SUITABILITY OF SISAL JUICE EXTRACT AS A RETARDER IN CEMENT CONCRETE

MICHAEL OKILATE ELOGET

MASTER OF SCIENCE
(Construction Engineering and Management)

JOMO KENYATTA UNIVERSITY OF

AGRICULTURE AND TECHNOLOGY

2022

Suitability of Sisal Juice Extract as a Retarder in Cement Concrete

Michael Okilate Eloget

A Thesis submitted in Partial Fulfilment of the Requirements
for the Degree of Master of Science in Construction Engineering
and Management of the Jomo Kenyatta University of
Agriculture and Technology

2022

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signature: ……………………………………………..Date: ……………………………

Eloget, Michael Okilate

This thesis has been submitted for examination with my approval as the University Supervisors.

Signature: ……………………………………………..Date: ……………………………

Prof. Silvester Abuodha, PhD
UoN, Kenya

Signature: ……………………………………………..Date: ……………………………

Mr. Mathew Winja
JKUAT, Kenya

DEDICATION

This thesis is dedicated to members of my family for their physical, emotional, and psychological support accorded to me throughout this course and the writing of this thesis.

ACKNOWLEDGEMENT

I have benefited from the help of many people in coming up with this thesis. Fellow students, lecturers, laboratory technicians, colleagues and business contact have provided numerous insightful comments, suggestion and contribution that have progressively enhanced this thesis. I am indebted to all stakeholders who have accelerated the development of the literature in this thesis.

I am particularly indebted to my supervisors, Prof. Silvester Abuodha and Mr. Mathew Winja. The development of this thesis has benefited from their generous commitment of time, energy and ideas. The valuable recommendations, ideas and support from this outstanding men have added quality to this thesis.

I would also want to thank all my lecturers in who through their lectures provided me with a wealth of information that I applied during the development and reporting of this thesis. My appreciations extend to the entire Jomo Kenyatta University of Agriculture and Technology fraternity for their support and readiness to share information.

Special thanks go to my family for their unwavering support.

I hope that you will find my thesis all that you expect. I welcome your ideas and recommendations about my material and earnestly solicit your feedback.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

ASTM	American Society for Testing and Materials
BS EN	British Standard European Norm
Ca	Calcium
$Ca(OH)_2$	Calcium Hydroxide
Hc	Hydroxylated Carboxylic
IS	International Standard
MK	Matakaolin
Na	Sodium
NCS	Nanocrystal Seeding Chemical
NH_4	Ammonium
OPC	Ordinary Portland Cement
Pb	Lead
Pc	Portland cement
SCMs	Supplementary Cementitious Material
W/C	Water cement ratio
W/CM	Water Cementitious Material
Zn	Zinc

DEFINATIONS OF NOMENCLATURE

Admixtures	These are chemicals used to give special properties to fresh or hardened concrete.
Coarse Aggregates	Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates.
Compaction	The process by which the porosity of a given form of sediment is decreased as a result of its mineral grains being squeezed together by the weight of overlying sediment or by mechanical means.
Creep	In materials science, creep (sometimes called cold flow) is the tendency of a solid material to move slowly or deform permanently under the influence of mechanical stresses. It can occur as a result of long-term exposure to high levels of stress that are still below the yield strength of the material.
Eco-friendly	means earth-friendly or not harmful to the environment. The products also prevent contributions to air, water and land pollution.
Final Testing Time	The time when the paste completely loses its plasticity. It is the time taken for the cement paste or cement concrete to harden sufficiently and attain the shape of the mould in which it is cast.
Fine Aggregates	Aggregate passing the 3/8 (9.5-mm) sieve and almost entirely passing the No.4 (4.75-mm) sieve and predominantly retained on the pan.

Flexural Strength	is one measure of the tensile strength of concrete. It is a measure of an un-reinforced concrete beam or slab to resist failure in bending
Hydration	a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates
Initial Testing Time	This is the beginning of the noticeable stiffening in the cement paste and correspond to the rapid rise in temperature normally takes about 45 – 175 minutes
Load	Structural loads or actions are forces, deformations, or accelerations applied to a structure or its components. Loads cause stresses, deformations, and displacements in structures.
Micro-structural	is the small scale structure of a material, defined as the structure of a prepared surface of material as revealed by a microscope above 25× magnification
Porosity	is the quality of being full of tiny holes. Liquids go right through things that have porosity.
Radioactivity	The emission of elementary particles by some atoms when their unstable nuclei disintegrate
Retarders	A retarder is a chemical agent that slows down a chemical reaction. For example, retarders are used to slow the chemical hardening of plastic materials such as wallboard, concrete, and adhesives.
Shrinkage	is defined as the contracting of a hardened concrete mixture due to the loss of capillary water

Slump	is a form of mass wasting that occurs when a coherent mass of loosely consolidated materials or rock layers moves a short distance down a slope. Movement is characterized by sliding along a concave-upward or planar surface
Stress	is the force per unit area applied to the material
Super Plasticizers	are chemical admixtures used where well-dispersed particle suspension is required.
Toxicity	The degree to which a substance (a toxin or poison) can harm humans or animals
Workability	is often defined in terms of the amount of mechanical energy, or work, required to fully compact concrete without segregation. This is important since the final strength is a function of compaction.

ABSTRACT

Admixtures are used to improve the properties of concrete or mortar to make them more suitable to work by hand or for other purposes such as saving mechanical energy. Retarding admixtures are used to slow the rate of setting of concrete. By slowing the initial setting time, the concrete mixture can stay in its fresh mix state longer before it gets to its hardened form. Retarders can be formed by organic and inorganic material. The organic material consists of unrefined CaO, K_2O, MgO, AL_2O_3, salts of lignosulfonic acids, hydroxycarboxylic acids, and carbohydrates. Agave sisalana Perrine, popularly known as sisal is a commercially used fiber yielding plant. Cement concrete production especially in hot climate experience a lot of challenges from mixing, transporting and placing of concrete because of the accelerated setting of cement concrete due to high temperatures. Workability is compromised to a large extend and there is need to prolong the setting time allow for execution of the concreting activities. The rapid heat generation from large concrete pours can also lead to cracks in the concrete structure. This results in the need to slow the rate of concreting thereby causing costly delays. Retarders go a long way in slowing down the hydration process hence reduce the heat of hydration. The study investigated the suitability of sisal juice as a retarder to influence the properties of hardened concrete at a lower cost. This research implored the use of experimental design. The study used quantitative techniques of data analysis to analyze the test results of different experiments. Descriptive statistics including means, cross-tabulation, frequencies and percentages was used for comparison and the results presented in form of frequency tables, line graphs and bar charts for easier understanding and interpretation. SJE was used as a retarder to influence the properties of fresh and hardened concrete. Sisal juice extract was used as a partial replacement of water at different dosages and in the concrete mix. A total of 84 concrete cubes were produced in 7 sets of 12no. specimen each. One set was made with the control mix which had zero SJE content. The remaining sets had varying dosages of SJE namely 5%, 10%, 15%, 20%, 25% and 30%. Twelve beam specimens measuring 150x150x530mm were also casted. Specimens were subjected to Compressive strength tests as per BS EN 12390–3:2009, setting time test as per BS EN 196-3:1995 and slump test as per BS EN 12359–2:2009. To establish the effect SJE on strength of concrete, compressive strength was tested at 7, 14, 28 and 56 days while flexural strength was tested at 28 days. The results of the tests showed that both the workability of fresh concrete and the setting times increased with increasing proportion of SJE admixture. The rate of strength gain slowed consistently for all dosages greater than 5% for curing periods beyond the 7th day. From the aforementioned, the study concluded that sisal juice extract is suitable for use as a retarder and is therefore recommended for use to compensate for high temperatures and average time for concreting operations in hot climate regions.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Concrete is the most used construction material worldwide for both building and civil engineering structures. It is manufactured by mixing predetermined quantities of cement and fine and coarse aggregates with water. During mixing, small quantities of another material called admixture are added in order to improve the desirable properties of the resulting concrete.

Freshly mixed concrete is plastic and can be transported, moulded and compacted to make it denser. Subsequently the wet/fresh concrete gradually hardens as a result of an exothermic chemical reaction between the cement and water called hydration which involves setting and hardening. Finally the material hardens and acquires its characteristic strength required to support the predetermined structural load.In hot climates the process of hydration takes place much faster causing the fresh concrete to stiffen and harden faster without allowing sufficient time to transport, place and compact it.

The resulting rapid generation of heat during hydration causes rapid expansion of the concrete mass that results in development of cracks in the concrete structures under construction during cooling especially where there are large concrete pours. This results in the need to slow the rate of concreting thereby causing costly delays. (Muhammad & Muhammad, 2004). The period of hydration can be prolonged by use of a retarding admixture simply called a retarder. There are many types of retarders which may be classified into two groups namely lignosulphonic and hydoxylated–carboxylic acids. Organic material based retarders belong to the lignosulphonic group.

Admixtures are the ingredients in cement concrete other than Portland cement, water, and aggregates that are added to the mix immediately before or during mixing.

Admixtures are used primarily to reduce the cost of concrete construction; to modify the properties of hardened concrete and to ensure the quality of concrete during mixing, transporting, placing, and curing. Admixtures are classified according to function. There are five distinct classes of chemical admixtures namely air-entraining, water-reducing, retarding, accelerating, and plasticizers (super plasticizers)

The purpose of the air-entraining agents is to entrain small air bubbles in the concrete which in turn helps the concrete achieve enhanced durability in freeze-thaw cycles in cold climates. The main benefit of water reducing admixtures is that it requires less water to make a concrete of equal slump, or increase the slump of concrete at the same water content. The retarding admixture on the other hand helps in slowing down hydration of cement and lengthening setting time and are beneficial in hot climate. Accelerators shorten the setting time of concrete, allowing cold-weather pour, early removal of forms, early surface finishing, and in some cases, early load application. The main purpose of using superplasticizers is to produce flowing concrete with a high slump in the range of seven to nine inches to be used in heavily reinforced structures and in placements where adequate consolidation by vibration cannot be readily achieved. The other major application is the production of high-strength concrete at w/c's ranging from 0.3 to 0.4. It has been found that for most types of cement, superplasticizer improves the workability of concrete.

In the manufacturing process of cement, clinkers are formed, cooled down and mixed with small amount of a mineral called gypsum before the final grinding process. For ordinary Portland cement the gypsum added is between 3 to 4% and in case of quick setting cement it can be reduced up to 2.5%. The main purpose of adding gypsum in the cement is to prevent flash set. Addition of gypsum allows the cement concrete mix to remain plastic and workable for a longer time to allow for mixing, transporting and placing of concrete.

Some of the elements found in natural gypsum are as shown in Table 1 below.

Table 1.1: Chemical Composition of natural Gypsum (Wilder, 1919)

Element	Percentage by Weight (%)
Calcium Oxide (CaO)	38.46
Potassium Oxide (K_2O)	0.19
Magnesium Oxide (MgO)	0.94
Aluminum Oxide (AL_2O_3)	0.14
Silicon Dioxide (SiO_2)	0.51
Iron (Fe_2O_2)	0.14
Sulphur Trioxide (SO_3)	39.53
Phosphorous Pentoxide (P_2O_5)	-
Chlorine (Cl)	0.04
Zinc (Zn)	-
Manganese (Mn	-
Titanium (Ti)	-
Strontium Oxide(SrO)	0.10

The table shows that Calcium Oxide (CaO) is the second most predominant elements in natural gypsum. The above table can be compared to table 4.1 on page 29 showing results on chemical analysis of sisal juice extract that shows presence of common elements. A similar study on sugar cane juice done by Otunyo, Onwusiri and Nwaiwu (2015) showed that setting time was retarded by the partial replacement of water with sugar cane juice.

The hardening of concrete is attained through hydration which is an exothermic chemical reaction between cement and water. Addition of water to concrete ingredient during mixing enable hydration to take place while the excess quantities form a slurry with the cement which coats aggregates in the mix thereby lubricating them and allowing their easy movement during compaction. The first stage of hydration that leads to stiffening is caused by the reaction between water and a chemical constituent of cement called Tricalcium Silicate (C_3S) (Linghong et. al, 2010). The time taken for concrete to harden after addition of water to the cement – aggregate mix is referred to as setting time. The last stage which occurs over a longer period is called final setting time and is due to reaction of water with Calcium Silicate (C_2S). It is during this stage that hardening and strength development occurs. Because of the exothermic nature of hydration, the higher the rate of hydration the higher the rate of both heat generation and strength development. In hot climatic conditions this results in a sharp rise in temperature in the concrete mass causing rapid expansion that results into development of cracks in the concrete mass during subsequent cooling.

The use of retarding admixture is defined in BS 5075 – Part 1 - 82. There are two categories of retarders, defined as Type B (Retarding Admixtures) and Type D (Water Reducing and Retarding Admixtures). The main difference between these two is the water-reducing characteristic in Type D that gives higher compressive strengths by lowering w/cm ratio.

Retarding admixtures are used to slow the rate of setting of concrete by slowing the initial setting time, enabling the concrete mixture to stay in its fresh mix state longer before it gets to its hardened form. Use of retarders is beneficial in hot climate for: complex concrete placement or grouting, special architectural surface finish, compensating the accelerating effect of high temperature towards the initial set and preventing cold joint formation in successive lifts. (Jammal, Nurdiana, & Ghulam, 2020; Chandio , Memon, Oad, Chandio, & Memon,, 2020)

Michael, (1972) classified retarders in two groups of organic and inorganic material. The organic material consists of unrefined Ca, Na, NH_4, salts of lignosulfonic acids, hydroxycarboxylic acids, and carbohydrates. The inorganic material consists of oxides of Pb and Zn, phosphates, magnesium salts, fluorates, and borates. Commonly used retarders are lignosulfonates acids and hydroxylated carboxylic (HC) acids, which act as Type D (Water Reducing and Retarding Admixtures). The use of lignosulfonates acids and hydroxylated carboxylic acids retard the initial setting time for at least an hour and no more than three hours when used at 65 to 100° F. (Flatt et al, 2016).

Agave sisalana Perrine (family: Agavaceae), popularly known as sisal is a commercially used fiber yielding plant. The global production of sisal fibre in 2007 amounted to 240,000 tons of which Brazil, the largest producing country, produced 113,000 tons, Tanzania produced approximately 37,000 tons, Kenya produced 27,600 tons, Venezuela 10,500 tons and 9,000 tons were produced in Madagascar. (Sharma &Varshney 2011).

