JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

STRUCTURAL ENGINEERING STREAM

Experimental Study on Effective Utilization of Steel Bottle Caps Fiber for Reinforced Concrete

A Research Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Structural Engineering

Mikiyas Meka Sorbaga

October, 2019

Jimma, Ethiopia

JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

STRUCTURAL ENGINEERING STREAM

Experimental Study on Effective Utilization of Steel Bottle Caps Fiber for Reinforced Concrete

A Research Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Structural Engineering

By:

Mikiyas Meka Sorbaga

Main advisor: Elmer C. Agon, Asso. Prof

Co. advisor: Kefiyalew Zerfu, M.Eng.

October, 2019

Jimma, Ethiopia

JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

STRUCTURAL ENGINEERING CHAIR

EXPERIMENTAL STUDY ON EFFECTIVE UTILIZATION OF STEEL BOTTLE CAPS FIBER FOR REINFORCED CONCRETE

MIKIYAS MEKA

APPROVED BY BOARD OF EXAMINERS

1. Engr. Elmer C. Agon	____________________	____/____/____
Main advisor	Signature	Date
2. Engr. Kifeyalew Zerfu	____________________	24 / 11 / 19
Co-advisor	Signature	Date
3. Dr. Binaya Patnaik, PhD	Binaya Patnaik	24 / 11 / 19
External Examiner	Signature	Date
4. Engr. Diosdado John Corpuz	____________________	24 / 11 / 19
Internal Examiner	Signature	Date
5. Engr. Menberu Elias	____________________	24 / 11 / 19
Chairperson	Signature	Date

DECLARATION OF RESEARCH THESIS

I assure that this research paper is totally my original work and has not been presented for any Degree in other Universities.

Research thesis submitted by: - Mikiyas Meka Sorbaga

Signature: _____________ Date: ____________

Approved by advisors:-

Main advisor: Elmer C. Agon, Asso. Prof.

Signature: ______________ Date: _____________

Co-advisor: Kefiyalew Zerfu, M.Eng.

Signature: ______________ Date: _____________

Internal Examiner: ____________________________

Signature: ______________ Date: _____________

External Examiner: ____________________________

Signature: ______________ Date: _____________

Chair Person: _________________________________

Signature: ______________ Date: _____________

ABSTRACT

Steel bottle caps (SBCs) are widely used materials in the world to preserve soft drinks and beers in glass bottle very well. But after the bottle is opened and the beverage is used these caps are disposed as waste materials inappropriately; which in return affects the surrounding environment adversely. In Ethiopia, mostly the cities surrounding are covered by these caps that are thrown away after used. This indicates that there is no proper way of disposing these solid wastes. If these wastes are not collected and disposed properly or reused again it will cause adverse effect on the environment. Using of SBCs in the concrete as fiber can reduce the adverse impacts of this material on the environment. Furthermore, the addition of steel bottle caps fiber (SBCF) in the concrete enhances the mechanical properties of concrete.

This research was carried out at Jimma institute of Technology (JiT), Ethiopia, from April to end of September, 2019. The materials used for this experimental study were OPC cement, locally available sand and gravel, and SBCF, which are waste products collected from hotels, cafés and restaurants at Jimma town.

By flattening SBCs and removing the plastic covers, the SBCs were cut in to seven parts to produce SBCF. These SBCF were added in to the concrete mix of C-25 grade in different percentage values such as 0%, 0.5%, 1% and 1.5% by total weight of concrete. By using the results obtained from laboratory, this research paper investigated and compared the effects of SBCF on the workability of concrete and mechanical properties of concrete, such as compressive strength, split tensile strength and flexural strength.

Finally, this research paper concluded that addition of 1% SBCF is the optimum percentage value to increase the concrete strengths. Addition of this 1% SBCF increased the concrete compressive, tensile and flexural strength by 2.84%, 1.27% and 5.97% respectively as compared to the controlled concrete.

Keywords: Concrete, SBCF, workability, compressive strength, split tensile strength and flexural strength**.**

ACKNOWLEDGMENT

First of all I would like to thank God, the creator of the world, for helping me through the ups and downs to be at this place; without His help nothing would happen.

My next sincere gratitude goes to for my main advisor Elmer C. Agon, Asso. Prof. for guiding me to do this research and for his endless efforts to give whatever he knows. And also I would like to thank my Co. advisor Kefiyalew Zerfu (M.Eng.) for his essential and helpful advice when this research was done. And for the lab assistances, Teklu and Habtamu, I am very grateful for your help.

At last but not least my heartful appreciation goes to Prof. Dr.-Ing Esayas Alemayehu (Ph.D.) for his excellent guidance and lecturing methods when he taught me scientific research method, which gave me a good knowledge to do this research thesis well, and for my friends who supported me with sharing ideas and for their unconditional helps to finalize this research.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

FRC	Fiber Reinforced Concrete
JiT	Jimma institute of Technology
NSC	Normal Strength Concrete
OPC	Ordinary Portland cement
SBCs	Steel Bottle Caps
SBCF	Steel Bottle Cap Fibers
SFHSC	Steel Fiber High Strength Concrete

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

The use of concrete in different structures, like buildings, highways, bridges, tunnels, canals, dams and so on, become increasing; and the importance and a high impact of this material in modern society is inevitable [1]. The uses of concrete material for different purposes started since cement was introduced as a good binding material [2].

Concrete, because of its strength in compression, durability, fire resistance capacity, easy of construction and molding made it the most common material to be used by human beings for construction purposes [3, 4]. Despite its strength, concrete is a brittle material and has low tensile strength, low strain capacity and it is highly susceptible to cracks. Therefore, in order to improve this deficiency of concrete steel bar reinforcement was introduced to reinforce the concrete. These materials, concrete and steel, are different material which acts together when they used for construction purposes; the combination of these two materials is called reinforced concrete (RC) [2].

Concrete have many mechanical properties which describe its quality. Out of these, the most important and common property of concrete is compressive strength, which is extremely strong, and tensile and flexural strength, which are extremely weak, [1]. Therefore, in order to improve these mechanical properties of concrete, different types of fiber has been introduced to be incorporate in a concrete mix, such as steel wires, plastics, steel bottle caps (SBCs), steel tins or cans, plastic bottle caps, and so on. These can be obtained from different types of wastes, which are considered hazardous in the environmental point of view. And also there are some synthetic fibers such as polypropylene, polyethylene terephthalate fibers that have been used in concrete [1].

The application and uses of Fiber Reinforced Concrete (FRC) is continuously growing in various application fields, spatially for structural purposes, because of their significant effects on the mechanical properties of concrete. The basic importance of adding fibers into a concrete mix is to improve its tensile and flexural strength and decrease the deformation which causes cracking. This means, addition of fibers into the concrete mix decreases cracking of concrete by increasing its flexural strength [5].

As mentioned above, addition of different fibers in concrete mix increases the mechanical properties of concrete, specially tensile and flexural strength. Because of these, utilization of different fibers in concrete started increasing. From different types of fiber that has been utilized, steel fibers are the widely utilized one, such as, steel can fiber, steel wire fiber and steel bottle caps fiber. Wong [6] said that steel fibers are widely used materials in civil engineering applications and concrete reinforcement; due to its relative availability, reasonable cost and better experience in its application with conventional steel reinforcement. Bentur and Mindness (1990) stated that the early research and studies on fiber reinforced concrete in 1950's to 1960's mainly were on the behavior of steel fiber reinforced concrete [6].

Therefore, by using SBCF, this research paper was done to investigate the effects of steel bottle caps fiber on the workability and mechanical properties of concrete, such as compressive strength, tensile strength and flexural strength of concrete for different percentage values, such as 0.5%, 1% and 1.5%.

1.2 Statement of the problem

A metal caps that are used to secure beverage in glass bottles affects the environment adversely when they disposed. And also if recycling process is used, as an option to decrease the adverse effect of these caps on the environment, it will produce various harmful greenhouse gases by consuming high amount of energy; which again adversely affects the environment. Utilization of this waste bottle caps as fiber reinforcement in the concrete decrease the adverse impact of these caps on the environment. Furthermore using of SBCs as fiber in the concrete can save the energy that can be used for recycling processes of the waste by improving the mechanical properties of concrete [7].

Concrete has many features which defines its characters. From these features durability, fire resistance capacity, and good compressive strength are its good quality side. In other hand, its tensile and flexural strengths are its weaker side as compared to its compressive strength. Furthermore, concrete has low ductile property, low energy absorption capacity, and also it is affects by shrinkage.

To improve these weaknesses of concrete, particularly the tensile and flexural strength of concrete, this research paper added SBCF on the concrete mix and studied its effect on the workability of concrete and mechanical properties of concrete.

1.3 Research question

- ❖ Did addition of SBCF on the concrete affect the workability of concrete?
- ❖ Did addition of SBCF in the concrete improve the mechanical properties of concrete?
- ❖ How much is the optimum percentage value of SBCF is enough to improve the mechanical properties of concrete?

1.4 Objectives of the study

1.4.1 General objective

The general objective of this research was to utilize SBCs as fiber in reinforced concrete and to study the effects of this SBCF on the workability and mechanical properties of concrete.

1.4.2 Specific objectives

- ✓ To examine effect of SBCF on the workability of concrete.
- ✓ To find out effect of SBCF addition on the strength capacity of concrete, such as tensile, flexural and compressive strength.
- ✓ To determine the optimum percentage value of SBCF used in concrete.

1.5 Significance of the study

Utilization of waste SBCs as fiber in concrete produces green structures by reducing the adverse impacts of this waste material on the environment world widely. It also serves as a good waste disposal method by saving the economy that will be spend for removal of the SBCs wastes, especially in Ethiopian where there is no good waste disposal method. It also saves the energy that will be used to recycle these waste materials.

Furthermore, addition of these waste materials in the concrete mix enhances the mechanical properties of concrete; especially tensile and flexural strength of concrete, which a concrete is weak at it. The improvement of these weaknesses of concrete will give a building to have good resistance of deflection and energy absorption capacity.

1.6 Scope and limitation of the study

The scope of this research was to investigate the effects of addition of different percentage value of SBCF on the workability and mechanical properties of concrete such as compressive, tensile and flexural strength of concrete and to determine the optimum percentage value of SBCF.

This research was conducted by adding different percentage value of SBCF, such as 0%, 0.5%, 1% and 1.5% by total weight of concrete, on the concrete mix of C-25 grade of concrete. Then different samples were taken for different tests, such as for compressive strength test 36 cube samples of 150x150x150 mm were used, for tensile strength test 36 cylinder samples of 100x200 mm were used and for flexural strength test 36 beam sample of 100x100x500 mm were used.

The limitation of this study was production of steel bottle caps fiber. The SBCF was made manually which made the width of fiber to vary and the production process more tedious. Therefore it is better to use mechanical machine in order to get same width of fiber and to make the production process less tedious.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 General

Generally, different researches suggested that addition of fibers in concrete mix increases the mechanical property of concrete. Shah and Ribakov [2] stated that 'Addition of fiber to high-strength concrete improves its mechanical properties and makes the material very attractive for applications in construction'. The ductile behavior of normal strength concrete (NSC) is very low; in order to with stand the dynamic loading safely, structure must have a good ductile property; therefore, utilization of steel fiber high strength concrete (SFHSC) improves the ductile behavior of concrete, see Figure 2.1 below [2].

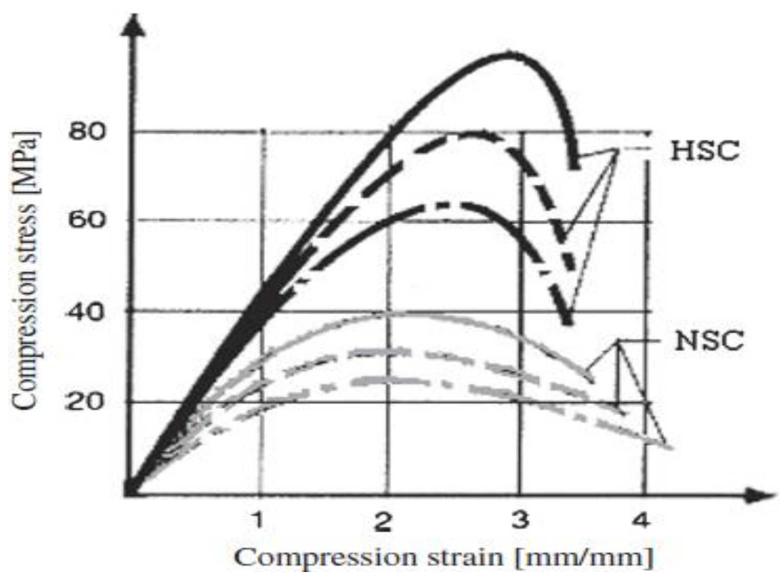
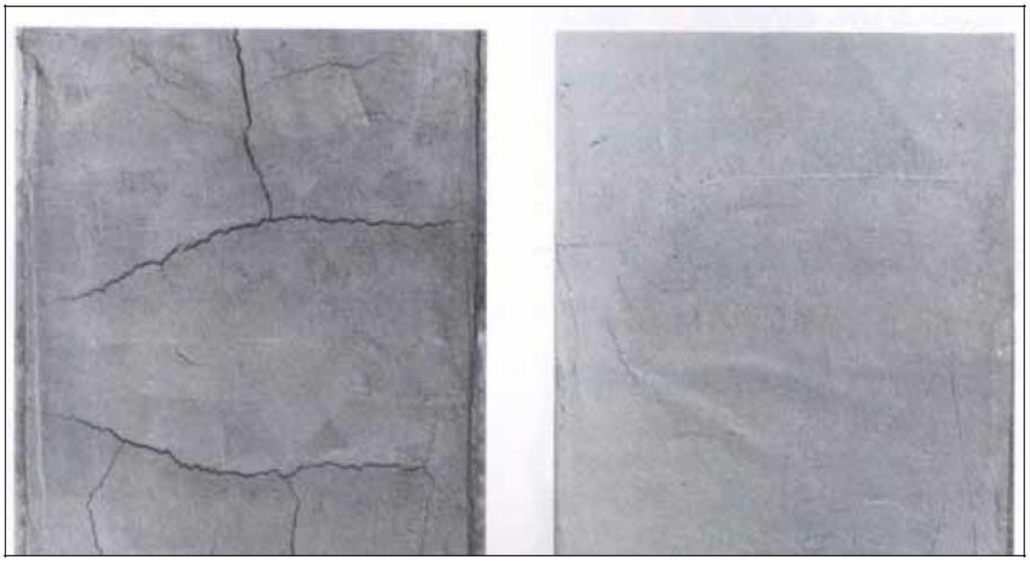


Figure 2.1 Stress–strain relationships of NSC and HSC [2]

Garg, et al. [7] also suggests that 'steel fibers are typically added to concrete in low volume dosages (often less than 1%), and have been shown to be effective in reducing plastic shrinkage cracking'. The experimental studies of Shah and Ribakov [2] showed that the remaining strength of SFHSC after the first crack has been seen is high and increasing and elongations of cracks are also limited by the steel fiber. Using of steel fiber decreases cracks width by increasing resistance to cracking and by holding the concrete together without significantly altering the free shrinkage of concrete [7]. Figure 2.2 shows that the effect of addition of fiber meshes on the cracking behavior of concrete.



A) Without fiber-reinforced B) With fiber-reinforced

Figure 2.2 Comparisons of cracks with and without Fiber mesh reinforced concrete [6]

Therefore, addition of different types of fibers to the concrete mix will have large influence and effects on the workability, indirect tensile strength, flexural strength, ductility, energy absorption capacity and the post-cracking state behavior. These influence and effects depends not only on the type of fiber used but also on the shape and geometry of fiber [6]. Christian et al. [1] concluded that 'compressive strength of concrete can be stepped up with prominently from the different waste materials which are hazardous from the view of solid waste disposal'.

