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MASTER OF SCIENCE IN CIVIL ENGINEERING

(STRUCTURAL OPTION)

RESEARCH THESIS REPORT

EFFECT OF SUGAR CANE BAGASSE ASH ON THE PHYSICAL AND MECHANICAL PROPERTIES OF PLASTIC FIBER REINFORCED CONCRETE

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CE300-0001/16

A research thesis submitted to the Pan African University Institute of Basic Sciences, Technology and Innovation in partial fulfillment for the award of the degree of Master of Science in Civil Engineering (Structural Option) of the Pan African University.

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DECLARATION

I, NAMAKULA HIDAYA, the undersigned do declare that this report is my original work and to the best of my knowledge, that it has not been presented for a degree in any other University or Institution.

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CE300-0001/16

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DEDICATION

This thesis study is first all dedicated to the Almighty Allah for granting me this golden opportunity of life and pursue my Masters in good health and my parents: my dear father; Mr. Ssemakula Ali Katamba, my dear mothers; Mrs. Wannyana Hanifah and the late Lunkuse Zaituni and my aunt Mrs. Lutaaya Kamiat Ssemakula for their unconditional love, care and support through this academic journey.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACI:	American Concrete Institute
ACV:	Aggregate Crushing Value
AIV:	Aggregate Impact Value
ANOVA:	Analysis of Variance
ASTM:	American Society for Testing Materials
BS:	British Standard
BS EN:	British Standard European Norm
CO_2:	Carbon dioxide
CS:	Compressive Strength
EAS:	East African Standard
FRC:	Fiber Reinforced Concrete
JKUAT:	Jomo Kenyatta University of Agriculture and Technology
KS:	Kenyan Standard
LOI:	Loss of Ignition
OPC:	Ordinary Portland cement
PET:	Polyethylene Terephthalate
PFRC:	Plastic Fiber Reinforced Concrete
RCC:	Reinforced Cement Concrete
SCBA:	Sugar Cane Bagasse Ash
UTM:	Universal Testing Machine

ABSTRACT

Concrete is a manmade material which is used for civil engineering construction and is preferred all over the world because of its advantageous properties like good compressive strength, high mould ability, and durability. Despite its advantages, concrete has some undesirable properties like weak in tension, brittleness, less resistance to cracking and heavy weight. Dwindling stocks have also been reported due to the over exploitation of the natural resources used in making conventional concrete. However, efforts have been made in finding alternatives to the traditional materials and to improve concrete properties. Research has shown that concrete properties can be improved by industrial, agricultural and domestic wastes such as plastics, sugar cane bagasse ash and so many others. Polyethylene Terephthalate (PET) fibers are used to improve fatigue strength and increase tensile strength. Sugar cane bagasse ash, from its chemical composition has exhibited pozzolanic properties and hence can be used to partially replace cement in order to improve concrete properties. In this study, the mechanical and physical properties of Plastic Fiber Reinforced Concrete were investigated with partial replacement of ordinary cement with Sugar cane bagasse ash by 0%, 10% and 15% by proportion of weight of cement and PET fibers were incorporated in the mixes at different percentage. An experimental analysis with a mix ratio of 1:2:3 for cement: fine aggregates: coarse aggregates with a constant water to cement ratio of 0.57 was used. The PET fibers were obtained by shredding the PET bottles that were collected from nearby restaurants and dustbins, into rectangular strips of 35mm length, 5mm width and 0.2mm thickness with an aspect ratio of 7, they were incorporated in to the mix at percentages of 1%, 2% and 3% of the weight of cement. Physical tests: workability on fresh concrete and water absorption on hardened concrete of each batch was carried out at 28 days. Mechanical tests like density of concrete, compressive strength and splitting tensile strength were carried out on hardened concrete at 7 days and 28 days of curing. The results showed that there was an improvement in splitting tensile strength and compressive strength at 10%SCBA substitution and 1%PET fibers but reduced on further addition of both PET fibers and SCBA substitution.

1. INTRODUCTION

1.1. Background of the Study

Construction industry is one of the rapidly growing industries across the world. In this industry, concrete plays an inherent role and is the most widely used manmade construction material. Concrete will continue to be the leading construction material all over the world due to its versatile advantageous properties such as good compressive strength, high mould ability, plastic and malleable when fresh and durable, impermeable and fire resistant when hardened (Mishra & Deodhar, 2015). Concrete is therefore used for advanced applications, design and construction techniques such as building houses, bridges, dams, pavements, stadiums, retaining structures, airports and sky scrapers. However, concrete has some undesirable properties like being weak in tension, brittleness, less resistance to cracking, low impact resistance and heavy weight, hence there is need to improve the concrete properties (Chavan & Rao, 2016).

Portland cement is the conventional binding material in concrete and is the most expensive ingredient. Cement manufacturing is a highly energy intensive process, which involves intensive fuel consumption for clinker making and results in emission of greenhouse gases like carbon dioxide (CO_2) in large quantities and other tracers like methane (CH_4) the main causes of global warming. Actually, cement production process produces about one ton of CO_2 for each one ton of cement produced and is therefore responsible for about 5%–8% of global CO_2 emissions (Akasaki, et al., 2013). This environmental problem will most likely be increased due to exponential demand of

Portland cement: By 2050, demand is expected to rise by 200% from 2010 levels, reaching 6000 million tons/year (Generale, 2013). In this context, during the Copenhagen Summit held in 2009, different countries agreed on the necessity of reducing CO_2 emissions by 2020. The United States, for example, made a pact to reduce its overall emissions by about 17% from 2010 in respect to the levels of 2005 (Akasaki, et al., 2013). Therefore, several research activities have been directed towards partial or total replacement of Portland cement by various materials including agricultural, industrial and agro-industrial by-products in concrete production without compromising concrete quality (Azhagarsamy & Jaiganesan, 2016). Utilization of such materials does not only conserve the environment, but also reduces the cost of construction and minimizes waste emission.

Lack of waste management and recycling in third world countries has come to the attention of many organizations (Wonderlich, 2014). Industrial activities are associated with significant amount of non-biodegradable solid wastes which include: industrial wastes (like: chemical solvents, paints, sandpaper, paper products, industrial by-products, metals, and radioactive wastes), agricultural wastes (like: sugar cane bagasse and natural fibers) and municipal waste (like: plastics). The inadequate means in collection and disposal of various wastes has led to most of the wastes being exposed to the environment causing serious issues to human health (diseases), water bodies through pollution and damaging the aquatic life, the atmosphere through air pollution and aesthetics bringing about ugly scenery.

Plastic is one of the most disposable materials in the modern world which makes up much of the street side litter in urban and rural areas. It is rapidly filling up landfills and choking water bodies. Plastics are produced from the oil that is considered as non-renewable resource. Because plastic has the insolubility of approximately 300 years in the nature, it is considered as a sustainable waste and an environmental pollutant (Webb et al.; 2013). Plastic bottles make up approximately 11% of the content landfills, causing serious environmental consequences due to the chemicals used in their manufacture, improper use and disposal. Global consumption of Poly Ethylene Terepthalate (PET) packaging was forecasted to reach 19.1 million tonnes by 2017, with a 5.2% increase per annum. Bottles for water, carbonated soft drinks and other beverages account for 84% of global PET resin demand (Van den Berg, 2014). This increase in consumption will also cause an increase in generated waste PET bottles. Reusing plastic bottles may seem safe, but a chemical found in reusable plastic bottles, known as Biphenyl A, is suspected of posing a health risk to human beings.

Previous researches and studies have proved that such wastes can be utilized in Civil Engineering construction and this has become an alternative for disposal and protecting environment (Saini et al., 2016).

Sugar cane bagasse ash is another waste causing serious pollution problem produced from burning of the bagasse which is a fibrous leftover after sugarcane stalks are crushed to extract their juice (Almola, 2011). Bagasse is often used as a primary fuel source for sugar mills, when burnt in quantity, it produces sufficient heat energy to supply all the needs of a typical sugar mill. One ton of sugar canes can generate approximately 26% of bagasse and 0.62% of 1 residual ash (SCBA) of one ton of sugar canes (Kumar., et al, 2016). Dumping of these industrial wastes like SCBA in open land poses a serious threat to the environment by polluting both air and water. Research has shown that even at the sugar mill factories, exposure to dust from the processing of sugar causes the chronic lung condition pulmonary fibrosis, referred to as bagassosis (Kulkarni et al, 2013). On the other hand, the SCBA produced contains high amounts of un-burnt silica, alumina and ferric oxides, and can therefore be utilized as a partial cement replacement in the manufacture of concrete.

This research was therefore geared towards evaluating the effectiveness of utilization of SCBA as a partial cement replacement exploiting its pozzolanic properties incorporated with concrete incorporated with PET waste fibers , assessing the basic physical and mechanical properties in terms of workability, water absorption and strength characteristics.

1.2. Statement of the Problem

Concrete has some undesirable properties such as low tensile strength, low ductility, heavy weight and low energy absorption. These disadvantages have triggered the civil engineers to make use of the conventional reinforcement in order to increase the tensile strength and ductility (Chavan & Rao, 2016).

On the other hand, solid waste management has become one of the major environmental issues in developing countries as the wastes generated are continually increasing both in rural and urban areas (Tan, 2012). These have become a menace to the environment due to the various hazardous effects such as wide spread of diseases like cholera, pollution of water, air and soils. Waste disposal also has an effect on the general appearance, and it reduces the crawling green, which has effects on the economy and the health.

Industrial activities are associated with significant amount of non-biodegradable solid wastes such as PET waste bottles in particular, which are increasingly becoming an eyesore and polluting the environment (Nienhuys, 2004). Predictions made by Van den Berg, (2014), global consumption of PET was forecasted to reach 19.1 million tonnes by 2017 with an increase of 5.2% per annum and yet about 18%-20% of the produced PET bottles are recycled. This leaves about 15.5 million tonnes of PET bottles which do not decompose and have an insolubility of approximately 300 years exposed to the environment.

The aim of this study was to investigate the feasibility of conserving the environment by utilizing wastes like PET bottle fibers and SCBA in production of Fiber Reinforced concrete and improvement of concrete properties.

1.3. Objectives

1.3.1. Main Objective

To investigate the effect of Sugar cane bagasse Ash on the physical and mechanical properties of Plastic Fiber Reinforced Concrete.

1.3.2. Specific Objectives

1) To determine the properties of Plastic fibers, Sugarcane bagasse Ash, fine aggregates, coarse aggregates, Cement and water.
2) To study the effect of Plastic fibers on the properties of Normal weight concrete.
3) To study the effect of partial replacement of cement with Sugarcane bagasse Ash on the properties of Normal weight concrete.
4) To study the effect of partial replacement of cement with Sugarcane bagasse Ash on the Physical and Mechanical properties of Plastic Fiber Reinforced Concrete.

1.4. Justification

The research was carried out to improve the concrete properties such as tensile strength and ductility by incorporation of waste PET fibers in the concrete matrix was achieved. Also incorporation of SCBA as a pozzolana in the concrete to improve the compressive strength of the matrix.

This study was carried out in order to promote the utilization of waste materials generated in the environment since plastic bottles and sugar cane bagasse ash wastes, which are a threat to the environment, putting them to better use in construction and hence preserving and protecting the environment.

From the research findings, Sugar cane bagasse ash is a conceivable material to use as a partial cement replacement. Portland cement is the conventional building material which is responsible for about 5% - 8% of global CO_2 emissions responsible for global warming. This environmental problem will most likely be increased due to exponential demand of Portland cement. Hence utilization of SCBA reduces the cement demand and amount of Carbon dioxide emitted and hence preserving the environment.

1.5. Scope of Study

This study involved investigating the mechanical and physical properties of plastic fiber reinforced concrete with sugarcane bagasse ash. Sugarcane bagasse ash used as a partial replacement of cement incorporated with ordinary Portland cement of 42.5 grade to produce different mixes. The mixes were then tested to study the mechanical i.e. compressive strength and split tensile test at 7 and 28 days of curing. The physical properties i.e. water absorption at 28 days curing and workability on fresh concrete were also carried out on the different mixes.

At the beginning of the study and execution of the thesis, there was a literature study encompassing collection of information particularly studies done with a brief summary on earlier research studies on the use of plastic bottles and sugarcane bagasse ash in construction all over the world. This was followed with experimental works and finally analysis and reporting of Research findings.

This project research was limited to Africa, and a case study of East Africa was used. All materials that were used in this study were obtained from suitable sites in Kenya or the neighboring countries in terms of geographical scope. The research project was carried out between February 2017 and December 2017.

2. LITERATURE REVIEW

2.1. Introduction

This chapter is concerned with a comprehensive review of the various research work and investigations done in the field of using PET fibers in concrete and sugar bagasse ash as a partial replacement of cement in concrete.

2.1.1. Concrete

Concrete is a composite material which consists of aggregates, cement and water used in construction. The aggregates are generally coarse gravel or crushed rocks such as limestone or granite and the fine aggregate could be a material such as sand or can be manufactured such as slag (Neville, 1995). The cement commonly used is Portland cement and other materials such as fly ash and slag cement serve as binder for the aggregates. Water is then mixed with this dry composite, which reacts with the cement through a chemical process called hydration. Through this reaction, the composite eventually solidifies and hardens creating a robust, compact stone like material known as concrete.

Concrete is the backbone for infrastructural development of whole world as it is an indispensable part of the fabric of modern society used for everything from road pavements to high rise building structures (Karim et al., 2011). Concrete is plastic and malleable when newly mixed, yet strong and durable when hardened, (Tapkire et al.; 2014). Concrete has advantageous properties such as good compressive strength, high mould ability, plastic and malleable when fresh and durable, impermeable and fire resistant when hardened (Mishra & Deodhar, 2015). These qualities explain why concrete can be used to build skyscrapers, bridges, sidewalks, highways, houses, retaining structures, stadiums and dams. Hence there is an increasing demand for concrete on the daily basis and also an increase in the price of the material.

Concrete has some undesirable properties such as low tensile strength, low ductility, heavy weight and low energy absorption. These disadvantages have triggered the civil engineers to make use of the conventional reinforcement in order to increase the tensile strength and ductility (Chavan & Rao, 2016). Concrete is also characterized by quasi-brittle failure, the nearly complete loss of loading capacity, once failure is initiated. Concrete can be modified to perform in a more ductile manner by the addition of randomly distributed discrete fibers in the concrete matrix, which prevent and control initiation, propagation and coalescence of cracks (John, 2014). The fibers inclusion in cement base matrix acts as unwanted micro crack arrester. The prevention of prorogation of cracks under load can result in improvement in static and dynamic properties of cement based matrix. The serviceability of fiber reinforced cement concrete is also enhanced due to restricting entry of water and other contaminants through micro cracks which causes corrosion to steel reinforcement (Nibudey.; et al, 2014).

2.1.2. Fiber Reinforced Concrete (FRC)

Concrete is relatively brittle, and its tensile strength is typically only about one tenths of its compressive strength. Regular concrete is therefore normally reinforced with steel reinforcing bars. For many applications, it is becoming increasingly popular to reinforce the concrete with small, randomly distributed fibers. Their main purpose is to increase the energy absorption capacity and toughness of the material, but also increase tensile and flexural strength of concrete.

Fiber-reinforced concrete (FRC) is concrete containing short discrete fibrous materials that are uniformly distributed and randomly oriented which increases its structural integrity. Fibers include steel fibers, synthetic fibers, natural fibers and glass fibers – each of which provide varying properties to the concrete. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities (Sivaraja, 2010). A fiber is a small piece of reinforcing material possessing certain characteristics properties and they can be circular or flat. The fiber is often described by a convenient parameter called “aspect ratio”. The aspect ratio of the fiber is the ratio of its length to its diameter.

The concept of using fibers to improve the characteristics of construction materials is very old. Early applications include addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce pottery (Al-lami, 2015). The most important contribution of fiber reinforcement in concrete is not to strength but to the flexural toughness of the material. When flexural strength is the main consideration, fiber reinforcement of concrete is not a substitute for conventional reinforcement. The greatest advantage of fiber reinforcement of concrete is the improvement in flexural toughness (total energy absorbed in breaking a specimen in flexure). When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility (Nibudey, 2013)..

Nowadays, fibers are produced from different materials such as steel, glass, carbon, and synthetic material. Each one of these fibers has its specific benefit sand steel fibers being the most commonly used. It was reported in ACI 544 (2003) that some of the first experiments to improve concrete characteristics using discontinuous steel reinforcing elements like nails was done in 1910. In order to overcome problems with steel fibers such rusting, researchers have studied other types of fibers (Al-lami, 2015). Plastic fibers, glass fibers, asbestos fibers, carbon fibers, organic fibers and synthetic fibers (polypropylene and nylon) are some of these fibers (Rai & Joshi, 2014) that can alternatively be used.

2.2. Properties of PET fibers and SCBA.

2.2.1. Properties of Polyethylene Terephthalate (PET)

Polyethylene Terephthalate (PET) is the most commonly used thermoplastic polyester (Sulyman et al.; 2016). Polyesters were first manufactured in the 1930's for use in synthetic fibers though much of the PET produced today is still used to produce fiber such as fleece sweaters, later, PET came to be used for packaging films. Film and magnetic tapes also use PET film as a carrier. Then, in the 1970's a production process of PET bottles was finally developed. PET bottles were initially used for soft drinks, but gradually their use with bottled water became more popular. PET is used predominantly in the form of bottles for storing carbonated and non-carbonated drinks as it is hygienic, strong, and lightweight (Ramaraj & Arch, 2014).