There has been a lot of studies on utilization of sisal fiber in production of concrete so as to enhance its properties. Vajje and Krishna. (2013) stated that according to study of natural fibers, compared to natural inorganic fibers, vegetable fibers (natural organic) are very much renewable, eco-friendly, economical and production cost is very low. The search for natural products from agro-industrial waste, which may become useful to society, has grown in recent years. Sisal leaf decortication residue is one of the most abundant agro-industrial residues in Tanzania. Only 5% of the decortications of the leaves of sisal produce the hard fiber that is used for various purposes; the remaining 95% consists of solid waste (mucilage) and waste liquid (juice of the sisal) that are normally discarded by sisal farms (Oashi, 1999). In general, sisal has many uses including the manufacture of various utensils such as carpets, ropes, twine, marine cables, bags, etc., and also for natural food source (feed) and alcoholic beverages like international tequila. (Neto et al, 2011)

1.2 Statement of the Problem

Cement concrete works and compacting in hot climate experience a lot of challenges from mixing, transporting, placing and compacting of concrete because of the accelerated setting of cement concrete due to high temperatures. Workability is compromised to a large extend and there is need to prolong the setting time and allow for execution of the concreting activities.

The rapid heat generation from large concrete pours can also lead to cracks in the concrete structure. This results in the need to slow the rate of concreting thereby causing costly delays. Retarders may be used in slowing down the hydration process hence reduce the heat of hydration.

The above stated effects can lead to major loses like collapsing of structures or buildings due to structural failure in concrete, expensive structural repairs in situation where structural components have failed and costly delays in the construction.

The cost for chemical retarders are high and its usage increases the overall cost of concrete manufacture. The high cost of concrete which is a major constituent material in building and civil engineering construction has inhibited construction of affordable housing and other infrastructure projects despite the growing demand. The use of sisal juice as a locally available organic retarder will reduce the cost of concrete and concreting in hot climatic conditions.

Studies have shown that sisal production in Kenya is very high mainly for extraction of fiber. (Denisova et al. 1999). After extraction of sisal fiber the sisal waste and juice is disposed away. These can be an environmental nuisance especially if in large quantity. The study investigated the suitability of sisal juice as a retarder to influence the properties of hardened concrete at a lower cost.

1.3 Justification and Significance of the Study

1.3.1 Government Departments/Ministries

The Government has a goal to drive technological advancement. There is need to identify locally available materials that can add value to the much needed performance characteristic of concrete at a lower cost.

The use of sisal juice as an organic retarder will benefit the construction industry by providing low cost retarders which will in turn profit the construction of infrastructure projects.

The study also provides the government a window of exploring the opportunity to setup large scale production of sisal and sisal juice retarder and hence impact the population economically.

1.3.2 Other Researchers

This research will be used as reference material for future research interested in the construction industry because it contains valuable information and literature on the use of sisal juice as a retarder in concrete manufacture.

1.4 Objective of the Study

1.4.1 Main Objective

To investigate the suitability of sisal juice extract as a retarder in cement concrete.

1.4.2 Specific Objective

1. To determine the chemical composition of sisal juice extract and its effects on setting time of cement
2. To evaluate the effect of sisal juice extract on the properties of hardened concrete.
3. To determine the optimum dosage of sisal juice extract for cement concrete.

1.5 Research Questions

In order to meet the above stated research objectives, the study answered the following research questions:

1. What are the important chemical compounds found in SJE and what are the effects of SJE on setting time of cement concrete?
2. What effect does sisal juice extract have on workability, Compressive strength and flexural strength of cement concrete?
3. What is the optimum dosage of sisal juice extract for cement concrete?

1.6 Scope of the Study

This study was conducted in the university laboratory located in Juja. It involved extracting the sisal juice from the sisal leaves by means of crushing and using the juice as an admixture in the preparation of cement concrete. The sisal used was harvested from one farm around Juja town. The workability and strength of concrete was determined for the fresh concrete and hardened concrete respectively. The study used Ordinary Portland Cement (OPC 32.5H) and locally obtained fine and coarse aggregates for concrete production

1.7 Limitation of the Study

Due to budget constraint and time available for the study below are the limitations were experienced;

i. SJE was obtained by manual squeezing of sisal leaves harvested from a single local farm in Juja area.
ii. The SJE was used fresh due to its short shelf life.
iii. The aggregate for the study were obtained from the local market
iv. The study used a nominal cement concrete mix of 1:2:4.

CHAPTER TWO

LITERATURE REVIEW

This chapter reviews literature on suitability of sisal juice as an admixtures. In particular, literature reviews major issues regarding retardation of concrete while using organic admixtures.

2.1 Theoretical Review

Admixtures have long been recognized as important components of concrete used to improve its performance. According to BS 5075: Part 1 : 1982, "Standard Specification for Chemical Admixtures for Concrete," classifies admixtures into categories based on performance: Type A Water-reducing admixtures; Type B Retarding admixtures; Type C Accelerating admixtures; Type D Water-reducing and retarding admixture; Type E Water-reducing and accelerating admixtures; Type F Water-reducing, high-range, admixtures; Type G Water-reducing, high-range, and retarding admixtures; and Type S Specific performance admixtures. Depending on the category, required properties may include the degree of water reduction, minimum or maximum variations in setting time, compressive strength, and the length change of hardened specimens. Some admixtures will meet the requirements of several categories, such as Type A and Type D. In such cases, the admixture will meet Type A requirements at low doses, and will meet Type D requirements at higher doses due to additional set retardation caused by higher dosages of those particular admixtures.

Increased retardation may be obtained with a higher dosage of the retarding admixture when high dosages of retarding admixture are used, however, rapid stiffening can occur with some sources of cement, resulting in severe slump loss and difficulties in concrete placement, consolidation, and finishing. (Topcu & Atesin, 2016)

The original use of admixtures in cementitious mixtures is not well documented. It is believed that the introduction of some of these materials may have been part of rituals or other ceremonies. It is known that cement mixed with organic matter was applied as a surface coat for water resistance or tinting purposes. (Bheel, Abbasi, Sohu, Abbasi, & Shaikh, 2019). Materials used in early concrete and masonry included milk and lard by the Romans; eggs during the middle ages in Europe; polished glutinous rice paste, lacquer, tung oil, blackstrap molasses, and extracts from elm soaked in water and boiled bananas by the Chinese; and in Mesoamerica and Peru, cactus juice and latex from rubber plants. (Vadivelan, Abirami, Agasthiya, Karthikayeni & Meena. 2018). It is known that the Mayans used bark extracts and other substances as set retarders to keep stucco workable for a long period of time. More recently chemical admixtures have been used to help concrete producers meet sustainability requirements that are necessary for modern construction. For concrete these requirements can be related to extended life cycles, use of recycled materials, storm water management, and reduced energy usage. Chemical admixtures are used to facilitate the increased use of supplementary cementitious materials, lower permeability, and improve the long term durability of concrete. (Nikhil, Kumar & Lakshmish, 2019)

Concrete is composed principally of aggregates, hydraulic cement, and water, and may contain supplementary cementitious materials (SCM) and chemical admixtures. It will contain some amount of entrapped air and may also contain purposely entrained air obtained by use of a chemical admixture or air-entraining cement. (Liu et al, 2016). Chemical admixtures are usually added to concrete as a specified volume in relation to the mass of Portland cement or total cementitious material. Admixtures interact with the hydrating cementitious system by physical and chemical actions, modifying one or more of the properties of concrete in the fresh or hardened states. Chemical admixtures are available in liquid and powder form. Liquid admixtures are dispensed through mechanical dispensers as the concrete is batched, but can be introduced to the concrete by other means, such as hand dosing or truck mounted dispensers. The effectiveness of any admixture will vary depending on its concentration in the concrete and the effect of the various other constituents of the concrete mixture. Each class of admixture is defined by its primary function. It may have one or more secondary functions, however, and its use may affect, positively or negatively, concrete properties other than those desired. (Jammal et al, 2020).

Ramírez Cano-Barrita, Caballero, & Gómez-Yañez (2012 used a cactus mucilage solution, an organic admixture to investigate its effects on the properties of concrete in a fresh state, on durability in a hardened state, and on the micro-structural changes in cement paste. The viscosity and setting times of the cement paste increased with the use of a cactus mucilage solution. X-ray diffraction analysis also showed the retardant effect on the hydration process. Therefore, adequate testing should be performed to determine the effects of an admixture on the plastic properties of concrete such as slump, rate of slump loss, air content, and setting time.

High-performance concrete mixtures may be dosed with as many as five admixtures, depending on the specific application. Therefore, it is imperative that the admixtures that are used in a given concrete mixture are compatible to prevent undesired effects such as rapid slump loss, air-entrainment difficulties, severe set retardation, or improper strength development. (Polyakov Padokhin, Akulova, & Syrbu, 2012)

A typical rule of thumb is for all admixtures to be added separately to a concrete mixture and not pre-blended before introduction into the mixture. In general, these chemicals act as dispersants for Portland cement particles. By separating and spreading out the cement particles, internal friction is reduced, and slump and workability of the concrete is increased. Alternatively, the same workability can be achieved using less water, which lowers the water–cementitious material ratio (w/cm) for a given cement content. Lowering w/cm is a key method for improving durability. These admixtures also provide the ability to control the time of setting to meet changing jobsite and climatic conditions. The strength improvement resulting from water-reducing admixtures is primarily a result of reducing the w/cm and increasing cement efficiency. For a given air content, concrete strength is inversely proportional to the w/cm and, therefore, the reduction in water needed to achieve the desired slump and workability when a water-reducing agent is used will result in an increase in strength.

2.2 Empirical Review

Factors that affect strength of development of concrete are several including material used, mixing procedure, curing environment, test methods etc. Water cement ratio controls workability of fresh concrete and the strength of the hardened concrete. (Pann, Yen, Teng & Lin, 2015). Abrams in 1918 put together engineering rules on relation between water cement ratios and concrete strength. Set-retarding admixtures (‘‘retarders’’) are used to delay the onset of cement hydration without affecting the material’s long-term mechanical properties, that is, to compensate for high temperatures or for delays between cement mixing and placement. Common organic retarders include sugars, lignosulfonates, and hydroxycarboxylic acids. Sucrose is one of the most effective; addition of 0.075 wt% to ordinary portland cement (OPC) increases the set time from approximately 2.5–31 h. (Zhang et. al. 2010: Dietmar, Stascheit, Dietmar, 2016).

Retarding admixtures are mainly based on materials having lignosulfonic acids and their salts, hydroxy-carboxylic acids and their salts, sugar and their derivatives and inorganic salts such as borates, phosphates, zinc and lead salts (Erdogan, 1992). Retarding effects of a retarder depends upon a number of factors including dosage of the admixture, time of addition to the mix and curing conditions. Some admixtures act as retarders when used in small amounts but behave as accelerators when used in large amounts. For example, sugar behaves as a set retarder but the large amount of sugar (0.2 to 1% by the weight of cement) will virtually prevent the setting of cement. At higher temperatures some retarders become less effective in cement set retardation than at lower temperatures (Alshamasi & Almasi, 1997)

Denisova et al, (1999) reported that sisal is one of strongest vegetable fibers and several studies have been reported in the literature based on its use as reinforcement in cement matrices (Gram et al, 1983 and Aziz et al, 1984). Little though has been done in the construction industry to utilize the sisal juice. In the contrary, scholars in the pharmaceutical industry have studied and established benefits of sisal juice. Sisal waste has been used as fertilizer (Lacerda et al, 2006), pesticides (Baker, 2003) and also animal feed (Faria et al., 2008). Pizarro et al, (1999) reported that the sisal waste has insecticidal properties particularly against larvae of mosquitoes, which transmit tropical diseases.

The chemical analysis of the sisal juice carried out revealed the presence of lingosulfonic salts, hydroxycarboxylic acids and carbohydrates. In particular the data revealed that Agave sisalana juice was acidic (pH = 5.42) in nature. The juice contained good amount of water (= 93.73%) along with 1.11% of total soluble sugar. Protein and ash content were found to be 11.56% and 1.48%, respectively. (Sharma & Varshney, 2011)

Neto et al, in 2011 reported the following results from the chemical analysis of sisal juice; total caloric value - 31.31 kcal/100g, total Carbohydrates - 7-12 g/100g, Fiber - 0 g/100g, Protein - 0.31 g/100g, Fat - 0.23 g/100g, Mineral Material - 1.03 g/100g, Moisture - 91-95 g/100g, Sodium (Na) - 97.71 mg/kg. The presence of chemical components of retarders such as Sodium and Carbohydrates in the sisal juice brought out the possibility of utilizing the juice as an organic retarder in manufacture of concrete.

2.3 Critique of the Existing Literature Relevant to the Study

The study of utilization of agro-residual waste in effective blending in Portland cement (Parande et. al. 2011) used agro residual that were thermally treated at a temperature of 650^{o}c into ashes. The action may have changed the chemical composition of the rice husk and bagasse. It would have been important to use the agro residual in its natural forms to eliminate any effect on its properties and reduce the cost of modification. This study intend to use sisal juice in its natural form so that the effect of sisal juice on concrete can be determined.

2.4 Summary of Literature Review

Chemical admixtures are used in concrete mixtures to produce engineering properties such as rapid-hardening, water-proofing or resistance to cold. The developments in admixture technology of the late 1990s explains the mechanisms by which admixtures produce their effects, and their selection and use. There has been a lot of interest from scholars to carry out studies on admixtures for special applications (Rixom et al., 1999).

Almost all organic compounds are retarders in cement setting, and many organic acids that strongly chelate calcium also have strong retarding capability. Organic compounds retard the cement setting process by forming a protective layer around the cement grain, thus hindering the formation of calcium hydroxide (Edmeades & Hewlett, 1998; Sora et al., 2002). Organic alcohols such as methanol and phenol not only retard the hydration process, but also form amorphous structures after drying, resulting in detrimental effects on the compressive strength of the cement (Sora et al., 2002). It is reported that phenol retards the initial and final setting times of cement by hindering the normal hydration reactions and by preventing the formation of calcium hydroxide during the initial period of setting and hardening (Vipulanandan & Krishnan 1993). Chlorophenol interferes with the hydration of cement by stabilizing ettringite formation and delaying its conversion to monosulfate (Pollard et al., 1991). In general, the mechanisms of retardation by organic compounds include: formation of insoluble calcium compounds, adsorption, and complexation.

2.5 Research gaps

According to Owen et al., 2011 in the study of use of nanocrystal seeding chemical admixture, the study used burnt rice husk and bagasse as an admixture. The act of burning the rice husk and bagasse might have changed their chemical composition. There is a gap resulting from the action of treating the agro residual because the action might have influence the end result. This study used sisal juice in its natural form without any heating that might alter its chemical composition.

In the same study of use of nanocrystal seeding (NCS) chemical admixture by Owens et al., (2011), there was evidence that the 56 day compressive strength was lowered. This study examined the compressive strength and found that in all case of dosages there was an increase in compressive strength at 56 days.

In the study of effect of sugar cane juice on slump values, setting times and strength of concrete by Otunyo et al., (2015), the compressive strength decreased from 39.0 N/mm2 at 0% sugar cane juice : 100% water to 13.08 N/mm2 at 100% sugar cane juice : 0% Water. The study also demonstrated that the setting time of concrete increased up to 0.05% sugar content in concrete. There was a gap in the study in that the compressive strength decreased with replacement of sugar cane juice at 25% even though slight retardation was experienced. This study considered replacement of water with sisal juice extract at percentages below 25% i.e. at 5%, 10%, 15% and 20%.