The experimental result of Ravinder [8] showed that the 28 days Compressive strength for different percentage, such as 0.5%, 1%, and1.5%, of fiber by volume of concrete decreased with increasing of fiber dosage; but the split tensile strength increased with increasing of fiber dosage. Kumar and Parashar [9] argued and studied the addition of 5% of 30mm & 50mm long steel fiber by weight of cement to the concrete mix; and found that, the strength of 7 days of curing concrete was increased for both types of fibers compared to concrete and then decreased after 28 days of curing. When they use 10% of these fibers the compressive strength concrete which had 30mm fiber increased for 7 & 28 days of curing; but, the compressive strength of concrete which had 50mm fiber increased only for 7 days and decreased for 28 days of curing. But, when they use 15%, 20% & 25% of these fibers the compressive strength increased for both 30mm & 50mm fiber for 7 & 28 days of curing. Also Arunakanthi and Kumar [10] stated that the compressive strength, flexural strength and split tensile strength of concrete increases when the addition of steel fiber in concrete was increased than glass fiber see Figure 2.3.

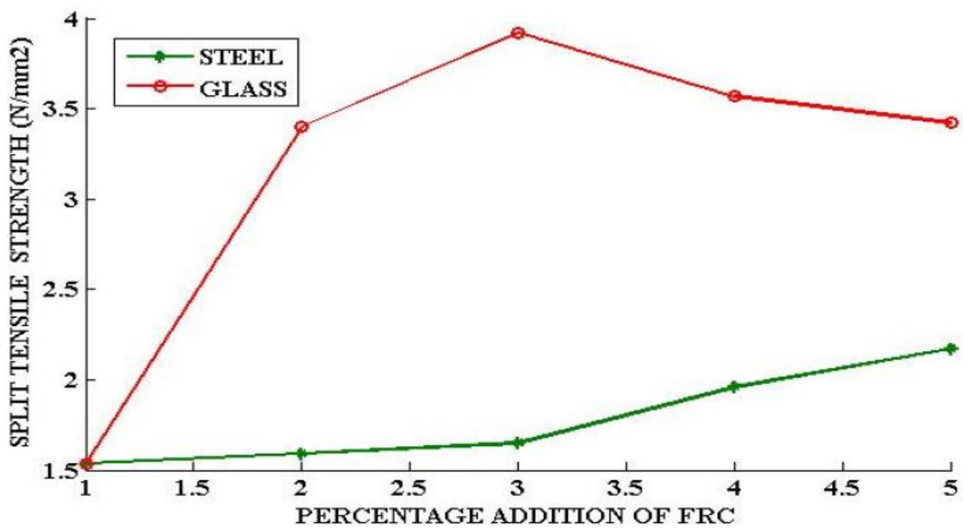


Figure 2.3 Effect of fiber on the split tensile strength of concrete [10]

Furthermore, an addition of steel fiber in concrete mix enhances the fatigue resistance of RC deep beam. In addition to this, using of steel fiber in concrete reduces the corresponding deformation of RC beam depending on the reinforcement ratio [12].

The different types of testes that can be used to check the mechanical properties of concrete specially compressive, tensile and flexural strength of concrete are shown in the Figure 2.4 below

Figure 2.4 Different types of test for concrete [11]

2.2 Compressive strength

For different percentage value, such as 0.5%, 1.00% & 1.5% by total weight of concrete mix, the compressive strength of concrete increases with the increasing dosage value of bottle caps fiber when the results are compared each other and with the controlled concrete, which has no bottle caps fiber in it, [7]. Wong [6] suggested that ‘0.5% fiber volume dosage rate was the optimum dosage applied to concrete’. However, steel fiber reinforced concrete increases its compressive strength capacity when dosage rate value of fiber is increased [6].

A concrete mix with some percentage value of fiber shows a better resistance of compressive force than that of control concrete mix, which has no fiber, at the age of 28 days; this indicates that the compressive strength of concrete will be improved by the addition of fiber [13]. Akhund, et al. [13] states that the increasing of fiber content up to the optimum dosage value with different size of fiber increases the compressive strength of concrete. Joseph, et al. [14] experimented on the effects of addition of steel fiber on the M30 grade concrete with 5% replacement of coarse aggregate by waste plastic caps and found a satisfactory result on the increasing of compressive strength of this concrete mix. The works of Reddy, et al. [15] also suggests that, the optimum percentage value of steel fiber by volume of concrete, which increases the compressive strength of concrete, is 1%; beyond this value the strength starts decreasing because, the addition of steel fiber decreases the amount of cement in concrete. The Figure 2.5 below shows the compressive force of concrete for different percentage of bottle cap fiber.

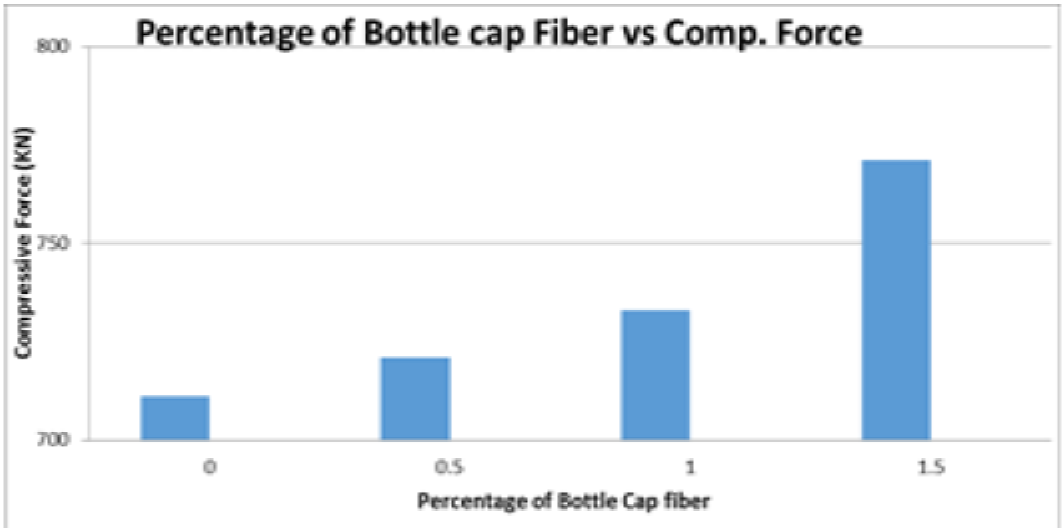


Figure 2.5 Comparison of Compressive Force [7]

The result of Murali, et al., [11], showed that, addition of steel fiber on the concrete mix increases the compressive strength of the concrete by 32.14% more than that of controlled concrete.

2.3 Tensile strength

The split tensile strength of concrete, which had bottle caps fiber, increases with the increasing of percentage value of bottle caps fiber by total weight of concrete, [7]. In indirect tensile strength test, all fibers that have been used in concrete mix shows their full ability of increasing the tensile strength value of the concrete, which concrete is very weak at it, by holding the concrete paste tightly and preventing the splitting of the concrete [6]. Figure 2.6 below shows the effect of fiber on the concrete tensile strength.

(a) With fiber reinforced. **(b) Without fiber reinforced.**

Figure 2.6 Specimens after indirect tensile test [6]

Wong [6] states that: if the steel fiber dosage rate increased the tensile strength of concrete will increase extremely. Also Joseph, et al. [14] implied that 'the split tensile strength of concrete was increased when cement is replaced by waste plastic caps by 15% with the addition of steel fibers of 0.75%'. Furthermore, Reddy, et al. [15] also suggested that 'fibers extensively increase the split tensile strength of the concrete since it inherently increases the materials resistance to the Poisson's effect'. Figure 2.7 below shows the effects of fiber on the tensile force of concrete graphically.

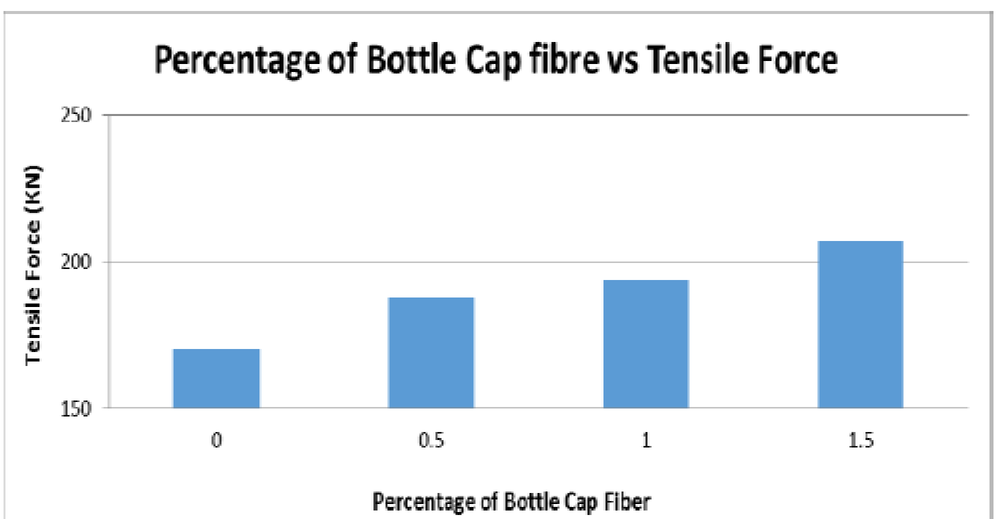


Figure 2.7 Comparison of tensile force [7]

The works of Murali, et al. [11] suggested that admirable split tensile strength was achieved with the addition of steel fiber in concrete; because of the addition of this fiber material on the concrete mix, the split tensile strength of the concrete showed the 52.38% more additional tensile strength of concrete than the concrete that has no fiber in its mix.

2.4 Flexural strength

Furthermore, researches made on addition of fibers in the concrete mix with different percentage value are concluded that, the flexural strength of concrete also increases with the increasing percentage of bottle cap fibers [7]. Addition of short fibers in the concrete mix gives excellent outputs in the properties of concrete; one of it is increasing of its flexural strength in pre-cracking stage and ductility of the concrete in post-cracking stage [6]. Joseph, et al. [14] also recommended that ‘the flexural strength of the concrete increases when the cement is replaced by waste plastic caps of 15% with the addition of steel fibers of 0.75%’.

The optimum dosage value of fiber, that increases the flexural resistance of the concrete well, is addition of 1% fiber in to the concrete mix [15]. Figure 2.8 below shows the effects of fiber on the flexural force of concrete.

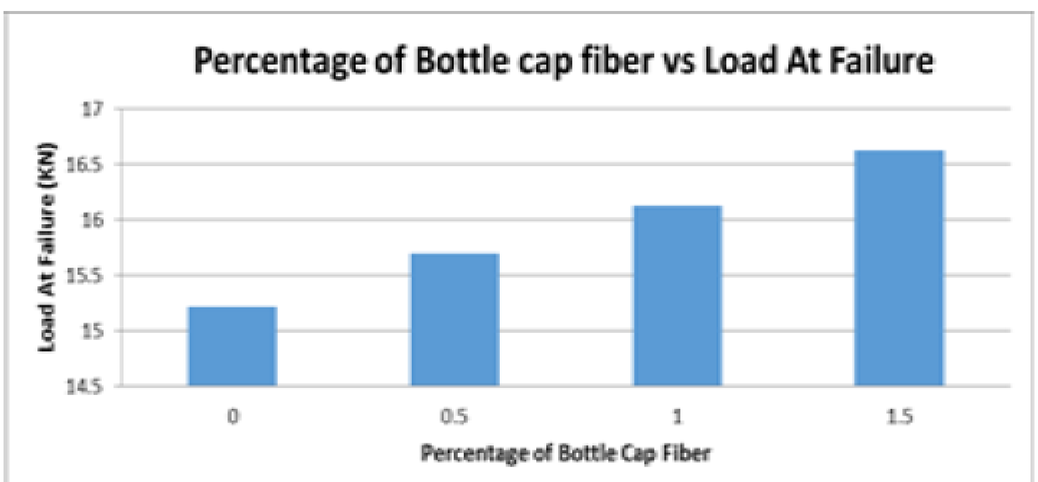


Figure 2.8 Comparison of flexural force [7]

Murali, et al. [11], by their experimental investigation, stated that the flexural strength of fiber containing concrete was found good and its value increased by 12.68% more than that of the controlled concrete.

2.5 Workability of concrete

Despite the benefits of fiber reinforcement, fiber can affect the workability of fresh concrete significantly. Addition of steel fibers reduces the slump thus increasing the stiffness of concrete [2]. Besides the increasing of compressive strength, split tensile strength and flexural strength of concrete, different researches concluded that addition of steel fiber in concrete decreases the workability of fresh concrete [6]. The gradual decreasing of workability of fiber reinforced concrete mixes depends not only because of the increasing percentage value of fiber but also on the size and geometry of the fibers [6, 13].

Fibers inter lock and entangle around aggregate particles and considerably reduce the workability, while mixing it becomes more cohesive and less prone to segregation see Figure 2.9 and Figure 2.10 [13, 6].

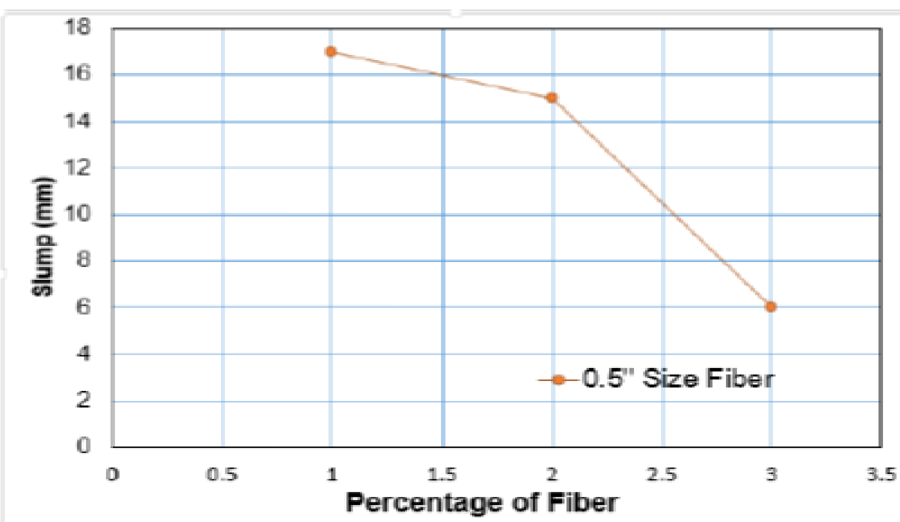


Figure 2.9 Slump Vs. percentage of soft drink tins fiber with 0.5”size of strips [13]

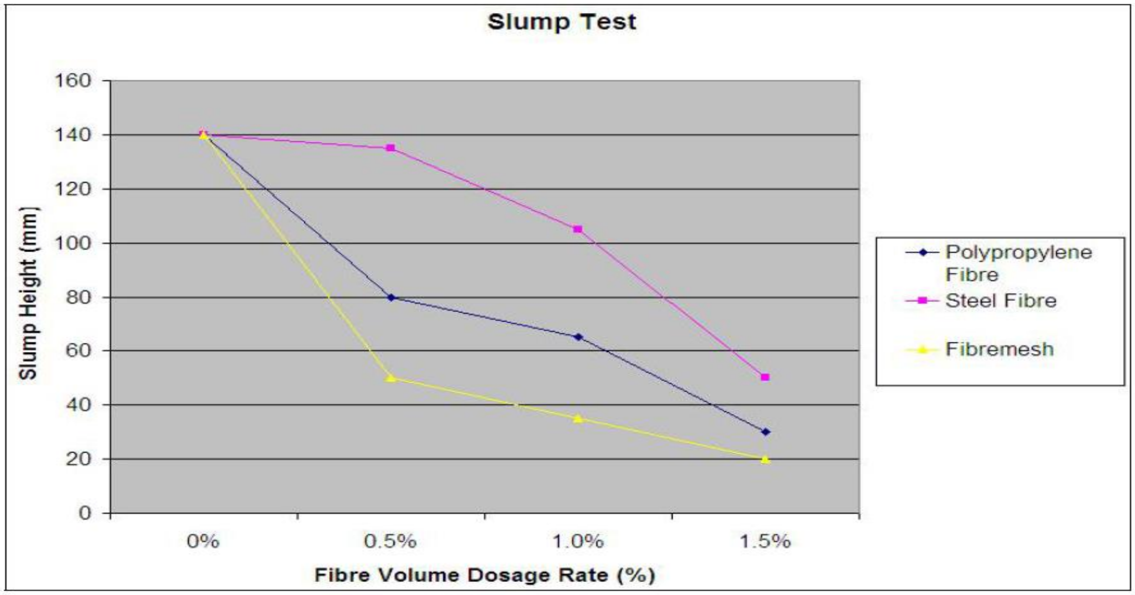


Figure 2.10 Average slump height vs. fiber volume dosage rate of each batch [6]

Therefore, as the percentage of fiber content in the concrete mix increase, the workability of the fresh concrete reduces [15]. The figure below indicates the relationship of addition of fiber with workability of concrete.