PET is manufactured from terepthalic acid (a dicarboxylic acid) and ethylene glycol (a dialcohol). The two substances react together to form long polymer chains, with water as a bi-product, as in figure 2-1 most processes of polymerization, a catalyst is also required. PET belongs to the thermoplastics with excellent physical properties.

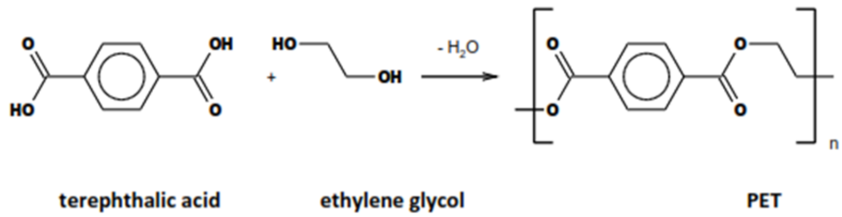

Figure 2-1: Structure and chemical equation of PET (John, 2014)

PET is a transparent polymer that has good mechanical properties and good dimensional stability under variable load. Semi crystalline thermoplastic polyester, durable, low gas permeability, chemically and thermally stable, easily processed and handled, wear and tear resistant and non-biodegradable are the common characteristics of PET (Chavan & Rao, 2016).

2.2.1.1. Advantages of using PET fibers:

a) They are chemically inert.

b) They do not corrode.

c) They are lighter than steel fibers of the same number.

d) They allow a better control of the plastic shrinkage cracking (Foti, 2011)

Hence reusing of PET wastes in the building industry is an effective approach in both, preventing environmental pollution and designing economical buildings (Dhote, 2016).

2.2.1.2. Disadvantages of using PET fibers:

1. Plastics have low bonding properties which results in reduction in compressive strength (Sung, 2009).

2. Its melting point is low so that it cannot be used in furnaces because it melts in high temperature.
3. Plastic production involves use of potentially harmful chemicals which were used as stabilizers or colorants. So, they may need environment risk assessment and need certain results in order to assess the risk to human health before used(Yadav, 2008).

2.2.2. Properties of Sugar cane Bagasse Ash

Bagasse is a fibrous leftover after sugarcane stalks are crushed to extract their juice (Almola, 2011). Bagasse is used as a biofuel, as a renewable resource in the manufacture of pulp and paper products and building materials. Figure 2-2 shows Sugar Cane Bagasse and SCBA. It is often used as a primary fuel source for sugar mills, when burnt in large quantities, it produces sufficient heat energy to supply all the needs of a typical mill. The combustion yields ashes known as Sugarcane Bagasse Ash (SCBA) containing high amounts of unburned matter, silicon and alumina oxides as main components (Payá et al., 2002). These materials would therefore react with the free calcium oxide in presence of water to form cementitious compounds.

Figure 2-2: Sugar cane Bagasse fibers and Sugar cane Bagasse Ash

2.2.2.1. Physical Properties of Sugar cane Bagasse Ash

Different researchers have carried out a study on the physical properties of sugarcane bagasse ash in terms of density, particle size, specific gravity, surface area, color and particle shape as summarized in table 2-1. The various differences could be seen in the density as this could be as a result of the different climates, soils and fertilizers used in the sugarcane plantations.

Table 2.1: Physical properties of SCBA (Kumar et al, 2016; Rambabu et al, 2016; Ajay et al, 2007)

Research	**Kumar et al, 2016**	**Rambabu et al, 2016**	**Ajay et al, 2007**
Density (kg/m^3)	575	994	252
Particle size (μm)	0.1-0.2	0.1-0.2	0.29
Specific gravity	2.20	2.88	1.305
Surface area(m^2/kg)	250	514	514
Color	-	Reddish grey	Reddish grey
Particle shape	Spherical	Spherical	-

From table 2-1, there is a difference in the density, specific gravity and surface area of the various SCBA as this was attributed to different sources, fertilizers used and burning temperatures in the boilers. Also, Ganesan et al; (2007) made a physical and chemical analysis comparison between OPC and SCBA and discovered that the particle size distribution of SCBA was nearly four times finer than that of OPC as shown in figure 2-3 and the particles of SCBA were more uniform in their distribution, this would imply more water for hydration is required where SCBA is substituted for OPC.

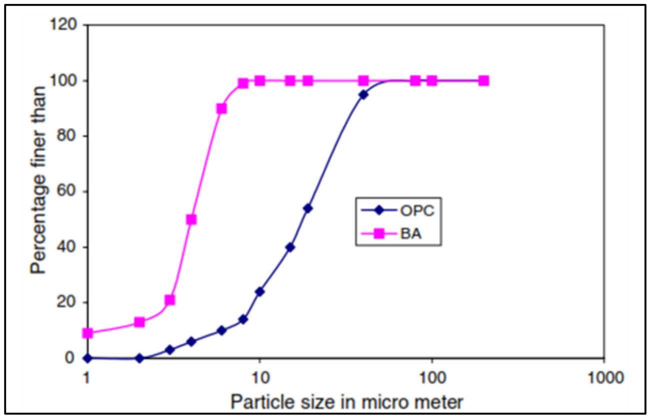

Figure 2-3: Particle size distribution curves of OPC and SCBA (Source: Ganesan et al; 2007)

Also the physical properties of OPC and SCBA were compared in Table 2-2 where the specific surface area of SCBA was found to be three times higher than that of OPC whereas the density, specific gravity and mean grain size of SCBA were found to be less than that of OPC.

Table 2.2: Comparison between the Physical properties of OPC and SCBA (Source: Ganesan et al; 2007)

Materials	**Bulk density (g/cm^3)**		**Specific gravity**	**Fineness passing 45µm sieve**	**Mean grain size (µm)**
	Compacted	**Loose**			
OPC	1.56	1.16	3.1	85	22.50
SCBA	0.59	0.41	1.85	99	5.40

2.2.2.2. Chemical Properties of Sugar cane Bagasse Ash

Researchers seek for pozzolanic materials in industrial and agricultural waste of mineral nature. Pozzolanas are materials that contain reactive silica and/ or alumina, which material has no binding property, but in presence of water and mixed with lime, will set and harden like a cement. They are important ingredients in the production of an alternative cementing material to ordinary Portland cement (Almola, 2011). For agricultural wastes to be used as pozzolanas, different factors like the calcining temperature and nature of source materials have to be considered (Payá et al., 2002).

A comparison between the chemical composition of OPC and SCBA was made in a study done by Ganesan et al; (2007), as shown in table 2-3 where conclusions were made that SCBA had three times higher silica content than OPC. This silica reacts with the free lime (CaO) from cement hydration through a pozzolanic reaction and reduces the free lime in the cement.

Table 2.3: Chemical compositions of OPC and SCBA (Source: Ganesan et al; 2007)

Material	Chemical composition (% weight)							
	SiO_3	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	LOI
OPC	18.4	5.6	3.0	66.8	1.4	2.8	0.5	2.0
SCBA	62.43	4.38	6.98	11.8	2.51	1.48	3.53	4.73

Research has revealed that sugar cane bagasse combustion products (ash) resembles pozzolanas in nature and therefore it should be considered as an important mineral and suitable as a binder, partially replacing cement (Ajay et al., 2007). Chemical investigations on bagasse ash indicated that it has chemical composition more or less similar to other artificial pozzolanic materials like fly ash or any other conventional pozzolana. (Patel, 2015).

In fact according to Almola, (2011), Comparison between chemical compositions of Kinana sugarcane bagasse ash and the pulverized coal fly ashes (ASTM C 618 1999) shows that the chemical composition of bagasse resembles that of Class F Coal Fly Ash, as the total of alumina, silica, and ferric oxide content is about 72 % and therefore may behave like Class F Fly Ash, in its engineering properties. Some of the chemical composition of Bagasse ash from different sugar cane mills is shown in Table 2-4 with the Standard ASTM (ASTM C618, 1999) requirements for Class F Fly Ash. The chemical composition of the ash may vary from ash to ash depending on the burning temperatures and other properties of the raw materials like soils on which the sugarcane is grown (Shruthi et al; 2014).

Table 2.4: Comparison between chemical compositions and coal fly ash ASTM C-618 classification. (Source: Priya & Ragupathy, 2016; Patel, 2015; Almola, 2011)

Chemical Compound	**Abbre viation**	**Sugar Factory (Country)- Average Chemical composition %**				**Class F fly ash (ASTM C618, 1999)**
		Guenaid (Sudan)	**Kinana (Sudan)**	**Ghodgara (India)**	**Maroli (India)**	
Silica	SiO_2	56.7	58.03	66.89	68.42	40-63
Alumina	Al_2O_3	6.81	9.69	29.18	5.812	17-28
Ferric oxide	Fe_2O_3	15.52	4.56		0.218	3-12
Calcium oxide	CaO	9.30	13.71	1.92	2.56	2-8
Magnesium Oxide	MgO	4.50	5.81	0.83	0.572	0.6-2
Loss of Ignition	LOI	6.40	8.66	0.72	15.90	0-5

From this comparison, therefore it might possible to use sugarcane bagasse ash (SCBA) as cement replacement material to improve quality of concrete in terms of strength and workability, to reduce the emissions of CO_2 into the atmosphere due to cement-production process and reduce the cost of construction materials such as mortar, concrete pavers, concrete roof tiles and soil cement interlocking block and so on (Patel, 2015).

2.3. Effect of waste PET fibers and SCBA on concrete properties

2.3.1. Mechanical and physical behavior of concrete modified with waste PET fibers

All over the world, many researchers are inventing materials which can be suitably added into concrete to enhance its properties. The incorporation of materials like waste PET bottle fibers in cementitious matrix improves the mechanical response of the resulting product; commonly known as PET fiber reinforced concrete (PFRCs), have the potential of exhibiting higher flexural strength and ductility in comparison to unreinforced mortar or concrete, which fail in tension immediately after the formation of a single crack (Magalhães & Fernandes, 2015). A comprehensive review of the work carried out by various researchers in the field of using plastics fibers on mechanical behavior of modified concrete is discussed below.

2.3.1.1. Compressive Strength:

Compressive strength is the most important mechanical property of concrete and is the most common performance measure used by the engineer in designing buildings and other structures. Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It is measured by breaking cubes of concrete specimens in a compression-testing machine. Compressive strength test results is primarily used to determine that the concrete mixture as delivered meets the requirements of the specified strength in the job Specification. All other mechanical parameters such as flexural strength, splitting tensile strength and modulus of elasticity directly depend on the compressive strength of the concrete (Alengaram et al., 2013).

According to the recent research and studies, it has been shown that compressive strength of PFRC depends on the amount, dimensions (sizes), shape and texture of the plastic fibers in the mix. Maqbool and Sood (2016) obtained a 3% maximum replacement for the grades, M20, M25 and M30 as this gave the maximum compressive strength as shown in figure 2-4.

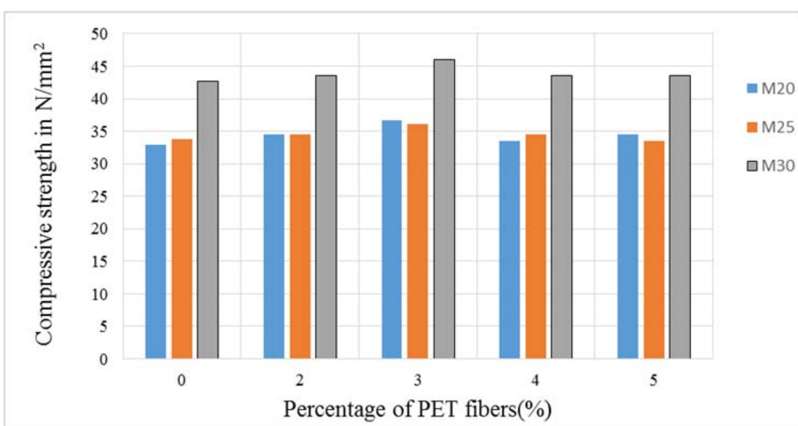

Figure 2-4: Average compressive strength for M20, M25 and M30 PFRC at 28days (Maqbool & Sood., 2016)

In a study done by Nibudey et al (2013), 1% fiber content gave the optimum strength at an increase of 7.35% compared to normal concrete for M20 grade with an aspect ratio of 50, which then reduced at higher percentage fiber additions, as they noted a 27% fall in compressive strength for 3% fiber volume fraction for the same grade and aspect ratio. And then an increase in compressive strength was obtained for PFRC with higher aspect ratios.

In the analysis of tests done by Ramadevi et al (2012) for a mix design of M25 grade concrete, an appreciable increase in compressive strength was observed till 2% replacement of fine aggregates by PET bottle fibers and then the compressive strength gradually decreased. For conventional concrete (M25 grade concrete) the replacement of fine aggregates by 2% increase the compressive strength by 12% (Sahil et al.; 2015). Regarding the structural performance of the concrete member, the ultimate strength and relative ductility of PET fiber in reinforced concrete beams was significantly larger than those specimen without fiber reinforcement (Kim et al, 2010). Table 2-5 shows a summary of the optimum dosages obtained by some of the researchers for the maximum compressive strength.

From table 2.5, it can be seen a wide range of the optimum fiber was realized from 1% to 3%, this was because of the difference in aspect ratios used, the shape as indicated, different mixes and mix ratios and how the fibers were incorporated either by addition into the mix or by replacement of the fine aggregates.

Table 2.5: Different optimum percentages for maximum compressive strengths obtained by various researchers.

Research	Volume of PET fiber (%)	Shape of PET fiber	Water-cement ratio	Optimum % for max Compressive Strength
Maqbool & Sood(2016)	2,3,4,5 & 6	-	-	3% by weight of cement
Nibudey et al (2013)	0.5,1.0,1.5,2.0,2.5,3.0	25mm by 2mm	-	1% replacement by fine aggregates
Irwan et al (2013)	0.5,1.0,1.5	Irregular	0.65	0.5% replacement of fine aggregates
Ramadevi et al (2012)	0.5,1,2,4, 6	grounded	-	2% replacement of fine aggregates
Foti (2011)	12.5% of OPC	32mm by 2mm and 30-50mm dia.	0.7	Increase in Compressive strength

2.3.1.2. Split Tensile Strength

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. Concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension and it develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

Experiments by Irwan et al (2013) showed that PET fibers enhanced the tensile strength of the concrete cylinder. Strength of concrete containing PET fibers increased by 0.5% - 1.5% compared to normal concrete at all ages. At 28 days the increment of splitting tensile strength of concrete containing PET fibers at 0.5%, 1.0% and 1.5% was by 9.1%, 15.5% and 23.6% respectively. Also according to Foti (2011) the tensile strength increased with the addition of PET fiber reinforcement at 8.19KN compared to ordinary concrete specimen at 7.88KN tensile strength. Kandasamy & Murugesan (2011) showed that the split tensile strength increased till the 2% replacement of fine aggregates with PET bottle fibers and then decreased gradually with increase in replacement. Foti (2011) also experimented on the effect of PET fibers on the ductility of concrete, and concluded that there was an improvement in ductility of concrete.

As the role of adding PET fiber in concrete is bringing across the crack and improving the bonding of its element in concrete, we can conclude that the PET fiber added will improve the bending strength as well as the splitting tensile strength (Chavan & Rao, 2016).

2.3.1.3. Density of concrete

The incorporation of the PET fibers in the concrete mix reduces the density of the concrete because of the light weight nature of the fibers. Al-Manaseer & Dalal (1997) studied the effect of the plastics as aggregates on the density of concrete and reported a decrease with the increasing content of the plastic aggregate. Therefore fibers can be used to reduce the density of the concrete and in production of Light weight concrete.

2.3.1.4. Workability

Workability is one of the physical parameters of concrete which affects the strength and durability of the hardened concrete. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e. without bleeding and segregation. Workability is affected by a number of factors some of which are the water-cement ratio, presence of admixtures, aggregate properties (grading, maximum size, shape and texture), ambient conditions and time.

From the recent research studies, it has been shown that the workability of concrete reduced with increasing percentage of plastic fibers. Ismail & Al-Hashmi (2008) found that the slump is prone to decreasing sharply with increasing the waste plastic ratio. Batayneh et al., (2007) also observed that there is a decrease in the slump with the increase in the plastic particle content. For a 2% replacement, the slump decreased by 25% of the original slump value with 0% plastic particle content. Olaoye (2013) also reported reduction in slump with the use of recycled plastic in concrete. Shamskia (2012) added different contents of PET fibers (0, 0.5, 1.0, and 1.5 %) to a concrete mixture and the workability of fresh concrete samples was observed to be decreasing on increasing the content of PET fibers.