Binici et al., (2013) in his study on Effect of Corncob, Wheat Straw, and Plane Leaf Ashes as Mineral Admixtures on Concrete Durability recommended that it is convenient to use more than three different components to achieve a durable concrete. But in the study of Chemical Admixtures for Concrete by Greene et al., (2013) it was established that it is imperative to use admixtures that are compatible to prevent undesired effects such as rapid slump loss, air-entrainment difficulties, severe set retardation, or improper strength development. The two conclusions elicit a gap in that one must understand the effect of all the mineral admixtures before using them together. This may give results that are skewed in the event that one of the minerals chemical components are not well known to the researcher. This study used one type of organic retarder to eliminate the possibility of skewed results which might give wrong inferences.

2.2 Conceptual Framework

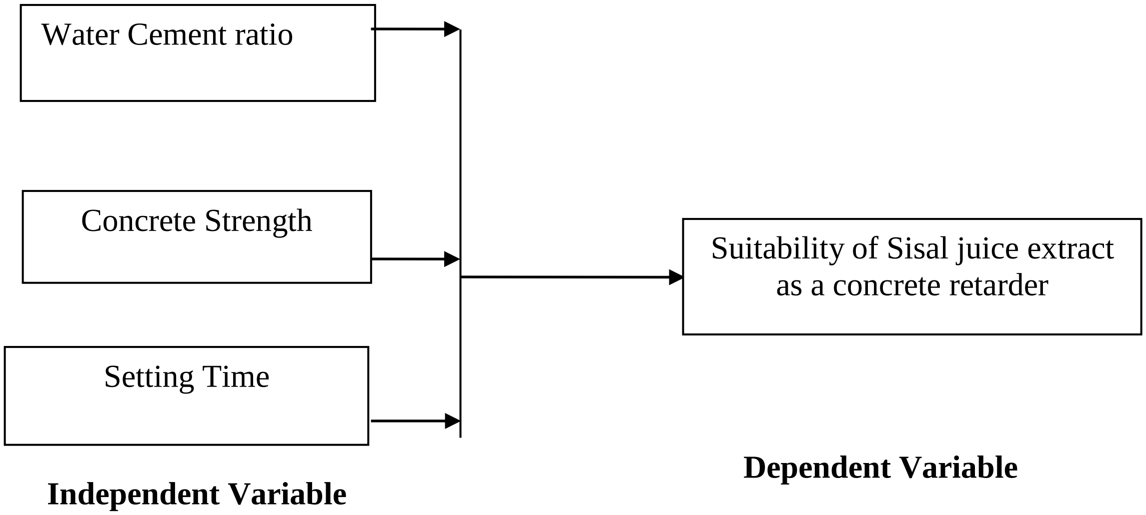

Figure 2.1: Schematic Diagram -Interpretation of Variables

2.2.1 Water/Cement Ratio

Water/cement ratio is one of the most important factors which influence the concrete workability. Generally, a water cement ratio of 0.45 to 0.6 is used for good workable concrete without the use of any admixture. Higher the water/cement ratio concrete will be more workable.

Higher water/cement ratio is generally used for manual concrete mixing to make the mixing process easier. For machine mixing, the water/cement ratio can be reduced. These generalized method of using water content per volume of concrete is used only for nominal mixes. For designed mix concrete, the strength and durability of concrete is of utmost importance and hence water cement ratio is mentioned with the design. Reduction in w/c ratio from 0.5 to 0.35 has proved to be extremely effective in terms of true slump formation, with 40% increase in compressive strength when the retarder content is 0.06% (Balasubramanya et al., 2016). Generally designed concrete uses low water/cement ratio so that desired strength and durability of concrete can be achieved.

2.2.2 Concrete Strength

Concrete maturity indicates how far curing has progressed. Maturity is the relationship between concrete temperature, time, and strength gain. It is represented by an index value that can be measured in real time in the field.

The maturity method, often simply referred to as “maturity,” is a way of evaluating new concrete’s in-place strength by relating time and temperature measurements to actual strength values.

To expedite schedules, increase safety, and improve construction methods, construction teams want to know the strength of their concrete at the job site in real time. Since maturity is related to concrete strength, the maturity method is a way to accomplish this without solely relying on standard test specimen and laboratory testing.

Maturity is calculated by tracking changes in fresh concrete temperature over time. Since each concrete mix has its own strength-maturity relationship, we can use maturity to estimate the strength of that mix at any moment after placement. When we know the maturity of a certain concrete, we can use that concrete’s specific strength-maturity relationship to make a reliable estimate of its strength. It is important to use retarders in ensuring minimum water-cement ratio or maximum cement content is achieved to give adequate durability for the particular site conditions (Day, 2016).

2.2.3 Setting Time

Division on setting time of cement is based on initial setting time of cement and final setting time of cement. Generally initial setting occurs between the moment water is added to the cement to the time at which paste starts losing its plasticity. Final setting time of cement is the time elapsed between the moment the water is added to the cement to the time at which paste has completely lost its plasticity and attained sufficient firmness to resist certain definite pressure. At normal construction the cement paste, mortar or concrete requires time for mixing, transporting, placing, compacting and finishing. During this time the above mentioned cement paste/mortar/concrete must be in plastic condition and is referred to as fresh concrete. Fresh concrete needs to remain in the plastic state long enough to enable all the working operations to be completed.

Once the concrete is finally placed it should lose its plasticity, so that it is least vulnerable to damages from external agencies. This time should not be more than 10hrs which is referred to as final setting time of cement (Azad et al., 2020).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

The ballast and sand used in the research were sourced locally from Juja while the sisal was harvested from Juja farm. This was significant because there was need of ensuring uniformity in the chemical composition of sisal juice and as such, same species of sisal will give the same chemical composition. The sisal juice was then extracted using a manually operated crushing machine. These materials and the different mixes were subjected to various tests as the research was purely experimental and was based on the standard applicable codes. The various tests were conducted in the structural and material laboratory at Jomo Kenyatta University and Agriculture and Technology (JKUAT), Kenya.

3.2 Research Materials and Method

The materials that were used in this research entailed the following;

3.2.1 Sisal Juice Extract (SJE)

The sisal leaves was harvested from Juja farm located within Juja town. This is because it was important to get large quantity of sisal leaves from the same species. The juice was extracted by crushing the leaves using a manually operated machine and sieved to remove fibers. The juice was stored under cool temperature so as to mitigate against evaporation which might affect concentration.

Sisal juice extract (SJE) was subjected to chemical analysis to determine its chemical composition. The exercise was conducted using XRF technology (X-Ray Florescence Spectra Analysis) in the Ministry of Mining, Mines and Geological Department, Nairobi. The sisal juice was dried in natural sun to form a hard paste that was subjected to the test.

The sisal juice extract was then added to the concrete mix as a percentage of water i.e 5%, 10%, 15%, 20%, 25% and 30% proportions. The moulds were thoroughly cleaned and wiped to ensure quality of cubes. Tests conducted for each set of mix were compaction factor tests, initial and final setting time, slump test, compressive and flexural tests. The results were compared with control experiment (0% SJE) in order to get the actual physical properties of the SJE.

3.2.2 Ordinary Portland Cement (OPC)

The study used ordinary Portland cement (OPC). The cement was purchased in 50kgs bags from local markert and was well stored to avoid dampness and formation of lumps.

Tests carried out on cement was initial and final setting time according to BS 196-3:1995

3.2.3 Fine Aggregates

The natural aggregate included both fine aggregates, river sand less than 5 mm in size. These material were sourced from a local supplier of building materials at Juja. The aggregates were well stored under a shade to eliminate the effect of adverse weather and to maintain the quality. The fine aggregate was subjected to particles size distribution test as per BS 3406-1: 1986 and specific gravity tests as per BS EN 1097 (2013).

3.2.4 Coarse Aggregate

The coarse aggregates from crushed stones of 5 mm were obtained from a local suppliers of building materials at Juja and stored under a shade to maintain the quality. The coarse aggregates were subjected to sieve analysis test as per BS 3406-1: 1986 and specific gravity tests to ensure that they conformed to BS EN 1097 (2013).

3.2.5 Water

Water available in the college campus lab tap was used for concreting and curing.

3.3 Preparation of Concrete Cube Specimens

Nominal concrete mix as per BS 8500-2 was used to determine the proportions of constituents of concrete that met the desired strength and other properties. The dosages were as indicated in table 3.1 below.

Table 3.1: Mix Proportions Class 25

	Mix A (OPC)	Mix B (OPC + Sisal Juice)					
Mix Set	1	2	3	4	5	6	7
Percentage Dosage (%)	0	5	10	15	20	25	30

In the preparation of all specimens, the required quantity of aggregates by dry weight of cement were measured and mixed in the dry state on a dry pan before addition of water and sisal juice. Water and the different dosage of sisal juice were mixed prior to addition to concrete mix. The mixing was done continuous to ensure production of a homogenous mix. Mix A (OPC) had 12 pieces of cubes and 2 pieces of beam specimens. Mix B (OPC + Sisal juice) had 72 pieces of cubes and 10 pieces of beam specimen. The first set without admixture was used as a baseline and the second set with sisal juice admixture used to form the basis of the study as indicated in table 3.2.

Table 3.2: Concrete Specimen

	No. of Cube Specimen Size (150x150x150mm)	No. of Beam Specimen Size (150x150x530mm)
Mix A (OPC)	12	2
Mix B (OPC + Sisal Juice)	72	10

All the 84 cubes and 12 beams were immersed in water to cure before testing for compressive and flexural strength test respectively. The compressive strength tests were done after 7 days, 14 days, 28 days and 56 days while the flexural strength tests were done after 28 days.

3.4 Determining the Effect of Sisal Juice Extract on Properties of Cement

3.4.1 Experimental Setup

3.4.1.1 Chemical Analysis of Sisal Juice Extract

Sisal juice extract (SJE) was subjected to chemical analysis to determine its chemical composition. The exercise was conducted using XRF technology (X-Ray Florescence Spectra Analysis) in the Ministry of Mining, Mines and Geological Department, Nairobi. The sisal juice was dried in natural sun to form a hard paste that was subjected to the test.

The fresh SJE was also subjected to a litmus test as per below observation shown in figure 3.4 below to check whether sisal juice extract is acidic or alkaline.

3.4.1.2 Initial and Final Setting Time Test

a) Consistency test of sisal juice cement

The standard consistency of a cement paste is defined as that consistency which permits the Vicat plunger to penetrate to a point 5 to 7mm from the bottom of the Vicat mould. Consistency test procedure.

i. Take 400 g of cement and place it in the enameled tray.
ii. Mix about 25% water by weight of dry cement thoroughly to get a cement paste. Total time taken to obtain thoroughly mixed water cement paste i.e. “Gauging time” should not be more than 3 to 5 minutes.
iii. Fill the vicat mould, resting upon a glass plate, with this cement paste.
iv. After filling the mould completely, smoothen the surface of the paste, making it level with top of the mould.
v. Place the whole assembly (i.e. mould + cement paste + glass plate) under the rod bearing plunger.

vi. Lower the plunger gently so as to touch the surface of the test block and quickly release the plunger allowing it to sink into the paste.

vii. Measure the depth of penetration and record it.

Prepare trial pastes with varying percentages of water content and follow the steps (2 to 7) as described above, until the depth of penetration becomes 33 to 35 mm.

The sisal juice was added to water by 0%, 5%, 10%, 15%, 20%, 25% and 30% by weight. A total of seven samples were prepared and four runs per sample were done to get the amount of water which made the paste per mix to resist the 10mm needle of the Vicat apparatus to penetrate to the bottom of the mould base. The consistency cement paste was expressed as a percentage by weight of dry cement and is usually this percentage varies from 26% to 33% for ordinary Portland cement.

b) The initial and final setting time as per BS 196-3:1995.

The consistency tests of the various dosages were obtained, the results were used to determine the initial and final setting time of SJE cement paste as per standard procedure stipulated in BS EN 196-3:1995.

3.4.1.3 Compaction Factor Test

The compaction factor test was carried out as per below procedure to check on the workability of concrete.

Apparatus for compaction factor test:

(i) Compaction Factor Machine
(ii) Weighing Machine & Compacting Rod
(iii) Mechanical Vibrator or Steel Trowel.
(iv) Hand scoop which is 15.2 cm long
(v) Balance
(vi) A rod of steel which is 1.6 cm diameter and a 61cm long rounded at one end.

The procedure of compaction factor test:

Steps in the procedure as given below;

a) By using the hand scoop, place the concrete sample gently in the upper hopper to its brim and level it and then cover the cylinder.
b) At the bottom of the upper hopper, open the trapdoor so that concrete falls into the lower hopper and with the rod, push the concrete sticking on its sides gently.
c) To fall into the cylinder below, open the trapdoor of the lower hopper and allow the concrete to fall.
d) By using trowels, cut off the excess of concrete above the top level of the cylinder and level it, then clean the outside of the cylinder.
e) To the nearest 10g weight the cylinder with concrete and this weight is called the weight of partially compacted concrete as W1.
f) Empty the cylinder and then with the same concrete mix in layers approximately 5 cm deep refill it and to obtain full compaction, each layer has to be heavily rammed.
g) Level the top surface and then weigh the cylinder with fully compacted which is known as the weight of fully compacted concrete as W2.
h) Then as W, find the weight of the empty cylinder

3.4.1.4 Slump Test

Slump test was done according to BS EN 12359–2: 2009. Workability may be defined as the amount of useful work to produce full compaction of concrete. Workability implies the case with which a concrete mix can be handled from the mixer to its finally compacted shape. The provision of adequate workability is critical to enable the transportation, placing and compaction of the concrete with the available equipment. It has been proposed that the workability should be defined by at least 3 separate properties. One of them is that compatibility or the ease with which the concrete can be compacted. A fully compacted mix contains minimal voids and hence will produce higher strength concrete of less permeability. The second one is mobility or ease with which concrete can flow into moulds around steel and be remoulded. The third property is stability or the ability of concrete to remain a stable coherent homogeneous mass during handling and vibration without the constituents segregating.

In determining the compressive and flexural strength effects of sisal juice on concrete, concrete mix of the ratio 1:2:4 (Cement: Sand: Ballast) was used where batching was done by weight. The slump test was performed according to BS EN: 12359: 2009 whereby the standard slump cone filled with concrete in four layers, rodding 25times per layer, then lifting the cone and measuring the extent to which the concrete collapsed. This collapse (slump) was maintained between 10 – 25 mm as required for vibrated concrete, this was done for all the dosages of sisal juice extract i.e. 0%, 5%, 10%, 15%, 20%, 25% and 30%.

3.4.1.5 Compressive Strength Test

The main objective of this experiment was to determine the strength of the hardened SJE concrete. It was done in accordance to BS EN 12390: 2000, whereby the specimen containing different proportions of sisal juice extract were prepared and cast into detachable moulds of internal dimensions of 150x150x150mm. The specimens were thereafter demoulded after 24 hours and immersed in water to cure for 7 days, 14 days, 28 days and 56 days before testing. The compressive strengths were then determined by crushing the samples for the respective curing days in a universal testing machine. For each proportion, three cubes were caster and the average taken, hence a total of 84 cubes were prepared.