Beside different fibers lowering the cement content of concrete with given water content will result in lower workability. But, the workability of concrete mixtures commonly is improved by using air entraining and water-reducing admixtures [2].

Porosity and absorption of aggregate will affect the water cement ratio and the workability of concrete and sometimes also affect the durability of concrete. The grading of aggregate affects the workability, which in turn, controls the water and cement requirements, segregation and influences the placing and finishing of concrete [9].

CHAPTER THREE

RESEARCH METHODOLOGY AND MATERIAL TESTS

3.1 Study area

This research was conducted at JiT University, Jimma, Ethiopia. Jimma is the largest city in South-western Ethiopia. It has latitude and longitude of $7^0 40'$N $36^0 50'$E and elevation of 1,780m.

The daily mean temperature of Jimma is in a comfortable range, between 20^oC to 25^oC year-round [16].

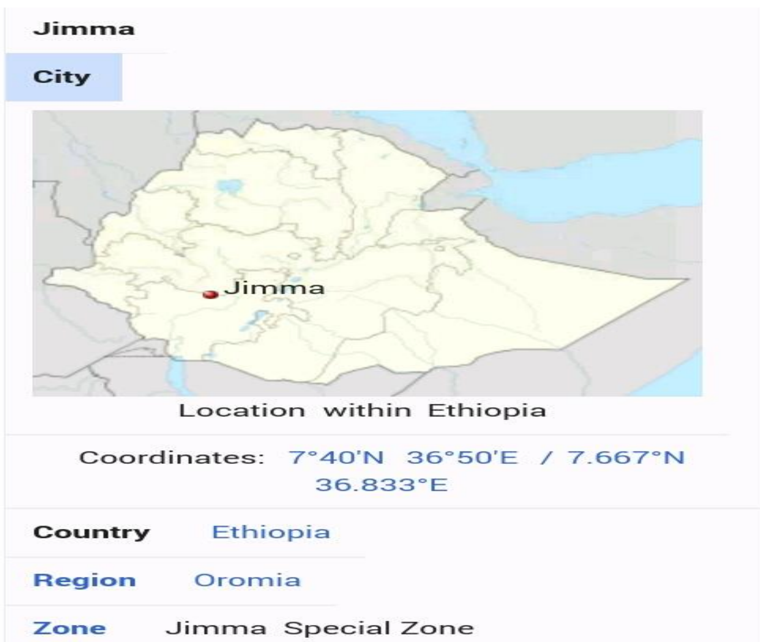


Figure 3.1 Jimma city maps [16]

3.2 Research design

The research design this study used was experimental research design method, to analyze the effect of SBCF on the workability and mechanical properties of concrete and to find the optimum percentage value of SBCF.

3.3 Study variables

3.3.1 Dependent variables

- Performance of concrete with steel bottle caps fiber

3.3.2 Independent variables

- Properties of materials
- Water cement ratio
- Percentage of SBCF
- Hardened and fresh properties of concrete

3.4 Population and sampling method

Grade of concrete used for this research was C-25 grade of concrete. By adding different percentage value of SBCF in the concrete different sample was taken for tests, such as cube, cylinder and beam sample were taken. Table 3.1 shows sampling method used for this research.

Table 3.1 Sampling method

No	Tests	Sample size (mm)	% of SBCF (by total weight of concrete)	Sample numbers	Curing and testing time	Remark
1	Compressive strength	Cube of 150x150 x150	0%	9	After 7, 14 and 28 days	The results of different test were compared with each other, 0% SBCF with other percent SBCF. And some conclusions and recommendations were given at the end of discussion.
			0.5%	9		
			1%	9		
			1.5%	9		
2	Split tensile strength	Cylinder of 100x200	0%	9		
			0.5%	9		
			1%	9		
			1.5%	9		
3	Flexural strength	Beam of 100x100 x500	0%	9		
			0.5%	9		
			1%	9		
			1.5%	9		

3.5 Source of data

3.5.1 Primary data

The primary data sources were taken from the output of laboratory experiment for 7, 14 and 28 days of curing time and test result.

3.5.2 Secondary data

The secondary data came from different literatures.

3.6 Data collection procedure

The specimens that were placed in the laboratory, for different curing and testing time with different percentage value of SBCF, such as 0%, 0.5%, 1% and 1.5%, were tested in their chronological order of curing and casting time, then the data were registered with their code written on them for 7, 14 and 28 days.

3.7 Data presentation and analysis

By using the results obtained from the laboratory experiment for different days of testing; this research paper analyzed the effects of SBCF on the workability and mechanical properties of concrete.

Furthermore, by using the laboratory results, this research paper gave conclusions and recommendations on the effect of SBCF on the workability and mechanical properties of concrete and suggested the optimum percentage value of SBCs that must be used as fiber for reinforced concrete.

3.8 Experimental procedure

The materials such as cement, fine aggregate, coarse aggregate and SBCF, brought to the place where the experiment was conducted, JiT. Then fine and coarse aggregate was washed to free from impurities and dirt. After that, certain material tests were done to check the mechanical properties of materials, like sieve analysis test of sand and gravel, silt content test of sand, specific gravity test of sand and gravel, and all tests were based on EBCS and ACI standards.

3.8.1 Sieve analysis test procedures

By using a nested column of sieves with wire mesh cloth (screen) a representative weighed sample is poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above. At the base there is round pan, called receiver. The column is typically placed in a mechanical shaker. The shaker shakes the column, usually for some fixed amount of time. After this is done the material weight of each sieve will be taken and it will be divided to the total weight of material to get the percentage retained on each sieve.

$$\%Retaind = \left(\frac{Wsieve}{Wtotal}\right) * 100 \text{..........................Eqn. 3.1}$$

Fine aggregate has a nominal maximum size of 4.75 (No.4 sieve) Therefore specifications will require that 100% of the aggregate pass the 9.5mm (3/6") sieve, and 90 (or 95%) pass 4.75mm. Coarse aggregates are predominantly retained on the No.4 (4.75mm) sieve. Figure 3.2 below shows the standard sieve test machine.

Figure 3.2 Standard sieves

3.8.2 Silt test

Fine aggregates can be checked by placing 50mm sand in a glass jar, which is then filled three-fourths full with clean water and sealed. Turn the jar on its side and shake vigorously for one minute. Set the jar upright, level the sand by shaking sideways, and let it stand for about three hours. Any silt present will be suspended by the shaking and will settle back on the sand surface when allowed to stand. If more than 6mm (EBCS) of silt skim is formed, then the sand is too dirty to form strong concrete.

3.8.3 Specific Gravity

The specific gravity of an aggregate is another characteristic of the material which needs to be determined. It is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water [17]. It is not a measure of aggregate quality but is used in making calculations related to mix design. The specific gravity of most normal weight aggregate will range from 2.4 to 2.9

Procedure [17]:-

1. Washed aggregate of about 2 kg will be immersed in water for 24 hours
2. The wetted aggregate will be weighed to get its total weight (W1)
3. The wetted aggregate will be allowed to surface dry and its weight will be taken (W2)
4. Then this surface dried aggregate will be again dried by oven and its weight will be taken (W3)
5. Specific gravity = $W2/(W1-W2)$
6. Apparent specific gravity = $W3/(W1-W3)$

After testing of materials was done the results were collected and mixing design was conducted for C25 grade of concrete. By adding different SBCF value, such as, 0.5%, 1% and 1.5% by total weight of concrete, in the concrete mix different test specimens were taken for different strength tests, such as, compressive strength, split tensile strength and flexural strength, by compacting with recommended layers, for 7, 14 and 28 days.

Finally, by testing the specimens and collecting the results obtained different test, this research paper compared and contrasted the effect of SBCF on the mechanical properties of concrete and gave recommendations and conclusions about the optimum percentage value of SBCF that must be used in the concrete.

3.9 Materials properties and mix design

3.9.1 Introduction

Concrete is a mixture of cement, sand, gravel and water and sometimes in addition of these it will have some percentage values of different types of fibers in order to enhance its mechanical properties, especially the flexural and tensile strength of concrete. Concrete can be produced everywhere by everyone, but the question is does the concrete met the accepted or the intended value of strength? Therefore, to produce acceptable quality of concrete or to get the intended concrete compressive strength physical test of materials must be carried out first before mixing of concrete ingredients began.

These materials tests helps to get the exact mixing ratio of different ingredients and also it give the exact amount of water to cement ratio by examining the aggregates water content and absorption capacity.

3.9.2 Material preparation

The materials that were used for this research were cement, sand, coarse aggregate, different percentage of SBCF and water. The physical characteristics of concrete materials, such as sand and gravel, were examined in the laboratory; and depending on these results appropriate mixing design by weight was made.

3.9.2.1 Cement

The cement used throughout the experiment was Ordinary Portland cement (OPC) produced as per CEM-II-AL 42.5R grades, which is the product of Dangote Cement PLC in Ethiopia.

Figure 3.3 Dangote cement (OPC)

3.9.2.2 Aggregate test

- ***Sieve analysis test***

By using a nested column of sieves with wire mesh cloth (screen) a representative weighed sample is poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above. At the base there is round pan, called receiver. The column is typically placed in a mechanical shaker. The shaker shakes the column, usually for some fixed amount of time. After this is done the material weight of each sieve will be taken and it will be divided to the total weight of material to get the percentage retained on each sieve.

$$\%Retaind = \left(\frac{Wsieve}{Wtotal}\right) * 100$$

Figure 3.4 JiT Sieve test machine

- ✓ **Sand**

River sand of commonly known as Worabie sand was used for this experiment in order to produce C-25 grade of concrete. The following Table 3.2 shows the sieve analysis test results of Worabie sand, the mass taken was 2000grm.

Table 3.2 Sieve analysis test of fine aggregate

sieve size (mm)	mass retained (grm)	Percentage retained (%)	Percentage pass (%)	Cumulative retained (%)	Cumulative pass (%)
9.5	0	0	100	0	100
4.75	0	0	100	0	100
2.36	171	8.55	91.45	8.55	91.45
1.18	437.5	21.875	78.125	30.425	69.575
0.6	865	43.25	56.75	73.675	26.325
0.3	413	20.65	79.35	94.325	5.675
0.15	85	4.25	95.75	98.575	1.425

$$Fineness\ modules = \frac{\sum Cumulative\ coarser\ retained\ \%}{100} \qquad \text{Eqn. 3.2}$$

$$= \frac{305.55}{100} = 3.06$$

This fineness modules value indicates that the third sieve that has 0.6mm sieve size is the average sieve size. Depending on this value, the sand is classified as coarse sand, because, sand which has fineness modules between 2.90 to 3.20 is coarse sand.

- ✓ **Coarse aggregate test**

Crushed stone or gravel was obtained from local area of Jimma. The following table 3.3 shows the sieve analysis test of coarse aggregate, the mass taken was 5000 grm.

Table 3.3 Sieve test of coarse aggregate

sieve size (mm)	mass retained (grm)	Percentage retained (%)	Percentage pass (%)	Cumulative retained (%)	Cumulative pass (%)
37.5	0	0	100	0	100
28	48.5	0.97	99.03	0.97	99.03
19	956	19.12	80.88	20.09	79.91
12.5	2323	46.46	53.54	66.55	33.45
9.5	892	17.84	82.16	84.39	15.61
4.75	753	15.06	84.94	99.45	0.55

- ***Unit weight test***
  - **Sand**

By taking passed mass of sieve size 4.75mm the cylinder was filled in three layers by compacting each layers of the sand for 25 times by steel rod, which has 922 grm weight. The weight of this compacted sand was taken and this weight was divided for the volume of the cylinder in order to get the unit weight of sand. Therefore, the compacted unit weight of Worabie sand was 1428 Kg/m^3.

Table 3.4 Unit weight of fine aggregate

Measured material	Weight
Mass of sample + cylinder	8194.5 grm
mass of cylinder	1055 grm
mass of sample	7139.5 grm
volume of cylinder	5 lit

$$\gamma_S = \frac{Msl}{Vcy} \text{ ....Eqn. 3.3}$$

$$\gamma_S = 1427.9 \ {}^{Kg}/_{m^3}$$

γ_S = Unit weight of sand

Msl = Mass of sample

Vcy = Volume of cylinder

Figure 3.5 Unit weight test of fine aggregate

- ✓ **Coarse aggregate**

The retained mass on the sieve size 4.75mm was taken for coarse aggregate unit weight calculation. By compacting each layer of the retained mass by steel rod for 25 times, the cylinder was filled in three layers. Then the weight of this compacted mass was taken and divided to the volume of the cylinder in order to get its unit weight. Therefore, the compacted unit weight of coarse aggregate was 1622 Kg/m^3.

Figure 3.6 Unit weight test of coarse aggregate

- ***Silt content test***

  - **Sand**

According to the Ethiopian Standards it is recommended to wash the sand or reject if the silt content exceeds a value of 6% [18]. From the test result obtained, the silt content of sand before washing was 6.25%, which is above the recommended standard value, for this reason the sand was washed and tested again for its silt content and the result was 4.5%, which is below 6%.

A, Silt content test using tube   B, Washing the sand   C, Oven drying the sand

Figure 3.7 Silt content test of fine aggregate

- **Specific gravity test**

The specific gravity of aggregate is another quality measurement method of materials, which must be determined to do mixing ratio. It is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water [17]. It is not a measure of aggregate quality but it uses for making calculations related to mixing design. The specific gravity of most normal weight aggregate will range from 2.4 to 2.9.

  - **Sand**

Bulk specific gravity (oven dried), bulk specific gravity (saturated surface dried), and apparent specific gravity of sand obtained from the laboratory material tests were 2.39, 2.4 and 2.42. And its water absorption capacity was 0.6%.

Figure 3.8 Specific gravity test of fine aggregate

- ✓ **Coarse aggregate**

Bulk specific gravity (oven dried), bulk specific gravity (saturated surface dried), and apparent specific gravity of coarse aggregate obtained from the laboratory material tests were 2.71, 2.72 and 2.74. And its water absorption capacity was 0.5%.

A, Soaking of coarse aggregate in water B, Surface drying of soaked aggregate

Figure 3.9 Coarse aggregate specific gravity test process

- **Moisture content test**

A moisture content of sand and coarse aggregate obtained from laboratory material tests were 1.01% and 1.06% respectively.

3.9.3 Water

The water used for this experiment was drinkable water supplied by Jimma water supply Authority.

3.9.4 Steel Bottle Caps Fiber preparation

The bottle caps were collected from different hotels, café and restaurants. The plastic covers of this cap were removed after they were flattened by hammering the caps using hammer, which made it easy for removing the plastic cover and cutting it to fibers. Then, these flattened steel bottle caps were cut in to 7 parts; the length of the fiber was 2.3-3.6 cm its average length was 2.9 cm and width of the SBCF was 0.3-0.6 cm, its average width was 0.45cm. Figure 3.10 shows the processes of making SBCF from SBCs.

Figure 3.10 Preparing SBCF

3.9.5 Concrete Mix design

Concrete mix design was used to produce C-25 grade of concrete after 28 days of curing time for the water to cement ratio of 0.5. The quantity and mixing ratio of different concrete materials were calculated depending on the material test results obtained from laboratory, see Table 3.5 below. The total quantity needed for this research was obtained by using the standard cast iron molds of cubes, cylinders and beams, and their dimension was 150x150x150 mm, 100x200 mm and 100x100x500 mm respectively.

Table 3.5 Quantity of materials for C-25 grade concrete and its mixing ratio

Materials	Cement (kg)	Sand (kg)	Gravel (kg)	Water (kg)
Quantity per volume (kg/m^3)	370	809.1	1004.01	176.82
Ratio	1	2.187	2.71353	0.4779

3.9.6 Concrete Production Processes

- Mixer and different molds were prepared and cleaned from dusts.
- The molds were coated with oil to smooth the surface in order to make dismantling of molds easy after 24 hrs. of concrete drying.
- The concrete ingredients were prepared including SBCF by measuring their proper weight by weight balance machine.
- After their respective weight is measured, coarse aggregate was added in to the mixer and by adding some water on it the mixer started mixing the gravel for a few seconds, then the sand was added on the coarse aggregate and mixed these two materials together properly, then SBCF was added and finally cement was added and by pouring water on these materials the mixer started mixing the concrete for 2 to 3 minutes.
- After mixing of concrete ingredients were done; the fresh concrete was checked for workability by filling the standard slump cone with three layers by blowing each layers for 25 times using steel rod.
- Then, filling of different molds, such as cubes, cylinders and beams, for compressive strength, split tensile strength and flexural strength tests respectively were proceeded, each test mold was filled with three layers by blowing each layers for 25 times using steel rod.

