JIMMA UNIVERSITY

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JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIROMENTAL ENGINEERING

STRUCTURAL ENGINEERING STREAM

EXPERIMENTAL STUDY ON STRENGTH CHARACTERISTICS OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY USING COFFEE HUSK ASH AND SUGARCANE BAGASSE ASH COMBINATION

A Research Submitted to School of Graduate Studies, Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Structural Engineering

By

MULIYE TAREKEGN GASHAW

June 2021

Jimma, Ethiopia

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DECLARATION

I declare that, this research entitled "EXPERIMENTAL STUDY ON STRENGTH CHARACTERISTICS OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY USING COFFEE HUSK ASH AND SUGARCANE BAGASSE ASH COMBINATION" is my original work and has not been presented by anyone for an award of degree at any university.

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As research Advisor, I hereby certify that I have read and evaluated this research paper prepared under any guidance, by Muliye Tarekegn Gashaw entitled "EXPERIMENTAL STUDY ON STRENGTH CHARACTERISTICS OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY USING COFFEE HUSK ASH AND SUGARCANE BAGASSE ASH COMBINATION'' recommend and would be accepted as a fulfilling requirement for the degree Master of Science in Structural Engineering.

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ABSTRACT

Concrete, as the world's most implemented construction material, is increasingly being used because of the rapid development of industrialization and urbanization. Limited resources and progressive depravation of the environment are forcing scientific efforts to seek alternative and effective materials from large amounts of natural resources as additives in the partial replacement of cement and Continuous generation of wastes arising from industrial by-products and agricultural residue, create acute environmental problems both in terms of their treatment and disposal. The construction industry has been identified as the one that absorbs the majority of such materials as filler in concrete. In Ethiopia we have enormous amount of coffee husk and Sugar cane bagasse ash. However, the utilization of this Coffee husk ash and Sugarcane bagasse ash waste in concrete production provides significant benefits in terms of reducing construction costs as well as greenhouse gas emissions.

This research was therefore, amid to examine the potential of combination of coffee husk ash sugarcane bagasse ash as partial replacement for Portland Pozzolana cement (PPC) in C-20/25 concrete production with investigation of optimum ratio of replacement and engineering properties of C-20/25 concrete.
Control and three different concrete mixes were prepared for 25MPa concrete containing 5%, 10% and 15% hybrid of CHA&SCBA replacement of cement. Workability of fresh concrete using slump and compaction factor test and compressive test, split tensile strength test and flexural test were performed.

From the research, it was observed that the addition combination of coffee husk ash and sugarcane bagasse ash reduces workability of wet concrete. The results harden concrete work have shown that, up to 10% replacement of the hybrid of CHA&SCBA achieved a higher compressive strength, split tensile strength and flexural strength at all test ages i.e. 7, 14, and 28 days of age by test.

It can therefore, be concluded that 10% replacement of cement by hybrid of coffee husk ash sugarcane bagasse ash results in a similar concrete properties with control test and it is the optimum replacement.

Key words*: Coffee husk ash, Sugarcane bagasse ash, compressive strength, Split tensile strength, Flexural strength*

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LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
CF	Compaction Factor Value
CFT	Compaction Factor Test
CF	Compaction Factor Value
CFT	Compaction Factor Test
CST	Compressive Strength Test
CH	Coffee Husk
CHA	Coffee husk ash
CM	Control Mix
CSA	Central Statistical Agency
ECC	Engineered Cementitious Composite
FC	Fully Compacted
FST	Flexural Strength Test
JiT	Jimma institute of Technology
MR	Modulus of Rupture
PC	Partially Compacted
SCB	Sugarcane Bagasse
SCBA	Sugarcane Bagasse Ash
ST	Slump Test
STST	Split Tensile Strength Test

LIST OF SYMBOLES

Roman Upper Case Letters

A	Area
A	Average distance between line of fracture and the nearest support measured on the tension surface of the beam
D	Diameter of the cylinder
E_{cm}	Secant modulus of elasticity of concrete
L	Length of the cylinder
L	Span length
P	Compressive load on the cylinder
P	Maximum applied load
T	Spilt tensile strength of the concrete

Roman Lower Case Letters

b	Average width of specimen
d	Average depth of specimen
f_c	Compressive strength of concrete
f_{ck}	Characteristic compressive cylinder strength of concrete at 28 days
$f_{ck}(t)$	Characteristic compressive cylinder strength of concrete at t
f_{cm}	Mean value of concrete cylinder compressive strength
$f_{cm}(t)$	Mean concrete compressive strength at an age of t days
f_{ct}	Tensile strength of concrete
$f_{ct,sp}$	Splitting tensile strength of concrete
f_{ctk}	Characteristic axial tensile strength of concrete
f_{ctm}	Mean value of axial tensile strength of concrete
$f_{ctm}(t)$	Mean value of axial tensile strength of concrete an age of t days
k	Coefficient
s	Coefficient which depends on the type of cement
t	Age of the concrete in days

Greek Lower Case Letters

η	Ratio of Compressive strain in the concrete to Compressive strain in the concrete at the peak stress *f*c
σ_c	Compressive stress in the concrete
α	Ratio which depends on the age of the concrete t
$\beta_{cc}(t)$	Coefficient which depends on the age of the concrete t
ε_c	Compressive strain in the concrete
ε_{c1}	Compressive strain in the concrete at the peak stress *f*c
ε_{cu}	Ultimate compressive strain in the concrete

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

Our environment is made up of three main land uses, those are Natural areas, Working landscapes and Built environments which includes: cities, suburbs, and towns with their components such as: buildings, transportation systems, sewer, water facilities, public spaces and parklands; and we have use concrete to make our built environments suitable and accessible.

Now a days, concrete is one of the most widely used construction materials in the construction industry of Ethiopia, like other countries of the world (Naidu & Edukondalu, 2020). It is a composite material composed of cement, fine aggregate (sand), and coarse aggregates mixed with water which hardens over time (Jayaraman, et al., 2020). The production of concrete making materials or ingredients usually needs high energy, costs, and causes environmental pollution (Warati, et al., 2019). Therefore, it is highly desirable to produce sustainable and eco-friendly concrete that helps to mitigate the carbon footprint of concrete (Luhar & Luhar, 2020). Besides, natural resources are increasingly consumed in today's world due to rapid urbanization and increased demand (Guntakal & Selvan, 2017). This increase in the demand for natural resources leads to the depletion of virgin concrete ingredients, which is a critical issue for all stakeholders of the construction industry for sustainable economic growth, particularly in developing countries (Warati, et al., 2019).

Limited resources and progressive depravation of the environment are forcing scientific efforts to seek alternative and effective materials from large amounts of natural resources as additives in the partial replacement of cement (Jing, et al., 2020). There are many Innovations are developing world wide to control and regulate the management of sub-products, residuals and industrial wastes in order to preserve the environment from contamination. A good solution to the problem of recycling of agro industrial residue would be by burning them in a controlled environment and use the ashes (waste) for more noble means. Utilization of such wastes as cement replacement materials may reduce the cost of concrete production and also minimize the negative environmental effects with disposal of these wastes (Batra & Maharashtra, 2019).

To minimize greenhouse effects, the addition of industrial byproducts and agricultural wastes have been observed as sustainable alternatives because they successfully replace bulk proportions of cement in ECCs without compromising strength and ductility (Kumar, et al., 2017; Shafiq, et al., 2018) . Agro-wastes can serve as alternative eco-efficient and sustainable pozzolans for future concrete industries. The incorporation of these residues into cementitious materials has proven that the addition of wastes is not only advantageous to the environment, but also brings about a great performance of concrete properties (Jing, et al., 2020).

The use of different cement replacing materials has become a common practice in the construction industry. Most of these cement replacement materials are byproducts of different industries and agricultural wastes. Blast furnace slags, silica fume, fly ash, bagasse ash and rice husk can be sited as an example. Coffee husk ash has also been founded to have such pozzolana property (Demissew, et al., 2019). Recently, coffee husk ash (CHA) had been tested in some countries for its pozzolanic possessions, which has been found to develop some of the properties of the paste, mortar and concrete-like compressive strength and water tightness in confident substitution percentages and fineness (Lin, et al., 2015). The trend of using biowastes from fuel sources in concrete, such as wheat straw ash, palm oil fuel ash, rice husk ash, and sugar cane bagasse ash, is increasing significantly in those countries that produce large amounts of these wastes that cause severe environmental issues if dumped in open fields (Binici, et al., 2008; Martirena & Monzó, 2017). Previous studies show that sugar cane bagasse ash, which is a byproduct of the sugar cane industry, can be an effective material to be used in producing sustainable concrete (Ganesan, et al., 2007; Aigbodion, et al., 2010).

Therefore, this research endeavors to make use of the combination of CHA and SCBA produced in Ethiopia, as a pozzolanic material to replace cement partially. An experimental exploration was carried out to examine the impact of adding hybrid of coffee husk ash and sugarcane bagasse ash to the mechanical and physical properties of pastes and concretes such as consistency, setting time, workability, unit weighs, compressive strength, split tensile strength and flexural strength.

1.2. Statement of the problem

The main problem in construction industries is the shortage of construction materials, on the other side the main environmental problem is industrial waste and agricultural residue.

Among concrete ingredients the binder and the most costly and environmental unfriendly element is cement. Cement production is one of the environmental unfriendly processes due to the release of CO_2 gases to the atmosphere and environmental degradations. In the experimental study, an attempt will be made to use the coffee husk ash and sugarcane bagasse ash in concrete as cement partial replacement. Utilization wastes as cement replacement materials may reduce the cost of concrete production and also minimize the negative environmental effects with disposal of these wastes (Batra & Maharashtra, 2019).

Instead of disposing, the industrial waste and agricultural residue can be recycled and use in the construction process. The attempt will be made to utilize the industrial waste of bagasse ash and agricultural waste coffee husk ash use as supplementary cement replacement materials. Continuous generation of wastes arising from industrial by-products and agricultural residue, create acute environmental problems both in terms of their treatment and disposal. The construction industry has been identified as the one that absorbs the majority of such materials as filler in concrete (Antiohos, et al., 2005). If these fillers have pozzolanic properties, they impart technical advantages to the resulting concrete and also enable larger quantities of cement replacement to be achieved (Hossain, 2003). Appropriate utilization of these materials brings ecological and economic benefits.

In Ethiopia we have enormous amount of coffee husk and bagasse ash which was not utilized efficiently, and the number of sugarcane factory is growth up also there are many coffee processing factories where the waste being dump in high volume. In Ethiopia 192000 metric tons of coffee is Husk cast adrift as byproduct per year. Coffee grounds are highly pollutant due to the presence of organic material that demands a great quantity of oxygen in order to degrade (Oliveira, et al., 2008). And Ethiopia has targeted to become one of the top ten sugar producing countries of the world in 2023. However, the utilization of this coffee husk ash and bagasse ash waste in concrete provides significant benefits in terms of reducing construction costs as well as greenhouse gas emissions.