3.4.1.6 Flexural Strength Test of SJE Concrete

The test was carried out to determine the tensile strength of concrete according to BS EN: 12390-5: 2009. The specimens for various sisal juice dosages were prepared and casted in moulds measuring 150x150x530mm and cured for 28 days. A total 12 beam specimens were then tested using three point flexural test method where by the beam specimen was placed between two supports and load applied at the center until failure occurred using universal testing machine as illustrated in figure 3.1.

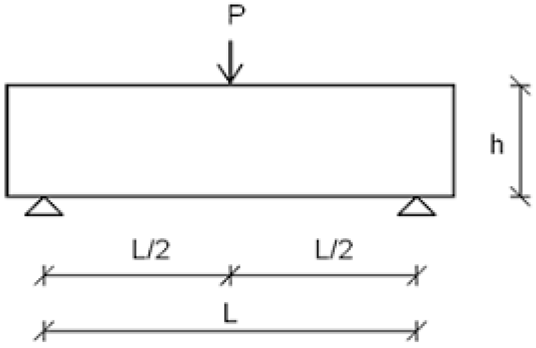

Figure 3.1: Illustration of Three Point Load Flexural Strength Test

3.4.2 Data Collection Procedure

All data from the experiments conducted were collected through observation. Data results sheets were developed for the different experiments. This was to ensure that no data is lost. The tests and experiments took slightly over 2 months. The results were then recorded in the respective test result tables depending on the type of experiment.

3.4.3 Data Analysis and Presentation

The study used quantitative techniques of data analysis to analyze the test results of different experiments. The results were presented in form of frequency tables and charts for easier understanding and interpretation.

3.5 Establishing Effects of Sisal Juice on Rheological Properties of Concrete.

Concrete is considered by most researchers in most circumstances to behave like a Bingham fluid. A Bingham fluid flow is characterized by two entities; the yield stress and the plastic viscosity. The yield stress is the stress needed to start moving the concrete, while plastic viscosity is a characterization of the flow of the concrete once the stress is higher than the yield stress (Ferraris, 2005**).**

The rheological test method for concrete tend to fall into one of the four general categories as confined flow, free flow, vibration or rotational rheometers. The free flow method was selected to describe the mode by which the concrete was forced to flow.

Free flow, the material either flows under its own weight, without any confinement, or an object penetrates the material by gravitational settling. Free flow methods include slump, modified slump, penetrating rod and turning tube viscometer.

3.6 Assessing Influence of Sisal Juice Extract on Structural Performance of Concrete

Concrete mix of ratio 1:2:4 of class 25 was used for the research work. This was because of its wide application for general structures. Batching of the ingredients was done by weight, mixing was done manually and vibrated using electric vibrator. Portable water was used conforming to BS EN: 3148: 1980 for all mixes. After mixing, the concrete was placed in demountable moulds. Removal of the moulds took place after 24 hours and curing proceeded for 28 days. The three – point load test was conducted as shown in figure 3.1.

CHAPTER FOUR

RESULTS AND DISCUSSION

The exercise was carried out to investigate the suitability of SJE as a retarder in concrete and the following observations were made.

4.1 Chemical Analysis of Sisal Juice Extract

The fresh SJE was subjected to a litmus test giving a PH of 5 which was an indication that juice is acidic. Table 4.1 shows results of the chemical analysis of SJE used in the study.

Table 4.1: Chemical Composition of Sisal Juice

Element	**Percentage by Weight (%)**
Calcium Oxide (CaO)	**35.88**
Potassium Oxide (K_2O)	**32.40**
Magnesium Oxide (MgO)	**13.74**
Aluminum Oxide (AL_2O_3)	**4.19**
Silicon Dioxide (SiO_2)	**4.08**
Iron (Fe)	**3.55**
Sulphur (S)	**2.95**
Phosphorous Pentoxide (P_2O_5)	**1.48**
Chlorine (Cl)	**1.00**
Zinc (Zn)	**0.62**
Manganese (Mn	**0.38**
Titanium (Ti)	**0.23**
Strontium(Sr)	**0.11**

From the results in table 4.1 it can be noted that the content of Calcium Oxide (CaO) is the most predominant element at 35% followed closely by Potassium Oxide (K_2O). The two elements are also found in gypsum which is a mineral used for retarding the setting of cement during manufacture. Other elements found in both gypsum and SJE include Magnesium Oxide (MgO) and Sulphur (S) (Wilder, 1919).

4.2 Properties of Aggregates

4.2.1 Grading of Aggregates

The grading of aggregates was done in accordance to BS 882(1985) and all the aggregates fell within the grading envelop indicating that they were within the acceptable limits as shown in Figures 4.1 and 4.2.

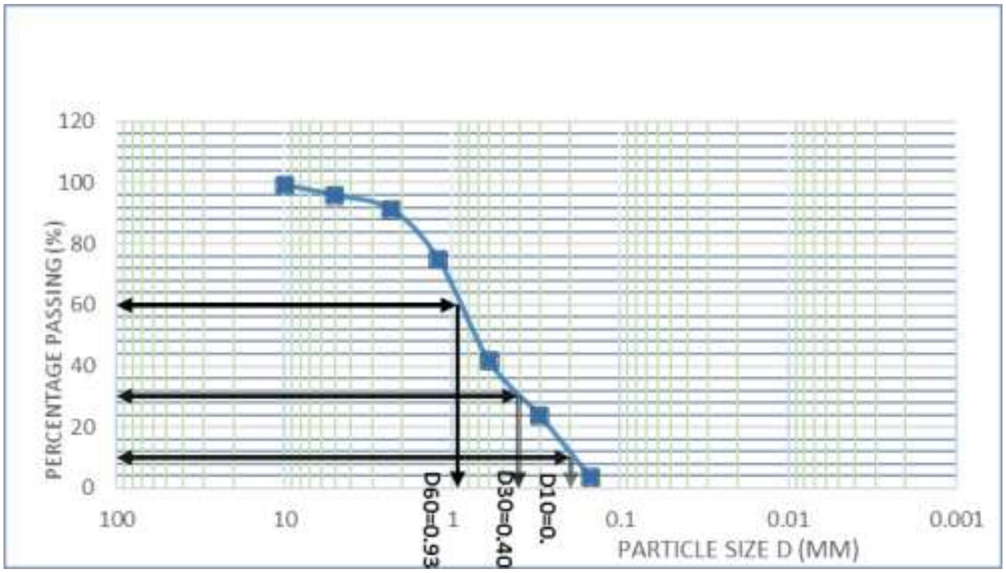

Figure 4.1: Fine aggregates grading

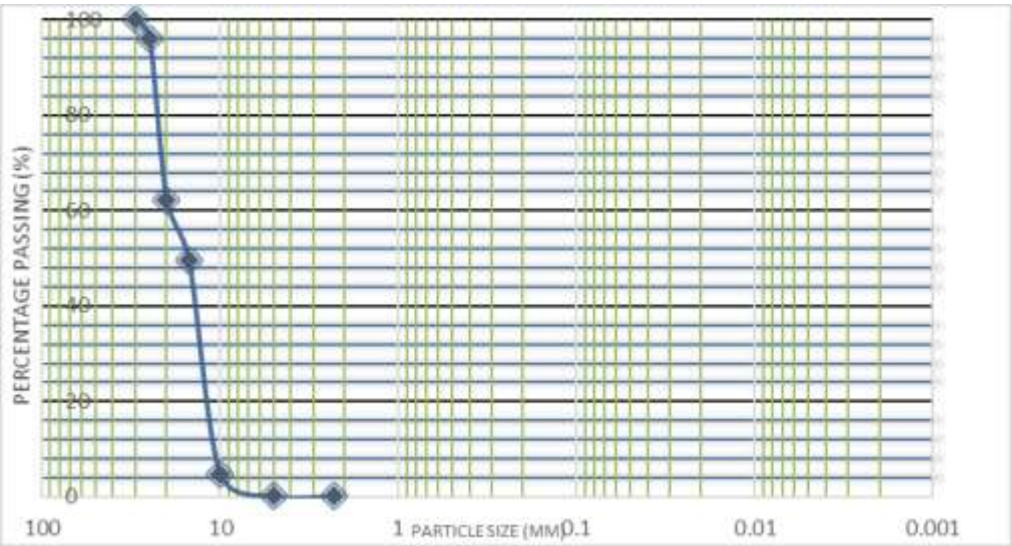

Figure 4.2: Coarse aggregate grading

From figure 4.1 it can be deduced that the Coefficient of Uniformity (Cu) which is the ratio of D60 to D10 is 4.9. By virtue of the coefficient being greater than 4 it means that the sand is well graded. Well graded aggregates impacts positively to the effects of aggregate type, size, and content on the compressive strength, workability, durability and other properties of fresh as well as hardened concrete (Pawar et al., 2016).

The Coefficient of Curvature (Cc) is 0.93 which is less than 1. This is an indication that the sand is gap graded.

4.2.2 The Specific Gravity, Water Absorption and Moisture Content

These tests were done in accordance with BS EN 1097-6 (2013)

Table 4.2: Materials properties of sand and ballast

Material	Fineness Modulus	Specific Gravity	Absorption (%)	Silt Content (%)
River sand	2.70	2.48	2.10	0.50
Ballast	4.82	2.50	3.10	**-**

For bulk densities, aggregates with density of less than 1120 kg/m^3 are classified as lightweight aggregates and more than 2080 kg/m^3 were classified as heavy weight aggregates and anything in between were natural mineral aggregates used for producing normal weight concrete (NWC).

On the specific gravity, most natural aggregates have specific gravities of 2.4 and 3.0 hence the aggregates fell within this range. From these properties the aggregates were found to be suitable for use in research as they possessed the required engineering properties.

4.3 Properties of Concrete with Sisal Juice Extract Admixture

4.3.1 Effects of SJE on Setting Time

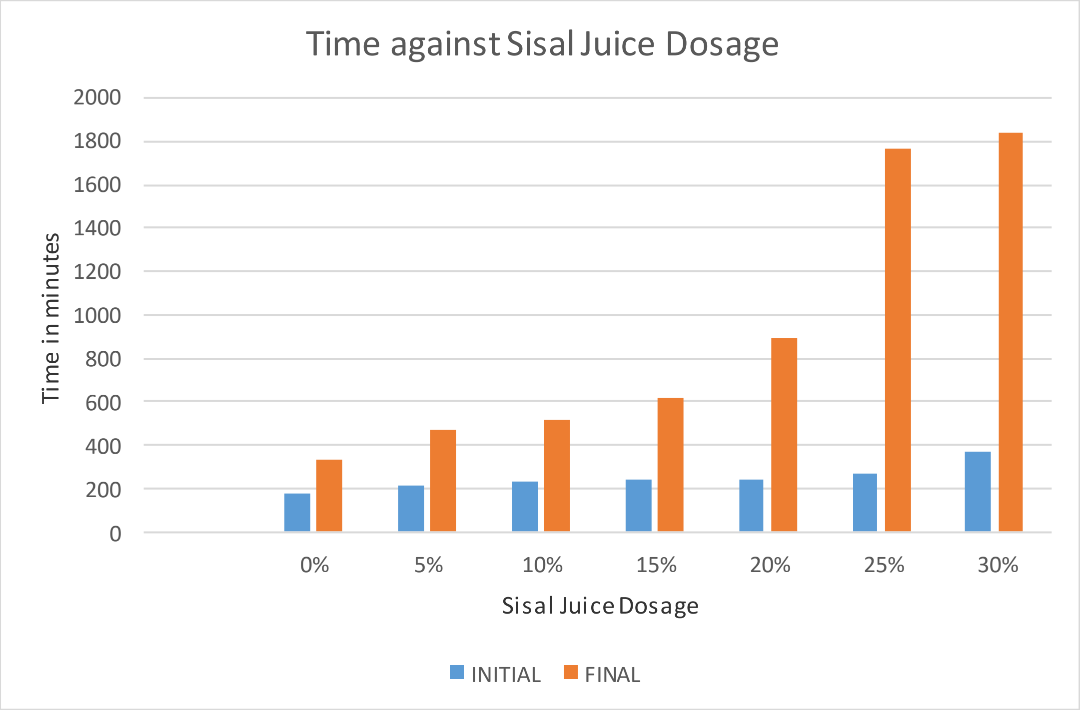

Figure 4.3: Effects of SJE on initial and final Setting time

Figure 4.3 above shows that both initial setting time and final setting time increased at an average of 14% and 23% respectively with increase in SJE dosage. The initial setting time of the cement paste, when compared to reference value increased with increase in sisal juice dosage.

The final setting time increased exponentially with increase in SJE dosage. This can be attributed to adsorption of the retarding SJE on the surface of cement particles, forming a protective skin which slows down the process of hydration hence the reason why there is steady rise of setting time. The layer of retarding admixture around the cement particles acts as a diffusion barrier. Due to this diffusion barrier, it becomes difficult for the water molecules to reach the surface of the un-hydrated cement grains and hence the hydration slows down, and the dormant period (period of relatively inactivity) is lengthened and thus the paste remains plastic for a longer time.

4.3.2 Effects of SJE on Workability

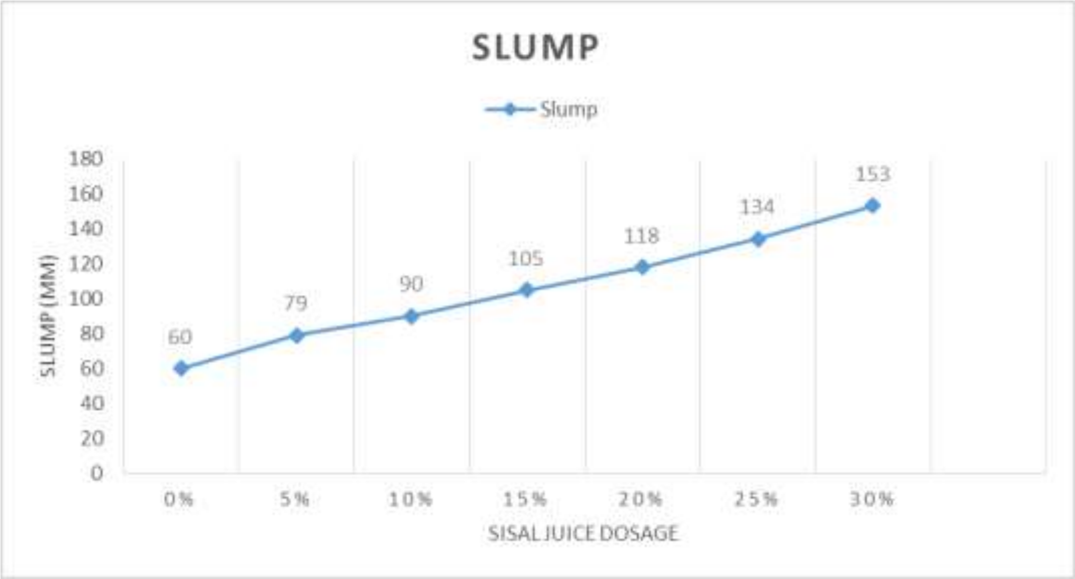

Figure 4.4: Effect of incremental dosage of SJE on the slump

Figure 4.4 is a graphical presentation of the results in Table A2. 11 showing that slump increased consistently with increase of proportions of SJE dosage. The increase of slump show increased workability of concrete as a result of retardation as a result of SJE dosage.

