermal cracking as well as enhancing workability. On the other hand the primary objective of chemical admixture is for reduction of water/cement contents, air entrainment as well as to control the setting time of concrete. The retarders admixture are also water reducers admixture, they reduce the void in the concrete by reducing the water content of the concrete to produce a high performance concrete with ultimate strength and durability.

2.3History of Admixtures

According to ACI Education Committee 2013, admixtures has been used to improve the properties of concrete since time immemorial, it was reported that Romans used natural materials such as milk, blood, lard and egg in a concrete to improve the performance of concrete. Blood was a very effective air-entraining agent and was used by the Romans to improve concrete durability (Zonglin, 2011). The use of object such as lacquer tung oil and polished glutinous rice paste as admixture was very common in china. However, latex from rubber plants and cactus juice were commonly used in places like Mesoamerica and pery to improve the performance of concrete (Suchorski, 2013).

Admixtures are commonly used in modern construction by Engineers. How they are used depends to a large extend on the structural performances required from the structures, because when used in concrete they produce the performance required from them.

Mineral admixtures such as fly ash, silica fumes and rice husk are referred to as additives, whereas admixture is a term used for materials other than the three basic ingredients in concrete - cement, aggregate and water added to the concrete mix before or during mixing to improve some of its properties in fresh or hardened state (Shetty, 2005).

2.4 Functions of Admixtures

Admixtures are more expensive and rear to find than cement but because of the many benefits of admixtures, they are still extensively used in concrete in spite of the cost (Garba, 2014). The functions of admixtures are:

I. Accelerate the initial setting time of concrete that is, to speed up the rate of development of strength at early ages.
II. Retard the initial set.
III. Increase the strength of concrete.
IV. Improves workability without changing water content.
V. To reduce water content without changing workability.
VI. Reduce heat of evolution.
VII. Increase durability of concrete – resistance to freezing and thawing.
VIII. Control expansion caused by aggregate – alkali reaction.
IX. Decrease capillary flow of water and to make it impermeable.
X. Increase the penetration and pumpability of concrete.
XI. Reduce segregation and/or bleeding in grouts.

XII. Strengthen the bond between old and new concrete surface and that between steel reinforcement and concrete.

XIII. Inhibit corrosion of concrete.

XIV. Increase resistance of chemical attack.

XV. Produce coloured and cellular concrete.

XVI. Produce concrete of fungicidal, germicidal and insecticidal properties.

XVII. Produce non – skid concrete surface.

2.5 Impact of admixtures on concrete

The importance of concrete in modern society cannot be underemphasized. Concrete are used for structures such as buildings, roads, bridges and dams. According to Portland Cement Association (2015), concrete is a mixture of paste and aggregates. The paste consist of Portland cement and water, coats the surface of the fine and coarse aggregate through a chemical reaction called hydration, the paste hardens and gains strength to form a rock-like substance known as concrete. Concrete is plastic and malleable when newly mixed, strong and durable when hardened.

According to Malhotra (2000) concrete is a building material made by mixing cement paste (Portland cement and water) and aggregate (sand and stone). The cement-paste is the glue which binds the particle in the aggregate together. Gambhir (2004) defined concrete as a combination of cementitious materials such as aggregate, water and cement, these constituents reacts chemically and is cured overtimes to form solid mass. Concrete is the most common building materials and is used due to the availability of its constituents. Concrete is formed by a chemical combination of filler and binder, the filler consists of sharp sand and aggregate while the binder is the hydraulic Portland cement.

Cement is the most active component of concrete (US department of transportation FHWA, 2015). ASTM C 150 (2017), defines Portland cement as “hydraulic cement (cement that not only hardens by reacting with water but also form a water resistant product) produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulphate as an inter ground addition. Not all admixtures produce the same result with different cements, therefore before using admixtures its suitability with cement must be established. Some properties of cement like fineness, chemical composition and C_3A content affect the performance of admixtures (The Constructor, 2014). Trail test has to be examined before finalizing on the optimum dosage of admixture.

According to Garba (2014), aggregates are granular filler material such as sand, stone dust, gravel, crushed stone, crushed blast-furnace slag, etc that are used with binder such as Portland cement to produce concrete or mortar. Proportioning and grading of coarse aggregate/silt content also influence the performance of concrete admixture.

All constituents of mix affect the performance of admixture. The amount of water used in a mixture will influence the strength and durability (for a given amount of cement) and will affect the slump or workability (El – Reedy, 2009). According to the Constructor (2014), more water in the concrete mixture improves the physical interaction and dispersion of admixture. Portland cement is the basic ingredient of concrete. Concrete is formed when Portland cement creates a paste with water that binds with sand and aggregates to harden. Cement is manufactured through a closely controlled chemical combination of calcium, silicon, aluminium, iron and other ingredients.

The provision of BS EN 206 1 – 2000 requires that materials of concrete constituents should be free from harmful substances that may affect concrete durability or cause corrosion to the reinforcement.

Concrete is a material that forms the basis of our modern life. It is the most widely used construction material because it is easy to place and mould, low cost, its ingredients are widely available and it has good compressive strength. Concrete is a composite material consisting of aggregates embedded in a hard matrix of cement filling the space between the aggregate particles.

Concrete also possesses some disadvantages such as brittleness and low tensile stress. Garba, (2014). For many years researchers were trying to find ways to decrease these disadvantages and make concrete more effective and improve its characteristics by using admixtures. According to Engineering Toolbox (2015), typical properties of normal strength Portland cement concrete are:

(I) Density: 2240 – 2400 kg/m^3(140 – 150 lb/ft^3)

(II) Compressive strength: 20 – 40 MPa (3000 – 6000 psi)

(III) Flexural strength: 3 – 5 MPa (400 – 700 psi)

(IV) Tensile strength: 2 – 5 MPa (300 – 700 psi)

(V) Modulus elasticity: 14000 – 41000 MPa (2 – 6 x 10^6 psi)

(VI) Permeability: 1 x 10^{-10} cm/sec

(VII) Co-efficient of thermal expansion: $10^{5o}C^{-1}$ (5.5 x $10^{-6o}F^{-1}$)

(VIII) Drying shrinkage: 4 – 8 x 10^{-4}

(IX) Drying shrinkage of reinforced concrete: 2 – 3 x 10^{-4}

(X) Poisson's ratio: 0.20 – 0.21

(XI) Shear strength: 6 – 17 MPa

(XII) Specific heat capacity: 0.75 KJ/kg k (0.18Btu/Lbm^oF (Kcal/Kg^oC))

Addition of admixtures can alter or modify these properties of hydraulic cement concrete. According to Rizvi (2008) using admixture in concrete improves workability, accelerating or retarding setting time, improve resistance to thermal cracking and alkali – aggregate reaction and enables reduction in cement content, makes mix economical, controlling development of concrete strength and enhancing durability.

Engineers 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 operations. Admixtures are used to give special properties to fresh or hardened concrete. Admixture may enhance the durability, workability or strength characteristics of a given concrete mixture. Admixtures are used to overcome difficult construction situations, such as hot or cold weather placement, pumping requirement, early strength requirement, or very low water – cement ratio specification.

2.6 Dosage of Admixture

Concrete is one of the most widely used construction materials in the world and over recent decades technical innovations, especially in the use of admixture have improved not only the quality but also the range of potential application for this versatile construction product. According to Ramachandran (1996), concrete admixtures are natural or manufactured chemical which are added to the concrete before or during mixing. The most used admixtures are air entraining agents, water reducers, water reducing retarders and accelerators.

Successful use of admixtures depends on the use of appropriate method of batching and concreting. Most admixtures are supplied in ready – to – use liquid form and are added to the concrete at the plant or at the jobsites. Certain admixtures such as pigments,

expansive agents, and pumping aids are used only in extremely small amount and are usually batched by hand from premeasured containers.

According to Whitney (2008), the effectiveness of an admixture depends on several factors including: type and amount of cement, water content, mixing time, slump and temperature of the concrete and air. Sometimes, effects similar to those achieved through the addition of admixtures can be achieved by altering the concrete mixture, reducing the water – cement ratio, adding additional cement, using a different type of cement or changing the aggregate and aggregate gradation.

The quantity of admixture should be optimum (The Constructor, 2014). Excess admixture to the concrete may cause segregation or bleeding and excessive retardation. The optimum should be estimated by trails. Admixture will be more effective if molecular weight of the admixture is high.

Dosage of admixture is usually defined based on the cement content (Sika, 2015). Concrete admixtures have significant impact on the fresh and/or hardened concrete properties. Admixture can act chemically and/or physical.

Table 2.3: Dosage of Admixture According to BS EN 206 1 (2000)

Permitted dosage	Less or equal to 5% by weight of the cement (the effect of a higher dosage on the performance and durability of the concrete must be verified).
Low dosage	Admixture quantities < 0.2% of the cement are only allowed if they are dissolved in part of the mixing water

Source: BS EN 206 1 (2000)

If the total quantity of the liquid admixture is >3 l/m^3 of concrete, the water quantity contained in it must be included in the water – cement ratio calculation. If more than one admixture is added, their compatibility must be verified by specific testing.

BS EN206 1 – 2000 limits normal admixture use to 5% by weight of cement but in practice most admixture are used considerably at lower dosages.

Analysis of sales information from the Cement Admixture Association (2012) suggests the type and normal dosage as shown in Table 2.4.

Table 2.4: Type and Dosage of Admixture

Admixture type to EN 934 – 2	Proportion of total admixture sales (%)	Typical dosage range (%) by weight of cement
Super plasticisers	31	0.5 to 2.2
Normal plasticisers	45	0.2 to 0.7
Accelerating	2	0.5 to0.2
Retarding	2	0.2 to 0.8
Air entraining (AEA)	4	0.2 to 0.5
All other concrete admixture	16	Up to 5

Source: Cement Admixture Association (2012)

In certain specialist application such as in very high strength concrete, these dosages may be exceeded. From the table above the vast majority (85%) of all admixtures are of the plasticiser/super plasticiser type and their dosage in most concrete does not exceed 2.2% by weight of cement.

2.6 Effects of over dosage of Admixture on Concrete

Admixtures are used extensively to produce high workable, high strength, high performance and highly durable concrete with minimum cost. Admixtures are used to alter or modify the properties of hydraulic cement concrete. In some cases hydraulic cement concrete may fail to perform its desirable requirement, admixtures are then used to complement hydraulic cement so as to achieve the desired properties or qualities (Shetty, 2005). However when these admixtures are not used judiciously and with the poor knowledge of admixtures among engineers on site and government regulatory bodies in charge of construction supervision results in the following adverse effects on concrete – rapid slum loss, severe segregation/breeding, over retardation and plastic shrinkage.

a. Rapid slum loss: this effect or syndrome is generally observed in mixes rich with higher cement content and it can be reduced by adding booster dosage at different intervals.
b. Severe segregation/breeding: This phenomenon generally occurs in lean mixes with low cement content and depends on dosage of admixture. This can be minimized either by reducing admixture dosage or by increasing content of fine in the concrete.
c. Over retardation: this effect is noticed when the admixture is added beyond the specified dosage and would affect the construction schedule, result in low strength development at early age. However ultimate strength of the concrete remains the same.
d. Plastic shrinkage: this is generally observed in large floor slabs of this section and due to excess evaporation of water from the surface of the concrete at high temperature are continuous breezing. However the plastic shrinkage cracks are detrimental to structure.

2.7 Classification of Admixtures

There are several types of admixtures; ASTM C 494 – 12(2002) classifies concrete admixtures as follows;

1) TYPE A - Water Reducing Admixtures
2) TYPE B - Accelerating Admixtures
3) TYPE C - Retarding Admixtures
4) TYPE D - Water reducing and retarding Admixtures
5) TYPE E - Water reducing and accelerating Admixtures
6) TYPE F - High range water reducing or superplacizing Admixtures
7) TYPE G - High range water reducing and retarding or superplaticizing and retarding Admixtures
8) TYPE S - Specific performance Admixtures

However, IS 9103: 1999, classified admixtures as follows

1) Accelerating admixture
2) Retarding admixture
3) Water reducing admixture
4) Air entraining admixture and
5) Superplaticing admixture

2.9 Type A - Water reducing admixtures

According to the National Ready Mixed Concrete Association (2001), water reducing admixtures are used for two different purposes;

a. To lower the water content in plastic concrete and increase its strength.
b. To obtain higher slump without adding water.

Water reducing concrete admixture and superplasticers are widely used to improve the mechanical and structural properties of fresh and hardened concrete. These admixtures are more frequently used in prestressed concrete, slender component with congested and densely packed reinforcement beams and slabs, precast element and longer slender column (Ahmad, Shah and Ali, 2004). Water reducing admixture can therefore be defined as a material that, either increase workability of freshly mixed concrete without increasing water cement ratio or maintains workability with a reduced amount of water.

According to the ACI Education Committee (2013), the function of water reducing admixture is to reduce the water content of the mix, usually by 5 to 12%. The actual reduction in water depends on dose of admixture, cement content, type of aggregate used, ratio of cement, fine and coarse aggregate. The use of water reducing admixture can achieve different purposes as listed in Table 2.5.

Table 2.5: Benefits Achieved By Using Water Reducing Admixtures

Test series	**Cement content (kg/m^3)**	**Water/cement ratio**	**Slump(mm)**	**Compressive strength (MPa)**	
				7days	28days
A given dosage of a water-reducing admixture is added with the purpose of	300	0.62	50	25	37
Consistency	300	0.62	100	26	38
Strength increase	300	0.56	50	26	46
Cement saving	270	0.62	50	25.5	37.5

Source: Rixom (1978)

2.9.1 Chemical Composition of Water Reducing Admixtures

The chemicals used as plasticizer (water reducing admixtures) are

are follows:

i. Lignosulfonic acids, derivatives and their salts.
ii. Hydroxylated carboxylic acids, their salts and derivatives.
iii. Nepthalenesulphonic acid based
iv. Sulfonated melamine polycondensation products
v. Blends of above
vi. Inorganic material like borates, phosphates, amines and their derivatives,carbohydrates, sugar and certain polymeric Compounds like cellulose, ethers etc.

2.9.2 Advantages of Water Reducing Admixture

i. They increase the workability of the concrete without reducing the compressive strength or without changing water-cement ratio. This is particularly useful when concrete pores are restricted either due to congested reinforcement or due to thin sections.
ii. High strength can be obtained with the same cement content by reducing water cement ratio.
iii. A saving in the quantity of cement (approx. upto 10%) can be achieved keeping the same water/ cement ratio and workability.

2.10Type C - Retarding Admixtures

Retarding admixtures slow down the initial hydration of cement, lengthening set time. According to the European Federation of Concrete Admixture Associations (2005), retarding admixture make up of 1.5% of admixtures sold in Europe. Retarders are beneficially used in hot weather condition in order to overcome accelerating effects of higher temperature and large masses of concrete on concrete setting time (American Concrete Institute, 1999). It functions by coating the surface of C_3S (Tricalcium Silicate) components, thus, delaying the reaction with water. Reaction products are slow to form as such the setting and hardening of concrete are delayed reducing early compressive strength (Rixom*et al*., 1999). According to the European Federation of Concrete Admixture Associations (2005) Retarders can be used in hot weather to prevent early stiffening and;

1. To increase working life, especially when used in conjunction with superplasticisers.
2. To allow the placing of a large pour of concrete over several hours.
3. To place concrete in layers without cold joints.
4. To extend the time between mixing and placing (e.g., for long transport time).
5. Prevent setting of the concrete in the truck in case of delay.

According to the National Ready Mixed Concrete Association (2001), for large jobs, or in hot weather, retarding admixture should be added to concrete to allow more time for placing and finishing. Most retarders also function as water reducers. Retarders should meet the requirements for type B or D in ASTM C 494 – 12 (2002). Retarding admixture are used to offset unwanted effect of high temperature such as acceleration of set and reduction of 28 day compressive strength and to keep concrete workable during the entire placing and consolidation period (ACI Education Committee, 2013).

2.10.1 Types of Retarding Admixture

According to ASTM C494 – 12 (2002), there are three (3) kinds of retarders namely

i. Type C (Retarding Admixtures) this simply retards the hydration of Portland cement

ii. Type D (water reducing and Retarding Admixtures) this does not only retards the hydration but also acts to disperse the cement particle and thereby provides water reduction. According to Dias, Dewapriya, Edirisooriya and Jayathunga (2010) the most commonly used chemical retarder is the type D. The main differences between type C and D are the water – reducing characteristic in type D that gives higher compressive strengths by lowering water – cement ration (Dias et al., 2010).

iii. Type G (High range water reducing and retarding admixture)

2.10.2 Chemical Composition of Retarding Admixture

Retarding Admixtures consists of both organic and inorganic agents. The main ingredients of organic retarders are asfollows:

i. Lignosulphonic acids and their salts. Example sodium (Na), Calcium (Ca) or Ammonium (NH4).

ii. Hydro-carboxylic acids and their salts.

iii. Carbohydrates including sugar.

The main ingredients of inorganic retarder are oxides of

i. Lead and zinc

ii. Phosphates

iii. Magnesium

iv. Fluorates and borates

2.10.3 Advantages of Retarding Admixtures.

i. In large scale construction, retarding admixtures permits greater flexibility in extending the time of set and prevention of cold joint.

ii. Retarding Admixtures improves workability, cohesion and extends setting time, provide protection against delays and stoppages and facilitates keeping workable concrete for extended period.

iii. Facilitates finishing in hot weather, improves pumpability, cohesion and workability of concrete.

iv. Reduces bleeding and segregation where poor sand grading are unavoidable.

v. Reduces adverse environmental effects of various nature on concrete and embedded steel by consideration of reduction in permeability.

2.10.4 Where Retarding Admixture Are Used

Retarding admixture are used in concrete to offset the accelerating effects of high temperature which decrease setting time to avoid compilation when unavoidable delays between mixing and placing occur (United State Department of Transportation (FHWA, 2015). Retarding concrete admixtures are used to delay the chemical reaction that take place when the concrete starts the setting process. Retarding admixture are used in concrete pavement construction, allowing more time for finishing concrete pavements reducing additional costs to place a new concrete batch plant on the job site and helps eliminate cold joints in concrete, retarders can also be used to resist cracking due to form deflection that can occur when horizontal slabs are placed in sections. Most retarder also functions as water reducers and may entrain some air in concrete, (Khan et al.,2004).