- Finally, these casted concrete specimens was removed from the molds after 24 hours of surface drying and placed in to the curing tank, which is filled with pure water, until the tasting day was reached.

A, Oil coated molds B, Casted concrete specimens

Figure 3.11 Concrete specimens production

3.10 Testing procedures

3.10.1 Introduction

Different tests were done for this research using different percentage values of SBCF, such as 0%, 0.5%, 1% and 1.5% by total weight of concrete, to investigate its effect on the workability and mechanical properties of concrete. These tests were workability test, compressive strength test, split tensile strength test and flexural strength test. These tests were done for C-25 grade of concrete for 7, 14 and 28 days of curing time. The different tests were discussed below.

3.10.2 Workability test

After proper mixing of concrete is done; the fresh concrete will be tested for workability, which measures the consistency of concrete. And the results obtained from this test will tell how easy or difficult is the concrete for casting and will answer the question; does a concrete has proper water content? The workability test is divided in to three, such as true slump, shear slump and lean slump. True slump concrete is a concrete which has sufficient water content and has good workability for casting and transporting through pipes for easiness of construction; the values of this type of slump is between 25mm to 50mm. Shear slump concrete has low water content than the concrete needs and it will be difficult to transport this type of concrete using pneumatic tube because of its harshness. And because of its deficiency of water the concrete paste will dry immediately when the concrete is exposed to air. Therefore, this type of concrete needs super-plasticizer to transport the concrete and to make it workable during casting time. And the last slump type is lean slump which has too much water than needed.

Therefore, for this research slump of fresh concrete was tested by using the standard cone, which has 10cm top diameter, 20cm bottom diameter and 30cm length. When the workability test was done; the concrete paste was filled in three layers, one third of a cone height at a time, and each layers of the paste were compacted by steel rod for 25 times. Finally, the top part was trimmed and the cone was easily removed and placed up right down on the side of the concrete just casted and the height of the slump measured from the top of the cone to the top of casted concrete as seen in the Figure 3.12 below.

Figure 3.12 Workability test of fresh concrete

3.10.3 Compressive strength test

When the load is applied towards the specimens; the specimen will be under compression and the result that will be obtained from dividing the applied load to the contact area is called compressive strength. The equipment this research paper used for this test was universal test machine (Utest); and the test was done by applying a load at the rate 6.79 kN/s. The specimens used for compressive strength test were prepared by using cube molds of 15cmx15cmx15cm. And before castings of cube specimens were started, the molds were lubricated by oil in order to make the contact surface area of the molds smooth for easiness of removing after the concrete is dried. Then after this; the cubes were casted by filling one thirds of its height at a time and by compacting each layer of the pastes by steel rod for 25 times and the molds were filled in three layers. Figure 3.13 shows compressive strength test machine and sample test.

$Compressive\ strength = \frac{Load}{Contact\ Area}$ (N/mm^2 or Mpa)……………………Eqn. 3.4

A, JiT compressive test machine (UTEST)   B, Cube test

Figure 3.13 Concrete compressive tests

3.10.4 Split tensile strength test

When the load is applied on the longitudinal direction of the cylinder specimen; the specimen will crack perpendicular to its longitudinal direction and this crack will split the specimen in to two. This phenomenon will happen when two loads, equal in magnitude but opposite in direction, is applied on the longitudinal surface of the cylindrical specimen. The magnitude or capacity of concrete that will be obtained from dividing the applied tensile load to the surface area of the specimen is called split tensile strength and this is indirect tensile test of concrete. The molds that were used for split tensile strength test for this research were 10cm diameter by 20cm length of cylinders. Castings of cylinders were started by lubricating the molds by oil, for easiness of removing the molds from the casted concrete specimens. Then the molds were filled by a concrete paste in three layers and each layers of the concrete paste were compacted by steel rod for 25 times. After 24 hours of casting the specimens were removed from the molds and soaked in the curing tank using pure water until the tasting age was reached. Figure 3.14 shows split tensile strength test.

$Split\ tensile\ strength = \frac{2P}{\prod dl}$ (KN/m^2 or Mpa)……………………………….Eqn. 3.5

$$Where, \quad P = crushing\ load, \ \ d = diameter, \quad l = length,$$

A, JiT Split tensile test machine B, Split test

Figure 3.14 Split tensile strength test of concrete

3.10.5 Flexural strength test

The flexural strength test result indicates that the concrete stiffness to support the applied load by going some deflection without failure. In other word this test shows that the ductility or brittleness of concrete.

For this research a beams of 10cmx10xcmx50cm were used for flexural strength test. The specimens were placed on the flexural testing machine support by measuring **d** distance or 10cm from the two edges of the beam. And then, the loads were applied on the beam at two points. This two point's load had a distance of 10cm between them, and was applied on the specimens gradually until the specimens were crushed as seen in the Figure 3.15 below. Then, by taking the failure load, the flexural stress can be calculated by using two points load method or modules of rupture formula.

- Two point load formula,

$$Flexural\ stress = \frac{Mc}{I} \quad \text{...Eqn. 3.6}$$

$$Where, \qquad M = \frac{pl}{3} \ \ but \ \ p = \frac{P}{2}\ , \qquad I = \frac{bd^3}{12}, \quad c = \frac{d}{2},$$

$where\ P = Total\ applied\ load\ on\ the\ beam,$

- Modulus of rapture formula,

$$f_r = \frac{Pl}{bd^2} \quad \text{...Eqn. 3.7}$$

A, JiT Flexural test machine B, Beam test

Figure 3.15 Flexural strength test of concrete

CHAPTER FOUR

RESULTS AND DISCUSSIONS

According to the research objectives and methodology; this research paper has done workability and mechanical properties of concrete tests to check the effects of SBCF on reinforced concrete. In this chapter, discussions are made by comparing SBCF concrete with controlled concrete which has no SBCF in it. By examining the effect of this fiber on the workability and mechanical properties of concrete using different concrete tests, namely, workability test, compressive strength test, split tensile strength test and flexural strength test this chapter clarifies effect of SBCF on the concrete properties.

4.1 Effect of SBCF on the concrete workability

Slump test is used to check the workability of fresh concrete. The aim of this test was to check whether the fresh concrete that has 0.5%, 1% and 1.5% SBCF is effective enough for easiness of compaction and placing before the concrete starts to harden.

The experiment result showed that addition of SBCF on the fresh concrete increases the resistance to flow by interlocking the fresh concrete together. Therefore, as the percentage value of SBCF increased, the slumps of the concrete were decreased; as seen in Figure 4.1.

Table 4.1 Slump of fresh concrete

SBCF %	Slump height (mm)
0%	27.5
0.5%	21.5
1%	15
1.5%	5

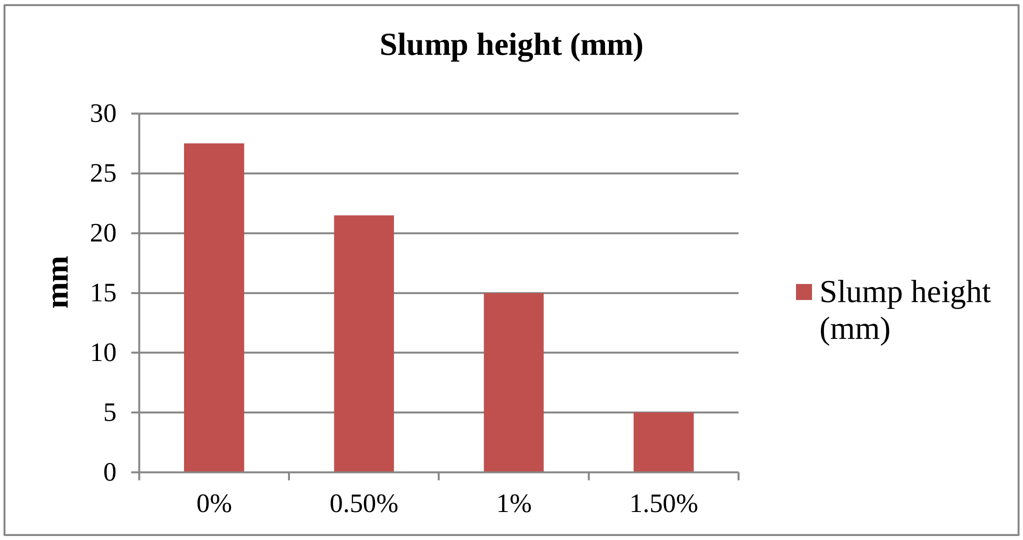


Figure 4.1 Workability of fresh concrete for different SBCF

4.2 Effect of SBCF on the compressive strength of concrete

Purpose of compressive strength test is to determine the compressive strength capacity of hardened concrete. The compressive strengths were determined for C-25 grade of concrete with different percentage value of SBCF, such as 0%, 0.5%, 1% and 1.5%.

a) Cube without SBCF b) Cube with 1% SBCF

Figure 4.2 Effect SBCF on compressive strength of concrete

The compressive strength of concrete was determined by dividing the compressive force to the contact area of cube specimen. This test was done for 7, 14 and 28 days of curing time, for each testing days 3 cube specimens were tested, as listed in Table 4.2 below.

Table 4.2 Mean compressive strength of C-25 grade concrete

SBCF percentage	No. Specimens	Mean compressive strength of concrete (Mpa.)		
		7 days	14 days	28 days
0%	3	24.88	29.93	32.36
0.50%	3	26.95	28.20	32.70
1%	3	27.06	31.47	33.28
1.50%	3	26.34	31.07	33.12

The compressive strength test of 7 days concrete stated in Table 4.2 shows that, when the percentage value of SBCF increases the compressive strength of the concrete also increases. Addition of 0.5%, 1% and 1.5% SBCF increased the compressive strength of C-25 grade of concrete by 8.32%, 8.76% and 5.87% respectively as compared to 0% SBCF concrete for 7 days of testing. From different percentage value of SBCF dosage 1% showed, see figure 4.3 below, a good result to enhance the compressive strength of reinforced concrete compared to other percentage value of SBCF.

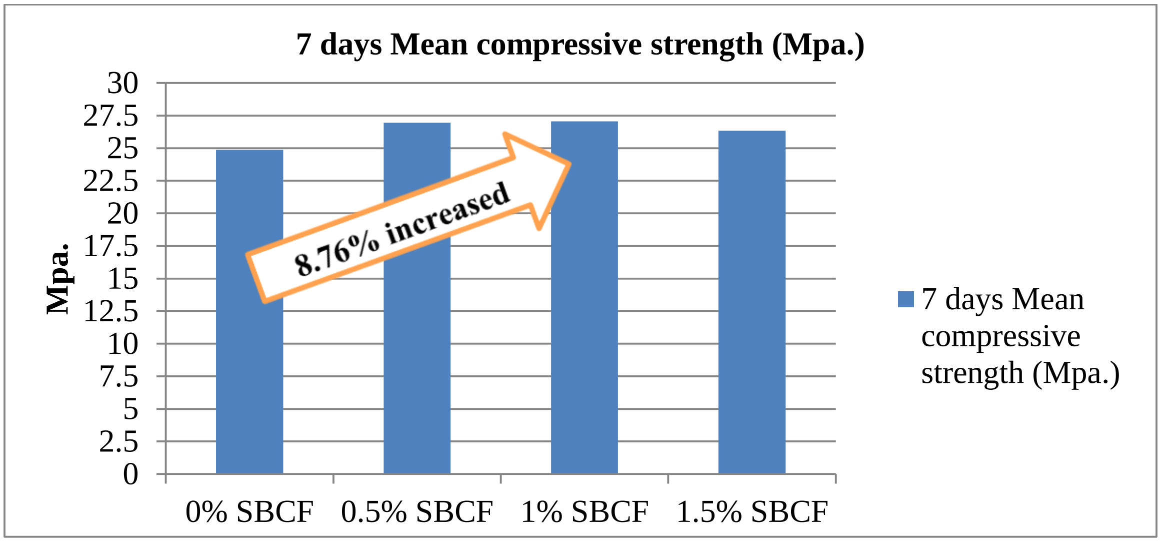


Figure 4.3 Comparison of 7days mean compressive strength

The compressive strength of 14 days concrete quantified in Table 4.2 shows a little bit decreasing of compressive strength value for 0.5% SBCF as compared to the controlled concrete, this is may be the cubes were not properly compacted, but the compressive strength started to increase for 1% and 1.5% SBCF addition. Addition of 1% and 1.5%

SBCF increased the compressive strength of concrete by 5.15% and 3.81% respectively compared to 0% SBCF concrete. From different percentage value of SBCF 1% showed a good result compared to others to increase the compressive strength of reinforced concrete.

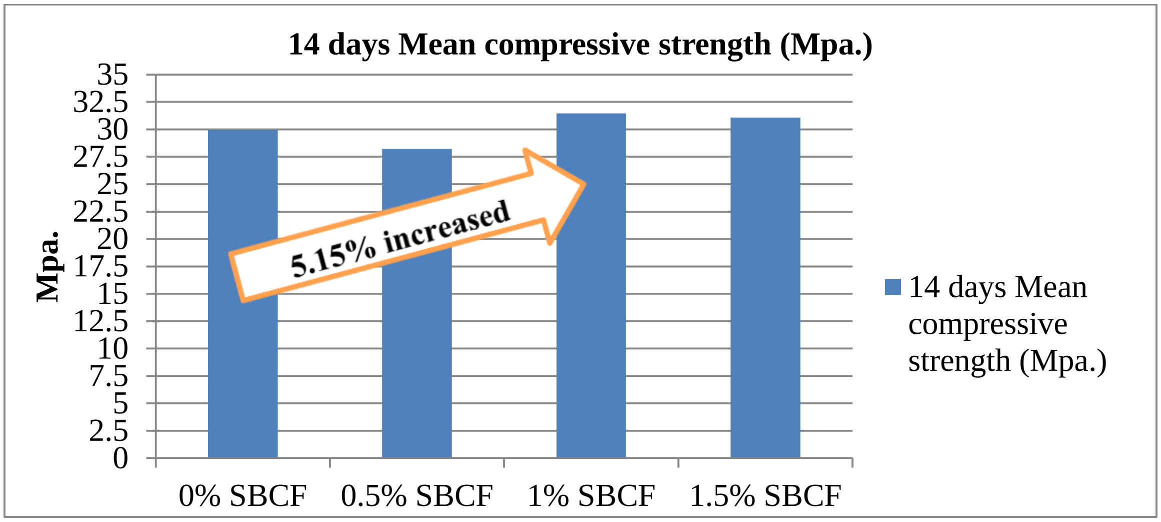


Figure 4.4 Comparison of 14 days mean compressive strength

The compressive strength of 28 days of concrete as stated in Table 4.2 was also increased when the SBCF percent were increased. Addition of 0.5%, 1% and 1.5% SBCF in the concrete increased the compressive strength the concrete by 1.05%, 2.84% and 2.35% respectively as compared to 0% SBCF concrete. From different percentage value of SBCF 1% again showed a good result compared to others percentage value to increase the compressive strength of reinforced concrete for 28 days of test, See Figure 4.5.