This research was done to use the combination of agricultural waste coffee husk ash and industrial waste sugarcane bagasse ash becoming beneficial material for partial replacement of cement in concrete production and the experiment has conducted to analyze the feasibility of combination of

CHA&SCBA recycling in terms of partial replacement of cement for concrete material as alternative sustainable construction materials.

1.3. Research Question

1. What are the effect of combination SCBA and CHA on the workability of concrete?
2. What are the effect of hybrid SCBA and CHA on the mechanical properties of concrete?
3. How much is the optimum percentage of SCBA and CHA can replace the cement for targeted grade of concrete?
4. What is the relationship of concrete stress and strain in the partial replacement of cement with combination of SCBA and CHA in concrete mix?

1.4. Objectives of the Study

1.4.1. General objective

- The general objective of this study will be to investigate the strength characteristics of concrete in which cement is partially replaced by SCBA and CHA.

1.4.2. Specific objective

1. To determine the effects of addition of combination of SCBA and CHA on the workability of concrete
2. To find out the effect of addition of combination of SCBA and CHA on the strength capacity of concrete such as, compressive, tensile and flexural strength.
3. To determine the optimum percentage of combination of SCBA and CHA used in concrete.
4. To find out the basic relationship of concrete stress and strain.

1.5. Significance of the Study

As we know that now day, most of developing country facing shortage of post consumers disposal waste site and it’s become very serious problems. For this reason, regenerating and using waste product as resources and prevent environmental pollutions.

To minimize greenhouse effects, the addition of industrial by products and agricultural wastes has been observed as sustainable alternatives (Kumar, et al., 2017).

In Ethiopia we have enormous amount of coffee husk and bagasse ash which was not utilized efficiently, and the number of sugarcane factory is growth up also there are many coffee mill where the waste being dump in high volume.

During the processing of its products from the coffee beans, the by-products (coffee husks) are rejected which in turn is becoming a worrying factor for environmentalists since Coffee husk contains some amount of caffeine and tannins, which makes it toxic in nature, resulting in disposal problems which makes them not eco-friendly to some extent. Residue from coffee processing factories, principally coffee processing effluent and release from the factory, can cause significant pollution to water courses, while those living around the coffee processing stations have complains about pollution of rivers and other associated health impacts (Ballesteros, et al., 2014). After burning the bagasse as a source of fuel, the ash waste is disposed of in landfills, which is causing serious environmental problems (Chusilp, et al., 2009).

Due to this reason, it was highly required to conduct research on study Strength Characteristics of Concrete with Partial Replacement of cement by combination of Coffee husk ash and bagasse ash. Therefore, the final result of the study provides the following information for stakeholders in the construction industry.

- As one of the partial replacement material.
- A way for reduction of industrial byproduct and agricultural waste.
- Reduce the environmental impact of the Cement production.
- As a reference for other researchers…etc.

1.6. Scope and Limitation of the Study

The scope of this research was investigating the effects of addition of different percentage value of combination SCBA and CHA on the mechanical properties of concrete, to get the optimum percentage value of combination of SCBA and CHA and to investigate stress strain of concrete.
The research was done by adding different percentage value of combination of SCBA and CHA, such as 0%, 5%, 10% and 15% by weight of cement, on the concrete mix of C-20/25 grade of concrete. Three specimens was casted for each tests conducted at the age of 7, 14 and 28 days. Then different samples for different tests was taken, for compressive strength test 36 samples of cube 150x150x150 mm, for tensile strength test 36 samples of cylinder 150x300 mm and for flexural strength test 36 sample of beam 150x150x700 mm.

This experimental investigation was not study strength characteristics of concrete with partial replacement of cement separately by CHA and SCBA.

CHAPTER TWO

LITERATURE REVIEW

2.1. General Overview

Concrete is the most common material in building construction. The word concrete comes from the Latin word ‘‘concretus’’ (meaning compact or condensed), the perfect passive participle of ‘‘concrescere’’, from the words ‘‘con’’ (together) and ‘‘crescere’’ (to grow) (PAVAN, et al., 2018). It is used more than any other man made material in the world and Concrete has been used in various structures all over the world since last two decades. Recently a few infrastructure projects have also seen specific application of concrete. The development of concrete has brought about the essential need for additives both chemical and mineral to improve the performance of concrete. Most of the developments across the work have been supported by continuous improvement of these admixtures. Concrete, one of the most important construction materials in the construction of infrastructure and development facilities, has the potential for significant and positive environmental participation (Tavakoli, et al., 2012).

It is currently one of the most common and extensively used materials in construction and it is one of the most durable building materials. It provides superior fire resistance compared with wooden construction and gains strength over time. Structures made of concrete can have a long service life. It is widely used in almost every type of construction among others, building, infrastructure and structures which are used to protect from rough environment and other developments. It became an important material in construction industry based on its strength of being able to support higher load and its durability against the environment compared to the other material. On the other hand, the usage of concrete for developmental purposes is double the usage of other material such as wood, glass and steel. Concrete is a manufactured product which consists of raw material such as cement, sand, aggregate and some admixture to improve the characteristic of concrete. High demand for concrete increases the use of raw materials in the mixture of concrete (Husain & Abas, 2015).

Also, (Tito & Gomez-Rivas, 2012) argued that, concrete is a strong, durable and economic construction material with different engineering applications. The principal components of concrete are coarse and fine aggregates, water, Portland cement and other bindings, and chemical additives, with a proper mix design and construction procedure, produce the concrete with the required engineering properties. In general, concrete is environmentally friendly because its components are found locally. However, the elaboration of the Portland cement and natural coarse aggregate, which are a basic component of concrete, requires large amount of energy and release large quantities of carbon dioxide (CO2) to the atmosphere (Tito & Gomez-Rivas, 2012). Though, the worldwide consumption of natural coarse aggregate in mortar/concrete production is very high and several developing countries have faced some problems in the supply of natural coarse aggregate. So, In order to reach increasing needs of infrastructural development in present days researchers has done experimental study on utility of recycled coarse aggregates as partial replacement of natural coarse aggregate (Ramprasad & Manikanta, 2019). Both methods lead to the environmentally friendly material called Green Concrete. This means concrete that uses less energy in its production and produces less carbon dioxide than normal concrete is green concrete.

2.2. Partial Replacement of cement by Agricultural residue and industrial waste

Globally, the researchers are concentrating on usage of both industrial and agricultural waste, as raw material sources for the industry, the appropriate usage of this waste material would not only be economical benefits, but may also result in foreign exchange wages and environmental pollution control (Idris & Yassin, 2015). Waste materials are common problems in modern living. Waste accumulates from a number of sources including domestic, industrial, commercial, construction and agricultural. These waste materials have to be eventually disposed of in ways that do not endanger human health and their environment. In light of this, waste minimization is increasingly seen as an ecologically sustainable strategy for alleviating the need for the disposal of waste materials, which is often costly, time and space consuming, and can also have significant detrimental impacts on the natural environment. Nowadays governments and organizations have been concerned with developing policies and programs to bring about successful outcomes to waste minimization. This is seen as being essential to reduce the total amount of waste materials going into landfill, especially in the urban areas where land is very scarce. The use of recycled materials is often cheaper for the consumers of the end product. Hence, there is also an economic justification for promoting its use (Demissew, et al., 2019).

From different point of view, locally available and economical view the provision of the locally available materials to be used in concrete production is help in lowering the cost of construction of housing units (low cost housing) for human dwelling and the construction period since the cement will not be transported from other regions (Reta & Mahto, 2019). Owing to considerable use of cement and concrete material, the natural material resources related to the construction industry has been continuously reduces in recent years. However, for each country particularly for developing country like Ethiopia, concrete is the most important material for fundamental and public constructions (Demissew, 2020). Thus, an innovative and alternative concrete material, which possesses feasibility and practicality, is critical and significant for mitigating environmental impact and promoting energy-saving performance.

Green concrete has nothing to do with color (Kuma, et al., 2017). It is a concept of thinking environment into concrete considering every aspect from raw materials manufactures over mixture design to structural design, construction and service life. The raw materials of concrete consist of cement, sand and crushed aggregates. Partial or 100% replacement of these raw materials by waste products may decrease the cost, reduce the energy consumption and also reduce the environment pollution (Krishnamoorthi & Kumar, 2013). Due to the use of recycled materials whereby avoiding the charges for the disposal of waste, less energy consumption and greater durability (Sharma, et al., 2020). Green concrete is very often considered to be cheap to produce due to the use of recycled material whereby avoiding the charges for the disposal of waste, less energy consumption and greater durability (Admute, et al., 2017). So, in recent years, recycled wastes are necessary to produce a new product for sustainable environment friendly construction. However, using coffee husk ash as and sugarcane bagasse ash in concrete production material important to solve: environmental pollution problem, reduce cost rise of concrete by producing.

2.3. Components of concrete with partial replacement of cement by using CHA & SCBA hybrid

The Components of Concrete with Partial Replacement of cement by using Coffee Husk ash and sugarcane bagasse ash Combination are Cement, Aggregate, water, coffee husk ash and sugarcane bagasse ash.

2.3.1. Cement

Portland cement is used as the main binder, and as additives to Portland cement the following is often used: fly ash, ground granulated-metallurgical slag and silica fume. It is recommended to conduct material testing of the mixture in order to verify compatibility of the mixture and that setting time, workability, strength and porosity can provide the necessary characteristics for the intended use of concrete (SESLIJA, et al., 2018).

The global cement industry is expanding in terms of production as well as consumption volume. The rise in construction activities is promoting the cement demand considerably, demand for cement from civil engineering is rising strongly, due to the increasing investment by government on residential as well as public work sectors, and these factors enable the cement manufacturers to produce cement on a large scale and thereby raise consumption volume.

2.3.2. Aggregate

Aggregates are inert granular materials such as sand, gravel, or crushed stone that, along with water and Portland cement, are an essential ingredient in concrete. For a good concrete mix, aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete.

Aggregates, which account for 60 to 75 percent of the total volume of concrete, are divided into two distinct categories fine and coarse. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Coarse aggregates are any particles greater than 0.19 inch, but generally range between 3/8 and 1.5 inches in diameter.

Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder. Natural gravel and sand are usually dug or dredged from a pit, river, lake, or seabed. Crushed aggregate is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. Recycled concrete is a viable source of aggregate and has been satisfactorily used in granular sub-bases, soil-cement, and in new concrete.

After harvesting, aggregate is processed: crushed, screened, and washed to obtain proper cleanliness and gradation. If necessary, a benefaction process such as jigging or heavy media separation can be used to upgrade the quality. Once processed, the aggregates are handled and stored to minimize segregation and degradation and prevent contamination. Aggregates strongly influence concrete's freshly mixed and hardened properties, mixture proportions, and economy. Consequently, selection of aggregates is an important process (Association, 2021).