According to Mihai et al., (2008), retarder serve best to compensate for unwanted accelerations of working times due to changes in temperature of cement or due to other admixture side effects. They also are used to extend the working time required for complicated or high – volume placements and for retarding the set of concrete at a surface where an exposed aggregate finish is desired. Retarding admixtures are used

i. Where long transportation of ready mixed concrete is required then premature setting can be usefully avoided by this type of admixture.
ii. When concrete is being placed or transported under conditions of high ambient temperature.
iii. In case of large concrete pours.
iv. Concrete construction involving sliding formwork.

Retarders are used in varying proportions, often in combination with other admixtures, so that, as working temperatures increase, higher doses of the admixture may be used to obtain a uniform setting time (Mihai et al.,2008). Simple retarders typically consist of one of four relatively inexpensive materials: lignin, borax, sugars, or tartaric acids or salts (Khan et al., 2004). Retarding admixtures are widely appreciated as these can improve both mixing water efficiency and delay initial set of concrete mixes. This improvement in water is used to provide increased strength, density and workability without rise in cement, while retardation of setting times permits ignorance of cold joint where delay in transporting and placing concrete take place. Retarding admixtures are used on towers, chimneys, high building, tunnels/shaft lining and offshore construction.

2.10.5 Problems Associated With the Use of Retarding Admixtures

The prime function of retarding admixture is to delay the setting of concrete. Over usage of retarding admixture on concrete can result to the following side effect

1. Excessive dosage may excessively delay hardening of concrete

2. A decrease of early strength within the first 24 hours
3. Increase bleedings
4. An increase in slump
5. A slight increase of the plastic shrinkage
6. Creep, drying shrinkage
7. Durability are not significantly affected by the inclusion of retarding admixture.

2.10.6 Possible Cost of Retarder Admixture

The production cost of concrete we use in construction is very high so we use different methodology to bring down the high price for example different types of admixtures are used to enhance the properties of concrete. Retarders are used to enhance the properties of concrete in hot weather (Kumar, 2015). Producers uses admixture to bring special properties to the fresh or hardened concrete; these special properties are related to the reduction of water consumption, increased resistance to compression or extension of the setting time, and others, they also can improve the durability, workability and strength of a concrete mixture and also is used to overcome difficult situations in construction such as casts in hot or cold weather, pumping requirements, early strength requirements or specifications of a water/cement ratio very low.

Retarding admixture are usually not manufactures in Nigeria, not really available and expensive. According to Alibaba (2017) the available retarding concrete admixtures in Nigeria market are:

1. Sodium Gluconate set retarding concrete admixture
2. Retarding concrete admixture
3. Sodium Naphthalene set retarder concrete admixture
4. Lignin Sulfonate water retarder

According to Alibaba (2017) one ton of sodium gluconate retarding concrete admixture cost range from 140,000 naira to 150,500 naira, one metric ton of sodium gluconate retarding concrete admixture cost range from 192,500 naira to 210,000 naira, one ton of retarding concrete admixture cost range from 140,000 naira to 525,000 naira, one ton of sodium Naphthalene set retarder cost range from 150,000 naira to 200,000 naira, and one metric ton of Lignin Sulfonate water retarder calcium cost range from 4,000 naira and above.

2.10.7 Effect of Retarders on Cement Paste

When water is first added to cement there is a rapid initial hydration reaction, after which there is little formation of further hydrates for typically 2–3 hours (Ballieu, 2013) The exact time depends mainly on the cement type and the temperature (Portland Cement Association, 2015). This is called the dormant period when the concrete is plastic and can be placed (Baradan, 1998). At the end of the dormant period, the hydration rate increases and a lot of calcium silicate hydrate and calcium hydroxide is formed relatively quickly (Portland Cement Association, 2015). This corresponds to the setting time of the concrete. Cement paste/concrete set gradually under the standard laboratory condition (temperature 23^0C and relative humidity not less than 90%) ASTM C 191 – 77, (2013). Outside the laboratory concreting is done under harsh or mild weather. In Northern part of Nigeria concreting is usually subjected to hot weather which is defined as any combination of high air temperature low relative humidity wind velocity and intensities of solar radiation (Khan et al., 2004) tending to adversely affect the quality of fresh and hardened concrete.

According to Khan et al., (2004) a retarding admixture causes cement set retardation by one or more offollowing mechanisms:

(1) Adsorption of the retarding compound on the surface of cement particles, forming a protective skin which slows down hydration;

(2) Adsorption of the retarding compound on to nuclei of calcium hydroxide, poisoning their growth, which is essential for continued hydration of cement after the end of induction period;

(3) Formation of complexes with calcium ions in solution, increasing their solubility and discouraging the formation of the nuclei of calcium hydroxide referred to in (2) above; and

(4) Precipitation around cement particles of insoluble derivatives of the retarding compounds formed by reaction with the highly alkaline aqueous solution, forming a protective skin.

According to Ballieu (2013), there are four different mechanisms of actions between retarders and cement. The mechanism depends on the combination of retarders and cement. The effects between cement and retarders are temporary after a predictable period the effects of the mechanism disappear and the hydration continues. Below all four mechanisms are described.

2.10.7.1 Adsorption

On the surface of the cement particles, a retarding admixture is adsorbed. This layer of retarding admixture creates a protective skin (diffusion barrier) around the cement particles. Due to this diffusion barrier the water molecules are hindered to reach the surface of the unhydrated cement particles and the hydration is slowed down. The result is that there is no considerable amount of hydration products to give rigidity to the cement paste so the paste remains plastic for a longer period. The retarding admixture is removed from the solution, among other by reacting with the C_3A from the cement, and is incorporated into the hydrated material.

2.10.7.2 Nucleation

When water is added to the cement, calcium ions and hydroxyl ions are released from the surface of the cement particles. When a critical value of the concentration of those ions is reached, the hydration products C_2S and CS start to crystallize. A retarding admixture, which is incorporated into the cement, is adsorbed by the calcium hydroxide nuclei, which prevents the growth of the calcium hydroxide nuclei until some level of super saturation. So the induction period has been extended because of the increase of the level of calcium hydroxide super saturation before crystallization starts.

2.10.7.3 Complexation

During the first few minutes, some kind of complexes with calcium ions, released by the cement grains, is formed. The formation of those complexes causes an increased solubility of the cement. During the hydration, in the presence of a retarding admixture, an increased concentration of $Ca2^{+}$, OH^{-}, Si, Al and Fe will occur in the aqueous phase of the cement paste. The accumulation of the calcium and hydroxyl ions in the solution prevent the precipitation of those ions to form calcium hydroxide. In that way, hydration is retarded.

2.10.7.4 Precipitation

Precipitation is nearly similar to adsorption but in the case of precipitation some kind of insoluble derivatives of retarder are formed by a reaction with the highly alkaline solution. Because of that, the pH of the solution rises over 12 after the first few minutes of the contact between water and cement. The precipitation of protective coatings of these insoluble derivatives around the cement particles suppresses the cement hydration. The protective coating acts as a diffusion barrier so the water molecules can’t make a good contact with the cement particles.

2.10.8 Effect of Retarding Admixture on Setting of Concrete

Concrete is made by the addition of water to the mixture of cement, sand and granulates, the product of the mixture result to a paste which starts stiffening and hardening (Baradan, 1998). The setting time of concrete is a transformation process that starts with a suspension of particles and ends when these particles are connected in a hardened state. The most important action during the setting of concrete is the hydration of cement (Cement Admixture Association, 2012).

According to Federal Highway Administration (2011), retarding admixtures delay the end of the dormant period and the start of setting and hardening. This is useful when used with plasticizers to give workability retention. Retarders allow later vibration of the concrete to prevent the formation of cold joints between layers of concrete placed with a significant delay between them (Khan et al., 2004).

The mechanism of set retards is based on absorption. The large admixture anions and molecules are absorbed on the surface of cement particles, which hinders further reactions between cement and water i.e. retards setting (Federal Highway Administration, 2011). The commonly known retards areCalciumLigno-sulphonates and Carbohydrates derivatives used in fraction of percent by weight of cement. Normal setting of cement is associated with the hydration of Alite (impure C_3S) and formation of the Calcium Silicate hydrate (CSH) phase (Myrdal, 2007).

A retarding admixture is adsorbed on the surface of cement particles. This layer of retarding admixture around the cement particles acts as a diffusion barrier. Due to this diffusion barrier, it becomes difficult for the water molecules to reach the surface of the unhydrated cement grains and hence the hydration slows down, and the dormant period (period of relatively inactivity) is lengthened. Due to the slow hydration, no considerable amount of the hydration products giving rigidity to the cement paste will be formed and thus the paste remains plastic for a longer time. Later, when the

admixture is removed from solution by reaction with C3A from cement or by some other way it is removed and incorporated into the hydrated material, further hydration is eliminated.Myrdal (2007), examined the setting time of cement influenced by various admixtures and showed those retarders are more effective when used with cements of low alkali and low C_3A. Khan et al., (2004) also show that cement low in C3A and high in C3S were the ones retarded to the greatest degree by either calcium lignosulfonate or salicylic acid.

2.10.9 Effect of Retarding Admixture on Soundness of Concrete

Soundness of cement is the property of hardened cement paste undergoing large change in volume after setting without delayed destructive expansion. This destructive expansion is caused by excessive amounts of free lime or magnesia. This change in volume may cause crack and disintegration of concrete.

2.10.10 Effect of Retarding Admixture on Hardened/Fresh Concrete

Retarding admixtures are used to give special properties to fresh or hardened concrete. The effects of retarding admixture on hardened/ fresh concrete are

2.10.10.1 Strength

According to Ballieu (2013), the initial (24hours) compressive strength of a concrete to which retarding admixtures are added, is lower than the compressive strength of a similar concrete which was not treated with retarding admixtures.This is the result of the slower setting time of the treated concrete. This slower setting time may result in a lower initial strength but it also allows the concrete to form a more ordered, denser cementitious matrix. This often (but not always) results in a higher ultimate strength relative to a similar unretarded mix.

2.10.10.2 Workability and Rheological values

Retarding admixture has little or no effect on the initial workability. However, they generally have a beneficial effect upon workability retention, particularly at elevated temperature. According to Ukessays (2015), retarding water reducing admixture, have a pronounced effect upon workability. They can cause an increase of initial slump by 60 – 100 mm.

2.10.10.3 Slump Loss

Slump loss is the rate of change in slump of concrete. The lower this slump loss, the longer the concrete stays in its fluid state. Retarding admixtures are effective to reduce slump loss particularly at elevated temperature but it is still vital to have high intial workability (Myrdal, 2007).

2.10.10.4 Setting Time

The main function of a retarder is to extend or delay the setting (stiffening) time of concrete, usually in order to prevent the formation of cold joints between deliveries of concrete (Baradan, 1998). Even if workability has fallen to almost zero slump, fresh concrete can be vibrated into, and will bond with, a preceding, older pour (Ukessays, 2015).

In hot weather, any little delay during batching or a short breakdown of the pump can result in the initial concrete pours setting before subsequent pours can be placed and vibrated to form a monolithic joint. In deep pours, if concrete placed early starts to set, the heat generated can cause faster setting of concrete above it and again lead to cold joints. In this situation, retarder dosage can be progressively reduced as the pour proceeds.

2.10.10.5 Bleeding

Bleeding is a form of segregation where some of the water in the concrete tends to rise to the surface of the freshly placed concrete. This can cause a bad quality of the top layer of the concrete mix. According to Ukessays (2015), the total volume of bleed water arising from concrete is often related to its setting time because once setting starts, bleeding stops. Thus retarded concretes are always more prone to bleed. Any reduction in air tends to aggravate this potential problem.

2.10.10.6 Air Entrainment

According to Ballieu (2013), Air entrainment is the phenomenon in which tiny air bubbles are enclosed in the concrete mix. This is caused by the combination of adding air entraining agents and mixing the concrete. The purpose of air entrainment is to increase the durability of the hardened concrete. Retarding admixtures do not normally entrain air, and some types, especially those based on hydroxycarboxylic acid, may actually reduce air content. This may cause these retarded mixes to feel harsher and have more tendency to bleed. Most types of retarder can be used effectively in combination with an air entraining agent.

2.10.10.7 Heat of Hydration

Retarding admixtures do not reduce the heat output of concrete but delay the rise of the peak temperature by a time interval similar to the one by which the concrete was retarded. In small sections this may allow more heat dissipation and so peak temperature may be a little lower. In thick sections there will be no reduction in peak temperature. In fact, there is evidence that the peak temperature may even be increased slightly.

2.11 Type D - Water reducing and retarding admixtures

Water reducing and retarding admixtures are used to improve the fresh and hardened properties of concrete. Water reducing and retarding admixture reduces the quantity of mixing water required to produce concrete of a given consistency and retard the setting of concrete (Merrit and Rickett, 2001). According to the National Precast Concrete Association (2013), these admixtures can significantly reduce the water – cement ratio while decreasing the use of cement in the mix and increasing strength. Water reducing and retarding admixtures not only delay the setting of the cement but also increase initial workability by plasticising the concrete or reduce the water demand. According to the ACI Education Committee (2013), water reducing and retarding admixture act as dispersants for Portland cement particles. By separating and spreading out the cement particles, internal friction is reduced, and slump and workability of the concrete is increased. Water reducing and retarding admixture provide water reduction. The amount of retardation depends upon many factors including: admixture concentration, dosage rate, concrete proportions, and ambient and concrete temperature.

According to the American concrete Institute (1999), water reducing and retarding admixture offer those in the business of precast concrete elements real advantages in improving their production capabilities. Water reducing admixtures are used to produce concrete of higher strength, obtain specified strength with lower cement content and increase the slump of a given mixture without an increase in water content.

The benefits of using water reducing and retarding admixture are;

a. Increased compressive and flexural strength.
b. Improved workability.
c. Reduced segregation.
d. Flexibility in the scheduling of placing and finishing operation.

e. Offset effect of early stiffening during extending delay between mixing and placing.

2.11.1 Chemical composition of water reducing and retarding admixtures

The main ingredients for water reducing and retarding admixture are

i. Lignosulfonic acids and their salts.
ii. Hydroxylated polymers.
iii. Hydroxylated carboxylic acids and their salts.
iv. Sulfonated melamine or naphthalene.
v. Formaldehyde condensates.
vi. Polyether – polycarboxylates.

2.11.2 Advantages of water reducing and retarding admixture

According to Cement Admixture Association (2012) the following are the advantages of using water reducing and retarding admixture:

i. Delay the setting time of concrete.
ii. Prevent the formation of cold joints.
iii. Increase initial workability.
iv. Improve workability retention to the concrete.
v. Increase ultimate strength.
vi. Produce economic in mix designs.

2.12 Type F - High range water reducing or superplacizing.

Type F high range water reducing is a special class of water reducer often called superplasticizers. It is a modern and more effective water reducing admixture. According to ASTM C 494 – 12 (2002), high range water reducing or superplacizing

can be used to impact properties induced by regular water reducers. They can greatly reduce water demand and cement contents and make low water – cement ratio, high strength concrete with normal or enhanced workability. This admixture can reduce water up to 12% to 30%.

High range water reducing is more powerful as dispersing agent. These admixtures are used in the construction of high rise building and long span bridges (Shetty, 2005). According to ACI EducationCommittee 2013, the benefits of using high range water reducing and superplacizing admixture are: it can be used to produce concrete with ultimate compressive strength of up to 70 Mpa (10,000psi), it increased early strength gain, increase slump to produce flowing concrete without adding water, it produce concrete with low permeability (ions like chloride penetration is reduced and produce concrete with low water – cement ratio up to 0.25.

2.12.1 Chemical Composition of High range water reducing or superplacizing

There exist four main categories of superplasticizers based on their chemical composition:

i. Sulfonated melamine formaldehyde condensates.
ii. Sulfonated naphthalene formaldehyde condensates.
iii. Modified lignosulfonates.
iv. Others such as sulfonic acid esters and carbohydrate esters

2.12.2 Advantages of High range water reducing or superplacizing admixtures

i. High range water reducing admixtures are economical as cement content can be reduced to a greater extent keeping the same water/cement ratio.

ii. When used in concrete lead to increase strength, water-cement ratio can be reduced significantly keeping same cement content and workability.

iii. Higher workability at very low water cement ratio like casting concrete with heavy reinforcement.

iv. Reduction in permeability.

v. Where early strength development is required in prestressed concrete or casting of floor, to allow finishing work to commence.

2.13 Type g - high range water reducing and retarding or superplaticizing and retarding.

High range water reducing and retarding admixture (HRWRR) or superplaticizing and retarding admixture, that reduces the quantity of mixing water required to produce concrete of a given consistency by 12% or greater and retards the setting of concrete. According to Merrit*et al.* (2001) High Range Water Reducer (HRWR) and retarding admixtures are used to reduce the amount of water by 12% to 30% while maintaining a certain level of consistency and workability (typically from 75 mm to 200 mm) and to increase workability for reduction in water - cement ratio.

These admixtures are capable of producing large water reduction or great flowability without causing undue set retardation or entrainment of air in cementitious mixtures. High range water reducing and retarding admixture must reduce the water content of a concrete mix by at least 12% and may reduce it by more than 30% from a control mix (Goguen, 2013). According to the Concrete Producer (2013), it also has the properties of interacting with fine grained materials such as cement, fly ash, slag and silicia fumes. The ability to disperse these finely ground particles creates strength that is higher than one would expect from just the decreased water – cement ratio.

High range water reducing and retarding admixture when added to concrete usually of higher grade produce concrete that is flowable or pumpable without bleeding and segregation (Simmons, 2015).

The benefits of using these admixtures are;

i. It produces concrete of high workability.
ii. Higher early and ultimate strength will be gained.
iii. It can be used in concrete work with congested reinforcement.
iv. It increases the durability and impermeability of the concrete.
v. It lowers pumping pressure of the concrete.