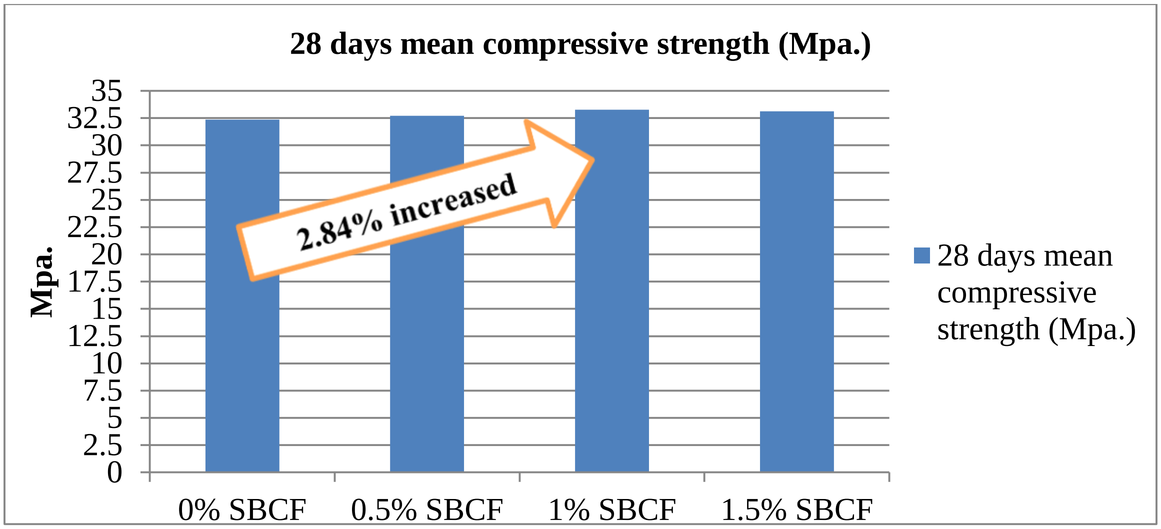


Figure 4.5 Comparison of 28 days mean compressive strength

The above figures, Figure 4.3, 4.4, and 4.5, shows that when the curing time was increased, the compressive strength of SBCF concrete decreases. For example, for 1% SBCF concrete the 7 day compressive strength test result compared with the controlled concrete was increased by 8.76%, for 14 day testing by 5.15% and for 28 day of testing by 2.84% which is decreasing. This indicates when the curing time increases the strength of 0% SBCF concrete increases rapidly than that of 0.5%, 1% and 1.5% SBCF concrete. Figure 4.6 shows the compressive strength comparisons of SBCF concrete.

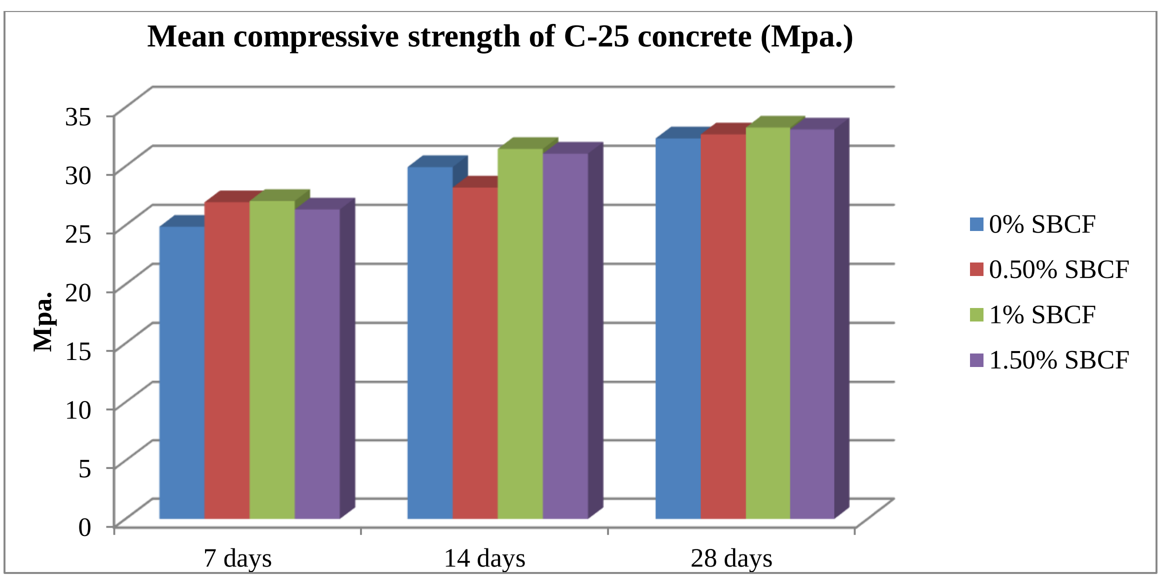


Figure 4.6 Mean compressive strength of C-25 grade of concrete

4.3 Effect of SBCF on the split tensile strength of concrete

Split tensile strength of concrete is indirect method of checking concrete tensile capacity. It is well-known that concrete is weak in tension as compared to its compressive strength capacity. Mostly the tensile capacity of concrete is 8% to 12% of its compressive strength. Therefore, in order to enhance this weakness of concrete various materials are added in the concrete as fiber, one of that is adding steel fiber.

SBCF were used as steel fiber to check its effect on the tensile strength capacity of concrete. To study the effects of SBCF different percentage values were added in the concrete, such as 0.5%, 1% and 1.5% by total weight of concrete and their test results were compared with the control concrete that has 0% SBCF. Three sample specimens were used for each curing and testing days, such as for 7, 14 and 28 days. The mean split tensile strength values of C-25 grade of concrete were quantified in Table 4.3 below.

Table 4.3 Mean tensile strength of C-25 grade concrete

SBCF percentage	No. Specimens	Mean Split tensile strength (Mpa)		
		7 days	14 days	28 days
0%	3	3.25	3.95	4.72
0.50%	3	3.75	4.13	4.88
1%	3	3.4	4.09	4.78
1.50%	3	3.31	4.08	4.38

Figure 4.7 shows effect of SBCF addition on C-25 grade of concrete. The figure shows that concrete which has no SBCF in it was spilt in to two, this is because the specimen does not have steel fiber that holds the concrete together, but concrete that has SBCF was not split in to two because of the SBCF.

A, Concrete without SBCF

B, Concrete with 0.5% SBCF

Figure 4.7 Effect of SBCF on tensile strength of concrete

As quantified in Table 4.3 the 7 day test result indicates that addition of SBCF in the concrete increased the tensile strength of concrete by making the concrete to hold together, and the best value was obtained when 0.5% of SBCF by total weight of concrete was added in to the concrete. Addition of 0.5% SBCF increased the tensile strength of concrete by 15.38% as compared to the controlled concrete, which has 0% SBCF. Figure 4.8 shows the tensile strength comparison for different percentage value of SBCF.

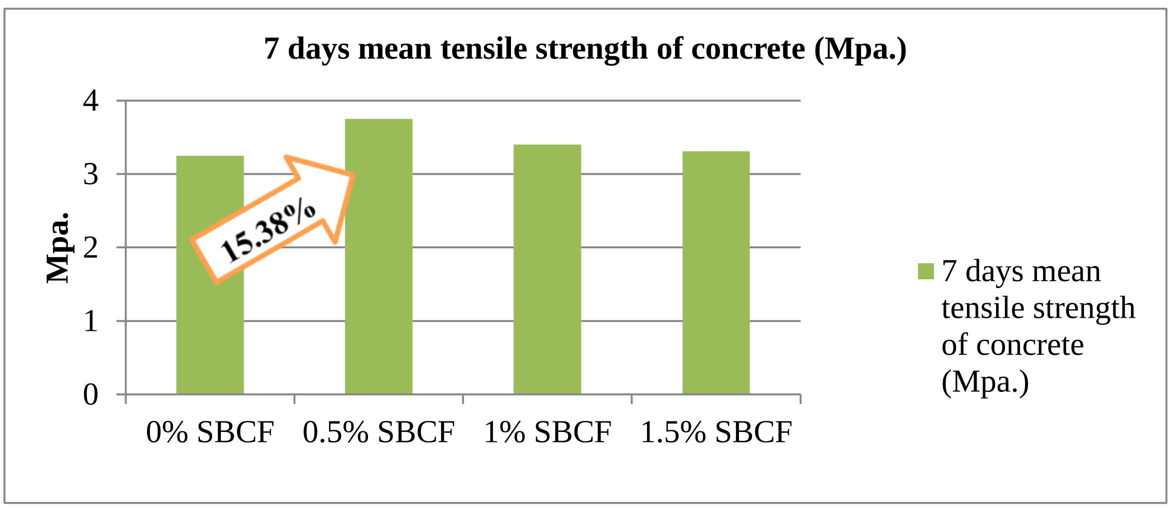


Figure 4.8 Comparison of 7 days mean split tensile strength

The tensile strength of 14 day concrete test suggests that; if addition of SBCF in a concrete is increased, the tensile strength of concrete would also increases. This is because by holding the concrete together the SBCF increases the load carrying capacity of a concrete. But, if more than 0.5% of SBCF is added in the concrete, the tensile strength of concrete starts to decrease slightly. This is because when the quantity of SBCF in the concrete mix increases the contact area of the concrete ingredients between them, which gives a good bondage, decreases. Good enhancement in tensile strength was obtained when addition of 0.5% SBCF in the concrete was used. This value increased the tensile strength of the concrete by 4.56% as compared to the controlled concrete, which has 0% SBCF. Figure 4.9 below shows the tensile strength of different SBCF concrete.

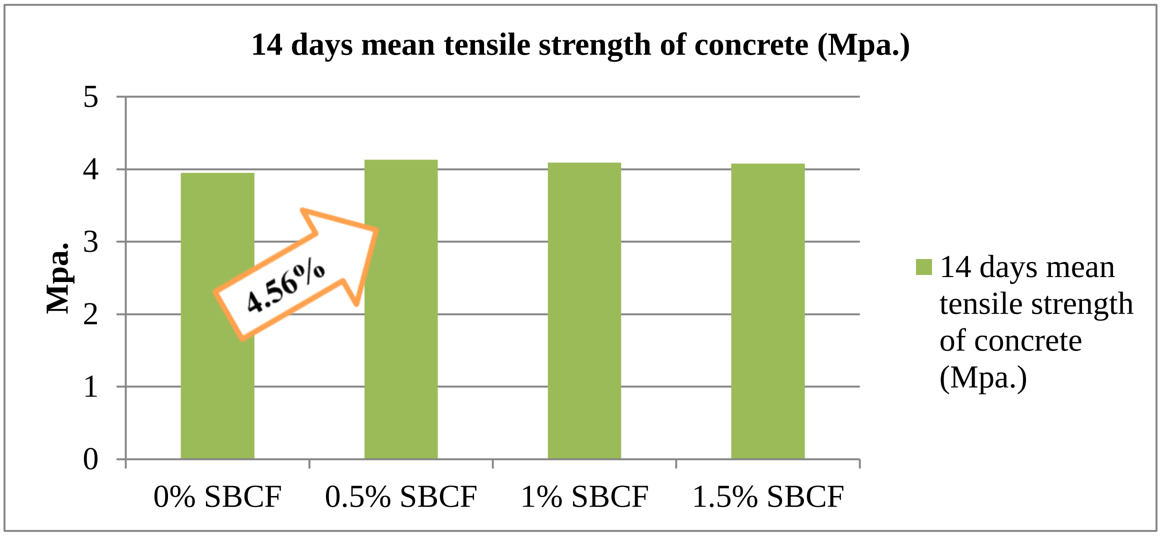


Figure 4.9 Comparison of 14 days mean split tensile strength

The 28 days test result as stated in Table 4.3 indicates that addition of SBCF up to 0.5% dosage increases the tensile strength of concrete well, but when the percentage value of SBCF was increased beyond 0.5%, such as for 1% and 1.5%, the tensile strength of concrete starts to decrease as compared to 0.5% SBCF concrete test result. The tensile strength of 1.5% SBCF concrete is even less than that of 0% SBCF concert as seen in the Figure 4.10. This is because when the percentage value of SBCF and curing time increased the bond strength and the contact area of the concrete ingredient decreases.

This research paper result showed that addition of 0.5% SBCF in the concrete increased the tensile strength of concrete by 3.39% as compared to the controlled concrete which has no SBCF in it.

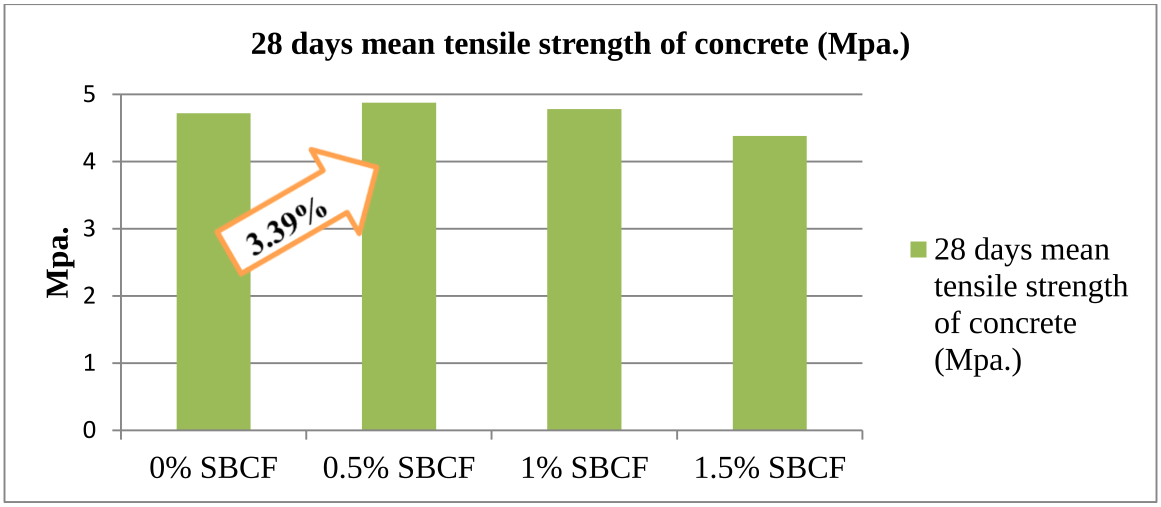


Figure 4.10 Comparison of 28 days mean split tensile strength

Therefore, addition of SBCF, by total weight of concrete, in the concrete mix increased the split tensile strength of concrete as compared to the controlled concrete. But when the percentage value of SBCF, beyond 1%, and curing time of concrete increased, the split tensile strength of concrete decreased as seen for 1.5% SBCF for 28 days of testing. Figure 4.11 below shows the comparison split tensile strength for different SBCF concrete for different curing and testing time.

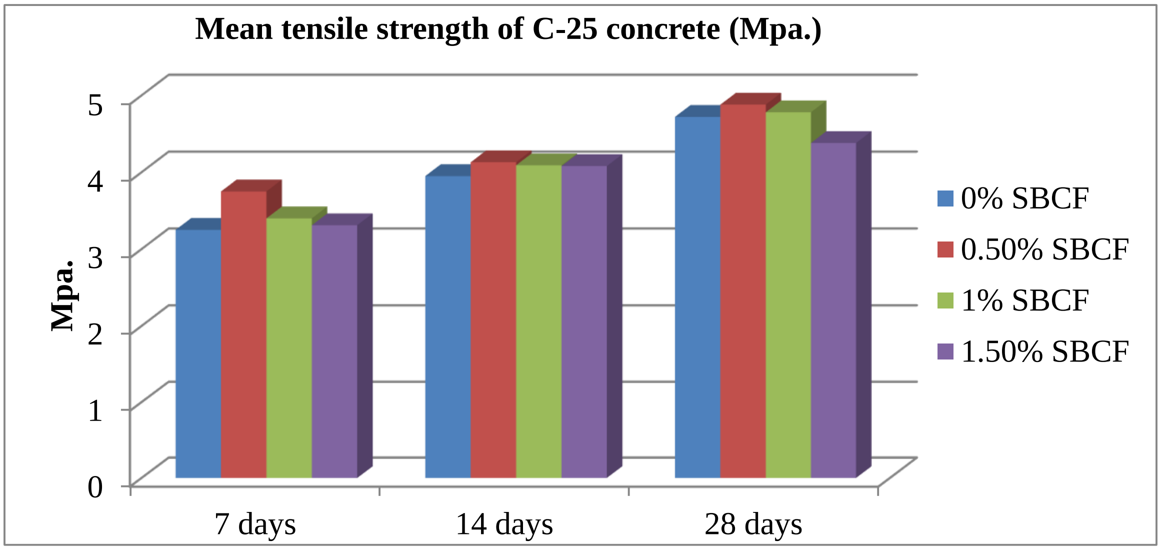


Figure 4.11 Mean tensile strength of C-25 grade of concrete

4.4 Effect of SBCF on the flexural strength of concrete

Flexural strength of concrete is used to check the concrete load resisting capacity, which will be induced on it, without going excess deformation or producing excess cracks. Concrete that has no reinforcement to resist flexural stress has low capacity of flexural stress. Therefore, in order to resist the induced flexural stress on the concrete; reinforcement bar will be used inside the concrete and this materials works together and the combination of these two materials is called reinforced concrete. But concrete without reinforcement bar has low flexural stress capacity. Different researchers are now trying to overcome this weakness of concrete by adding different materials in the concrete as fiber; steel fiber is one of that.