2.3.3. Water

Water is an important ingredient of concrete as it is actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into carefully.

2.3.4. Coffee Husk ash

Coffee husk has been considered a waste material and has generally been disposed-off by damping or burning. The bean is the main crop. Currently experimental work briefly describes that the suitability of the locally available coffee husk (CH) is environmentally friendly and present important attributes, such as light weight, low cost, high tensile strength. Using CHA, which is a recycled material, will save a great deal of materials used for concrete production.

Various studies have performed two-fold blends of OPC with different cementitious materials, such as fly ash, blast furnace slag, silica fume, rice husk ash, CHA, and metakaoline, in making cement composites confirmation to be valuable in meeting of the necessities of environmental-friendly, sustainable and durable concrete structures (OBILADE, 2014).

Recently, coffee husk ash (CHA) had been tested in some countries for its pozzolanic possessions, which has been found to develop some of the properties of the paste, mortar and concrete-like compressive strength and water tightness in confident substitution percentages and fineness (Lin, et al., 2015).

Using CHA, which is a recycled material, will save a great deal of materials used for concrete production. For one ton of OPC, 1.52 tons of raw materials are required (Stajanča & Eštokova, 2012).

2.3.5. Sugarcane bagasse ash

There are many Innovations are developing world wide to control and regulate the management of sub-products, residuals and industrial wastes in order to preserve the environment from contamination. A good solution to the problem of recycling of agro industrial residue would be by burning them in a controlled environment and use the ashes (waste) for more noble means.

Utilization of such wastes as cement replacement materials may reduce the cost of concrete production and also minimize the negative environmental effects with disposal of these wastes. Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. After the extraction of all economical sugar from sugarcane, large fibrous residue is obtained. When bagasse is burnt in the boiler of cogeneration plant under controlled conditions, reactive amorphous silica is formed due to the combustion process and is present in the residual ashes known as Sugarcane Bagasse Ash. This amorphous silica content makes bagasse ash a useful cement replacement material in concrete. Each ton of sugarcane generates approximately 20% of bagasse (at a moisture content of 50%) and 0.62% of residual ash. The residue after combustion presents a chemical composition dominates by silicon dioxide (SiO_2). In this study the bagasse ash is planned to use as the partial replacement for cement in order to utilize the wastages and to protect the environment from the hazards. Sugarcane bagasse ash is normally used as fertilizer in sugarcane plantation (Batra & Maharashtra, 2019).

Sugarcane bagasse is an agricultural waste that can be transformed by incineration into a cement replacement material for various cementing purposes. SCBA is conventionally used as fertilizer or is disposed of in landfills, both of which are not sustainable from the standpoint of environmental and health concerns. Utilization of SCBA in construction materials offers a promising solution for superior recycling and management of SCBA wastes (Xu, et al., 2019).

Bagasse ash was used as a partial replacement of cement for various volume ratios (5%, 10%, and 15%). It acts as a good pozzolanic material and can be used as an add-on for cementitious material (Inbasekar, et al., 2016).

The bagasse waste is disposed to the landfills or disposal sites where ever present in the country. The bagasse ash can is used in concrete. Meanwhile, in the present era there is a huge rise in the production of sugar worldwide, and almost 1500 Million tons of sugarcane are yearly produced in all over the world, which leaves around 40 - 45% bagasse afterward juice removal. So, a normal yearly production of bagasse is projected as 600Million tons, which is a bulky waste from sugar industry (R.Srinivasan & K.Sathiya, 2010).

Srinivasan & Sathiya (Srinivasan & Sathiya, 2010) studied chemical and physical characterization of SCBA, and partially replaced in the ratio of 0%, 5%, 15% and 25% by weight of cement in concrete. Compressive strength, split tensile strength, flexural strength and modulus of elasticity at the age of 7 and 28 days was obtained as per Indian Standards. It was found that the cement could be advantageously replaced with SCBA up to a maximum limit of 10%. Therefore it is possible to use sugarcane bagasse ash (SCBA) as cement replacement material to improve quality and reduce the cost of construction materials such as concrete (Baguant, 1995).

2.3.6. Pozzolanic property of coffee husk ash and sugarcane bagasse ash combination

Pozzolanas are siliceous or siliceous and aluminous materials which alone possess little or no cementitious value but which will, in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties (H.Kosmatka & Beatrix, 2003). Coffee husk ash and sugarcane bagasse ash combination was also tested to have such property. It acts as a pozzolanic material when added to cement because of its silica (SiO_2) and aluminate content.

Table 2.1: Major chemical composition of cements raw materials, CHA, SCBA Vs hybrid of CHA&SCBA

Component	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O
Limestone	2.68	0.62	0.46	51.85	1.94	0.03	0.05	0.02
Sandy Cay	81.56	11.29	1.79	0.12	0.09	0.05	0.14	0.03
Clay	65.18	21.91	3.36	0.11	0.08	0.06	0.19	0.04
Iron ore	14.88	16.79	57.74	0.12	0.56	0.04	0.04	0.03
Shale	61.10	16.42	7.01	1.02	2.34	0.01	4.12	1.65
Sand	94.70	2.90	0.24	0.35	0.13	0.01	0.60	0.21
Bauxite	3.11	57.59	15.74	4.16	0.16	0.29	0.08	0.08
Gypsum	4.31	0.34	0.14	31.19	0.11	43.88	-	-
Fuel Ash	57.20	17.36	9.11	3.95	1.80	3.40	0.78	2.50
SCBA	65.58	5.87	4.32	1.78	1.23	0.18	6.41	1.02
CHA	16.55	17.18	3.98	5.68	1.12	1.9	19.3	1.84
Hybrid SCBA &CHA	31.32	3.16	1.66	5.86	1.68	-	16.70	0.56

Source (Fentaw, 2011; Hailu, 2011; Demissew, et al., 2019) and hybrid CHA&SCBA complete silicate analysis appendix J.

2.4. Properties of concrete with partial replacement of cement by using CHA & SCBA hybrid

The most important properties of Concrete with Partial Replacement of cement by using Coffee Husk ash and sugarcane bagasse ash Combination analyzed within this study are:

- ✓ Fresh Properties and
- ✓ Harden Properties.

2.4.1. Fresh Concrete

Fresh concrete or plastic concrete is a freshly mixed material that can be molded into any shape. The relative quantities of cement, aggregates, and water combined, control the properties of concrete (SHETTY, 2006). The strength of concrete affected by the degree of compaction for a given mix proportion; it is vital that consistency or ability to flow the mix such that, concrete can be transported, placed and finished sufficiently quickly and without segregation.

2.4.1.1. Workability

The American Concrete Institute (ACI 116R-00) describes workability as “that property of freshly mixed concrete or mortar that determines the ease with which it can be mixed, placed, consolidated, and finished to a homogenous condition” (ACI 116R, 2000). Workability can be measured with slump test, compaction factor test, flow table test, VeBe test and Kelly ball test. It is one of the important parameters of measuring the consistency of the fresh concrete. Slump test is the most commonly used method of measuring the consistency of the concrete.

Slump test

The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The inexpensive test, which measures consistency, is used on job sites to determine rapidly whether a concrete batch should be accepted or rejected. The test method is widely standardized throughout the world, including in ASTM C143 in the United States and EN 12350-2 in Europe. The apparatus consists of a mold in the shape of a frustum of a cone with a base diameter of 8 inches (20cm), a top diameter of 4 inches (10cm), and a height of 12 inches (30cm).

Four types of slumps are commonly encountered

1. True slump - where the concrete just subsides, keeping its shape approximately
2. Shear slump-where the top half of the cone shears off and slips sideways down an inclined plane
3. Collapse slump - where the concrete collapses completely
4. Zero slump- no subsidence.

The only type of slump permissible under ASTM C143 is frequently referred to as the “true” slump, where the concrete remains intact and retains a symmetric shape. A zero slump and a collapsed slump are both outside the range of workability that can be measured with the slump test. Specifically, ASTM C143 advises caution in interpreting that, test results having slump less than ½ inch may not be adequately plastic and slump greater than 9 inches may not be adequately cohesive . If part of the concrete shears from the mass, the test must be repeated with a different sample of concrete. A concrete that exhibits a shear slump in a second test is not sufficiently cohesive and should be rejected (Fowler & Kohler, 2003).

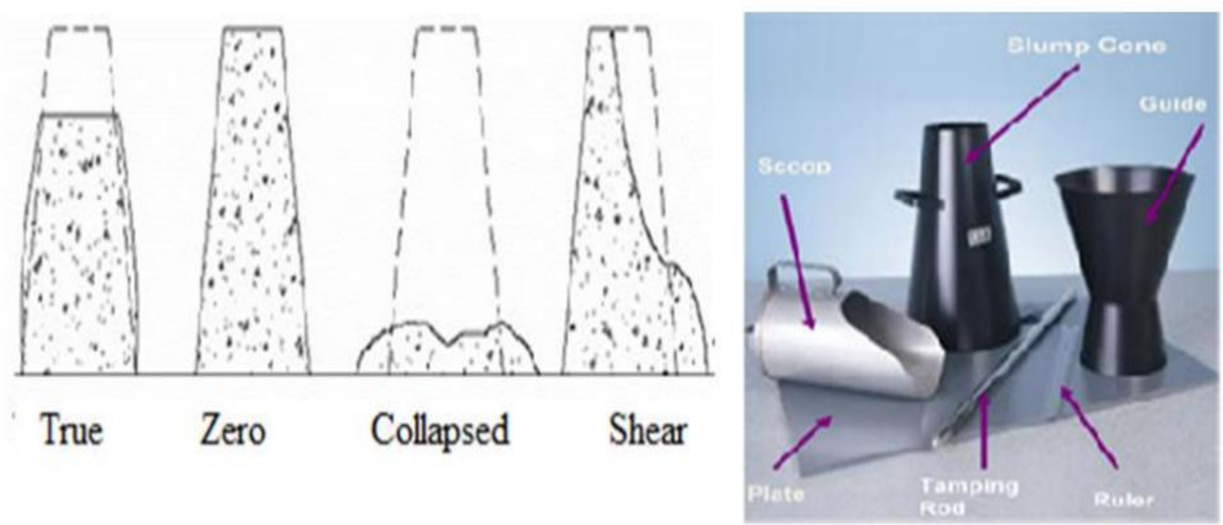

Figure 2.1: Types of slump and its apparatus (Fowler & Kohler, 2003; ELE & International, 2019)

Tests perform on the fresh concrete give an idea about the workability of concrete mix. In order to determine the workability slump cone test is perform. To determine consistency of concrete, Slump test is conduct, before concrete is placed, the slump will be check in terms of the specifications using the slump cone test.