2.3.2. The Effect of Sugar cane Bagasse Ash on concrete properties.

2.3.2.1. Physical Properties of Concrete with SCBA

In the recent years, the use of Sugar cane Bagasse ash in concrete as a partial replacement to cement has been researched and studied. There are many advantages of using pozzolans in concrete such as improved workability at low replacement levels, reducing bleeding and segregation, low heat of hydration, lower creep and shrinkage, high resistance to chemical attack at later ages and low diffusion rate of chloride ions resulting in higher resistance to corrosion of steel (Kartini, 2011). According to Kawade et al., (2013), concluded that the partial replacement of SCBA for cement in concrete improves the workability of fresh concrete and that the use of super plasticizer is not essential. These properties are rather difficult to be achieved with the use of Pure Portland Cement alone and therefore necessitate incorporation of pozzolans in the mix.

2.3.2.2. Mechanical Properties of Concrete with SCBA

According to the recent studies made, partial replacement of ordinary Portland cement with SCBA increases the strength (Compressive, Flexural and Split Tensile) of concrete (Priya & Ragupathy, 2016). Ellatif et al, (2014), and Srinivasan & Sathiya., (2010) obtained an increase in Strength with increase in replacement of cement with a maximum strength obtained at 10% partial replacement. Kawade et al, (2014) as demonstrated in figure 2-5, obtained maximum compressive strength at 15% replacement of cement with SCBA for M30 grade concrete. Priya & Ragupathy, (2016), in their study on the effect of bagasse ash on strength of concrete obtained a maximum limit of 15% for all grades M20, M30 and M40 also Ajay et al., (2007), from their study on the properties and reactivity of SCBA concluded that up to 15% substitution of OPC with SCBA can be made with better strength results than that with pure cement. The workability of fresh concrete mixed with partial replacement of SCBA also gave better performance and hence no substantial need for a super plasticizer (Srinivasan & Sathiya, 2010).

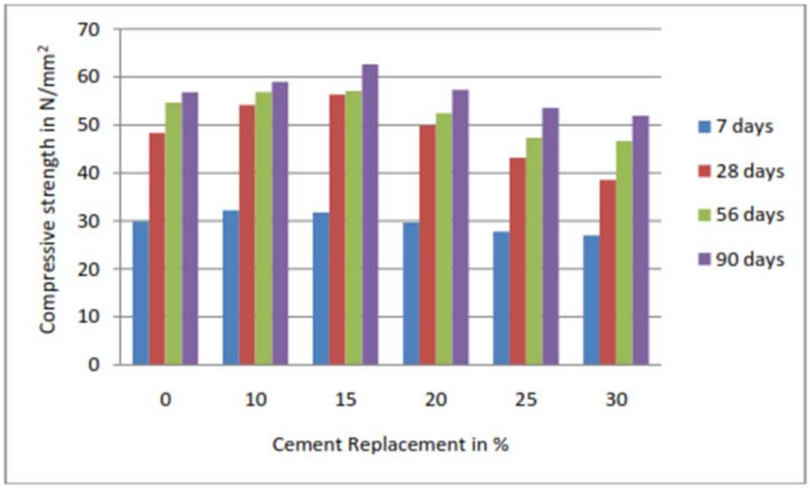

Figure 2-5: Compressive strength for M30 grade concrete at 0, 10, 15, 20, 25 and 30 percent replacement for cement with SCBA (Kawade et al, 2013).

For the splitting tensile strength tests, tests done by Ganesan et al, (2007) of SCBA blended concretes after 28 days of curing as shown in figure 2-5. Found out that up to 20% of SCBA, an increase in the splitting tensile strength values then at 25% and 30% of SCBA, the value decreases, therefore, from tensile strength point of view, 20% of SCBA was the optimal limit.

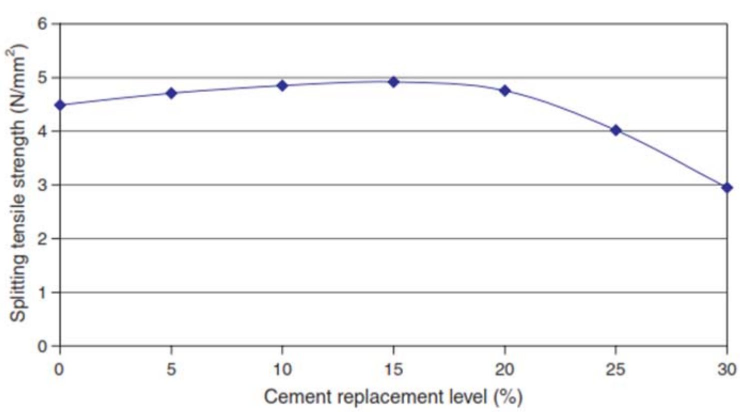

Figure 2-6: Splitting tensile strength of BA blended concretes at 28 days curing (Ganesan et al., 2007)

From the above literature, it is shown that the use of Sugar cane bagasse Ash should considerably be increased given the fact that it significantly contributes to green building and therefore solves the problem of waste disposal. It also reduces the amount of cement which is the most expensive constituent material used in concrete hence reducing the cost of construction.

2.4. Summary:

Case studies based on researches, experimental works and scientific reports have shown that waste PET fibers and Sugarcane Bagasse ash may be applied for the modification of concrete. The incorporation of PET bottle fibers as reinforcement in concrete and SCBA as a partial replacement of cement as a pozzolana, on the basis of different tests on its mechanical properties, that there is a significant improvement in the modified concrete. The use of various wastes in cement is a promising technique for developing sustainable materials to be applied in the civil construction industry. And hence utilization of wastes in concrete can be used not only as an effective solid waste management practice but also as a strategy to produce more economic and sustainable building materials in the future (Chavan & Rao, 2016).

2.5. Research Gap

With reference to the literature review, Plastic fibers have proven a suitable material in concrete as they improve the tensile and flexural properties of concrete. Though, the use of Plastic fibers is associated with shortcomings of reduction in Compressive Strength and workability of concrete. From the recent researches, for PET waste used as fibers, Chavan & Rao (2016), Nibudey et al., (2014), Sulyman et al., (2016) and Ramadevi &

Manju (2012) made recommendations that further studies should be carried out on how to improve the compressive strength and bonding properties of Plastic Fiber Reinforced Concrete.

Sugar Cane Bagasse Ash on the other hand, has proven both chemically and mechanically as a good pozzolana and classified as Class F Fly Ash, there is limited research of the effect of SCBA on the properties of Plastic Fiber Reinforced Concrete. This research therefore aimed at investigating the effect of Sugar Cane Bagasse Ash (as an agricultural pozzolana) on the mechanical and physical properties of PFRC.

3. METHODOLOGY

3.1. Introduction:

This chapter deals with the methodology that was used in this research. This research focused on investigating the effect of SCBA on the mechanical and physical properties of PFRC. The main parameters that were studied are compressive strength, spit tensile strength, density, workability and water absorption of concrete. Analyses of the concrete raw materials, actual laboratory tests on fresh and hardened concrete were all undertaken at different laboratories.

3.2. Methodology Flow Chart

The project will be executed as per the processes highlighted below in Plate 3-1.

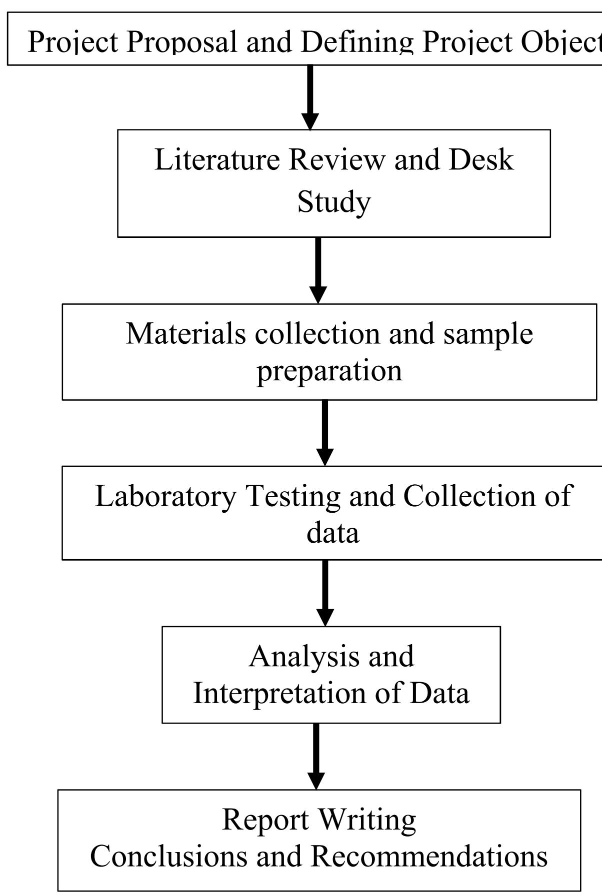

Plate 3-1: The methodology flow chart to be used for research project

3.3. Materials collection and Sample Preparation

3.3.1. Cement

The type of cement that was used in this study was Ordinary Portland Cement 42.5 locally manufactured. This cement has a wide range of applications from domestic building construction to large civil engineering projects. It has a minimum compressive strength of 42.5MPa at 28 days of curing, and is manufactured to harmonize East African Standard KS EAS 18-1.

3.3.2. Fine aggregates

River sand was be obtained locally from Meru in Kenya. In this study, sand conforming to BS 882:1992 was used. The fine aggregates that passed the 5.0mm BS 410 test sieve and containing no more coarser material were considered as sand for the study.

3.3.3. Coarse aggregates

The coarse aggregates were obtained locally with a maximum size of 15mm and retained on a 5.0mm BS 410 test sieve, conforming to BS 882:1992 specification used in this study. The aggregates were first sieved then washed to remove dust and dirt and air dried to surface dry condition as shown in figure 3-1.

Figure 3-1: Sample of coarse aggregates used in the study.

3.3.4. PET waste fibers

The PET fibers were obtained by collecting plastic bottles from the nearby hostels and restaurants, labels removed, cleaned, dried and then shredded into rectangular strips manually using a pair of scissors and a knife as shown in figure 3-2.

Figure 3-2: Sample of shredded PET fibers

3.3.5. Sugar cane Bagasse Ash

The Sugar cane Bagasse Ash used in this study was produced by burning the Bagasse produced from Lugazi Sugar Factory in Uganda. The bagasse was used as a fuel in the boilers, burnt in a range of 500^{o}C to 800^{o}C to produce sugarcane bagasse ash as shown in figure 3-3. The burnt ash was then deposited on a nearby land site and mixed with water and left to cool. After the ash had cooled, it was then placed in packaging bags and transported. The collected ash was then sundried for about 12 hours to remove the water present and after which it was standardized by sieving it through a 300μm sieve.

Figure 3-3: Sample of Sugarcane Bagasse Ash

3.3.6. Water

In this study, portable water conforming to BS 1348-2(1980) was used for mixing the materials and curing the concrete samples. The water used in this research was obtained from general supply water system of JKUAT University.

3.4. Test Regime

The proposed sequence for analysis entailed characterization tests done on SCBA, PET fibers and OPC, followed by tests done on both the coarse and fine aggregates that were used in concrete, then tests on fresh concrete and lastly on hardened concrete. Tests on SCBA and OPC involved chemical analysis tests to establish the elemental oxide contents in the ash and the physical tests covering geometric properties which included; particle size distribution, density and specific gravity. Tests that were done on the aggregates covered the geometric properties, mechanical properties and physical properties following guidelines given in BS EN 12620. Tests on fresh concrete included slump following guidelines given in BS EN 12350-1, while tests on hardened concrete included density, compressive strength, splitting tensile strength and water absorption.

3.5. Characterization of Constituent materials

Tests that were done on the constituent materials can broadly be grouped into two categories namely: Physical tests and Chemical tests.

3.5.1. Physical tests carried out

3.5.1.1. Hydrometer Analysis- Particle Size Distribution

Particle Size Distribution for Sugarcane Bagasse Ash was determined by hydrometer analysis test performed at the JKUAT University Transportation and Soils Laboratory. The hydrometer analysis is based on Stoke's Law, which gives the relationship between the velocities of fall of spheres in a fluid, the diameter of the sphere, the specific weights of the sphere and of the fluid, and the fluid viscosity. In equation form this relationship is:

$$\mathbf{v} = \frac{2}{9} \times \frac{(G_s - G_f)}{\eta} + \left(\frac{D}{2}\right)^2 \text{ ....Equation 3.1}$$

Where: v-velocity of fall of spheres (cm/s)

G_s- Specific gravity of sphere

G_f- Specific gravity of fluid (varies with temperature)

η- Absolute, or dynamic, viscosity of the fluid (g/(cmxs)

D- Diameter of the sphere (cm)

Solving the equation for D and using the specific gravity of water, G_w, we obtain:

$$\mathbf{D} = \sqrt{{}^{\mathbf{18\eta v}}/_{(\mathbf{G_s} - \mathbf{G_w})}}$$ ……………………………………………...….Equation 3.2

$$\mathbf{v} = {}^{\mathbf{L}}/_{\mathbf{t}}$$ …………………………………………………..……Equation 3.3

$$\mathbf{A} = \sqrt{{}^{\mathbf{18\eta}}/_{(\mathbf{G_s} - \mathbf{G_w})}}$$ ……………………………………...…….….Equation 3.4

$$\mathbf{D} = \mathbf{A}\sqrt{{}^{\mathbf{L(cm}}/_{\mathbf{t(min)}}}$$ ……where 0.002mm≤ D ≤0.2mm…………Equation 3.5

With reference to BS 1377: Part 2:1990, the hydrometer test was carried out with sodium hexametaphosphate as the dispersing agent. The obtained hydrometer readings were used to calculate the particle sizes in samples using equation 3.1.

3.5.1.2. Sieve Analysis and Fineness Modulus

Particle size Distribution for fine and coarse aggregates was determined by Sieve analysis in accordance with BS 812-Part 103-1. Sampling of the aggregates to obtain a representative sample was done in accordance with the procedure described in clause 5 of BS 812:102: 1990 using the quartering method. From the finest sieve upwards, the cumulative percentage passing each sieve was calculated and used for plotting the grading curves. The grading curves were plotted on a semi-logarithmic graph showing the cumulative percentage passing on the abscissa while the sieve apertures plotted on a logarithmic scale.

From the sieve analysis tests, fineness modulus was computed for the fine aggregates by dividing the sum of the cumulative percentage retained on the standard sieves divided by 100.

3.5.1.3. Specific gravity and Water absorption

Specific gravity for SCBA was determined from the hydrometer analysis test, and for samples of sand (fine aggregates) and ballast (coarse aggregates) was determined according to BS 812: Part 2: 1990. The water absorption and specific gravity were determined using a pyknometer and calculated equations 3.6 and 3.7 respectively.

Water absorption (in % of dry mass), $\mathbf{Wabs} = \mathbf{100}\frac{(\mathbf{A}-\mathbf{D})}{\mathbf{D}}$…………………Equation 3.6

Relative Density, $\boldsymbol{\rho}_{\mathbf{s}} = \frac{\mathbf{A}}{\mathbf{A}-(\mathbf{B}-\mathbf{C})}$ in (ton/m^3)………………………………Equation 3.7

Where: A- Is the mass of the saturated surface-dry aggregate in air (g)

B- Is the mass of the pyknometer containing sample and filled with water (g)

C- Is the mass of the pyknometer filled with water only (g)

D- Is the mass of the oven-dry aggregate in air (g)

3.5.1.4. Aggregate Impact Value and Aggregate Crushing Value

Aggregate Crushing Value

The Aggregate Crushing Value was carried out on the ballast with reference to BS 812: Part 110: 1990. The ACV value was calculated as;

$\mathbf{ACV} = \frac{\mathbf{M_1}}{\mathbf{M_2}} \times \mathbf{100}$ …………………… Equation 3.8

Where M_2- is the mass of test specimen passing the 2.36mm sieve (in g)

M_1- is the mass of the test specimen (in g)

Aggregate Impact Value

The strength of the aggregate may be measured in terms of crushing or impact tests. The Aggregate Impact Value (AIV) gives a relative measure of resistance of an aggregate to sudden shock or impact. The AIV test was carried out with reference to BS 812: Part 112: 1990.

AIV value was calculated as; $\mathbf{AIV} = \frac{\mathbf{M_1}}{\mathbf{M_2}} \times \mathbf{100}$ …………………….…. Equation 3.9

Where M_2- is the mass of test specimen passing the 2.36mm sieve (in g)

M_1- is the mass of the test specimen (in g)

3.5.1.5. Density

Densities of SCBA, OPC, fine aggregates and the ballast were obtained as per BS 812: Part 2: 1995 clause 5.7 and density of each material recorded.

3.5.1.6. Tensile Strength

The tensile strength of the PET fibers was obtained using a tensometer machine shown in figure 3-4 where the PET fiber was subjected to tensile force up to failure and the maximum values were obtained for three (3) samples and average value recorded. The tensile strength of the fiber was obtained using equation 3.10.

Figure 3-4: The Tensometer machine

Tensile Strength= $\frac{\mathbf{P}}{\mathbf{A}}$……………………………………………Equation 3.10

Where P- is the ultimate tensile force applied on the fiber (in N)

A-is the cross sectional area of the fiber (in mm^2)

3.5.2. Chemical tests carried out

Samples of SCBA and cement were taken for chemical testing at the Ministry of Mining Laboratory in industrial area Nairobi for chemical analysis.