By adding SBCF in the concrete with different percentage value this research paper investigates the effect of this fiber on the concrete flexural stress capacity. The different percentage values of SBCF used for this research were 0%, 0.5%, 1% and 1.5% by total weight of concrete. The effects of this fiber on the C-25 grade of concrete were studied for 7, 14 and 28 days of curing and testing time by using 3 beams of 100x100x500mm for each testing days, see table 4.4 below.

Table 4.4 Mean flexural strength of C-25 grade concrete

SBCF percentage	No. Specimens	Mean Flexural strength (Mpa.)		
		7 days	14 days	28 days
0%	3	6.31	6.33	6.53
0.50%	3	6.41	6.57	6.62
1%	3	6.60	6.79	6.92
1.50%	3	6.48	6.68	6.72

Figure 4.12 shows the effect of SBCF addition on the concrete flexural strength. The concrete beam that has no SBCF in it to resist the applied load showed a brittle characteristic. Because of this the beam cannot resist the applied load effectively and as seen in the Figure 4.12 the beam will crack widely and fail totally. But the concrete beam that has SBCF showed a good ductile property because of this its crack and deflection was very small and did not failed by the applied load totally.

A, Beam without SBCF   B, Beam with 1% SBCF

Figure 4.12 Effect of SBCF on flexural strength test of concrete

As quantified in Table 4.4 the addition of SBCF in the concrete enhanced the flexural capacity of the concrete. The 7 day test indicated that when percentage of SBCF increases the flexural strength of the concrete also increases. The addition of 0.5%, 1% and 1.5% of SBCF, for the 7th day test, increased the concrete flexural strength capacity by 1.58%, 4.60% and 2.69% respectively as compared to the controlled concrete. Figure 4.13 shows the comparison of flexural strength for different SBCF concrete test.

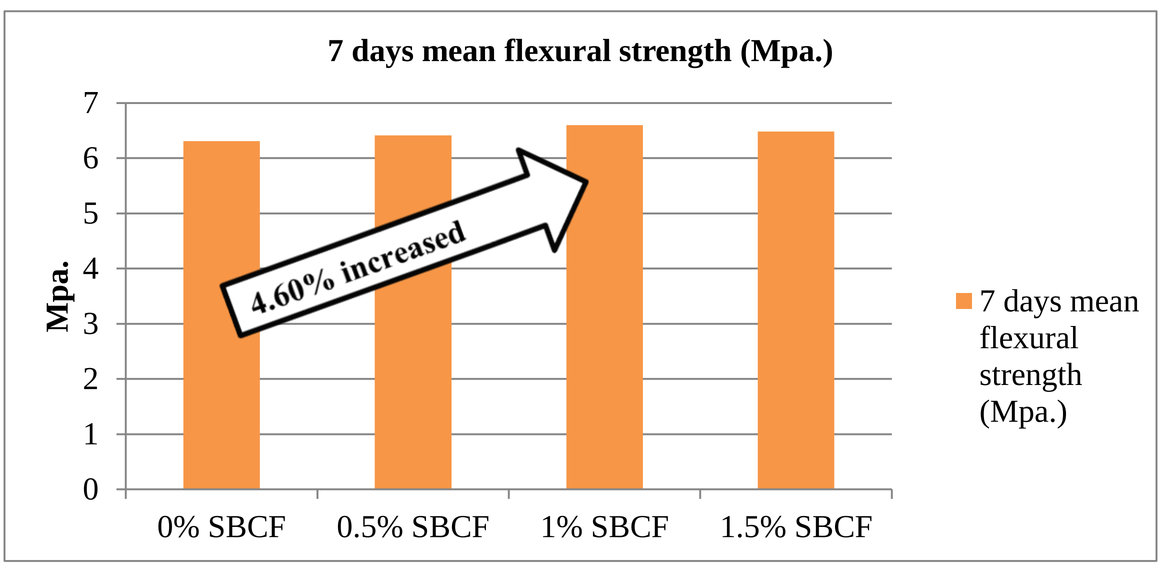


Figure 4.13 Comparison of 7 days mean flexural strength

The 14 day flexural strength test result stated in Table 4.4 of concrete shows that; concrete that has SBCF has more strength to resist the flexural stress induced on it than that of the concrete which has no SBCF. The addition of 0.5%, 1% and 1.5% SBCF in the C-25 grade of concrete enhanced the concrete flexural strength by 3.79%, 7.27% and 5.53% respectively as compared to the controlled concrete, as seen in the Figure 4.14.

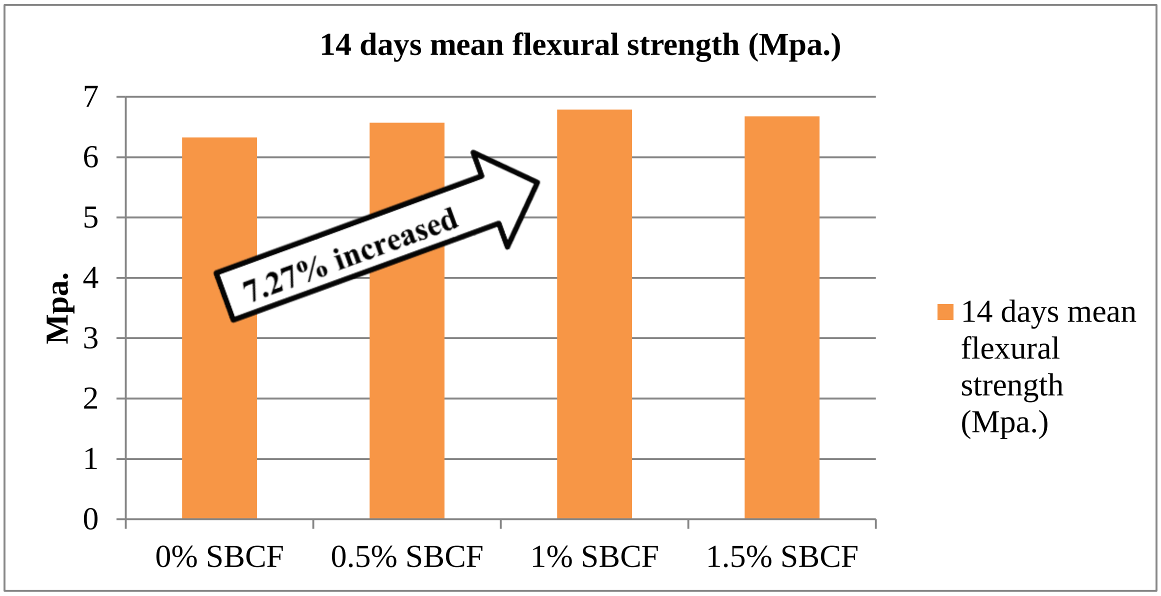


Figure 4.14 Comparison of 14 days mean flexural strength

Also the 28 day flexural strength test result stated in Table 4.4, shows that addition of different percentage value of SBCF, by total weight of concrete, increases the flexural strength of concrete. The addition of 0.5%, 1% and 1.5% SBCF in the concrete mix increased the flexural capacity of C-25 grade of concrete by 1.38%, 5.97% and 2.91% respectively as compared to the controlled concrete that has 0% SBCF in its mix, see Figure 4.15.

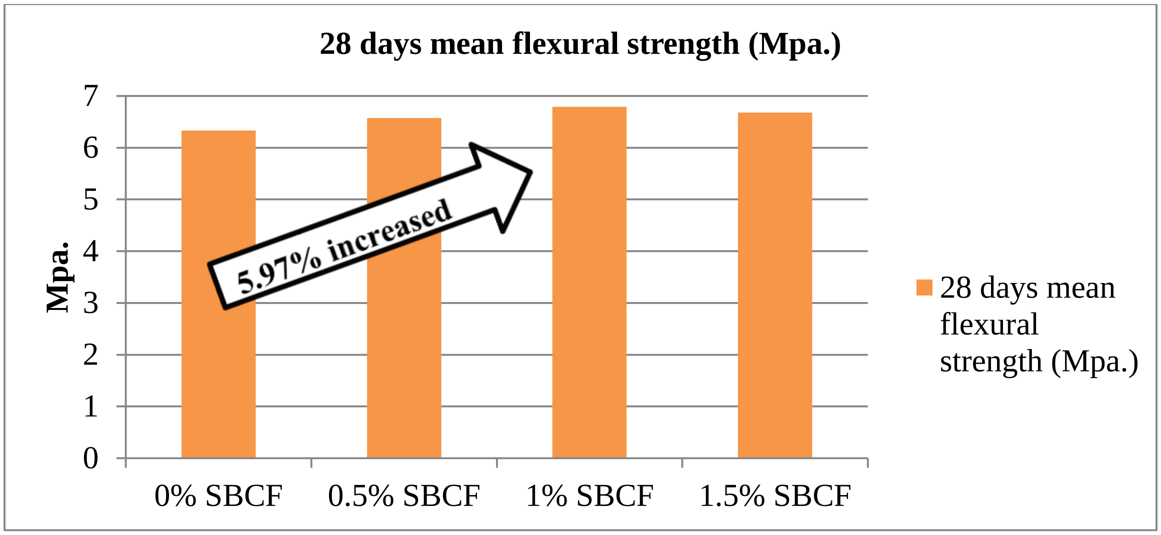


Figure 4.15 Comparison of 28 days mean flexural strength

Generally, as shown in table 4.4, if the SBCF percent in the concrete increases the flexural strength of concrete also increases. In other words, addition of SBCF in concrete also increases the deflection capacity of concrete by enhancing the ductility of concrete by making the concrete to hold together even after crack was produced. Figure 4.16 shows comparison of flexural strength for different SBCF concrete.

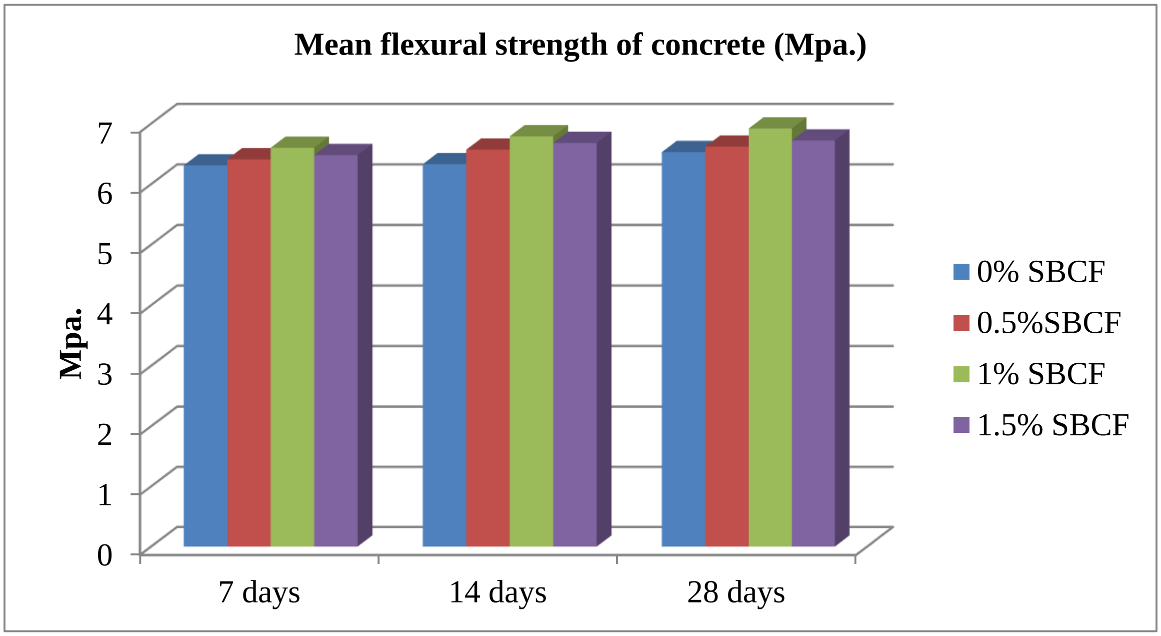


Figure 4.16 Mean flexural strength of C-25 grade of concrete

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study was made by adding different percentage value SBCF, such as 0%, 0.5%, 1% and 1.5% by the total weight of concrete, to check its effect on the concrete capacity. Its effects were studied on the workability and mechanical properties of concrete, namely, compressive strength, split tensile strength and flexural strength of concrete. By interpreting the results obtained from lab, the following conclusions are stated;

- ✓ According to lab result, addition of 0.5%, 1% and 1.5% SBCF in the concrete mix decreases the workability of the concrete by interlocking the concrete paste together.
- ✓ The results of this research paper shows that addition of 0.5%, 1% and 1.5% SBCF in the concrete, increases the compressive strength of concrete as compared to the controlled concrete. But from these percentage value of SBCF, addition of 1% SBCF in the concrete increased the compressive strength of concrete by 2.84% as compared to the controlled concrete.
- ✓ According to the observed result, addition of SBCF in the concrete increases tensile strength of concrete by holding the concrete materials together. This fiber gives additional strength for the concrete to resist the applied split force on it, but when the percentage of SBCF increased the tensile strength of concrete starts to decrease slightly. Despite the decreasing of concrete tensile strength, when the percentage of SBCF exceed 0.5%, addition of SBCF in the concrete made the concrete more ductile to resist deflection and additional load even after crack was produced. But from the other percentage value of SBCF 0.5% SBCF increased the split tensile strength of concrete by 3.39% as compared to the controlled concrete. This is because; if the value of SBCF added in the concrete is small, the concrete materials will have enough contact area to form good bondage and the binding material will have sufficient spaces to contact with aggregates.

- ✓ This study also concluded that, addition of 0.5%, 1% and 1.5% SBCF increased the flexural strength of the concrete. Especially addition of 1% SBCF in the concrete increased the flexural strength of concrete by 5.97% as compared to the controlled concrete.
- ✓ And also addition of these SBCF in the concrete mix made the concrete more ductile than that of the controlled concrete.

5.2 Recommendations

Based on what was obtained in this study the following recommendations are made;

1. Addition of super plasticizer or water will enhance the workability of concrete.
2. Even though addition of 0.5% SBCF in the concrete for split tensile strength showed a better result than 1% SBCF, this research paper recommends using of 1% SBCF for all concrete tests; this is because addition of 1% SBCF in the concrete showed a good result for compressive and flexural strength.
3. Beside the enhancement of mechanical properties of concrete this research paper recommends to uses SBCF in a concrete to reduce the adverse impacts of this solid waste material on the environment by reducing the energy and greenhouse gasses that will be produce when recycling of these waste materials are made. And also it will be used as a good disposing method for these solid wastes.

5.3 Further studies

1. This study was only made for C-25 grade of concrete using OPC cement and local aggregate materials obtained from Jimma town; therefore, other researchers can do this type of research for high strength concrete with different cement and aggregate materials.
2. They can also study the effect of this SBCF on the workability point of view by using different admixtures to optimize the workability of the concrete and also on the process they can check the effect of this admixture on the concrete strength.
3. This study will extend further to check the effect of SBCF addition on the deflection capacity of concrete and stress-strain diagram of concrete.

REFERENCES

[1] Christian, S., Patel, K., Vasava, M., Vasava, P. And Purohit, S. Evaluating Strength of Concrete Using Bottle Caps and PET. Journal of Advance Engineering and Research Development. 2017; 4(3).

[2] Shah, A.A. And Ribakov, Y. Recent Trends in Steel Fibered High Strength Concrete. ELSEVIER. 2011; 32:4122-4151.

[3] Ishaiba, A.A. Mechanical Properties of Concrete Using Recycled Plastics. 2015.

[4] Rathod, S.T., Banker, L.R., Hakepatil, U.R., Vhanamane, M.M. and Warpe, S.S. Utilization of Bottle Caps in Concrete. International Journal of Engineering Research & Science (IJOER). 2017; 3(6):29-32.