Some researchers have reported that the slumps of the concrete containing CHA displayed a reduction as the CHA content increased, the workability of the concrete mixes decreases. The results of the slump tests carried out on the fresh concrete is when the amount of replacement of PPC with CHA increases, the workability of the concrete mixes decreases. The reasons being, concrete containing CHA requires more water for a given consistency due to its absorptive character of cellular CHA particles and of high fineness (this increases its specific surface area). As the replacement of cement with coffee husk ash increase the concrete decrease due to absorption of the water by the Coffee Husk ash (Reta & Mahto, 2019). The slump of the study was found in the range of 30-38 mm, wherein CHA concrete is good in plastic and cohesive properties. As a result, it was found that CHA concrete will be good to minimize segregation of fresh concrete during placing and consolidating of concrete (Demissew, et al., 2019).

Also for SCBA as SCBA content increased, workability decreased proportionally. As percentage of SCBA increases then workability gradually decreases. This drop-in workability due to the surface area of SCBA is greater than cement; therefore it absorbs some amount of water. When the amount of SCBA increases then workability of fresh concrete gradually decreases. (Das, et al., 2019).

2.4.2. Hardened Concrete properties

The properties of fresh concrete are important only in the first few hours of its history whereas the properties of hardened concrete assume an importance which is retained for the remainder of the life of concrete. The important properties of hardened concrete are strength, deformation under load, durability, permeability and shrinkage.

In general, strength is considered to be most important property and quality of concrete is often judged by its strength. In most cases an improvement in strength results in an improvement of the other properties of concrete but there are exceptions. For example, increasing the cement content of a mix improves strength but results in higher shrinkage which in extreme cases can adversely effect on durability and permeability. Since the properties of concrete change with age and environment, it is not possible to attribute absolute values to any of them.

Strength: - The strength of concrete is defined as the maximum loads (stress) it can carry. As the strength of concrete increase, its other properties usually improve and since the tests for strength, particularly in compression, are relatively simple to perform (Rahman, 2007).

2.4.2.1. Compressive strength

Concrete is employed primarily to resist the compressive stresses. Concrete compressive strength is commonly used in the construction industry for the purpose of specification and quality control. Porous concrete compressive strength is relatively reduced because of large content of voids. Also the sequence of the increase of the aggregate size, the values or mixture ratios as well as effort invested in compaction during casting of the concrete have the most effect on compressive strength of porous concrete. Hence, the total content of cementitious material, presence of additives such as polymeric additives and mineral admixtures lead to increase in development of compressive strength porous (SESLIJA, et al., 2018). In connection with this, several researchers have examined the aspects linked to the compressive strength of porous concrete but not standard methods are available. As a result, drilled cores have been regarded as a relevant method for the determination of in site porous concrete compressive strength. Porous concrete compressive strength is known to be lower than that of traditional concrete because of high porosity. Because of that the compressive strength ranges between 2.8 MPa to 28 MPa with ideal values of (17 MPa) (Hilal & Hama, 2007).

Generally, the compressive strength of concrete is taken as the maximum compressive load it can carry per unit area. The specimen will place in machine in such a manner that the load will applied to opposite sides of the cubes i.e., not top and bottom. The applied load will increase continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load applied on specimen will recorded. Lastly, the load at the failure divided by area of specimen gives the compressive strength of concrete (Lidiya, 2018).

$$\delta c = \frac{P}{A}\ (N/mm2) \ldots\ldots\ldots.. \text{eq } 2.1$$

Where δc = compressive strength of the concrete

P = is the maximum load and

A = is the cross-sectional area

Coffee husk ash as contains silica, which is the most important component of cement replacing materials. It also found in large amount as a byproduct of agriculture. Despite this abundance and silica content, relatively little was been done to examine the potential of this material for concrete production. Even though little, the conducted researches confirm the suitability of this material for concrete production by replacing cement in some percentage for mortar and concrete. When CHA used as cement replacing material, it results in some improvement on the properties of concrete. At 28 days, concrete containing coffee husk ash at 10 % replacement showed compressive strength higher than the control concrete (Demissew, et al., 2019).

Demissew, Fufa, & Assefa investigated the compressive strength increased with curing period, but decreased with increased amount of CHA. for CHA concrete, the addition of CHA resulted in reduction of concrete compressive strength, when compared to control, CHA0. This shows that when CHA increased, the compressive strength of the concrete reduced. However, the compressive strength of the CHA concrete increased as it aged [37] (Demissew, et al., 2019) .

Also Reta and Mahto investigated the compressive strength of CHA concrete, in early ages which are slightly lower than reference mix as the percentage of CHA replacement increases.

As a result, the structure is less compact, causing the strength to be lower than that of the concrete specimens without CHA. The result of the compressive strength of concrete cube show that compressive strength reduced the percentage of CHA increased (Reta & Mahto, 2019).

Nasir, et al., study that at early ages (14 days of curing), all the ECC mixes containing SCBA possessed lower compressive strength compared to that of the control mix. Moreover, the reduction in compressive strength gradually increased with increasing amounts of SCBA in the mix.

This phenomenon of strength reduction can be attributed to slight or no pozzolanic activity at earlier stages. However, with increasing curing age, this phenomenon of strength reduction with increasing amounts of SCBA was completely reversed, particularly at later ages such as 91 days of curing. The results indicated that the compressive strength of ECC mixes gradually decreased with increasing amounts of SCBA. The addition of SCBA in ECCs reduced the compressive strength at early ages (14 days), which, however, was enhanced significantly at later ages. The mix containing 10% SCBA (10ECC) exhibited the highest compressive strength among all the other ECC mixes, including CM, at the age of both 28 and 91 days. The compressive strength of 10ECC in comparison to that of CM was found to be higher, almost 3 and 7% higher at 28 and 91 days, respectively. The other ECC mixes with high amounts of SCBA (20ECC and 30ECC) produced slightly higher strengths than that of CM only at 91 days. (Nasir, et al., 2020). Batra and

Maharashat investigated Compressive strength constantly increases as the curing period goes on increasing. Maximum compressive strength achieved on 15% replacement of SCBA (Batra & Maharashtra, 2019).

K. Ganesan, K. Rajagopal and K. Thangavel study on Evaluation of bagasse ash as supplementary cementitious material. The experimental study shows that the concrete with SCBA up to 20% develops early compressive strength as compared to control concrete specimens (Ganesan, et al., 2007).

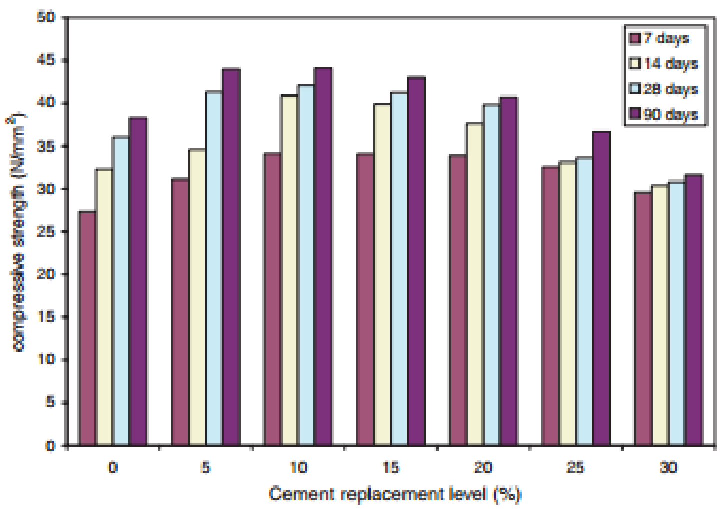

Figure 2.2: Compressive strength of BA blended concretes

Nunta chai et al. (Chusilp, et al., 2009) examined the importance of bagasse ash for development as pozzolanic materials in concrete. The physical properties of concrete containing ground bagasse ash (BA) including compressive strength, water permeability, and heat evolution were investigated and all tests were done in accordance with American Standards. When bagasse ash is ground up into small particles, the compressive strength of concrete containing this ground bagasse ash improves significantly (Cordeiro, et al., 2008).

2.4.2.2. Split tensile strength

Concrete is a comparatively brittle material which is relatively weak in tension. This test is conducted by compressive testing machine placing cylindrical specimen of the concrete. So, that its axis is horizontal between the plates of the testing machine.

The experimental setup for split tensile test is that, load will be applied at constant rate until failure by splitting along the vertical diameter. Load at which the specimen failed is recorded and the splitting tensile stress is obtained using the following formula.

$$T = \frac{2P}{\pi DL} \ldots\ldots\ldots eq\ 2.2$$

Where,

T= the spilt tensile strength of the concrete

P= compressive load on the cylinder

L= length of the cylinder

D= diameter of the cylinder (Achal & Chandak, 2017).

cylinders having mathematical dimensions of 150mm diameter and 300mm length are used as test specimen to determine the split tensile strength of concrete .the various ingredients of concrete are mixed thoroughly until uniform consistency is achieved .the cylinders are compact properly. All the cylinders are de moulded within 24 hours after casting .the demoulded test specimens were properly cure in water which is available in the laboratory for an age of 7, 14 and 28 days .The split tensile strength is conduct as per IS:5816-1976 .the specimen is place horizontally between the loading surfaces of the compression testing machine and the load is applied without any sudden impact until the failure of the specimen occurred.

Based on the tensile strength comparison among the different ECC mixes, the use of 10% SCBA can be recommended in producing optimized ECCs without compromising tensile strength (Amin, et al., 2020). Das, et al., investigated the indirect tensile strength was improved by 5.40% and 8.55% by using 10% of SCBA as a cement substitute material in concrete after 7^{th} and 28^{th} days respectively. The split tensile strength was reduced by 9.19% and 6.25% at 20% of SCBA as a cementitious material in concrete after 7^{th} and 28^{th} days respectively (Das, et al., 2019).

The splitting tensile strength values of BA blended concretes after 28 days of curing up to 20% of BA, the splitting tensile strength values increase, obviously from tensile strength point of view also, 20% of BA is the optimal limit (Ganesan, et al., 2007).

K. Lakshmi Priya and R. Ragupathy investigate the effect of sugarcane bagasse ash on strength properties of concrete. The experimental study show that the split strength of SCBA blended cement concrete is more than zero percent mix up to 20% replacement of cement with SCBA (Priya & Ragupathy, 2016).