3.5.2.1. Chemical composition

The Chemical composition of both SCBA and OPC were determined in this study. The gravimetric method was used to determine the silica (SiO_2) content, a residue from the filler paper was heated at about 900^oC, cooled and then weighed. A drop of concentrated sulphuric acid was added followed by treatment with hydrofluoric acid in order to expel the silica present. The residue of each sample was then dried, cooled and weighed. The difference between the weight of the residue and the weight of each sample represent the weight of silica present in the sample which was then expressed as a percentage of the original sample. The atomic absorption Spectromy method was used to determine the Al_2O_3, CaO, Fe_2O_3, MnO_2 and CuO contents in both the cement and SCBA samples. The Flame Photometry method was used to determine Na^+ and K^+ content in the cement and SCBA samples.

3.5.2.2. Loss of Ignition (LOI)

This was used to determine the organic content in the SCBA and cement samples. A representative known weight of the sample was ignited in a muffle furnace and heated gradually to 600^oC and 1000^oC, the heating was maintained at this temperature for 30 minutes. The crucible was cooled and weighed. The LOI was expressed as a percentage of original sample weight representing the organic content.

% Loss on Ignition= Loss in weight X 100……………………………Equation 3.11

3.6. Mix Design

The mix design ratio that was calculated using the DOE method and depending on the target strength which was 30MPa a mix ratio of 1:2:3 for OPC, fine aggregates and coarse aggregates respectively by weight with a water cement ratio of 0.57 was adopted as in accordance with BS 1881-125 (1990).

3.6.1. Mix Proportions

From the adopted mix design, various calculations of OPC, fine aggregates, coarse aggregates and water were made for each mix. On completion of the initial mix proportion calculations, a control mix was first made of normal weight concrete without any additions or substitutions i.e. 100% OPC+0% PF+0%SCBA and tests run. Thereafter, a total of other 11 other mixes were conducted which included addition of 1%, 2% and 3% PET by weight of the cement and also partial replacement of OPC with SCBA added to the mix in three different proportions of 10% and 15% by weight of the cement. This gave an experimental matrix of 4x3 as shown in Table 3.1, hence 12 different mixes were made and 3 samples were made for each test.

Each of the batches made, slump test was performed on the fresh concrete, thereafter concrete cubes and cylinders were cast for water absorption and mechanical tests i.e. compressive strength, splitting tensile strength and density of concrete that were carried out at 7 and 28 days of curing.

Table 3.1: Experimental matrix that was used:

PET fibers (PF) %	SCBA content % replacement of cement		
	0	**10**	**15**
0	0%SCBA+0%PF	10%SCBA+0%PF	15%SCBA+0%PF
1	0%SCBA+1%PF	10%SCBA+1%PF **(B10P1)**	15%SCBA+1%PF **(B15P1)**
2	0%SCBA+2%PF	10%SCBA+2%PF **(B10P2)**	15%SCBA+2%PF **(B15P2)**
3	0%SCBA+3%PF	10%SCBA+3%PF **(B10P3)**	15%SCBA+3%PF **(B15P3)**

3.7. Batching, Mixing, Casting and Curing

3.7.1. Batching and Mixing

In this study batching was done by weight. The batching procedure first entailed weighing all the individual material fractions as per the mix design calculations which included coarse aggregates, fine aggregates and OPC. This was followed by weighing of SCBA percentages of 10% and 15% and PET fibers of 1%, 2% and 3% of the cement weight. The weighed coarse aggregates were placed on a moist metallic tray used as a mixing pan, this was followed by fine aggregates, then OPC and SCBA in that respective order. The dry- fractions were pre-mixed for a period of 5 minutes prior to addition of PET fibers, which were then added, mixing continued for more 2 minutes. Finally, addition of the calculated quantity of mixing clean water made. After addition of water, mixing (shown in figure 3-5) was extended for a further period of 3 minutes to obtain a homogenous mix.

Figure 3-5: Mixing of concrete to obtain a homogenous mix.

3.7.2. Casting

Before casting, all the cubic moulds and cylindrical moulds were cleaned and oiled properly. Cube steel mould dimensions of 150x150x150mm conforming to BS EN 12390-1(2000) were used for compressive, density and water absorption tests while cylinders of 100mm diameter and 200mm length dimensions were used for splitting tensile strength. The moulds were tightly screwed to ensure that there were no spaces left which could lead to a possibility of a slurry leakage. The cleaned and oiled moulds for each category were filled with concrete in three (3) layers using a poker vibrator up to when a cement slurry appeared on top of the moulds as shown in figure 3-6. The specimens were then left in the moulds covered with a wet sack for 24hours.

Figure 3-6: Casting and compacting concrete into the concrete moulds

3.7.3. Curing

Open air curing was done for 24hours, after which the specimens were removed from the moulds and then placed in the curing tank containing clean water before 7 days and 28 days of testing of mechanical and other properties.

3.8. Physical Tests carried out

3.8.1. Workability

The workability of the concrete was determined using the Slump test as shown in figure 3-7. The Slump Test measures the consistency of fresh concrete before it sets. It is a test performed to check the workability of fresh made concrete; and therefore the ease with which concrete flows. In this study, a slump test was carried out on every batch of freshly mixed concrete conforming to BS 1881 Part 102:1983.

Figure 3-7: Slump test on concrete

3.8.2. Water Absorption Test:

The water absorption test was carried out on hardened concrete cubes casted and cured for 28 days conforming to specification of BS 1881-122 (1983). The cubes cured at 28 days, were placed in an oven at a temperature of 105^0C for 72 hour period. Then, after removal, the cubes were cooled for 24 hours in a dry airtight vessel. After cooling, the cubes were weighed and immediately immersed completely in a tank of water for 30 minutes. The cubes were then removed from the tank and dried with a cloth to remove bulk of the water from the surface and then weighed. Water absorption was be calculated as the increase in mass resulting from immersion and was expressed as a percentage of the mass of the dry specimen as expressed by Equation 3.12.

Water Absorption, percent = $\frac{(\mathbf{A}-\mathbf{B})}{\mathbf{B}} \times \mathbf{10}$ ……………………………..…. Equation 3.12

Where: A= wet mass of unit in kg

B= dry mass of unit in kg.

3.9. Mechanical tests carried out

With reference to the second, third and fourth specific objectives of this research, compressive, splitting tensile strength and density of concrete tests were carried out on hardened concrete after 7 and 28 days of curing.

3.9.1. Compressive Strength

The Compressive strength test for this research was determined using Universal Testing Machine (UTM) at the material lab of Civil Engineering as specified in the test method BS 1881-Part 116,1983. Mean compressive strength was obtain by calculating the average of the three (3) values that were calculated using equation 3.13 for each mix. A total of 108 cubes were casted, cured and tested after 7 and 28 days of curing.

Compressive Strength was calculated by $CS=\frac{P}{A}$……….…………Equation 3.13

Where: P: Ultimate compressive load of concrete (kN)

A: Surface area in contact with the platens (mm^2)

3.9.2. Splitting Tensile Strength

The most commonly used tests for estimating the tensile strength of concrete is the BS 1881-117(1983) splitting tensile strength of cylindrical concrete specimen. Three (3) concrete cylinders of each mix were casted and a total of 72 cylinders were casted and cured at 7 days and 28 days. A Universal Testing Machine (UTM) at the material lab of Civil Engineering was also used for test and the splitting tensile strength, σ_{ct}, in N/m^2 was calculated using equation 3.14.

$$\sigma_{ct} = \frac{2P}{\pi \times l \times d}$$ ………………………………….…………Equation 3.14

Where P is the maximum load (in N), l is the length of the specimen (in mm), and d is the cross-sectional dimension of the specimen.

3.9.3. Density of Concrete

The density of concrete was determined with reference to BS 1881-114 using the 150x150x150mm cubes. The density (ρ) is the mass of a unit volume of hardened concrete expressed in kilograms per cubic meter as shown in equation 3.15. Density was carried out at both 7 days and 28 days of curing, three (3) times for each mix that was made and an average was obtained.

$$\boldsymbol{\rho = \frac{m}{v}} \quad \text{.. Equation. 3.15}$$

Where: m- mass of the saturated specimen in air (in kg)

v- Volume of specimen calculated from its dimensions (in m^3)

4. RESULTS AND DISCUSSIONS

4.1 PROPERTIES OF CONSTITUENT MATERIALS (OBJECTIVE 1)

4.1.1 PROPERTIES OF SCBA AND OPC

The Properties of SCBA and OPC are grouped into two (2) i.e. Chemical Properties and Physical Properties as discussed in the subsequent sections 4.1.1.1 and 4.1.1.2.

4.1.1.1 Chemical Properties of SCBA and OPC

Table 4.1: Percentage Chemical composition for SCBA and Class F fly ash (ASTM C618-1999)

PARAMETER	CHEMICAL COMPOSITION FOR SCBA	Class F fly ash (ASTM C618, 1999)
SiO_2	63.0	40-63
Al_2O_3	6.0	17-28
Fe_2O_3	6.30	3-12
CaO	2.2	2-8
MgO	0.75	0.6-2
Na_2O	0.15	-
K_2O	2.0	-
MnO	0.30	-
TiO_2	0.75	-
LOI at 600^oC	11.4	0-6
LOI at 1000^oC	16.6	0-6

According to the tests that were carried out on Sugarcane Bagasse Ash from the Ministry of Mining Laboratory as shown in table 4-1, the total of alumina, silica, and ferric oxide content is 75.3% with the silica content being 63%. Comparison with the Ordinary Portland Cement (OPC) which has a total of silica, alumina and ferric oxide as 29.24% showing that SCBA has components that will react with the reactive Calcium Oxide (CaO) in the cement to form cementitious compounds.

The loss on Ignition (LOI) however was relatively high with values of 11.4 at 600^{o}C temperature and 16.6 at 1000^{o}C as compared to the specified requirement of 0-5 of pozzolanas to be used as cement replacement materials. This could be due to some small quantities of unburnt material as the bagasse is burnt at temperatures of about 500 – 600^{o}C in the boilers. The high LOI could reduce the reactivity of the SCBA because of the presence of carbon which might lead to reduction in early strength (7days) compressive strength. The Alumina (Al_2O_3) content was found to be 6% which was out of range of 17-28. Also the Calcium oxide (CaO) content within the SCBA was 2.2% which is relatively low. This low Calcium oxide content has been found to be effective in reducing pore solution alkalinity.

From the results and discussions above, conclusion can be made that the SCBA used in the study possesses pozzolanic behavior and may behave like Class F Fly Ash as it conformed to the requirements as per the Standard ASTM C618, 1999 for use in concrete production.

The chemical composition for OPC CEM I 42.5N is summarized in table 4-2 as the cement used in the study was compared with the standard requirement as per EN 197-1 and was found suitable for use in normal weight concrete production. The Chemical composition showed that cement contained 59% lime which was available for pozzolanic reaction to form cementitious products in the concrete hence improving the performance of concrete.

Table 4.2: Chemical Composition for Ordinary Portland cement CEM I 42.5N.

PARAMETER	FROM MNISTRY OF MINING	FROM MANUFACTURER	EN 197-1
SiO_2	22.0	20.61	-
Al_2O_3	4.80	5.05	Not more than 8.0
Fe_2O_3	2.44	3.24	-
CaO	59.0	63.37	-
MgO	0.75	0.81	Not more than 3.0
Na_2O	0.28	0.15	-
K_2O	0.60	0.52	-
MnO	0.04	0.04	-
TiO_2	0.20	-	-
LOI at 600^oC	4.0	2.90	Not more than 5.0
LOI at 1000^oC	6.30	-	-

4.1.1.2 Physical Properties of SCBA and OPC

The Physical Properties of Sugarcane Bagasse Ash compared with those of Ordinary Portland Cement are summarized in table 4-3.

Table 4.3: Summary of Physical Properties of SCBA and OPC

Property	Description	
	SCBA	**OPC**
Density	Bulk-674.33kg/m^3 Loose-544.79kg/m^3	Bulk-1396.1kg/m^3 Loose-1162.75kg/m^3
Specific gravity	2.15	3.11
Particle size	1.7µm - 7µm	-
Characterization	Clayey silt	-
Water Demand	-	25.65%
Specific Surface	-	3197cm^2/g
Color	Greyish black	Grey

The Physical properties that were carried out showed that the bulk density of the SCBA was 674.33kg/m^3 with a specific gravity of 2.15 while that of OPC was 3.11. The difference in the specific gravity would have an impact on the density of hardened and workability of fresh concrete as the values will reduce where substitutions for OPC are made with SCBA.

The specific surface area for OPC was 3197cm^2/g which meets the ASTM standards as the value was within the range of 3000 - 5000cm^2/g.

Particle size distribution for SCBA was done using hydrometer analysis and then results were plotted on a semi-logarithmic curve as shown in figure 4-1.

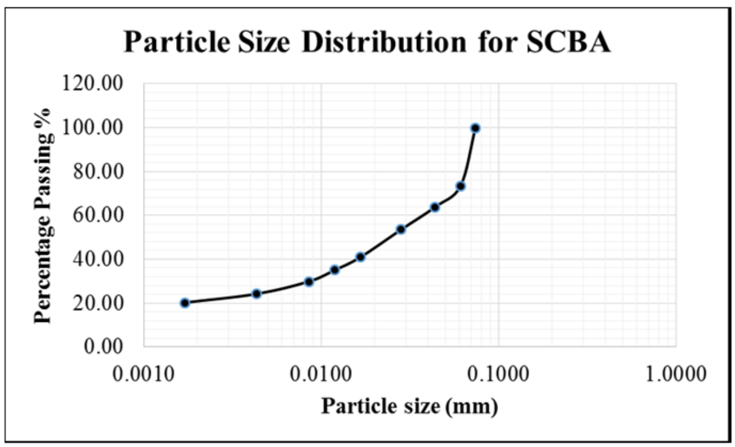

Figure 4-1: Particle Size Distribution for SCBA

From the curve, particle size of the SCBA was found to be between 1.7μm to 7μm and the SCBA was characterized as a clayey silt. This meant that at a constant water/cement ratio, fresh concrete with SCBA substitution for OPC would require more compacting effort in order to make the mix workable and achieve the required strength, also this would reduce the workability of the material since more water would be required for hydration since the SCBA is more finer than the OPC.

The cement that was used in the study was Ordinary Portland cement CEM I 42.5N meaning that it contained about 95-100% clinker with minor additional constituents of about 0-5 during the manufacture. The Physical Properties of OPC are shown in table 4-4 which conform to the EN 197-1 standard and therefore suitable for the research.

Table 4.4: Physical Properties of Ordinary Portland cement CEM I 42.5

Property	**Description**	**Requirement as per EN 197-1**
Soundness	0.3mm	Not more than 10mm
Compressive Strength @2days	19.30MPa	Not less than 10MPa
Compressive Strength @ 28days	48.94MPa	Not less than 42.5MPa
Setting Time	Initial - 160minutes Final - 252minutes	Not less than 60 minutes Not more than 600 minutes

4.1.2 PROPERTIES OF AGGREGATES

4.1.2.1 Physical Properties of Coarse Aggregates

The coarse aggregates that were used in the study were of Particle size between 5-15mm, they were crushed and of angular shape free from dust. The coarse aggregate physical properties are summarized in table 4-5 as it can be seen that the bulk density of the aggregates is 1365.33kg/m^3 which meant the requirement for production of normal weight concrete with a specific gravity of 2.58.

Table 4.5: Physical Properties of Coarse Aggregates

Property	**Description**	**Requirement as per BS 882:1992**
Density	Bulk-1365.33kg/m^3 Loose-1254.58kg/m^3	-
Specific gravity	2.58	-
Particle size	5mm- 15mm	Envelope
Water Absorption	2.916	Less than 3.00
Shape	Angular	-
Surface texture	Rough	-
AIV	7.61	Less than 45
ACV	17.40	Less than 30

The water absorption of an aggregate indicates the quantity of water which will be absorbed into the pore structure. It is an important property as it influences the bond between the aggregate and the cement paste, the resistance of the concrete to freezing and thawing as well as the chemical stability and resistance to abrasion. The water absorption for the coarse aggregate was 2.916 which conforms to the requirement of a coarse aggregate to be used in concrete which should be less than 3.00 as per BS 5337:1998. Also the shape of the aggregates was angular as shown in figure 3-2 which would provide a high surface-to-volume ratio, better bonding characteristics though would require more cement to produce a workable mix, while the surface texture was rough generating a stronger bond between the paste and the aggregate since a greater area is in contact with the cement paste creating a higher strength though would reduce the workability and increase the paste demand.

As compared to the BS 882:1992 requirement for the coarse aggregates to be suitable for use in construction, the coarse aggregate purchased was therefore suitable for use in the experimental research.

The Particle Size Distribution curve of the coarse aggregates is shown in figure 4-2 and from which it was concluded that the coarse aggregates were singly sized of sized of 15mm meaning that most of the aggregate passed the 15mm sieve and were retained on the 10mm sieve. The curve also shows the envelope (lower and upper limit curves) of coarse aggregates of single sized aggregate of 14mm referenced in BS 882 Table 3 and since the curve for the coarse aggregates was within the envelope therefore they were suitable for use in concrete.