According to Simmons (2012), high range water reducing and retarding admixtures are used for the following types of concrete: high flow concrete, concrete with higher water reduction, high strength concrete including slabs, foundations, walls, columns, and piers, piles, prestressed concrete, bridges and cantilever structures.

2.13.1 Composition of High Range Water Reducing and Retarding Admixture

These admixtures composed of the following;

i. Melamine
ii. Naphthalene
iii. Polycarboxylates

2.13.2 Advantages of High Range Water Reducing and Retarding Admixtures

i. Increases ultimate strength of concrete.
ii. Improves workability of the concrete without increased water.
iii. Decreases risk of segregation.
iv. Extends the casting and placing time of concrete.
v. Provides smooth surface finish for concrete in the formwork without segregation.

vi. Prevent cold joints during concrete production with long casting time.

vii. Does not contain chloride or other steel corrosion promoting ingredients, therefore it may be used for reinforced and pre – stressed concrete production.

2.14 Type S - Specific performance admixtures.

Specific performance admixture that provides desired performance characteristics, other than reducing water content or changing the time of setting of concrete or both, without any adverse effects on fresh, hardened, and durability properties of concrete (Ontario Provincial Standard Specification, 2012).

Specific performance are recommended for use in the Production of high performance concrete, Production of liquid impermeable concrete, including crude oil, Fineness and corrosion resistant precast concrete, Abrasion and salt resistant trafficable concrete, Non-shrinking concrete for flat works, Waterproofing concrete structure.

The benefits of special performance admixtures are;

a. Provides flexibility in placing and finishing operations.
b. Offsets the effects of slump loss.
c. Reduces waste associated with wet loads of concrete.
d. Increased strength – compressive and flexural.
e. Reduced early-age shrinkage.
f. Improved resistance to de-icing chemicals.
g. Improved durability

2.14.1 Advantage of Specific Performance Admixture

i. Increased productivitythrough higher throughput.

ii. Concrete moves easier and fasterthrough machinery.

iii. Improved paste creaminessand enhanced finish ability.

iv. Concrete consolidates with reduced vibration.

v. Provides superior water toleranceto the concrete making it less susceptible to normal manufacturing moisture fluctuations.

vi. Facilitates the use of angular aggregates and/or manufactured sandsin concrete.

vii. Produces finishes with a noticeable reduction in surface defects.

viii. Concrete requires less cementto close surfaces, resulting in lower material costs.

2.15 Factors Affecting the Performance of Admixtures

According to the Jayasree and John (2011), the following are factors that affect the performance of admixtures in concrete;

i. Type and dosage of admixture.

ii. Nature of cement and aggregates.

iii. Water – cement ratio.

iv. Environment condition.

v.Addition procedure of admixture.

2.16 Cereal flour

Cereals are generally of the gramineous family. FAO (1994) refers to cereal as crop harvested for dry grain only. According to Henson (2007), cereal crops or grain crops are important food source in many parts of the world. Cereal crops or grain crops are all grass plants that contain an edible seed or kernel called caryopsis (Harold, 2015). The word cereal is derived from Ceres, the Roman god of agriculture. Cereals are a vital part of farming and agricultural industries in many countries.

According to Henson (2007), cereal crops belong to the Poaceae grass family. These plants are often planted for commercial purposes. When the grass is fully grown, it can be harvested by hand or using agricultural machinery. The kernel found on a poaceae

grass plant is high in nutritional content, and can either be eaten whole or ground into derivatives products, including flour.

2.17 Cereal flour as Retarding Admixtures

Cereal flours are carbohydrate derivatives; they are good source of retarding admixture. ASTM C494 – 12 (2002), defined retarding admixture as admixture that are used to slow down the speed of the reaction between cement and water by affecting the growth of the hydration products and/or reducing the rate of water penetration to the cement particles.

According to the European Federation of Concrete Admixture Association (2005), Retarding admixture are used for the following purpose

i. In hot weather to prevent early stiffening;
ii. To increase working life, that is increase workability;
iii. To allow the placing of a large pour of concrete over several hours;
iv To place concrete in layers without cold joints;
v. To extend the time between mixing and placing (e.g., for long transport time);
vi. Prevent setting of the concrete in the truck in case of delay.

Soluble carbohydrate derivative admixtures like sugar, water soluble carbohydrate such as soluble starch (cassava and cereal flours) and dextrins are effective retarding admixtures. Very small dosage of the order of 0.05 to 0.1 percent of mass of cement is enough. 0.05 percent sugar can delay initial setting time by about four hours (Gambhir, 2004)

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Materials

The materials used in the research include cement, sand, crushed granite, water, cereal flour (maize and sorghum).

3.1.1 Cement

The cement used for this research work was ordinary Portland cement OPC, grade 42conforming to BS 12:1996manufactured by Dangote Cement Company obtained from Samaru Zaria.

3.1.2 Coarse Aggregate

The coarse aggregates used were crushed granite with maximum nominal size of 20mm and was then sieved by using sieves conforming to BS 812 – 103.1:1985

3.1.3 Fine Aggregate

The fine aggregate used in this research work was sieved conforming to BS 812 - 103.1:1985. The fine aggregate used was sourced from a river in Zaria and having nominal maximum size of 5mm.

3.1.4 Water

Clean tap water deemed for drinking was used for the production and curing of concrete samples for this research. The water conforms to BS EN 1008.2:2002.

3.1.5 Cereal Flours

The cereal was obtained from Seed Production unit of InstituteforAgricultural Research (IAR), AhamduBello University, Zaria. The maize used is Sammaz 15 and the sorghum used is Samsara 17. The cereals were grinded in the milling centre ofthe same Institute.

The milling machine was thoroughly washed, allowed to dry and used to ground the cereal seeds to powdered texture. The cereal flour was taken to the laboratory of Department of Building, Ahamdu Bello University Zaria and sieved in accordance with BS sieve number 85 to remove any chaff present in the flour.

Proximate Analysis of cereal flour

The samples of the sieved cereal flours weretaken to Faculty of Agriculture, Department of Animal Sciences (Biochemical Laboratory Unit),Ahamdu Bello University, Zaria to determine the starch content, PH value, solubility and cyanide content.

3.2 Production of concrete

3.2.1 Trail mix

A trail mix was designed using BRE method from which the quantities of the various constituents of concrete was derived using concrete mix of 1:1.13: 3.40 and water cement ratio of 0.6.

The various constituents of the concrete mix were batched as obtained from the design, the batching was done by weight using an electronic scale, after which the portion of the cereal flour was thoroughly mixed with the cement and added to the aggregates mixed dry until an homogenous mixture was achieved.Water was then added and the mixing continued for few minutes after which the concrete was placed in a 100 x 100 x 100 mm mould in three layers, each layer was compacted 25 times with a tamping rod to exclude all voids in the concrete, the cast concrete was allowed to set for 24 hours after which it was demoulded and put in a curing tank; the curing method used was complete immersion.

This process was repeated for concrete mixes containing four different cereal flours namely maize, sorghum, millet and wheat and percentages of cereal flours added to the cement were 1% to 5% respectively. After 7 days of curing the cast samples were removed from the curing tank and sun dried for 2 hours and then tested for compressive and tensile strengths by placing them in crushing machine and the crushing load of each specimen was recorded. These tests were carried out in accordance to BS 1881-201:1986.

After the tests were carried out and the results compared with the control mix (that is mix without any cereal flour). It was observed that the samples containing maize and sorghum had the higher and highest values of compression and tensile strengths respectively; hence they were used to conduct this research.

3.2.2 Final mix

For this research work a total of 495 number of 100 x 100 x 100 mm cube samples and 275 number of 100 mm x 200 mm cylinders samples were produced, to carried out the various tests to evaluate the effect of cereal flour on the properties of cement Concrete; 275 cubes were crushed to determine the compressive strength, 110 cubes were used for the abrasive strength tests, 110 cubes were used to conduct the water absorption test and 275 cylinder samples were used to determine the tensile strength test.

The proportioning of the mix was carried out by batching the various quantities of the constituents as derived from the concrete mix design using the BRE method. The mixing was carried out as in the trail mix, but each cast sample was cured for different period of 1, 3, 7, 28 and 56 days. For the control mix (that is no cereal flour added) and the specimen with maize and sorghum in the various percentages of 1% to 5% respectively. The mould were clamped together to prevent leakage of cement paste and

it was ensured that every batch of mix was placed in mould to produce cube and cylinder samples with regular surfaces. The samples were demoulded after 24 hours and then transferred into the curing tank for curing until the desired age for testing (1, 3, 7, 28 and 56 days) was attained.

The properties of the hardened concrete samples tested were compressive strength, tensile strength at 1, 3, 7, 28 and 56 days then abrasive strength and water absorption test were carried out at 28 and 56 days.

Table 3.1: Typical representation of the combination scheme of cereal flour added to concrete

Designation	**Cement**	**Fine aggregate**	**Coarse aggregate**	**Cereal flour**	**Remarks**
M_0	1	1.13	3.40	0%	Control
M_1	1	1.13	3.40	1%	1% of cereal flour added
M_2	1	1.13	3.40	2%	2% of cereal flour added
M_3	1	1.13	3.40	3%	3% of cereal flour added
M_4	1	1.13	3.40	4%	4% of cereal flour added
M5	1	1.13	3.40	5%	5% of cereal flour added

Table 3.2: Typical tests to be carried out on the concrete cubes with their quantities

Types of Test	Type of Specimen	Sample Concrete Specimen					Control Specimen				
		1	**3**	**7**	**28**	**56**	**1**	**3**	**7**	**28**	**56**
Compressive Strength	Cube	5	5	5	5	5	5	5	5	5	5
Abrasion	Cube	-	-	-	5	5	-	-	-	5	5
Resistance											
Tensile Strength	Cylinder	5	5	5	5	5	5	5	5	5	5
Water absorption	Cube	-	-	-	5	5	-	-	-	5	5

3.3Tests on Fresh Concrete

3.3.1 Slump test

In accordance to BS 188-102.1 (1983)Slump test was carried out on each mix with each mix having water cement ratio of 0.6 for consistency. The dimensions of the slump cone are 300mm in height, base diameter of 200mm and a top diameter of 100mm. It was lubricated with engine oil in order to prevent bond between the concrete and slump cone. The test was carried out and placed on a metal plate board which was held firmly at the handle. The mould was filled in three layers of thesame depth with hand scoop. Each of these layers was tempered twenty five times with a tamping rod of diameter 16mm and 600mm long. After compaction, the top of the mould was levelled and the mould was gently removed by lifting it up vertically, after which it was placed beside the fresh concrete with a straight edge placed on top of the mould and passed over the fresh concrete. The slump was then measured using a measuring tape to determine the

difference between the top of the mould and displaced original center of the top surface of the concrete as shown in Plate I



Plate 1: Slump Test

3.3.2 Setting time

Setting time testwas done in accordance with BS EN 196-3:2005.The initial and final setting times were carried out using Vicat apparatus, plunge, needle and le-chartelier apparatus, eleven difference mixes; 0% of cereal flour, 1% of maize flour, 2% of maize flour, 3% of maize flour, 4% of maize flour, 5% of maize flour, 1% of sorghum flour, 2% of sorghum flour, 3% of sorghum flour, 4% of sorghum flour, and 5% of sorghum flour were by weight by of the cement.

Procedure to determine initial and final setting time of the cement

I. Prepare the cement paste by carefully mixing 400g of cement and reasonable amount of water, starting with water content of 30% by mass of dry cement to give a paste of standard consistency.

II. Start a stop-watch, the moment the desired water – cement ratio is achieved.

III. Fill the vicat mould completely with the cement paste gauge as above, the mould resting on a non-porous plate and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.

A. Initial setting time

Place the test block under the rod bearing the needle. Lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the test block. Repeat the procedure till the needle fails to pierce the test block to a point 5.0 + 0r – 0.5mm measured from the bottom of the mould. The time period elapsing between the time, water is added to the cement and the time the needle fails to pierce the test block by 5.0 + or – 0.5mm measured from the bottom of the mould, is the initial setting time.

B. Final setting time

Replace the above needle by the one with an annular attachment. Allow this to come gently into contact with the surface of the cement paste each 15 minutes. Final setting is achieved when the needle makes an impression on surface but annular cutting edge fails to do so.

3.3.3 Soundness Test

Materials

I. Cement .

II. Cereal flour.

III. Water

Apparatus:

I. Le- chatelier's apparatus.

II. Weighing balance.

III. Measuring cylinder.

IV. Trowel.

V. Mixing pans.

VI. Heater.

VII. Thermometer.

Procedure

Le-chatelier's mould was placed on a small glass plate and filled with each of the cement paste of standard consistency. The paste were levelled up and covered with another glass plate and the whole assembly immersed in water at room temperature of about 28°c for 24 hours.The gap between the indicators of the mould was measured and the whole assembly was immersed in boiling water of temperature $100^{o}C$ and 4.74g weight for one hour thirty minutes after which the moulds were removed from the boiling water and allowedto cool for hours. The vertical gap in space between the indicators of the mould and the sample were re-measured after cooling and the values earlier recorded were subtracted from the current values. Le-chatelier's apparatus is the standard apparatus prescribed as per IS:5514 -1969 to check the presence of the

impurities in cement. Test was performed as per IS: 4031 (part - 1) - 1988, cement is said to be sound when the expansion is below 10 mm.

3.4 Physical properties test on materials

The physical property tests on materials include: particle size distribution, bulk density, water absorption capacity and Specific gravity.

3.4.1 Specific Gravity Test

The specific gravity test was conducted at the Laboratory of Department of Building Ahamdu Bello University, Zaria.

Materials Used

I. Fine Aggregate.

II. Coarse Aggregate.

III. Portland cement.

Apparatus

I. Three(3) numbered specific gravity tubes measuring 25ml, designated as A, B, and C.

II. Weighing balance.

Procedure

The empty specific gravity tubes were weighed on the scale and the results tabulated, the tubes were then filled with water up to the 25ml mark and weighed again. A small quantity of the materials were placed in each of the tubes and weighed, water was added to the materials and filled up to the 25ml mark and weighed. The results were compared with that of cement and are as follows;

Data

W_1= weight of empty bottle, W_2 = weight of water in the bottle, W_3= weight of bottle + materials, W_4= weight of bottle + materials + water, A= bottle 1, B= bottle 2, C= bottle 3

The specific gravity is given by Gs= $\frac{WS}{VS\beta w}$

Where:

Wsis the weight of the solid, Vs is the volume of solid and βw is the bulk density of water.

3.4.2 Bulk Density test

The bulk density was determined by using a cube at the Laboratory Department of Building Ahamdu Bello University, Zaria.

Materials

I. Cereal Flour.

II. Portland Cement.

III. Fine Aggregate.

IV. Coarse Aggregate.

Apparatus

I. Hand scoop.

II. Measuring scale.

III. Cube.

IV.Tamping rod.

Procedure

The bulk density of the materials was determined based on saturated surface dry. The dimension of the cube 100 x 100 x 100 mm was clean. The cube has a detach sole plate and the top was open then filled with materials in three equal layers with each layer tamped 25 times with the tamping rod for compaction. The top of the container was then levelled and the materials empty into a container and was then weighed. The experiment was repeated three times and the average was then taken.

3.4.3 Particle size distribution

Materials

I. Fine aggregates.

II. Coarse aggregates.

Apparatus

I. The BS sieves.

II. Weighing balance.

Procedure

100g of fine aggregate was weighed and the aggregate was passed through the BS sieves of 5mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm and pan. The weight of the aggregates retained on each sieve were taken and the percentage passing each sieve was calculated.

The same procedure was repeated for coarse aggregate of 200g passing through the BS sieves of 20mm, 10mm, 5mm and pan.

This is the distribution of various particle sizes in an aggregate sample. It is usually done to determine the grading to be used for the concrete. The particle size distribution

for fine aggregate was determined by sieve analysis which complies with the requirements in BS 812-103.1 (1985).

3.4.4 Water Absorption Capacity of Aggregates

Materials

I. Coarse aggregates.

II. Fine aggregates.

III. Water.

Apparatus

I. Weighing balance.

II. BS sieves.

Procedure

The aggregates were sieved using the BS sieves and 500g of dry aggregates were weighed using a weighing balance known as W1, 500g of saturated aggregates in water for 24 hours was surface dried in accordance to BS 812 part 2 – 1995 after drying, the weight of the material obtained was taken as W2.

The absorption capacity of the aggregates was computed using;

Absorption capacity $=\frac{w2-w1}{w1}$ X 100

Where: W1 = dry weight and W2 = Saturated weight

3.5Test on hardened concrete

3.5.1Compressive strength test on hardened concrete

The compressive strength test of the concrete cubes was done in accordance to BS 1881: part 116 (1983). The concrete cubes were surfaced dried after removal from water and weighed before subjected to the crushing machine. Each sample was placed between the plates of the machine and pressure was exerted until the point of failure. The failure load measured in Kilo Newton was expressed as follows:

Compressive strength = $\frac{P}{A}$

Where:

P = failure load (KN)

A = cross sectional area (mm2)

Plate II presents the pictorial of compressive strength test on hardened concrete



Plate II: Compressive Strength Test

3.5.2Split Tensile strength test on hardened concrete

Split tensile strength was done in accordance to BS 1881: part 116 (1983). The concrete cylinders were surfaced dried after removal from water and weighed before it was

subjected to the crushing machine. The cylinder was placed horizontally on the crushing machine. Each sample was placed between the plates of the machine with a flat wood at the top and bottom of the cylinder and pressure was exerted until the point of failure. The failure is measured in Kilo Newton. It is expressed below as follows:

The failure is measured in Kilo Newton.

Cylinder = $\frac{2xP}{\pi LD}$

Where; P = failure load (KN)

π = 3.142

L= Height of cylinder (mm).

d = diameter of cylinder (mm)

Plate III presents the pictorial of the split tensile strength test on hardened concrete



Plate III: Split Tensile Strength

3.6 Durability tests of concrete

3.6.1 Water absorption test on hardened concrete

The water absorption test was carried out after 28 and 56 days of curing and in accordance to ASTM 140.The concrete cubes were surfaced dried after curing before they were oven dried for 24 hours at temperature of 105^0C. After the samples were removed from the oven, they were cooled and weighed before they were immersed in water for 24 hours and weighed again after removing them from the water.

