EFFECTS OF SUGAR AS RETARDER ON THE PROPERTIES OF CONCRETES MADE WITH SELECTED BRANDS OF PORTLAND CEMENT IN NIGERIA

By

AMINU ALHAJI MUSA

DEPARTMENT OF BUILDING

AHMADU BELLO UNIVERSITY, ZARIA

NIGERIA

DECEMBER, 2016

EFFECTS OF SUGAR AS RETARDER ON THE PROPERTIES OF CONCRETES MADE WITH SELECTED BRANDS OF PORTLAND CEMENT IN NIGERIA

By

Aminu Alhaji MUSA, B.Tech. (FUT, MINNA) 2006

P13EVBD8063

A DISSERTATION SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER DEGREE IN CONSTRUCTION TECHNOLOGY

DEPARTMENT OF BUILDING,
FACULTY OF ENVIRONMENTAL DESIGN
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

DECEMBER, 2016

DECLARATION

I declare that the work in this dissertation entitled "Effects of Sugar as Retarder on the Properties of Concretes Made with Selected Brands of Portland Cement in Nigeria" has been carried out by me in the Department of Building under the supervision of Prof. Magaji M. Garba and Dr. Dauda Dahiru Danwata. The information derived from the literature has been duly acknowledged in the text and list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other Institution.

Aminu Alhaji MUSA		
Name of Student	Signature	Date

CERTIFICATION

This dissertation entitled " EFFECTS OF SUGAR AS RETARDER ON THE PROPERTIES OF CONCRETES MADE WITH SELECTED BRANDS OF PORTLAND CEMENT IN NIGERIA" by Aminu Alhaji MUSA meets the regulations governing the award of the degree of Master of Science in Construction Technology of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Prof. Magaji M. Garba		
Chairman, Supervisory Committee	Signature	Date
Dr. Dauda D. Danwata		
Member, Supervisory Committee	Signature	Date
Dr. Dikko Kado		
Head of Building Department	Signature	Date
Prof. Kabiru Bala		
Dean School of Postgraduate Studies	Signature	Date

DEDICATION

This dissertation work is dedicated to my parents, Alhaji Musa Hussaini Garba and Hajiya Aishatu Musa and also my late grandparents, Alhaji Hussaini Kamba and Hajiya Khadijat Hussaini Kamba. May their gentle soul continues to rest in perfect peace ameen.

ACKNOWLEDGEMENT

All praise be to the almighty Allah for his infinite mercy and guidance throughout my period of study. May his peace and blessings be upon his messenger Muhammad (S.A.W.).

I wish to express my profound gratitude and appreciation to my supervisors: Prof. Magaji M. Garba and Dr. Dauda D. Danwata for their absolute guidance and contribution toward the accomplishment of this research work. My gratitude also goes to Dr. Dikko Kado (Head of Building Department), Prof. O. Godwin Okoli, Prof. Ikemefuna Mbamali, Prof. Ibrahim K. Zubairu, Prof. Kabir Bala, Dr. Isa H. Mshelgaru, Mal. Masʻud Mamman, Dr. Shehu Muhammad, Dr. Andrew M. Stanley, Mal. Khalil M. Ismaʻil, Dr. Dalhatu Abdulsalam, Dr. Jamilu Usman, Dr. S. Shika Aliyu, Mal. M. Mustapha Ibrahim, Mal. Mu'awiya, Mal. Buhari M. Manzuma and Mal. Zia-ul- haq M. Muhammad for the knowledge and moral advice given to me during the course of my study, may Almighty Allah (S.W.T.) bless them and their families ameen.

I would like to extend my appreciation to my parents, my wife, children and my entire family for their moral and financial support given to me throughout my period of study. I would sincerely wish to appreciate the assistance rendered to me by the Laboratory technician in Building Department Concrete Laboratory in persons of Alhaji Saidu Bomo, Mallam Abdulazeez and Alhaji Audi Shika. Finally, my acknowledgement goes to my friends Bldr Tukur Almustapha, Musa Pele, Bldr Ephraim Kaase Tersoo, Bashir Umar, Kabiru Muhammad, Murtala Hussaini Kamba and Alhaji Musa Mansur.

ABSTRACT

Hot weather, which is characterized by high ambient temperature and low relative humidity causes rapid setting of cement paste and difficulties during concreting. Admixtures that retard rapid setting of cement paste and modify workability of concrete are necessary to prevent fresh concrete from the adverse effects of hot weather. However, in Nigeria the retarding admixtures are imported and also expensive. Sugar a locally sourced admixture is another substitute that has been established to be a retarder, but its effects varies with the chemical composition of cement. This research therefore assessed the effects of sugar as retarder on properties of concretes made with selected brands of Portland cement produced in Nigeria. The concrete specimens were prepared by using 0%, 0.06% and 0.1% additions of sugar by weight of cement. A nominal mix of 1:2:4 with water cement ratio of 0.5 was used for the research. Setting time tests were performed at two different temperatures; at normal laboratory temperature of 27^{o}C and simulated hot ambient temperature of 43^{o}C (similar to that of Sokoto, Birnin Kebbi, Maiduguri, etc.). A total of 540 concrete cubes of size 100mm× 100mm × 100mm were produced, out of this number 360 cubes were used for compressive and split tensile strengths tests at 3, 7, 28 and 56 days curing periods. The remaining 180 cubes were also used for abrasion and water absorption test at 28 and 56 days curing periods. The results showed that the initial setting times of the control pastes made with cements A, B, C, D and E at 43^{o}C reduced by 45.94%, 40%, 38%, 24.73% and 51.85% respectively when compared with the control pastes at normal laboratory temperature of 27^{o}C. The reduction effects were completely eliminated by the addition of 0.1% and 0.06% of sugar in all the brands of cement at 43^{o}C. Thus, significant increase in initial setting times were recorded. Similar trends were observed for the final setting time in all the brands of cement. The results further revealed that the 0.06% addition of sugar had the best results in strengths tests of the specimens made with cements A, B and D therefore 0.06% proved to be

optimum dosage. On the other hand, 0.1% addition of sugar had the best results in strengths test of the specimens made with cement C which implies 0.1% as optimum dosage. However, cement E showed a decrease in strengths at every percentage additions of sugar at all the curing periods. The research concluded that the use of sugar as a retarding admixture in concretes made with the brands of cement enhanced the properties of concretes when an optimum dosage was used. It is recommended that, sugar can be used as retarder when concreting in hot dry weather regions in Nigeria, but should not be used as a retarding admixture in cement E brand.

TABLE OF CONTENTS

Chapter **page**

Cover page …… i

Title page …… ii

Declaration …….. iii

Certification …..... iv

Dedication ……..……v

Acknowledgement ……..…. vi

Abstract ……..……..vii

Table of Contents ……..……..…. ix

List of Figures ……xiii

List of Tables…….……xiv

List of Appendices …….…… xv

1.0 INTRODUCTION

1.1 Background of the Study ……...…… 1

1.2 Statement of Research Problem …….. 4

1.3 Justification of the Study ……...… 5

1.4 Aim and Objectives ……...… 5

1.5 Scope and Limitations ……..... 6

1.5.1 Scope …….……..…. 6

1.5.2 Limitations ……..……6

2.0 LITERATURE REVIEW

2.1 Admixtures …...……...……7

2.1.1 History of admixtures ….……..7

2.1.2 Chemical admixtures……..…… 8

2.2 Retarding Admixtures…….……11

2.2.1 Lignosulphonates…… 13

2.2.2 Hydroxycarboxylic acid salt …….…….……13

2.2.3 Phosphates……. ……13

2.2.4 Sugar……. …….……14

2.2.5 Benefit of retarding admixtures …….……14

2.2.6 General mechanism of retarding admixtures……..14

2.3 History of Sugar…….. …….…….. 15

2.3.1 Origin of sugar…….16

2.3.2 Chemical structures of sugar…….……..17

2.4 Sugar as a Retarding Admixture in Concrete……..…… 18

2.4.1 Retardation mechanism of sugar on cement hydration……. ……20

2.4.2 Effects of sugar as retarding admixture on the properties of fresh concrete…….21

2.4.3 Effects of sugar as retarding admixture on the properties of hardened concrete …..24

2.5 Climatic Problems in Concreting …….……..25

2.5.1 Hot weather concreting…….…….…….27

2.6 Cement…….....……..….31

2.6.1 Chemical composition of Portland cement……..31

2.6.2 Composition of cement clinker……32

2.6.3 Calculation of percentage of major compound ……..……34

2.6.4 Classification of Portland cement……35

2.6.5 Setting and hardening of cement…….…37

2.6.6 Fineness of cement……...…39

2.6.7 Soundness of cement……...39

3.0 EXPERIMENTAL PROGRAMME

3.1 Research Materials …….41

3.1.1 Cement …….…..41

3.1.2 Fine aggregates …….……...…41

3.1.3 Coarse aggregates …….……..41

3.1.Sugar (Admixture).. ……42

3.1.5 Water ……..42

3.1 Test Methods ……42

3.2.1 Preliminary tests of materials ……..……..……42

3.2.2 Production of concrete specimens ……..……44

3.2.3 Testing of fresh concrete ……...…….…….46

3.2.4 Curing of concrete specimens ……...…….47

3.2.5 Testing of hardened concrete samples 47

4.0 DATA PRESENTATIO, ANALYSIS AND DISCUSSION

4.1 Presentation of Results ……..... 50

4.2 Chemical and Physical Properties of Materials ……..…… 50

4.2.1 Chemical composition of ordinary Portland cement brands …… 50

4.2.2 Physical properties of materials ……..…….. 51

4.3 Effects of sugar on the cement paste and fresh concrete …… 53

4.3.1 Setting time test …… 53

4.3.2 Workability tests of fresh concrete ……..…… 55

4.4 Hardened properties of concrete specimens...……..…… 56

4.4.1 Compressive strength test …….. 56

4.4.2 Split tensile strength test …… 61

4.4.2 Abrasion resistance test …… 63

4.4.3 Water absorption test ……..…… 65

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings …… 67

5.2 Conclusion ……..…….. 68

5.3 Recommendations …….. 69

5.3.1 Recommendations …… 69

5.3.2 Recommendations for further studies …… 69

5.4 Contribution to Knowledge …… 70

REFERENCES …… 71

APPENDICES …….. 77

LIST OF FIGURES

Figure 4.1 Relationship between the Compressive Strengths of the Brands of Cement and Percentage Addition of Sugar at 3 days Curing Periods …… ...…… 57

Figure 4.2 Relationship between the Compressive Strengths of the Brands of Cement and Percentage Addition of Sugar at 7 days Curing Periods ……...……..… 58

Figure 4.3 Relationship between the Compressive Strengths of the Brands of Cement and Percentage Addition of Sugar at 28 days Curing Periods ……..…… 60

Figure 4.4 Relationship between the Compressive Strengths of the Brands of Cement and Percentage Addition of Sugar at 56 days Curing Periods ……..…… 61

Figure 4.5 Relationship between the Split Tensile Strengths of the Brands of Cement and Percentage Addition of Sugar at 28 days Curing Periods …..…… 62

Figure 4.6 Relationship between the Split Tensile Strengths of the Brands of Cement and Percentage Addition of Sugar at 56 days Curing Periods ……...…… 63

LIST OF TABLES

Table 2.1 Physical Requirements for Retarding Admixture……..12

Table 2.2 Approximate Oxide Composition of Ordinary Portland Cement……. 32

Table 2.3 Composition of Cement Clinker ……. 32

Table 2.4 Typical Average values of Compound Compositions of Portland Cements ….35

Table 4.1 Percentage Composition of Chemical Constituents of Cement Brands …..… 50

Table 4.2 Fineness Test for the Cement Brands ……. 51

Table 4.3 Sieve Analysis of Fine Aggregates ……. 52

Table 4.4 Bulk Density and Specific Gravity of Materials ……. 53

Table 4.5 Comparison of the Setting Time of Cement Brands with Percentage Addition of Sugar at Two Different Temperatures ……..…….. 55

Table 4.6 Slump and Compacting Factor Tests of the Fresh Concrete ……..…...56

Table 4.7 Relationship between Abrasion Resistance of Concrete Specimens made with Brands of Cement and Percentage Addition of Sugar at 28 days Curing Period …… 64

Table 4.8 Relationship between Abrasion Resistance of Concrete Specimens made with Brands of Cement and Percentage Addition of Sugar at 56 days Curing Period …… 64

Table 4.9 Relationship between Percentage Water Absorption of Concretes Made with Brands of Cement and Percentage Addition of Sugar at 28 days Curing Period……65

Table 4.10 Relationship between Percentage Water Absorption of Concretes Made with Brands of Cement and Percentage Addition of Sugar at 56 days Curing Period……..66

LIST OF APPENDICES

Appendix A1: Percentage Composition of Chemical Constituents of Cement A Brand……...…….……...78

Appendix A2: Percentage Composition of Chemical Constituents of Cement B Brand……...…….……...79

Appendix A3: Percentage Composition of Chemical Constituents of Cement C Brand……....…….……...80

Appendix A4: Percentage Composition of Chemical Constituents of Cement D Brand……...…….……...81

Appendix A5: Percentage Composition of Chemical Constituents of Cement E Brand…… ……...82

Appendix B1: Relationship between Compressive Strengths of Concrete made with Brands of Cement and Percentage Addition of Sugar at 3 days Curing Period…….83

Appendix B2: Relationship between Compressive Strengths of Concrete made with Brands of Cement and Percentage Addition of Sugar at 7 days Curing Period…….83

Appendix B3: Relationship between Compressive Strengths of Concrete made with Brands of Cement and Percentage Addition of Sugar at 28 days Curing Period…….84

Appendix B4: Relationship between Compressive Strengths of Concrete made with Brands of Cement and Percentage Addition of Sugar at 56 days Curing Period…….84

Appendix C1: Relationship between Split Tensile Strengths of Concrete made with Brands of Cement and Percentage Addition of Sugar at 3 days Curing Period…..……..85

Appendix C2: Relationship between Split Tensile Strengths of Concrete made with Brands of Cement and Percentage Addition of Sugar at 7 days Curing Period……..…..85

Appendix C3: Relationship between Split Tensile Strengths of Concrete made with Brands of Cement and Percentage Addition of Sugar at 28 days Curing Period……..…..86

Appendix C4: Relationship between Split Tensile Strengths of Concrete made with Brands of Cement and Percentage Addition of Sugar at 56 days Curing Period……...86

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Concrete is a heterogeneous material which consists of a chosen mixture of binding materials such as lime or cement, well graded fine and coarse aggregates, water and admixtures to produce concrete with special properties (Duggal, 2008). Khan (2006) opines that concrete is the most widely used construction material in the world and has gained a unique place in the construction industry. The most important characteristics of fresh and hardened concrete are workability, setting time, rate of strength development, ultimate strength, durability and impermeability of the concrete. The desired properties of fresh and hardened concrete can often be economically achieved through proper mixing of the ingredients, placing, and compacting. However, there are instances where the aforementioned properties may be adversely affected during the production of the concrete due to hot weather effect (Khan, 2006).

Furthermore, Okereke (2003) noted that extreme North East and North Western parts of Nigeria such as Maiduguri, Yola, Sokoto, Birnin kebbi etc. are categorized as hot dry regions with temperature which ranges between 35 to 43^{o}C with the low relative humidity of 40%. According to ACI 305R (1991) hot weather is any combination of high air temperature, low relative humidity, wind velocity, and solar radiation tending to impair the quality of fresh or hardened concrete. Also, Neville and Brooks (2010) defined hot weather concreting as concreting at an atmospheric temperature above 35^{o}C. BS 8110-1 (1997) specifies that the maximum temperature for placing concrete should not exceed 30^{o}C.

Therefore, to achieve good properties of concrete it depends upon the climatic conditions under which concrete is produced. High temperature is one of the important factors that adversely affects setting times, ultimate strength and durability of cement concrete (Khan, 2006). In addition, Suryawanshi *et al.* (2014) noted that another effect of hot weather concreting is the problem of cold joint which is a plane of weakness in concrete caused by an interruption, delay and rapid loss of workability in the fresh concrete. It occurs when the first batch of concrete has begun to set as a result of rapid evaporation of mix water before the next batch is added, so that the two batches do not intermix. A more serious problem associated with a cold joint is the possibility of moisture intrusion into the concrete section (Rathi and Kolase, 2013). But, Rana (2014) noted that it is more practical and economical to achieve such desired properties in concrete by adding extra materials such as admixture to the basic concrete making materials during the process of concrete production. Thus, retarder admixtures are used to slow down the speed of the reaction between cement and water by affecting the growth of the hydration products and reducing the rate of water penetration to the cement particles (Myrdal, 2007).

Alsadey (2013) defined retarder admixture as a type of chemical admixture that delays the initial rate of reaction between cement and water and hence, retards the setting time of concrete and also lengthens the setting time and workability retention. It is particularly important for concreting in hot weather. A retarding admixture holds back the hydration process, leaving more water for workability and allowing sufficient time for the concrete to be placed, compacted and finished. Also, it stop the rapid set shown by tricalcium aluminate which causes false set of the cement paste (Abalaka, 2011b).

Sugar (sucrose) is a very efficient retarder admixture which is capable of delaying or prolonging the setting of cement paste in concrete (Gupta and Gupta, 2004). The use of

sugar as a retarder admixture also, slow down the chemical process of hydration, so that concrete may remain in plastic state and workable for longer period (Suryawanshi *et al.*, 2014). The mechanism of function of sugar as a retarding admixture is that its retardation arises from the adsorption of sugar molecules on to the surfaces of growing particles of hydrating products (calcium silicate hydrate) and hence the hydration process slows down (Khan and Ullah, 2004). Due to the slow in hydration process the cement paste remains in plastic state for a longer time. Moreover, Greesan *et al.* (2014) states another mechanism of precipitation theory that the sugar increases the concentrations of calcium, aluminum and iron in concrete. The sugar molecules combine with these metals to form insoluble chemical complexes that coat the cement grains. Several key chemical processes that harden the concrete are then impeded. Hydration process is slow down and therefore, the concrete takes longer to set. For this reason, refined sugar is known as one of the best retarder (Greesan *et al.*, 2014).

Abalaka (2011a) noted that sugar content of 0.06% by weight of cement can improve compressive strength of concrete by 3.62% as compared with control at 28 days and delay initial setting time by 1.556 hours (94 minutes). No adverse effect on concrete and cement paste have been observed at this level of sugar concentration for the age of 28days curing period. In addition, Rana (2014) found that 0.1% of sugar by weight of cement delays both the setting times and also shows around 4% increase in compressive strength, but above 0.13% by weight of cement accelerated the setting time of cement paste. Shetty (2009) opines that when sugar is added to concrete mix in a careful controlled manner (about 0.05% to 0.1% by weight of cement), the setting time of the mix will be delayed by about 4hours. However, Shetty (2009) asserted that the exact effects of sugar as retarding agent on concrete mix depends on the chemical composition of cement. Furthermore, research conducted by Khan and Baradan (2002) in Pakistan on three

different types of cement under the same curing condition (namely; PKC/A42.5 cement, PKC/B32.5 cement and PC 42.5 cement), the findings revealed that 0.8% sugar content acted as an optimum sugar content for retarding the setting of PKC/A42.5 cement, 0.1% for PKC/B32.5 cement and 0.2% for PC42.5 cement. This means the retardation effects of sugar in concrete depends on the brand of OPC used. Hence, this research work assessed the effects of sugar as retarder on the properties of concretes made with selected brands of Portland cement in Nigeria.