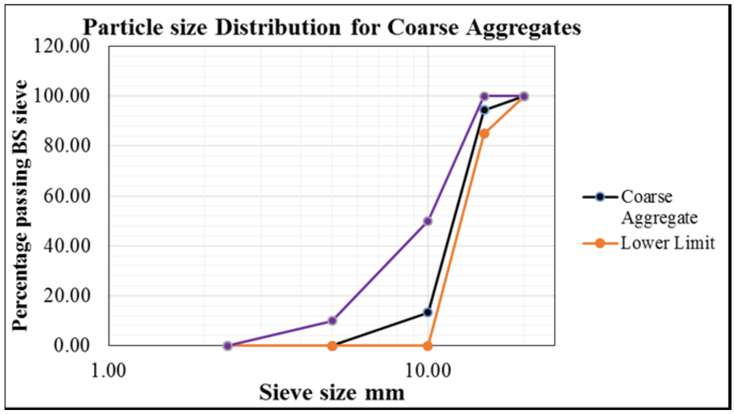

Figure 4-2: Particle Size Distribution for coarse Aggregates.

4.1.2.2 Physical Properties of Fine Aggregates

The fine aggregates used in the study was river sand with particle size ranging from 0.15mm to 15mm with bulk and loose density of 1661.3kg/m^3 and 1522.06kg/m^3 respectively and specific gravity of 2.441. The water absorption of the sand was 6.534 and the fineness modulus was 2.68 which meant that the average aggregate size of the sand was between 300µm and 150µm. The fineness modulus of the sand was between the range of 2.6- 2.9 showing that the sand used was of medium type i.e. falling between fine and coarse. The physical properties of the fine aggregates are summarized in table4-6 which show that the geometrical properties of the fine aggregates used in this study were satisfactory for production of normal concrete mixes.

Table 4.6: Physical Properties for fine aggregates

Property	**Description**
Density	Bulk-1661.3kg/m^3 Loose-1522.06kg/m^3
Specific gravity	2.441
Particle size	0.15mm- 15mm
Fineness Modulus	2.68
Water Absorption	6.534

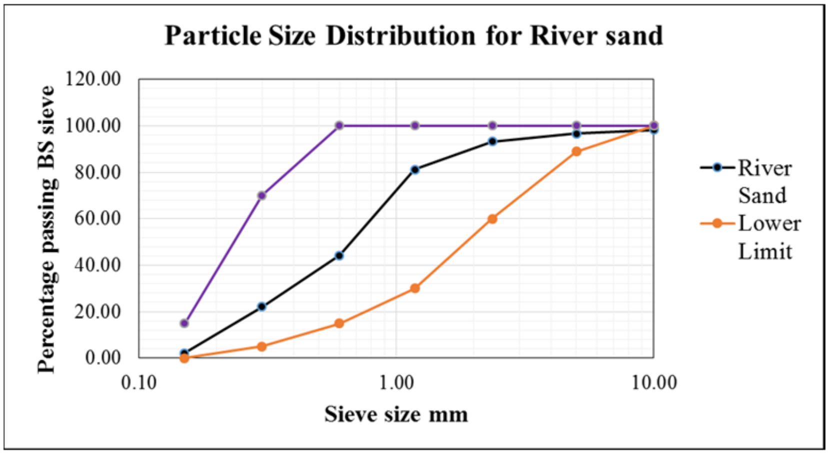

Figure 4-3: Particle Size Distribution curve for fine aggregates

The Particle size distribution of the river sand was done using sieve analysis and a graph plotted of percentages passing the standard BS sieve sizes against the sieve sizes as shown in figure 4-3. The envelope (minimum and maximum limits) for the sand as per BS 882 was also plotted on the same graph and as shown the sand was within the envelope hence suitable for use in concrete.

4.1.3 PROPERTIES OF PET FIBERS

Polyethylene Terephalate fibers (PET) used in the study are thermoplastic polyesters with insignificant water absorption, the color varying between colorless and opaque with a tensile strength of 254MPa as summarized in figure 4-7.

Table 4.7: Properties of the PET fibers

Property	Description
Length	35mm
Width	5mm
Thickness	0.2mm
Aspect ratio	7
Tensile Strength	254MPa
Surface Texture	Smooth
Shape	Rectangular
Color	Colorless and opaque

4.1.4 PROPERTIES OF WATER

The properties of water used in the study are summarized in the table 4-8 from which conclusions can be made that the water was suitable for use in production of concrete.

Table 4.8: Properties of water

Property	Unit	Result	Requirement as per KS 05-459P:1 (max)
pH	-	8.10	6.5 – 8.5
Turbidity	N.T.U	5	5
Color	mgPt/l	<5	15
Manganese(Mn)	mg/l	0.02	0.1
Iron (Fe)	mg/l	0.01	0.3
Calcium (Ca)	mg/l	0.9	250
Sodium (Na)	mg/l	180	200
Potassium (K)	mg/l	12	-
Magnesium(Mg)	mg/l	4.25	100
Chloride (Cl)	mg/l	121	250
Fluoride (Fl)	mg/l	4.54	1.5
Nitrate(NO_4)	mgN/l	3.9	10
Nitrite(NO_3)	mgN/l	0.01	-
Sulphate(SO_4)	mg/l	46.0	-
Free Carbon dioxide(CO_2)	mg/l	Nil	-
Total Dissolved Solids	mg/l	784.5	1500

4.2 EFFECT OF PET FIBERS ON THE PROPERTIES OF NORMAL WEIGHT CONCRETE (OBJECTIVE 2)

4.2.1 PHYSICAL PROPERTIES OF CONCRETE WITH PET FIBERS

4.2.1.1 Workability

The workability of concrete is influenced by a number of factors which include: the water/cement ratio, the aggregate/cement ratio, the particle size distribution and shape of the constituent aggregates as well as the fineness and consistencies of the binder constituents. For this specific objective, the design approach undertaken entailed keeping all factors constant while the PET fibers were added in the mix at different percentages of 1%, 2% and 3%. Determination of workability in this study was done by the slump test which was carried out three times on every mix that was made and an average value obtained. Results of the slump test are presented in figure 4-4 showing the average slump for each mix versus the percentage addition of PET fibers in the mix.

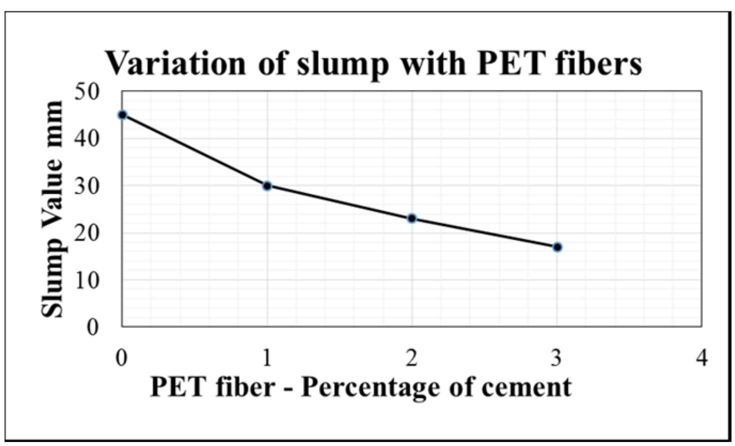

Figure 4-4: Effect of PET fibers on the workability of concrete- Slump Test Results

Considering a constant water/cement ratio of 0.57 which was used in the mix design, as seen from figure 4-4, as the content of PET fibers were increased in the mix, there was a reduction in the workability levels as reported by a reduction in the slump values from 45 for normal concrete to 17 at 3% PET fiber addition in the concrete. The workability of fresh concrete reduced from 45mm slump value for the control to 30mm slump value at 1% PET fibers, showing a percentage reduction of 33% of the slump value. On addition of PET fibers in the mix from 1% to 2%, the slump value reduced further to 23mm showing a percentage reduction of 23% of the slump value compared to 1% PET fibers. On further addition of PET fibers i.e. 3% in the mix, a further reduction in the slump value was recorded from 23mm to 17mm with a percentage reduction of 26% compared to 2% PET fibers.

From the recorded slump values, it can clearly be stated that addition of PET fibers in the mix generally reduces the slump of fresh concrete though the mix remained workable in nature. This reduction in slump of concrete was attributed to the presence of fibers in the mix as they lump on each other reducing the slump while the mixture is still workable. Also a reduction in the workability of fresh concrete may be caused by an adhesion within the concrete and holding the other ingredients of concrete together impeding easy flow as was reported by Nibudey et al (2014).

4.2.1.2 Water absorption

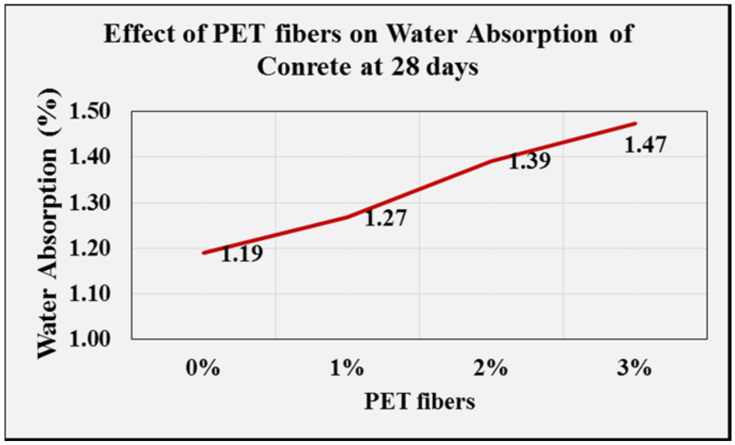

Figure 4-5: Effect of PET fibers on the water absorption of concrete at 28 days.

As portrayed in figure 4-5, PET fibers incorporation in the concrete mix increased the water absorption of the mixes as the control had the least water absorption whereas there was a subsequent increment as the PET fibers were increased in the mix. PET fibers added at percentages of 1%, 2% and 3% had a percentage increase in the water absorption of 6.7%, 16.5% and 23.5% respectively as compared to the control mix (0% PET).

The increment in water absorption as the PET fibers are increased could be as a result of the poor compaction leading to poor bonding as a result of the smooth texture of the fibers and this increased the number of pores in the concrete specimen causing it to absorb more water. As a result, this makes the concrete more susceptible to damage when exposed to corrosive environment and hence making the concrete less durable.

One way ANOVA test was also carried out to check if the PET fibers had a significant impact on the water absorption of concrete and conclusions made from its results

(F=6.444, sig=0.141) as shown in table B1, Appendix B that the incorporation of the fibers did not have a significant impact on the water absorption of concrete at 0.05 significance level.

4.2.2 MECHANICAL PROPERTIES OF CONCRETE WITH PET FIBERS

4.2.2.1 Compressive Strength

The compressive strength of concrete was tested at both 7days and 28 days for the various PET fiber additions of 1%, 2% and 3% of the weight of cement compared to the control mix (without fibers).

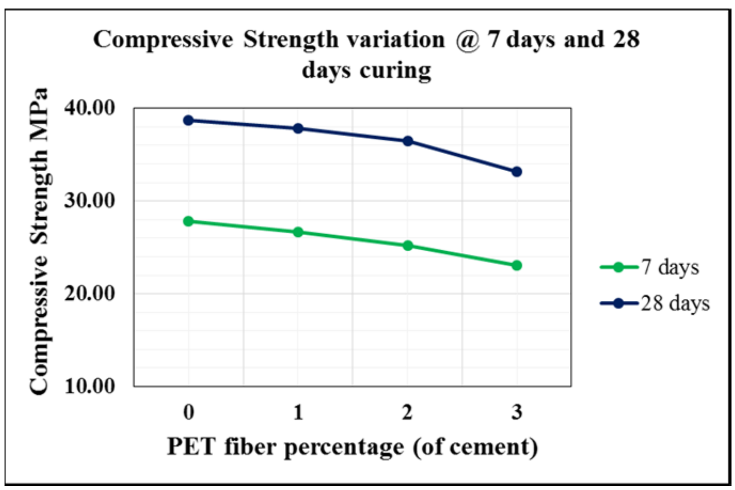

Figure 4-6: Effect of PET fibers on the Compressive Strength of concrete at 7 and 28 days.

As shown in figure 4-6, a reduction in compressive strength was recorded for both the 7 days and 28 days though there was an increase in compressive strength with curing time as 28 days compressive strength values were greater than those at 7 days curing. Percentage reductions of 4.2%, 9.5% and 17.0% at 1%, 2% and 3% PET fiber additions respectively were obtained as compared to the control mix at 7days testing where as

2.2%, 5.8% and 14.3% percentage reductions at 1%, 2% and 3% PET fiber additions respectively as compared to the control mix were obtained at 28 days curing time. The reduction at 28 days was less than that at 7 days because concrete ages with time and the fibers did not have any influence on the curing time.

From these results, it can be seen that 1% PET fiber addition had the less percentage reduction in compressive strength compared to normal weight concrete and therefore it offers better compressive strength properties as compared to other percentages of 2% and 3% PET fibers.

One way ANOVA analysis was carried out at 0.05 significance level and indicated that 2% and 3% PET fiber addition had significant impact on the Compressive strength of concrete both at 7days (F=37.979, sig=0.000) and 28days (F=19.220, sig=0.001) as portrayed in table B2 and B3, appendix B.

From these results, conclusion can be made that addition of PET fibers in normal weight concrete reduces its compressive strength. This could be attributed to the adhesion properties due to the smooth texture of the PET fibers in the mix which reduce the bonding properties of the concrete mix and hence more compacting energy is required to achieve the desired compressive strength of the concrete. Therefore rectangular PET fibers of 35mm length by 5mm width cannot be used to enhance the compressive strength properties of normal weight concrete.

4.2.2.2 Splitting Tensile Strength

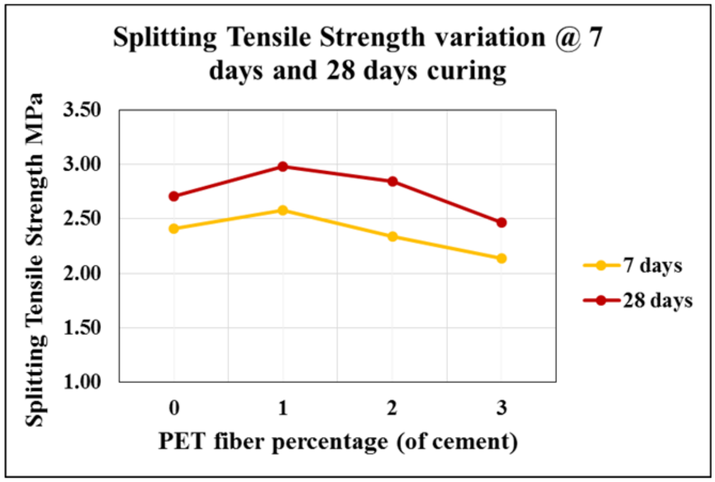

Figure 4-7: Effect of PET fibers on the Splitting Tensile Strength of concrete at 7 and 28 days.

As depicted in figure 4-7, the PET fibers can enhance the splitting tensile strength of concrete. The Splitting Tensile Strength at all percentages of PET fiber addition increased with curing time as 28 days at each percentage had a larger Splitting Tensile Strength value than those at 7 days curing. Figure 4-7 shows that there was an improvement in the tensile splitting values at 1% PET fibers for both 7days and 28 days curing times. At 7 days curing time, a percentage increment of 7.1% as compared to normal weight concrete (control) was obtained at 1% PET fiber incorporation in the mix while on further addition of PET fibers of 2% and 3% PET fibers a percentage reduction of 3% and 11.2% respectively was realized in the splitting tensile strength of the concrete. While at 28 days, figure 4-7 also portrays an improvement in the splitting tensile strength at both 1% and 2% PET fiber incorporation with a percentage increment of 10% and 5.2% compared with the control whereas a percentage reduction of 8.9% was realized at 3% PET fiber incorporation in the concrete mix.

One way ANOVA test at 0.05 significance level portrayed that PET fibers did not have a significant impact on the Splitting Tensile strength of concrete at 7days (F=3.447, sig=0.072) as shown in table B4, appendix B, while at 28 days the PET fibers had a significant impact on the Splitting Tensile Strength of normal weight concrete (F=27.508, sig=0.000) as shown in table B5, appendix B.

From these results, it can be seen that the addition of PET fibers in the concrete mix improves the splitting tensile strength up to 2% PET fiber incorporation though 1% PET fibers portrayed the optimal strength values of splitting tensile for both 7days and 28days. This affirms to the results obtained by previous researchers like Kaothara et al (2015); Asha and Resmi (2015); Nibudey et al (2014) and Prabhu et al (2014).

Figure 4-8: Concrete cylinder with PET fibers after splitting tensile strength test

The reason for the improvement in the splitting tensile strength of concrete with PET fiber addition would be that the fibers bridge across the cracks and impart more ductility of the concrete as the specimens took more time to break down into pieces than normal concrete specimens as shown in figure 4-8 therefore incorporation of fibers in the concrete can also improve first crack strength and ultimate ductility index.