4.3.3 Effects of SJE on Compaction Factor

Compaction factor tests with varying SJE contents were performed. The results are presented in figure 4.5.

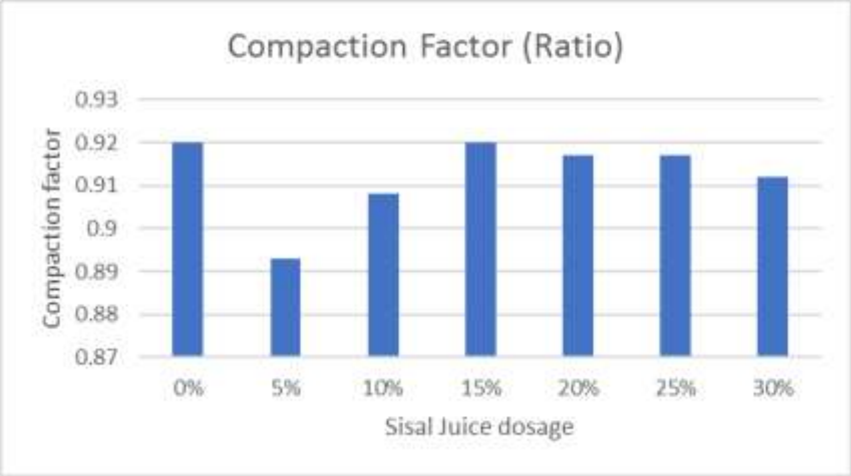

Figure 4.5: Effect of incremental dosage of sisal juice on compaction factor

From figure 4.5, Compaction factor at 0% dosage was at 0.92 but decreased significantly after 5% SJE dosage addition. Further addition of SJE dosage shows that the compaction factor increased at dosage of 10% and the highest compaction factor 0.92 was achieved at 15% SJE dosage which is the same as control mix. It can also be noted that the compaction factor decreased to 0.917, 0.917 0.912 at 20%, 25% and 30% dosage respectively. This increase in compaction faction factor is as a result of increased workability. The normal range of concrete compaction factor lies between 0.8 – 0.92. The value of compactness shows that workability of concrete is within range.

4.3.4 Effect of SJE on Compressive Strength

Figure 4.6 to 4.12 shows strength gain comparisons for different SJE dosages. The compressive strength with varying SJE contents were performed in accordance with BS 12390. From the strength gain comparison results, it can be noted that there is an increase in strength between control and 5% SJE dosage increase but beyond 5% i.e. 10%. 15%, 20%, 25% and 30% the strength decreases steadily.

The decrease in compressive strength can be attributed to the fact that SJE is acidic with a PH of 5 and increase in SJE breaks down components of concrete during contact. **(**Otunyo et. al., 2015**)**

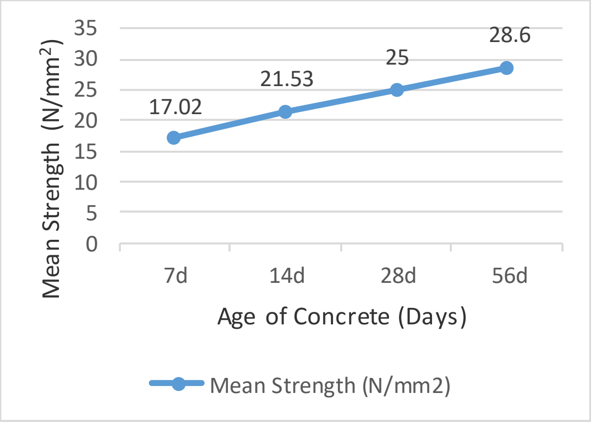

Figure 4.6: Strength Gain for Control Mix

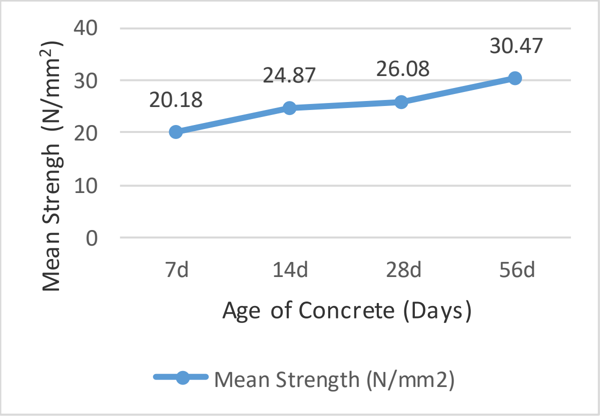

Figure 4.7: Strength Gain for 5% Dosage

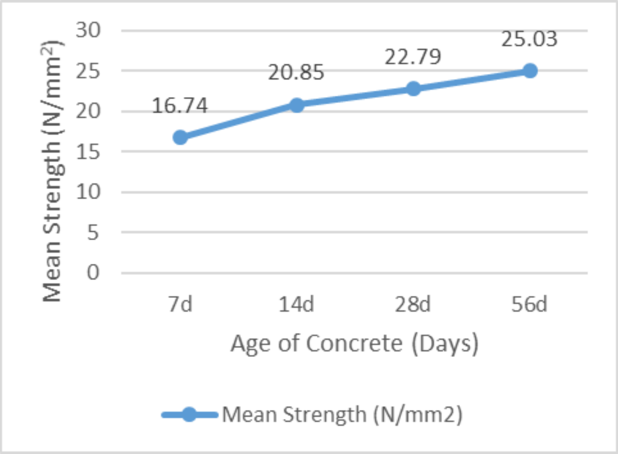

Figure 4.8: Strength Gain for 10% Dosage

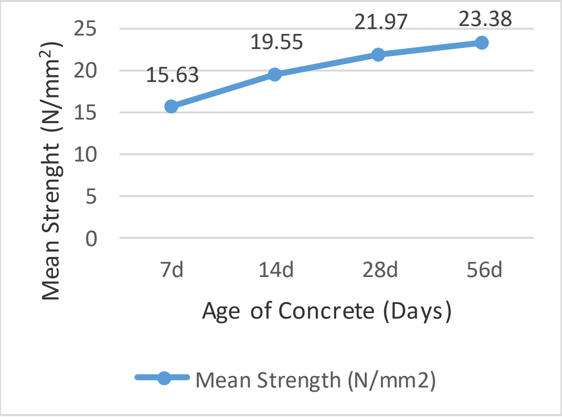

Figure 4.9: Strength Gain for 15% Dosage

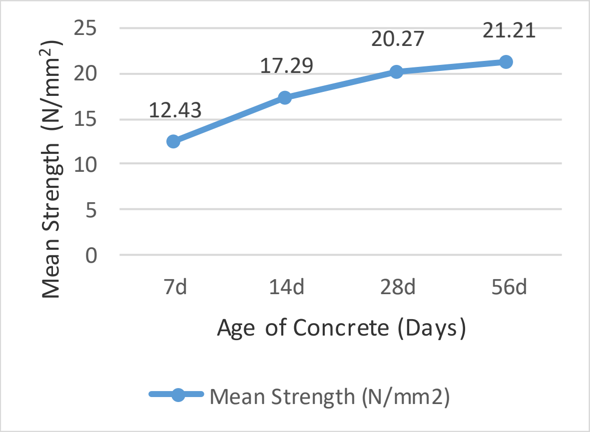

Figure 4.10: Strength Gain for 20% Dosage

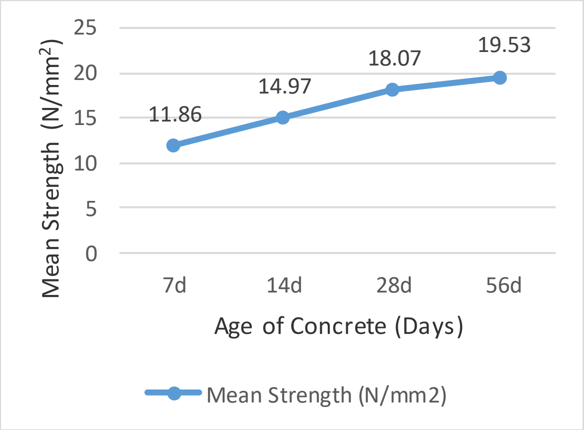

Figure 4.8: Strength Gain for 25% Dosage

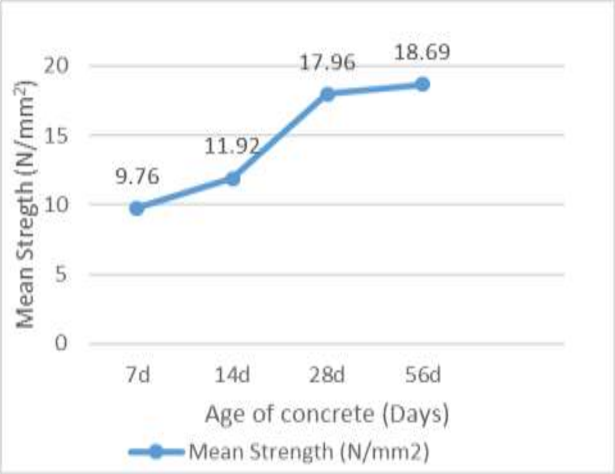

Figure 4.9: Strength Gain for 30% Dosage

From Figures 4.6 to 4.12, the line graph shows the compressive strength at various ages. Concrete gains strength with time after casting. It takes much time for concrete to gain 100% strength. The rate of concrete compressive strength gain is higher during the first 14 days of casting and then it slows down (Lee et al., 2020).

Thus, it is clear that concrete gains its strength rapidly in the initial days because of the SJE dosage. Furthermore, the use of SJE as retarders in cement concrete is an effective approach to improve on early compressive strength gain owing to the fact that the strength attained at 5% dosage of 20.18, 24.87, 26.08 and 30.47 at 7days, 14days, 28days and 56days respectively are higher than the strengths achieved for all the other dosages.

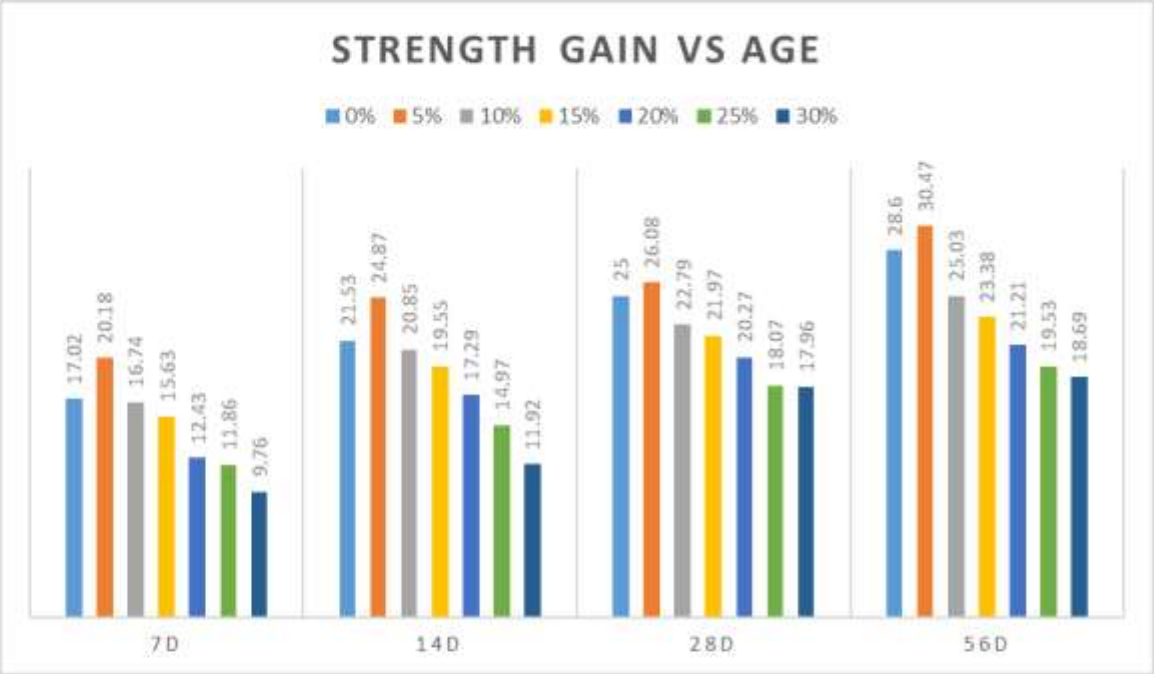

Figure 4.13: Strength for concrete at different ages

Results in Figure 4.13 shows a trend in strength gain with age. 5% dosage attracted a high strength while 30% SJE dosage gained the least strength.

Concrete gains strength with age. It also gains strength more rapidly the higher the temperature. It is desirable to establish a relationship between strength, time and temperature so that the strength of a particular concrete after any particular time can be established from a knowledge of its strength after any other time (Neville, 1996).

Figures 4.13 depicts a trend in compressive strength gain where at 0% SJE dosage cement concrete gives a strength gain percentage of 68%, 86%, 100% and 114 % at 7, 14, 28 and 56 days respectively. 5% dosage of SJE which is the optimum dosage shows early strength gain of 81%, 99%, 104% and 121% at 7, 14, 28 and 56 days. These results indicate that the use of SJE increases the rate of hydration hence improving the initial compressive strength due to faster ionization of cement making it possible to load the concrete after 14 days.

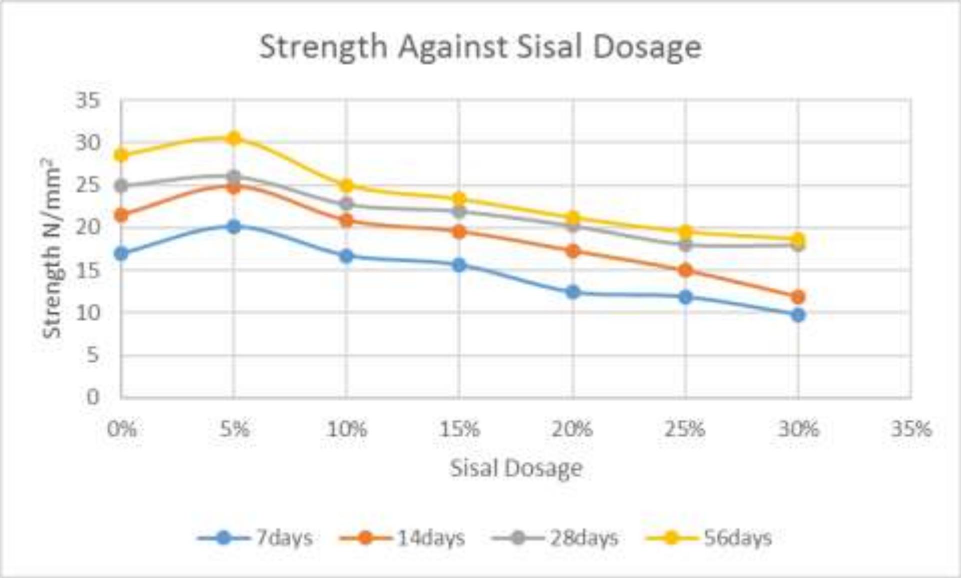

Figure 4.104: Effects of sisal juice dosage on concrete strength

Results in Fig. 4.14 indicate that compressive strength achieved at 5% dosage was higher compared to the control mix. There was an increase in strength of 4.32 % between control mix and 5% SJE dosage mix.