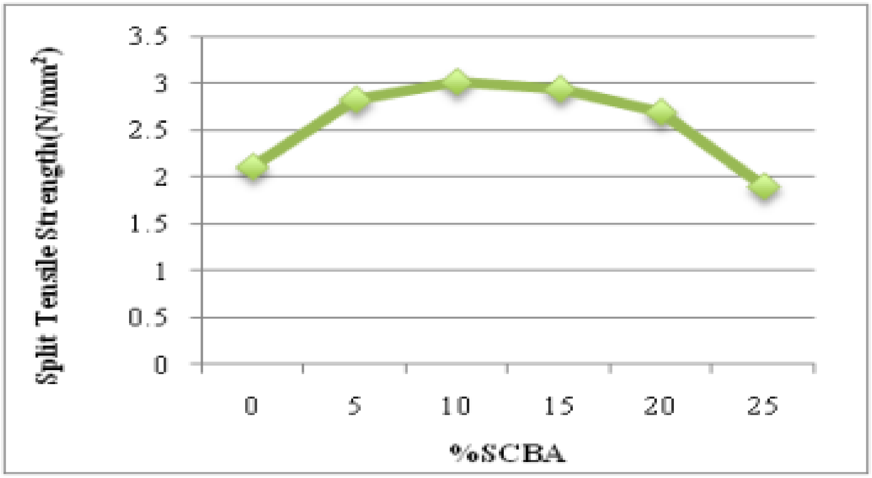

Figure 2.3: Variation of Split Tensile Strength.

2.4.2.3. Flexural Strength

Flexural test on concrete based on the ASTM standards are explained. Flexural test evaluates the tensile strength of concrete indirectly. It tests the ability of unreinforced concrete beam or slab to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (*MR*) in MPa or psi. According to ASTM the size of the specimen is 150mm width, 150mm depth and the length should not be at least three times the depth of the specimen.

The flexural strength of the ECCs containing SCBA remained lower than that of the CM at early ages (14 days). The trend of gradual reduction with increasing percentages of SCBA at early ages demonstrated decreased pozzolanic activity with increasing SCBA. This trend of decreasing flexural strength in the ECCs with increasing percentages of SCBA continued at 28 days as well, except in 10ECC (Nasir, et al., 2020).

K. Lakshmi Priya and R. Ragupathy investigate the effect of sugarcane bagasse ash on strength properties of concrete. The experimental study show that in flexural strength for different cement replacements with SCBA, respect to control mix concrete. Highest flexural tensile strength is obtained for mix containing 10% SCBA as partial replacement of cement and for mix having 25% SCBA strength it is less than that of control mix (Priya & Ragupathy, 2016).

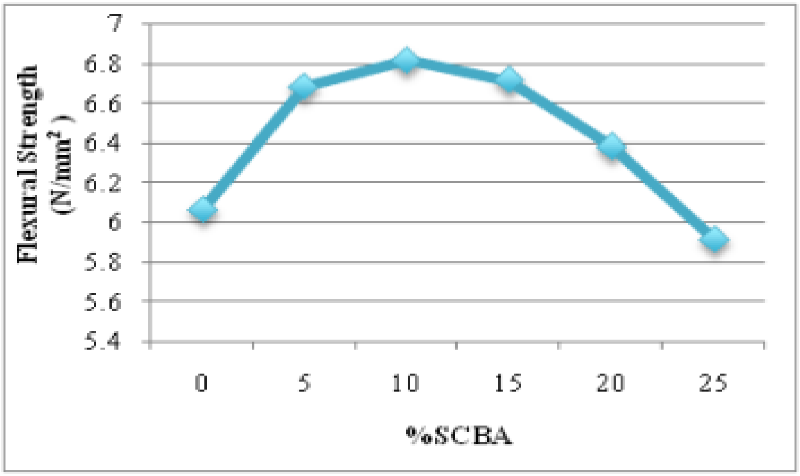

Figure 2.4: Variation of Flexural Strength.

2.4.3. Concrete Stress and Strain

A typical relationship between stress and strain for normal strength concrete is presented in Figure 8. After an initial linear portion lasting up to about 30 – 40% of the ultimate load, the curve becomes non-linear, with large strains being registered for small increments of stress. The non-linearity is primarily a function of the coalescence of microcracks at the paste-aggregate interface. The ultimate stress is reached when a large crack network is formed within the concrete, consisting of the coalesced microcracks and the cracks in the cement paste matrix. The strain corresponding to ultimate stress is usually around 0.003 for normal strength concrete. The stress-strain behavior in tension is similar to that in compression (Scott, et al., 1982).

The descending portion of the stress-strain curve, or in other words, the post-peak response of the concrete, can be obtained by a displacement or a strain controlled testing machine. In typical load controlled machines, a constant rate of load is applied to the specimen. Thus any extra load beyond the ultimate capacity leads to a catastrophic failure of the specimen. In a displacement controlled machine, small increments of displacement are given to the specimen. Thus, the decreasing load beyond the peak load can also be registered. The strain at failure is typically around 0.005 for normal strength concrete, as shown in Figure 6. The post peak behaviour is actually a function of the stiffness of the testing machine in relation to the stiffness of the test specimen, and the rate of strain. With increasing strength of concrete, its brittleness also increases, and this is shown by a reduction in the strain at failure (Scott, et al., 1982).

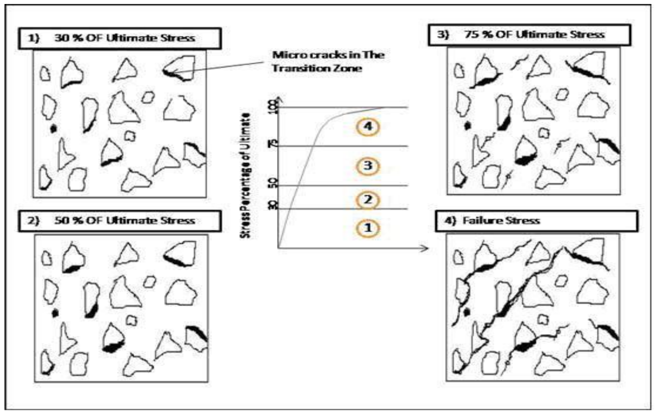

Figure 2.5: Stress-strain relationship for ordinary concrete

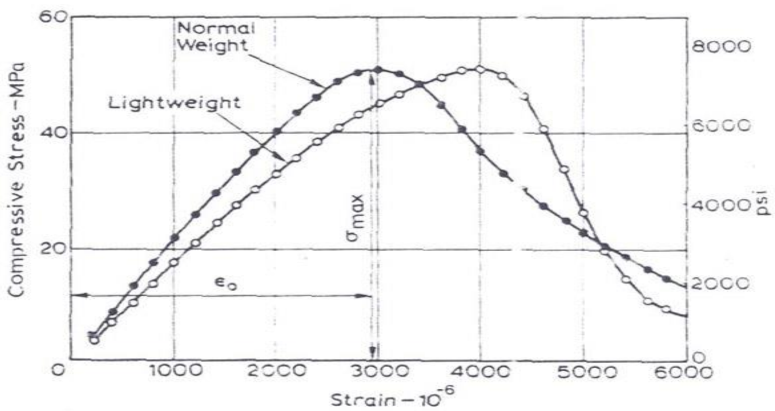

Figure 2.6: Complete stress-strain curve including post-peak response

It is interesting to note that although cement paste and aggregates individually have linear stress-strain relationships, the behavior for concrete is non-linear. This is due to the mismatch and microcracking created at the interfacial transition zone.

Understanding the post peak response of concrete

Concrete belongs to a class of materials that can be called 'Strain – softening', indicating a reduction in stress beyond the peak value with an increase in the deformation (as against the strain hardening behavior commonly exhibited by metals like steel). Figure10 shows different types of material behavior (Scott, et al., 1982).

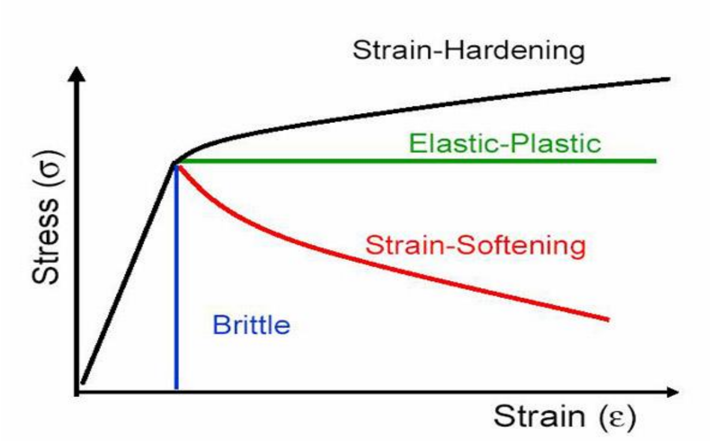

Figure 2.7: Different types of material behavior (post peak response) (Scott, et al., 1982)

2.5. Availability of Coffee Husk ash and sugarcane bagasse ash in Ethiopia

2.5.1. Availability of Coffee Husk ash in Ethiopia

Coffee production in Ethiopia is a longstanding tradition which dates back dozens of centuries. Ethiopia is where *Coffea arabica*, the coffee plant, originates. The plant is now grown in various parts of the world; Ethiopia itself accounts for around 3% of the global coffee market (Wikipedia, 2020). Ethiopia is the world's seventh largest producer of coffee, and Africa's top producer, with 260,000 metric tonnes in 2006 (Wikipedia, 2020).

Coffee is one of the top commodities produced and commercialized worldwide, and the processing of coffee generates significant amounts of agricultural waste, ranging from 50% to 60% the weight of the total coffee produced, depending on the type of processing. Coffee husks are the major solid residues from the processing of coffee, for which there are no current profitable uses, and their adequate disposal constitutes a major environmental problem. In Ethiopia 192000metric tons of coffee is Husk cast adrift as byproduct per year and there is 134,400 metric ton of coffee husk disposed per year in Jimma area (Sime, et al., 2017). Most of these husks were disposed to the environment and this represents a serious environmental problem thus using this waste for partial replacement of cement in concrete has a great benefit.

Ethiopia is one of the prevalent coffee producer countries in the world. This coffee generates large amount of coffee husks during processing. Depending upon the method of coffee cherries processing, different residues are obtained. Coffee husks are the major solid residues from the handling and processing of coffee, since for every 2kg of coffee beans produced, approximately 1kg of husks are generated (Sime, et al., 2017).

However, considering the high amounts generated, there is still a need to find other alternative uses for this solid residue. Although the coffee wastewater emanating from the traditional coffee processing plants in Jimma zone is a valuable resource, it is disposed off to the nearby water course without any treatment. As a result, it becomes a sever e threat to the aquatic ecosystem and downstream users (Dejen, et al., 2014). To tackle this problem it is great important that converting to value added product such as partial cement replacement instead of disposing to rivers or simply burning of these coffee husks.

2.5.2. Availability of sugarcane bagasse ash in Ethiopia

Ethiopia has targeted to become one of the top ten sugar producing countries of the world in 2023. When the remaining five sugar factories under construction are completed Ethiopia would have thirteen factories and its annual sugar production would become 2 million 250 thousand tons. Collaborating existing industries with the future ones, the total bagasse ash to be disposed is estimated to be 1.9 million tons per year (Miheret, 2017).