[5] Nishane, U.R. And Thakare, N.U. Experimental Studies On Fiber Reinforced Concrete. International Journal of Engineering Research and Application. 2017: 7(5):40-44.

[6] Wong, C.M. Use of Short Fibers in Structural Concrete to Enhance Mechanical Properties. 2004.

[7] Garg, H., Suman, S., Jain, A., Srivastava, S.P., Bhadauria, S. And Sohoni, V.S. Study on the Properties of Concrete Using Waste Bottle Caps as Ingredient. International Research Journal of Engineering and Technology (IRJET). 2017; 04(05):1861-1867.

[8] Ravinder, K. Strength Characteristics of Coca-Cola Tin Waste as Fibers In Concrete. International Journal of Advanced Research Foundation. 2016; 3(2):9-12.

[9] Kumar .P.A, And Parashar, R. The Effect of Size of Fibres on Compressive Strength of M-20 Concrete Mix. International Journal of Engineering Research and Applications (IJERA). 2012; 2(4):1232-1236.

[10] Arunakanthi, E. And Kumar, J.D.C. Experimental Studies on Fiber Reinforced Concrete (FRC). International Journal of Civil Engineering and Technology (IJCIET). 2016; 7(5):329-336.

[11] Murali, G., Vardhan, C.M.V. And Charmily, P. Influence of Steel Fiber on Concrete. International Journal of Engineering Research and Applications. 2012; 2(3):75-78.

[12] Isojeh, B., El-Zeghayar, M. And Vecchio, F.J. Fatigue Resistance Of Steel Fiber-Reinforced Concrete Deep Beams. ACI Structural Journal. 2019: 114(99):1215-1226.

[13] Akhund, M.A., Sannd, A., Memon, U. And Oad, S.J. Utilization Of Soft Drink Tins As Fiber Reinforcement In Concrete. Engineering Science and Technology International Research Journal. 2017; 1(1):1-7.

[14] Joseph, J.A., Saji, B.A., Gideon, R.A., Sanchuna, J.A. And Sivadharani, V.S.I. Experimental Investigation of Steel Fiber Reinforced Concrete With Partial Replacement of Coarse Aggregate By Waste Plastic Bottle Caps. International Journal of Innovative In Science, Engineering and Technology. 2018; 7(5):95-100.

[15] Reddy, T.V.T., Kumara, S.S.A., Ranjith, B., Kumar, M.K.P And Ranju, K.N.G. Reducing Environmental Impact Of Metal Bottle Crown Caps By Reusing Them As Fibers In Concrete. International Conference on "Recent Trends in Environmental Science and Engineering" (RTESE'17), APSCE, Bengaluru, India. 2017; 351-355.

[16] Www. https://en.m.wikipedia.org/wiki/Jimma, accessed on 25 March, 2019.

[17] Www.https://theconstructor.org/building/aggregate-specific-gravity-water absorption-test/1358/, accessed on 11 April, 2019.

[18] Dinku, A., Construction Materials Laboratory Manual, Addis Ababa University, June 2002

APPENDIX 1

MATERIALS TEST RESULTS

1.1 Sand or fine aggregate properties

1.1.1 Silt content

- ✓ Before the sand was washed

Volume of sample sand taken = V_1 = 50ml

Volume of sample sand + water = V_2 = 187.5ml

Silt content 1 = 2.75ml

Silt content 2 = 3.5ml

Avg. silt content = (2.75+3.5)/2 = 3.125ml

$$\text{Silt content \%} = \frac{(Avg.silt\ content)}{V_1} * 100 = \frac{3.125ml}{50ml} * 100 = 6.25\%$$

- ✓ After the sand was washed

Mass taken = M_a = 1000grm

Oven dried mass = M_o = 955grm

$$\text{Silt content \%} = \frac{(M_a - M_o)}{M_a} * 100 = \frac{(1000 - 955)grm}{1000grm} * 100 = 4.5\%$$

1.1.2 Moisture content

Mass taken = A = 500grm

Oven dried mass = B = 495 grm

$$Moisture\ content\ \% = \mu = \frac{(A - B)}{B} * 100 = \frac{(500 - 495)}{495} * 100 = 1.01\%$$

1.1.3 Unit weight

Passed mass of sieve size of 4.75mm was taken for the analysis purpose.

- ✓ Data taken

Mass of sample + cylinder = A = 8194.5 grm

Mass of cylinder = B = 1055 grm

Mass of sample = C = (A – B) = 7139.5 grm

Volume of cylinder = V_{cy} = 5 litter

$$Unit\ weight = \gamma_s = \frac{Mass\ of\ sample\ (grm)}{Volume\ of\ cylinder\ (lit.)} = \frac{C}{Vcy} = \frac{7139.5\ grm}{5\ lit.} = 1427.9\frac{Kg}{m^3}$$

1.1.4 Sieve analysis

Mass taken for sieve analysis test was 2000 grm

sieve size (mm)	mass retained (grm)	Percentage retained %	Percentage pass %	Cumulative % retained	Cumulative % pass
9.5	0	0	100	0	100
4.75	0	0	100	0	100
2.36	171	8.55	91.45	8.55	91.45
1.18	437.5	21.875	78.125	30.425	69.575
0.6	865	43.25	56.75	73.675	26.325
0.3	413	20.65	79.35	94.325	5.675
0.15	85	4.25	95.75	98.575	1.425
Pan	28.5	1.425	98.575	100	0
Total	2000				

1.1.5 Specific gravity and absorption capacity

Mass of sand taken		500	grm
oven dried mass	A	497	grm
Pycnometer + water + sand	B	1846	grm
Pycnometer + water	C	1554	grm

- ✓ Apparent Specific. Gravity

$$Appt.sp.gr. = \frac{A}{(C + A - B)} = \frac{497}{(1554 + 497 - 1846)} = 2.42$$

- ✓ Bulk Specific Gravity (oven dried)

$$Bulk\ sp.gr.OD = \frac{A}{(C + 500 - B)} = \frac{497}{(1554 + 500 - 1846)} = 2.39$$

- ✓ Bulk Specific Gravity (Saturated surface dry)

$$Bulk\ sp.gr.SSD = \frac{500}{(C + 500 - B)} = \frac{500}{(1554 + 500 - 1846)} = 2.40$$

- ✓ Absorption capacity

$$Abson.capacity\ \% = \frac{(500 - A)}{A} * 100 = \frac{(500 - 497)}{497} * 100 = 0.6\%$$

1.2 Gravel or Coarse aggregate properties

1.2.1 Moisture content

Mass taken = A = 2000 grm

Oven dried mass = B = 1979 grm

$$Moisture\ content\ \% = \mu = \frac{(A - B)}{B} * 100 = \frac{(2000 - 1979)}{1979} * 100 = 1.06\%$$

1.2.2 Unit weight

Retained mass of sieve size of 4.75mm was taken for analysis purpose.

- ✓ Data taken

Mass sample + cylinder = A = 17904 grm

Mass of cylinder = B = 1683 grm

Mass of sample = C = (A-B) = 16221 grm

Volume of cylinder = Vcy = 10 litter

$$Unit\ weight = \gamma_g = \frac{Mass\ of\ sample\ (grm)}{Volume\ of\ cylinder\ (lit.)} = \frac{C}{Vcy} = \frac{16221\ grm}{10\ lit.} = 1622.1\frac{Kg}{m^3}$$

1.2.3 Sieve analysis

Mass taken for sieve analysis test was 5000 grm.

Sieve size (mm)	Mass retained (grm)	Percentage retained %	Percentage pass %	Cumulative % retained	Cumulative % pass
37.5	0	0	100	0	100
28	48.5	0.97	99.03	0.97	99.03
19	956	19.12	80.88	20.09	79.91
12.5	2323	46.46	53.54	66.55	33.45
9.5	892	17.84	82.16	84.39	15.61
4.75	753	15.06	84.94	99.45	0.55
Pan	26.5	0.53	99.47	99.98	0.02
Total	4999				

1.2.4 Specific gravity and absorption capacity

Mass of gravel taken		2000	grm
Aggregate + wire basket in water		1165	grm
Aggregate + wire basket in water (after 24 hrs. of soaking)		1732	grm
Basket wire mass in water		464	grm
Mass of aggregate in water	C = 1732 - 464	1268	grm
Saturated surface dried mass	B	2005	grm
Oven dried mass	A	1995	grm

- ✓ Apparent Specific. Gravity

$$Appt.sp.gr. = \frac{A}{(A - C)} = \frac{1995}{(1995 - 1268)} = 2.74$$

- ✓ Bulk Specific Gravity (oven dried)

$$Bulk\ sp.gr.OD = \frac{A}{(B - C)} = \frac{1995}{(2005 - 1268)} = 2.71$$

- ✓ Bulk Specific Gravity (Saturated surface dry)

$$Bulk\ sp.gr.SSD = \frac{B}{(B - C)} = \frac{2005}{(2005 - 1268)} = 2.72$$

- ✓ Absorption capacity

$$Abson.capacity\ \% = \frac{(B - A)}{A} * 100 = \frac{(2005 - 1995)}{1995} * 100 = 0.5\%$$

APPENDIX 2

EXPERIMENTAL RESULTS

2.1 Effects of different percentage of SBCF on C-25 grade of concrete

2.1.1 Compressive strength

Compressive strength of C-25 concrete 0% SBCF											
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (cm)			Volume (cm3)	Weight (grm)	Failure load (kN)	Comp. Strength (Mpa.)	Unit weight (grm/cm3)
				L	W	H					
1	7	0.5	27.5	15	15	15	3375	8350.5	539.56	23.98	2.47422
2				15	15	15	3375	8316	563.26	25.03	2.464
3				15	15	15	3375	8067	576.42	25.62	2.39022
Mean								8244.5	559.7467	24.8767	2.44281
1	14	0.5	27.5	15	15	15	3375	8240	688.16	30.59	2.44148
2				15	15	15	3375	8284	576.65	25.64	2.45452
3				15	15	15	3375	8464	754.79	33.55	2.50785
Mean								8329.33	673.2	29.9267	2.46795
1	28	0.5	27.5	15	15	15	3375	8048	729.4	32.42	2.38459
2				15	15	15	3375	8498	634.28	28.19	2.51793
3				15	15	15	3375	8259	820.41	36.47	2.44711
Mean								8268.33	728.03	32.36	2.44988

Compressive strength of C-25 concrete 0.5% SBCF											
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (cm)			Volume (cm3)	Weight (grm)	Failure load (kN)	Comp. Strength (Mpa.)	Unit weight (grm/cm3)
				L	W	H					
1	7	0.5	21.5	15	15	15	3375	8544	628.425	27.93	2.53156
2				15	15	15	3375	8256	564.56	25.1	2.44622
3				15	15	15	3375	8394	626.08	27.83	2.48711
Mean								8398	606.355	26.9533	2.4883
1	14	0.5	21.5	15	15	15	3375	8399	631.6	28.09	2.48859
2				15	15	15	3375	8414	628.48	27.94	2.49304
3				15	15	15	3375	8078	642.51	28.56	2.39348
Mean								8297	634.1967	28.1967	2.45837
1	28	0.5	21.5	15	15	15	3375	8634	693.12	30.81	2.55822
2				15	15	15	3375	7970	800.36	35.58	2.36148
3				15	15	15	3375	8187	713.46	31.72	2.42578
Mean								8263.67	735.6467	32.7033	2.44849

Compressive strength of C-25 concrete 1% SBCF											
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (cm)			Volume (cm3)	Weight (grm)	Failure load (kN)	Comp. Strength (Mpa.)	Unit weight (grm/cm3)
				L	W	H					
1	7	0.5	15	15	15	15	3375	8663	609.18	27.08	2.56681
2				15	15	15	3375	8426	625.91	27.82	2.49659
3				15	15	15	3375	8545	591.52	26.29	2.53185
Mean								8544.67	608.87	27.0633	2.53175
1	14	0.5	15	15	15	15	3375	8761	766.35	34.06	2.59585
2				15	15	15	3375	8302	681.67	30.31	2.45985
3				15	15	15	3375	8525	675.98	30.04	2.52593
Mean								8529.33	708	31.47	2.52721
1	28	0.5	15	15	15	15	3375	8140	740.2	32.9	2.41185
2				15	15	15	3375	8153	696.96	30.99	2.4157
3				15	15	15	3375	8662	808.97	35.96	2.56652
Mean								8318.33	748.71	33.2833	2.46469

Compressive strength of C-25 concrete 1.5% SBCF											
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (cm)			Volume (cm3)	Weight (grm)	Failure load (kN)	Comp. Strength (Mpa.)	Unit weight (grm/cm3)
				L	W	H					
1	7	0.5	5	15	15	15	3375	8522	631.88	28.09	2.52504
2				15	15	15	3375	8475	541.36	24.06	2.51111
3				15	15	15	3375	8299	604.69	26.88	2.45896
Mean								8432	592.6433	26.3433	2.49837
1	14	0.5	5	15	15	15	3375	8371	657.78	29.24	2.4803
2				15	15	15	3375	8404	737.5	32.79	2.49007
3				15	15	15	3375	8308	701.89	31.19	2.46163
Mean								8361	699.0567	31.0733	2.47733
1	28	0.5	5	15	15	15	3375	8644	747.74	33.24	2.56119
2				15	15	15	3375	8417	683.16	30.37	2.49393
3				15	15	15	3375	8276	803.96	35.74	2.45215
Mean								8445.67	744.9533	33.1167	2.50242

2.1.2 Split tensile strength

Split tensile strength of C-25 concrete 0% SBCF									
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (m)		Surface area (m2)	Weight (grm)	Max. applied load (kN)	Split tensile Strength (Mpa)
				L	D				
1	7	0.5	27.5	0.2	0.1	0.0628	3724	106.5	3.39
2				0.2	0.1	0.0628	3740	98.1	3.12262
3				0.2	0.1	0.0628	3705	101.3	3.224479
Mean							3723	101.967	3.2457
1	14	0.5	27.5	0.2	0.1	0.0628	3800	129.7	4.128479
2				0.2	0.1	0.0628	3722	120.02	3.820355
3				0.2	0.1	0.0628	3756	122.5	3.899296
Mean							3759.33	124.073	3.949377
1	28	0.5	27.5	0.2	0.1	0.0628	3696	140.3	4.465888
2				0.2	0.1	0.0628	3682	133.28	4.242434
3				0.2	0.1	0.0628	3682	170.94	5.441189
Mean							3686.67	148.173	4.716504

Split tensile strength of C-25 concrete 0.5% SBCF									
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (m)		Surface area (m2)	Weight (grm)	Max. applied load (kN)	Split tensile Strength (Mpa)
				L	D				
1	7	0.5	21.5	0.2	0.1	0.0628	3736	129.9	4.134845
2				0.2	0.1	0.0628	3738	108.5	3.453662
3				0.2	0.1	0.0628	3758	115.3	3.670113
Mean							3744	117.9	3.752874
1	14	0.5	21.5	0.2	0.1	0.0628	3708	120.55	3.837226
2				0.2	0.1	0.0628	3701	128.42	4.087736
3				0.2	0.1	0.0628	3818	140.43	4.470026
Mean							3742.33	129.8	4.131662
1	28	0.5	21.5	0.2	0.1	0.0628	3753	160.16	5.098051
2				0.2	0.1	0.0628	3702	155.29	4.943034
3				0.2	0.1	0.0628	3725	144.83	4.610082
Mean							3726.67	153.427	4.883722

Split tensile strength of C-25 concrete 1% SBCF									
No.	Test age (days)	Water cement ratio	Slump height (mm)	Dimensions (m)		Surface area (m2)	Weight (grm)	Max. applied load (kN)	Split tensile Strength (Mpa)
				L	D				
1	7	0.5	15	0.2	0.1	0.0628	3831	115.6	3.679662
2				0.2	0.1	0.0628	3774	107.9	3.434564
3				0.2	0.1	0.0628	3719	97.1	3.090789
Mean							3774.67	106.867	3.401672
1	14	0.5	15	0.2	0.1	0.0628	3785	131.83	4.196279
2				0.2	0.1	0.0628	3734	129.63	4.126251
3				0.2	0.1	0.0628	3713	124.12	3.950862
Mean							3744	128.527	4.091131
1	28	0.5	15	0.2	0.1	0.0628	3827	141.27	4.496764
2				0.2	0.1	0.0628	3885	159.17	5.066538
3				0.2	0.1	0.0628	3833	149.6	4.761916
Mean							3848.33	150.013	4.775073