Increases in mass as a percentage of initial mass is expressed as its absorption and can be mathematically expressed as:

Water absorption $=\frac{New\ weig\,ht - Air\ dry\ weig\,ht}{Air\ dry\ weig\,ht}$ X 100

Where;

Air dry weight = weight of concrete cubes after oven dried

3.6.2Abrasion resistance test on hardened concrete

After 28 and 56 days of curing abrasion resistance test was conducted. The concrete samples were removed from the curing tank and allowed to surface dry. The method used was abrasion coefficient through subjecting the concrete cube samples to mechanical erosion by brushing for 60 circles in backward and forward motion for about 60 seconds with a 3.5 kg mass attached to the brush.

Percentage weight loss = $\frac{Weig\,ht\ before\ \ abrasion\ - weig\,ht\ after\ \ abrasion}{weig\,ht\ before\ \ abrasion}$ X 100

CHAPTER FOUR

4.0 DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Test Results

The results presented in this chapter are obtained from the tests carried out on the materials and concrete samples used for this research. Proximate analysis test and physical properties for the materials used in the experiment as well as the test results for both the fresh and hardened concretes are presented in tables 4.1 to 4.16

4.2Proximate Analysis test of Cereals Flours

4.2.1 Proximate analysis of cereal flour

Table 4.1 presents results of the proximate analysis test of cereal flour used for the research, Maize (Sammaz 15) and sorghum (Samsara 17). It was observed that the maize has higher starch content, PH and solubility than the sorghum. The starch content of the maize was 85.62%, PH was 7.94%, and solubility was 4.78% while the starch content of sorghum was 83.57%, PH was 7.31% and solubility was 4.19%. The cyanide content of sorghum was higher than maize, the cyanide content of sorghum was 2.22% and maize was 0.8%. The maize flour is more alkaline than the sorghum flour this means that the maize flour may have lower compressive strength of the test sample (Sharma and Sood, 2015). From Table 4.1, the P value shows that there is significant

difference between the starch content, PH, solubility, cyanide content of maize flour and sorghum flour.

Table 4.1 Proximate Analysis of maize and sorghum flour

Parameters	**Maize** **Mean ± S.E**	**Sorghum** **Mean ± S.E**	**P Value**
STARCH (%)	85.62 ± 0.00	83.57 ± 0.00	0.00
PH(%)	7.94 ± 0.00	7.31 ± 0.00	0.00
SOLUBILITY(%)	4.78 ± 0.00	4.19 ± 0.00	0.00
CYANIDE(%)	0.80 ± 0.00	2.22 ± 0.00	0.00

Source: Laboratory Research work (2016)

4.3 Physical Properties of Materials

4.3.1 Specific gravity of aggregates and Portland cement

Table 4.2 gives the specific gravity of the materials used for the research. The specific gravity of Portland cement is 2.97 as against 3.1 given in the BS 4550 – 3.4: 1978. The specific gravity of fine aggregate and coarse aggregate is 2.62 and 2.73 respectively as against 2.65 and 2.16 of the BS 812 – 2: 1995.

Table 4.2 specific gravity of materials used

Materials	Specific gravity (Mean)
Portland cement	2.97
Fine Aggregate	2.62
Coarse Aggregate 2.73	

Source: Laboratory Research work (2016)

4.3.2 Bulk density of materials used

Table 4.3 gives the bulk density of the materials. The bulk density of maize is 865 kg/m^3 and sorghum is 819kg/m^3. It was observed during the sieving that the sorghum is lighter than maize in weight. The bulk density of Portland cement is 1770kg/m^3. The bulk density of the fine aggregate and coarse aggregate is 1568kg/m^3 and 1498kg/m^3 respectively. These were used in batching of the concrete mix. According to the specification by Garba (2014), when dry normal aggregates has bulk density of not less than 1200 kg/m^3, the fine aggregate and coarse aggregate are suitable for the production of normal weight concrete.

Table 4.3 Bulk density of materials used

Materials	(Bulk Density Kg/m^3)
Portland cement	1770
Fine Aggregate	1568
Coarse Aggregate	1498
Maize Flour	865
Sorghum Flour	819

Source: Laboratory Research work (2016)

4.3.3 Density of materials used

Table 4.4 gives the density of materials used. It was observed that the density of cement was 1440kg/m^3, fine aggregate was 1600kg/m^3, coarse aggregate was 1500kg/m^3 and water was 1000kg/m^3. These data were used in the batching of the concrete mix.

Table 4.4 Density of Materials used

Materials	Density (kg/m^3) (Mean)
Cement	1440
Fine Aggregate	1600
Coarse Aggregate	1500
Water	1000

Source: Laboratory Research work (2016)

4.3.4 Physical Properties of Fine and Coarse Aggregates

Table 4.5 present results of the physical properties of fine aggregate and that of coarse aggregate. It was observed that the water absorption of the fine aggregate was 2.6% which is greater than that of the coarse aggregate at 0.6%. From the values, it indicates that the fine aggregate used for this study absorbed more moisture than the coarse aggregate.

Table 4.5 Physical Properties of Fine and Coarse Aggregates

Aggregate	**24 hour water absorption (%)**	**Maximum aggregate size (mm)**	**Fineness modulus**

		(mm)	
Fine Aggregate	2.6	-	5
Coarse Aggregate	0.6	20	-

Source: Laboratory Research work (2016)

4.3.5 Sieve Analysis of Aggregates

4.3.5.1 Sieve Analysis of Fine Aggregates

Table 4.6 present results of the sieve Analysis of Fine Aggregate. It was observed that the percentage of fine aggregate passing through the 5mm sieves is 99.9%. Majority of the fine aggregate was retained on 600μm sieves. 998g of the total weight passed through the sieve was retained and 441g retained on the 1.18mm sieves. According to Garba (2014), the more the content of aggregate less than 600μm, the less is its suitability for making concrete.

Table 4.6 sieve Analysis of Fine Aggregate

BS Sieve Size	Weight retained (g)	Weight Passing (g)	Percentage Passing (%)
5mm	2	1998	99.9
2.36mm	140	1858	92.9
1.18mm	441	1417	70.85
600μm	998	419	21
300μm	340	79	3.95

150μm	51	28	1.4
Pan	10	18	0.9

Source: Laboratory Research work (2016)

4.3.5.2 Sieve Analysis of Coarse Aggregates

Table 4.7 present results of the sieve analysis of coarse aggregates. It was observed that the percentage of coarse aggregate passing through the 20mm sieve was 99.65% and 7g was the total weight retained. For the 10mm sieve size, 34.65% was the percentage passing and 1300g was retained. It was seen that the majority of the coarse aggregate was retained in the 10mm sieve size. For the 5mm sieve size 0.6% was the percentage passing, 681g was the total weight retained. Coarse aggregate falls between the range of 20mm and 5mm sieve size (Garba, 2014).

Table 4.7 Sieve Analysis of coarse aggregate

BS Sieve Size	Weight Retained (g)	Weight Passing (g)	Percentage Passing (%)
20mm	7	1993	99.65
10mm	1300	693	34.65
5mm	681	12	0.6
Pan	12	0	0

Source: Laboratory Research work (2016)

4.4 Results for Tests on Fresh Concrete Specimens

4.4.1 Workability Test of Concrete

Table 4.8 presents the Slump test results of the fresh concrete made with maize and sorghum flours as admixture.It was observed as the dosage of the cereal flour increases, the slump increased for both maize and sorghum. The maize flour increased from 49mm to 120mm while the sorghum increased from 38mm to 98mm.the P value shows that there are significant differences between the slump test result of maize flour added to concrete and sorghum flour added to concrete.

Table 4.8 Slump Test Result of Maize and Sorghum Flour Added To Concrete

Percentage dosage of cereal flour added to concrete	**Maize**	**Sorghum**	**P Values**
	Mean ± S.E	**Mean ± S.E**	
0 %	30.00 ± 0.32	30.00 ± 0.32	1.00
1 %	49.00 ± 0.32	38.00 ± 0.32	0.00
2 %	55.00 ± 0.32	51.00 ± 0.32	0.00
3 %	60.00 ± 0.32	57.00 ± 0.32	0.00
4 %	80.00 ± 0.32	74.00 ±0.32	0.00
5 %	120.00 ± 0.32	98.00 ± 0.32	0.00

Source: Laboratory Research Work (2016)

4.4.2 Setting time test

Table 4.9 presents the setting time of cement produced with different dosage of cereal flour. The results and P value show a significant delay in both the initial and final setting time of cement added with cereal flour. For the maize flour added to cement both the initial and final setting time increases as the dosage level of maize flour

increases. For sorghum flour added to cement the initial setting time increase from 1% to 4% and falls at 5% this might probably be due to the fact that the cyanide content of sorghum is higher than that of maize while the final setting time of sorghum increases as the dosage level of sorghum flour increases.

As the accumulation of cyanide content increase the initial setting time increase. This is attributed to the increased cyanide content of the cement due to the increased quantity of the admixture, the cyanide probably alter the alkalinity of the cement environment. However, this condition appears to cease as cyanide becomes exhausted and the retarding action of the carbohydrate restored hence, the final setting time remains unaffected (Okafor, 2008).

Table 4.9 Setting time of cement with cereal flour as admixtures

Dosage of admixture (%)	**Initial setting time maize flour added to cement** **Mean ± S.E**	**Initial setting time sorghum flour added to cement** **Mean ± S.E**	**P**	**Final setting time maize flour added to cement** **Mean ± S.E**	**Final setting time sorghum flour added to cement** **Mean ± S.E**	**P**
0	111.02±0.31	111.02 ± 0.32	1.00	201.2±0.34	201.20 ± 0.34	1.00
1	150.04±0.32	221.10 ± 0.33	0.00	248.0±0.32	242.10 ± 0.33	0.00
2	178.06±0.32	338.00 ± 0.31	0.00	317.3±0.20	379.00 ± 0.31	0.00
3	353.22±0.32	381.00 ±0.32	0.00	353.0±0.16	399.10 ± 0.33	0.00
4	210.04±0.35	410.10 ± 0.33	0.00	402.2±0.34	446.1 ± 0.31	0.00
5	248.00±0.32	212.50 ± 0.44	0.00	437.9±0.19	492.00 ± 0.27	0.00

Source: Laboratory Research Work (2016)

4.4.3 Soundness of Concrete

Table 4.10 presents the soundness of concrete produced with different dosage of maize flour. It was observed that the cement with maize flour admixture of 0%, 1% and 2% are sound as the soundness values are 1, 2 and 3mm respectively. This conforms to IS: 4031(part – 1) – 1988, cement is said to be sound when the expansion is below 10mm. It is also observed that cement with maize admixture of 3%, 4% and 5% does not have value for the final length (L_2) due to the fact that the sample melt when boiling.

Table 4.10 Soundness of Concrete with Maize Flour as Admixture

Dosage of admixture (%)	Initial Length (L_1) (mm)	Final Length (L_2) (mm)	Soundness ($L_2 - L_1$) (mm)
0	1	2	1
1	5	7	2
2	4	7	3
3	3	-	-
4	4	-	-
5	2	-	-

Source: Laboratory Research Work (2016)

Table 4.11 presents the soundness of concrete produced with different dosage of sorghum flour. It was observed that the soundness values of cement with sorghum admixture of 0%, 1%, 2% and 3% are 1, 1, 2 and 3 respectively. This conforms to IS: 4031 (part – 1) – 1988, which indicated that cement is said to be sound when the expansion is below 10mm. It was also observed that cement with sorghum dosage of 4% and 5% melts when boiling and does not have final length (L_2).

Table 4.11 Soundness of concrete with sorghum flour as admixture

Dosage of	Initial Length L_1	Final Length L_2	Soundness ($L_2 - L_1$)

Admixture (%)	(mm)	(mm)	(mm)
0	1	2	1
1	5	6	1
2	3	5	2
3	2	5	3
4	5	-	-
5	3	-	-

Source: Laboratory Research Work (2016)

4.4Results for Tests on Hardened Concrete

4.4.1 Density

Table 4.12 shows the average density of concrete test samples at different ages of curing. It was observed that there is no uniform change in the density of the sample as the dosage of cereal flour increases with increase in time of storage in water tank. This may be due to the shape of the mold, mixing and compaction. It was also observed that the density of the test concrete samples with cereal flour is higher than that of the control samples. This might be due to the increase in consistency achieved when cereal flour was introduced to the concrete.

Table 4.12 Densities of concrete with cereal flour admixtures

Cereal flour Dosage (%)	**1 day (Kg/m^3)**	**3 days (Kg/m^3)**	**7 days (Kg/m^3)**	**28 days (Kg/m^3)**	**56 days (Kg/m^3)**
0%(control)	2300	2421	2486	2440	2526
1% maize	2335	2485	2493	2534	2547
2% maize	2417	2490	2498	2562	2546

3% maize	2380	2483	2497	2450	2547
4% maize	2368	2448	2312	2537	2549
5% maize	2370	2370	2480	2543	2546
1% sorghum	2360	2510	2479	2480	2540
2% sorghum	2375	2490	2460	2486	2544
3% sorghum	2349	2477	2425	2510	2500
4% sorghum	2342	2486	2450	2523	2511
5% sorghum	2344	2480	2400	2480	2440

Source: Laboratory Research Work (2016)

4.4.2 Compressive Strength

Compressive strength of concrete with cereal flour as admixture

Table 4.13 shows the compressive strength of concrete containing cereal flour as admixture, it was observed that the compressive strength increases as the dosage of the cereal flour increases. There was increase in strength from 1% to 3% dosage of the maize flour and drop at 4% and 5%. The trends of strength development in sorghum flour added to concrete is similar to that of maize flour added to concrete except that the sorghum flour has more higher results due to the effect of dispersion of cement particle and formation of denser gel due to delayed setting (Okafor, 2008). Other factor may include improved degree of compaction, increase in consistency and enhanced workability (Neville et al., 2010). It can also be observed that at 28 and 56 days the 4% and 5% dosage level of maize flour admixture added to concrete has a lower compressive strength compared tothe control concrete. From 1% to 3% dosage of maize flour admixture added to the concrete the strength increases more than the control concrete.

From Table 4.13, 1% to 3% dosage of sorghum flour added to concrete the compressive strength increases as the ages of curing increases, at 4% and 5% dosage of sorghum flour added to concrete there is a negative effect on the compressive strength at 28 and 56days, the test sample is lower in strength compared to the control concrete. This is attributed to the prolonged retarding action of the sorghum flour due to the high dosage level of the sorghum flour (Okafor, 2008). The optimum dosage is 3%, the compressive strength increases as the age of curing increases. From Table 4.13 the F – factor and P – values are significant where the superscripts a and b are different. For instance at 1% dosage of sorghum flour added to concrete as admixture the F – factor and P – value are significant at day 1, 3 and 56.

Table4.13 Compressive Strength of Concrete Containing Cereal Flour

Percentage (%)	**Day**	**Control**	**Maize**	**Sorghum**	**F - factor**	**P - value**
		Mean ± S.E	**Mean ± S.E**	**Mean ± S.E**		
1	1	7.92 ± 0.18^{a}	8.30 ± 0.37^{a}	11.80 ± 1.20^{b}	8.51	0.05
	3	11.00 ± 0.55^{a}	13.40 ± 0.29^{a}	17.80 ± 1.24^{b}	18.53	0.00
	7	16.60 ± 0.73	17.00 ± 0.27	19.50 ± 1.56	2.42	0.131
	28	25.30 ± 0.37	25.50 ± 0.39	25.20 ± 1.30	0.035	0.965
	56	30.20 ± 0.58^{b}	25.80 ± 0.37^{a}	25.20 ± 1.30^{a}	20.76	0.00
2	1	7.92 ± 0.18^{a}	10.20 ± 0.26^{b}	12.10 ± 0.33^{c}	63.66	0.00
	3	11.00 ± 0.55^{a}	14.60 ± 0.73^{b}	19.40 ± 0.48^{c}	49.79	0.00
	7	16.60 ± 0.73^{a}	17.20 ± 0.56^{a}	21.52 ± 0.72^{b}	15.65	0.00
	28	25.30 ± 0.37	25.60 ± 0.67	25.20 ± 1.30	0.057	0.94
	56	30.20 ± 0.58	27.90 ± 2.00	30.80 ± 0.34	1.57	0.25
3	1	7.92 ± 0.18^{a}	13.60 ± 0.45^{b}	13.60 ± 0.67^{b}	45.99	0.00
	3	11.00 ± 0.55^{a}	17.20 ± 0.64^{b}	20.50 ± 0.75^{c}	54.10	0.00
	7	16.60 ± 0.73^{a}	19.40 ± 0.81^{a}	23.90 ± 0.71^{b}	23.86	0.00
	28	25.30 ± 0.37	26.10 ± 0.74	28.02 ± 1.17	2.80	0.10
	56	30.20 ± 0.58	30.80 ± 0.59	32.80 ± 1.14	2.78	0.10
4	1	7.92 ± 0.18^{a}	11.80 ± 0.37^{b}	11.10 ± 0.18^{b}	62.15	0.00
	3	11.00 ± 0.55^{a}	14.10 ± 0.60^{ab}	15.60 ± 1.19^{b}	7.88	0.007
	7	16.60 ± 0.73	18.40 ± 0.50	18.32 ± 0.99	1.74	0.216
	28	25.30 ± 0.37^{b}	20.04 ± 0.56^{a}	24.80 ± 1.39^{b}	10.54	0.002
	56	30.20 ± 0.58^{b}	24.90 ± 0.64^{a}	23.42 ± 2.26^{a}	6.51	0.01
5	1	7.92 ± 0.18^{a}	8.80 ± 0.46^{a}	11.60 ± 0.29^{b}	33.43	0.00
	3	11.00 ± 0.55^{a}	11.40 ± 0.66^{a}	14.50 ± 0.50^{b}	11.18	0.002
	7	16.60 ± 0.73	18.00 ± 0.57	18.00 ± 0.44	1.85	0.20

	28	25.30 ± 0.37^{c}	20.40 ± 0.43^{a}	23.42 ± 0.55^{b}	29.13	0.00
	56	30.20 ± 0.58^{b}	23.60 ± 1.12^{a}	28.28 ± 1.91^{ab}	6.57	0.01

Source: Laboratory Research Work (2016)

n = 5; data analyzed using one –way ANOVA followed by turkey multiple comparison post hoc test. Values along the same rows with different superscripts [a, b], are significantly different ($p \leq 0.05$).