2.6. Advantage of concrete with partial replacement of cement by using CHA & SCBA hybrid

2.6.1. Advantages of CHA as partial replacement of cement

The reduction of Portland cement in concrete can be achieved by replacing it with different supplementary cementitious materials that are a by-product of another industry. Fly ash, silica fume, GGBFS, etc. have been use for this purpose successfully. Coffee husk ash as described before contains silica, which is the most important component of cement replacing materials. It also found in large amount as a byproduct of agriculture. Despite this abundance and silica content, relatively little was been done to examine the potential of this material for concrete production. Even though little, the conducted researches confirm the suitability of this material for concrete production by replacing cement in some percentage for mortar and concrete. When CHA used as cement replacing material, it results in some improvement on the properties of concrete (Demissew, et al., 2019).

Coffee husk which is the most abundant and nonedible agricultural waste has many advantages while using as partial replacement of cement for concrete productions: Environmental advantages, Energy saving, Reduction of CO_2 emission, Economic advantages (Demissew, 2020).

2.6.2. Advantages of SCBA as partial replacement of cement

The ash disposal problem from sugar industry is reduced since it is usually disposed of in open land area. Due to partial replacement of cement in concrete results, overall price involved in the construction is reduced

CHAPTER THREE

METHODOLOGY

3.1. Study area

This research conducted Jimma, Ethiopia, at JiT University. Ethiopian Region of Oromia Jimma is named for the former Kingdom of Jimma, which was absorbed into the former province of Kaffa in 1932. Jimma is bordered on the south by the Southern Nations, Nationalities and Peoples Region, the northwest by Buno Bedele , on the north by East Wollega , and on the northeast by West Shewa; part of the boundary with East Shewa is defined by the Gibe River. The highest point in this zone is Mount Maigudo (2,386 m). Towns and cities in Jimma include Agaro, Genet and Saqqa. The town of Jimma was separated from Jimma Zone and is a special zone now.

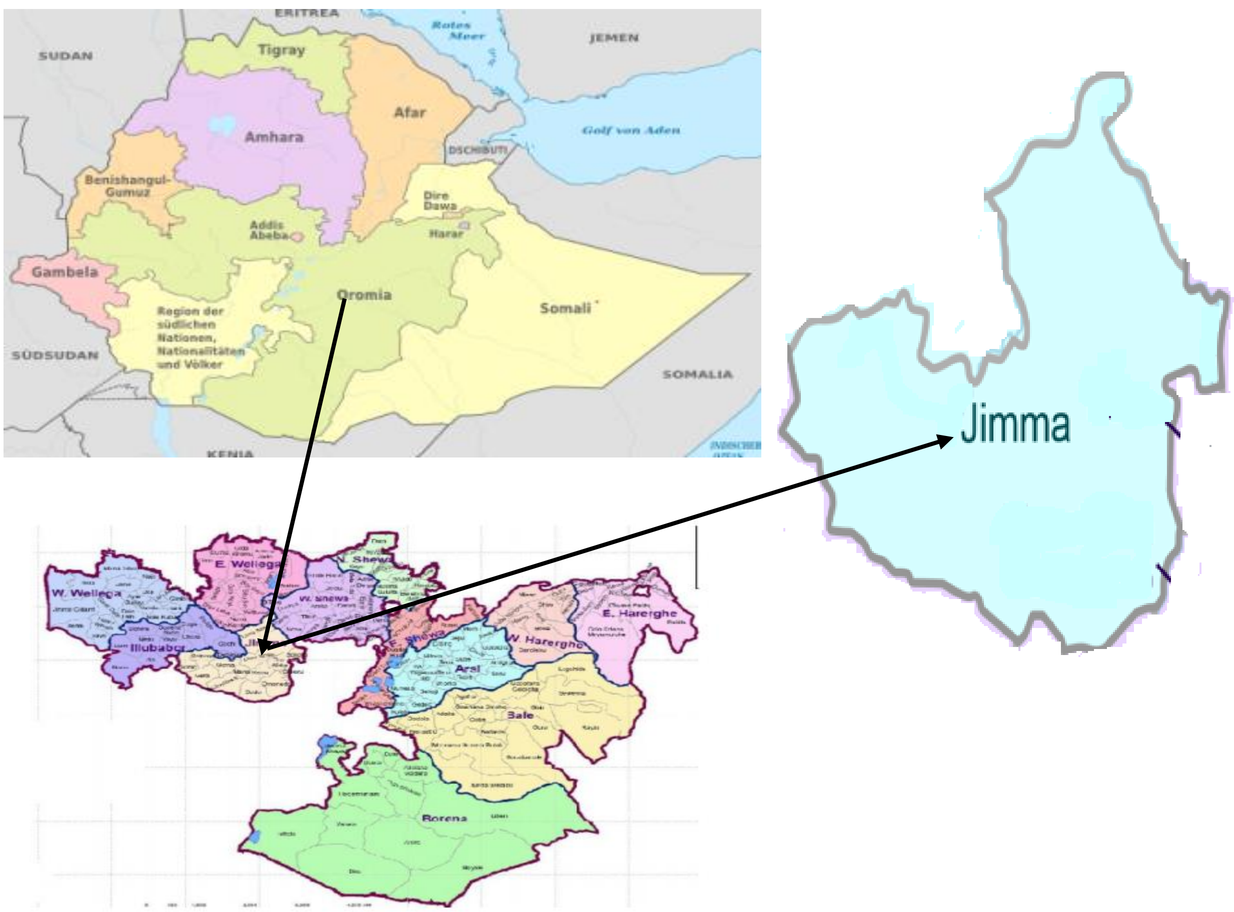

Figure 3.1: Map of Oromia Regional State (JIMMA) (Belew, et al., 2019)

3.2. Data requirement

For the experimental analysis of the hybrid coffee husk ash and sugarcane bagasse ash concrete with the available workability testing apparatus and universal testing machine the following properties was conducted.

A. For fresh concrete
   1. Slump test
   2. Compaction factor test

B. Harden Concrete
   1. Compressive strength
   2. Split tensile strength
   3. Flexural strength

3.3. Research design

This research used experimental research design method in order to investigate the effect of Combination of CHA and SCBA in the mechanical properties of concrete, to determine the optimum percentage of combination of SCBA and CHA used in concrete and find out the basic relationship of concrete stress and strain.

3.4. Study variables

3.4.1. Dependent variables

- Property of concrete
  - Workability
  - Compressive strength
  - Split tensile strength
  - Flexural strength

3.4.2. Independent variables

- Percentage of SCBA and CHA

Properties of concrete such as workability of fresh concrete hardened concrete strength; compressive strength, split tensile strength and flexural strength were depend on the percentage of hybrid coffee husk ash and sugarcane bagasse ash.

3.5. Population and sampling method

The grade of concrete that used for this research is C25. By adding different percentage value of combination of CHA and SCBA in concrete, sample taken for the different tests. The study used purposive sampling technique and the procedure taken according to ASTM and ACI standards which means minimum of cube samples per each test day was 3 samples. The samples for compressive strength, split tensile strength and Flexural strength for all 4 groups such as 0%, 5%, 10% and 15%, partially cement replaced by combination of CHA and SCBA concrete cured by ponding method and test taken on 7th, 14th and 28th days. For compressive strength, split tensile strength and Flexural strength the cube size was 150mm*150mm*150mm, cylinder of size 150mm diameters and 300mm length and beam of 150mm*150mm*700mm casted respectively. Total number of specimens casted for Mix control, compressive strength test, Split tensile strength and Flexural strength Flexural strength were 108 specimens. The samples casted to determine mix control (0% replacement) and partially replaced concrete are summarized on the table 3.1.

Table 3.1: Summary of total population

Types of specimen	Types and number of tests on 7, 14 and 28 days			Total
	Compressive	Split Tensile	Flexure Beam	
Control	9	9	9	27
Hybrid 5% CHA&SCBA	9	9	9	27
Hybrid 10% CHA&SCBA	9	9	9	27
Hybrid 15% CHA&SCBA	9	9	9	27
Total				**108**

3.6. Source of data

There are primary and secondary data were used for this study

3.6.1. Primary data

The primary data sources are from field study for material source determination and sample size, test results obtained on physical properties of material, Mix design results for both control and experimental groups and laboratory chronological test results of specimens after 7, 14 and 28 days curing.

3.6.2. Secondary data

The secondary data come from various published and unpublished sources, Books, journals and research reports.

3.7. Data collection procedure

In this study, descriptive and analytical methods of data collection process were followed. In descriptive data collection method, secondary sources of data from different published journals, books, conference and standard manuals were assessed. Whereas, primary data collection methods like field study for material source determination and laboratory investigation to determine physical properties of materials were used. Also, specimens that are placed in laboratory for different curing and testing time with different percentage ratio of Combination of CHA and SCBA , such as 0%, 5%, 10% and 15%, tested in their chronological order of curing and casting time, then the data registered with their code tagged on it for 7, 14 and 28 days.

3.8. Data presentation and analysis

After collecting the necessary materials for the production of concrete those are cement, aggregates, clean water, coffee husk ash and sugarcane bagasse ash, the laboratory experiment was continued. By using the results obtained from the laboratory the researcher analyzed the data by comparing and contrasting the effects of Hybrid coffee husk ash and sugarcane bagasse ash concrete with the control group using Microsoft word and excel 2013. The analyzed data then presented using charts, figures, and tables. Furthermore, this research paper was present the facts of laboratory result and recommend the optimum percentage of Hybrid coffee husk ash and sugarcane bagasse ash that must be used as a partial replacement of cement in concrete.

3.9. Experimental procedure

In this study coffee husk sample was collected from Jimma town coffee processing factory and was expose to sun to eliminate surface moisture and burn in an enclosed place then the ash was ground until the particle pass the 75µm sieve size; SCBA sample was collected from Arjo Didessa Sugar factory which is already burned to ash in furnace and sieve by 75µm sieve size to discard impurities and course size particle. The material such as cement, fine aggregate and course aggregate was buy from Jimma town and collected to the place where the experiment was conducted.

3.10. Ethical Consideration

Formal letter will be obtained from JIT postgraduate and research program office, and submitted to JiT laboratory office for official permission and for facilitating of laboratory to conduct different tests. Credits will be given for the authors of previous journal. They were acknowledged by citing their name and referencing their materials. The author may not plagiarize others work without citation.

3.11. Data Quality Assurance

The quality of data was enhanced and checked by taking enough number of specimens for each replacement level according to the standards. Similarly, the testing instrument was checked before and on ongoing progress to avoid the error that occurred during the experimentation. Also, a well-prepared checklist or sheet was prepared to record the results of the samples to avoid later confusions happen during the writing of the final paper.