1.2 Statement of Research Problem

As highlighted by Okereke (2003) the extreme North West and North Eastern parts of Nigeria are considered as hot dry zones in Nigeria with approximate maximum mean ambient temperature of 43^{o}C and low relative humidity of 45%. Alsadey (2013) opines that hot weather causes rapid setting of cement paste and difficulties during concreting. Admixtures that retard rapid setting of cement paste and modify workability of concrete are necessary. However, in Nigeria the retarder admixtures are imported and also expensive. Sugar is another substitute that has been established to be a retarding admixture (Rathi and Kolase, 2013), but its effects varies with the chemical composition of cement (Neville and Brooks, 2010). Because, cement with low tricalcium aluminate (C_3A) and alkali contents are easier to retard compared to cement with large amounts of these constituents (Myrdal, 2007). One explanation might be that at lower C_3A contents, smaller amounts of retarder are adsorbed, leaving larger amounts of the admixture to affect and retard the hydration of the C_3S component. In line with this, the research question arise, which brand of cement in Nigeria can give an optimum results when sugar is used as admixture in it? Therefore, research needs to be carried out on selected brands of cement in Nigeria to ascertain the best cement brand to be used so as to achieve effectiveness in terms of setting as well as desirable strength results.

1.3 Justification of the study

The use of sugar to retard the rapid setting of cement paste and to modify the workability of fresh concrete at construction site seems reasonable as it is cheap and readily available as compared to other retarding admixtures (Rana, 2014). Thus, the need for proper guide for its use as admixture in concrete becomes necessary due to the fact that its retarding effect depends on the type of cement brand used in the concrete production (Dransfield, 2012). The results of this research work could provide some basic information to professionals in construction industry on the best and appropriate cement brand as well as the optimum dosage of sugar to be used as a retarding admixture when concreting in hot dry regions in Nigeria. Another importance of this study is to improve the quality of concrete produce in hot weather regions in Nigeria. This could be attained by using sugar as retarding admixture in concrete during the production stage of concrete so that to prevent it from adverse effects of high temperature.

1.4 Aim and Objectives

1.4.1 Aim

The aim of this research is to assess the effects of sugar as retarder on the properties of concretes made with selected brands of Portland cements with a view to establishing its effectiveness in retardating setting time of cement.

1.4.2 Objectives

The specific objectives are:

1. To determine the chemical composition of the different brands of Portland cement.
2. To assess the effects of sugar on the setting times of the different brands of the cement at two different temperatures of 27^{o}C and 43^{o}C.

3. To determine both the fresh and hardened properties of concretes made with the different brands of cements and sugar as retarding admixture.
4. To ascertain an optimum dosage of sugar as an admixture in concretes made with the different brands of cement.
5. To compare the properties of concretes made with the different brands of cement and sugar as retarding admixture.

1.5 Scope and Limitations

1.5.1 Scope

The research focused on the effects of sugar as retarder on the properties of concretes made with selected brands of Portland cement in Nigeria. The five different brands of cement selected for the research were; Ashaka, Bua, Dangote, Elephant and Sokoto cements. The cement brands were chosen because they are the ones readily available in the Northern parts of Nigeria.

The tests carried out in order to achieve the objectives of this research includes; workability test, setting time test, density test, compressive strength test, split tensile test, abrasion test and water adsorption test and the percentage addition of sugar were 0%, 0.06% and 0.1% by weight of cement. The setting time tests were performed at two different temperatures; at normal laboratory temperature of 27^{o}C and at an oven temperature of 43^{o}C−approximate maximum ambient temperature for Sokoto, Birnin Kebbi, Maiduguri, Yola etc.

1.5.2 Limitations

The hardened concretes were not subjected to the temperature of 43^{o}C, they were prepared at treated normal room temperature of 27^{o}C. Other properties such as shrinkage, durability index, water content and elastic properties were not checked due to equipment constraints.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Admixtures

Admixtures are the materials other than the standard combination of Portland cement, water and aggregates which are added to concrete to improve its properties. Some of these properties are workability, strength, and rate of setting, frost resistance, impermeability and colour (Oladiran *et al*., 2012). According to Adefemi *et al.,* (2013) admixtures are used to enhance the properties of concrete and mortar in the plastic and hardened state. These properties may be modified to increase compressive and flexural strength at all ages, decrease permeability and improve durability, reduce shrinkage, accelerate or retard initial set, increase slump and workability, improve pumpability and finishability, increase cement efficiency, and improve the economy of the mixture.

Shetty (2009) asserted that concrete is being used for wide varieties of purposes to make it suitable in different conditions. In these conditions ordinary concrete may fail to exhibit the required performance or durability. In such cases, admixture is used to modify the properties of ordinary concrete so as to make it more suitable for any situation. Furthermore, an admixture should be employed only after an appropriate evaluation of its effects on concrete. A degree of control must also be exercised to ensure proper quantity of admixture in concrete production (Shetty, 2009).

2.1.1 History of admixture

History has shown that admixture is as old as concrete itself. The Romans used animal fat, milk, and blood to improve their concrete properties. Although these were added to improve workability, blood was a very effective air-entraining agent and might well have improved Roman concrete durability, the Chinese used polished glutinous, rice paste and

boiled bananas and the Persians used cactus juice and latex from rubber plants. In more recent times, calcium chloride was often used to accelerate the hydration of cement. The systematic study of admixtures began with the introduction of air-entraining agents in the 1930s, when it was accidentally found that cement ground with beef tallow (grinding aid) had more resistance to freezing and thawing than a cement ground without beef tallow (Li, 2011).

In addition, Shetty (2009) noted that admixture embraces a very vast field in area of construction. Water reducers generally referred as plasticizers, retarders and superplasticizers are of recent interest. They are specifically developed in Japan and Germany around 1970. Later on, they were made popular in USA and Europe even in Middle East. Nowadays, admixtures are important and necessary components for modern concrete technology. The concrete properties, both in fresh and hardened states, can be modified or improved by admixtures. However, it will be slightly difficult to predict the effects and the results of using admixtures because, many a times, the change in the brand of cement, aggregate grading and mix proportions alters the properties of concrete.

2.1.2 Chemical admixtures

According to ASTM C494 (1999) chemical admixtures are any chemical additives to the concrete mixture that enhances the properties of concrete in the fresh or hardened state. The general purpose chemicals include those that reduce the water demand for a given workability which are called water reducers, and those chemicals that control the setting time and strength gain rate of concrete are called accelerators and retarders. According to ASTM C494 (1999) chemical admixtures are categorized as Type A- water reducing admixture, Type B- retarding admixture, Type C- accelerating admixture, Type D- water-reducing and retarding admixture, Type E water- reducing and accelerating admixture,

Type F- water- reducing, high range admixture, Type G water- reducing, high range and retarding and Type S- specific performance admixture.

2.1.2.1 Water reducing admixtures

Water reducing admixtures are sometimes called plasticizer admixtures these types of chemical admixtures are used in concrete to reduce the water content of the mix, usually by 5 to 10%, sometimes (in concrete of very high workability) up to 15%. Thus, the purpose of using a water reducing admixture in a concrete mix is to allow a reduction in the water cement ratio while retaining the desired workability or, alternatively, to improve its workability at a given water cement ratio. The actual reduction in water depends on dose of admixtures, cement content and type of aggregate used (Li, 2010). The reasons for using water reducing admixtures as specifies by Neville and Brooks (2010) are to:

1. Achieve a higher strength by reducing water/cement ratio at the same workability.
2. Increase the workability of concrete so as to ease placing in inaccessible location. This is particularly useful when concrete pores are restricted either due to congested reinforcement or due to thin sections.
3. Save in the quantity of cement (approx. up to 10%) can be achieved keeping the same water/ cement ratio and workability.

2.1.2.2 Retarding admixtures

This type of chemical admixtures capable of delaying or prolonging the setting of cement paste, thus concrete remains plastic and workable for a longer time than normal concrete without changing its mechanical properties. It is also used to overcome the accelerating effect of hot weather on setting time of concrete. It functions by coating the surface of tricalcium silicate (C_3S) components, thus delaying this reaction with the water (Greesan *et al.,* 2014).

2.1.2.3 Accelerating admixtures

These admixtures when added to concrete or mortar increases the rate of hydration of hydraulic cement, shortens the time of set, and accelerates the hardening or development of strength of concrete or mortar. Accelerating admixtures function by interaction with tricalcium silicate (C_3S) component of the cement thus increasing the reaction between cement and water. The reasons for using accelerating admixtures are to:

1. Shortens the setting time of cement and therefore increases the rate of gain of strength.
2. Enables earlier removal concrete formwork thus speeding production.
3. Reduces segregation and increase density and compressive strength.
4. Reduces water requirements, bleeding, shrinkage and time required for initial set.

2.1.2.4 Superplasticizer admixtures

Superplasticizer admixtures are also called high range water reducers. The use of super plasticizers can permit the reduction of water in the concrete mix up to 30% without producing any ill effect on the workability of the concrete. The reasons for using Super plasticizer admixtures as specifies by Gupta and Gupta (2012) are:

1. To produce more workable concrete than the concrete without super plasticizer at the same water/cement ratio
2. For the same workability, water-cement ratio can be reduced significantly keeping same cement content and workability. This will lead to increase in strength
3. The use of super plasticizer also permits the reduction in cement content to a greater extent keeping the same water/cement ratio. This will lead to economy.

2.2 Retarding Admixtures

The rates of cement hydration reactions can be influenced by chemicals added to the cement-water mix. Retarding admixtures are types of chemical admixtures affecting these reactions to produce a delay in the process of cement paste stiffening (Myrdal, 2007). Retarders 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. The use of a retarder will increase the setting time and the early strength may be reduced but the ultimate strength of the concrete can be improved (EFCA, 2005). Some retarders might have other characteristics as well, like water reduction properties at a wide range of dosages for example sugar (Greesan *et al.,* 2014) and also lignosulphonates (Ramachandran, 1999).

According to ASTM C 494 (1999) categorized such retarders as Type B which have set-retarding properties, and are used widely under hot weather conditions. Thus, they can be classified as both retarding and water reducing admixtures. Since the rate of stiffening of concrete can be too fast in hot weather conditions, sufficient time for the concrete is required for transportation and placement before setting. In such conditions retarding admixtures can be very useful. Retardation in setting time up to 8-10 hours is possible by suitable use of retarders. ASTM 494 (1999) specifies the physical requirements retarding admixture (Type B) as given in table 2.1

Table 2.1 Physical Requirements for Retarding Admixture

Property	Requirements
Setting time, allowable deviation from control	Initial : at least 1hour later no more than 3:30min later Final: at least…… no more than 3:30min. later
Compressive strength min % control	3 days: 90 7 days: 90 28 days: 90 6 months: 90 1 year: 90
Flexural strength min % control	3 days : 90 7 days: 90 28 days: 90
Length change, max. Shrinkage (max.) % of control	135
Increase over control	0.010
Relative durability factor min	80

Source: ASTM C494 (1999)

According to Myrdal (2007) retarding admixtures can be divided in several categories based on their chemical composition. The main ingredients of retarders are as follows:

1. Lignosulphonates acids and their salts
2. Hydroxycarboxylic acids and their salts
3. Carbohydrates (sugar).
4. Inorganic compounds such as phosphates.

2.2.1 Lignosulphonates

Lignosulphonates may vary from unrefined sodium and calcium salts of lignosulphonic acids to refined sugar-free lignosulphonates, or even modified versions blended with small amounts of alkanolamines to compensate for set retardation (Ramachandran, 1999). These types of retarding admixtures contains 30% of carbohydrates (reducing sugars) and this makes them not efficient in terms of retarding of cement paste (Myrdal, 2007).

2.2.2 Hydroxycarboxylic acid salts (Fruit acid)

Hydroxycarboxylic acids and their salts have chemical properties related to those of sugars, and some of them promote retardation of cement hydration in the same way as sugars do (Ramachandran, 1999). But, the drawback of these retarding admixtures as opined by Dransfield (2012) is that, they reduce cohesion in the mix potentially enhancing bleeding and segregation of the concrete. Hydroxycarboxylic acids are characterized by carboxyl groups and hydroxyl groups which interact with the cement. The best hydroxycarboxylic based retarders are found among the α-hydroxycarboxylic acids (with a hydroxyl group adjacent to the carboxyl group). Salts of hydroxycarboxylic acids were developed as retarders in the 1950s. The chemical structure of typical hydroxycarboxylic acids that are efficient set retarders for cement. Salicylic acid, a phenolic carboxylic acid, has been used as a model compound to study the interaction between cement and hydroxycarboxylic acids (Dransfield, 2012).

2.2.3 Phosphates

Phosphates are the types of inorganic retarding admixtures. Most phosphates retard the setting of cement by precipitation mechanism. For example, the adsorption of phosphate ions at the surface of the clinker phase, or on the first hydration product, is thought to result in the precipitation of Ca- phosphates. Because once insoluble and dense coatings

are formed around the cement grains, further hydration slows down considerably, thus the setting of cement paste is retarded (Myrdal, 2007). According to Dransfield (2012) retarding admixtures based on phosphates are designed to have a more linear effect of dosage upon setting time. The dosage rate used may be quite high than other retarders and the typical dosage of 0.1 to 3.0% by weight of cement is require to yield a significant results in retardation of cement paste.

2.2.4 Sugar

Refined white sugar (sucrose) is one of the best retarding admixture that can be used as water- reducing and set- retarder admixture (Greesan *et al.,* 2014). They are capable of reducing the required mixing water by up to 15 percent without affecting the workability of the mix. This results in a higher strength concrete with lower shrinkage.

2.2.5 Benefits of retarding admixtures

According to Schaeffel *et al*. (2014) retarders are used to delay the setting of concrete:

1. to offset the accelerating effect of hot weather instead of expensive cooling
2. for long transport distances
3. when difficult or unusual condition of placement occur.

And also, when casting massive concrete structures:

1. to avoid construction joints or lack of bond between concrete layers
2. to reach a uniform strength developments
3. to reduce the maximum hydration heat (lower the risk of cracking).

2.2.6 General mechanisms of retarding admixtures

The mechanisms of action of retarding admixtures in cement-water systems are described by four different types of interaction between the retarder and the cement grains. Most

retarders act by more than one of these mechanisms (Myrdal, 2007). These mechanisms are as follows:

1. Adsorption: the admixture molecules are adsorbed on the surface of cement particles which hinders further reactions between cement and water, thus setting of cement paste is retarded (Gadzama *et al.,* 2015).
2. Complexation: the admixture makes complexes with calcium ions that is liberated by hydration and thereby enhancing the early hydration sheath that surrounds the cement grains.
3. Precipitation: the admixture reacts with one or more components of the cement to form a precipitate on the cement particles, imparting a low- permeability coating on the cement particles and forming a protective skin which slows down the hydration. This retard the setting of cement paste (Khan and Baradan, 2002).
4. Nucleation: adsorption of retarding compound on the nuclei of calcium hydroxide which defers the growth which is necessary for the hydration process. By this reason the setting time of concrete is retarded (Greesan *et al.,* 2014).

2.3 History of Sugar

Sugar is sucrose, a carbohydrate an organic compound commonly known as table sugar. The molecules of sugar is a disaccharide that is composed of one glucose unit and one fructose unit joined together by a chemical bond with the molecular formula of $C_{12}H_{22}O_{11.}$ Sucrose is found naturally in fruits and vegetables, but in the highest quantities in sugar beets and sugar cane. Duna (2014) asserted that the word sucrose was coined in 1857 by the English chemist William Miller from the French word sucre means sugar and the generic chemical suffix for sugars-ose. The abbreviated term Suc is often used for sucrose in scientific literature.

2.3.1 Origin of sugar

Sugar (sucrose) is found in the stems of sugar cane and roots of sugar beet. It also occurs naturally alongside with fructose and glucose in other plants, in particular fruits and some roots such as carrots. The different proportions of sugars found in these foods determine the range of their sweetness. The molecules of sucrose is formed by the combination of a molecule of fructose with a molecule of glucose.

2.3.1 Sugarcane

Sugarcane (saccharum spp) is a perennial grass in the family of poaceae. It is cultivated in tropical and sub-tropical regions for the sucrose that is found in its stems. It requires a frost-free climate with sufficient rainfall during the growing season to make full use of the plant's great growth potential. The crop is harvested mechanically or by hand, chopped into lengths and conveyed rapidly to the processing plant. Here, it is either milled and the juice extracted with water or extracted by diffusion. The juice is then clarified and heated to kill enzymes. The resulting thin syrup is concentrated in a series of evaporators, after which further water is removed by evaporation in vacuum containers. The resulting supersaturated solution is seeded with sugar crystals and the sugar crystallizes out, is separated from the fluid and then dried. Molasses is a by-product of the process and the fibre from the stems known as bagasse is burned to provide energy for the sugar extraction process. The crystal of raw sugar have a sticky brown coating and either can be used as they are or can be bleached by sulphur dioxide or can be treated in a carbonatation process to produce a white product.

Sugar is extracted from sugarcane by the process of mill extraction. Mills extract raw sugar from freshly harvested cane and mill-white sugar is sometimes produced immediately after the stage at sugar- extraction mills. Sugar crystals appear naturally in

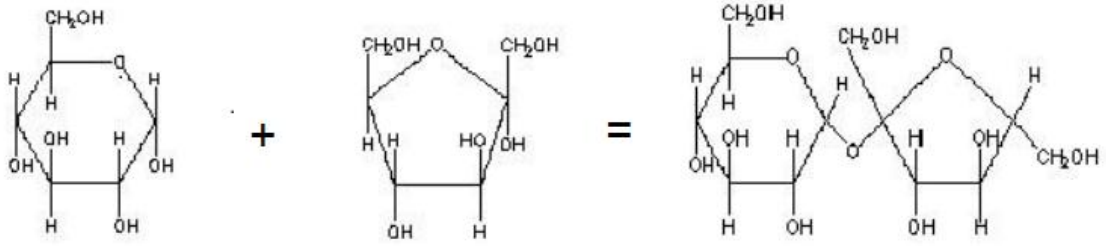
white colour during the crystallization process. Sulphur dioxide id added to inhibit the formation of colour-inducing molecules as well as to stabilize sugar juice during evaporation.

2.3.2 Sugar beet

Sugar beet (Beta vulgaris) is abiennial plant in the family Amaranthaceae, the tuberous root of which contains a high proportion of sucrose (Duna, 2014). It is cultivated in temperate regions with adequate rainfall and requires a fertile soil. The crop is harvested mechanically in the autumn and crown of leaves and excess soil removed. The roots do not deteriorate rapidly and may be left in a clamp in the field for some weeks before being transported to the processing plant. Here the crop is washed and sliced and the sugar is extracted by diffusion. Milk of lime is added to the raw juice and carbonatated in a number of stages in order to purify it. Water is evaporated by boiling the syrup under a vacuum. The syrup is then cooled and seeded with sugar crystals. The white sugar that crystallizes out can be separated in a centrifuge and dried. It requires no further refining.