4.4.3 Tensile Strength

Tensile strength of concrete with cereal flour as admixture

Table4.14 shows the tensile strength text of cereal flour added to concrete at different percentages or dosage. It was observed that the tensile strength of maize flour admixture added to concrete increases as the age of curing increases. From 1% to 3% dosage of maize flour added to concrete, the tensile strength increases more than the control mix for all ages of curing. From 4% to 5% dosage of maize flour admixture added to concrete, the tensile strength increases more than the control concrete from day 1 to days 7, at 28 days the tensile strength is almost at the same value.

From Table 4.14, the trend of tensile strength of maize admixture added to concrete is similar to that of sorghum admixture added to concrete except that the sorghum admixture added to concrete has more impressive results. The test specimens have high tensile strength than the control specimen except at 28 days where the 5% sorghum is lower than the control.From Table 4.14 the F – factors and P – values are significant at early ages of curing for all dosage of the cereal flour admixture added to the concrete.

Table4.14 Tensile Strength of Concrete Containing Cereal Flour

Percentage (%)	Day	Control	Maize	Sorghum	F	P
		Mean ± S.E	Mean ± S.E	Mean ± S.E		
1	1	0.64 ± 0.09^{a}	0.88 ± 0.05^{ab}	0.92 ± 0.05^{b}	5.13	0.02
	3	0.78 ± 0.07^{a}	1.18 ± 0.09^{ab}	1.44 ± 0.17^{b}	8.01	0.01
	7	1.30 ± 0.15^{a}	1.76 ± 0.17^{ab}	1.90 ± 0.04^{b}	5.51	0.02
	28	2.02 ± 0.15	1.98 ± 0.21	2.06 ± 0.12	0.057	0.94
2	1	0.64 ± 0.09^{a}	1.24 ± 0.11^{b}	0.96 ± 0.02^{ab}	12.40	0.001
	3	0.78 ± 0.07^{a}	1.50 ± 0.16^{b}	1.44 ± 0.09^{b}	12.94	0.001
	7	1.30 ± 0.15^{a}	1.90 ± 0.09^{b}	1.98 ± 0.04^{b}	12.40	0.001
	28	2.02 ± 0.15	2.10 ± 0.28	2.12 ± 0.08	0.076	0.93
3	1	0.64 ± 0.09^{a}	1.38 ± 0.17^{b}	1.26 ± 0.11^{b}	9.17	0.004
	3	0.78 ± 0.07^{a}	1.52 ± 0.15^{b}	1.66 ± 0.10^{b}	18.43	0.00
	7	1.30 ± 0.15^{a}	2.00 ± 0.22^{b}	2.20 ± 0.09^{b}	8.07	0.01
	28	2.02 ± 0.15	2.26 ± 0.23	2.26 ± 0.09	0.66	0.53
4	1	0.64 ± 0.09^{a}	0.94 ± 0.06^{b}	1.20 ± 0.05^{b}	15.50	0.00
	3	0.78 ± 0.07^{a}	1.52 ± 0.19^{b}	1.56 ± 0.12^{b}	10.45	0.002
	7	1.30 ± 0.15	1.92 ± 0.27	2.04 ± 0.16	3.816	0.052
	28	2.02 ± 0.15	2.02 ± 0.16	2.26 ± 0.11	0.909	0.429
5	1	0.64 ± 0.09^{a}	1.10 ± 0.08^{b}	1.20 ± 0.09^{b}	11.34	0.002
	3	0.78 ± 0.07^{a}	1.52 ± 0.21^{b}	170 ± 0.12^{b}	11.01	0.002
	7	1.30 ± 0.15	1.92 ± 0.20	1.56 ± 0.17	3.09	0.083
	28	2.02 ± 0.15	2.00 ± 0.16	1.76 ± 0.25	0.556	0.588

Source: Laboratory Research Work (2016)

n = 5; data analyzed using one –way ANOVA followed by turkey multiple comparison post hoc test. Values along the same rows with different superscripts [a, b], are significantly different ($p \leq 0.05$).

4.4.4 Water Absorption

Water absorption test of concrete containing cereal flour as admixture at 28 and 56 days

Table4.15 shows the water absorption test of concrete containing cereal flour as admixture at 28 and 56 days. For concrete containing maize as admixture at 28 days, the result observed at 0%, 1%, 2%, 3%, 4% and 5% dosageare 3.99, 5.41, 5.67, 5.65, 4.16 and 4.11 respectively. At 56days, the result observed at 0%, 1%, 2%, 3%, 4% and 5% are 4.48, 5.61, 5.83, 4.88, 4.96 and 4.8 respectively. At 28 4% and 5% maize dosages added to concrete conform to ASTM C 140 water absorption test for hardened concrete which states that‘the average water absorption of the test samples shall not be greater than 5%. At 28 days, 1% to 3% does not satisfy the requirement as regards to ASTM C 140 water absorption.This may be as a result of the following factors as classified by ASTM C1585 – 13 which includes: concrete mixture proportions, the presence of chemical admixtures and supplementary cementations materials, the composition and physical characteristics of the cementations components and the aggregates, the entrained air content, the type and duration of curing, the degree of hydration or age, the

presence of micro cracks and placement method. Water absorption is also strongly affected by the moisture condition of the concrete at the time of testing.At 56 days 1% and 2% dosage of maize flour added to concrete does not conform to ASTM C 140 water absorption test for hardened concrete while 3% to 5% conform to ASTM C 140 water absorption test for hardened concrete.

From Table4.15,at 28 days 0%, 1%, 2%, 3%, 4% and 5% dosage of sorghum flour admixture added to concrete has water absorption values of 3.99, 5.91, 5.33, 5.00, 5.02 and 4.81 respectively. 1% to 2% dosage of sorghum flour admixture added to concrete does not conform to ASTM C 140 water absorption for hardened concrete, 3% to 5% conform to ASTM C 140 water absorption for hardened concrete. At 56 days 0%, 1%, 2%, 3%, 4% and 5% dosage of sorghum flour admixture added to concrete has water absorption values of 4.48, 4.67, 4.48, 4.99, 4.07 and 3.85 respectively. At 56 days, the entire test samples of sorghum flour admixture added to concrete conform to ASTM C 140 since the water absorption value is less than 5. It is observed that the sorghum flour samples have a better and impressive result than the maize flour samples at 56 days. From Table 4.15 it is observed that there is significant different between the F – factor and P – values of the cereal flours added to the concrete except at 56 days 3% of the cereal flour.

Table4.15 Water absorption test of concrete containing cereal flour as admixture

Percentage (%)	**Day**	**Control**	**Maize**	**Sorghum**	**F**	**P**
		Mean ± S.E	**Mean ± S.E**	**Mean ± S.E**		
1	28	3.99 ± 0.04^{a}	5.41 ± 0.16^{b}	5.91 ± 0.03^{c}	99.74	0.00
	56	4.48 ± 0.19^{a}	5.61 ± 0.29^{b}	4.67 ± 0.08^{a}	8.41	0.05
2	28	3.99 ± 0.04^{a}	5.67 ± 0.07^{b}	5.33 ± 0.25^{b}	34.00	0.00
	56	4.48 ± 0.19^{a}	5.86 ± 0.19^{b}	4.48 ± 0.06^{a}	24.001	0.00
3	28	3.99 ± 0.04^{a}	5.65 ± 0.11^{c}	5.00 ± 0.19^{b}	39.696	0.00
	56	4.48 ± 0.19	4.88 ± 0.18	4.99 ± 0.07	2.808	0.10

4	28	3.99 ± 0.04^{a}	4.16 ± 0.21^{b}	5.02 ± 0.15^{b}	13.16	0.001
	56	4.48 ± 0.19^{ab}	4.96 ± 0.18^{b}	4.07 ± 0.01^{a}	8.292	0.005
5	28	3.99 ± 0.04^{a}	4.11 ± 0.09^{a}	4.81 ± 0.14^{b}	19.44	0.00
	56	4.48 ± 0.19^{ab}	4.80 ± 0.14^{b}	3.85 ± 0.21^{a}	6.726	0.01

Source: Laboratory Research Work (2016)
n = 5; data analyzed using one –way ANOVA followed by turkey multiple comparison post hoc test. Values along the same rows with different superscripts [a, b], are significantly different ($p \leq 0.05$).

4.4.5 Abrasion

Abrasion test of concrete containing maize flour as admixture at 28 and 56 days

Table4.16 shows the abrasion resistance of the concrete containing maize flour as retarding admixture at 28 and 56 days. At 1% maize flour addition to concrete, the percentage wear was obtained as 0.06% at 28 days while that at 56 days was achieved as 0.043%. At 5% it was obtained as 0.107% at 28 days while 56 days was achieved as 0.064%. It was observed that the abrasion resistance of the control mix and the 1% addition of maize is the same value. There is increase in abrasion resistance from 0% to 3% addition of maize, it dropped at 4% and slightly increased at 5%. It is also observed that the abrasion resistance decreases as the age of curing increases.

The abrasion resistance of concrete containing sorghum flour is lower than the concrete containing maize flour as retarding admixture as shown in Table 4.16. At 1% sorghum flour addition to cement, the percentage wear was obtained as 0.027% at 28 days while at 56 days 0.053% was achieved. At 5% it was obtained as 0.046% at 28 days while at 56 days 0.055% was achieved. The values for abrasion of sorghum flour are lower than that of maize flour which implies that the maize flour is denser than the sorghum flour.

Table4.16 Abrasion resistance test of concrete containing cereal flour as admixture

Percentage (%)	Day	Control	Maize	Sorghum	F	P
		Mean ± S.E	Mean ± S.E	Mean ± S.E		
1	28	0.06 ±0.01	0.06 ± 0.01	0.05 ± 0.01	0.16	0.85
	56	0.04 ± 0.00	0.04 ± 0.00	0.05 ± 0.01	1.378	0.287
2	28	0.06 ±0.01[a]	0.16 ± 0.01[b]	0.09 ± 0.01[a]	20.491	0.00
	56	0.04 ± 0.00	0.05 ± 0.01	0.07 ± 0.01	2.294	0.14
3	28	0.06 ±0.01[a]	0.18 ± 0.01[b]	0.09 ± 0.05[ab]	4.33	0.038
	56	0.04 ± 0.00	0.04 ± 0.00	0.043 ± 0.00	1.146	0.35
4	28	0.06 ±0.01	0.52 ± 0.01	0.07 ± 0.02	0.452	0.647
	56	0.04 ± 0.00	0.05 ± 0.01	0.06 ± 0.00	1.705	0.223
5	28	0.06 ±0.01[ab]	0.11 ± 0.02[b]	0.04 ± 0.00[a]	6.88	0.01
	56	0.04 ± 0.00	0.06 ± 0.01	0.05 ± 0.00	3.15	0.08

Source: Laboratory Research Work (2016)

n = 5; data analyzed using one –way ANOVA followed by turkey multiple comparison post hoc test. Values along the same rows with different superscripts [a, b], are significantly different (p $\leq$ 0.05).

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of findings

1. It was observed that the maize flour has higher starch content, PH and solubility than the sorghum flour. The cyanide content of sorghum is higher than that of maize.

2. The slump increases as the percentage or dosage of the cereal flour increases.

3. The maximum compressive strength of sorghum flour is obtained at 3% dosage which is 32.8N/mm^2 at 56 days while the control is 30.2 N/mm^2. The target strength is 31.56 N/mm^2.

4. The maximum tensile strength for maize flour is obtained at 3% at 56 days which is 2.75 N/mm^2 and the control mix is 2.68 N/mm^2.

5. The maximum tensile strength for sorghum is obtained at 3% which is 2.7 N/mm^2 at 56 days while the control mix is 2.68 N/mm^2.

6. It was observed that the maximum dosage for optimum compressive and tensile strength was 3% for both maize and sorghum. The strength increases as the age of curing increases.

7. It was observed that at 28 days 1% to 3% dosage of maize flour does not satisfy the requirements of ASTM C 140 water absorption. 4% and 5% dosages whose average values for water absorption are 4.65 and 4.11 satisfy the requirements of ASTM C 140 for water absorption of hardened concrete. At 56 days the average values for water absorption from 3% to 5% dosage of maize do not conform to ASTM C 140 since the values are less than 5.

8. It was observed that at 28 days 3% to 5% dosage of sorghum flour satisfy the requirement of ASTM C 140 water absorption test for hardened concrete. At 56 days 1% to 5% dosage of sorghum satisfies the requirement of ASTM C 140.

5.2 Conclusion

After carrying out the experiments, observation, analysis and discussion on the effects of cereal flour on the properties of concrete the following conclusion were drawn

1. Physical properties such as bulk density, specific gravity, moisture and absorption capacity of maize was found to be higher than those of sorghum. Chemical properties by proximate analysis showed that maize flour has higher starch content, PH and solubility than sorghum flour. The cyanide content of sorghum flour is higher than maize.
2. 3% dosage of maize and sorghum flour appeared to be the approximate dosage for the concrete mix. The optimum compressive and tensile strength of the test specimen is achieved at 3% dosage of maize and sorghum flour.
3. Maize flour and sorghum flour delays the setting time of cement, for sorghum the setting time is achieved at 410 minutes while maize is 248 minutes. Good soundness for maize is achieved at 1% to 2% while for sorghum is achieved at 1% to 3%. Maize flour as admixture in concrete did not adversely affect the compressive strength of concrete. At 56 days the maximum compressive strength is 30.8 N/mm^2while that of sorghum at 56 days is 32.5 N/mm^2. The control is 30.2 N/mm^2.
4. The use of sorghum flour as admixture in concrete gives better result in the compressive strength than maize flour.

5.3 Recommendations

From the results of this research work, the following recommendations were made:

1. Flours of maize and sorghum can be used as retarding admixture in concrete production. It retards the initial and final setting time, sorghum flour have a better retarding power than the maize flour due to it's high cyanide content.
2. The cereal flour improves the compressive and tensile strengthsof concrete. The increase in strength of test specimen with cereal flour is slightly above the control (test specimen without cereal flour). The optimum compressive and tensile strengthsis obtained at 3% dosage of the admixture.
3. Cereal flour as admixture in concrete can improve the consistency, compaction and density of the test specimen. The starch content improves the plasticizing effect of the concrete
4. Cereal flour as retarding admixture in concrete production can avail opportunities for our farmers since they are available locally.

5.4 Recommendation for Further Studies

1. Research should be carried out on the comparative effects of sorghum flour and cassava flour on the properties of Portland cement concrete.
2. Research should be carried out on the use of cereal flours as water reducing admixture.

5.5 Contribution to Knowledge

1. The study established that the slump test increases as the dosage of the cereal flour admixture increases from 1% to 5%. For maize flour added to cement its increases from 49 to 120 while for sorghum flour added to cement its increases

from 38 to 98. This showed that there is improve in workability, consistency and compaction of the fresh concrete.

2. The study established that sorghum and maize flour added to concrete can be used as retarding admixture. Sorghum flour markedly delay the initial setting time up to 410 minutes at 4% dosage and final setting time of up to 492 minutes at 5%. The maximum initial setting time achieved for maize flour was 248 minutes at 5% and the final setting was 438 minutes at 5%.
3. The research established that 3% dosage of the cereal flour (sorghum and Maize) is the optimum compressive and tensile strength of the test sample.