4.2.2.3 Density of concrete

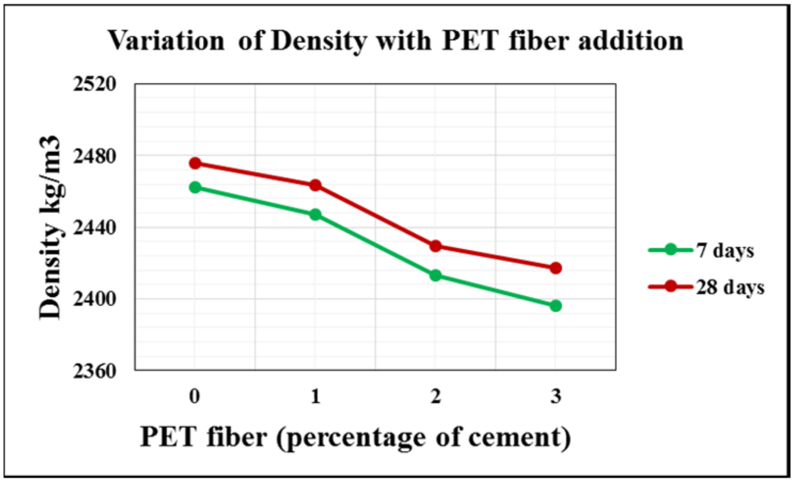

Figure 4-9: Effect of PET fibers on the Density of concrete at 7 and 28 days.

There was a general reduction in the density of concrete as PET fibers were added to the control mix and as there percentage was increased as portrayed in figure 4-9. The density of the concrete reduced for both 7 days and 28 days though the one at 28 days was less than that of 7 days at the different percentages of PET fiber incorporation. The density of the concrete was reduced at percentages of 0.53%, 1.9% and 2.4% at 1%, 2% and 3% PET fiber addition respectively as compared with the control mix (0% PET fibers) for 7 days curing. While at 28 days curing, the percentage reductions in the density were 0.61%, 2.0% and 2.7% at 1%, 2% and 3% PET fiber addition respectively.

One way ANOVA test portrayed that both at 7days (F=15.048, sig=0.001) and 28days (F=5.662, sig=0.022) as shown in table B6 and B7 in appendix B respectively, the PET fiber addition at all percentages had a significant impact on the Density of normal weight concrete at 0.05 significance level.

Taherkhani (2014) also reported a reduction in density of concrete with the incorporation of PET fibers during his research. This reduction in density of concrete may be attributed to the incorporation of light weight PET fibers as compared to other concrete constituents in the concrete mix occupying a fixed volume that would be occupied by heavier constituents of concrete.

4.3 EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH SCBA ON THE PROPERTIES OF NORMAL WEIGHT CONCRETE (OBJECTIVE 3)

4.3.1 PHYSICAL PROPERTIES OF CONCRETE WITH SCBA

4.3.1.1 Workability

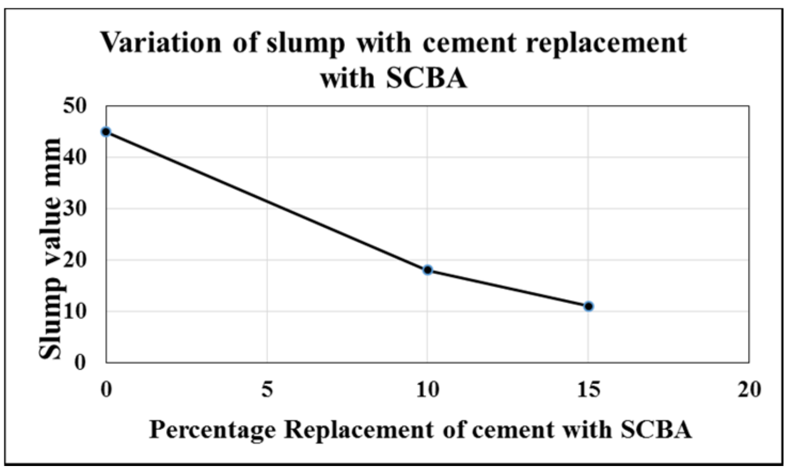

Figure 4-10: Effect of SCBA replacement of cement on the workability of concrete-Slump Test Results.

Considering a fixed water/cement ratio, as it is shown in figure 4-10, as the SCBA content was increased in the concrete mix, there was a reduction in workability levels which were reported by a reduction in slump values from 45mm of normal concrete to 18mm at 10% SCBA replacement of cement and further reduced to 11mm at 15% SCBA replacement of cement. This means that a stiff- lesser workable mix was obtained when SCBA was used as OPC substitution. This reduction in slump indicated that the OPC: SCBA water demand was very high and hence more water was required to produce a workable concrete.

The presence of SCBA in the mix resulted in increased amount of fines as seen by the Particle size Distribution curve of the SCBA concrete mix which increased the water demand for the mix i.e. high specific surface of SCBA resulted in high water demand and this also conforms to the fact that pozzolanic reactions require more water as compared to normal concrete made with OPC. This reduction in slump therefore had an impact on the compatibility of the mix and the density of concrete as more compacting effort was required to achieve desirable strength.

4.3.1.2 Water absorption

Water absorption is a result of permeability of a membrane to let the water penetrate and figure 4-11 shows a trend of values of SCBA blended concrete specimens at 28 days curing time.

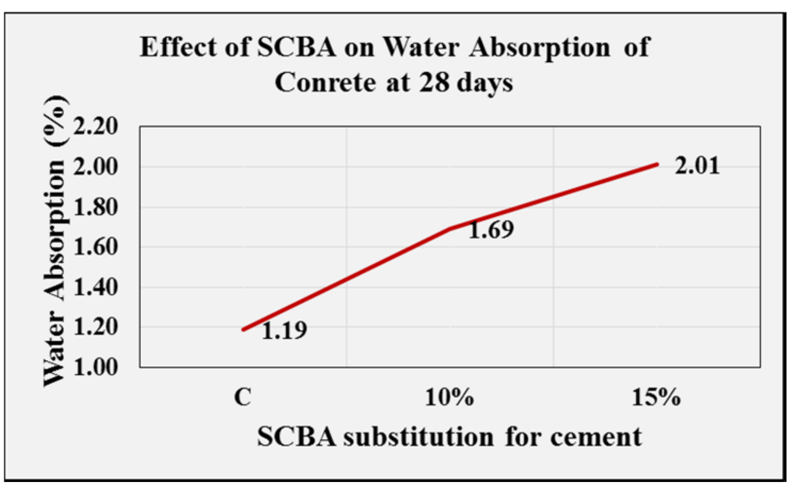

Figure 4-11: Effect of SCBA on the water absorption of concrete at 28 days.

As shown from figure 4-11, the percentage of water absorption increases with increase in the SCBA content substitution for cement in the mix. The percentage increase in in the water absorption was 42% and 68.9% at 10% and 15% SCBA substitution for cement respectively. One way ANOVA test confirmed that SCBA content at both 10% and 15% substitution for OPC had a significant impact on the 28 days water absorption of concrete at 0.05 significance level (F=414.812, sig=0.000) as shown by the results in tables B8 in Appendix B.

The reason for this increase in water absorption could be a result of the SCBA being finer than OPC and the poor compaction of the mix implying that it would therefore absorb more water as compared to the concrete with only OPC. This increase in water absorption with SCBA is in agreement with Ganesan et al (2007) research findings.

4.3.2 MECHANICAL PROPERTIES OF CONCRETE WITH SCBA

4.3.2.1 Compressive Strength

The Compressive Strength of concrete replaced with SCBA for cement was done at two (2) percentages of 10% SCBA and 15% SCBA compared to the control mix and this was done at both 7 days and 28 days curing times as displayed in figure 4-12.

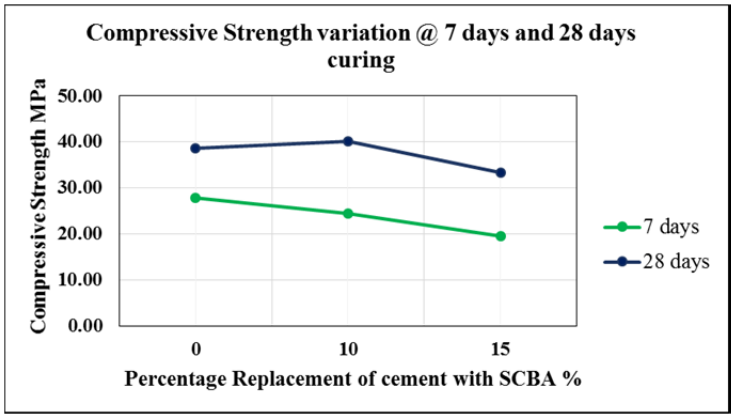

Figure 4-12: Effect of SCBA replacement of cement on the Compressive Strength of concrete at 7 and 28 days.

From figure 4-12, it can be seen that the compressive strength of concrete increased with curing time as all the 28 days compressive strength values were greater than those at 7 days for all the percentage replacements of cement with SCBA.

However, as displayed in figure 4-12 Compressive Strength of concrete at 7 days curing time decreased with increasing percentage replacement of cement with the SCBA. The Compressive Strength of the SCBA concrete blends decreased at percentages of 12.25% and 29.6% for 10% SCBA and 15% SCBA respectively as compared with the control mix.

Further statistical analysis using the one way- Analysis of Variance (ANOVA) technique was also used to determine the significance of the effect of the SCBA on the compressive strength of normal concrete at 5% significance level, and according to the results obtained as displayed in table B9, Appendix B (F=127.413, sig=0.000), which showed that the SCBA had a significant impact on the compressive strength of concrete at 7 days testing. A further Post- Hoc statistical analysis tool was used to check which of the replacements had a significant impact on normal concrete, and from the results, both the percentage substitutions of 10% and 15% SCBA had a significant impact on the compressive strength of concrete. The significant reduction in Compressive Strength can be attributed to early age testing since SCBA is a pozzolanic material and therefore its reaction with free Calcium oxide is slow and likely to improve over a period of time.

On a contrary to 7 days compressive strength, at 28 days compressive strength showed an increase in compressive strength from 38.7MPa to 40.10MPa at 10% SCBA cement replacement hence there was a percentage increase in compressive strength of 3.6%. Increase in the SCBA content in the mix from 10% to 15% however reduced the compressive strength from 40.10MPa to 29.94MPa a value even less than that of the control mix, hence 15% SCBA reduced the compressive strength of normal concrete by 22.63% at 28 days curing. According to the one-way ANOVA test, results in table B10, appendix B show that 10% SCBA (F=93.144, sig=0.132) had no significant impact on the compressive strength whereas 15% SCBA cement replacement had a significant impact on the compressive strength (F=93.144, sig=0.000) as there was a great reduction in the compressive strength of concrete as compared to the control.

The increase in compressive strength at 10% SCBA may be as a result of the silica content, fineness, degree of reactivity, specific surface area and the pozzolanic reaction between the free Calcium hydroxide and reactive silica in the SCBA as this was reported by previous research works like Priya & Ragupathy (2016). Therefore, 10% SCBA cement substitution in the mix gave the best results in terms of compressive strength, and therefore SCBA can be utilized up to 10% to improve the strength properties of normal weight concrete.

4.3.2.2 Splitting Tensile Strength

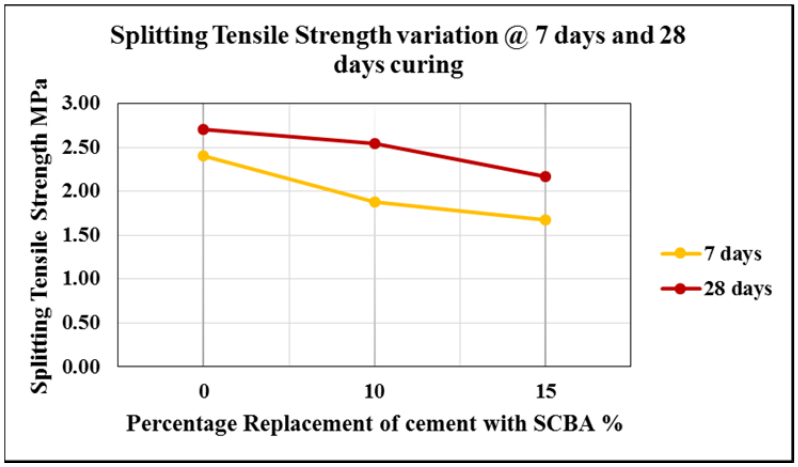

Figure 4-13: Effect of SCBA replacement of cement on the Compressive Strength of concrete at 7 and 28 days.

As depicted in figure 4-13, substitution of cement with SCBA in the concrete mix reduced the splitting tensile strength at both cuing times of 7 days and 28 days though splitting tensile strength increased with curing time. The control mix (0% SCBA) had the highest tensile splitting strength at 7 days of curing which reduced by a percentage of 22% and 30.7% at 10% SCBA and 15%SCBA cement substitution respectively. Also at 28 days of curing substitution of cement with SCBA at 10% and 15% reduced the splitting tensile strength at percentages of 5.9% and 20% respectively as compared to normal concrete i.e. one without substitutions. One-way ANOVA test showed that SCBA had a significant impact on the Splitting Tensile Strength of Concrete both 7days and 28days of curing at 0.05 significance level as shown in tables B11 and B12, appendix B.

The results portray that 28 days curing had better results as the reductions in the splitting tensile strength were less than the reductions at 7days curing. The reductions in the Splitting Tensile Strength could have been related to the reduction in compressive strength and that the SCBA could have reduced the bonding properties of the constituent materials in the concrete as compared to the cement.

4.3.2.3 Density of concrete

The density of the various concrete specimens was calculated at both 7 days and 28 days of curing time.

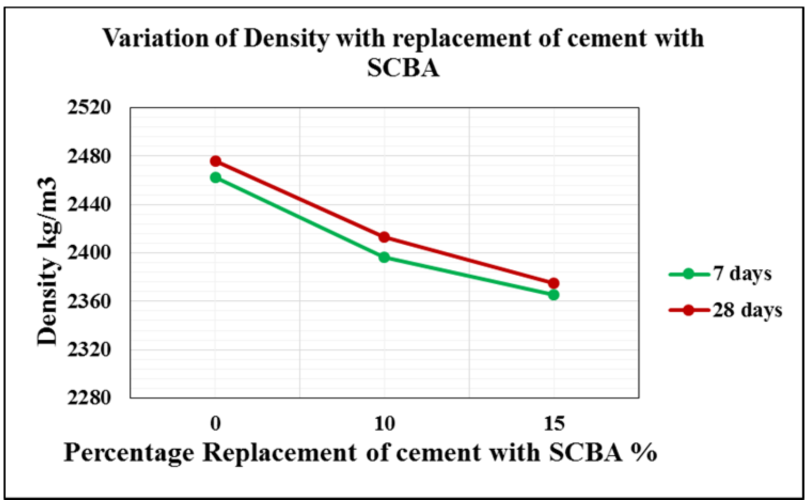

Figure 4-14: Effect of SCBA on the Density of concrete at 7 and 28 days.

As shown in figure 4-14, the density of concrete at 7 days was slightly greater than that at 28 days for all the substitutions and that there was a reduction in the density of concrete with increase in the percentage of OPC substitution with SCBA. The percentage reductions recorded were 2.5% and 4.1% at 10% and 15% SCBA substitution for OPC respectively in comparison with the control (0% SCBA) at 7days of curing. While at 28 days of curing, percentage decrease of 2.6% and 3.9% were recorded for 10% and 15% SCBA substitution for OPC respectively as compared to the control mix.

The one-way ANOVA test showed that at both 7days (F=14.586, sig=0.005) and 28days (F=13.716, sig=0.006), the SCBA had a significant impact on the density of concrete at 0.05 significance level as shown in tables B13 and B14, appendix B.

The reduction in density could be as a result that SCBA had a less bulk density of 674.33kg/m^3 as compared to that of OPC which was 1396.1kg/m^3.

4.4 EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH SCBA ON THE PHYSICAL PROPERTIES OF PFRC (OBJECTIVE 4)

4.4.1 PHYSICAL PROPERTIES OF PFRC WITH SCBA

4.4.1.1 Workability

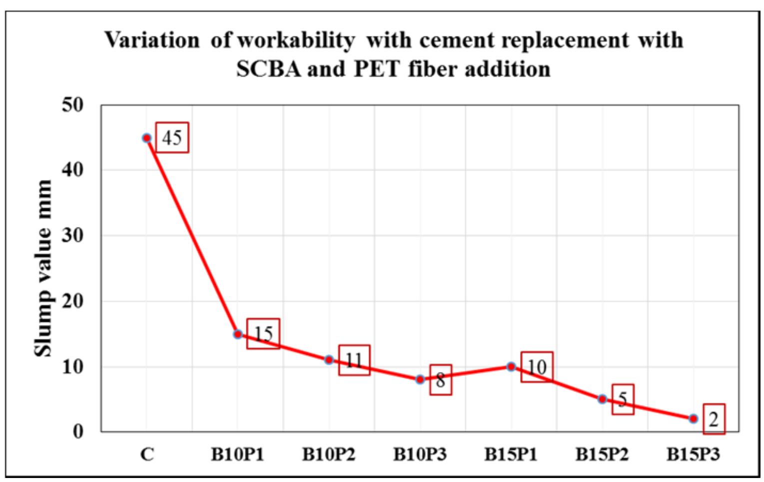

Figure 4-15: Effect of SCBA on the workability of concrete incorporated with PET fibers.