2.3.1 Chemical structures of sugar

Sugar is a carbohydrate, a substance composed of only carbon, oxygen and hydrogen. Sucrose, fructose, dextrose, lactose and other 'Oses' are members of this chemical class. It occurs in sugar cane and sugar beet. The basic unit of carbohydrate is a linear chain of four to seven carbon atoms with a hydoxyl group on each one, the terminal carbon being an aldehyde (Khan and Baradan, 2002). According to Myrdal (2007) the chemical structure of sugar (sucrose) is shown in Figure 2.1.



Glucose $C_6H_{12}O_6$ Monosaccharide

Fructose $C_6H_{12}O_6$ Monosaccharide

Sucrose $C_{12}H_{22}O_{11}$ Disaccharide

Figure 2.1 Chemical structures of sucrose (table sugar).

2.4 Sugar as a Retarding Admixture in Concrete

Sugar is a carbohydrate, a substance composed of only carbon, oxygen and hydrogen. Fructose and glucose, are members of this chemical class. It normally occurs in sugar cane and sugar beet and with the chemical structure of $C_{12}H_{22}O_{11}$ and sugar, which has five members ring, is classified as non - reducing sugar (Khan and Baradan, 2002). Sugar (sucrose) is very efficient retarder admixture used in concrete. According to Gupta and Gupta (2012) for retarding effect, the dosage of sugar as a retarder ranges between 0.05 to 0.15% by weight of cement will delay the rapid setting of cement paste for 4hours and the early strength of concrete is also reduced but the 28 days strength improves. However, the exact effect of the sugar depends greatly on the chemical composition of cement (Neville and Brooks, 2010). A large quantity of sugar, say 0.2 to 1.0% of the weight of cement will virtually prevent the setting of cement, thus trial test should be carried out to determine the optimum dosage of sugar to be used as retarder.

Jayakumaran (2005) opines that the use of sugar as retarder in concrete can reduce the early strength of concrete, but beyond 7 days an increase in strength of several per cent has been observed in comparison to a non- retarded concrete mix. This probably could be due to the fact that delayed setting produces a denser cement gel and also Kumar (2015) opines that the reason for improvement of strength was bonding within the concrete. Sugar had good bonding

property. However, Myrdal (2007) states that not all sugars retard cement hydration. The reducing sugars are moderate retarders, while the non-reducing sugars are very efficient retarders depending on their chemical structures. The different groups of sugars are as follows:

2.4.1 Reducing Sugars

1. Glucose
2. Fructose
3. Maltose (malt sugar)
4. Lactose (milk sugar).

2.4.2 Non reducing Sugar

1. Sucrose (composed of glucose and fructose)
2. Trehalose (composed of two glucose units)
3. Reffinose.

However, sugar (sucrose) can be an accelerating admixture in concrete at high dosage content. For example, Abalaka (2011b) undertaken a study on the comparative effects of cassava and sugar in cement mortar and concrete. The investigations revealed that sugar content at 0.6% by weight of cement accelerates the initial setting times of cement pastes to 54 minutes which is below the maximum time of 60 minutes requirement prescribed by BS EN 197-1: 1992. Similarly, Khan and Baradan (2002) investigated the effect of sugar on setting time of various types of cement. The results of the findings revealed that the setting time of cement was retarded by incorporation of sugar in cement under all conditions of curing. The extension in setting time was increasing with an increase in sugar content up to a certain limit (approximately 0.15%) and then started to drop with further increase in sugar content, accelerated the cement-setting when a higher sugar content (>0.3%) was used.

2.4.1 Retardation mechanism of sugar on cement hydration

Sugar causes cement set retardation by the following mechanisms:

1. Formation of complexes with calcium ions in solution, increasing their solubility and discouraging the formation of the nuclei of calcium hydroxide.
2. Precipitation around cement particles in this mechanism the sugar molecules reacts with one or more components of the cement to form a precipitate on the cement particles, imparting a low- permeability coating on the cement particles.

According to the first mechanism, when ordinary Portland cement is hydrated in sucrose solution, lime is solubilized and a sucrose calcium complex (R - O – Ca^{+} - OH) is formed in which Ca^{+} - OH group is attached to the five membered ring (R) of the sucrose molecule. Such sucrose–calcium complex will be able to become absorbed on the growing calcium hydroxide nucleus. The adsorption of the complex on the calcium hydroxide nucleus will inhibit its growth as the calcium and hydroxyl ions will not be able to precipitate and hence the hydration slows down. Due to the slow hydration, no considerable amount of the hydration products giving rigidity to the cement paste will be formed and thus the concrete remains plastic for a longer time. The reason is because formation of the complexes increase the solubility of cement, i.e., increased concentration of Ca^{2+} $^{-}$OH, Si, Al and Fe in the aqueous phase of the cement pastes when hydrated in the presence of the sugar. Thus the calcium ions and hydroxyl ions will accumulate in solution and will be unable to precipitate to form calcium hydroxide (Khan and Ullah, 2004).

According to the second mechanism, sugar interferes with the cement binding process in the concrete. A theory suggests that when concrete mixture contains sugar, the sugar molecules attach themselves to the hydrating cement and inhibit the chemical reactions

involved in stiffening the concrete and hence the setting of cement paste is retarded (Otunyo *et al.*, 2015). For this reason, sugar is known as a best retarder. Retarders increase the setting time of concrete. Refined white sugar is one of the best retarders (Greesan *et al.,* 2014). In addition, Giridhar *et al.* (2013) states another mechanism known as coating theory (adsorption) in this mechanism the sugar molecules are adsorbed on the surface of cement particles. This thin layer of sugar 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 thus the rate of hydration of tricalcium silicate (C_3A) is retarded, and the dormant period is lengthened (Ramachandran, 1999).

2.4.1 Effects of sugar as retarding admixture on the properties of fresh concrete

Fresh concrete or plastic concrete is a freshly mixed material which can be moulded into any 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 (Shetty, 2009). According to Giridhar *et al.* (2013) sugar as a retarding admixture has a significant effect on the properties of fresh concrete.

2.4.1.1 Workability

The workability of concrete is affected by many factors including initial slump, type and amount of cement, temperature, relative humidity and presence of chemical admixtures (Gupta and Gupta, 2004). Also, Neville and Brook (2010) defined workability as the amount of useful internal work necessary to produce full compaction. The useful internal work is a physical property of concrete alone and is the work or energy required to overcome the internal friction between the individual particles in the concrete.

Retarding admixtures like sugar allow a reduction in water content of the concrete without affecting its workability (Greesan *et al.*, 2014). The extent of reduction is even higher for

mixes with higher slump values. In fact the incorporation of a given dosage of a retarding admixture increased the slump by 30% (Maroliya, 2012). Also, Giridhar *et al.* (2013) investigated the effects of sugar and jiggery on the strength properties of concrete. The findings revealed that the workability increased by 50% at 0.1% addition of sugar as compared to the concrete sample. The compressive strength of concrete is enhanced by 12% at 28days. Alsadey (2013) pointed the good workability can be achieved by incorporating retarder in the concrete, which will delay the setting time and allow suitable compaction done without segregation. However, very high dosages of retarder admixture tends to impair the cohesiveness of concrete.

2.4.1.2 Segregation and Bleeding

Segregation refers to the separation of the mixture components due to the difference in their specific gravity and size, resulting in a nonuniform mixture. Bleeding is a particular form of segregation where some of the mixing water rises to the surface of the fresh mix. Bleeding increases the water cement ratio of the upper layer of concrete causing weakness, increased porosity and durability problems. However, limited bleeding is desirable because it allows the excess water to leave the fresh mix and protects against plastic shrinkage cracking. Finally, less bleeding takes place in mixes with low water cement ratio (Neville and Brooks, 2010).

According to Dransfield (2012) concretes containing sugar as a retarding admixture are more cohesive and therefore, less likely to experience segregation. The degree of bleeding however was found to depend on the type of retarder used. For a given slump value, retarding admixtures containing hydroxy-carboxylic acids were found to increase the rate of bleeding. The rate of bleeding is however reduced with non-reducing sugar and especially sucrose (sugar). The rate of bleeding of a particular retarder should be

investigated before using it in the field in order to prevent plastic cracks due to high rate of evaporation especially under hot and windy weather conditions (Ramachandran, 1999).

2.4.1.3 Setting times

Generally, retarding admixtures delay both initial and final setting time. The amount of retardation depends on the dosage of admixture used, the type of cement used, the amount of mixing water, and the temperature of the concrete (Greesan *et al.*, 2014). In addition, Dransfield (2012) the delay of setting time usually prevent the formation of cold joints between deliveried of concrete. Even if workability has fallen to almost zero slump, fresh concrete that has not actually set can be vibrated into, and will bond with the preceding older pour.

Abalaka (2011b) undertaken a study on the comparative effects of cassava starch and simple sugar in cement mortar concrete. The study showed that the initial and final setting times increased with sugar content of 0.05% by weight of cement and concluded that sugar increased compressive strength at 28days by 3.62% at sugar concentration of 0.06%. Rana (2014) determined the effects of sugar on setting time and compressive strength of ordinary Portland cement paste. The research concluded that sugar of 0.07% by weight of cement improved the compressive strength by 4% and also delays the initial setting of cement paste for 3hours and 35minutes which greater than 45minutes minimum values stipulated by BS EN 197-1 (2000). It can be said that sugar is very good retarding agent. Moreover, Khan and Baradan (2002) studied on the effects of sugar on setting time of various types of cements. The results revealed that sugar content of 0.15% limit extends the setting time of cement paste and also accelerated the cement setting at the percentage addition of 0.3% by weight of cement.

2.4.2 Effects of retarding admixture on the properties of hardened concrete

2.4.2.1 Compressive Strength

The use of retarder and water reducer admixture allows a reduction in the amount of water in the mixture, and therefore a decrease in the water/cement ratio and an increase in compressive strength (Dias *et al.*, 2010). However, Ramachandran (1999) asserted that this increase in strength is not only due to a reduction in water content, and also, Kumar (2015) opines that the reason for improvement of compressive strength by sugar is as a result of bonding within the concrete. Because sugar had good bonding property. Furthermore, (Rana, 2014) noted that the rate of strength gain after one day is also decreased due to the use of sugar as a retarding admixture in concrete. However, the compressive strength of concrete at 28 days age is higher as compared to the non- retarding concrete (Gupta and Gupta, 2012).

In research conducted by Suryawanshi *et al.* (2014) the experimental study on the effects of sugar powder on strength of cement. The findings reveals that sugar of 0.1% by weight of cement gives an increased in initial and final setting time and also at this percentage addition of sugar the compressive strength of the concrete has increased by 20% as compared with the reference sample. Similarly, Otunyo *et al.* (2015) established that the sugar has a significant effect on the compressive strength. The results showed that 0.05% addition of sugar increased the compressive strength to about 17% at 28days hydration period. However, Alsadey (2013) noted that addition of retarders not able to increase the compressive strength of concrete, on the other hand, it reduces the strength significantly, and become worse when the dosages increase. The reason for this phenomenon is that addition of retarder to the concrete will delay the reaction of C_3S and C_3A. As a result, strength development is low. The situation varies only after 7 days from casting, where inclusion of retarder will slightly improve compressive strength at later age, but this only

depends greatly upon the chemical composition of the cement. Also, some retarders, increase in dosage will increase the compressive strength for all ages (Alsadey, 2013).

2.4.2.2 Split tensile strength

Split tensile strength is slightly increased due to the use of retarders. The increase in tensile strength was found to be about 10 percent after 7 days. Previous researchers reported that the relationship between compressive and tensile strength is not affected by retarding admixtures composed of lignosulfonates and hydroxy-carboxylic acids. It was found, however, that other types of retarding admixtures like sugar causes a slight change in this relationship (Ramachandran, 1999).

In the study conducted by Rathi and Kolase (2013) titled effect of cold joint on strength of concrete. The results showed that the split tensile strength, compressive strength and flexural strength at 0.1% addition of sugar increased to 17.79%, 4.11% and 17.41% respectively as compared with normal concrete. In addition, Naqash *et al.*, (2014) noted that chemical admixtures increased split tensile strength by 33%, 14% and 10% at 3, 7 and 28days of age respectively.

2.4.2.3 Abrasion resistance

The abrasion resistance of concrete is generally improved due to reduced water content when using a retarder. The resistance to abrasion is further improved due to the retarding effects of the admixture. In fact, better finishing is possible due to delayed setting time, especially under hot weather conditions.

2.5 Climatic Problems in Concreting

Neville (2006) noted that laboratory testing of concrete is usually undertaken at a control temperature of 18 to 27^{o}C with the relative humidity of not less than 90% as specifies by (B S EN 197-3: 1995), but outside laboratory concreting has to be done under prevailing

climatic conditions. The most unsuitable conditions for concreting are hot, sunny, windy and dry (having low relative humidity) weather. The increase in temperature of weather increases the rate of evaporation of water from fresh concrete mix. For example, an increase of 10^{o}C in temperature increase the evaporation about 2times. Also, when humidity in the air decreases the evaporation of water becomes easy and fast and this bring about rapid setting of cement paste of concrete with detrimental effects on the concrete.

According to Okereke (2003) extreme North East and North western parts of Nigeria like Sokoto, Birnin Kebbi, Yola, Maiduguri, etc. are categorized as hot dry zones in Nigeria for the purposes of concreting with the mean maximum temperature of 35 to 43^{o}C and relative humidity of 40%. In addition, Dahiru (2010) noted that these zones are characterized with low relative humidity coupled with dry and dusting wind. These climatic conditions have adverse effect on the concrete. Firstly, the fresh concrete loses its workability very fast. Secondly, harden faster than under normal conditions because of the drying effect of the harmatan wind on the fresh concrete. This could be due to the fact that the hydration process of the cement is prematurely eliminated thus leading to the early stopping of the strength development of the concrete with age as it is usually the case under normal conditions (Dahiru, 2010).

B.S 5328-3 (1990) specifies that the temperature of fresh concrete at the time of delivery into the construction shall not exceed 30^{o}C. But, BS 5328-1 (1997) states that part of overall approach to work in hot dry weather, the following considerations should be given to modify the concrete properties:

1. Use admixtures to retard the hydration and increase initial workability;
2. Use a cement or combination that has a low heat evolution;

3. Specific a maximum temperature of fresh concrete less than 30^{o}C.

2.5.1 Hot weather concreting

There is no simple definition of 'hot weather' for concreting purposes. It is not just a matter of a limiting temperature, as a hot humid, calm day may not pose so many problems as a cooler day with lower humidity and high winds. In the latter case there will be a greater tendency for water to evaporate from exposed surfaces of concrete (Newman and Choo, 2003). But, ACI 305(1999) defines hot weather as 'any combination of high air temperature, low relative humidity, and wind velocity tending to impair the quality of fresh or hardened concrete or otherwise resulting in abnormal properties. In addition, Neville and Brooks, (2010) defined hot weather concreting as concreting at an atmospheric temperature above 35^{o}C.

Rowland (2014) opines that as the temperature of concrete increases, the rate of hardening increases. Setting time is reduced by 35minutes with an increase of 20 degree in concrete temperature. Furthermore, Khan and Ullah, (2004) noted that when the temperature of cement mortar with water/cement (w/c) ratio of 0.6 is increased from 27^{o}C to 46^{o}C, both the initial and final setting times are halved. Other problems such as rapid decrease of slump, formation of cold joints and plastic shrinkage cracking, increased difficulty in air entrainment, enhanced permeability and reduced durability, and reduction in ultimate strength all may arise due to hot weather.

Moreover, high temperatures can affect concrete at all stages of the production and placing process and most of the effects can have consequences for long-term strength or durability. They are a consequence of high temperature increasing the rate of the hydration reaction and the movement of moisture within and from the surface of concrete.

In the latter case relative humidity and wind speed also have a significant influence on the strength of the concrete (Newman and Choo, 2003).

2.5.1 Potential problems of hot weather on the properties of fresh concrete

The effects of hot weather on the properties of fresh concrete includes the followings:

a. Higher water demand

The temperature of concrete has an effect on its workability for a given water content. It can be said that an increase in concrete temperature from 27°C to 46°C results in a reduction of slump of approximately 25 mm. If water alone is used to provide the required workability at high temperatures there is a resultant loss in strength and durability. Increased water content also leads to increased drying shrinkage (Rowland, 2014).

b. Rapid decrease in workability

Concrete at high temperature loses workability at a faster rate because of the combined effects of loss of water through evaporation and the more rapid rate of the hydration reaction. Hydration of cement in concrete is an exothermic reaction, i.e. it produces heat. In general, the rate at which an exothermic reaction takes place doubles for each 10°C rise in temperature. Clearly, if the hydration reaction proceeds more rapidly, the paste will tend to stiffen earlier and the mix will lose workability. This can lead to a temptation to compensate for lack of workability at site by addition of water with detrimental consequences to strength and durability. Low workability can lead to difficulties in achieving adequate compaction which can again affect the strength and durability of the concrete (Khan and Ullah, 2004).

c. Decrease in setting time

For similar reasons related to the rate of the hydration reaction, concrete mixes pass initial set more quickly at higher temperatures. This also shortens the time available for transit,

placing and finishing. The rate of set is also dependent on cement type, the physical properties of the cement such as fineness and the presence of other cementitious materials such as pulverized fly ash and ground granulated blast furnace slag (Li, 2011). Furthermore, Hassan (2010) noted that the higher temperature increases the internal temperature of hydration of the cement paste and thereby increases the rate of chemical reaction, which in turn accelerates the setting time of the cement paste.

d. Plastic shrinkage

There is a tendency in concrete mixes for the solid more dense constituents to move downwards while at the same time water, which is the least dense of the constituents, tends to move upwards. This upward movement of water in recently placed concrete is known as bleeding. The bleed water finds its way to the upper surface of concrete members such as slabs where it may be lost by evaporation. The rate of evaporation increases with increasing temperature and wind speed and with decreasing relative humidity. If moisture is lost from the surface at a greater rate than the rate at which it is replaced by bleeding from below, there is a reduction in volume of the surface layer. This change in volume is resisted by the mass of concrete below which does not experience a volume change. The restraint from the underlying concrete can cause tensile stresses in the surface layer sufficient to result in cracks in the immature concrete of the surface layer. This is known as plastic shrinkage cracking.

e. Hydration peak temperature/thermal cracking

The hydration reaction produces heat and the temperature of the concrete rises. If the initial temperature of the concrete is higher, the reaction proceeds more rapidly and the rate of heat evolution is increased. This means that the peak temperature reached is also

increased. There is consequently a greater tendency for cracking as the concrete shrinks as it cools from the peak temperature.