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Appendices

Appendix A1

Particle Size Distribution Result for Natural Coarse Aggregate and Fine Aggregate

Table A1.1: Fine Aggregate

BS Sieve Size	Weight Retained (g)	Weight Passing (g)	Percentage Passing (%)
5mm	2	1998	99.90
2.36mm	140	1858	92.90
1.18mm	441	1417	70.85
600	998	419	21
300	340	79	3.95
150	51	28	1.4
pan	10	18	0.9

Source: Laboratory Research Work(2016)

Table A1.2: Coarse Aggregate

BS Sieve Size	Weight Retained (g)	Weight Passing (g)	Percentage Passing (%)
20mm	7	1993	99.65
10mm	1300	693	34.65
5mm	681	12	0.60
Pan	12	0	0

Source: Laboratory Research Work (2016)

Appendix A2

Mix Design for Grade C25 Concrete Using Building British Research Establishment Method (BRE)

Design Stipulations and Test data for Materials

Compressive strength at 28 days = 25 N/mm^2

Type of concrete = Plain Concrete

Grade of Cement = 42.5

Coarse Aggregate type = crushed granite

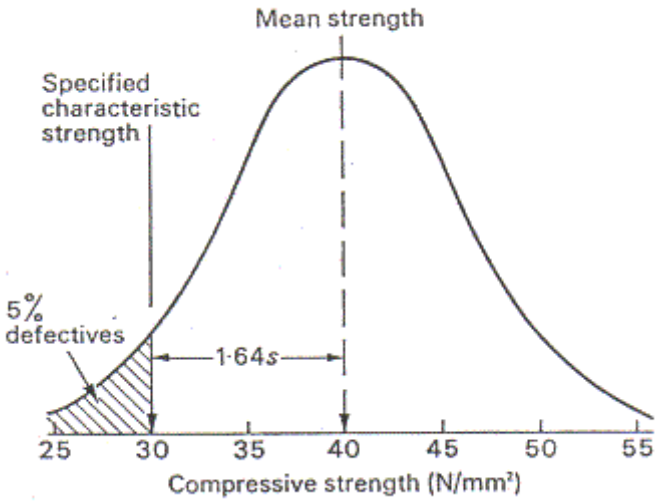


Fig. A2.1: Normal Distribution of Concrete Strength

Source: Building Research Establishment (1997)

Table A2.1: K factor used in Statistical Control

Percentage (%)	**K**
16	1.00
10	1.28
5	1.64
2	2.05
1	2.33

Source: Building Research Establishment (1997)

Step 1: Compute Mean Target Strength

$f_m = f_c + ks$

where

f_m= the target mean strength

f_c= the specified characteristic strength

ks= the margin, which is the product of :

s= the standard deviation and

k = a constant

from fig A2.1 select margin factor = 5

from table A2.1, k=1.64 and s=4

f_m= 25N/mm2+ (1.64x4)

f_m=25+6.56

f_m=31.56N/mm^2

Step 2: Information on the Materials to be used

i. Coarse aggregate = 20mm Maximum sieve size

ii. Percentage of fine aggregate passing through 600µm sieve=21%

iii. Specific gravity of coarse aggregate based on SSD = 2.7

iv. Condition of Exposure = Alternate wetting and Drying

Step 3: Determine the Required Water Cement Ratio

Using cement grade 42.5 and crushed coarse aggregates at 28 days as it is seen from table A2.2

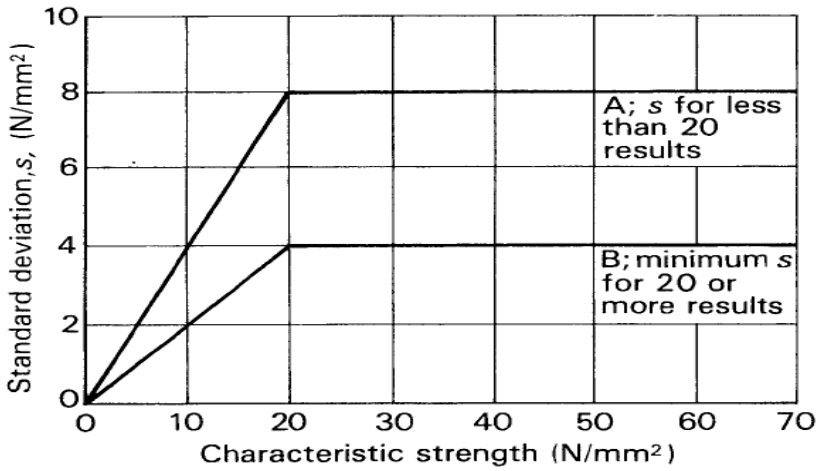


Fig. A2.2: Characteristic Strength Versus Standard Deviation Relationship

Source: Building Research Establishment (1997)

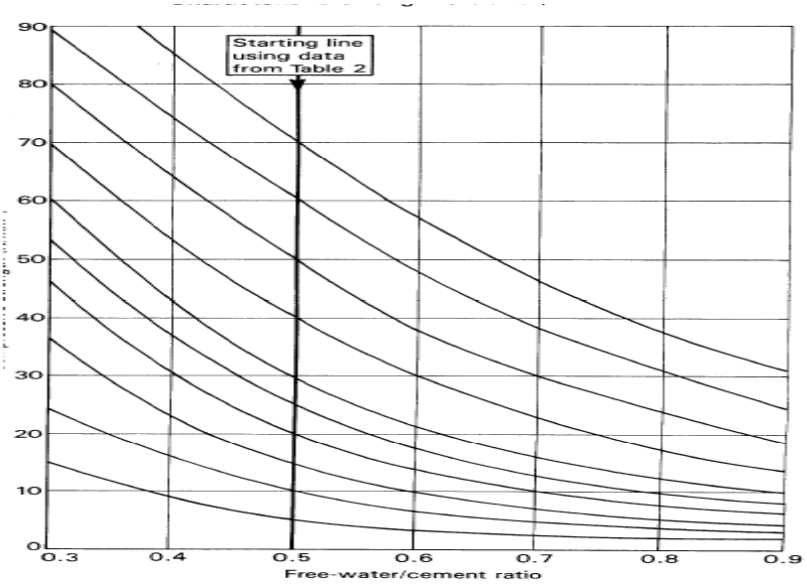


Figure A2.3 Relationship between Compressive Strength and Water/Cement Ratios

Source: Building Research Establishment (1997)

Table A2.2: Approximate Compressive Strength of Concrete Mix with A Free – Water/Cement Ratio Of 0.5

Cement strength class	Type of coarse aggregate	Compressive strengths (N/mm^2) Age (days) 3	7	28	91
42.5	Uncrushed	22	30	42	49
	Crushed	27	36	49	56
52.5	Uncrushed	29	37	48	54
	Crushed	34	43	55	61

Source: Building Research Establishment (1997)

Table A2.3: Maximum water cement ratio for reasonable durability

Condition of Exposure	Maximum Water Cement Ratio	
	Plain Concrete	Reinforced Concrete
Internal, Subject to heavy condensation	-	0.60
Alternate wetting and drying	0.60	0.60
Freezing and Thawing	0.55	0.50
Seawater or salt spray	0.50	0.45
Water retaining structure	-	0.50

Source: Building Research Establishment (1997)

Anticipate strength = $49N/mm^2$

Target Strength = $31.56N/mm^2$

Free water/cement ratio = 0.5

To determine the new free water/cement ratio to be used:

From Figure A2.3

Use the curve drawn from 0.5 free water/cement ratio and 49N/mm^2 anticipated strength to trace the new water/cement ratio with target strength of 31.56N/mm^2

New free water/cement ratio = 0.53 which is ok according to the standard because from the table A2.3, maximum allowable water/cement ratio for alternate wetting and drying condition of exposure, plain concrete = 0.6

Therefore, maximum allowable water/cement ratio = 0.60

Step 4: Selecting an Appropriate Degree of Workability (Slump)

Table A2.3: Workability, Slump and Compacting factor of concrete with 19mmor 38mmsize of aggregate

Degree of workability	Slump		Compacting factor	Use for which concrete is suitable
	mm	in.		
Very low	0–25	0–1	0.78	Roads vibrated by power-operated machines. At the more workable end of this group, concrete may be compacted in certain cases with hand-operated machines.
Low	25–50	1–2	0.85	Roads vibrated by hand-operated machines. At the more workable end of this group, concrete may be manually compacted in roads using aggregate of rounded or irregular shape. Mass concrete foundations without vibration or lightly reinforced sections with vibration.
Medium	25–100	2–4	0.92	At the less workable end of this group, manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibration.
High	100–175	4–7	0.95	For sections with congested reinforcement. Not normally suitable for vibration.

(Building Research Establishment, Crown copyright)

From A2.3,Select medium degree of workability with a slump ranging from 25 - 100mm.

Step 5: Determine the Required Free Water Content (kg/m3)

From Table A2.4, based on the selected workability, maximum size and type of aggregate, the required free water content =210kg/m^3

Table A2.4: Approximate Free-Water Content (Kgm^3) Required to Give Various Levels of Workability.

Slump (mm)		**0-10**	**10-30**	**30-60**	**60-180**
Vebe time (s)		**>12**	**6-12**	**3-6**	**0-3**
Max. size of aggregate (mm)	**Type of Aggregate**				
10	Uncrushed	150	180	205	225
	Crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	Crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	Crushed	155	175	190	205

Source: Building Research Establishment (1997)

Step 6: Calculate the Cement Content by using the W/C Ratio

Cement content (kg/m^3) $= \frac{water\ \ content\ \ (\frac{kg}{m3})}{w/c}$

Cement content (kg/m^3) $= \frac{210\ kg/m3}{0.53}$

Cement content (kg/m^3) = 396 kg/m^3

<u>Step 7:</u> Compare the Amount of the Cement Obtained with the minimum Allowable Content for Durability.

Table A2.5: Maximum Cement Content for Concretes with 20mm Maximum Aggregate Size under Different Condition of Exposure

Exposure Conditions	Minimum Cement Content for Concrete (Kg/m^3)		
	Plain	**Reinforced**	**Pre-stressed**
Non-corrosive	220	250	300
buried or sheltered from rain	250	290	300
Exposed to alternate wetting and drying or seawater	310	360	360
subject to de-icing salt	280	390	300

Source: Building Research Establishment (1997)

From Table A2.4, the minimum cement content for plain concrete exposed to alternate wetting and drying = $310kg/m^3$ which is less than the $396kg/m^3$. Therefore, $396kg/m^3$ is adequate.

<u>Step 8</u>:Determine the Wet Density of the Concrete using Free Water Content

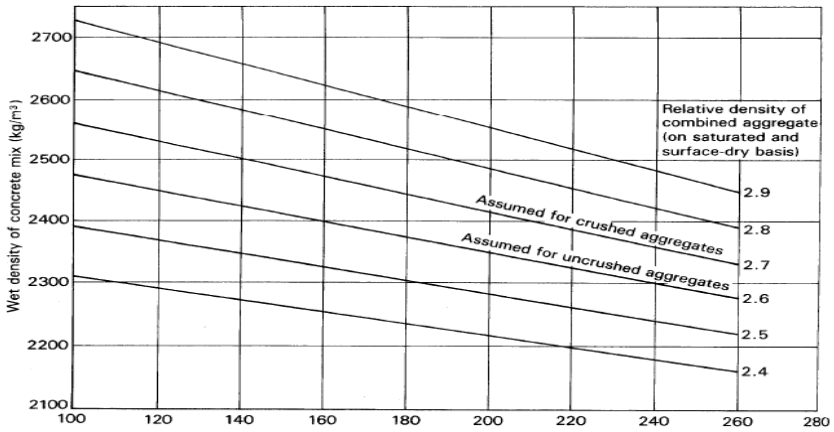


Figure A2.3: Relationship between free-water content and wet density of concrete

Source: Building Research Establishment (1997)

From Figure A2.3

Free water content = $210kg/m^3$ (from step 5)

Combined specified gravity of aggregate at SSD = 2.70

Therefore, Wet density (plastic density) =2400 kg/m^3

<u>Step 9</u>:Deducing the Proportion of the Fine Aggregate.

Water/cement ratio= 0.53, Slump = 50mm Maximum aggregate size = 20mm

Percentage of fine aggregate that passed through 600µm BS sieve = 21%

From Figure.A2.4,the proportion of fine aggregate = 25%

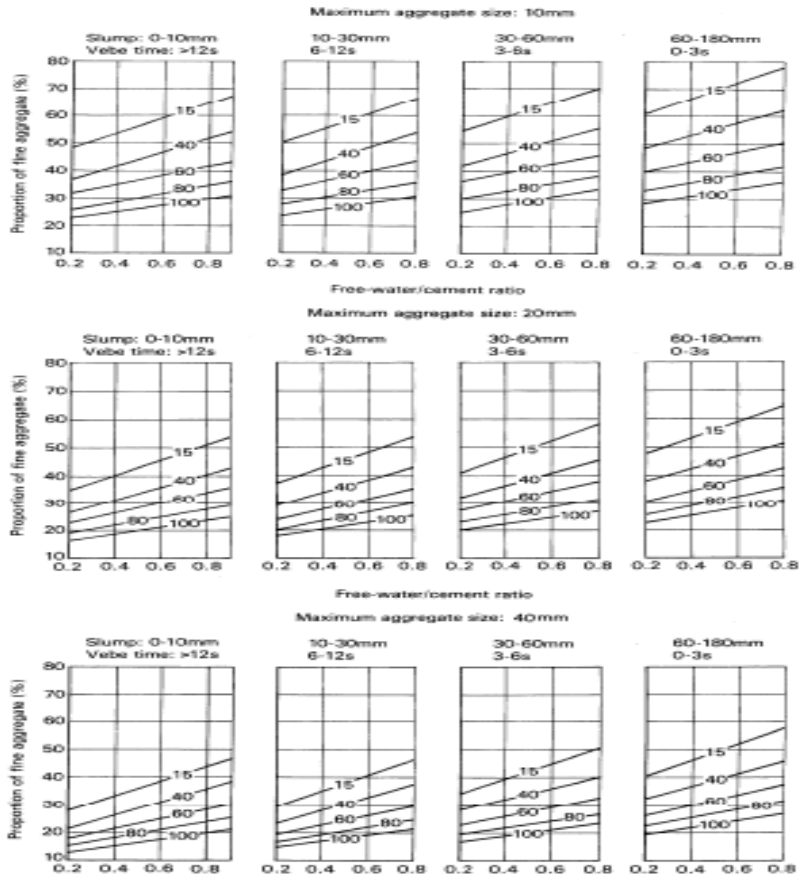


Figure A2.4: Recommended Percentages of fine aggregate in total aggregate as a function of free-water/cement ratio for values of workability and maximum size of aggregate

Source: Building Research Establishment (1997)

<u>Step 10</u>:Compute the Quantity of Aggregate

1. Total Aggregate Content based on Supersaturated surface dry (SSD)

Total Aggregate Content= Plastic Density – Cement content – Water content
(TAC) (PD) (CC) (WC)

TAC = 2400kg/m^3 – 396kg/m^3– 210kg/m^3

TAC = 1794kg/m^3

2. Fine Aggregate Content (FAC) = TAC x Proportion of fine aggregate(FA)

$$FAC = 1794kg/m^3 x \frac{25}{100}$$

$$FAC = 449kg/m^3$$

3. Coarse Aggregate Content (CAC) = TAC – FAC

$$CAC = 1794kg/m^3 – 449kg/m^3$$

$$CAC = 1345kg/m^3$$

<u>Step 11</u>: Deducing the Mix Proportion by WeightTaking Cement as 1

Cement Content = 396kg/m^3

Fine Aggregate Content = 449kg/m^3

Coarse Aggregate Content = 1345kg/m^3

Water Content = 210kg/m^3

Mix Proportion $= \frac{396}{396} : \frac{449}{396} : \frac{1345}{396}$ and $\frac{210}{396}$

$= 1 : 1\frac{13}{100} : 3\frac{2}{5}$ and W/C = 0.53

<u>Step 12:</u> Adjust the quantity of mix water to take care of moisture condition of the aggregate on site if necessary (the aggregates used were at saturated surface dry condition)

<u>Step 13</u>: Quantity of materials in grams

Computing the absolute volume of materials required.

Table 2.6: Density and Specific Gravity of Materials used

Materials	Density(g/mm^3)	Specific Gravity
Cement	1440	3.15
Sharp Sand	1600	2.65
Gravel	1500	2.52
Water	1440	1.0

Source: Building Research Establishment (1997)

Mix ratio: 1: $1\frac{13}{100}$: $3\frac{2}{5}$

Absolute Volume of Cement = $\frac{densityxratio}{specific\ \ gravity}$

$$= \frac{1440x1}{3.15}$$

$$= 457.143\text{mm}^3$$

Absolute Volume of Sand = $\frac{density\ xratio}{specific\ \ gravity}$

$$= \frac{1600x1\frac{13}{100}}{2.65}$$

$$= 682.264\text{mm}^3$$

Absolute Volume of Gravel = $\frac{densityxratio}{specific\ \ gravity}$

$$= \frac{1500 x 3\frac{2}{5}}{2.52}$$

$$= 2023.81 mm^3$$

Absolute Volume of Water = $\frac{density x ratio}{specific\ \ gravity}$

$$= \frac{1440 x 0.53}{1}$$

$$= 742 mm^3$$

Total Absolute Volume = Absolute Volume of Cement + Absolute Volume of Sand + Absolute Volume of Gravel + Absolute Volume of Water

Total Absolute Volume = 457.143 + 682.264+ 2023.81 + 742

$$= 3905.217\ mm^3$$

Quantity of Materials per cubic Volume

Cement = $\frac{density x ratio}{Total\ \ absolute\ \ volume}$ X 15% waste

$$= \frac{1440 x 1}{3905.217} \text{ X 15\% waste}$$

= 424g

Sand = $\frac{density x ratio}{Total\ \ absolute\ \ volume}$ X 15% waste

$$= \frac{1600 x 1\frac{13}{100}}{3905.217} \text{ X 15\% waste}$$

=532g

Gravel = $\frac{density x ratio}{Total\ \ abso\ lute\ \ volume}$ X 15% waste

$= \frac{1600 x 3\frac{2}{5}}{3905.217}$ X 15% waste

=1502g

Water $= \frac{density x ratio}{Total\ absolute\ volume}$ X 15% waste

$= \frac{1600 x 0.53}{3905.217}$ X 15% waste

=224g

Percentage of Cereal Added to the Cement

1% of Cereal added = 1% of 424 = 4.24g

2% of Cereal added = 2% of 424 = 8.48g

3% of Cereal added = 3% of 424 = 12.72g

4% of Cereal added = 4% of 424 = 16.96g

5% of Cereal added = 5% of 424 = 21.20g

Appendix A3

A3.1 Compressive Strength result of Concrete Specimens Produced

Table A3.1 Compressive Strength of Concrete Specimens Produced With 0% Cereal Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
0% cereals	W1 = 2.26	75.0	7.5	
	W2 = 2.28	80.0	8.0	
at 1st Day	W3 = 2.32	80.0	8.0	7.92
	W4 = 2.40	85.0	8.5	
	W5 = 2.24	76.0	7.6	
0% cereal	W1 = 2.24	110.0	11.0	
	W2 = 2.62	100.0	10.0	
At 3rd days	W3 = 2.44	110.0	11.0	11.2
	W4 = 2.30	110.0	11.0	
	W5 = 2.48	130.0	13.0	
0% cereal	W1 = 2.38	150.0	15.0	
	W2 = 2.38	160.0	16.0	
at 7th days	W3 = 2.54	175.0	17.5	16.6
	W4 = 2.42	190.0	19.0	
	W5 = 2.30	155.0	15.5	
0% cereal	W1 = 2.40	250.0	25.0	
	W2 = 2.58	260.0	26.0	
at 28th	W3 = 2.44	260.0	27.5	25.3
	W4 = 2.46	205.0	20.5	
days	W5 = 2.34	240.0	24.0	

Source: Laboratory Research Work (2016)

Table A3.2 Compressive Strength of Concrete Specimens Produced With 1% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1% maize flour at 1st Day	W1 = 2.16	85.0	8.5	
	W2 = 2.42	90.0	9.0	
	W3 = 2.22	70.0	7.0	8.3
	W4 = 2.42	90.0	9.5	
	W5 = 2.22	80.0	8.6	
1% Maize flour At 3rd days	W1 = 2.34	130.0	13.0	
	W2 = 2.34	125.0	12.5	
	W3 = 2.36	140.0	14.0	13.4
	W4 = 2.50	140.0	14.0	
	W5 = 2.34	135.0	13.5	
1% Maize flour at 7th days	W1 = 2.30	180.0	18.0	
	W2 = 2.38	170.0	17.0	
	W3 = 2.34	182.0	18.2	17.0
	W4 = 2.52	165.0	16.5	
	W5 = 2.42	160.0	16.0	
1% Maize flour at 28th days	W1 = 2.44	260.0	26.0	
	W2 = 2.38	246.0	24.6	
	W3 = 2.46	256.0	25.6	25.5
	W4 = 2.34	268.0	26.8	
	W5 = 2.52	245.0	24.5	