3.12. Plan for dissemination

The result of the study was presented to Jimma University Institute of Technology, Faculty of Civil and Environmental Engineering for Post Graduate Program in Structural Engineering Department, and a copy of it were be kept in Jimma University Institute of Technology library for all concerned individuals.

3.13. Properties of Materials Used

3.13.1. Tests on Aggregates

Coarse aggregates of a normal weight extracted from crushed rock and with a maximum diameter of 20 mm were used. Aggregates were washed and dried. Excess fines in coarse aggregates were removed by sieving through 4.75mm sieve to confirm as per the requirements of ASTM C33. Fines contain many impurities and results in strength loss in the concrete and increase the surface area for water absorption increasing the characteristics of the mix.

Natural river sand collected from Cewaka River having maximum size of 4.75mm diameter was used. Each physical properties of the fine aggregate required for the mix design as per the specification was done in the laboratory. The detailed procedure for finding aggregate properties are illustrated under Appendix -A. The following Table 3.2 shows summary of physical properties of aggregate.

Table 3.2: Summary of water absorption, specific gravity, unit weight and total moisture content of aggregates.

Aggregate	Apparent specific gravity	Bulk specific gravity (SSD)	Bulk specific gravity (oven dry)	Absorption Capacity (%)	Unit weight (kg/m3)	Moisture content (%)
Fine	2.52	2.47	2.44	1.32	1587	0.5
Coarse	2.87	2.82	2.79	0.9	16765	0.4

3.13.2. Cement

Portland Pozzolana Cement (PPC) Dangote product cement with 32.5 grade was used for all mix of concrete specimens' preparation. It was brought from one of the Jimma's building materials shop. The normal consistency and setting time for cement were tested.

Table 3.3: Physical properties of Cement

Cement brand	**PPC**
Initial setting time(min)	150
Final setting time(min)	270
Specific gravity (g/cm3)	2.9

3.13.3. Water

A potable water used for drinking supplied from Jimma town water supply and sewerage authority was used for washing aggregate, mixing and curing of concrete.

3.13.4 Coffee Husk

The coffee husk for this research was collected from Jimma town, Ethiopia it was filled in sacks and transported to the research Centre at JiT Construction Laboratory.

In this research, coffee husk burned in a carbonate furnace for three hours at 550^{o}C to get the CH ash at JiT, Highway Engineering Department laboratory (Demissew, et al., 2019).

Figure 3.2: Burning Coffee husk

3.13.5 Sugarcane Bagasse As

SCBA sample was collected from Arjo Didessa Sugar factory which is already burned to ash in furnace and it was sieved by 75µm sieve size to discard impurities and course size particle.

Figure 3.3: Disposed Sugarcane bagasse ash at Arjo Didessa Sugar factory

The hybrid ash was then taken to the Geological Survey center of Ethiopia for the complete silicate analysis to determine major oxide and minor oxide element, the result of which are given in Table 3.4. Hybrid CHA&SCBA was analysed by LiBO2 FUSION, HF attacks, GRAVIMETRIC, COLORIMETRIC and Atomic Absorption Spectrophotometer (AAS) methods.

Table 3.4: Chemical composition of SCBA, CHA and hybrid of CHA&SCBA

Chemical composition (%)	SCBA (Hailu, 2011)	CHA (Demissew, et al., 2019)	Hybrid CHA&SCBA	Ethiopian Standard (ESA, 2013)
SiO_2	65.58	16.55	31.32	17-25
AlO_3	5.87	17.18	3.16	3-8
Fe_2O_3	4.32	3.98	1.66	0.5-6
CaO	1.78	5.68	5.86	60-67
MgO	1.23	1.12	1.68	0.1-4
Na_2O	1.02	1.84	0.56	0.3-1.3
K_2O	6.41	19.3	16.70	
MnO	0.05	<0.01	0.08	-
P_2O_5	1.35	1.72	2.30	-
TiO_2	0.25	0.04	0.20	-
H_2O	0.2	2.55	1.52	-
SO_3	0.18	1.9		1-3
SiO2+ Al2O3+ Fe2O3	75.77	37.71	36.14	

3.14. Mix design

Mix design is the process of determining the required and specified characteristics of a concrete mixture. These materials to achieve the desired strength. Mix proportioning on the other hand is the process of determining the quantities of concrete ingredients using local materials to achieve the specified characteristics of the concrete. Accurate concrete mix design makes concrete construction economical. In order to calculate the right amount of cement, sand and aggregate required in $1m^3$ of concrete; knowing the grade of concrete comes first. It is intended to prepare concrete grades C-25 which is the most commonly used grade of concrete throughout the country. The mix design for C-25 used in this study have a ratio of proportion 1:1.885:3.017**,** indicate cement, fine aggregates and coarse aggregates respectively. The steps for the mix design done based on ACI code are listed as follow.

Step 1: The desired strength is 25MPa

Collected data for mix design:-

- Fineness modulus of selected fine aggregate =2.4
- Unit weight of dry rodded coarse aggregate (Normal aggregate) =1676Kg/m3
- Specific gravity of coarse and fine aggregate in saturated surface dry condition is 2.82 and 2.47 respectively
- Absorption characteristic of both coarse and fine aggregate is 0.9%and 1.32% respectively
- Specific gravity of Portland Pozzolana cement = 2.9
- Free surface moisture in sand and coarse Aggregate 0.5% and 0.4% respectively

Step 2: The expected slump for workability selected as between 30 – 50mm

Step 3: The coarse aggregate used has nominal maximum size of 20mm

Step 4: The concrete is non-air entrained since the structure is not exposed to severe weather as per ACI code for 20mm aggregate size the total density of water is 185 kg/m3

Step 5: The required water cement ratio for the given mix design of non–air entrained concrete of 25MPa

- Maximum water-cement ratio is 0.5 for durability requirement with moderate condition of exposure and maximum aggregate size of 20mm.
- Maximum water-cement ratio is 0.62 for strength requirement, of 25MPa concrete strength. Taking the minimum of the two values; water-cement ratio to be used for the mix design is w/c 0.50.

Step 6: from the information developed in a step 4 and 5 the required cement contents obtained as:

$$\frac{185}{0.5} = 370\,Kg/m^3 \;\geq 360\,Kg/m^3 \;\ldots\ldots..\text{OK!}$$

Where 360 kg/m3 is the minimum cement content for C-25 with maximum size of 20mm Step 7: The quantity coarse aggregate is estimated from bulk volume of dry rodded gravel for maximum size of 20mm and fineness modulus of sand 2.4 which is found 0.66 m^3 per cubic meter of concrete is:

$$0.66 * 1676 = 1106.16Kg$$

Step 8: weight of fine Aggregate

From ACI table 11.9 the first estimate of density of fresh concrete for 20mm maximum size of aggregate and non-air entrained concrete =2355kg/m3

Weight of fine Aggregate = 2355 – (1106.16 + 370 + 185) = 693.84

Step 9: The absolute volume of mix ingredients per cubic meter of concrete based Volume basis is:

Cement $= \frac{Weight\ of\ cement}{sp.gravity} = \frac{370}{2.9*1000}$

$= 0.1276\ m^3$

Water $= \frac{185}{1*1000} = 0.185m^3$

Coarse Aggregate $= \frac{1106.16}{2.82*1000}$

$= 0.3923m^3$

Air (2%)$= \frac{2}{100} = 0.02$

Total volume without sand = $0.1276\ +\ 0.185\ +\ 0.3923\ +\ 0.02$

$=\ 0.7249m^3$

Volume of Sand = $1 -\ 0.7262m^3$

$=\ 0.2751m^3$

Then the dry mass of sand = $0.2738 *\ 2.47 * 10^3$

$= 679.497Kg$

Therefore, the mass of ingredients per cubic meter of concrete on dry weight basis is:

Cement = 370 kg

Water = 185 kg

Sand (fine aggregate) = $679.497Kg$

Coarse aggregate = $1106.16Kg$ Kg

Step 10: Proportion

Table 3.5: Content of concrete constituent before adjustment

Ingredients	Cement	sand	gravel	water
Quantity (kg/m^3)	370	679.641	1106.16	185
Ratio	1	1.84	2.989	0.5
One bag cement, Kg	50	91.8434	149.481	25

Step 11: Adjustment for field condition

Adjustment are made on concrete based on the moisture and dry content present in the aggregate.

Fine aggregate has surface moisture of 0.5% = 0.005

Weight of fine aggregates = 693.84 + 0.005*693.84

= 697.309

Coarse aggregate absorbs 0.9% of water = 0.009

Weight of coarse aggregate = 1106.16 + 0.009*1106.16

= 1116.115

Adjust the amount of water based on moisture content

The required mixing water = 185- 679.497(0.005-0.009) – 1106.16*(0.004 - 0.0132)

= 197.895

Step 12: Final design proportion

Table 3.6: Adjusted content of concrete constituent

Ingredients quantity (kg/m^3)	Cement	sand	gravel	water
	370	697.309	1116.11544	197.895
Ratio	1	1.885	3.017	0.535
One bag cement, Kg	50	94.231	150.826411	26.743

3.15. Tests Conducted on Concrete

Two different tests of concrete are applied for the experiment, they are test on fresh concrete properties for achieving comparable level of workability by slump cone and compaction factor test and test on hardened concrete which include compressive strength test, flexural strength test and split tensile strength test.

3.15.1. Workability Test

The workability of a concrete mix is the relative ease with which concrete can be placed, compacted and finished without separation or segregation of the individual materials. Workability is important because of two reason.

- If the concrete mixture is too wet, coarse aggregates settle at the bottom of concrete mass and as a result concrete becomes non-uniform composition and
- If the concrete mixture is too dry it will be difficult to handle and place it in position.

There are various types of workability testing methods implemented both in the laboratory and at site. These are Slump cone test, Compaction factor test, Vee-bee Consistometer test and flow meter test. Among this slump cone test and compaction factor test found in the laboratory of Jimma Institute of Technology were conducted for this research.

A. Slump Test

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.

Apparatus

Mold for slump test i.e. slump cone, non-porous base plate, measuring scale, temping rod. The mold for the test is in the form of the frustum of a cone having height 30 cm, bottom diameter 20 cm and top diameter 10 cm.

Procedure for Concrete Slump Cone Test

1. Clean the internal surface of the mould and apply oil.
2. Place the mould on a smooth horizontal non- porous base plate.
3. Fill the mould with the prepared concrete mix in 4 approximately equal layers.
4. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould.
5. Remove the excess concrete and level the surface with a trowel.
6. Clean away the mortar or water leaked out between the mould and the base plate.
7. Raise the mould from the concrete immediately and slowly in vertical direction.
8. Measure the slump as the difference between the height of the mould and that of height point of the specimen being tested.