2.5.2 Potential problems of hot weather on the properties of hardened concrete

The increase in water/ cement ratio due to the addition of water in fresh concrete to compensate the slump loss at the construction site could results to the following effects on the properties of hardened concrete (Alsadey, 2013).

a. Ultimate strength

The strength of a concrete is mainly affected by the water/cement ratio of the concrete mixture that is the strength decreases as the w/c ratio increases. The ultimate strength of concrete depends on the rate and degree of hydration of the cement. Higher rate of hydration of the cement paste results in higher early strength, but lower ultimate strength (Rowland, 2014).

b. Durability

Many deterioration mechanisms depend on the passage of fluids or gasses through the concrete pore structure. Achieving a less 'permeable' concrete is one if the principal objectives when trying to obtain durability. The main reason of doing this is to produce a concrete with low water/cement ratio. The high temperature effects both the initial workability and the rate at which workability is lost and hence there can be a temptation to add more water at the mixer or at site. This would lead directly to concrete which is more vulnerable to freeze–thaw, weathering, sulfate attack and the penetration of carbon dioxide and chloride solutions leading to reinforcement corrosion (Rathi and Kolase, 2013). The lower workability resulting from high temperature can lead to poor compaction which also leaves the concrete more vulnerable to deterioration. Plastic shrinkage or early thermal cracks can also lead to reduced durability as they may permit

moisture, carbon dioxide, oxygen or chlorides to gain easy access to the concrete or reinforcement (Newman and Choo, 2003).

2.6 Cement

Cement is a core component of concrete; its properties affect the properties of concrete made using the particular brands of cement (Anejo *et al., 2014).* According to Duggal (2008) cement is classified into hydraulic and non-hydraulic types. The non- hydraulic types do not need water to increase its strength an example is Plaster of Paris. While the hydraulic cement sets and hardens in water. The ordinary portland cement is the commonest type of hydraulic cement. The raw materials from which it is made are lime, silica, alumina and iron oxide. These constituents are crushed and blended in the correct proportions and burnt in a rotary kiln. The clinker is cooled, mixed with gypsum and ground to a fine powder to give cement. The main chemical compounds in cement are calcium silicates and aluminates (Neville and Brooks, 2010). When water is added to cement and the constituents are mixed to form cement paste, chemical reactions occur and the mix becomes stiffer with time and sets. The addition of gypsum retards and control the setting time. This ensures that the concrete does not set too quickly before it can be placed or too slowly so as to hold up construction (Yahaya *et al., 2014).*

2.6.1 Chemical composition of ordinary Portland cement

The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. These oxides interact with one another in the kiln at high temperature to form more complex compounds. These compounds reacts together to produce the four key compound of Portland cement. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement; in

addition to rate of cooling and fineness of grinding (Shetty, 2009). Table 2.2 shows the approximate oxide composition limits of ordinary portland cement.

Table 2.2 Approximate oxide composition limits of ordinary portland cement

Oxide	common name	per cent content
CaO	lime	60-67
SiO_2	silica	17-25
Al_2O_3	alumina	3.0-8.0
Fe_2O_3	ferric oxide	0.5-6.0
MgO	magnesia	0.1-4.0
K_2O and Na_2O	alkalies	0.4-1.3
SO_3	sulfur trioxide	1.3-3.0

Source: Shetty (2009)

2.6.2 Composition of cement clinker

The various constituents combine in burning and form cement clinker. The compounds formed in the burning process have the properties of setting and hardening in the presence of water. They are known as Bogue compounds after the name of Bogue who identified the compounds. The following Bogue compounds shown in Table 2.3 are formed during clinkering process which are the major compounds of ordinary Portland cement (Duggal, 1990).

Table 2.3 Composition of cement clinker

Compound	Formular	Symbol
Tricalcium silicate	$3CaO.SiO_2$	C_3S
Dicalcium silicate	$2CaO.SiO_2$	C_2S
Tricalcium aluminate	$3CaO.Al_2O_3$	C_3A
Tetracalcium aluminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF

Source: Duggal (1990).

2.6.2.1 Tricalcium silicate

The tricalcium silicate is supposed to be the best cementing material and is well burnt cement. It is about 25-50% (normally about 40 per cent) of cement. It renders the clinker easier to grind, increases resistance to freezing and thawing, rapid hardening giving early strength and fast evolution of heat. However, raising of C_3S content beyond the specified limits increases the heat of hydration and solubility of cement in water. The hydrolysis of C_3S is mainly responsible for 7 day strength and hardness. The rate of hydrolysis of C_3S and the character of gel developed are the main causes of the hardness and early strength of cement paste.

2.6.2.2 Dicalcium silicate

Dicalcium silicate is about 25-40% (normally about 32 per cent) of cement. It hydrates and hardens slowly and takes long time to add to the strength (after a year or more). It imparts resistance to chemical attack. In reality, the C_2S in the cement is not pure compounds, but contain minor oxides in solid solution. These oxides have significant effects on the atomic arrangements, crystal form and hydraulic properties of the silicate. Raising of C_2S content renders clinker harder to grind, reduces early strength, decreases resistance to freezing and thawing at early ages and decreases heat of hydration. The hydrolysis of C_2S proceeds slowly. At early ages, less than a month, C_2S has little influence on strength and hardness. While after one year, its contribution to the strength and hardness is proportionately almost equal to C_3S.

2.6.2.3 Tricalcium aluminate

Tricalcium aluminate is about 5-11% (normally about 10.5 per cent) of cement. It rapidly reacts with water and is responsible for flash set of finely grounded clinker. The rapidity of action is regulated by the addition of 2-3% of gypsum at the time of grinding cement.

The content of gypsum retard the quick setting of the cement paste and amount of gypsum added to the clinker is crucial, and depends on the C_3A content and also the alkali content of cement. Increasing the fineness of cement has the effect of increasing the quantity of C_3A and this raises the gypsum requirement. An excess of gypsum leads to expansion and consequent disruption of set cement paste (Neville and Brooks, 2010).

Furthermore, tricalcium aluminate is responsible for the initial set, high heat of hydration and has greater tendency to volume changes causing cracking. Raising the C_3A content reduces the setting time, weakens resistance to sulphate attack and rapid hardening but lower final strength. Likewise, in the hydration of the cement powder, it is C_3A that causes the sudden hardening of the cement paste. Hence it is usually retarded by addition of gypsum. High amount of C_3A in cement is undesirable (Ibrahim *et al.*, 2012).

2.6.2.4 Tetracalcium aluminoferrite

Tetracalcium aluminoferrite is about 8–14% (normally about 9 per cent) of cement. It is responsible for flash set but generates less heat and causes grey colour in the cement. It has poorest cementing value. Raising the C_4AF content reduces the strength slightly. (Duggal, 1990).

2.6.3 Calculation of percentage of major compounds

According to ASTM C 150 (2005), the percentage of major compounds in a clinker can be found based on boguès formular as given in the following equations as:

$C_3S = 4.07(CaO) – 7.60(SiO_2) – 6.72(Al_2O_3) – 1.43(Fe_2O_3) – 2.85(SO_3)$ ……...….. 2.2

$C_2S = 2.87(SiO_2) – 0.754\ (3CaO.\ SiO_2)$ ……..…….. 2.3

$C_3A = 2.65(Al_2O_3) – 1.69(Fe_2O_3)$ ……..…….. 2.4

$C_4AF = 3.04(Fe_2O_3)$ ……..……. 2.5

2.6.4 Classification of Portland cement

According to American Society of Testing and Materials ASTM C150-05 Portland cement can be broadly classified as follows:

Type I Ordinary Portland cement

Type II Modified cement

Type III Rapid hardening Portland cement

Type IV Low – heat Portland cement

Type V Sulfate resistance Portland cement

Table 2.4 Typical average values of compound composition of Portland cement of different types

Cement type	Compound composition, (per cent)							
	C_3A	C_2S	C_3A	C_4AF	$CaSO_4$	Free CaO	MgO	LOI
I	59	15	12	8	2.9	0.8	2.4	1.2
II	46	29	6	12	12	0.6	3.0	1.0
III	60	12	12	8	3.9	1.3	2.6	1.9
IV	30	46	5	13	2.9	0.3	2.7	1.0
V	43	36	4	2	2.7	0.4	1.6	1.0

Source: Neville and Brooks (2010)

2.6.4.1 Ordinary Portland (Type I) cement

Ordinary Portland cement is by far the most common cement used in general concrete construction when there is no exposure to sulfate in the soil or in groundwater. A limitation on the composition is that the (C_3A) shall not exceed fifteen per cent.

It is made by heating limestone and clay to a temperature of about 1300^0C to form a clinkers, rich in calcium silicates. The clinker is ground to a fine powder with a small proportion of gypsum, which regulates the rate of setting when cement is mixed with water (Barry, 1999).

2.6.4.2 Modified (Type II) cement

In some applications, a very low early strength may be a disadvantage, and for this a modified cement was developed in the USA. This cement has a higher rate of heat development than that of Type IV cement, and a rate of gain of strength is similar to that of Type I cement.

2.6.4.3 Rapid hardening Portland (Type III) cement

This cement is similar to type I cement and is covered by the same standards. As the name implies, the strength of this cement develops rapidly because of a higher C_3S content up to 70 per cent and a higher fineness minimum of $325m^2/kg$.

The principal reason for the use of Type III cement is when formwork is to be removed early for re- use or where sufficient strength for further construction is required quickly. Rapid hardening Portland cement should not be used in mass concrete construction or in large structural sections because of its high rate of heat development.

2.6.4.4 Low heat Portland (Type IV) cement

The percentage of C_2S and C_4AF are relatively higher than that of C_3S and C_3A. Limitation on this type of cement is that the maximum percentage of C_3A is seven per cent. This causes the heat given off by the hydration reaction to develop at a slower rate. However, as a consequence the strength of the concrete develops slowly.

2.6.4.5 Sulfate- resisting (Type V) cement

This cement has a low C_3A content so as to avoid sulfate attack from outside the concrete, otherwise the formation of calcium sulfoaluminate and gypsum would cause disruption of the concrete due to an increased volume of the resultant compounds. The salt particularly active are magnesium and sodium sulfate, and sulfate attack is greatly

accelerated if accompanied by alternate wetting and drying, e.g. in marine structure subject to ride or splash.

To achieve sulfate resistance, the C_3A content in sulfate resisting cement is limited to 3.5 per cent with a limit of SO_3 content of 2.5 per cent; otherwise this cement conform to the specification for ordinary Portland cement.

2.6.5 Setting and hardening time of cement

Portland cement is hydraulic; when mixed with water it forms a paste, which sets and hardens as a result of various chemical reactions between the cementitious compounds and water. Setting and hardening are not dependent upon drying out; indeed, Portland cement will harden under water. Only a small proportion of the added water is actually required for the chemical hydration of the cementitious constituents to hydrated calcium silicates. The additional water is needed to ensure the workability of the mix when aggregates are added, so that concrete, for example, can be successfully placed within formwork containing steel reinforcement. Water in excess of that required for hydration will ultimately evaporate leaving capillary pores in the concrete and mortar products. Typically, an increase in void space of 1% reduces crushing strength by 6%. It is therefore necessary to control carefully the water content of the mix by reference to the water/cement ratio. A minimum water/cement ratio of 0.23 is required to hydrate all the cement, although as the cement powder is hydrated it expands, and thus a ratio of 0.36 represents the point at which cement gel fills all the water space. However, a water/cement ratio of 0.42 more realistically represents the minimum water content to achieve full hydration without the necessity for further water to be absorbed during the curing process (Lyons, 2007).

The setting and hardening processes should be distinguished. Setting is the stiffening of the cement paste, which commences immediately the cement is mixed with water. Because the major cementitious constituents set at different rates it is convenient to refer to initial set and final set. Typically, Initial set is the point in time when the cement paste starts to stiffen considerably. Beyond this point, further mixing of the concrete is harmful. Final set on the other hand, is the point in time when the concrete starts to gain strength. Initial set usually occurs within 1 hour, while final set takes 10 hours after initial water-cement contact (Duggal, 2008). The setting process is controlled by the quantity of gypsum added to the cement in the final stage of production. Hardening is the gradual gain in strength of the set cement paste. It is a process which continues, albeit at a decreasing rate, over periods of days, months and years. The rate of hardening is governed partially by the particle-size distribution of the cement powder. Finely ground cement hydrates more rapidly, and therefore begins to set and harden more quickly (Lyons, 2007).

2.6.5.1 Condition affecting setting time of cement

The factors influencing the setting properties of cement are its composition, the percentage of retardant, degree of calcination, fineness of grinding, aeration subsequent to grinding clinker, percentage of water used to make cement paste, the temperature of the mixing water, cement and the atmosphere where the cement paste is placed, and the amount of manipulation the paste receives.

The effect of gypsum is to increase the setting time of freshly ground cement. It is usually mixed with the clinker before final grinding, or just after the clinker has received preliminary grinding. The addition of gypsum before calcination causes it to decompose into lime and sulphur trioxide. Since the latter is liberated in the kiln, there is resulting effect on the setting time. Often, an underlimed cement becomes quick setting after

seasoning. This can be avoided by adding to the cement 1 or 2% of hydrated lime or the fraction of a per cent of Plaster of Paris. Setting time of cement is rapid with the increase in the fineness of cement. When the mixing water used in testing cement paste is increased by 1% above that required for normal consistency, an increase of about 30 minutes or more is observed in the initial or final set (Gupta and Gupta, 2004).

2.6.6 Fineness of cement

Regardless of composition, fineness is a vital property of cement, which influences the rate of reaction of cement with water. For a given weight of a finely ground cement, the surface area of the particles is greater than for a coarsely ground cement. For a satisfactorily ground cement, usually there should be 1.1×10^{12} particles per kg of cement. However if the cement is ground too finely, the extremely fine particles may be pre-hydrated by moisture present as vapour in the grinding mills or during storage. If the particles are coarser than normal, the rate of hydration of cement will be slower (Gupta and Gupta, 2004).

2.6.7 Soundness of cement

It is essential that the cement paste, once it has set, does not undergo a large change in volume. One restriction is that there must be no appreciable expansion, which under conditions of restraint could result in disruption of the hardened cement paste. Such expansion may occur due to reaction of free lime, magnesia and calcium sulphate, and cement exhibiting this type of expansion are classified as unsound (Neville and Brook, 2010).

Free lime is present in the clinker and is intercrystallized with other compounds; consequently, it hydrates very slowly occupying a large volume than the original free calcium oxide. Free lime cannot be determined by chemical analysis of cement because

it is not possible to distinguish between unreacted CaO and $Ca(OH)_2$ produced by a partial hydration of the silicates when the cement is exposed to the atmosphere.

Magnesia reacts with water in a manner similar to CaO, but only the crystalline form is deleteriously reactive so that unsoundness occurs. Calcium sulfate is the third compound liable to cause expansion through the formation of calcium sulfoaluminate (ettringite) from excess gypsum not used up by C_3A during setting (Neville and Brook, 2010).

CHAPTER 3

3.0 EXPERIMENTAL PROGRAMME

This chapter contains a detailed description of all the materials used in the experimental programme, as well as the methods followed in conducting the various tests.

3.1 Research Materials

The materials used in this experimental study were; Portland cement, fine aggregate, coarse aggregate, sugar and water.

3.1.1 Cement

The Portland cement used in this research work were cement brands A, B, C, D and E which conformed ASTM C150 (2005). They were obtained from accreditated dealers in Kaduna metropolis, Nigeria.

3.1.2 Fine aggregates

The fine aggregate used in this research was natural sharp river sand obtained from Shika and sieved using a 5mm BS 812 sieve in order to remove large aggregates and impurities. It did not contain particles exceeding 5mm in size and was in conformity with BS EN 933-1 (1997)

3.1.3 Coarse aggregates

The coarse aggregate used was crushed granite with maximum normal size of 20mm and retained on 10mm sieve minimum, and was obtained from quarry site along Sokoto – Zaria road, Zaria which was conformed to BS EN 933-5: (1998). It was in saturated surface dry condition before it was used in the mixing.

3.1.4 Sugar (Admixture)

The Sucrose (table sugar) used as admixture in this experimental study was white crystalline solid (Dangote sugar) soluble in water and was obtained from Samaru market, Zaria.

3.1.5 Water

The clean tap water was used for the experimental works. The quality of the water used was in conformity to the specification of BS EN 1008-2 (2002) which specified the use of water to be free from odour, colour, taste and impurities.

3.2 Tests Method

In this research various tests were conducted and the tests are as follows:

3.2.1 Preliminary tests of materials

The preliminary tests were carried out on research materials to determine the chemical composition of the five brands of ordinary Portland cement and also the physical properties materials used in this experimental research work.

3.2.1.1 Chemical analysis test

The chemical analysis test of the brands of ordinary Portland cement was carried out at Defence Industrial Corporation of Nigeria (DICON) Research and Development Centre, Kaduna using XRF method. The machine used to carry out the test was X-Ray Florescence machine. The primary filter used was kapton, x-ray current was 14kv, air as the current gas medium, and the time used to measure the sample was 100seconds. Then the major oxides were analyzed and recorded.

3.2.1.2 Fineness test

This test was carried in accordance with B.S EN 196-6 (1992) so as to determine the fineness of the brands of Portland cement by using sieve method. 100g of cement was weighed and then poured on 90µm BS sieve. The sieve was agitated by swirling in both planetary and linear movement for the period of 15minutes. The residue was weighed and its mass was expressed as a percentage R_1 of the quantity of sample first placed on the sieve. The particles on the sieve were gently brushed off from the base of the sieve and the whole procedure was repeated using a fresh 100g cement sample in order to obtain R_2. The value of total residue (R) was obtained from the mean of R_1 and R_2. The total residue R shall not exceed 10% of total weight of the sample B.S EN 196-6 (1992).

3.2.1.2 Particle size distribution

The sieve analysis test was conducted in accordance with B.S EN 933-2 (1996). The sample of 6kg of fine aggregate was weighed and then poured on different B. S sieve sizes of 5.00mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm, and pan. After shaking the sieves vigorously, the sample retained on each sieve was recorded as weight of sample retained. The fineness modulus was then determined as summation of cumulative percentage retained divided by 100.

3.2.1.3 Specific gravity of materials

The specific gravity of the fine and coarse aggregate were determined using pycnometre method and the procedure followed was conducted in accordance with BS 812-2 (1995). The specific gravity was calculated using the formular in equation 3.1.

$$Gs = \frac{C - A}{(B - A) - (D - C)} \quad \text{……………………………………………………….. 3.1}$$

Where: A is the weight of empty density bottle

B is the weight of empty density bottle plus water

C is the weight of empty density bottle plus aggregate sample

D is the weight of empty density bottle plus water plus aggregate sample

3.2.1.4 Bulk density of materials

Bulk density is the weight of aggregate confined within a container of unit volume when compacted under specified conditions. This test was conducted in accordance with BS 812-2 (1995). This test was conducted for the three materials used in this experiment i.e. brands of Portland cement, sand and granite. The result was used for the calculation of quantity of materials used in the experiment.

3.2.1.5 Initial and Final Setting times

The setting time is used to describe the stiffening of the cement paste. The test for initial and final setting times was conducted on the cement pastes made with five brands of Portland cement with the percentage addition of sugar of 0.06% and 0.1% by weight of cement and also the 0% as a control. The assessment of the setting times of standard cement paste was carried out using Vicat apparatus in conformity with BS EN 196- 3 (1987) standard. The tests were performed at two different temperatures at the normal laboratory room temperature of 27^{o}C and at an oven temperature of 43^{o}C−approximate maximum ambient temperature for Sokoto, Birnin Kebbi, Maiduguri and Yola etc.