However, after the 5% dosage there was a general decrease in strength with increasing SJE dosage from 5% to 30% for all the curing periods. The decrease in compressive strength with increasing SJE content is due to the fact that the components of concrete breakdown during contact with acids in the SJ (Otunya et al., 2015).

The rate of strength decrease between 10% and 15% SJE dosage is low but beyond 15% through to 25% the rate increases.

The retarding effect is exhibited at 15% dosage and 28days age. The strength of concrete achieved is 22.79 N/mm which is not very far from control. The concrete can be used for low loading retaining walls with low surcharge.

4.3.5 Flexural Strength Test

The test was conducted in accordance with BS EN 12390: 2009 by using three point load system, beam size of 150*150*530mm was used.

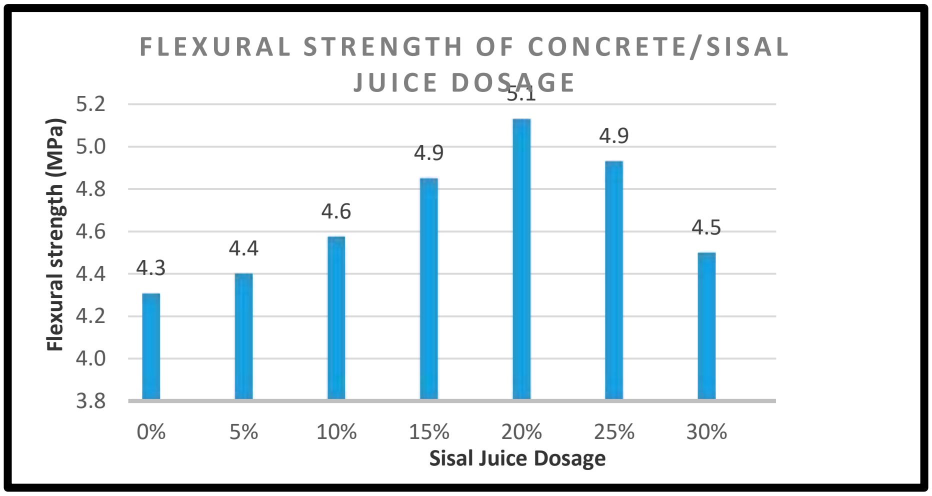

Figure 4.115: Flexural strength of concrete at different sisal dosages

The result for flexural strength of SJE concrete is plotted against various percentages of SJE dosage. From figure 4.15 it can be seen that when SJE dosage is increased a significant increase in flexural strength is obtained. The predominant increase in flexural strength is found at 20% SJE dosage. The percentage of increase in flexural strength is found to be 18% compared to control concrete. There was a slight decrease in flexural strength noticed at 25% and 30% dosage of sisal juice.

Furthermore, diagonal cracks were observed on all the concretes both for control and concrete containing sisal juice, ultimate collapse occurred by concrete crushing within the compression zone for all the concrete.

4.3.6 Comparison between Flexural Strength and Compressive Strength

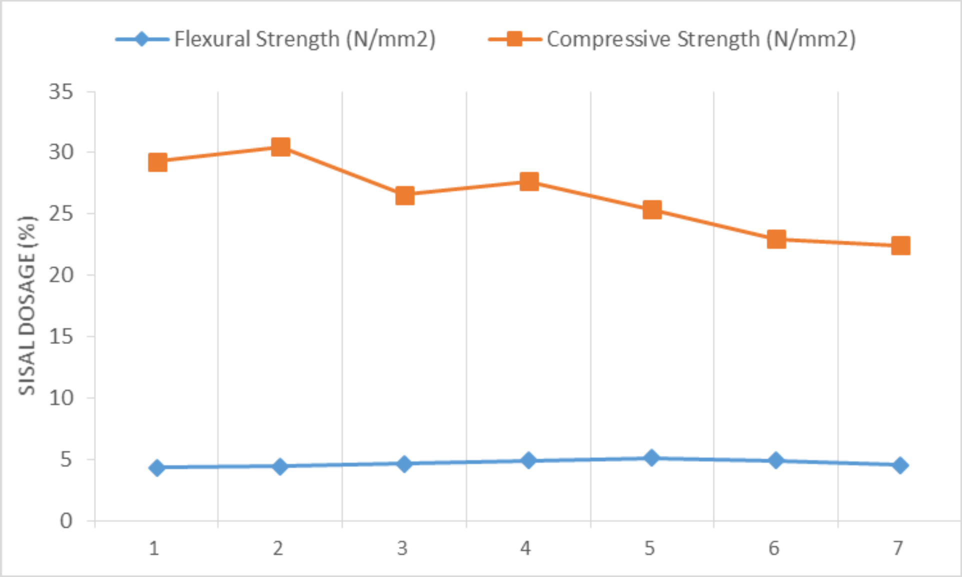

Figure 4.16: Comparison between flexural and compressive strength at different sisal dosages

Flexural Modulus Resistance is about 10 to 20 percent of compressive strength depending on type, size and volume of coarse aggregate used (NRMCA CIP. 2000).

High flexural strength is essential for stress-bearing restorations, when high pressure/stress is exerted on the material or restoration.

From Table A2. 15, an increase of about 4.32% in compressive strength is witnessed and a significant improvement in flexural toughness is observed in the case of replacing water by 5% SJE. The flexural strength of 4.4 N/mm^2 falls within the required range of 10% to 20% of compressive strength.

The appropriate SJE dosage for production of SJE concrete was found to be 5%. The water replacement by SJE dosage enhanced the flexural strength compared to control mix.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter indicates detailed information obtained from analysis of results during the study, in relation to suitability of SJE as a retarder in concrete. This chapter presents findings of the study, conclusions and recommendations.

5.1 Summary of Findings

a)

i. SJE is acidic in nature and contains considerable quantities of chemical compounds such as Calcium Oxide (CaO) and Potassium oxide (K_2O) which are also found in known retarders such as gypsum.
ii. Addition of SJE to a concrete mix increased its initial and final setting times progressively up to an optimum dosage of 5% of the water content by weight.

b)

i. The values of the compressive strength of the SJE cement concrete at 5% dosage were higher at all ages of 7days, 14days and 28 days than control. Beyond this dosage the strength progressively reduced as seen in figure 4.14
ii. The flexural strength on the other hand increased at all ages as above but up to a maximum dosage of 20% beyond which it decreased with further increase of SJE dosage as seen in Figure 4.15.

c)

i. The results showed that the values of the compressive strength of SJE cement concrete at 5% dosage were higher than those of the control specimen.

5.2.2 What is the optimum ratio of SJE to cement concrete?

a) The optimum ratio of SJE was found to 5% of water in a concrete mix.

5.2 Conclusions

a)

(i) SJE is acidic in nature and contains calcium oxide (CaO) and potassium oxide (K_2O) which are predominant compounds found in known retarders such as the additive Gypsum usually added to cement during manufacture to prevent flash set.

(ii) The addition of SJE to the concrete mix at a dosage of 5% of water content has the effect of extending the setting time of the concrete by up to 7.5 hours.

b)

(i) The usage of SJE as an admixture in cement concrete at a dosage of 5% results in a higher compressive strength than that of normal concrete.

(ii) The use of SJE has the effect of increasing the flexural strength up to a dosage of 20%.

c)

(i) The optimum ratio of SJE for cement concrete (1:2:4) is 5% by weight of water content of cement concrete mix.

d)

It can be concluded that SJE is suitable for use as a retarder in cement concrete at a mix proportion of 5% by weight of water content since it has the effect of increasing the setting and hardening time of cement and both the compressive strength and flexural strength of hardened concrete.

5.3 Recommendations

5.3.1 Recommendation from the Study

a) SJE Concrete at higher dosages can be used as flow concrete
b) SJE Concrete can be used to compensate for high temperatures and average time taken between mixing and placing concrete in arid areas.
c) The 5% SJE concrete can be used to improve site capacity by increasing formwork rotation and also fasten construction time.
d) SJE may be used as a retarder in large concrete pours under hot climatic conditions since it extends setting time of cement concrete.
e) Methods of drying the sisal juice extract into powder form should be explored in order to extend its shelf life for commercial use.

5.3.2 Recommendations for Further Research

The following research areas are recommended for further research pertaining the use of SJE as a retarder in concrete.

a) Further research work in determining the suitability of sisal juice as retarder be carried out at controlled hot conditions in order to determine the variation of setting time with ambient temperature.
b) In this study SJE was extracted manually and used in its fresh form and therefore further work is recommended to find methods of extracting the SJE commercially and dry it to powder form in order to increase its self-life.
c) Further work should also be done to determine the effect on cement concrete properties' with SJE obtained from different sources.
d) This study was done using nominal mixes therefore it is recommended that further work that includes concrete mix design be carried out in order to improve on the reliability of the results.

REFERENCES

Azad, K., Rahman, S., & Chowdhury, R.H. (2020). Effect of sugar on setting time of cement and Compressive strength of concrete. *Proceedings of 2nd International Conference on Research and Innovation in Civil Engineering*, ICRICE.

Aziz, M. A., Paramasivam, P., & Lee, S. L. (1981). Prospects for natural fibre reinforced concretes in construction. *International Journal of Cement Composites and Lightweight Concrete*, *3*(2), 123-132.

Baker, A. F. (2003). *Effects of the use of agave juice in the treatment of seeds, control of spider mite [Tetranychus urticae (Koch, 1836)] and phytotoxicity in cotton (Gossypium hirsutum L. r. latifolium Hutch)* (Doctoral dissertation, Dissertation, Federal University of Paraíba, Brazil).

Balasubramanya, N., Adarsh, A., Vinay., Patil, Vidyadhar., & Sunil Kumar. (2016). Laboratory Studies for Determining Effect of Sugar on Setting Time of Cement and Properties of Concrete. *The International Reviewer*, *3*(1), 12-14.

Bheel, N, Abbasi, R.A, Sohu, S., Abbasi, S.A., & Shaikh, Z.H. (2019). Effect of tile Powder used as a cementitious material on the mechanical properties of concrete. *Engineering, Technology & Applied Science Research, 9(5),4596-4599.*:

Binici, H., Kaplan, H., & Yilmaz, S. (2007). Influence of marble and limestone dusts as additives on some mechanical properties of concrete. *Scientific Research and Essays* , 2(9), 372-379.

Chandio, S. A., Memon, B. A., Oad, M., Chandio, F. A., & Memon, M. U. (2020). Effect of Fly Ash on the Compressive Strength of Green Concrete. *Engineering, Technology & Applied Science Research*, *10*(3), 5728-5731.

Day, K. W. (2016). Concrete mix design, quality control and specification. CRC press.

Edmeades, R., & Hewlett, P. (1998). Cement admixture. *Materials Science*, *Chemistry*, Pg 841-905. https://doi.org/10.1016/B978-075066256-7/50027-8

Erdogan, T.Y. (1997). Admixtures for concrete. Middle East Technical University Ankara Turkey.

Faria, M.S., Jaeger, P.L., Oliveira, G.J., Oliveira, R.L., Ledo, S.A., & Santana, F.S. (2008). Chemical composition of the co-product of the pulping of sisal treated with urea. Bras. *Zootec*., 37, 377-382.

Ferraris, C., Stutzman, P.,Winpigler, P& Peltz, M. (2005). Developing a More Rapid Test to Assess Sulfate Resistance of Hydraulic Cements. *Journal of Research of the National Institute of Standards and Technology,* 110.5, 529-540 . doi:DOI:10.6028/jres.110.080

Greene, T.M., Aldea, C., & Bohan, R.P. (2013). Chemical Admixtures for Concrete.

Jammal, M., Nurdiana, J. & Ghulam, A.M. (2020). The effect of the combination additive Admixtures to increase setting time and compressive strength at the concrete casting in warm tropical temperature. *International Journal of Civil Engineering and Technology*, Vol. 11, Issue 04, Pp 61-72.

Lacerda, M.R, Passos, M.A, Rodrigues, J.V., & Levy, P. (2006). Physical and chemical substances based on coconut and sisal residue to a producer of changes of sage.

Lee, T., Lee, J., & Choi, H. (2020). Effects of Accelerators and Retarders in Early Strength Development of Concrete Based on Low-Temperature-Cured Ordinary Portland and Calcium Sulfoaluminate Cement Blends. *Materials*.

Zhang, L., Catalan, L. J., Balec, R. J., Larsen, A. C., Esmaeili, H. H., & Kinrade, S. D. (2010). Effects of saccharide set retarders on the hydration of ordinary Portland cement and pure tricalcium silicate. *Journal of the American ceramic society*, *93*(1), 279-287.

Liu, G., & Chem, L. (2016). Advance in Material Science and Engineering.

Michael, H.L. (1972). Retarders for Concrete and their effects on setting time and Shrinkage.

Muhammad, K., & Muhammad, U. (2004). Effect of a Retarding Admixture on the Setting Time of Cement Pastes in Hot Weather.

Neto, P.O., Santos, L., Carvalho, A.F., Silvia, R.M., De Douza, E.B & Cherici, I.C, (2011). Transforming Biomass into a Resource fiber waste management systems.

Neville, A. M. (2000). Properties of Concrete. 4th Edition, Longman England.

Nikhil, T.R, Kumar, H.S, & Lakshmish, T.P (2019). Effect of sugar on Strength and Durability Characteristics of HVFAC Pavements, *International Journal of Engineering Research & Technology*, vol. 8, no. 11, pp. 288–291.

Oashi, M.C. (1999). Study of the production chain as a subsidy for research and development of agribusiness in Paraíba sisal. *Federal University of Santa Catarina, Brazil.*

Otunyo, A.W., Onwusiri, S.C., & Nwaiwu, N. (2015). Effect of sugar cane juice on slump values, setting times and strength of concrete. *Nigerian Journal of Technology*, 34, (1), 254-258.

Owens, K., Russell, M.I., & Donnelly, G. (2014). Use of nanocrystal seeding chemical admixture in improving Portland cement strength development: application for precast concrete industry”. *Advances in Applied Ceramics*, 113(8), 478-484. https://doi.org/10.1179/1743676114Y.0000000176

Pann, K.S, Yen, T., Teng, C.W., & Lin.T.D. (2015). A new strength model based on water/cement ration and capillary porosity.