Source: Laboratory Research Work (2016)

Table A3.3 Compressive Strength of Concrete Specimens Produced With 2% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
2% Maize flour at 1st Day	W1 = 2.38	100.0	10.0	
	W2 = 2.32	105.0	10.5	
	W3 = 2.44	95.0	9.5	10.2
	W4 = 2.46	110.0	11.0	
	W5 = 2.44	100.0	10.0	
2% Maize flour At 3rd days	W1 = 2.54	140.0	14.0	
	W2 = 2.40	135.0	13.5	
	W3 = 2.56	170.0	17.0	14.6
	W4 = 2.36	155.0	15.5	
	W5 = 2.10	130.0	13.0	
2% Maize flour at 7th days	W1 = 2.30	165.0	16.5	
	W2 = 2.50	180.0	18.0	
	W3 = 2.42	190.0	19.0	17.2
	W4 = 2.24	165.0	16.5	
	W5 = 2.48	160.0	16.0	
2% Maize flour at 28th days	W1 = 2.54	250.0	25.0	
	W2 = 2.36	240.0	24.0	
	W3 = 2.36	240.0	24.0	25.6
	W4 = 2.50	260.0	26.0	
	W5 = 2.40	290.0	29.0	

Source: Laboratory Research Work (2016)

Table A3.4 Compressive Strength of Concrete Specimens Produced With 3% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
3% Maize flour at 1st Day	W1 = 2.32	125.0	12.5	
	W2 = 2.40	125.0	12.5	
	W3 = 2.30	145.0	14.5	13.6
	W4 = 2.42	145.0	14.5	
	W5 = 2.46	140.0	14.0	
3% Maize flour At 3rd days	W1 = 2.38	175.0	17.5	
	W2 = 2.32	160.0	16.0	
	W3 = 2.42	170.0	17.0	17.2
	W4 = 2.34	160.0	16.0	
	W5 = 2.42	195.0	19.5	
3% Maize flour at 7th days	W1 = 2.32	190.0	19.0	
	W2 = 2.38	220.0	22.0	
	W3 = 2.40	170.0	17.0	19.4
	W4 = 2.32	200.0	20.0	
	W5 = 2.52	190.0	19.0	
3% Maize flour at 28th days	W1 = 2.48	248.0	24.8	
	W2 = 2.42	270.0	27.0	
	W3 = 2.36	265.0	26.5	26.1
	W4 = 2.46	276.0	27.6	
	W5 = 2.52	250.0	25.0	

Source: Laboratory Research Work (2016)

Table A3.5 Compressive Strength of Concrete Specimens Produced With 4% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
4% Maize flour at 1st Day	W1 = 2.28	110.0	11.0	
	W2 = 2.22	118.0	11.8	
	W3 = 2.38	100.0	10.0	11.8
	W4 = 2.38	125.0	12.5	
	W5 = 2.56	120.0	12.0	
4% Maize flour At 3rd days	W1 = 2.44	160.0	16.0	
	W2 = 2.56	130.0	13.0	
	W3 = 2.44	120.0	12.0	14.1
	W4 = 2.46	130.0	13.0	
	W5 = 2.28	165.0	16.5	
4% Maize flour at 7th days	W1 = 2.38	206.0	20.6	
	W2 = 2.28	178.0	17.8	
	W3 = 2.00	181.0	18.1	18.4
	W4 = 1.94	165.0	16.5	
	W5 = 2.00	190.0	19.0	
4% Maize flour at 28th days	W1 = 2.20	186.0	18.6	
	W2 = 2.34	200.0	20.0	
	W3 = 2.36	202.0	20.2	20.7
	W4 = 2.32	196.0	19.6	
	W5 = 2.64	220.0	22.0	

Source: Laboratory Research Work (2016)

Table A3.6 Compressive Strength of Concrete Specimens Produced With 5% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
5% Maize flour at 1st Day	W1 = 2.40	80.0	8.0	
	W2 = 2.26	90.0	9.0	
	W3 = 2.36	100.0	10.0	8.8
	W4 = 2.34	95.0	9.5	
	W5 = 2.48	75.0	7.5	
5% Maize flour At 3rd days	W1 = 2.20	100.0	10.0	
	W2 = 2.34	112.0	11.2	
	W3 = 2.46	120.0	12.0	11.4
	W4 = 2.36	115.0	11.5	
	W5 = 2.48	123.0	12.3	
5% Maize flour at 7th days	W1 = 2.34	145.0	14.5	
	W2 = 2.34	170.0	17.0	
	W3 = 2.20	190.0	19.0	18.0
	W4 = 2.40	195.0	19.5	
	W5 = 2.14	200.0	20.0	
5% Maize flour at 28th days	W1 = 2.52	215.0	21.5	
	W2 = 2.42	200.0	20.0	
	W3 = 2.40	190.0	19.0	20.4
	W4 = 2.34	210.0	21.0	
	W5 = 2.33	205.0	20.5	

Source: Laboratory Research Work (2016)

Table A3.7 Compressive Strength of Concrete Specimens Produced With 1% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1% sorghum flour at 1st Day	W1 = 2.36	130.0	13.0	11.8
	W2 = 2.36	150.0	15.0	
	W3 = 2.32	130.0	13.0	
	W4 = 2.26	90.0	9.0	
	W5 = 2.48	90.0	9.0	
1% Sorghum flour At 3rd days	W1 = 2.54	210.0	21.0	17.8
	W2 = 2.48	190.0	19.0	
	W3 = 2.56	140.0	14.0	
	W4 = 2.56	190.0	19.0	
	W5 = 2.40	160.0	16.0	
1% Sorghum flour at 7th days	W1 = 2.46	200.0	20.0	19.5
	W2 = 2.56	150.0	15.0	
	W3 = 2.46	220.0	22.0	
	W4 = 2.42	235.0	23.5	
	W5 = 2.44	170.0	17.0	
1% Sorghum flour at 28th days	W1 = 2.54	271.0	27.1	25.2
	W2 = 2.42	279.0	27.9	
	W3 = 2.44	236.0	23.6	
	W4 = 2.44	265.0	26.5	
	W5 = 2.54	209.0	20.9	

Source: Laboratory Research Work (2016)

Table A3.8 Compressive Strength of Concrete Specimens Produced With 2% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
2% sorghum flour at 1st Day	W1 = 2.44	147.0	14.7	12.1
	W2 = 2.38	105.0	10.5	
	W3 = 2.38	110.0	11.0	
	W4 = 2.26	140.0	14.0	
	W5 = 2.40	100.0	10.0	
2% Sorghum flour At 3rd days	W1 = 2.40	210.0	21.0	19.4
	W2 = 2.40	205.0	20.5	
	W3 = 2.38	210.0	21.0	
	W4 = 2.42	169.0	16.9	
	W5 = 2.36	180.0	18.0	
2% Sorghum flour at 7th days	W1 = 2.32	220.0	22.0	21.5
	W2 = 2.52	225.0	22.5	
	W3 = 2.18	200.0	20.0	
	W4 = 2.42	230.0	23.0	
	W5 = 2.34	190.0	19.0	
2% Sorghum flour at 28th days	W1 = 2.48	269.0	26.9	26.5
	W2 = 2.48	264.0	26.4	
	W3 = 2.58	281.0	28.1	
	W4 = 2.52	286.0	28.6	
	W5 = 2.34	225.0	22.5	

Source: Laboratory Research Work (2016)

Table A3.9 Compressive Strength of Concrete Specimens Produced With 3% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
3% sorghum flour at 1st Day	W1 = 2.34	120.0	12.0	13.6
	W2 = 2.34	130.0	13.0	
	W3 = 2.22	135.0	13.5	
	W4 = 2.38	145.0	14.5	
	W5 = 2.40	150.0	15.0	
3% Sorghum flour At 3rd days	W1 = 2.52	221.0	22.1	20.5
	W2 = 2.44	180.0	18.0	
	W3 = 2.34	225.0	22.5	
	W4 = 2.48	229.0	22.9	
	W5 = 2.58	170.0	17.0	
3% Sorghum flour at 7th days	W1 = 2.48	200.0	20.0	23.9
	W2 = 2.52	255.0	25.5	
	W3 = 2.24	228.0	22.8	
	W4 = 2.52	254.0	25.4	
	W5 = 2.34	258.0	25.8	
3% Sorghum flour at 28th days	W1 = 2.40	309.0	30.9	28.0
	W2 = 2.62	284.0	28.4	
	W3 = 2.56	256.0	25.6	
	W4 = 2.44	262.0	26.2	
	W5 = 2.52	289.0	28.9	

Source: Laboratory Research Work (2016)

Table A3.10 Compressive Strength of Concrete Specimens Produced With 4% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
4% sorghum flour at 1st Day	W1 = 2.30	115.0	11.5	11.1
	W2 = 2.42	110.0	11.0	
	W3 = 2.38	110.0	11.0	
	W4 = 2.10	105.0	10.5	
	W5 = 2.48	115.0	11.5	
4% Sorghum flour At 3rd days	W1 = 2.34	150.0	15.0	15.6
	W2 = 2.42	120.0	12.0	
	W3 = 2.34	135.0	13.5	
	W4 = 2.34	140.0	14.0	
	W5 = 2.48	195.0	19.5	
4% Sorghum flour at 7th days	W1 = 2.46	190.0	19.0	18.3
	W2 = 2.42	190.0	19.0	
	W3 = 2.36	150.0	15.0	
	W4 = 2.26	140.0	21.5	
	W5 = 2.26	170.0	17.0	
4% Sorghum flour at 28th days	W1 = 2.50	238.0	23.8	24.8
	W2 = 2.46	229.0	22.9	
	W3 = 2.56	216.0	21.6	
	W4 = 2.54	262.0	26.2	
	W5 = 2.64	289.0	29.5	

Source: Laboratory Research Work (2016)

Table A3.11 Compressive Strength of Concrete Specimens Produced With 5% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
5% sorghum flour at 1st Day	W1 = 2.30	115.0	11.5	11.6
	W2 = 2.34	120.0	12.0	
	W3 = 2.36	112.0	11.2	
	W4 = 2.32	110.0	11.0	
	W5 = 2.38	115.0	11.5	
5% Sorghum flour At 3rd days	W1 = 2.36	130.0	13.0	14.5
	W2 = 2.14	140.0	14.0	
	W3 = 2.30	150.0	15.0	
	W4 = 2.28	145.0	14.5	
	W5 = 2.34	160.0	16.0	
5% Sorghum flour at 7th days	W1 = 2.38	170.0	17.0	18.0
	W2 = 2.32	190.0	19.0	
	W3 = 2.14	190.0	19.0	
	W4 = 2.42	180.0	18.0	
	W5 = 2.26	170.0	17.0	
5% Sorghum flour at 28th days	W1 = 2.52	184.0	23.5	23.4
	W2 = 2.50	216.0	21.6	
	W3 = 2.58	231.0	23.1	
	W4 = 2.38	234.0	23.4	
	W5 = 2.44	254.0	25.4	

Source: Laboratory Research Work (2016)

Appendix A4

Split Tensile Strength Result of Concrete Specimens Produced

Table A4.1 Split Tensile Strength of Concrete Specimens Produced With 0% Cereal Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
0% Cereal flour at 1st Day	W1 = 2.22	5.0	0.5	
	W2 = 2.26	4.0	0.4	
	W3 = 2.22	6.0	0.6	0.64
	W4 = 2.40	8.0	0.8	
	W5 = 2.28	9.0	0.9	
0% Cereal flour At 3rd days	W1 = 2.32	7.0	0.7	
	W2 = 2.40	8.0	0.8	
	W3 = 2.22	8.0	0.8	0.78
	W4 = 2.22	1.0	1.0	
	W5 = 2.36	6.0	0.6	
0% Cereal flour at 7th days	W1 = 2.22	15.0	1.5	
	W2 = 2.32	10.0	1.0	
	W3 = 2.40	12.0	1.2	1.30
	W4 = 2.30	10.0	1.0	
	W5 = 2.34	18.0	1.8	
0% Cereal flour at 28th days	W1 = 2.28	21.0	2.1	
	W2 = 2.24	25.0	2.5	
	W3 = 2.46	20.0	2.0	2.02
	W4 = 2.42	15.0	1.5	
	W5 = 2.44	20.0	2.0	

Source: Laboratory Research Work (2016)

Table A4.2 Split Tensile Strength of Concrete Specimens Produced With 1% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
1% Maize flour at 1st Day	W1 = 2.34	10.0	1.0	0.82
	W2 = 2.42	8.0	0.8	
	W3 = 2.42	10.0	1.0	
	W4 = 2.38	8.0	0.8	
	W5 = 2.30	8.0	0.8	
1% Maize flour At 3rd days	W1 = 2.48	10.0	1.0	1.18
	W2 = 2.20	15.0	1.5	
	W3 = 2.18	12.0	1.2	
	W4 = 2.28	10.0	1.0	
	W5 = 2.48	12.0	1.2	
1% Maize flour at 7th days	W1 = 2.36	15.0	1.5	1.76
	W2 = 2.42	15.0	1.5	
	W3 = 2.26	20.0	2.0	
	W4 = 2.32	15.0	1.5	
	W5 = 2.44	23.0	2.3	
1% Maize flour at 28th days	W1 = 2.62	20.0	2.0	1.97
	W2 = 2.46	25.0	2.5	
	W3 = 2.44	15.0	1.5	
	W4 = 2.34	15.0	1.5	
	W5 = 2.30	24.0	2.4	

Source: Laboratory Research Work (2016)

Table A4.3 Split Tensile Strength of Concrete Specimens Produced With 2% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
2% Maize flour at 1st Day	W1 = 2.38	12.0	1.2	1.24
	W2 = 2.32	15.0	1.5	
	W3 = 2.44	10.0	1.0	
	W4 = 2.46	10.0	1.0	
	W5 = 2.44	15.0	1.5	
2% Maize flour At 3rd days	W1 = 2.54	15.0	1.5	1.50
	W2 = 2.40	15.0	1.5	
	W3 = 2.56	20.0	2.0	
	W4 = 2.36	10.0	1.0	
	W5 = 2.10	15.0	1.5	
2% Maize flour at 7th days	W1 = 2.30	18.0	1.8	1.90
	W2 = 2.50	16.0	1.6	
	W3 = 2.42	20.0	2.0	
	W4 = 2.24	20.0	2.0	
	W5 = 2.48	21.0	2.1	
2% Maize flour at 28th days	W1 = 2.54	30.0	3.0	2.10
	W2 = 2.36	25.0	2.5	
	W3 = 2.36	18.0	1.8	
	W4 = 2.50	15.0	1.5	
	W5 = 2.40	17.0	1.7	

Source: Laboratory Research Work (2016)

Table A4.4 Split Tensile Strength of Concrete Specimens Produced With 3% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
3% Maize flour at 1st Day	W1 = 2.32	15.0	1.5	1.38
	W2 = 2.40	10.0	1.0	
	W3 = 2.30	12.0	1.2	
	W4 = 2.42	12.0	1.2	
	W5 = 2.46	20.0	2.0	
3% Maize flour At 3rd days	W1 = 2.38	18.0	1.8	1.52
	W2 = 2.32	18.0	1.8	
	W3 = 2.42	15.0	1.5	
	W4 = 2.34	10.0	1.0	
	W5 = 2.42	15.0	1.5	
3% Maize flour at 7th days	W1 = 2.32	25.0	2.5	2.00
	W2 = 2.38	20.0	2.0	
	W3 = 2.40	15.0	1.5	
	W4 = 2.32	15.0	1.5	
	W5 = 2.52	25.0	2.5	
3% Maize flour at 28th days	W1 = 2.48	30.0	3.0	2.25
	W2 = 2.42	24.0	2.4	
	W3 = 2.36	16.0	1.6	
	W4 = 2.46	20.0	2.0	
	W5 = 2.52	23.0	2.3	

Source: Laboratory Research Work (2016)

Table A4.5 Split Tensile Strength of Concrete Specimens Produced With 4% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
4% Maize flour at 1st Day	W1 = 2.28	8.0	0.8	
	W2 = 2.22	8.0	0.8	
	W3 = 2.38	10.0	1.0	0.93
	W4 = 2.38	10.0	1.0	
	W5 = 2.56	11.0	1.1	
4% Maize flour At 3rd days	W1 = 2.44	15.0	1.5	
	W2 = 2.56	20.0	2.0	
	W3 = 2.44	12.0	1.2	1.51
	W4 = 2.46	10.0	1.0	
	W5 = 2.28	19.0	1.9	
4% Maize flour at 7th days	W1 = 2.38	20.0	2.0	
	W2 = 2.28	25.0	2.5	
	W3 = 2.00	12.0	1.2	1.92
	W4 = 2.94	14.0	1.4	
	W5 = 2.00	25.0	2.5	
4% Maize flour at 28th days	W1 = 2.20	15.0	1.5	
	W2 = 2.34	20.0	2.0	
	W3 = 2.36	25.0	2.5	2.02
	W4 = 2.32	20.0	2.0	
	W5 = 2.64	21.0	2.1	

Source: Laboratory Research Work (2016)

Table A4.6 Split Tensile Strength of Concrete Specimens Produced With 5% Maize Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
5% Maize flour at 1st Day	W1 = 2.40	12.0	1.2	1.10
	W2 = 2.26	9.0	0.9	
	W3 = 2.36	9.0	0.9	
	W4 = 2.34	12.0	1.2	
	W5 = 2.48	13.0	1.3	
5% Maize flour At 3rd days	W1 = 2.20	20.0	2.0	1.52
	W2 = 2.34	20.0	2.0	
	W3 = 2.46	15.0	1.5	
	W4 = 2.36	10.0	1.0	
	W5 = 2.48	11.0	1.1	
5% Maize flour at 7th days	W1 = 2.34	20.0	2.0	1.92
	W2 = 2.34	20.0	2.0	
	W3 = 2.20	15.0	1.5	
	W4 = 2.40	15.0	1.5	
	W5 = 2.14	26.0	2.6	
5% Maize flour at 28th days	W1 = 2.52	25.0	2.5	2.00
	W2 = 2.42	20.0	2.0	
	W3 = 2.40	15.0	1.5	
	W4 = 2.34	20.0	2.0	
	W5 = 2.33	20.0	2.0	