3.2.2 Production of Concrete Specimens

3.2.2.1 Batch Calculation

Absolute volume of nominal mix method was used in this research of 1:2:4 mix ratio with water cement ratio of 0.5 to determine the quantity of materials used for this experimental works. The water cement ratio was obtained by trial method prior to the main experiment.

The quantity of percentage addition of sugar was obtained based on the calculated weight of cement.

3.2.2.2 Mixing of materials

The materials used were batched by weight and mixing was carried out with concrete mixing machine in the mix ratio of 1: 2: 4 with w/c ratio of 0.5. While the percentage of sugar was dissolved in water before adding to the mix water of the concrete. The mixing was carried out in accordance with B.S 1881- 125 (1986). Three different samples of concrete were produced using three different percentage additions of sugar for each brands of cement. These percentages were 0% as a control and the other two with 0.06% and 0.1% of sugar by weight of cement. The percentage additions of sugar were based on the research by Abalaka (2011) and Rana (2014) who established that sugar tends to retard both the initial and final setting time of cement paste and improves the compressive strength of concrete at 0.06% and 0.1% by weight of cement.

3.2.2.3 Casting of concrete specimens

After the concrete was thoroughly mixed and the slump and compacting factor tests were carried out for the each batch of percentage addition of sugar. The cube specimens were cast by filling each cube mould in three layers each layer been compacted manually with 25 blows from a steel rod of 25 diameter before the next layer was poured. The size of cube mould used for the production of concrete specimens was 100 mm × 100 mm × 100 mm which was conformed to BS EN 12390-1 (2000).

A total of 540 number of concrete specimens were produced out of which 180 number (cubes) were used to determine the compressive strength at the end of curing period of 3, 7, 28 and 56 days for each percentage addition of sugar of 0%, 0.06% and 0.1% for all the five brands of cement and also 180 concrete specimens were used for split tensile

strength test at 3, 7, 28 and 56 days for addition percentage of sugar at 0%, 0.06% and 0.1% for all the five brands of cement. Another 180 cubes were used for abrasion resistance and water absorption test at the end of 28 and 56 days curing periods.

3.2.3 Testing of fresh concretes

Fresh concrete was assessed to test its level of workability prior to the casting of concrete samples using the following tests

3.2.3.1 Slump test

The test was carried out for each batch of fresh concrete produced i.e. for each percentage addition of sugar for 0%, 0.06% and 0.1% for all the five brands of cement to assess the workability of the fresh concretes. The apparatus used to carry out this test consist of mould, scoop, sampling tray, trowel, tamping rod and measuring ruler. The internal surface of the mould was cleaned lubricated with engine oil and then placed on the sampling tray and hold firmly against the surface. The fresh concrete was poured into the mould in three layers, approximately one third of the height of the mould where each layer was tamped 25 strokes and the mould was removed vertically upward. The different between height of the mould and slump concrete was measured as a slump value. This test was carried out in accordance with B.S EN 12350-2 (2009).

3.2.3.2 Compacting factor test

Compacting factor test measured the degree of compaction of fresh concrete. The test was carried out for each batch of fresh concrete produced i.e. for each percentage addition of sugar for 0%, 0.06% and 0.1% for all the five brands of cement used in the experiment. This test was carried out in accordance with BS 1881: part 103 (1993).

3.2.4 Curing of concrete specimens

The concrete specimens cast were cured by complete immersion in water for the required period of hydration of 3, 7, 28 and 56 days. The curing water was conformed to BS EN 1008-2 (2002).

3.2.5 Testing of hardened concrete specimens

3.2.5.1 Compressive strength test

This test was undertaken at different ages of curing period of 3, 7, 28 and 56 days and at each addition level of 0%, 0.06% and 0.1% of sugar by weight of cement for all the five brands of cement used in the experiment, it was carried out in accordance with B.S EN 12390- 3 (2000). The concrete specimens (cubes) were removed from the curing tank and placed outside to surface dried, then weighed and positioned at the centre of manual hydraulic compression machine for crushing. The force was applied at the specimen by swinging the handle of the crushing machine till the specimen was crushed. The maximum load at failure was then recorded. The compressive strength was calculated using the formular in equation 3.2.

$$\text{Compressive strength} = \frac{\text{Maximum load (KN)} \times 1000}{\text{Cross- sectional Area (mm}^2\text{)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

3.2.5.2 Split tensile strength test

This test was carried out at different ages of curing period of 3, 7, 28 and 56 days and at each addition level of 0%, 0.06% and 0.1% of sugar by weight of cement for all the five brands of cement used in the experiment, it was carried out in accordance with B.S EN 12390- 6 (2000). The concrete specimens (cubes) were removed from the curing tank and placed outside to surface dried. The specimens were then weighed and placed at the centre of hydraulic manual compression machine for splitting. Each specimen was positioned diagonally on the centre of the square plate on the machine and the load was applied at a

constant rate. After failure, the maximum load was recorded as P. The split tensile strength of concrete was calculated using the formular in equation 3.3.

$$\text{Split tensile strength} = \frac{0.518 \times P}{S^2} \quad \ldots \quad 3.3$$

Where; P is load at failure and S is the side of the concrete cube

3.2.5.3 Water absorption test

This test was undertaken at the end of hydration period of 28 and 56 days for concrete specimens (cubes) and at each addition level of 0%, 0.06% and 0.1% of sugar by weight of cement and it was carried out in accordance with B.S 1881- 122 (1983). The concrete specimens (cubes) were removed from curing tank and allowed to dry. The cubes were then placed in an electric oven to dry at 105°C for 72 hours. The specimens were then removed from the oven and allowed to cool down to room temperature, weighed to determine the initial weight (W_1). The final weight (W_2) was determined after concrete specimen were immersed in water for 24 hours then removed, dried with cloth and re-weighed again. The water absorption of concrete specimen was calculated using formular in equation 3.4.

$$\text{Water absorption} = \frac{W_2 - W_1}{W_1} \times 100 \quad \ldots \quad 3.4$$

Where, W_1 is initial weight of a concrete specimen and W_2 is final weight of the specimen

3.2.5.4 Abrasion resistance test

The concrete specimens were removed from the curing tank and then allowed to be surface dried under the sun, the surface dried specimens were weighed to obtain value of W_1 as initial weight. A weight of 3.5 kg was mounted and tightly fixed to a wire brush and the specimen surface stroke for 60 times at equal speed. The specimens were then re-

weighed and the value recorded as W_2. The abrasion resistance was obtained using the formular in equation 3.5.

$$\text{Abrasion resistance} = \frac{W_1 - W_2}{W_2} \times 100 \qquad \text{3.5}$$

Where, W_1 is initial weight of a concrete specimen and W_2 is final weight of a specimen

CHAPTER 4

DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Chemical and Physical Properties of Materials

The results of the chemical analysis test for the cement brands and physical properties tests carried out on materials used for the research are presented and discussed.

4.1.1 Chemical compositions of Portland cement brands

Table 4.1 presents the chemical compositions of the five brands of Portland cement used for the research. It can be observed that the percentage of aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3) in all the brands of cement satisfies the chemical requirements of ASTM C 150 (2005) which states that the percentage of Al_2O_3 and Fe_2O_3 in OPC should be within the range of 3.0 to 8.0 and 0.5 to 6.0 respectively. But, cement brand C has the lower percentage of Al_2O_3 content and high Fe_2O_3 content which leads to low content of tricalcium aluminate (C_3A). Furthermore, it can be seen that cement brand A has the higher content of calcium oxide (CaO) of 75.57% while cement brand B has the least values of 67.91% as compared to the other brands.

Table 4.1 Percentage Compositions of Chemical Constituent of Cement Brands

Constituent	Brands of Cement				
	A	**B**	**C**	**D**	**E**
Aluminum Oxide (Al_2O_3)	3.5	5.0	4.1	4.2	5.6
Silicon Oxide (SiO_2)	11.3	15.1	15.8	14.1	14.8
Iron Oxide (Fe_2O_3)	4.50	5.05	6.03	3.20	4.53
Sulphur Oxide (SO_3)	2.53	3.48	2.38	2.28	2.25
Potassium Oxide (K_2O)	0.079	0.100	0.290	0.160	0.812
Calcium Oxide (CaO)	75.57	67.91	68.49	71.54	69.07
Titanium Oxide (TiO_2)	0.18	0.30	0.23	0.22	0.33
Chromium Oxide (Cr_2O_3)	0.010	0.027	0.012	0.027	0.013
Manganese Oxide (MnO)	0.032	0.140	0.077	0.053	0.244

Source: Laboratory Research Work (2015)

4.2.2 Physical properties of the materials

4.2.2.1 Fineness test for the brands of cement

Table 4.2 shows the fineness test results for the various brands of cement. It can be observed that all the cement brands meet the requirement specifies by ASTM C150 (2005) that the maximum requirement of the fineness of Portland cement should not exceed 10% residue. However, it can be observed that cement brand E has the higher per cent residue of 4.8%, while cement brand C has the lower per cent residue of 1.5%. For this reason, cement brand C should develop strength at higher rates than the other brands. Because fineness of cement controls the rate and completeness of hydration in cement (Anejo *et al.,* 2014).

Table 4.2 Fineness test for the brands of cement

Cement brands	Total weight of cement (g)	Total residue (%)	Average residue (%)
A	100 100	R_1= 2 R_2= 2	2
B	100 100	R_1= 2.5 R_2= 3	2.3
C	100 100	R_1= 1 R_2= 2	1.5
D	100 100	R_1= 4.5 R_2= 5	4.8
E	100 100	R_1= 5 R_2= 4	4.5

Source: Laboratory Research Work (2015)

4.2.2.2 Particle size distribution

The particle size distribution of the fine aggregate was determined by the sieve analysis method. Table 4.3 shows the result of sieve analysis.

Table 4.3 Sieve analysis of fine aggregates

B.S Sieve size	Weight Retained (g)	Weight Passing (g)	Percentage passing (%)
5.00mm	7.00	1993	99.6
2.36mm	197	1797	89.9
1.18mm	505	1292	64.6
600µm	753	539	26.9
300µm	405	134	6.7
150µm	78	56	2.8
Pan	37	19	0.95

Source: Laboratory Research Work (2015)

Table 4.3 presents the result of sieve analysis of fine aggregate which has been used to determine the fineness modulus calculated as 2.90. According to Garba (2008) the fineness modulus of fine aggregate should be within the range of 2.0 to 3.5 (±0.2). Therefore, the fine aggregate used for this research was in conformity with statement. Also, this result indicates that the fine aggregate falls under grading limit of zone 1 as specified by BS 4550: Part 5 (1978). Thus, the fine aggregate is suitable for the production of concrete.

4.2.2.3 Bulk density and specific gravity of materials

Table 4.4 presents the results of bulk density and specific gravity of the materials used for the research work. It can be observed that the results of bulk density and specific gravity of aggregates falls within the range of 1280 to 1920 and 2.30 to 2.90 specifies by ACI EI 201 (2001). However, the specific gravity of the various brands of cement were observed to be a little higher than 3.15 value specifies by BS 12 (1996).

Table 4.4 Bulk density and specific gravity of materials

Materials	Bulk Density (kg/m^3)	Specific Gravity
Coarse aggregate	1591	2.50
Fine aggregate	1600	2.70
Cement A	1340	3.45
Cement B	1355	3.35
Cement C	1357	3.55
Cement D	1381	3.45
Cement E	1367	3.35

Source: Laboratory Research Work (2015)

4.2 Effects of Sugar on the Cement Paste and Fresh Concrete

In this subsection, the results of initial and final setting time tests carried at two different temperatures; at normal laboratory temperature of 27^{o}C and at an oven temperature of 43^{o}C−approximate maximum ambient temperature for Sokoto, Birnin Kebbi, Maiduguri and Yola are presented and discussed. The results of workability tests of the fresh concrete are as well presented and discussed.

4.2.1 Setting time test

The test results for initial and final setting times of various cement pastes made with brands of cement at two different temperatures are shown in Table 4.5. The result revealed that both the initial and final setting times increased continuously with increase in percentage additions of sugar by weight of cement at all the temperatures. Apart from Bua cement that showed decrease in setting time as the percentage addition of sugar increases. The initial setting times of the control pastes at 27^{o}C for A, B, C, D and E cement brands were recorded as 111minutes, 125minutes, 100minutes, 93minutes and

108minutes respectively. Generally, at 43^{o}C the control pastes recorded a decrease in the initial setting times by 45.94%, 40%, 38%, 24.73% and 51.8% for A, B, C, D and E cement brands respectively when compared with the control pastes at 27^{o}C. This effect could be attributed to the fact that higher temperature increases the internal temperature of hydration of the cement paste and thereby increasing the rate of chemical reaction, which in turn accelerates the setting time of the cement paste (Hassan, 2010).

To overcome this effect of rapid decrease in setting times, 0.06% and 0.1% of sugar by weight of cement were added to all the brands of cement subjected to setting time test at 43^{o}C. At 0.1% four brands of cement recorded the higher percentage increase in initial setting times more than at 0.06% addition of sugar. The percentages increase recorded were 175%, 124%, 100% and 196 for A, B, D and E cement brands respectively, while cement C recorded a decrease in initial setting time of 49%, but recorded an increase of 88% at 0.06% addition of sugar. In addition, it can be observed that there were an increase in the final setting times in all the brands of cement as the percentage addition of sugar increases with cement B recorded the higher increase of 108% and cement C recorded lower increase of 80% when compared with the control pastes.

The increased in the setting times in all the brands of cement could be as a result of retarded hydration due to the presence of sugar. Because sugar increases the concentrations of calcium, aluminum and iron in concrete. The sugar molecules combine with these metals to form insoluble chemical complexes that coat the cement grains. Another reason for the extention of the setting time is adsorption of sugar molecules which acts as thin layer over the cement particles. Furthermore, cement C brand that showed a decrease in setting times as the percentage addition of sugar increases, the reason for this phenomenon could be the low content of tricalcium aluminate C_3A as

compared to the other brands of cement. This observation concurs with an earlier findings by Myrdal (2007).

Table 4.5 Comparison of the setting times of cement brands with percentage addition of sugar at two different temperatures

Setting time	Cement Brands	27ºC			43ºC		
		0%	0.06%	0.1%	0%	0.06	0.1%
Initial setting (Minutes)	A	111	270	320	60	75	165
	B	125	370	440	75	150	168
	C	100	254	147	62	188	51
	D	93	367	425	70	117	140
	E	108	210	290	52	130	154
Final setting (Minutes)	A	201	363	465	123	180	225
	B	218	515	575	125	230	270
	C	108	377	198	110	261	150
	D	167	494	560	102	217	245
	E	189	345	500	100	195	247

Source: Laboratory Research Work (2015)

4.2.2 Workability tests of fresh concrete

Table 4.6 presents the results of workability tests for the brands of the cement. It can be observed that the slump and compacting factor values increased as the percentage addition of sugar increases for all the brands of the cement. The slump values for the control samples of A, B, C, D and E cement brands were observed to be 10mm, 22mm, 8mm, 14mm and 7mm respectively, this shows that the degree of workability was very low (Gupta and Gupta, 2010). But at 0.1% addition of sugar all the cement brands recorded the higher increases in workability more than at 0.06%. Cement C has the higher value of 84mm (representing medium degree of workability) while cement B has the lower value of 25mm indicating low degree of workability. Similar trends were observed for the compacting factor test in all the brands of cement.

The increased in the workability could be attributed to the presence of sugar which acts as a thin layer over the cement particles and it slows down the hydration process, thereby increased the workability of concrete. This observation is in agreement with the findings of (Giridhar *et al.,* 2013).

Table 4.6 Slump and Compacting Factor Tests of the Fresh concrete

Workability	**Cement Brands**	**Percentage addition of sugar**		
		0%	0.06%	0.1%
Slump (mm)	A	7.0	10	48
	B	10	15	25
	C	22	63	84
	D	14	18	34
	E	8.0	25	60
Compacting factor	A	0.87	0.88	0.92
	B	0.83	0.87	0.90
	C	0.89	0.93	0.94
	D	0.86	0.88	0.89
	E	0.85	0.88	0.93

Source: Laboratory Research Work (2015)

4.3 Hardened Properties of Concrete Specimens

4.3.1 Compressive strengths test

4.3.1.1 Compressive strengths at 3 days

Figure 4.1 shows the compressive strengths of each brand of cement at 3 days curing period. The compressive strengths of the control specimens made with A, B, C, D and E cement brands are 11.8 N/mm^2, 14.0 N/mm^2, 14.2 N/mm^2, 12.1 N/mm^2 and 11.0 N/mm^2 respectively. It can be observed that there is an increase in compressive strengths by adding 0.06% of sugar in A and C cement brands by 5.9% and 2.1% respectively, while B, D and E cement brands showed a decrease in compressive strength of 6.0%, 8.0% and

12.6% respectively. Furthermore, at 0.1% addition of sugar only cement C showed an increase in compressive strength by 5.6% over the control specimen. All the remaining brands showed a decrease in compressive strengths. The compressive strengths of A, B, D and E cement brands were decreased by 5.08%, 20.7%, 19.0% and 13.6% respectively when compared with the control specimens.

The decrease in the early age strengths in some cement brands could be attributed to the fact that the use of a sugar as admixture in concrete severely reduces the early strength of concrete. This observation concurs with the assertion made by (Neville, 2006). Another reason could be the delay in the reaction of tricalcium silicate (C_3S) and tricalcium aluminate (C_3A) caused by sugar molecules, resulting in low early strength development.

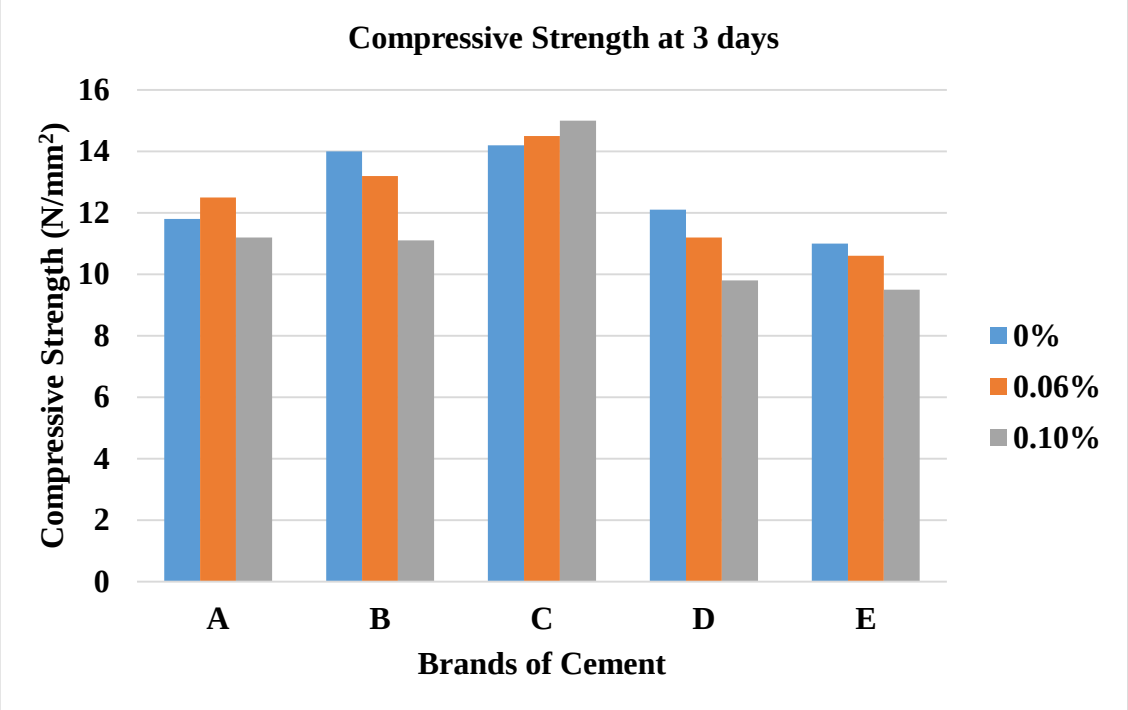


Figure 4.1 Relationship between the Compressive strengths of the Brands of cement and Percentage addition of sugar at 3 days curing period

4.3.1.2 Compressive strengths at 7 days

Figure 4.2 presents the compressive strengths of each brand of cement at 7 days curing period. The compressive strengths of the control specimens made with A, B, C, D and E

cement brands are 16.6 N/mm^2 18.0 N/mm^2, 16.3 N/mm^2, 15.8 N/mm^2 and 16.7 N/mm^2 respectively. It can be observed that there is an increase in compressive strength by adding 0.06% of sugar in A, B, C and D cement brands by 7.0%, 7.6%, 4.5% and 6.0% respectively over the control specimens, while cement E recorded a decrease in compressive strength of 5.99% when compared with the control specimen. Likewise, at 0.1% addition of sugar cement E also recorded a decrease in compressive strength of 6.59%. But all the remaining cement brands showed an increase in compressive strengths. The compressive strengths of A, B, C and D cement brands were increased by 1.2%, 3.3%, 11.0% and 6.9% respectively over the control specimens.