Parande , A.K., Stalin, K., & Thangarajan, R.K (2011). Utilization of Agro residual Waste in Effective Blending in Portland cement. *International Scholarly Research Network* - ISRN Civil Engineering.

Pawar, C., Sharma , P., & Titiksh, A. (2016). Gradation of Aggregates and its Effects on Properties of Concrete . *International Journal of Trend in Research and Development*, Volume 3(2), Pg. 581-584.

Pizarro, A.P., Oliveira, A.M., & Parente, J.P (1999). The use of sisal waste industry in controlling mosquito larvae. *Rev Soc Bras Med Trop*, 32(1), 23-9. https://doi.org/10.1590/S0037-86821999000100005

Polyakov, V.S., Padokhin, V.A., Akulova, M.V. & Syrbu, S.A. (2012). Improving Strength Properties of Heavy Concrete with Chemical additive. *Technological advancements in construction*, Vol. 55 Issue 8.

Ramírez-Arellanes, S., Cano-Barrita, P.F., Caballero, F & Gómez-Yañez, C (2012). Concrete durability properties and microstructural analysis of cement paste with nopal cactus mucilage as a natural additive. *Mater Construcc*, 62 [302], 327–341.

Rixom, R., & Mailvaganam, N. (1999). Chemical Admixtures for Concrete. *E&FN Spon, London*, http://dx.doi.org/10.4324/9780203017241

Sharma, S., & Varshney, V.K (2012). Chemical Analysis of Agave Sisalana Juice for its Possible Utilization. *Chemistry Division, Forest Research Institute*, 2(1), 60-66. https://www.researchgate.net/publication/267558438_Chemical_analysis_of_Agave_sisalana_juice_for_its_possible_utilization

Topçu, İ. B., & Ateşin, Ö. (2016). Effect of high dosage lignosulphonate and naphthalene sulphonate based plasticizer usage on micro concrete properties. *Construction and Building Materials, 120*, 189-197.

Vadivelan, S., Abirami, K., & Agasthiya, R., Karthikayeni, D. & Meena, V. (2018). Influence of Cactus Milk and Blood in Natural Soil Concrete For Improving Compressive Strength of Concrete. *International Journal of Engineering Research & Technology*, vol. 6, no.4, pp. 1–5.

Vajje, S., & Krishna, N.R (2013). Study on Addition of the Natural Fibers into Concrete. *Journal of Science & Technology Research.*

Wilder, F.A. (1919). Gypsum: Its occurrence, origin, technology and uses. *Iowa Geological Survey Annual Report,* 28(1), p.47-245. https://doi.org/10.17077/2160-5270.1205

APPENDICES

Appendix I: List of Publication

Michael O. Eloget, Silvester O. Abuodha, Mathew O. Winja "The Effect of Sisal Juice Extract Admixture on Compressive and Flexural Strength of Cement Concrete", Engineering, Technology & Applied Science Research, Volume: 11 | Issue: 2 | Pages: 7041-7046 | April 2021 | https://doi.org/10.48084/etasr.4030

Appendix II. Results

Table A2 1: Laboratory Test on Geotechnical Properties of Fine Aggregate

LABORATORY TESTS ON GEOMETRICAL PROPERTIES OF AGRREGATES
Particle Size Distribution (Sieve Analysis) & Flakiness Index
ASTMC33-03

Client:		**Project:**		**Location:**	JUJA	**Date Tested:**	2/7/2019
MICHAEL OKILATE ELOGET		MSC RESEARCH PROJECT					
EN251/3115/2013							
Material Description		**Source:**	Juja market	**Sample No:**	102	**Lab Ref:**	
River Sand						JKUAT/LAB 102	
		Weight of Container (g):	2979		Weight of Container & Soil (g)		6958
		Weight of Dry Sample (g):	3979				

Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Sand (g)	Sand Retained (g)	Sand Retained (%)	Cummulative Sand Retained (%)	Sand Passing (%)
10		511	519	8	0.8	0.8	99.2
5		475	508	3.3	3.3	4.1	95.9
2.3		457	504	47	4.7	8.8	91.2
1.2		442	607	165	16.5	25.3	74.7
0.6		393	725	332	33.2	58.5	41.5
0.3		344	522	178	17.8	76.3	23.7
0.15		357	558	201	20.1	96.4	3.6
pan			36	36	3.6	100	0
			TOTAL:	970.3	100		

Grain Size Distribution Curve Results

% Gravel:			D10
% Sand:			D30
% Fines:			D60

Table A2. 1: Laboratory Test on Geotechnical Properties of Coarse Aggregate

LABORATORY TESTS ON GEOMETRICAL PROPERTIES OF AGRREGATES
Particle Size Distribution (Sieve Analysis) & Flakiness Index
ASTMC33-03

Client:	**Project:**	**Location:**	JUJA	**Date Tested:**	2/7/2018
MICHAEL OKILATE ELOGET	MSC RESEARCH PROJECT				
EN251/3115/2013					
Material Description	**Source:**	Sample No:	101	Lab Ref:	JKUAT/LAB/101
Graded Crushed Stone	Juja market				

Weight of Container (g): 3639.5
Weight of Dry Sample (g): 5639.0
Weight of Container & Soil (g) 9278.5

Plot Data

Size (mm)	% Passing
30	100
25	96.2
20	62.2
15	49.5
10	4.9
5	0.1
2.3	0.1
pan	

FLAKINESS INDEX

Sample Fraction (mm)	Weight (g)	Individual FI (%)
37.5-50		
28-37.5		
20-28		
14-20		
14-10		
6.3-10		
WEIGHTED AVERAGE		

Grain Size Distribution Curve Results

% Gravel:		D10
% Sand:		D30
% Fines:		D60

Table A2. 2: Control Mix Laboratory Report

CONCRETE MIX DESIGN REPORT - CONTROL MIX

Name:	**Project:**	**Specified Characteristic Mean Strength:**	**Targeted Mean Streng**
MICHAEL OKILATE ELOGET	MSC RESEARCH PROJECT		
EN251/3115/2013		25N/mm2	34.32N/mm2

MATERIAL PROPERTIES

Cementitious Material	Type	Source	Specific Gravity
Powermax	CEM 1 42.5	BAMBURI CEMENT	2.98
Admixture	**Name**	**Source**	**Dosage Details**
N/A			

Aggregates	Type	Source	Specific gravity SSD	Absorption (%)	FM	Bulk Density (Kg/m3)
No. 1	Natural River Sand	Juja Market	2.48	2.1	2.3	1396
No. 2	Graded Crushed Stone	Juja Market	2.5	3.1	3.3	1315

BATCH QUANTITIES: Mass at SSD

Material	Quantities (Kg)	Lab Quantity (Kg)
CEMENT	360	29.69
RIVER SAND	768	62.34
BALLAST	1182	98
WATER	180	12.6
SISAL JUICE	0	0
TOTALS	**0**	**202.63**

Fresh Concrete Test Results	
Slump	60
Compaction	0.92

COMPRESSIVE STRENGTH

CUB REF	DATE CAST	DATE TESTED	AGE (Days)	WEIGHT IN AIR (kg)	DENSITY (Kg/m3)	FAILURE LOAD (KN)	STRENGTH (N/mm2)	MEAN STRENGTH (N/mm)
Control 01	04.07.2018	11.07.2018	7d	8.2	2429.63	375.30	16.68	17.02
Control 02	04.07.2018	11.07.2018	7d	8.1	2400.00	371.25	16.50	
Control 03	04.07.2018	11.07.2018	7d	7.8	2311.11	402.30	17.88	
Control 04	04.07.2018	18.07.2018	14d	8.3	2459.26	484.43	21.53	21.53
Control 05	04.07.2018	18.07.2018	14d	8.0	2361.48	484.43	21.53	
Control 06	04.07.2018	18.07.2018	14d	7.9	2333.93	492.08	21.53	
Control 07	04.07.2018	01.08.2018	28d	7.9	2334.81	580.03	25.01	25.11
Control 08	04.07.2018	01.08.2018	28d	8.6	2560.00	580.05	25.16	
Control 09	04.07.2018	01.08.2018	28d	9.6	2856.30	580.05	25.16	
Control 10	04.07.2018	29.08.2018	56d	8.3	2459.26	635.18	28.23	28.60
Control 11	04.07.2018	29.08.2018	56d	7.7	2278.52	607.28	26.99	
Control 12	04.07.2018	29.08.2018	56d	7.9	2334.81	688.05	30.58	

Remarks	The mean strength is for three specimens for each age. 12 Specimen for each dosage of admixture
	Target strength was established using K=2.33 and standard deviation of 4N/mm2

Table A2. 3: 5% SJE Dosage Mix Laboratory Report

CONCRETE MIX DESIGN REPORT - 5% JUICE DOSAGE IN THE MIX

Name:	**Project:**	**Specified Characteristic Mean Strength:**	**Targeted Mean Strength:**
MICHAEL OKILATE ELOGET	MSC RESEARCH PROJECT		
EN251/3115/2013		25N/mm2	34.32N/mm2

MATERIAL PROPERTIES

Cementitious Material	Type	Source	Specific Gravity
Powermax	CEM 1 42.5	BAMBURI CEMENT	2.98
Admixture	**Name**	**Source**	**Dosage Details**
Sisal Juice Extract	Sisal Juice	JUJA FARM	0.7 Kg

Aggregates	Type	Source	Specific gravity SSD	Absorption (%)	FM	Bulk Density (Kg/m3)
No. 1	Natural River Sand	Juja Market	2.48	2.1	2.3	1396
No. 2	Graded Crushed Stone	Juja Market	2.5	3.1	3.3	1315

BATCH QUANTITIES: Mass at SSD

Material	Quantities (Kg)	Lab Quantity (Kg)
CEMENT	360	29.69
RIVER SAND	768	62.34
BALLAST	1182	98
WATER	180	12.6
SISAL JUICE	14.8	0.74
TOTALS	2504.8	203.37

Fresh Concrete Test Results	
Slump	79
Compaction	0.83

COMPRESSIVE STRENGTH

CUB REF	DATE CAST	DATE TESTED	AGE (Days)	WEIGHT IN AIR (kg)	DENSITY (Kg/m3)	FAILURE LOAD (KN)	STRENGTH (N/mm2)	MEAN STRENGTH (N/mm)
14800ML 01	17.07.2018	24.07.2018	7d	8.64	2560.00	436.45	19.40	20.18
14800ML 02	17.07.2018	24.07.2018	7d	7.986	2366.22	459.40	20.42	
14800ML 03	17.07.2018	24.07.2018	7d	8.65	2562.96	466.21	20.72	
14800ML 04	17.07.2018	31.07.2018	14d	8.611	2551.41	585.00	26.00	24.87
14800ML 05	17.07.2018	31.07.2018	14d	8.2	2429.33	508.84	22.62	
14800ML 06	17.07.2018	31.07.2018	14d	8.7	2565.93	585.00	26.00	
14800ML 07	17.07.2018	14.08.2018	28d	8.0	2376.30	600.08	26.67	26.08
14800ML 08	17.07.2018	14.08.2018	28d	7.9	2334.81	580.05	25.78	
14800ML 09	17.07.2018	14.08.2018	28d	8.6	2560.00	580.05	25.78	
14800ML 10	17.07.2018	11.09.2018	56d	8.2	2426.37	720.00	32.00	30.47
14800ML 11	17.07.2018	11.09.2018	56d	8.4	2502.22	679.50	30.20	
14800ML 12	17.07.2018	11.09.2018	56d	8.2	2418.96	657.00	29.20	

Remarks	The mean strength is for three specimens for each age. 12 Specimen for each dosage of admixture
	Target strength was established using K=2.33 and standard deviation of 4N/mm2

Table A2. 4: 10% SJE Dosage Mix Laboratory Report

CONCRETE MIX DESIGN REPORT - 10% JUICE DOSAGE IN THE MIX

Name:	**Project:**	**Specified Characteristic Mean Strength:**	**Targeted Mean Strength:**
MICHAEL OKILATE ELOGET	MSC RESEARCH PROJECT		
EN251/3115/2013		25N/mm2	34.32N/mm2

MATERIAL PROPERTIES

Cementitious Material	Type	Source	Specific Gravity
Powermax	CEM 1 42.5	BAMBURI CEMENT	2.98

Admixture	Name	Source	Dosage Details
Sisal Juice Extract	Sisal Juice	JUJA FARM	1.5 Kg

Aggregates	Type	Source	Specific gravity SSD	Absorption (%)	FM	Bulk Density (Kg/m3)
No. 1	Natural River Sand	Juja Market	2.48	2.1	2.3	1396
No. 2	Graded Crushed Stone	Juja Market	2.5	3.1	3.3	1315

BATCH QUANTITIES: Mass at SSD

Material	Quantities (Kg)	Lab Quantity (Kg)
CEMENT	360	29.69
RIVER SAND	768	62.34
BALLAST	1182	98
WATER	180	12.6
SISAL JUICE	30	1.5
TOTALS	2520	204.13

Fresh Concrete Test Results	
Slump	79
Compaction	0.83

COMPRESSIVE STRENGTH

CUB REF	DATE CAST	DATE TESTED	AGE (Days)	WEIGHT IN AIR (kg)	DENSITY (Kg/m3)	FAILURE LOAD (KN)	STRENGTH (N/mm2)	MEAN STRENGTH (N/mm)
30000ML 01	16.07.2018	23.07.2018	7d	8.49	2515.56	397.98	17.69	16.74
30000ML 02	16.07.2018	23.07.2018	7d	7.99	2367.41	355.18	15.79	
30000ML 03	16.07.2018	23.07.2018	7d	7.85	2325.93	377.04	16.76	
30000ML 04	16.07.2018	30.07.2018	14d	7.902	2341.33	404.49	17.98	20.85
30000ML 05	16.07.2018	30.07.2018	14d	8.0	2372.74	527.78	23.46	
30000ML 06	16.07.2018	30.07.2018	14d	8.3	2467.26	475.13	21.12	
30000ML 07	16.07.2018	13.08.2018	28d	8.4	2491.56	440.33	19.57	21.97
30000ML 08	16.07.2018	13.08.2018	28d	7.9	2355.26	460.13	20.45	
30000ML 09	16.07.2018	13.08.2018	28d	8.1	2388.15	582.53	25.89	
30000ML 10	16.07.2018	10.09.2018	56d	7.9	2328.00	479.25	21.30	25.03
30000ML 11	16.07.2018	10.09.2018	56d	8.5	2515.56	580.05	25.78	
30000ML 12	16.07.2018	10.09.2018	56d	7.8	2307.26	630.00	28.00	

Remarks: The mean strength is for three specimens for each age. 12 Specimen for each dosage of admixture

Target strength was established using K=2.33 and standard deviation of 4N/mm2

Table A2. 5: 15% SJE Dosage Mix Laboratory Report

CONCRETE MIX DESIGN REPORT - 15% JUICE DOSAGE IN THE MIX

Name:	**Project:**	**Specified Characteristic Mean Strength:**	**Targeted Mean Stren**
MICHAEL OKILATE ELOGET	MSC RESEARCH PROJECT		
EN251/3115/2013		25N/mm2	34.32N/mm2