Split tensile strength of C-25 concrete 1.5% SBCF									
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (m)		Surface area (m2)	Weight (grm)	Max. applied load (kN)	Split tensile Strength (Mpa)
				L	D				
1	7	0.5	5	0.2	0.1	0.0628	3853	114.5	3.644648
2				0.2	0.1	0.0628	3675	101.3	3.224479
3				0.2	0.1	0.0628	3745	96.1	3.058958
Mean							3757.67	103.967	3.309362
1	14	0.5	5	0.2	0.1	0.0628	3762	120.23	3.82704
2				0.2	0.1	0.0628	3821	136.49	4.344612
3				0.2	0.1	0.0628	3799	127.55	4.060043
Mean							3794	128.09	4.077231
1	28	0.5	5	0.2	0.1	0.0628	3768	135.88	4.325195
2				0.2	0.1	0.0628	3713	127.07	4.044764
3				0.2	0.1	0.0628	3751	150.28	4.783561
Mean							3744	137.743	4.384506

2.1.3 Flexural strength

Flexural strength of C-25 concrete 0% SBCF												
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (m)			Weight (Kg)	P (kN)	M (kN.m)	I (m4)	C (m)	Stress (Mpa)
				L	B	D						
1	7	0.5	27.5	0.3	0.1	0.1	12.55	10.675	1.0675	8.3E-06	0.05	6.405
2				0.3	0.1	0.1	11.846	10.575	1.0575	8.3E-06	0.05	6.345
3				0.3	0.1	0.1	11.192	10.298	1.0298	8.3E-06	0.05	6.1785
Mean							11.8627	10.516	1.0516	8.3E-06	0.05	6.3095
1	14	0.5	27.5	0.3	0.1	0.1	11.699	10.6	1.06	8.3E-06	0.05	6.36
2				0.3	0.1	0.1	12.621	10.54	1.054	8.3E-06	0.05	6.324
3				0.3	0.1	0.1	11.342	10.513	1.0513	8.3E-06	0.05	6.3078
Mean							11.8873	10.551	1.0551	8.3E-06	0.05	6.3306
1	28	0.5	27.5	0.3	0.1	0.1	11.985	10.95	1.095	8.3E-06	0.05	6.57
2				0.3	0.1	0.1	11.749	10.98	1.098	8.3E-06	0.05	6.588
3				0.3	0.1	0.1	11.873	10.71	1.071	8.3E-06	0.05	6.426
Mean							11.869	10.88	1.088	8.3E-06	0.05	6.528

Flexural strength of C-25 concrete 0.5% SBCF												
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (m)			Weight (Kg)	P (kN)	M (kN.m)	I (m4)	C (m)	Stress (Mpa)
				L	B	D						
1	7	0.5	21.5	0.3	0.1	0.1	12.233	10.09	1.009	8.3E-06	0.05	6.054
2				0.3	0.1	0.1	12.238	10.78	1.078	8.3E-06	0.05	6.468
3				0.3	0.1	0.1	12.804	11.16	1.116	8.3E-06	0.05	6.696
Mean							12.425	10.68	1.068	8.3E-06	0.05	6.406
1	14	0.5	21.5	0.3	0.1	0.1	11.732	11.15	1.115	8.3E-06	0.05	6.69
2				0.3	0.1	0.1	12.198	11.83	1.183	8.3E-06	0.05	7.098
3				0.3	0.1	0.1	11.643	9.85	0.985	8.3E-06	0.05	5.91
Mean							11.8577	10.943	1.0943	8.3E-06	0.05	6.566
1	28	0.5	21.5	0.3	0.1	0.1	11.985	11.8	1.18	8.3E-06	0.05	7.08
2				0.3	0.1	0.1	12.255	10.48	1.048	8.3E-06	0.05	6.288
3				0.3	0.1	0.1	11.442	10.82	1.082	8.3E-06	0.05	6.492
Mean							11.894	11.033	1.1033	8.3E-06	0.05	6.62

Flexural strength of C-25 concrete 1% SBCF												
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (m)			Weight (Kg)	P (kN)	M (kN.m)	I (m4)	C (m)	Stress (Mpa)
				L	B	D						
1	7	0.5	15	0.3	0.1	0.1	12.426	11.43	1.143	8.3E-06	0.05	6.858
2				0.3	0.1	0.1	13.255	11.96	1.196	8.3E-06	0.05	7.176
3				0.3	0.1	0.1	11.683	9.6	0.96	8.3E-06	0.05	5.76
Mean							12.4547	10.997	1.0997	8.3E-06	0.05	6.598
1	14	0.5	15	0.3	0.1	0.1	12.913	10.87	1.087	8.3E-06	0.05	6.522
2				0.3	0.1	0.1	12.686	12.75	1.275	8.3E-06	0.05	7.65
3				0.3	0.1	0.1	12.753	10.32	1.032	8.3E-06	0.05	6.192
Mean							12.784	11.313	1.1313	8.3E-06	0.05	6.788
1	28	0.5	15	0.3	0.1	0.1	11.353	11.78	1.178	8.3E-06	0.05	7.068
2				0.3	0.1	0.1	11.363	11.23	1.123	8.3E-06	0.05	6.738
3				0.3	0.1	0.1	12.22	11.61	1.161	8.3E-06	0.05	6.966
Mean							11.6453	11.54	1.154	8.3E-06	0.05	6.924

Flexural strength of C-25 concrete 1.5% SBCF												
No.	Test age (days)	W/c	Slump height (mm)	Dimensions (m)			Weight (Kg)	P (kN)	M (kN.m)	I (m4)	C (m)	Stress (Mpa)
				L	B	D						
1	7	0.5	5	0.3	0.1	0.1	11.681	10.28	1.028	8.3E-06	0.05	6.168
2				0.3	0.1	0.1	12.833	11.59	1.159	8.3E-06	0.05	6.954
3				0.3	0.1	0.1	12.242	10.515	1.0515	8.3E-06	0.05	6.309
Mean							12.252	10.795	1.0795	8.3E-06	0.05	6.477
1	14	0.5	5	0.3	0.1	0.1	11.66	11.16	1.116	8.3E-06	0.05	6.696
2				0.3	0.1	0.1	11.416	10.87	1.087	8.3E-06	0.05	6.522
3				0.3	0.1	0.1	11.512	11.35	1.135	8.3E-06	0.05	6.81
Mean							11.5293	11.127	1.1127	8.3E-06	0.05	6.676
1	28	0.5	5	0.3	0.1	0.1	11.147	10.7	1.07	8.3E-06	0.05	6.42
2				0.3	0.1	0.1	12.846	11.16	1.116	8.3E-06	0.05	6.696
3				0.3	0.1	0.1	13.002	11.75	1.175	8.3E-06	0.05	7.05
Mean							12.3317	11.203	1.1203	8.3E-06	0.05	6.722

APPENDIX 3

SAMPLE PICTURES

Picture-1: Soaking and surface drying of coarse aggregate for specific gravity test

Picture-2: Specific gravity test for fine aggregate

Picture-3: Preparing coarse aggregate for unit weight test

Picture-4: Preparing fine aggregate for unit weight test

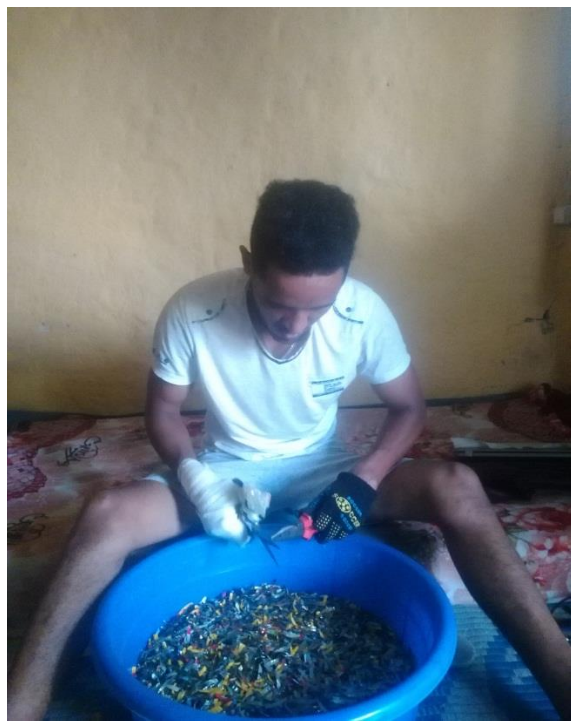
Picture-5: Washing of sand to check its silt content

Picture-6: Washed sand sample to be oven dried

A, Flattened SBC

B, Plastic cover of SBC

C, SBC after the plastic cover is removed



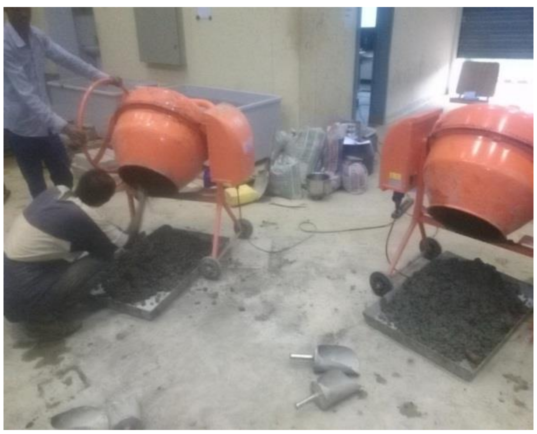
D, Cutting SBC to make fiber

Picture-7: SBCF preparation process

Picture-8: Washing and surface drying of aggregates

Picture-9: Dangote cement (OPC)

Picture-10: Concrete preparation (mixing of concrete)



A, Fresh concrete

B, Workability test of fresh concrete

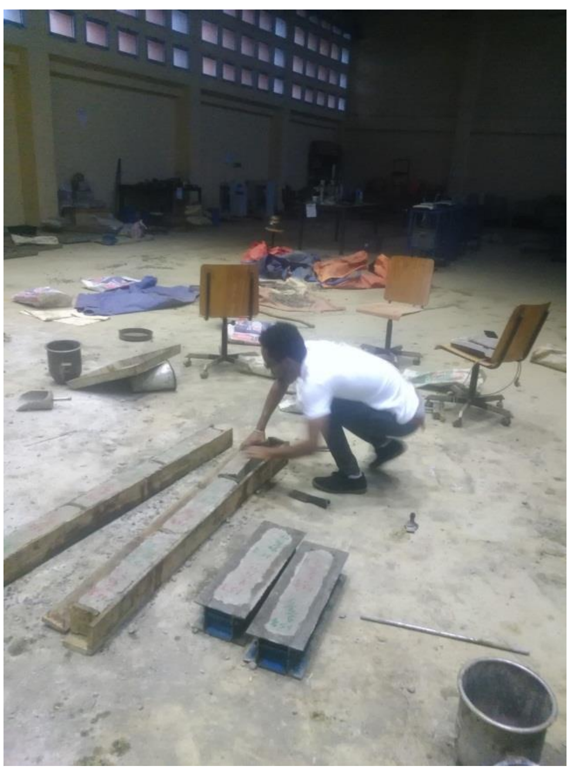
C, 0% SBCF concrete slump

D, 1.5% SBCF concrete slump

Picture-11: Slump test of fresh concrete

A, Oil coated molds

B, Casting of concrete specimen



C, Removing of formworks

D, Marking of concrete specimen

Picture-12: Preparation of concrete specimens for different tests

Picture-13: Curing of concrete specimens in tank

A, Measuring the weight of the specimen B, Drawing center line alight on specimen

Picture-14: Preparing the specimens for different test

A, 0% SBCF concrete

B, 1% SBCF concrete

C, 0% SBCF concrete

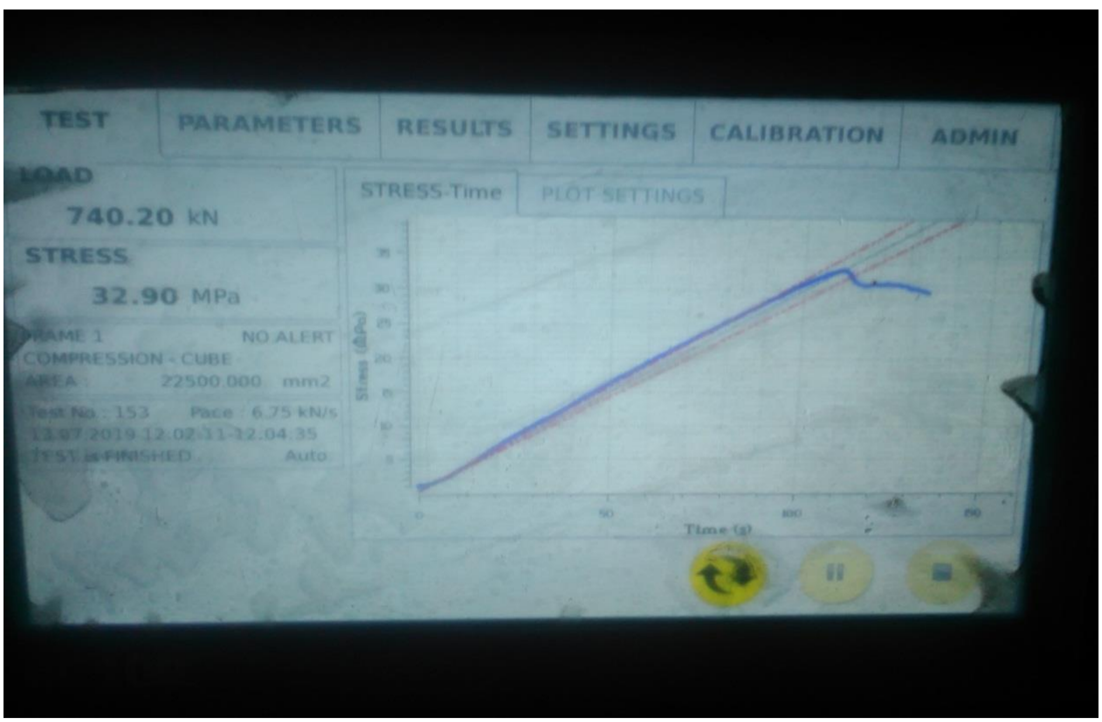
D, 1% SBCF concrete

E, 0% SBCF concrete

F, 1% SBCF concrete

Picture-15: Different concrete spcimen tests

Picture-16: 0% SBCF Compressive test (load (KN) vs. time (s) graph)



Picture-17: 1% SBCF Compressive test (load (KN) vs. time (s) graph)

❖ **Specification of steel bottle caps**

	Company Name: የኢትዮጵያ ቆርኪና ጣሳ ማምረቻ ኢንዱስትሪ አ.ማ. Ethiopian Crown Cork & Can Manufacturing Industry Share Company	Document No.: OF/ECCCMI/166
Revision. 2	Document Title: ደብዳቤ Letter	Page No: Page 1 of 1

ቀን/Date: 2 6 SEP 2019

ቁጥር/Ref. No. WE-1/9-37

JIMMA UNIVERSITY

Jimma Institue of Technoloogy

Faculty of Civil & Enviromental Enginnering

Structural Engineering Stream

Jimma

Regarding your letter ref. No. JJT/SE/100/2019 dated April 22, 2019, your student Ato Mikiyas Meka, RM0474/10 has asked our factory to verify the technical specification of the material from which bottle caps (Crown Cork) is produced.

Accordingly we would like to inform you that Steel Bottle Caps, we produce in our factory is made out of Tin free steel cut sheet ,steel MR Law carbon steel with carbon content 0.05% -0.13% coated with metallic chromium >30mg.m^2 & cromium oxide >5mg/m^2.. With this we remain.

Best Rgards

Yidenekal Elifnew
General Manager

ስልክ(PHONE): PBX 251-11-4390299, 4390332, 4390645-48; GM: 4390403; Sales: 4394095; Commercial 4392350; Production & Technic: 4390215; 4392348, Finance: 4392349; HR: 4391481 ፋክስ FAX: 251-11-4390216
ፖ.ሣ.ቁ. (P.O.BOX): 5501 E-MAIL: ecccma@ethionet.et ecccmisco@ethionet.et