Furthermore, cement E brand that showed a decrease in compressive strength at every percentage additions of sugar. The reason for this could be as a result of its high percentage content of tricalcium aluminate (C_3A) over the other brands of cement.

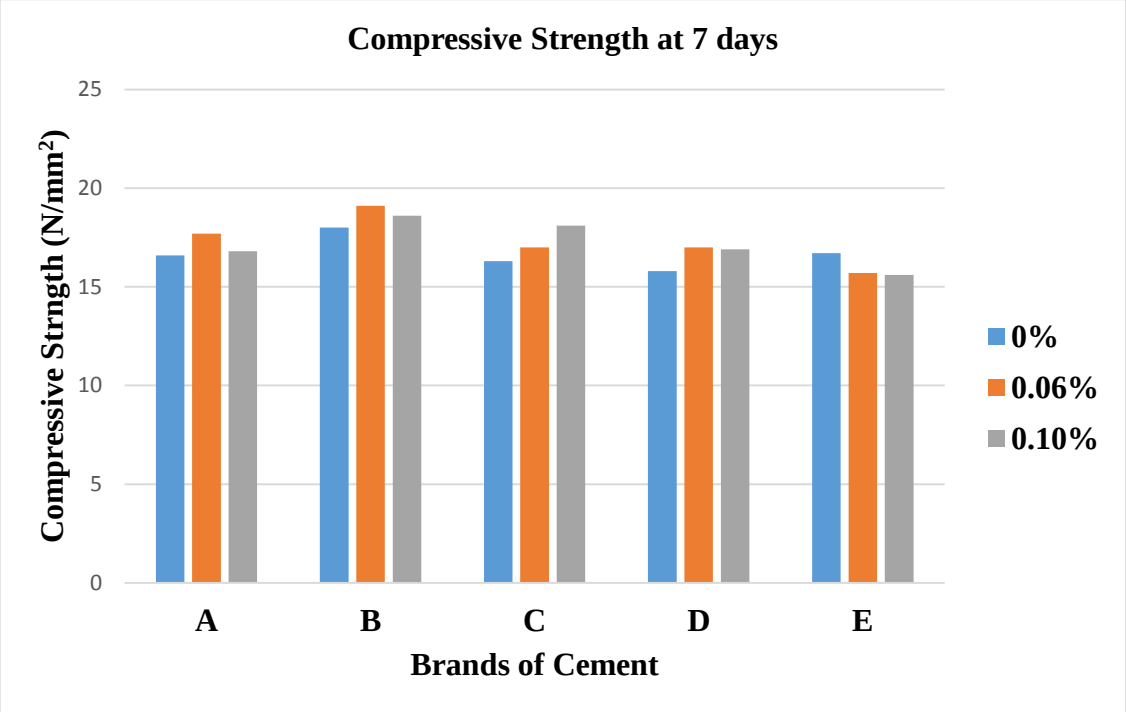


Figure 4.2 Relationship between the Compressive strengths of the Brands of cement and Percentage addition of sugar at 7 days curing period

4.3.1.3 Compressive strengths at 28 days

Figure 4.3 shows the compressive strengths of each brand of cement at 28 days curing period. The compressive strengths of the control specimens made with A, B, C, D and E cement brands are 30.7N/mm^2, 30.1 N/mm^2, 29.9N/mm^2, 28.5 N/mm^2 and 29.5 N/mm^2 respectively. It can be observed that there is higher increase in compressive strength by adding 0.06% of sugar in A, B and D cement brands by 8.8%, 6.6% and 9.5% respectively over the control specimens, while cement E showed a decrease in compressive strength of 8.47% when compared with the control specimen. At 0.1% addition of sugar only cement C recorded higher increase in compressive strength by 21.4% over the control specimen. Therefore, 0.06% addition of sugar proved to be the optimum dosage for A, B and D cement brands, while 0.1% is the optimum dosage cement C. The reason behind the increase in compressive strengths could be related to the fact that when sugar is used as a set retarder in concrete, the early strength of concrete is reduced but beyond about seven days there is an increase in strength as compared with non-retarded concrete as a result of delayed the setting of cement paste and produce a denser cement gel. This observation concurs with an earlier findings by (Rathi and Kolase, 2013).

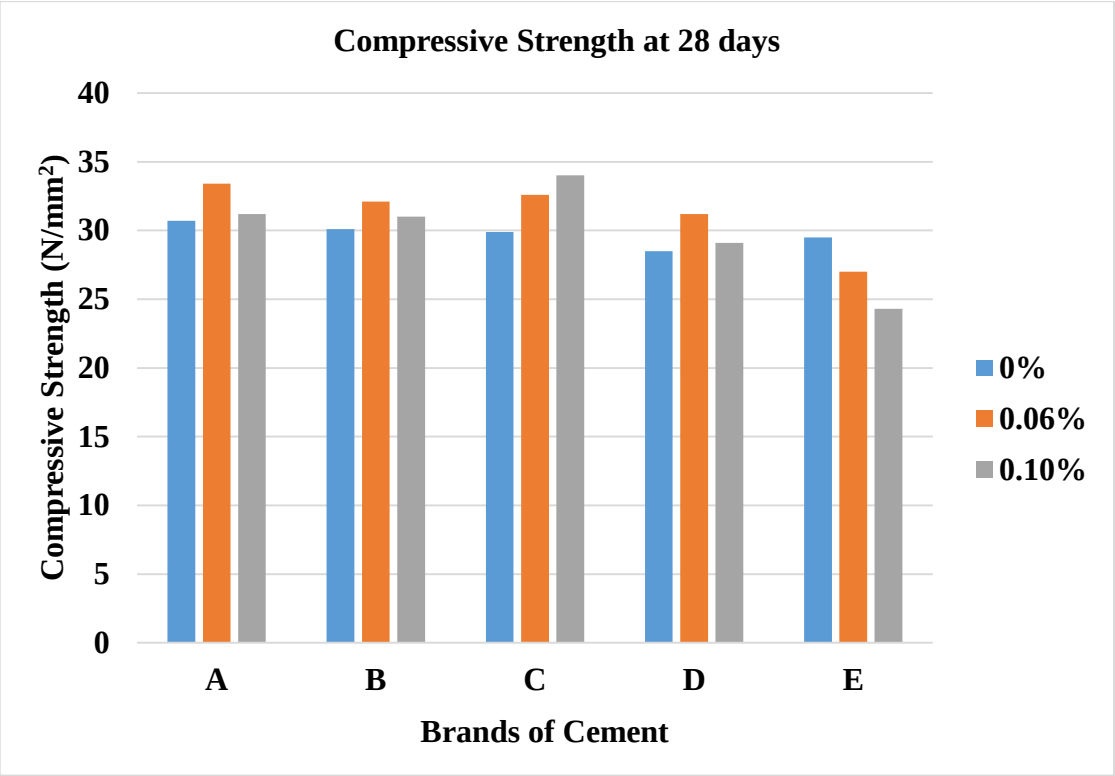


Figure 4.3 Relationship between the Compressive strengths of the Brands of cement and Percentage addition of sugar at 28days curing period

4.3.1.4 Compressive strengths at 56 days

Figure 4.4 shows the compressive strengths of each brand of cement at 56 days curing period. The compressive strengths of the control specimens made with A, B, C, D and E cement brands are 34.0 N/mm^2, 34.5 N/mm^2, 35.1N/mm^2, 33.2 N/mm^2 and 32.0 N/mm^2 respectively. It can be observed that there is an increase in compressive strengths by adding 0.06% of sugar in A, B and D cement brands by 3.8%, 4.0% and 4.2% respectively. On the other hand, cement E showed a decrease in compressive strength by 4.69% when compared with the control. At 0.1% addition of sugar only cement C showed higher increase in compressive strength by 5.4% when compared with the control.

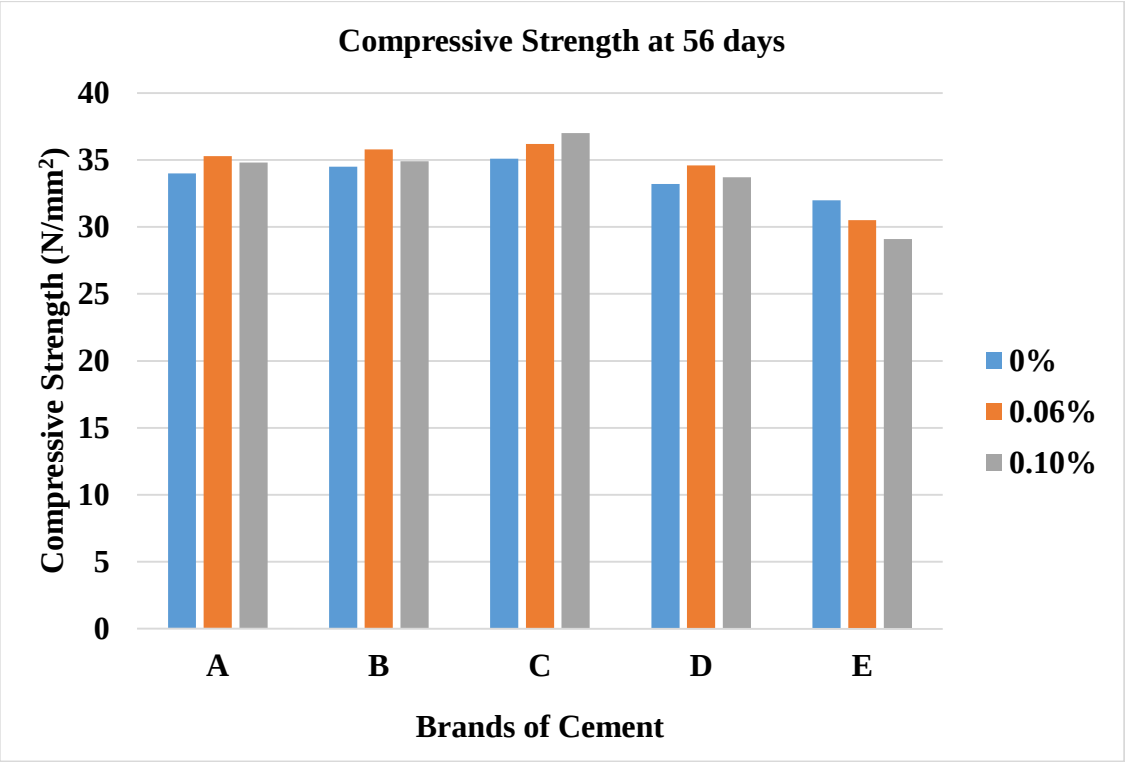


Figure 4.4 Relationship between the Compressive strengths of the Brands of cement and Percentage addition of sugar at 56 days curing period

4.3.2 Split tensile strength test

4.3.2.1 Split tensile strengths at 28 days

Figure 4.5 shows the split tensile strengths of each brand of cement at 28days curing period. The split tensile strengths of the control specimens made with A, B, C, D and E cement brands are 1.90 N/mm^2, 1.33 N/mm^2, 1.90 N/mm^2, 1.34 N/mm^2 and 2.01 N/mm^2 respectively. It can be observed that there is higher increase in split tensile strength by adding 0.06% of sugar in A, B and D cement brands by 8.9%, 27.8% and 34% respectively, while cement E showed a decrease in split tensile strength of 23.88% when compared with the control. At 0.1% addition of sugar, only cement C recorded higher increase in split tensile strength of 16% when compared with the control. However, at every percentage additions of sugar only A and C cement brands attained the limited

values of split tensile strength of concrete specimen specifies by Garba (2008) which should be within the range of 1/12 to 1/13 of compressive strength.

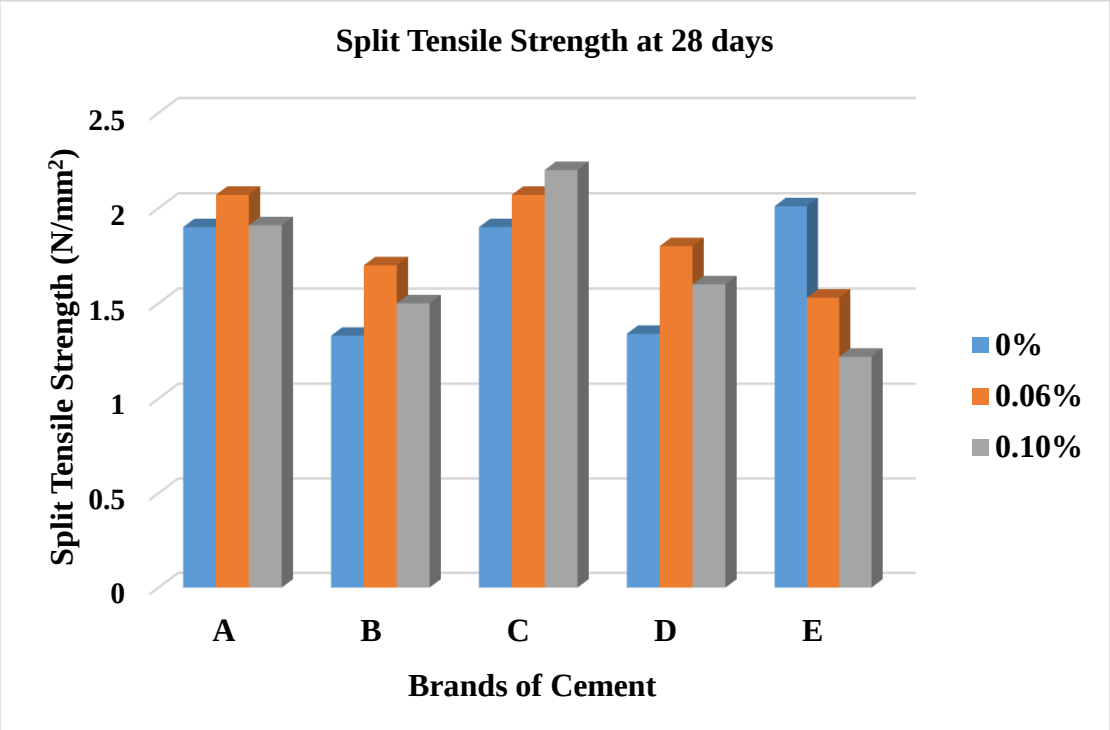


Figure 4.5 Relationship between the Split Tensile strengths of the Brands of cement and Percentage addition of sugar at 28 days curing period

4.3.2.2 Split tensile strengths at 56 days

Figure 4.6 shows the split tensile strengths of each brand of cement at 56 days curing period. The split tensile strengths of the control specimens made with A, B, C, D and E cement brands are 2.15 N/mm^2, 1.60N/mm^2, 2.30 N/mm^2, 1.53 N/mm^2 and 2.33 N/mm^2 respectively. It can be observed that there is higher increase in split tensile strength by adding 0.06% of sugar in A, B, C and D cement brands by 18.1%, 25%, 30.7% and 8.7% respectively. This shows that these brands of cement recorded higher split tensile strengths more than control specimens. However, only A and C cement brands attained the limited values of split tensile strength of concrete specimen specifies by Garba (2008) which should be within the range of 1/12 to 1/13 of compressive strength. Moreover, at

0.1% only cement C brand recorded a higher increase in split tensile strength of 21.7% when compared with the control specimen.

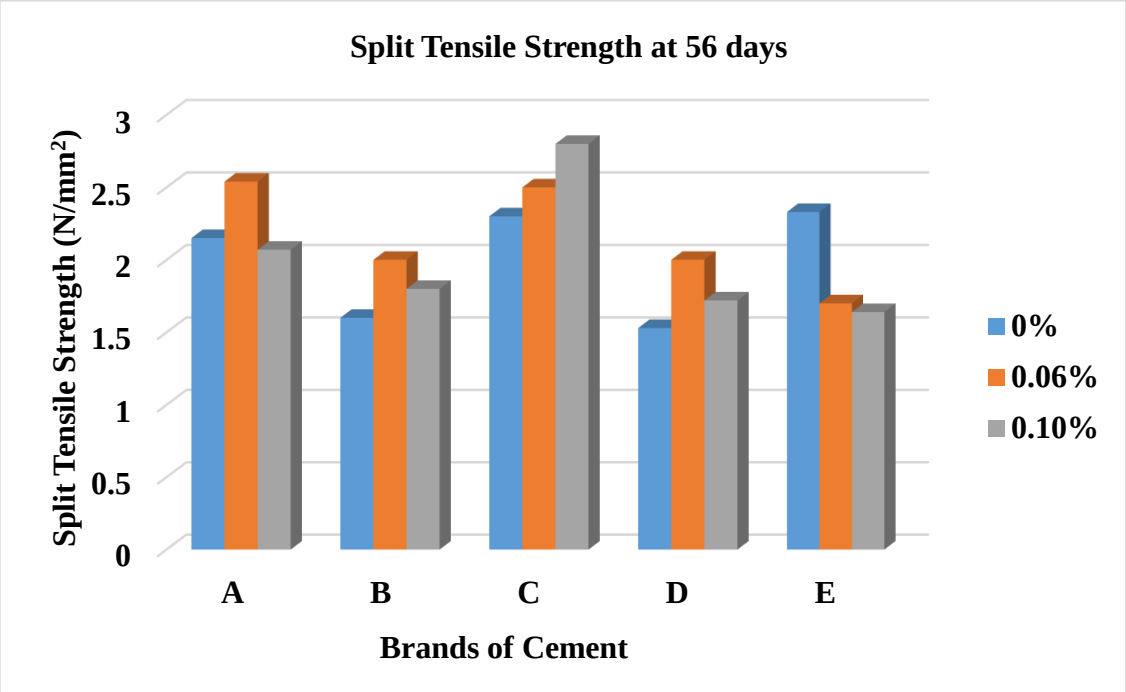


Figure 4.5 Relationship between the Split Tensile strengths of the Brands of cement and Percentage addition of sugar at 56 days curing period

4.3.3 Abrasion resistance

Tables 4.7 and 4.8 presents the abrasion resistance (% weight loss) of concrete specimens made with the various brands of Portland cement at 28 and 56 days curing periods respectively. From the result it can be observed that, the percentage weight loss decreased as the percentage additions of sugar increases in all the brands of cement. At 0.06% all the brands of cement showed a decrease in percentage weight loss when compared with the control specimens. B and C cement brands recorded lower percentage weight loss of 0.04% each at 56 days curing period. Similarly, at 0.1% all the concrete specimens made with the various brands of cement recorded lower percentage weight loss less than the control specimens. This means that 0.06% and 0.1% addition of sugar in all the concrete specimens made with the various brands of cement resist abrasion impact more than the

control specimens at all the curing periods. This result is in agreement with the finding of Naqash *et al.,* (2014).