As shown in figure 4-15; the workability of concrete was seen to decrease with the incorporation of both PET fibers and OPC substitution with SCBA in the mix. There was a great decrease in workability from 45mm slump for the control to 15mm slump for B10P1 i.e. 1% PET and 10%SCBA substitution as the percentage reduction of 66.7% was recorded. The subsequent percentage reductions recorded were 75.4%, 82.2%, 77.8%, 88.9% and 95.6% for B10P2, B10P3, B15P1, B15P2 and B15P3 respectively. This general reduction in slump was a result of incorporation of both PET fibers and SCBA in the mix. The PET fibers were building on each other while the SCBA also increased the water demand for the mix because it increased the amount of fines in the mix as compared to the OPC. This reduced the slump value at a constant water-cement ratio since more water was required to make the concrete more workable. Therefore when using both PET fibers and SCBA, super plasticizers should be used in order to improve the workability of the concrete.

4.4.1.2 Water Absorption

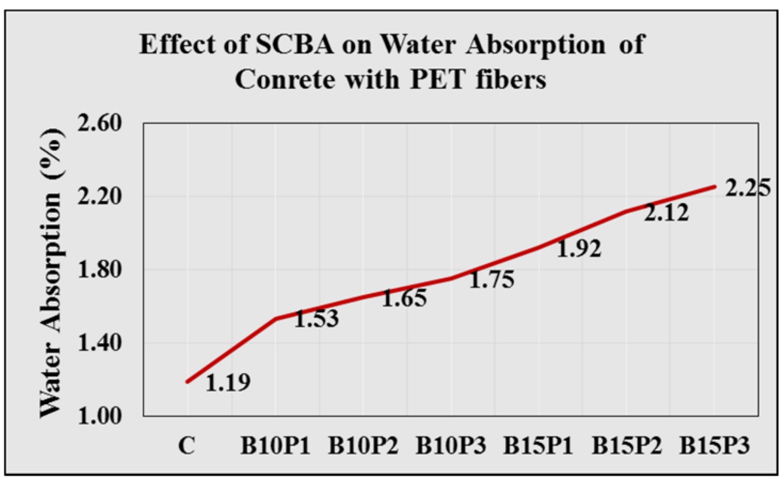

Figure 4-16: Effect of SCBA on the water absorption of concrete incorporated with PET fibers

As shown in figure 4-16, the water absorption of the concrete increased with increase in both PET fibers and percentage replacement of OPC with SCBA. The percentage increment in the water absorption that was recorded as 28.6%, 38.7%, 47.1%, 61.3%, 78.7% and 89.1% for B10P1, B10P2, B10P3, B15P1, B15P2 and B15P3 respectively as compared with the control.

From the ANOVA factorial analysis test as shown in table B15, appendix B (F=9.958, sig=0.000), the interaction effect had a significant impact on the water absorption of concrete at 0.05 significance level. Both the PET fibers and the SCBA substitution for OPC had also a significant impact on the water absorption of concrete when used independently and even after the combination there was an increase in the water absorption of the concrete. This can be attributed to the fineness of SCBA as compared to OPC as it would absorb more water than the OPC and also the PET fibers creating some pores in the concrete because of the poor bonding between the fibers and other constituent materials which will allow more water to penetrate into the concrete hence increasing the water absorption of the concrete.

4.4.2 MECHANICAL PROPERTIES OF PFRC WITH SCBA

4.4.2.1 Compressive Strength

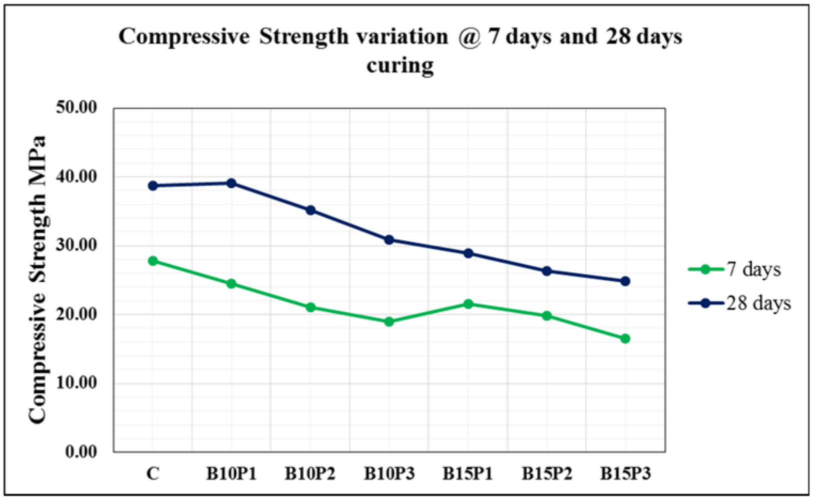

Figure 4-17: Effect of SCBA on the compressive strength of concrete incorporated with PET fibers at 7days and 28days of curing.

As portrayed in figure 4-17, the compressive strength of concrete at 28 days curing was greater than that at 7 days curing at all percentages of the combination of PET fibers and SCBA substitution showing that the blended concrete gained strength over time. At 7days curing, a decrease in compressive strength as compared to the control was realized at 10% SCBA with the various percentages of PET fibers of 1%, 2% and 3% with the corresponding percentage decrease of 11.8%, 24.4% and 31.8% respectively, and at 15% SCBA substitution there was a percentage decrease of 22.6%, 28.8% and 40.5% with the respective PET fiber addition percentages as compared to the control. 1% PET fiber addition gave the best compressive strength for both 10% and 15% SCBA substitution for OPC though the values were still below the strength of the control mix. While at 28 days, an initial increase in compressive strength was realized at 10%SCBA substitution with 1% PET fiber addition (B10P1), and then followed by a decrease in strength with the subsequent PET and SCBA percentage blends. A percentage increase for B10P1was 1.14% was realized as compared to the control while percentage reductions of 9.1% and 20.1% for B10P2 and B10P2 at 10% SCBA with 2% and 3% PET fiber addition respectively. At 15% SCBA substitution for OPC percentage reductions of 25.2%, 32.1% and 35.7% were recorded for 1%, 2% and 3% PET fiber addition into the blend.

An ANOVA factorial analysis for the combination was carried out with the results displayed in tables B16 (F=3.987, sig=0.007) and B17 (F=4.003, sig=0.006), appendix B for 7days and 28 days respectively, which showed the interaction effect of PET fiber and SCBA substitution for OPC in the blend had a significant impact on the compressive strength of normal concrete at 0.05 significance level.

The reduction in compressive strength could be attributed to both the adhesion properties of the PET fibers responsible for a weak bond within the concrete and also the early age testing of concrete since the SCBA as a pozzolanic reaction with the free Calcium Oxide happens over a period of time. And from the results, a blend of 1% PET and 10% SCBA (B10P1) gave the optimal results in terms of compressive strength and therefore can be obtained in production of structural concrete.

4.4.2.2 Splitting Tensile Strength

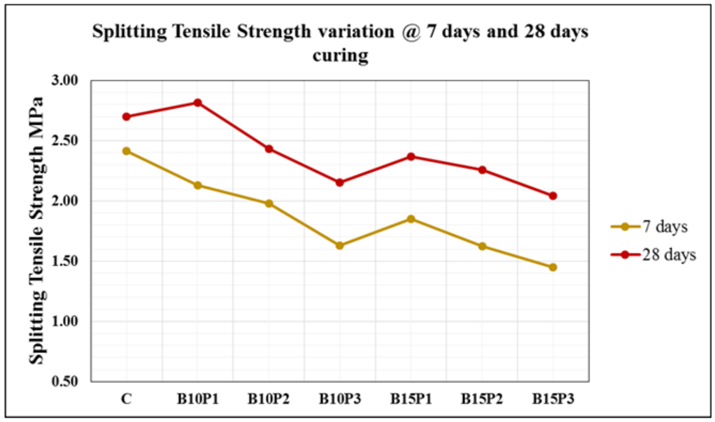

Figure 4-18: Effect of SCBA on the splitting tensile strength of concrete incorporated with PET fibers at 7days and 28days of curing.

The Splitting tensile strength of concrete increased with curing time as portrayed in figure 4-18 as values recorded at 28days were higher than those recorded at 7 days for the PET fiber and SCBA blends. At 7days curing time, there was a decrease in compressive strength of the concrete as compared to the control mix at all the PET and SCBA percentage blends. Percentage reductions of 11.6%, 17.8%, and 32.4% were recorded 10% SCBA substitution at 1%, 2% and 3% PET fiber addition respectively as compared to the control, while at 15% SCBA percentage reductions of 23,.2%, 32.4% and 39.8% were recorded at 1%, 2% and 3% PET fiber addition in the mix respectively as compared to the control. 1%PET fiber at 10% SCBA (B10P1) gave the best results of 2.13MPa Splitting Strength as compared to other blends and also at 15%SCBA (B15P1) as compared to other PET fiber additions in the mix. A factorial analysis (Attached in Appendix B) also indicated that the combination of PET fibers and SCBA in the mix had a significant impact on the Splitting tensile strength of normal concrete and even the elements added independently in the mix also had a significant impact on the control mix.

At 28days of curing, there was an initial increase in the Splitting tensile strength of concrete at 10%SCBA with 1% PET fiber addition followed by a decrease with the subsequent PET fiber and SCBA percentage blends in the mix. At 10% SCBA substitution, a percentage increment of 4.4% was obtained for B10P1 while percentage reductions of 10% and 20% were realized at 2% and 3% PET fibers while at 15% SCBA, percentage reductions of 12%, 16.3% and 24.4% were recorded for 1%, 2% and 3% PET fiber addition in the mix respectively.

An ANOVA factorial analysis carried out on the interaction effect at 7days (table B18, appendix B) of the various blends showed that they had no significant impact (F=0.914, sig=0.502) on the splitting tensile strength of normal concrete at 0.05 significance level, while at 28 days (table B19, appendix, B) show that PET fibers had a significant impact (F=2.622, sig=0.042) on the splitting tensile strength of concrete. The optimum blend obtained from the results was B10P1 as 10%SCBA and 1% PET fiber addition in the mix as they portrayed the best results in terms of splitting tensile strength.

The reduction in splitting tensile strength of concrete could be as a result of PET fibers and SCBA reducing the bonding properties of the constituent materials though the PET fibers bridge across the cracks and therefore impart more on the ductility of concrete as the specimens took more time to break as compared to the normal concrete.

4.4.2.3 Density of concrete

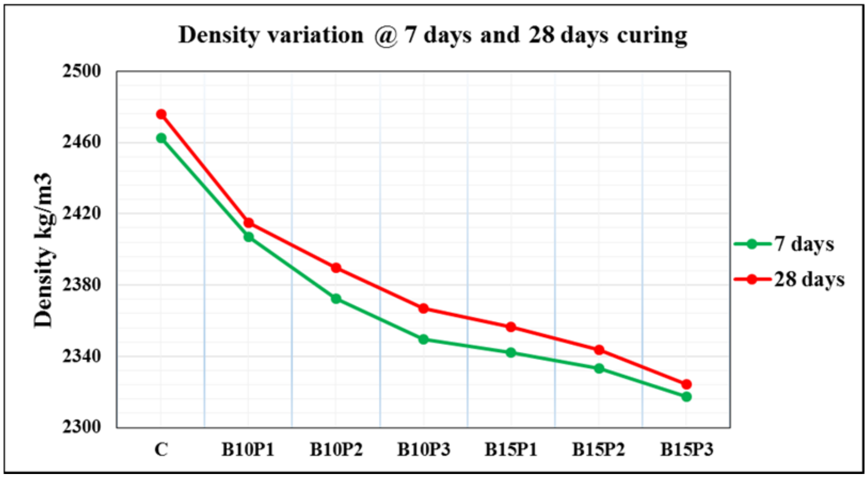

Figure 4-19: Effect of SCBA on the density of concrete incorporated with PET fibers at 7days and 28days of curing.

As displayed in figure 4-19, the density of concrete at 28days was greater than at 7days of curing implying that density increased with curing time for all the blends of SCBA and PET fibers. There was a general reduction in the densities of concrete with the subsequent increase in the PET fibers and the SCBA substitution in the mix for both curing times.

At 7days of curing, percentage reductions of 2.5%, 3.5% and 4.4% at 10%SCBA with 1%, 2% and 3% PET fiber addition respectively as compared to the control were recorded. While at 15% SCBA percentage reductions of 4.8%, 5.4% and 6.1% at 1%, 2% and 3% PET fiber additions were recorded. A factorial analysis in ANOVA also indicated that the combination of the PET fibers and SCBA substation in the mix did not have a significant impact (F=1.620, sig=0.185) on the density of concrete at 0.05 significance level as shown in table B20, appendix B.

While at 28 days of curing, percentage reductions of 2.2%, 3.7% and 4.6% at 10% SCBA with 1%, 2% and 3% PET fibers respectively as compared to the control were realized; at 15%SCBA, percentage reductions of 4.9%, 5.2% and 6.2% were realized for 1%, 2% and 3% PET fibers respectively as compared to the control. The factorial analysis also indicated that the combination of the PET fibers and SCBA did not have a significant impact (F=0.851, sig=0.544) on the density of normal concrete at 0.05 significance level as shown in table B21, appendix B.

The slight reductions in the density of concrete could be as a result of substituting OPC with SCBA which has a less bulk density and the incorporation of the PET fibers that are also light weight in nature, reducing the overall mass of the concrete hence reducing the density of concrete at a constant volume.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

From the study the following conclusions can be made:

1. The materials used in the study were found to be suitable for use in the study both physically or chemically for production of structural concrete.
2. The PET fibers reduced the workability of fresh concrete, density of concrete and the compressive strength of hardened concrete with the increasing percentage of the fibers. An increase in water absorption was realized on increase in the PET fiber content. Though there was an increase in splitting tensile strength observed at 1% fiber content only. Therefore the PET fiber incorporation in the concrete matrix bridges across the cracks and hence impact more ductility of the concrete up to 1% fiber content.
3. The SCBA partial substitution for OPC also had an impact on the properties of concrete as a reduction in workability, density and splitting tensile strength were realized on increase in the SCBA content in the mix. SCBA substitution increased the water absorption and the compressive strength though only up to 10%SCBA content and reduced on further addition of the pozzolana. Therefore SCBA can be utilized to enhance the compressive strength of concrete up to 10% substitution.
4. SCBA also had a significant impact on the Physical and Mechanical properties of PFRC as a reduction in workability of fresh concrete and density of concrete with increasing percentages of both SCBA and PET fibers. An increase in water

absorption was also realized with increasing percentages of both SCBA and PET fibers in the concrete mix. However, an improvement in splitting tensile strength and compressive strength were realized at 10%SCBA substitution and 1%PET fibers (B10P1) but reduced on further addition of both PET fibers and SCBA substitution.

5.2 RECOMMENDATIONS

From the study the following recommendations were made:

For possible applications:

1. SCBA and PET fibers can be used in the production of structural concrete with improved mechanical properties. Using PFRC with SCBA can be done up to 1% PET fibers and 10% SCBA in construction.

For further studies:

2. However for further studies, investigations should be made on how to improve the bonding properties of the PET fibers either by coating them with some materials that can roughen their texture.
3. The durability aspect of PFRC with SCBA should also be studied to ascertain their suitability for use in the different environments and documentation should be made on the effect of the various aspect ratios of the PET fibers on the properties of concrete.
4. There is need for standardization and documentation of the physical properties of PET fibers to be incorporated in the concrete mix.

5. For the incorporation of the PET fibers in the concrete mix another test besides slump test should be carried out since the slump test alone cannot give conclusive statement about the workability of concrete.
6. A machine or equipment should be designed to help in the shredding of the PET fibers in order to obtain large volumes in a short period of time.

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APPENDICES

APPENDIX A

Laboratory results for all the combinations.

Table A1: Slump results

PET %	SCBA %	Initial Slump mm	Final Slump mm	Slump Value mm
0	**0**	45	90	45
1	**0**	44	74	30
2	**0**	44	67	23
3	**0**	45	62	17
0	**10**	44	62	18
0	**15**	44	55	11
1	**10**	45	60	15
2	**10**	45	56	11
3	**10**	44	52	8
1	**15**	44	54	10
2	**15**	41	46	5
3	**15**	41	43	2

Table A2: Water absorption at 28 days curing time.

PET %	SCBA %	Trial 1	Trial 2	Trial 3	Average
0	**0**	1.20	1.22	1.15	**1.19**
1	**0**	1.24	1.34	1.22	**1.27**
2	**0**	1.39	1.35	1.44	**1.39**
3	**0**	1.48	1.47	1.47	**1.47**
0	**10**	1.71	1.70	1.66	**1.69**
0	**15**	2.00	2.06	1.98	**2.01**
1	**10**	1.48	1.58	1.54	**1.53**
2	**10**	1.64	1.59	1.71	**1.65**
3	**10**	1.76	1.74	1.76	**1.75**
1	**15**	2.01	1.90	1.86	**1.92**
2	**15**	2.11	2.11	2.12	**2.12**
3	**15**	2.27	2.23	2.26	**2.25**

Table A3: Compressive Strength at 7 days curing time.