MATERIAL PROPERTIES

Cementitious Material	Type	Source	Specific Gravity
Powermax	CEM 1 42.5	BAMBURI CEMENT	2.98
Admixture	**Name**	**Source**	**Dosage Details**
Sisal Juice Extract	Sisal Juice	JUJA FARM	2.2 Kg

Aggregates	Type	Source	Specific gravity SSD	Absorption (%)	FM	Bulk Density (Kg/m3)
No. 1	Natural River Sand	Juja Market	2.48	2.1	2.3	1396
No. 2	Graded Crushed Stone	Juja Market	2.5	3.1	3.3	1315

BATCH QUANTITIES: Mass at SSD

Material	Quantities (Kg)	Lab Quantity (Kg)
CEMENT	360	29.69
RIVER SAND	768	62.34
BALLAST	1182	98
WATER	180	12.6
SISAL JUICE	44.0	2.2
TOTALS	2534	204.83

Fresh Concrete Test Results	
Slump	105
Compaction	0.92

COMPRESSIVE STRENGTH

CUB REF	DATE CAST	DATE TESTED	AGE (Days)	WEIGHT IN AIR (kg)	DENSITY (Kg/m3)	FAILURE LOAD (KN)	STRENGTH (N/mm2)	MEAN STRENGTH (N/mm)
44000ML 01	05.07.2018	12.07.2018	7d	8.0	2367.41	320.64	14.25	
44000ML 02	05.07.2018	12.07.2018	7d	8.2	2426.07	368.08	16.36	
44000ML 03	05.07.2018	12.07.2018	7d	7.8	2299.85	366.25	16.28	15.63
44000ML 04	05.07.2018	19.07.2018	14d	7.8	2310.81	445.72	19.81	
44000ML 05	05.07.2018	19.07.2018	14d	7.8	2299.26	423.08	18.75	
44000ML 06	05.07.2018	19.07.2018	14d	7.9	2325.93	451.95	20.09	19.55
44000ML 07	05.07.2018	02.08.2018	28d	7.9	2330.37	514.33	22.86	
44000ML 08	05.07.2018	02.08.2018	28d	8.2	2438.52	501.85	22.30	
44000ML 09	05.07.2018	02.08.2018	28d	8.2	2421.63	522.34	23.22	22.79
44000ML 10	05.07.2018	30.08.2018	56d	7.7	2290.07	570.68	22.36	
44000ML 11	05.07.2018	30.08.2018	56d	8.3	2447.70	601.66	26.74	
44000ML 12	05.07.2018	30.08.2018	56d	8.2	2439.41	475.34	21.04	23.38

Remarks: The mean strength is for three specimens for each age. 12 Specimen for each dosage of admixture

Target strength was established using K=2.33 and standard deviation of 4N/mm2

Table A2. 6: 20% SJE Dosage Mix Laboratory Report

CONCRETE MIX DESIGN REPORT - 20% JUICE DOSAGE IN THE MIX

Name:	**Project:**	**Specified Characteristic Mean Strength:**	**Targeted Mean Stren**
MICHAEL OKILATE ELOGET	MSC RESEARCH PROJECT		
EN251/3115/2013		25N/mm2	34.32N/mm2

MATERIAL PROPERTIES

Cementitious Material	Type	Source	Specific Gravity
Powermax	CEM 1 42.5	BAMBURI CEMENT	2.98
Admixture	**Name**	**Source**	**Dosage Details**
Sisal Juice Extract	Sisal Juice	JUJA FARM	3.0 Kg

Aggregates	Type	Source	Specific gravity SSD	Absorption (%)	FM	Bulk Density (Kg/m3)
No. 1	Natural River Sand	Juja Market	2.48	2.1	2.3	1396
No. 2	Graded Crushed Stone	Juja Market	2.5	3.1	3.3	1315

BATCH QUANTITIES: Mass at SSD

Material	Quantities (Kg)	Lab Quantity (Kg)
CEMENT	360	29.69
RIVER SAND	768	62.34
BALLAST	1182	98
WATER	180	12.6
SISAL JUICE	60.0	3.0
TOTALS	2550	205.63

Fresh Concrete Test Results

Slump	118
Compaction	0.92

COMPRESSIVE STRENGTH

CUB REF	DATE CAST	DATE TESTED	AGE (Days)	WEIGHT IN AIR (kg)	DENSITY (Kg/m3)	FAILURE LOAD (KN)	STRENGTH (N/mm2)	MEAN STRENGTH (N/mm)
60000ML 01	11.07.2018	18.07.2018	7d	7.6	2257.78	268.05	11.01	11.86
60000ML 02	11.07.2018	18.07.2018	7d	8.1	2394.07	269.10	11.96	
60000ML 03	11.07.2018	18.07.2018	7d	8.0	2375.11	283.41	12.60	
60000ML 04	11.07.2018	25.07.2018	14d	7.8	2299.26	369.10	16.40	17.29
60000ML 05	11.07.2018	25.07.2018	14d	7.7	2266.67	390.59	17.36	
60000ML 06	11.07.2018	25.07.2018	14d	7.8	2308.15	407.52	18.11	
60000ML 07	11.07.2018	08.08.2018	28d	7.8	2311.11	450.00	20.00	20.27
60000ML 08	11.07.2018	08.08.2018	28d	7.6	2254.81	485.00	21.50	
60000ML 09	11.07.2018	08.08.2018	28d	8.3	2465.19	435.00	19.30	
60000ML 10	11.07.2018	05.09.2018	56d	8.1	2402.96	533.76	23.72	21.21
60000ML 11	11.07.2018	05.09.2018	56d	7.9	2334.81	463.21	20.59	
60000ML 12	11.07.2018	05.09.2018	56d	8.2	2420.74	434.62	19.32	

Remarks	The mean strength is for three specimens for each age. 12 Specimen for each dosage of admixture
	Target strength was established using K=2.33 and standard deviation of 4N/mm2

Table A2. 7: 25% SJE Dosage Mix Laboratory Report

CONCRETE MIX DESIGN REPORT - 25% JUICE DOSAGE IN THE MIX

Name:	**Project:**	**Specified Characteristic Mean Strength:**	**Targeted Mean Streng**
MICHAEL OKILATE ELOGET	MSC RESEARCH PROJECT		
EN251/3115/2013		25N/mm2	34.32N/mm2

MATERIAL PROPERTIES

Cementitious Material	Type	Source	Specific Gravity
Powermax	CEM 1 42.5	BAMBURI CEMENT	2.98
Admixture	**Name**	**Source**	**Dosage Details**
Sisal Juice Extract	Sisal Juice	JUJA FARM	3.7 Kg

Aggregates	Type	Source	Specific gravity SSD	Absorption (%)	FM	Bulk Density (Kg/m3)
No. 1	Natural River Sand	Juja Market	2.48	2.1	2.3	1396
No. 2	Graded Crushed Stone	Juja Market	2.5	3.1	3.3	1315

BATCH QUANTITIES: Mass at SSD

Material	Quantities (Kg)	Lab Quantity (Kg)
CEMENT	360	29.69
RIVER SAND	768	62.34
BALLAST	1182	98
WATER	180	12.6
SISAL JUICE	74.0	3.7
TOTALS	2564	206.33

Fresh Concrete Test Results	
Slump	134
Compaction	0.92

COMPRESSIVE STRENGTH

CUB REF	DATE CAST	DATE TESTED	AGE (Days)	WEIGHT IN AIR (kg)	DENSITY (Kg/m3)	FAILURE LOAD (KN)	STRENGTH (N/mm2)	MEAN STRENGTH (N/mm)
74000ML 01	13.07.2018	20.07.2018	7d	8.3	2458.96	298.18	13.25	12.43
74000ML 02	13.07.2018	20.07.2018	7d	7.9	2328.89	287.14	12.76	
74000ML 03	13.07.2018	20.07.2018	7d	7.9	2328.89	253.74	11.28	
74000ML 04	13.07.2018	27.07.2018	14d	7.8	2299.26	335.70	14.92	14.97
74000ML 05	13.07.2018	27.07.2018	14d	7.8	2302.22	341.76	15.18	
74000ML 06	13.07.2018	27.07.2018	14d	8.2	2438.52	333.74	14.82	
74000ML 07	13.07.2018	10.08.2018	28d	7.9	2329.48	420.00	18.66	18.07
74000ML 08	13.07.2018	10.08.2018	28d	8.1	2388.15	390.00	17.33	
74000ML 09	13.07.2018	10.08.2018	28d	8.5	2505.19	410.00	18.22	
74000ML 10	13.07.2018	07.09.2018	56d	8.2	2432.59	427.28	18.99	19.53
74000ML 11	13.07.2018	07.09.2018	56d	8.3	2468.15	472.80	21.01	
74000ML 12	13.07.2018	07.09.2018	56d	7.7	2266.67	418.07	18.58	

Remarks	The mean strength is for three specimens for each age. 12 Specimen for each dosage of admixture
	Target strength was established using K=2.33 and standard deviation of 4N/mm2

Table A2. 8: 30% SJE Dosage Mix Laboratory Report

CONCRETE MIX DESIGN REPORT - 30% JUICE DOSAGE IN THE MIX

Name:	**Project:**	**Specified Characteristic Mean Strength:**	**Targeted Mean Streng**
MICHAEL OKILATE ELOGET	MSC RESEARCH PROJECT		
EN251/3115/2013		25N/mm2	34.32N/mm2

MATERIAL PROPERTIES

Cementitious Material	Type	Source	Specific Gravity
Powermax	CEM 1 42.5	BAMBURI CEMENT	2.98
Admixture	**Name**	**Source**	**Dosage Details**
Sisal Juice Extract	Sisal Juice	JUJA FARM	4.4 Kg

Aggregates	Type	Source	Specific gravity SSD	Absorption (%)	FM	Bulk Density (Kg/m3)
No. 1	Natural River Sand	Juja Market	2.48	2.1	2.3	1396
No. 2	Graded Crushed Stone	Juja Market	2.5	3.1	3.3	1315

BATCH QUANTITIES: Mass at SSD

Material	Quantities (Kg)	Lab Quantity (Kg)
CEMENT	360	29.69
RIVER SAND	768	62.34
BALLAST	1182	98
WATER	180	12.6
SISAL JUICE	88.0	4.4
TOTALS	2578	207.03

Fresh Concrete Test Results	
Slump	153
Compaction	0.91

COMPRESSIVE STRENGTH

CUB REF	DATE CAST	DATE TESTED	AGE (Days)	WEIGHT IN AIR (kg)	DENSITY (Kg/m3)	FAILURE LOAD (KN)	STRENGTH (N/mm2)	MEAN STRENGTH (N/mm)
88000ML 01	06.07.2018	13.07.2018	7d	7.6	2251.85	208.69	9.20	
88000ML 02	06.07.2018	13.07.2018	7d	7.8	2308.15	236.25	10.50	
88000ML 03	06.07.2018	13.07.2018	7d	7.7	2290.37	215.33	9.57	9.76
88000ML 04	06.07.2018	20.07.2018	14d	8.2	2420.74	2.46.15	10.94	
88000ML 05	06.07.2018	20.07.2018	14d	8.3	2452.44	294.98	13.11	
88000ML 06	06.07.2018	20.07.2018	14d	7.7	2289.78	263.25	11.70	11.92
88000ML 07	06.07.2018	03.08.2018	28d	8.2	2425.19	410.00	18.22	
88000ML 08	06.07.2018	03.08.2018	28d	8.1	2386.96	407.00	18.09	
88000ML 09	06.07.2018	03.08.2018	28d	7.9	2327.70	395.00	17.56	17.96
88000ML 10	06.07.2018	31.08.2018	56d	7.8	2320.00	422.64	18.78	
88000ML 11	06.07.2018	31.08.2018	56d	8.2	2414.81	425.15	18.90	
88000ML 12	06.07.2018	31.08.2018	56d	8.1	2404.74	413.74	18.39	18.69

Remarks: The mean strength is for three specimens for each age. 12 Specimen for each dosage of admixture

Target strength was established using K=2.33 and standard deviation of 4N/mm2

Table A2. 9: Setting times of cement mortar with varying dosages of SJE

Sisal Juice Dosage (%)	Initial Setting Time (Min)	Percentage Increase (%)	Final Setting Time (Min)	Percentage Increase (%)
0	179		334	
5	214	20	467	40
10	234	31	521	56
15	237	32	620	86
20	242	35	893	167
25	265	48	1767	429
30	372	107	1840	451

Table A2. 10: Slump Test results

Sisal Juice Dosage (Kg) (%)	Slump
0	60
5	79
10	90
15	105
20	118
25	134
30	153

Table A2. 11: Compaction Factor results

	Dosage of Sisal Juice in Test Specimen (Kg) (%)	Compaction Factor (Ratio)
	0	0.920
	5	0.893
	10	0.908
	15	0.920
	20	0.917
	25	0.917
	30	0.912

Table A2. 12: Effect of Incremental Dosing of SJE on Compressive Strength

	Mean Strength (N/mm)						
	0%	5%	10%	15%	20%	25%	30%
7d	17.02	20.18	16.74	15.63	11.86	12.43	9.76
14d	21.53	24.87	20.85	19.55	17.29	14.97	11.92
28d	22.19	26.08	21.97	22.79	20.27	18.07	17.96
56d	28.6	30.47	25.03	23.38	21.21	19.53	18.69

Table A2. 13: Flexural Strength Test Results

Sisal Juice Dosage (%)	**S/No**	**Load (N)**	**Flexural Strength (N/mm^2)**	**Average**
0	Specimen 1	32.21	4.29	4.3
	Specimen 2	32.40	4.32	
5	Specimen 1	33.00	4.40	4.4
	Specimen 2	33.00	4.40	
10	Specimen 1	33.75	4.50	4.6
	Specimen 2	34.88	4.65	
15	Specimen 1	36.00	4.80	4.9
	Specimen 2	36.75	4.90	
20	Specimen 1	39.98	5.33	5.1
	Specimen 2	36.98	4.93	
25	Specimen 1	37.95	5.06	4.9
	Specimen 2	36.00	4.80	
30	Specimen 1	31.50	4.20	4.5
	Specimen 2	36.00	4.80	

Table A2. 14: Flexural and Compressive strength Comparison

Sisal Dosage (%)	Flexural Strength (N/mm^2)	Compressive Strength (N/mm^2)
0	4.3	25.00
5	4.4	26.08
10	4.6	21.97
15	4.9	22.79
20	5.1	20.27
25	4.9	18.07
30	4.5	17.96

Table A2. 15: Tests used for analysis of samples

Property test	**Test used**
Sisal juice chemical analysis	XRF technology (X-Ray Florescence Spectra Analysis)
Setting time	BS EN 196-3:1995
Specific gravity	BS EN 1097 : 2013
Sieve analysis	BS 3406-1: 1986
Compaction factor	BS 1881-116:1983
Slump Test	BS EN 12350-2:2009
Compressive strength	BS EN 12390-3:2009
Flexural strength	BS EN 12390-5:2009