Table 4.7 Relationship between abrasion resistance of concrete specimens made with brands of cement and percentage addition of sugar at 28 days curing period

Cement brands	Abrasion resistance (% weight loss)		
	Percentage Addition of Sugar		
	0%	0.06%	0.1%
A	0.18	0.08	0.42
B	0.16	0.04	0.04
C	0.08	0.08	0.04
D	0.13	0.08	0.04
E	0.28	0.08	0.17

Source: Laboratory Research Work (2015)

Table 4.8 Relationship between abrasion resistance of concrete specimens made with brands of cement and percentage addition of sugar at 56 days curing period

Cement brands	Abrasion resistance (% weight loss)		
	Percentage Addition of Sugar		
	0%	0.06%	0.1%
A	0.12	0.08	0.09
B	0.08	0.04	0.04
C	0.08	0.04	0.07
D	0.12	0.08	0.08
E	0.11	0.08	0.09

Source: Laboratory Research Work (2015)

4.4.3 Water absorption

Tables 4.9 and 4.10 presents the water absorption of concrete specimens made with the various brands of Portland cement at 28 and 56 days curing periods respectively. From the result it can be observed that the level of sorptivity of concrete specimens reduced with increased in curing days in all the concrete specimens made with the various brands of cement. Only at 0.06% that the concrete specimens made with the various brands of cement recorded a higher decrease in percentage water absorption when compared with the control specimens. Cement brand C has the lower value of 3.82%. This means that at 0.06% all the concrete specimens made with the various brands of cement absorbed less water than at 0.1% and also at 0% addition of sugar. Furthermore, only at 0.06% that the concrete specimens satisfies the assertion made by Pitroda and Shah (2014) that the average water absorption of concrete specimens shall not be greater than 5% at 28 days curing age.

Table 4.9 Relationship between percentage water absorption of concrete specimens made with brands of cement and percentage addition of sugar at 28 days curing period

Cement brands	Average Water Absorption (%)		
	Percentage Addition of Sugar		
	0%	0.06%	0.1%
A	5.45	4.39	4.91
B	4.36	4.52	5.28
C	5.90	3.82	4.40
D	5.17	4.62	4.52
E	5.48	4.92	5.00

Source: Laboratory Research Work (2015)

Table 4.10 Relationship between percentage water absorption of concretes made with brands of cement and percentage addition of sugar at 56 days curing period

Cement brands	Average Water Absorption (%)		
	Percentage Addition of Sugar		
	0%	0.06%	0.1%
A	3.50	3.20	3.40
B	3.95	3.63	3.70
C	3.94	3.15	3.19
D	5.10	3.18	3.63
E	3.24	3.70	3.60

Source: Laboratory Research Work (2015)

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Major Findings

This research assessed the effects of sugar as retarder on the properties of concretes made with selected brands of Portland cement in Nigeria. Highlight of the major findings are as follows:

1. The percentage content of aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3) in all the cement brands investigated were found to be within the range of 3.0 to 8.0 and 0.5 to 6.0 respectively, this satisfies the ASTM C 150 (2005) requirement. Cement brand A has the higher content of CaO of 75.57% while cement brand B has the least values of 67.91%.
2. The initial setting times for control pastes made with cement brands A, B, C, D and E were reduced by 24.73%, 40% 38%, 45.94% and 51.85% respectively at simulated hot ambient temperature of 43^{o}C when compared to the initial setting time control pastes at the normal laboratory temperature of 27^{o}C.
3. At the temperature of 43^{o}C, addition of 0.1% of sugar to the cement pastes made with cement brands A, B, D and E recorded a significant increase in initial setting times of 175%, 124%, 100% and 196% respectively, while cement C recorded higher increase of 88% at 0.06%.
4. Based on the workability tests, it was revealed that the slump and compacting factor values of fresh concrete increased as the percentage addition of sugar increases.
5. The compressive strength test results at 28 days curing period showed that addition of 0.06% sugar in concrete specimens made with cement brands A, B and D leads to the higher increase in compressive strengths of 8.8%, 6.6%, and 9.5%

respectively over the control specimens, while cement brand C recorded higher increase of 13.7% at 0.1%. Cement brand E recorded a decrease in compressive strength of 8.47% and 17.63% at 0.06% and 0.1% respectively when compared with the control specimens.

6. Split tensile strength test results at 28 days curing period showed that the addition of 0.06% sugar in concrete specimens made with cement brands A, B and D leads to the higher increase in strengths of 8.9%, 34% and 27.8% respectively over the control specimens, while cement brand C recorded higher increase of 16% at 0.1%.
7. The abrasion resistance and water absorption tests results at 56 days of curing periods revealed that the addition of 0.06% sugar in all the brands of cement leads to the higher resistance to abrasion and less sorptivity than at 0.1% and also 0% (control).

5.2 Conclusions

Based on the findings of the research, the following conclusions were drawn:

1. The result of the chemical analysis revealed that the brands of cement satisfies the ASTM C 150 (2005) requirements. However, cement brand C seems to be the best having the low content of aluminum oxide (Al_2O_3) and high percentage of iron oxide (Fe_2O_3) which implies low content of C_3A.
2. The addition of sugar to the cement pastes made with cement brands A, B, C, D and E retards the setting times of the cement paste both at the normal laboratory temperature of 27^{o}C and 43^{o}C.
3. The addition of sugar in concrete specimens made with the brands of cement increased the workability of the fresh concrete. It also enhanced the properties of

hardened concrete such as compressive strength, split tensile strength, abrasion resistance and less water absorption when an optimum dosage is used.

4. The optimum dosage of sugar for cement brands A, B and D was 0.06%. While for cement brand C 0.1% proved to be the optimum dosage. However, cement brand E recorded a decrease in strengths at every percentage addition of sugar.
5. Based on the findings, additions of sugar in concrete specimens made with the cement brands A, B, C and D had the higher strengths and better durability properties compared to those of control specimens.

5.3 Recommendations

5.3.1 Recommendations

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

1. The use of ordinary sugar as a retarding admixture in cement brands A, B, C and D is recommended in concrete production especially when concreting in hot dry weather regions in Nigeria such as Sokoto, Birnin Kebbi, Yola, Maiduguri, etc.
2. It is further recommended that sugar should not be used as a retarding admixture in cement brand E, because it negatively affects the cement's compressive strength at 3, 7, 24 and 56 days curing age.
3. Heat affects the setting time of the cement brands A, B, C and D as such retarding admixture should be used in these cement brands when concreting in the hot weather regions.

5.3.2 Recommendations for further research

1. Further research should be carried out to compare the effects of sugar on concrete with other retarding admixtures.

2. It is recommended that studies should be conducted to assess durability properties of concrete made with sugar as an admixture when exposed to chemically aggressive environments.
3. Further research should be carried out to evaluate the long term effects of sugar on the properties of concrete such as creep, long term shrinkage, etc.

5.4 Contribution to Knowledge

The research work established that:

1. the optimum dosage of sugar that can be used as retarder in cement brands A, B, and D as 0.06% by weight of cement while for cement brand C as 0.1%.
2. when sugar is used as retarder in cement E the compressive strength decreases at 28 days by 8.47% and 17.63% at the dosage of 0.06% and 0.1% respectively.
3. sugar when used as a retarder in cement brands A, B, C, and D has the potential of improving the desirable properties of concrete such as workability, compressive strengths and less water absorption when an optimum dosage is used.

REFERENCES

Abalaka, A.E. (2011a). Effects of sugar on physical properties of ordinary Portland cement paste and concrete. *AUJ.T.*14 (3): 225- 228.

Abalaka, A.E. (2011b). Comparative Effects of cassava starch and simple sugar in cement mortar and concrete. *ATBU journal of Environmental Technology*: 4(1).

Aka, A., Usman M., Umar M. B. and Samuel, O. (2013). Effect of Admixture on Fire Resistance of Ordinary Portland Cement Concrete. *Civil Environmental Research.* 3(1), 105-107. Retrieved from http://www.iiser.org

Alsadey, S. (2013). Effects of superplasticizing and Retarder Admixture on Properties of Concrete. *International Conference on Innovations in Engineering and Technology,* (ICIET 2013). Bangkok, Thailand. 1-2.

American Concrete Institute (ACI). (1993). Specifications for Chemical admixtures for concrete. ACI committee 212 Detroit, Michigan, 1-5.

American Concrete Institute committee 305R. (1991). Hot weather concreting. American concrete institute, Hills, Michigan ACI 305-99, 23-24.

American Society for Testing and Material (1999): Standard Specification for Chemical Admixture in Concrete. ASTM C494-99. West, Conshohocken, PA19428-2959, United States, 1-3.

American Concrete Institute (2001). Guide to Durable Concrete. *American Concrete Institute*, ACI EI-99 Committee Report E-701, Farmington Hills, Michigan, USA. 1-8.

American Concrete Institute (2001). Aggregate for Concrete. *American Concrete Institute*, ACI EI 201 2R-01, Farmington Hills, Michigan, USA, 1-14.

American Society for Testing and Material (2005): Standard Specification for Portland cement. ASTM C150-05. West, Conshohocken, PA19428-2959, United States, 1-3.

American Society for Testing and Material (2005). Test method for Abrasion Resistance of Horizontal concrete surface. *Annual Book of ASTM Standards;* (4)2.

Anejo, J. A., Habeeb, G. and Audu A. (2014). Comparative Study of the Physical Properties of Some Selected Cement Brand in Nigeria. *International Journal of Engineering Research and Development,* 10(12), 39- 44. Retrieved from http://www.ijerd.com

Barry R. (1999). *The Construction of Building*. Volume (4). Blackwell Science Ldt, Great Britain.

British Standard 4550 part 5 (1978). Standard sand aggregate for concrete cubes. British Standard Institution, 389 Cheswick high Road, London.

British Standard 812 part 2 (1975). Methods of sampling and testing of minerals aggregate, sand and fitters. British Standard Institution 389 Cheswick High Rofel, London

British Standard 3148 (1980). Standard for quality of mixing water. British Standard Institution, London, England, U.K

British Standard European Norm, (1992). Determination of fineness. B. S EN 196-6: 1992, BSI 389 Chiswick High Road London.

British Standard 5328: part 3 (1990). Specification for the procedures to be used in producing and transporting concrete, BSI 389 Chiswick High Road London. 6-8.

British Standard 1881: part 103 (1993). Method for determination of compacting factor, BSI 389 Chiswick High Road London.

British Standard 812 part 2 (1995). Testing aggregate part 2. Methods of determination of density. BSI Publication British Standard Institution, London.

British Standard European Norm 196-3 1995. Methods of testing cement: Determination of setting time and soundness. European standard, European committee for standardization, Brussels, Belgium.

British Standard European Norm, (1996). Testing for geometrical properties of aggregate; Determination of particle size distribution-Test sieves, nominal size of apertures. BS EN 933-2, BSI, Milton Keynes MK14 6LE, U.K

British Standard Institution BS 12 (1996). Ordinary Portland cement and Rapid Hardening cement. British Standard Institution 389 Cheswick High Rofel, London

British Standard 5328: part 1 (1997). Guide to specifying concrete, BSI 389 Chiswick High Road London. 14-15.

British Standard 8110- part 1: (1997). Structural use of concrete technology- code of practice for design and construction, London. 141- 142.

British Standard European Norm, (2000). Testing Hardened Concrete; shape, dimension, and other requirements for specimens and moulds. BS EN 12390-1, BSI, Linfordwood, Milton Keynes MK14 6LE, U.S

British Standard European Norm, (2000). Testing Hardened Concrete; Density of hardened concrete, BS EN 12390-7, BSI, Linfordwood, Milton Keynes MK14 6LE, U.S

British Standard European Norm, (2000). Composition, Specification and Conformity Criteria for Common Cements. *BS EN 197-00,* BSI 389, Chiswick High Road London, 15- 17.

British Standard European Norm, (2000). Testing Hardened Concrete; Compressive strength test. BS EN 12390-3, BSI, Linfordwood, Milton Keynes MK14 6LE, U.S

British Standard European Norm, (2000). Testing Hardened Concrete; Tensile splitting strength of test specimens BS EN 12390-6, BSI, Linfordwood, Milton Keynes MK14 6LE, U.S

British Standard European Norm, 1008, (2002). Mixing Water for Concrete. Specification for Sampling, Testing and Assessing the Suitability of Water, Including Water Recovered from Processes in the Concrete Industry, as Mixing Water in Concrete.

British Standard European Norm, 12350-2 (2009). Testing fresh concrete Slump. BSI 389 Chiswick High Road, London.

British Standard European Norm, 12390-3, (2009). Determination of setting time and soundness. BSI 389 Chiswick High Road, London.

British Standard European Norm, (1995). Method of testing cement; Chemical analysis of cement. BS EN 196-2, BSI, Linfordwood, Milton Keynes MK14 6LE, U.S

British Standard, (1983). Testing concrete; Method for determination of slump. BS 1881-102, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K

British Standard, (1983). Testing fresh concrete. Method for determination of water absorption. BS 1881-122, BSI, Linfordwood, Milton Keynes MK14 6LE, U.S

British Standard, (1986).Testing Concrete; Method for mixing and sampling fresh concrete in the laboratory. BS 1881-125, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

Castro, J. Bentz, D. and Weiss, J. (2011). Effect of Sample Conditioning on the Water Absorption of Concrete. *Cement and Concrete Composition,* 33(1), 805-813. Doi:10.1016/j.cemconcomp.2011.05.007

Dahiru, D. (2010). Problem of Ready- Mix Concrete Production in the Construction Industry in Nigeria and its Cost Implication. Paper presented on *West Africa Built Environment Research (WABER) Conference Jult 27-28,* Accra, Ghana 449-451.

Dias, W.P.S., Dewapriya, M. A.N., Edirisooriya, E.A.C.K., and Jayathunga, C. G. (2010). Effects of Large Retarder Overdose on Concrete Strength Development. *The Institution of Engineers,* Sri Lanka, 13- 16.

Dransfield, J. (2012). Cement Admixture Association. *EFCA.* 38a Tilehouse Green Lane, Knowle, West Midland B939EY, UK. 1-4. Retrieved from htt://www.admixtures.org.uk

Duggal, S. K. (2008). *Building Material*. Ansari road Daryaganji, New Delhi- 110002: New Age International Ltd, 144-245.

Duna, W. (2014). Effect of Sucrose on the Setting time of Concrete. *Unpublished B.Sc Thesis Work,* Department of Building Faculty of Environmental Design, Ahmadu Bello University, Zaria, Nigeria.

European Federation of Concrete Admixtures Association (EFCA). (2005). Retarding admixtures. EFCA Environmental Declaration, United Kingdom, 1-2.

Gadzama E. W., Ekele O. J., Anametemfiok V. E. and Abubakar A. U. (2015). Effects of Sugar Factory Wastewater as Mixing Water on the Properties of Normal Strength Concrete. *International Journal of Science, Environmental and Technology*, 4(3), 818- 819.

Giridhar. V., Gnaneswar. K. and Kishore Kumar Reddy. P. (2013). Effect of sugar and jiggery on strength properties of concrete. *The International Journal of Engineering and Science*.2 (10): 2319- 1805. Retrieved from http//:www.theijes

Greesan, R., Prathap P. & Vijayakumar R. (2014). Manufacturing of Concrete with Retarders. *International Journal of Scientific & Engineering Research,* 5(4), 1637- 1639. Retrieved from http://www.ijser.org

Gupta, B.L and Gupta Amit (2004). *Concrete Technology*, A. K. Jain, Standard Publishers Distributor. 1705-B, Nai Sarak, Delhi- 110006, 121-290.

Gupta, B.L and Gupta A. (2012). *Concrete Technology*, Bhargare Laser Printers, Delhi: Prabhat offset press, Delhi, 151-153.

Ibrahim, H. H., Birnin Yauri, U. A., Muhammad, C. and Umar, A. (2012). Assessment of Pollution Potentialities of Some Portland Cement. *Nigerian Journal of Basic and Applied Science,* 20(2). 183-184. Retrieved from htt://www.ajol.info/index.php/njbas/index

Jayakumaran, al G. (200). The Effect of Over Dosage of Concrete Daratard 40 in Concrete. *Master Thesis Work,* University Teknologi Malaysia, Malaysia. 19-22.

Khan, B.and Baradan, B. (2002). The effect of sugar on setting time of various types of cement. *Quarterly Science Vision.* 8(1). Izmir, Turkey, 71-78.

Khan, B. and Ullah, M. (2004). Effect of a retarding admixture on setting time of cement pastes in hot weather. *JKAU: English Science*. 15(1): 63- 79.

Khan B. (2006). Effects of high early temperatures on the setting time and strength of cement paste and mortar blended with barite powder. *International workshop CBM-CI*, Karachi, Pakistan, 456-461.

Kumar D. (2015). Sugarcane Molasses in Concrete as a Water Reducing- Retarding Admixture. *International Journal of Civil Engineering*. ISSN: 2348-8352, 123-124.

Li, Z. (2011). *Advanced Concrete Technology*. Hoboken, New Jersey: John wiley and sons. Inc., 7-135.

Lyons. A. (2007). *Materials for Architects and Builders*. 3th edition. British library caraloguing: Linacre House, Jordan hill, Oxford OX2, United Kingdom, 50-55.

Macginley and Choo, B. S. (2003) *Reinforced Concrete Design Theory and Examples*. Taylor and Francis e-library London, 9-15.

Maroliya, M.K. (2012). Influence of Chemical Admixtures on Density and Slump loss of Concrete. *International Journal of Modern Engineering Research,* 2(6), 4077-4079. Retrieved from http://www.ijmer.com

Myrdal, R. (2007). Retarding Admixtures for Concrete. *Sintef Report*.No.7465 Trondheim, Norway, 5- 16. Retrieved from http://www.sintef.no/coin

Naqash, J. A., Zahid, B. B., Mohammad, I. M., Subzar, A. and Dharvinder, K. (2014). Effect of Accelerating Admixture on Properties of Concrete. *International Organization of Scientific Research,* 4(3), 50-53.