PET %	SCBA %	Trial 1 MPa	Trial 2 MPa	Trial 3 MPa	Average MPa
0	**0**	28.08	27.52	27.90	27.83
1	**0**	26.18	27.14	26.70	26.67
2	**0**	25.01	25.32	25.28	25.20
3	**0**	24.24	22.40	22.71	23.11
0	**10**	24.98	24.30	23.99	24.42
0	**15**	20.44	18.58	19.75	19.59
1	**10**	21.48	20.51	19.64	20.54
2	**10**	19.59	17.22	20.20	19.04
3	**10**	17.95	18.32	17.49	17.92
1	**15**	18.49	19.55	17.56	18.53
2	**15**	17.68	18.11	17.85	17.88
3	**15**	17.53	15.86	16.32	16.57

Table A4: Compressive Strength at 28 days curing time.

PET %	SCBA %	Trial 1 MPa	Trial 2 MPa	Trial 3 MPa	Average MPa
0	**0**	38.55	37.93	39.60	38.70
1	**0**	39.63	37.00	36.83	37.82
2	**0**	36.30	37.20	35.84	36.45
3	**0**	33.06	33.20	33.28	33.18
0	**10**	39.68	39.58	41.04	40.10
0	**15**	30.06	31.12	28.63	29.94
1	**10**	39.92	39.77	39.24	39.64
2	**10**	36.57	35.29	33.64	35.16
3	**10**	32.08	30.65	30.05	30.93
1	**15**	29.11	29.69	28.00	28.93
2	**15**	26.75	25.94	26.19	26.29
3	**15**	23.64	26.76	24.21	24.87

Table A5: Splitting Tensile Strength at 7 days curing time.

PET %	SCBA %	Trial 1 MPa	Trial 2 MPa	Trial 3 MPa	Average MPa
0	0	2.50	2.08	2.67	2.41
1	0	2.65	2.59	2.51	2.58
2	0	2.20	2.47	2.34	2.34
3	0	2.19	2.07	2.16	2.14
0	10	1.82	1.86	1.98	1.88
0	15	1.79	1.68	1.55	1.67
1	10	2.05	2.03	1.98	2.02
2	10	1.91	1.93	1.88	1.90
3	10	1.37	1.64	1.43	1.48
1	15	1.75	1.79	1.73	1.76
2	15	1.69	1.60	1.59	1.63
3	15	1.42	1.45	1.48	1.45

Table A6: Splitting Tensile Strength at 28 days curing time.

PET %	SCBA %	Trial 1 MPa	Trial 2 MPa	Trial 3 MPa	Average MPa
0	0	2.72	2.71	2.70	2.71
1	0	2.90	3.07	2.98	2.98
2	0	2.83	2.78	2.92	2.85
3	0	2.57	2.39	2.44	2.47
0	10	2.50	2.51	2.63	2.55
0	15	2.14	2.28	2.09	2.17
1	10	2.83	2.87	2.76	2.82
2	10	2.36	2.50	2.44	2.43
3	10	2.22	2.09	2.15	2.16
1	15	2.26	2.33	2.51	2.37
2	15	2.18	2.37	2.22	2.26
3	15	1.95	2.25	1.92	2.04

Table A7: Density of concrete at 7 days curing time.

PET %	SCBA %	Trial 1 (kg/m3)	Trial 2 (kg/m3)	Trial 3 (kg/m3)	Average (kg/m3)
0	**0**	2474.8	2472.0	2440.1	2462.3
1	**0**	2451.6	2445.9	2444.3	2447.2
2	**0**	2417.5	2414.0	2408.0	2413.2
3	**0**	2416.9	2387.6	2383.8	2396.1
0	**10**	2382.5	2402.6	2404.2	2396.4
0	**15**	2332.0	2370.5	2394.3	2365.6
1	**10**	2408.3	2406.1	2407.0	2407.2
2	**10**	2385.1	2369.5	2362.5	2372.4
3	**10**	2353.3	2352.0	2343.1	2349.5
1	**15**	2346.6	2343.1	2337.4	2342.3
2	**15**	2336.4	2330.7	2332.3	2333.1
3	**15**	2321.8	2320.2	2310.6	2317.5

Table A8: Density of concrete at 28 days curing time.

PET %	SCBA %	Trial 1 (kg/m3)	Trial 2 (kg/m3)	Trial 3 (kg/m3)	Average (kg/m3)
0	**0**	2477.7	2469.7	2480.9	2476.1
1	**0**	2497.1	2447.8	2445.2	2463.4
2	**0**	2408.3	2454.8	2424.5	2429.2
3	**0**	2429.6	2402.0	2419.8	2417.1
0	**10**	2383.5	2398.5	2457.3	2413.1
0	**15**	2373.6	2371.4	2379.4	2374.8
1	**10**	2416.3	2411.8	2416.9	2415.0
2	**10**	2384.5	2397.2	2387.0	2389.5
3	**10**	2372.4	2368.5	2360.3	2367.1
1	**15**	2317.6	2362.8	2388.9	2356.5
2	**15**	2378.7	2321.1	2330.4	2343.4
3	**15**	2323.7	2331.3	2318.0	2324.3

APPENDIX B

Analysis of Variance (ANOVA) test results done 0.05 significance level.

Table B1: Effect of PET on water absorption of concrete at 28 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.500	9	1.611	6.444	.141
Within Groups	.500	2	.250		
Total	15.000	11			

Table B2: Effect of PET on Compressive strength of concrete at 7 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	37.291	3	12.430	37.979	.000
Within Groups	2.618	8	.327		
Total	39.909	11			

Post Hoc Test- Multiple Comparisons

(I) PET Addition	(J) PET Addition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0% PET	1%PET	1.16233*	.46711	.038	.0852	2.2395
	2%PET	2.63400*	.46711	.000	1.5568	3.7112
	3%PET	4.71900*	.46711	.000	3.6418	5.7962

Table B3: Effect of PET on Compressive strength of concrete at 28 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	52.740	3	17.580	19.220	.001
Within Groups	7.317	8	.915		
Total	60.057	11			

Post Hoc Test- Multiple Comparisons

(I) PET Addition	(J) PET Addition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0% PET	1%PET	.87267	.78089	.296	-.9281	2.6734
	2%PET	2.24833*	.78089	.021	.4476	4.0491
	3%PET	5.51400*	.78089	.000	3.7133	7.3147

Table B4: Effect of PET on Splitting Tensile strength of concrete at 7 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.303	3	.101	3.447	**.072**
Within Groups	.235	8	.029		
Total	.538	11			

Table B5: Effect of PET on Splitting Tensile strength of concrete at 28 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.436	3	.145	27.508	.000
Within Groups	.042	8	.005		
Total	.478	11			

Post Hoc Test- Multiple Comparisons

(I) PET Addition	(J) PET Addition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0% PET	1%PET	-.27167*	.05936	.002	-.4086	-.1348
	2%PET	-.13533	.05936	.052	-.2722	.0016
	3%PET	.24467*	.05936	.003	.1078	.3816

Table B6: Effect of PET on Density of concrete at 7 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8311.827	3	2770.609	15.048	.001
Within Groups	1472.923	8	184.115		
Total	9784.750	11			

Post Hoc Test- Multiple Comparisons

(I) PET Addition	(J) PET Addition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0% PET	1%PET	15.06033	11.07897	.211	-10.4878	40.6085
	2%PET	49.10633*	11.07897	.002	23.5582	74.6545
	3%PET	66.18200*	11.07897	.000	40.6338	91.7302

Table B7: Effect of PET on Density of concrete at 28 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6965.941	3	2321.980	5.662	.022
Within Groups	3280.725	8	410.091		
Total	10246.666	11			

Post Hoc Test- Multiple Comparisons

(I) PET Addition	(J) PET Addition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0% PET	1%PET	12.72733	16.53462	.464	-25.4016	50.8562
	2%PET	46.87900*	16.53462	.022	8.7501	85.0079
	3%PET	58.96967*	16.53462	.007	20.8408	97.0986

Table B8: Effect of SCBA on water absorption of concrete at 28 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.032	2	.516	414.812	.000
Within Groups	.007	6	.001		
Total	1.040	8			

Post Hoc Test- Multiple Comparisons

(I) SCBA Substitution	(J) SCBA Substitution	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%SCBA	10%SCBA	-.50000*	.02880	.000	-.5705	-.4295
	15%SCBA	-.82333*	.02880	.000	-.8938	-.7529

Table B9: Effect of SCBA on Compressive strength of concrete at 7 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	102.972	2	51.486	127.413	.000
Within Groups	2.425	6	.404		
Total	105.396	8			

Post Hoc Test- Multiple Comparisons

(I) SCBA Substitution	(J) SCBA Substitution	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%SCBA	10%SCBA	3.41167*	.51903	.001	2.1416	4.6817
	15%SCBA	8.24467*	.51903	.000	6.9746	9.5147

Table B10: Effect of SCBA on Compressive strength of concrete at 28 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	181.998	2	90.999	93.144	.000
Within Groups	5.862	6	.977		
Total	187.860	8			

Post Hoc Test- Multiple Comparisons

(I) SCBA content	(J) SCBA content	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%SCBA	10%SCBA	-1.40433	.80704	.132	-3.3791	.5704
	15%SCBA	8.75933*	.80704	.000	6.7846	10.7341

Table B11: Effect of SCBA on Splitting Tensile strength of concrete at 7 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.896	2	.448	11.382	.009
Within Groups	.236	6	.039		
Total	1.132	8			

Post Hoc Test- Multiple Comparisons

(I) SCBA Substitution	(J) SCBA Substitution	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%SCBA	10%SCBA	.53000*	.15809	.015	.1432	.9168
	15%SCBA	.74100*	.15809	.003	.3542	1.1278

Table B12: Effect of SCBA on Splitting Tensile strength of concrete at 28 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.461	2	.230	45.875	.000
Within Groups	.030	6	.005		
Total	.491	8			

Post Hoc Test- Multiple Comparisons

(I) SCBA Substitution	(I) SCBA Substitution	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%SCBA	10%SCBA	.16300*	.05787	.030	.0214	.3046
	15%SCBA	.54033*	.05787	.000	.3987	.6819

Table B13: Effect of SCBA on Density of concrete at 7 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14643.938	2	7321.969	14.586	.005
Within Groups	3011.833	6	501.972		
Total	17655.770	8			

Post Hoc Test- Multiple Comparisons

(I) SCBA Substitution	(J) SCBA Substitution	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%SCBA	10%SCBA	65.86367*	18.29476	.011	21.0980	110.6293
	15%SCBA	96.72700*	18.29476	.002	51.9613	141.4927

Table B14: Effect of SCBA on Density of concrete at 28 days curing time.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14938.841	2	7469.421	13.716	.006
Within Groups	3267.495	6	544.583		
Total	18206.336	8			

Post Hoc Test- Multiple Comparisons

(I) SCBA Substitution	(J) SCBA Substitution	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0%SCBA	10%SCBA	63.00000*	18.69452	.015	17.2562	108.7438
	15%SCBA	101.28800*	18.69452	.002	55.5442	147.0318

Table B15: Effect of SCBA on water absorption of concrete incorporated with PET fibers at 28 days curing time.

Tests of Between-Subjects Effects- Factorial analysis

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.304[a]	11	.391	196.438	.000
Intercept	104.210	1	104.210	52323.047	.000
PET	.434	3	.145	72.671	.000
SCBA	3.750	2	1.875	941.529	.000
PET * SCBA	.119	6	.020	9.958	.000
Error	.048	24	.002		
Total	108.562	36			
Corrected Total	4.351	35			

a. R Squared = .989 (Adjusted R Squared = .984)

Table B16: Effect of SCBA on Compressive strength of concrete incorporated with PET fibers at 7 days curing time.

Tests of Between-Subjects Effects- Factorial Analysis

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	483.787[a]	11	43.981	67.344	.000
Intercept	16550.136	1	16550.136	25341.977	.000
PET	108.898	3	36.299	55.582	.000
SCBA	359.264	2	179.632	275.057	.000
PET * SCBA	15.625	6	2.604	3.987	.007
Error	15.674	24	.653		
Total	17049.597	36			
Corrected Total	499.461	35			

a. R Squared = .969 (Adjusted R Squared = .954)

Table B17: Effect of SCBA on Compressive strength of concrete incorporated with PET fibers at 28 days curing time.

Tests of Between-Subjects Effects- Factorial Analysis

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	922.934[a]	11	83.903	72.411	.000
Intercept	40349.962	1	40349.962	34823.334	.000
PET	238.781	3	79.594	68.692	.000
SCBA	656.324	2	328.162	283.215	.000
PET * SCBA	27.828	6	4.638	4.003	.006
Error	27.809	24	1.159		
Total	41300.705	36			
Corrected Total	950.743	35			

a. R Squared = .971 (Adjusted R Squared = .957)

Table B18: Effect of SCBA on Splitting Tensile strength of concrete incorporated with PET fibers at 7 days curing time.

Tests of Between-Subjects Effects- Factorial Analysis

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.492[a]	11	.408	29.912	.000
Intercept	135.350	1	135.350	9914.033	.000
PET	.872	3	.291	21.292	.000
SCBA	3.545	2	1.773	129.835	.000
PET * SCBA	.075	6	.012	.914	.502
Error	.328	24	.014		
Total	140.170	36			
Corrected Total	4.820	35			

a. R Squared = .932 (Adjusted R Squared = .901)

Table B19: Effect of SCBA on Splitting Tensile strength of concrete incorporated with PET fibers at 28 days curing time.

Tests of Between-Subjects Effects- Factorial Analysis

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.054[a]	11	.278	30.633	.000
Intercept	221.960	1	221.960	24487.972	.000
PET	1.151	3	.384	42.313	.000
SCBA	1.761	2	.881	97.145	.000
PET * SCBA	.143	6	.024	2.622	.042
Error	.218	24	.009		
Total	225.232	36			
Corrected Total	3.272	35			

a. R Squared = .934 (Adjusted R Squared = .903)

Table B20: Effect of SCBA on Density of concrete incorporated with PET fibers at 7 days curing time.

Tests of Between-Subjects Effects- Factorial Analysis

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	67321.104[a]	11	6120.100	34.002	.000
Intercept	204549806.972	1	204549806.972	1136440.651	.000
PET	16435.085	3	5478.362	30.437	.000
SCBA	49136.160	2	24568.080	136.496	.000
PET * SCBA	1749.859	6	291.643	1.620	.185
Error	4319.799	24	179.992		
Total	204621447.875	36			
Corrected Total	71640.903	35			

a. R Squared = .940 (Adjusted R Squared = .912)

Table B21: Effect of SCBA on Density of concrete incorporated with PET fibers at 28 days curing time.

Tests of Between-Subjects Effects- Factorial Analysis

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	77090.257[a]	11	7008.205	2.489	.030
Intercept	208217444.567	1	208217444.567	73946.998	.000
PET	4745.950	3	1581.983	.562	.645
SCBA	57973.081	2	28986.540	10.294	.001
PET * SCBA	14371.226	6	2395.204	.851	.544
Error	67578.384	24	2815.766		
Total	208362113.207	36			
Corrected Total	144668.641	35			

a. R Squared = .533 (Adjusted R Squared = .319)

APPENDIX C

Some of the pictures that were taken during the research:

Figure C1: BS Test siesves used for Particle size distribution for fine and coarse aggregates

Figure C2: Hydrometer Analysis for SCBA

Figure C3: Density test for coarse aggregates

Figure C4: Density test for SCBA

Figure C5: Tensile Testing of PET fibers using a Tensometer.

Figure C6: Cubes and cylinders left to cure for 24hours before demolding

Figure C7: Compressive Testing using the UTM machine.

Figure C8: Cubes after crushing


Figure C9: Splitting Tensile Testing using UTM Machine

MINISTRY OF MINING

e-mail:cg@mining.go.ke
When replying please quote ref No & date
Ref. No.ORIGINAL CERT NO.4422&24/17

MINISTRY OF MINING
MACHAKOS ROAD
P.O. Box 30009-00100 GPO
NAIROBI

Date… 28[th] July, 2017

ASSAY CERTIFICATE

SENDER'S NAME : NAMAKULA HIDAYA
DATE : 12.07.2017
SAMPLE TYPE : CEMENT& SUGARCANE BAGGASE ASH
SAMPLE NO : 4422&24/17

RESULT

Lab No.	Sender's Ref.	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	TiO_2	MnO	Fe_2O_3	LOI at 600 ^0C	LOI at 1000 ^0C
4422/17	CEMENT	22.0	4.80	59.0	0.75	0.28	0.60	0.20	0.04	2.44	4.0	6.30
4424/17	SUGAR CANE BAGGASE ASH	63.0	6.0	2.2	0.75	0.15	2.0	0.75	0.30	6.30	11.4	16.6

The results are expressed in percentages (%) unless otherwise indicated.

FOR DIRECTOR OF
GEOLOGICAL SURVEYS
28 JUL 2017
P. O. Box 30009-00100
NAIROBI

JORAM W. KATWEO
FOR: DIRECTOR OF GEOLOGICAL SURVEYS.

The results are based on test sample only.