Source: Laboratory Research Work (2016)

Table A4.7 Split Tensile Strength of Concrete Specimens Produced With 1% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
1% Sorghum flour at 1st Day	W1 = 2.38	10.0	1.0	0.91
	W2 = 2.44	10.0	1.0	
	W3 = 2.36	8.0	0.8	
	W4 = 2.46	8.0	0.8	
	W5 = 2.46	10.0	1.0	
1% Sorghum flour At 3rd days	W1 = 2.22	15.0	1.5	1.44
	W2 = 2.36	12.0	1.2	
	W3 = 2.32	10.0	1.0	
	W4 = 2.32	15.0	1.5	
	W5 = 2.20	20.0	2.0	
1% Sorghum flour at 7th days	W1 = 2.60	18.0	1.8	1.90
	W2 = 2.48	18.0	1.8	
	W3 = 2.32	20.0	2.0	
	W4 = 2.36	20.0	2.0	
	W5 = 2.28	19.0	1.9	
1% Sorghum flour at 28th days	W1 = 2.40	20.0	2.0	2.06
	W2 = 2.40	18.0	1.8	
	W3 = 2.42	20.0	2.0	
	W4 = 2.40	20.0	2.0	
	W5 = 2.36	25.0	2.5	

Source: Laboratory Research Work (2016)

Table A4.8 Split Tensile Strength of Concrete Specimens Produced With 2% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
2% Sorghum flour at 1st Day	W1 = 2.48	9.0	0.9	0.96
	W2 = 2.44	10.0	1.0	
	W3 = 2.40	9.0	0.9	
	W4 = 2.30	10.0	1.0	
	W5 = 2.22	10.0	1.0	
2% Sorghum flour At 3rd days	W1 = 2.38	17.0	1.7	1.44
	W2 = 2.42	15.0	1.5	
	W3 = 2.36	15.0	1.5	
	W4 = 2.42	12.0	1.2	
	W5 = 2.30	13.0	1.3	
2% Sorghum flour at 7th days	W1 = 2.44	19.0	1.9	1.97
	W2 = 2.26	20.0	2.0	
	W3 = 2.48	20.0	2.0	
	W4 = 2.68	19.0	1.9	
	W5 = 2.52	21.0	2.1	
2% Sorghum flour at 28th days	W1 = 2.32	22.0	2.2	2.12
	W2 = 2.40	20.0	2.0	
	W3 = 2.42	24.0	2.4	
	W4 = 2.36	20.0	2.0	
	W5 = 2.42	20.0	2.0	

Source: Laboratory Research Work (2016)

Table A4.9 Split Tensile Strength of Concrete Specimens Produced With 3% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
3% Sorghum flour at 1st Day	W1 = 2.42	13.0	1.3	1.26
	W2 = 2.64	10.0	1.0	
	W3 = 2.38	15.0	1.5	
	W4 = 2.26	10.0	1.0	
	W5 = 2.24	15.0	1.5	
3% Sorghum flour At 3rd days	W1 = 2.22	20.0	2.0	1.63
	W2 = 2.24	18.0	1.8	
	W3 = 2.36	15.0	1.5	
	W4 = 2.30	15.0	1.5	
	W5 = 2.16	15.0	1.5	
3% Sorghum flour at 7th days	W1 = 2.42	20.0	2.0	2.2
	W2 = 2.40	25.0	2.5	
	W3 = 2.42	20.0	2.0	
	W4 = 2.28	22.0	2.2	
	W5 = 2.52	23.0	2.3	
3% Sorghum flour at 28th days	W1 = 2.38	25.0	2.5	2.25
	W2 = 2.36	22.0	2.2	
	W3 = 2.32	24.0	2.4	
	W4 = 2.36	20.0	2.0	
	W5 = 2.32	22.0	2.2	

Source: Laboratory Research Work (2016)

Table A4.10 Split Tensile Strength of Concrete Specimens Produced With 4% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
4% Sorghum flour at 1st Day	W1 = 2.36	10.0	1.0	1.19
	W2 = 2.52	12.0	1.2	
	W3 = 2.44	12.0	1.2	
	W4 = 2.46	13.0	1.3	
	W5 = 2.36	13.0	1.3	
4% Sorghum flour At 3rd days	W1 = 2.24	15.0	1.5	1.56
	W2 = 2.40	15.0	1.5	
	W3 = 2.48	20.0	2.0	
	W4 = 2.44	15.0	1.5	
	W5 = 2.46	13.0	1.3	
4% Sorghum flour at 7th days	W1 = 2.38	15.0	1.5	1.84
	W2 = 2.28	20.0	2.0	
	W3 = 2.38	20.0	2.0	
	W4 = 2.16	15.0	2.5	
	W5 = 2.50	22.0	2.2	
4% Sorghum flour at 28th days	W1 = 2.40	23.0	2.3	2.23
	W2 = 2.40	20.0	2.0	
	W3 = 2.32	20.0	2.0	
	W4 = 2.42	25.0	2.5	
	W5 = 2.42	25.0	2.5	

Source: Laboratory Research Work (2016)

Table A4.11 Split Tensile Strength of Concrete Specimens Produced With 5% Sorghum Flours

Sample	Weight(KN)	Failure load (KN/mm^2)	Split Tensile Strength (N/mm^2)	Average Split Tensile Strength (N/mm^2)
5% Sorghum flour at 1st Day	W1 = 2.32	10.0	1.0	1.20
	W2 = 2.46	14.0	1.4	
	W3 = 2.30	10.0	1.0	
	W4 = 2.14	14.0	1.4	
	W5 = 2.30	12.0	1.2	
5% Sorghum flour At 3rd days	W1 = 2.46	20.0	2.0	1.43
	W2 = 2.06	20.0	2.0	
	W3 = 2.32	15.0	1.5	
	W4 = 2.32	15.0	1.5	
	W5 = 2.40	13.0	1.5	
5% Sorghum flour at 7th days	W1 = 2.28	20.0	2.0	1.61
	W2 = 2.50	18.0	1.8	
	W3 = 2.36	15.0	1.5	
	W4 = 2.46	15.0	1.5	
	W5 = 2.48	10.0	1.0	
5% Sorghum flour at 28th days	W1 = 2.26	25.0	2.5	1.76
	W2 = 2.24	20.0	2.0	
	W3 = 2.30	18.0	1.8	
	W4 = 2.26	15.0	1.5	
	W5 = 2.24	10.0	1.0	

Source: Laboratory Research Work (2016)

Appendix A5

Abrasion Resistant of Concrete Specimens Produced

Table 5.1 Abrasion Resistance Result of Concrete Containing Maize Flour Specimen at 28 Days

SAMPLE	28 days				
	Weight before Brushing	Weight After Brushing	Difference	%	Average %
Control Mix	2182	2180	2	0.092	
	2362	2360	2	0.085	
	2220	2219	1	0.045	0.061
	2363	2362	1	0.042	
	2405	2404	1	0.042	
1% Maize	2245	2243	2	0.089	
	2543	2542	1	0.039	
	2331	2330	1	0.042	0.06
	2413	2411	2	0.083	
	2204	2203	1	0.045	
2% Maize	2224	2220	4	0.180	
	2440	2436	4	0.164	
	2394	2390	4	0.167	0.163
	2318	2314	4	0.173	
	2325	2322	3	0.129	
3% Maize	2171	2167	4	0.185	
	2288	2284	4	0.175	
	2285	2282	3	0.131	0.178
	2276	2271	5	0.220	
	2226	2222	4	0.180	
4% Maize	2339	2337	2	0.086	
	2352	2351	1	0.043	
	2264	2263	1	0.044	0.052
	2204	2203	1	0.045	
	2245	2244	1	0.045	
5% Maize	2268	2267	1	0.044	
	2195	2192	3	0.137	
	2223	2221	2	0.090	0.107
	2272	2269	3	0.132	
	2279	2276	3	0.132	

Source: Laboratory Research Work (2016)

Table 5.2 Abrasion Resistance Result of Concrete Containing Maize Flour Specimen at 56 Days

SAMPLE	56 days				
	Weight before Brushing	Weight After Brushing	Difference	%	Average %
Control Mix	2323	2322	1	0.043	
	2276	2275	1	0.044	
	2257	2256	1	0.044	0.043
	2372	2371	1	0.042	
	2405	2404	1	0.042	
1% Maize	2241	2240	1	0.045	
	2203	2202	1	0.045	
	2322	2321	1	0.043	0.044
	2206	2205	1	0.045	
	2367	2366	1	0.042	
2% Maize	2231	2230	1	0.045	
	2265	2264	1	0.044	
	2145	2143	2	0.093	0.054
	2231	2230	1	0.045	
	2268	2267	1	0.044	
3% Maize	2297	2296	1	0.044	
	2295	2294	1	0.044	
	2302	2301	1	0.043	0.122
	2295	2294	1	0.044	
	2293	2292	1	0.044	
4% Maize	2273	2272	1	0.044	
	2281	2280	1	0.044	
	2110	2109	1	0.047	0.054
	2243	2242	1	0.045	
	2276	2274	2	0.088	
5% Maize	2190	2188	2	0.091	
	2220	2218	2	0.090	
	2183	2182	1	0.046	0.064
	2167	2166	1	0.046	
	2206	2205	1	0.045	

Source: Laboratory Research Work (2016)

Table 5.3 Abrasion Resistance Result of Concrete Containing Sorghum Flour Specimen at 28 Days

SAMPLE	28 days				
	Weight before Brushing	Weight After Brushing	Difference	%	Average %
Control Mix	2182	2180	2	0.092	
	2362	2360	2	0.085	
	2220	2219	1	0.045	0.061
	2363	2362	1	0.042	
	2405	2404	1	0.042	
1% Sorghum	2252	2251	1	0.044	
	2148	2147	1	0.047	
	2165	2164	1	0.046	0.06
	2303	2302	2	0.087	
	2304	2303	1	0.043	
2% Sorghum	2306	2304	2	0.087	
	2263	2260	3	0.133	
	2299	2297	2	0.087	0.087
	2320	2319	1	0.043	
	2364	2362	2	0.085	
3% Sorghum	2261	2260	1	0.280	
	2276	2275	1	0.044	
	2244	2243	1	0.045	0.091
	2294	2293	1	0.044	
	2374	2373	1	0.042	
4% Sorghum	2340	2338	2	0.086	
	2316	2315	1	0.043	
	2280	2277	3	0.132	0.070
	2250	2249	1	0.044	
	2318	2217	1	0.045	
5% Sorghum	2253	2252	1	0.044	
	2174	2173	1	0.046	
	2205	2204	1	0.045	0.046
	2157	2156	1	0.046	
	2167	2166	1	0.046	

Source: Laboratory Research Work (2016)

Table 5.4 Abrasion Resistance Result of Concrete Containing Sorghum Flour Specimen at 56 Days

SAMPLE	56 days				
	Weight before Brushing	Weight After Brushing	Difference	%	Average %
Control Mix	2323	2322	1	0.043	
	2276	2275	1	0.044	
	2257	2256	1	0.044	0.043
	2372	2371	1	0.042	
	2405	2404	1	0.042	
1% Sorghum	2300	2299	1	0.044	
	2346	2345	1	0.047	
	2256	2255	1	0.046	0.053
	2294	2292	2	0.087	
	2322	2321	1	0.043	
2% Sorghum	2446	2444	2	0.082	
	2385	2384	1	0.042	
	2326	2325	1	0.043	0.068
	2344	2342	2	0.085	
	2291	2289	2	0.087	
3% Sorghum	2230	2229	1	0.045	
	2293	2292	1	0.044	
	2364	2363	1	0.042	0.052
	2240	2239	1	0.045	
	2331	2329	2	0.086	
4% Sorghum	2392	2391	1	0.052	
	2132	2131	1	0.057	
	2335	2334	1	0.053	0.055
	2246	2245	1	0.055	
	2176	2175	1	0.058	
5% Sorghum	2253	2252	1	0.044	
	2174	2173	1	0.046	
	2205	2204	1	0.045	0.046
	2157	2156	1	0.046	
	2167	2166	1	0.046	

Source: Laboratory Research Work (2016)

Appendix A6

Water Absorption of Concrete Specimens Produced

Table 6.1 Water Absorption Result of Concrete Containing Maize Flour Specimen at 28 Days

SAMPLE	28 days				
	Weight After Oven	Weight SSD	Difference	%	Average %
Control Mix	2091	2178	87	3.99	
	2263	2356	93	3.94	
	2129	2217	88	3.97	3.99
	2268	2360	92	3.89	
	2298	2398	100	4.16	
1% Maize	2110	2241	131	5.85	
	2404	2538	134	5.28	
	2210	2326	116	4.99	5.41
	2270	2408	138	5.73	
	2080	2194	114	5.20	
2% Maize	2100	2222	122	5.49	
	2394	2536	142	5.59	
	2257	2397	140	5.82	5.67
	2180	2315	135	5.84	
	2192	2322	130	5.61	
3% Maize	2047	2172	125	5.75	
	2153	2285	132	5.77	
	2162	2285	123	5.38	5.65
	2152	2275	123	5.40	
	2092	2224	132	5.95	
4% Maize	2229	2338	109	4.66	
	2253	2360	107	4.53	
	2184	2266	82	3.61	4.16
	2111	2205	94	4.26	
	2161	2245	84	3.74	
5% Maize	2176	2266	90	3.97	
	2191	2284	93	4.07	
	2131	2220	89	4.01	4.11
	2170	2261	91	4.03	
	2171	2273	102	4.47	

Source: Laboratory Research Work (2016)

Table 6.2 Water Absorption Result of Concrete Containing Maize Flour Specimen at 56 Days

SAMPLE	56 days				
	Weight After Oven	Weight SSD	Difference	%	Average %
Control Mix	2205	2320	115	4.94	
	2178	2272	94	4.13	
	2163	2252	89	3.93	4.48
	2259	2368	109	4.59	
	2269	2384	115	4.81	
1% Maize	2103	2236	133	5.95	
	2064	2200	136	6.18	
	2214	2318	104	4.49	5.61
	2077	2201	124	5.63	
	2224	2361	137	5.80	
2% Maize	2106	2236	130	5.80	
	2143	2277	134	5.87	
	2028	2158	130	6.02	5.83
	2092	2235	143	6.42	
	2161	2280	119	5.23	
3% Maize	2190	2299	109	4.75	
	2190	2300	110	4.77	
	2190	2318	128	5.53	4.88
	2200	2301	101	4.40	
	2185	2299	114	4.95	
4% Maize	2136	2338	109	4.66	
	2229	2360	131	5.53	
	2162	2266	104	4.61	4.96
	2089	2205	116	5.26	
	2139	2245	106	4.74	
5% Maize	2077	2186	109	4.97	
	2110	2219	109	4.93	
	2071	2178	107	4.91	4.80
	2059	2166	107	4.95	
	2109	2202	93	4.24	

Source: Laboratory Research Work (2016)

Table 6.3 Water Absorption Result of Concrete Containing Sorghum Flour Specimen at 28 Days

SAMPLE	28 days				
	Weight After Oven	Weight SSD	Difference	%	Average %
Control Mix	2091	2178	87	3.99	
	2263	2356	93	3.94	
	2129	2217	88	3.97	3.99
	2268	2360	92	3.89	
	2298	2398	100	4.16	
1% Sorghum	2123	2254	131	5.79	
	2032	2160	128	5.93	
	2048	2177	129	5.91	5.91
	2175	2314	139	5.99	
	2176	2313	137	5.93	
2% Sorghum	2174	2310	136	5.89	
	2136	2267	131	5.78	
	2176	2303	127	5.51	5.33
	2214	2324	110	4.73	
	2257	2369	112	4.74	
3% Sorghum	2254	2367	113	4.77	
	2154	2278	124	5.44	
	2129	2246	117	5.21	5.00
	2176	2296	120	5.23	
	2275	2378	103	4.35	
4% Sorghum	2220	2339	119	5.09	
	2206	2317	111	4.79	
	2153	2277	124	5.44	5.02
	2133	2250	117	5.21	
	2212	2318	106	4.57	
5% Sorghum	2124	2237	113	5.07	
	2048	2161	113	5.21	
	2091	2191	100	4.56	4.81
	2045	2146	101	4.71	
	2059	2156	97	4.50	

Source: Laboratory Research Work (2016)

Table 6.4 Water Absorption Result of Concrete Containing Sorghum Flour Specimen at 56 Days

SAMPLE	56 days				
	Weight After Oven	Weight SSD	Difference	%	Average %
Control Mix	2205	2320	115	4.94	
	2178	2272	94	4.13	
	2163	2252	89	3.93	4.48
	2259	2368	109	4.59	
	2269	2384	115	4.81	
1% Sorghum	2208	2310	102	4.41	
	2246	2360	114	4.83	
	2165	2270	105	4.61	4.67
	2201	2309	108	4.67	
	2217	2330	113	4.83	
2% Sorghum	2344	2459	115	4.67	
	2295	2399	104	4.34	
	2237	2341	104	4.46	4.48
	2254	2358	104	4.42	
	2201	2305	104	4.51	
3% Sorghum	2122	2232	110	4.91	
	2181	2295	114	4.95	
	2247	2368	121	5.11	4.99
	2140	2248	108	4.80	
	2214	2335	121	5.18	
4% Sorghum	2298	2396	98	4.10	
	2048	2135	87	4.06	
	2228	2323	95	4.09	4.07
	2243	2338	95	4.06	
	2091	2179	88	4.04	
5% Sorghum	2097	2182	85	3.90	
	2017	2112	95	4.50	
	2070	2158	88	4.08	3.85
	2112	2184	72	3.28	
	2077	2152	75	3.49	

Source: Laboratory Research Work (2016)