Nensok, M. H. (2010). The Effect of Environment and Curing Medium on the Properties of Blended Concrete. *Unpublished M. Sc Thesis Research Work,* Department of Building, Faculty of Environmental Science, University of Jos, Nigeria. 86-100.

Neville A. M. (2006). *Properties of Concrete*. Fourth edition. Pitman Publishing Corporation, Dorling Kindersley, New Delhi, India. 97-98.

Neville A. M and Brooks J. J. (2010). *Concrete Technology*. Longman Group United Kingdom Limited 8-178.

Newman, J. and Choo. B. S. (2003). *Advanced Concrete Technology: Theory and Practice,* Replika press Ltd, India: Printed and bound in Great Britain, 358-368.

Nura, M. I. (2015). Influence of Effective Microorganisms Made From Locally Available Fruit Wastes on Concrete. *Unpublished M.Sc Thesis Work,* Department of Building Faculty of Environmental Design, Ahmadu Bello University, Zaria, Nigeria. 12-17

Okereke, P. A. (2003). *Construction Material: Testing and Quality Control in Tropical Climate*, 72 Mbaise Road, Owerri: Crown publisher Limited, 6-10.

Oladiran, A., Olufikayo A. and Moses T. (2012). Effect of a locally sourced water Reducing/Retarding admixture on concrete. *Journal of Civil Engineering and Urbanism*. 2(5): 170- 175. Retrieved from http://www.ojceu.ir

Otunyo, A. W., Onwusiri, S. C. and Nwaiw N. (2015). Effect of Sugar cane Juice on Slump values, Setting times and Strength of Concrete. *Nigerian Journal of Technology*, 34(2), 254-256.

Pitroda, J. and Shah, D. S. (2014). An Experimental Study on Durability and Water Absorption Properties of Pervious Concrete. *International Journal of Research in Engineering and Technology*, 3(3), 439-443. Retrieved from http://www.ijret.org

Ramachandran, V. S. and Lowery, M. S. (1992). Conduction Calorimetric Investigation of the Effect of Retarders on the Hydration of Portland Cement. *Thermochimica Acta, 195*.Elservier Science Publisher B. V. Amsterdam, 382-383.

Ramachandran, V. S. (1999). *Concrete Admixture Handbook; Properties, Science and Technology.* Noyes Publications, Park Ridge. New jersy, USA. 121- 193.

Rana, S. (2014). Effect of sugar on setting time and compressive strength of ordinary Portland cement paste. *World conference on Applied Science, Engineering and Technology.* Kathmandu, Nepal, 1-3. ISBN 13: 978-81-930222-0- 7.

Rathi, V. R. and Kolase, P. K. (2013). Effect of Cold Joint on Concrete. *International Journal of Innovative Research in Science, Engineering and Technology*, 2(9), 461- 462. Retrieved from http://www.ijirset.com

Rowland, G. O. (2014). Minimizing Hot Weather Effects on Fresh and Hardened Concrete by Use Cassava Powder as Admixture. *European International Journal of Science and Technology*, 3(2), 1-2. Retrieved from http://www.eijst.org.uk

Schaeffel, P., Joerg R. and Gerhard S. (2014). Modern admixtures for concrete. *Think on the end before you begin*. Nesher, Israel, 40-41.

Shetty, M.S. (2009).*Concrete Technology: Theory and Practice*, S. chad and company Ltd, Ram Nagar, New Delhi 110055, India, 124-554

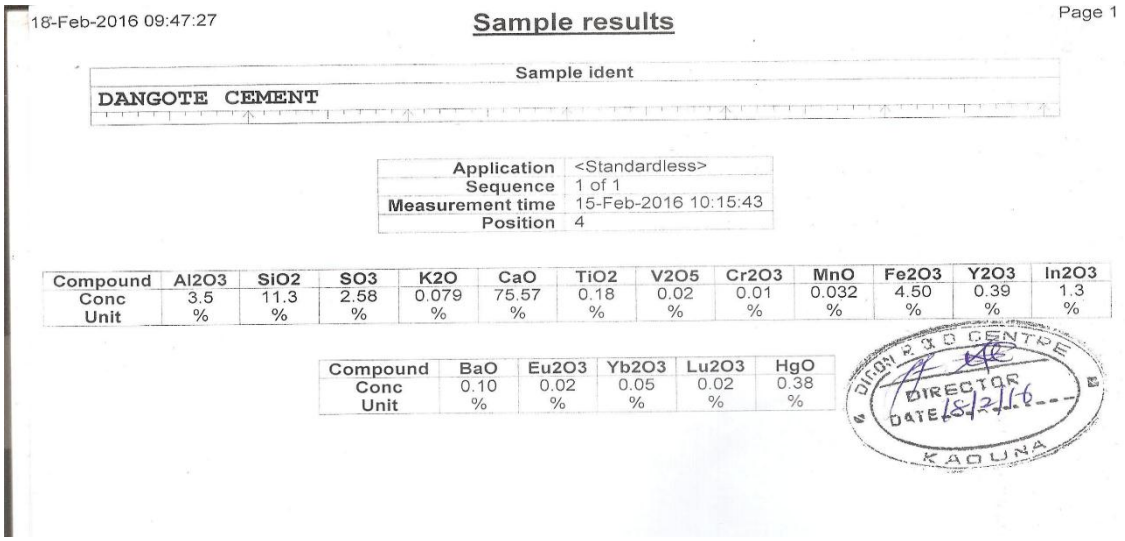
Suryawanshi, Y. R., Pankaj N. B., Shinde, R.R, Pawar S.B. and Namrata M. (2014). Experimental study on effect of sugar on strength of cement, *International Journal of Research in Engineering and Technology. 2(4): 2499- 252*. Retrieved from http//:www.impactsjournals.us

Susilorini, R., Nikodemus M. I. and Budi, S. (2009). The Performance of Low Dosage of Sucrose as Green Admixture for Concrete. *Konferensi Nasional Teknik Sipil 3 (Konteks 3)*, Jakarta 6(7), 211-217.

Yahaya B.S., Egbuna I.C., Apeh E.S., Ogwu E., Achema F., and Fabiyi M.O. (2014). Comparism of the Compressive Strength of Concrete Made with Different Brands of Ordinary Portland cement. *International Journal of Engineering and Innovative Technology*, 4(3), 36- 39. Retrieved from http://www.ijeiset.com

APPENDIX

APPENDIX A1: Percentage Composition of Chemical Constituents of Cement A Brand.



18-Feb-2016 09:47:27

Sample results

Page 1

Sample ident
DANGOTE CEMENT

Application	<Standardless>
Sequence	1 of 1
Measurement time	15-Feb-2016 10:15:43
Position	4

Compound	Al2O3	SiO2	SO3	K2O	CaO	TiO2	V2O5	Cr2O3	MnO	Fe2O3	Y2O3	In2O3
Conc	3.5	11.3	2.58	0.079	75.57	0.18	0.02	0.01	0.032	4.50	0.39	1.3
Unit	%	%	%	%	%	%	%	%	%	%	%	%

Compound	BaO	Eu2O3	Yb2O3	Lu2O3	HgO
Conc	0.10	0.02	0.05	0.02	0.38
Unit	%	%	%	%	%

DIGON 2 3 0 CENTRE
DIRECTOR
DATE 15/12/16
KADUNA

APPENDIX A2: Percentage Composition of Chemical Constituents of Cement B Brand.

18-Feb-2016 09:47:21 Page 1

Sample results

Sample ident
SOKOTO CEMENT

Application	<Standardless>
Sequence	1 of 1
Measurement time	15-Feb-2016 10:05:35
Position	2

Compound	Al2O3	SiO2	SO3	K2O	CaO	TiO2	V2O5	Cr2O3	MnO	Fe2O3	Y2O3	In2O3
Conc	5.0	15.1	3.48	0.100	67.91	0.30	0.040	0.027	0.14	5.05	0.76	1.3
Unit	%	%	%	%	%	%	%	%	%	%	%	%

Compound	BaO	Eu2O3	Lu2O3	Au	HgO
Conc	0.14	0.03	0.059	0.26	0.34
Unit	%	%	%	%	%

DIRECTOR
DATE 16/2/16
KADUNA

APPENDIX A3: Percentage Composition of Chemical Constituents of Cement C Brand.

18-Feb-2016 09:47:16

Sample results

Page

Sample ident
BUA CEMENT

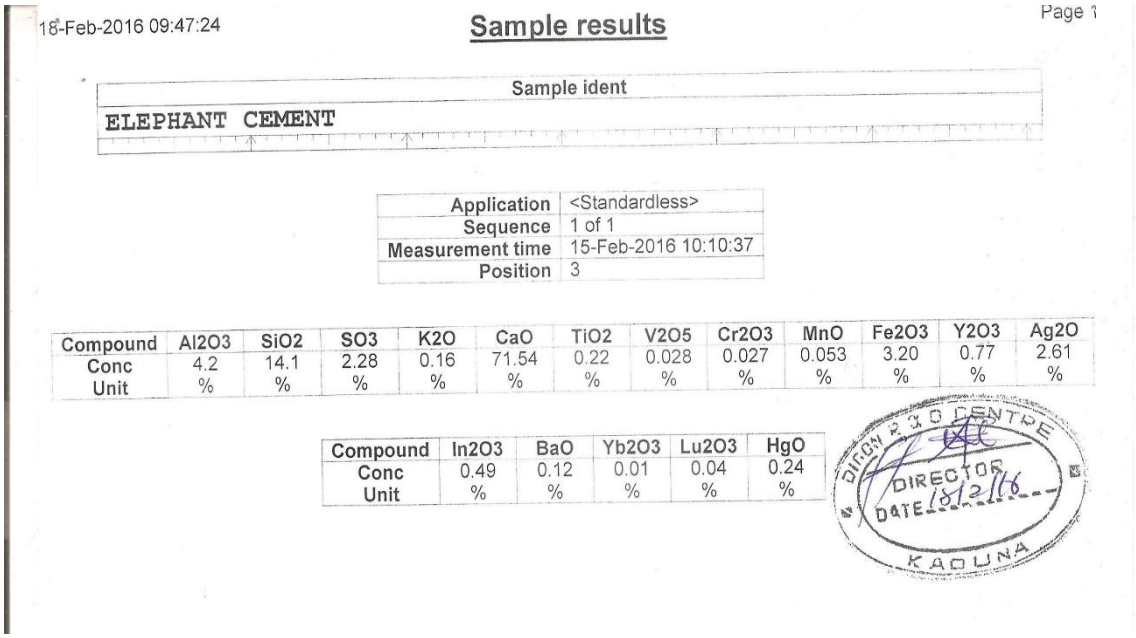
Application	<Standardless>
Sequence	1 of 1
Measurement time	15-Feb-2016 10:00:31
Position	1

Compound	Al2O3	SiO2	SO3	K2O	CaO	TiO2	V2O5	Cr2O3	MnO	Fe2O3	Y2O3	In2O3
Conc	4.1	15.8	2.38	0.29	68.49	0.23	0.023	0.012	0.077	6.36	0.46	1.2
Unit	%	%	%	%	%	%	%	%	%	%	%	%

Compound	BaO	Eu2O3	Yb2O3	Lu2O3	HgO
Conc	0.12	0.001	0.01	0.02	0.42
Unit	%	%	%	%	%



APPENDIX A4: Percentage Composition of Chemical Constituents of Cement D Brand.



18-Feb-2016 09:47:24

Page 1

Sample results

Sample ident
ELEPHANT CEMENT

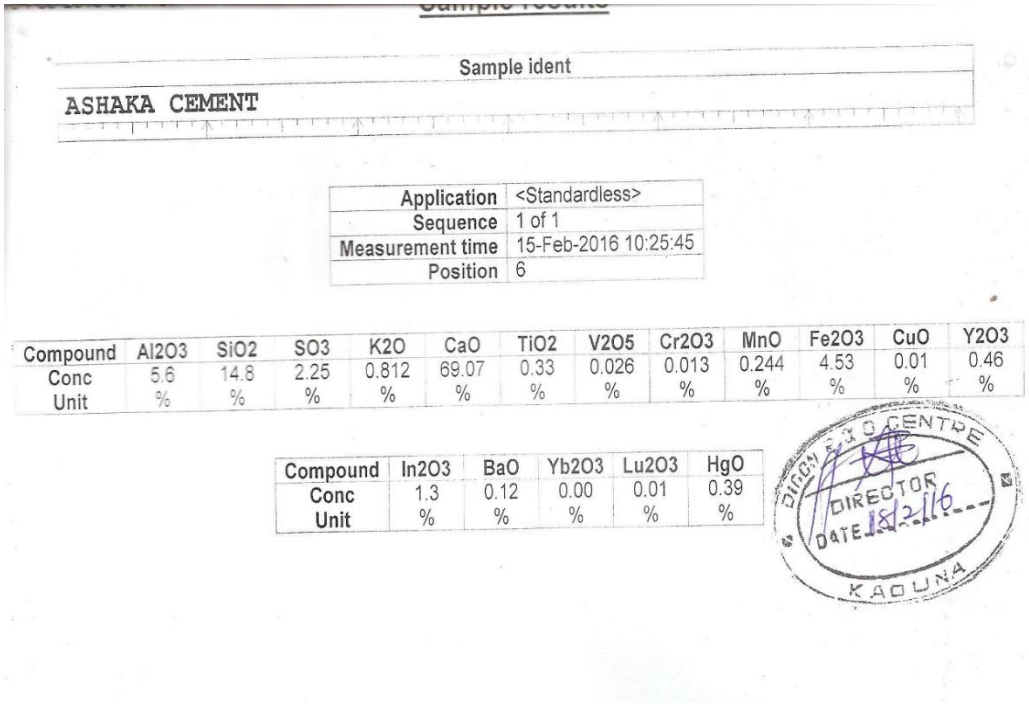
Application	<Standardless>
Sequence	1 of 1
Measurement time	15-Feb-2016 10:10:37
Position	3

Compound	Al2O3	SiO2	SO3	K2O	CaO	TiO2	V2O5	Cr2O3	MnO	Fe2O3	Y2O3	Ag2O
Conc	4.2	14.1	2.28	0.16	71.54	0.22	0.028	0.027	0.053	3.20	0.77	2.61
Unit	%	%	%	%	%	%	%	%	%	%	%	%

Compound	In2O3	BaO	Yb2O3	Lu2O3	HgO
Conc	0.49	0.12	0.01	0.04	0.24
Unit	%	%	%	%	%

DIFCON 2 3 0 CENTRE
DIRECTOR
DATE 18/2/16
KADUNA

APPENDIX A5: Percentage Composition of Chemical Constituents of Cement E Brand



Sample ident

ASHAKA CEMENT

Application	<Standardless>
Sequence	1 of 1
Measurement time	15-Feb-2016 10:25:45
Position	6

Compound	Al2O3	SiO2	SO3	K2O	CaO	TiO2	V2O5	Cr2O3	MnO	Fe2O3	CuO	Y2O3
Conc	5.6	14.8	2.25	0.812	69.07	0.33	0.026	0.013	0.244	4.53	0.01	0.46
Unit	%	%	%	%	%	%	%	%	%	%	%	%

Compound	In2O3	BaO	Yb2O3	Lu2O3	HgO
Conc	1.3	0.12	0.00	0.01	0.39
Unit	%	%	%	%	%

APPENDIX B1

Table B1: Relationship between compressive strengths of concrete specimens made with brands of cement and percentage addition of sugar at 3 days curing period

Cement brands	**Average Compressive Strength (N/mm^2)**		
	Percentage Addition of Sugar		
	0%	**0.06%**	**0.1%**
A	11.8	12.5	11.2
B	14.0	13.2	11.1
C	14.1	14.5	15.0
D	12.1	11.2	9.8
E	11.0	10.6	9.5

Source: Laboratory Research Work (2015)

APPENDIX B2

Table B2: Relationship between compressive strengths of concrete specimens made with brands of cement and percentage addition of sugar at 7 days curing period

Cement brands	**Average Compressive Strength (N/mm^2)**		
	Percentage Addition of Sugar		
	0%	**0.06%**	**0.1%**
A	16.6	17.7	16.8
B	18.0	19.1	18.6
C	16.3	17.0	18.1
D	15.8	17.0	16.9
E	16.7	15.7	15.6

Source: Laboratory Research Work (2015)

APPENDIX B3

Table B3: Relationship between compressive strengths of concrete specimens made with brands of cement and percentage addition of sugar at 28 days curing period

Cement brands	**Average Compressive Strength (N/mm^2)**		
	Percentage Addition of Sugar		
	0%	**0.06%**	**0.1%**
A	30.7	33.4	31.2
B	30.1	32.1	31.0
C	29.9	32.6	34.0
D	28.5	31.2	29.1
E	29.5	27.0	24.3

Source: Laboratory Research Work (2015)

APPENDIX B4

Table B4 Relationship between compressive strengths of concrete specimens made with brands of cement and percentage addition of sugar at 56 days curing period

Cement brands	**Average Compressive Strength (N/mm^2)**		
	Percentage Addition of Sugar		
	0%	**0.06%**	**0.1%**
A	34.0	35.3	34.8
B	34.5	35.8	34.9
C	35.1	36.2	34.0
D	33.2	34.6	33.7
E	29.5	27.0	24.3

Source: Laboratory Research Work (2015)

APPENDIX C1

Table C1 Relationship between split tensile strengths of concrete specimens made with brands of cement and percentage addition of sugar at 3 days curing period

Cement brands	**Average Split tensile Strength (N/mm^2)**		
	Percentage Addition of Sugar		
	0%	**0.06%**	**0.1%**
A	1.10	1.20	1.02
B	1.12	1.02	0.93
C	1.00	1.20	1.40
D	1.13	1.14	1.00
E	1.10	1.00	0.90

Source: Laboratory Research Work (2015)

APPENDIX C2

Table C2: Relationship between split tensile strengths of concrete specimens made with brands of cement and percentage addition of sugar at 7 days curing period

Cement brands	**Average Split tensile Strength (N/mm^2)**		
	Percentage Addition of Sugar		
	0%	**0.06%**	**0.1%**
A	1.30	1.56	1.32
B	1.21	1.30	1.16
C	1.50	1.60	1.80
D	1.18	1.30	1.23
E	1.61	1.03	0.90

Source: Laboratory Research Work (2015)

APPENDIX C3

Table C3: Relationship between split tensile strengths of concrete specimens made with brands of cement and percentage addition of sugar at 28 days curing period

Cement brands	**Average Split tensile Strength (N/mm^2)**		
	Percentage Addition of Sugar		
	0%	**0.06%**	**0.1%**
A	1.90	2.07	1.91
B	1.33	1.70	1.50
C	1.90	2.07	2.20
D	1.34	1.80	1.60
E	1.33	1.70	1.50

Source: Laboratory Research Work (2015)

APPENDIX C4

Table C4: Relationship between split tensile strengths of concrete specimens made with brands of cement and percentage addition of sugar at 56 days curing period

Cement brands	**Average Split tensile Strength (N/mm^2)**		
	Percentage Addition of Sugar		
	0%	**0.06%**	**0.1%**
A	2.15	2.54	2.07
B	1.60	2.00	1.80
C	2.30	2.50	2.80
D	1.53	2.00	1.72
E	2.33	1.70	1.80

Source: Laboratory Research Work (2015)