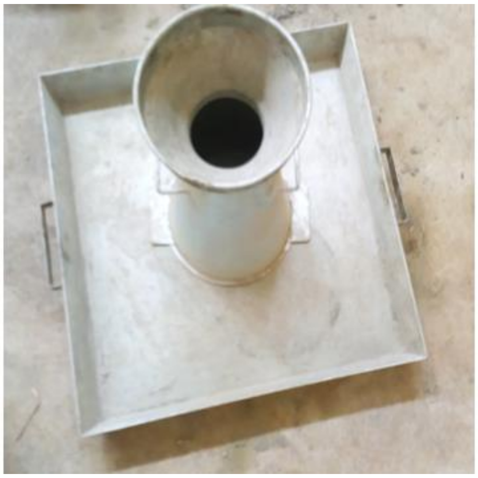

Figure 3.4: Slump test on concrete

B. Compaction Factor Test for Concrete Workability

The compaction factor test is used to calculate the degree of workability of fresh concrete with regard to the internal energy required for computing the concrete perfectly.

It is an alternative way of measuring workability of concrete and it is more accurate than slump test and it is better for low workability below -25mm slump.

Apparatus

Compaction factor apparatus consists of trowels, hand scoop, a rod of steel or other suitable material and a balance.

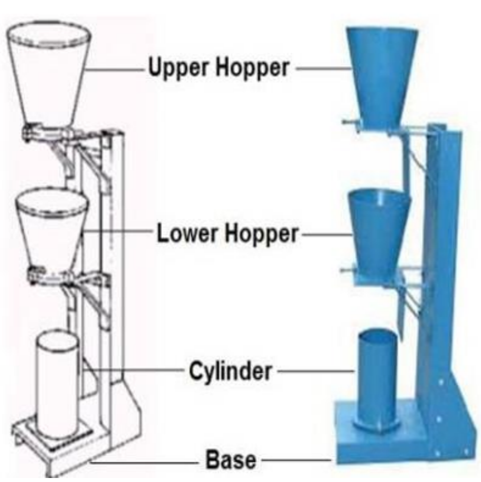

Figure 3.5: Compaction Factor test on concrete

Procedure of Compaction Factor Test on Concrete

1. Clean and dry the internal surface of the moulds.
2. Place the concrete sample gently in the upper hopper by using the hand scoop and level it.
3. Open the trapdoor at the bottom of the upper hopper so that concrete fall into the lower hopper. Push the concrete sticking on its sides gently with the road.
4. Open the trapdoor of the lower hopper and allow the concrete to fall into the cylinder below.
5. Cut of the excess of concrete above the top level of cylinder using trowels and level it.
6. Clean the outside of the cylinder.
7. Weight the cylinder with concrete to the nearest 10 g.
8. Fill the cylinder with the same concrete mix in three layers and compact each layers layers approximately 5 cm deep, each layer 100% compaction is achieved
9. Level the top surface and weigh the cylinder with fully compacted.
10. Calculate the value of compaction factor using the following

$$\text{Compaction Factor Value} = \frac{\text{weight of partially compacted concrete}}{\text{weight of fully compacted concrete}}$$

$$CF = \frac{PC}{FC} \ldots \ldots eq\ 3.1$$

3.16. Mixing and casting

The mix of hybrid coffee husk ash and sugarcane bagasse ash blended concrete takes place the same as the normal concrete mix procedure. All ingredients of concrete are measured for required volume of concrete. Ten mix types prepared including the control for each mix type.

The volume of concrete mixed are three cubes, three cylinders and three flexure which gives total of 0.02984m^3 volume of concrete. The hybrid of coffee husk ash and sugarcane bagasse ash mix properly with cement then sand and properly mixed cement with ash are dry mixed.

Then the coarse aggregate added with little amount of water step by step and mix until getting evenly mixed hybrid coffee husk ash and sugarcane bagasse ash blended concrete.

Figure 3.6: Mix and casting

First of all the moulds made of cast iron were used to prepare the specimens of size 150 x 150 x150 mm for cubes, 100 x 100 x 500mm beams and cylinders of 100mm diameter and 200mm long. The wooden moulds are made as per the specification to maximize number of molds since there is limited number of molds are available in the laboratory for flexure.

During the placing of concrete in the moulds, before assembling the mould, it’s mating surfaces and insides was covered with a thin layer of oil, to prevent concrete and the mould bonding then the moulds were placed on the appropriate place and compacted until the specified conditions were attained.

After 24 hours the specimens were removed from the moulds, then date of casting are written on the concrete specimens and immediately submerged in to water for curing in the curing tank. After 7, 14 and 28 days of curing, the specimens were taken out and tested using the cube crushing test, tensile test, and the two point bending test.

Different types of casted specimens like beams, cylinders and cubes shape are shown in the below picture.

Figure 3.7: Demolding and curing Casted specimen

After the mixing operation had been completed, a total of 108 specimens in which 36 cube specimens for compression test, 36 beam specimens for flexure test, and 36 cylinder specimens for Split tensile tests were prepared and cured in curing tank for 7^{th}, 14^{th} and 28^{th} day test.

3.17. Test on hardened concrete

3.17.1. Cube Crushing Test

The compressive strength test of concrete is the most common test type for the hardened concrete. The reasons for these are; many codes and design manuals are based on this property, many other properties of concrete depend on the compressive strength and when compared to other tests this is an easy one. The size of specimen is 15×15×15 cm was cast for C25 grade of concrete added with hybrid CHA & SCBA, these cubes were tested on compression testing machine. This test was done by using universal testing machine that can apply maximum load of 2000KN and records the peak load and the corresponding compressive stress of concrete.

Figure 3.8: Cube tested on compression testing machine.

The compressive strength is given by:

$$copressive\ stress(\sigma) = \frac{Peak\ load}{cross\ sectional\ area} = \frac{P}{A} = \frac{P}{b*d} = \frac{P}{150*150}(MPa) \ldots\ldots eq\ 3.2$$

3.17.2. Split Tensile Strength test

The tensile strength of concrete is very important to concrete because concrete structures are very vulnerable to tensile cracking due to various effects and applied loading. The tensile strength of concrete is very low however compared to its compressive strength.

Due to difficulty in applying uniaxial tension to a concrete specimen, the tensile test is obtained by indirect methods. For the experiments carried out, the method used was the split cylinder test. The method adopted was the indirect tensile splitting test of cylindrical concrete specimens. Concrete mixes were prepared and the fresh concrete cast in 100mm diameter moulds. Compaction were done in three layers to achieve the required compaction. The upper surfaces of the cylinders were smoothened using a plasterer’s float and the outside of the moulds wiped clean. The specimens were stored in an undisturbed environment for 24 hours then cured in a curing tank for the required number of days.

The split-cylinder test is a method of determining the tensile strength of concrete in an indirect way. A cylinder of 100mm by 200mm length was placed horizontally on a compression testing machine. The load was applied diametrically and uniformly along the length of the cylinder. To allow for uniform distribution of load and to avoid high compressive stress at the point of application, plywood strips were placed between the loading specimen and the compressive surface of the compression test machine. The cylinders were tested using compression testing machine having 2000 KN capacity. The load will then be applied and gradually increased and maintained until failure of the specimens. The maximum loads applied to each specimen was recorded.

The splitting tensile stress is obtained using the following formula.

$$\mathrm{T} = \frac{2\mathrm{P}}{\pi \mathrm{DL}} \ldots\ldots\ldots\ldots..eq\ 3.3$$

Where, T= the spilt tensile strength of the concrete P= compressive load on the cylinder L= length of the cylinder D= diameter of the cylinder

Figure 3.9: Split tensile strength test setup

3.17.3. Flexural Strength test

The concrete beam specimen with standard size of 100 mm x 100 mm x 500 mm was loaded atone third point from the support and at its interior location by a gradual increasing load at failure. The specimen was loaded gradually increasing the bending load using a bending testing machine According to ASTM C 42 the failure load (loading value at which the concrete cracks heavily) was then recorded and used to determine the tensile stress at which the member failed.

Three samples for 7^{th}, three samples for 14^{th} and three samples for 28^{th} day test from each mix was casted. After 24 hours the moulds are removed and the specimens are cured in curing tank using potable water up to the date of test. A two-point loaded flexural strength testing machine having 2000KN was used. The beam sample was marked at 10cm from each end and at the mid span. The loads are applied at one-third from the support in both sides as shown in the following flexural strength setup

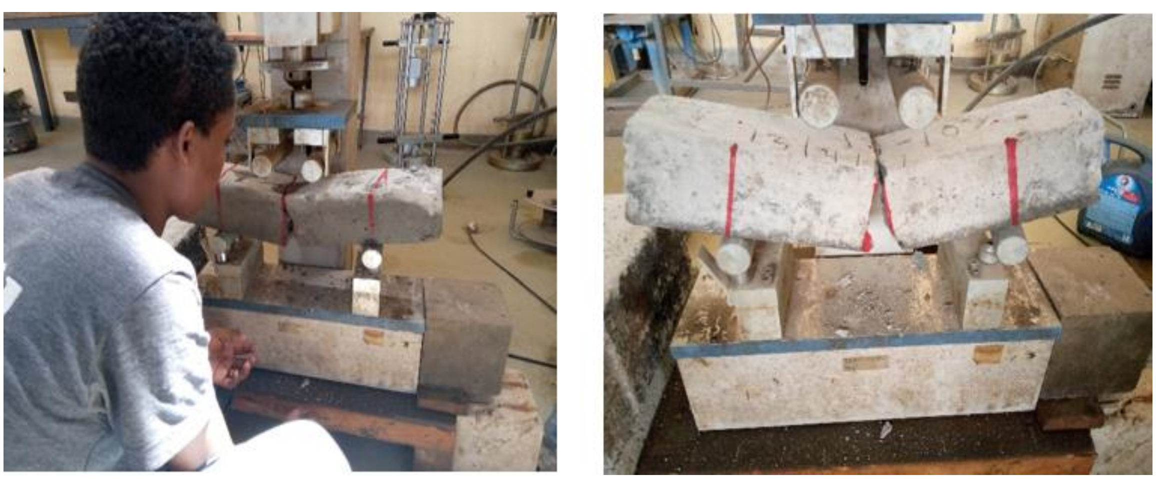

Figure 3.10: Flexural strength setup

The strength was determined from the general formula of flexural stress.

a) If failure with in the middle third of the span

$$M.R = \frac{PL}{bd^2} \dots \dots .. eq\ 3.4$$

b) If the failure occurs outside the middle third of the span length by not more than 5% of the span length

$$M.R = \frac{3PA}{bd^2} \dots \dots .. eq\ 3.5$$

Where:

M.R= modulus of rupture

P = maximum applied load, N

L = span length, mm

b = average width of specimen, mm

d = average depth of specimen, mm

A = average distance between line of fracture and the nearest support measured on the tension surface of the beam

3.18. The structural framework of the study

Generally, the methodology which was carried out during the study is presented in the form of sequential steps as illustrated in the following figure 3.11.

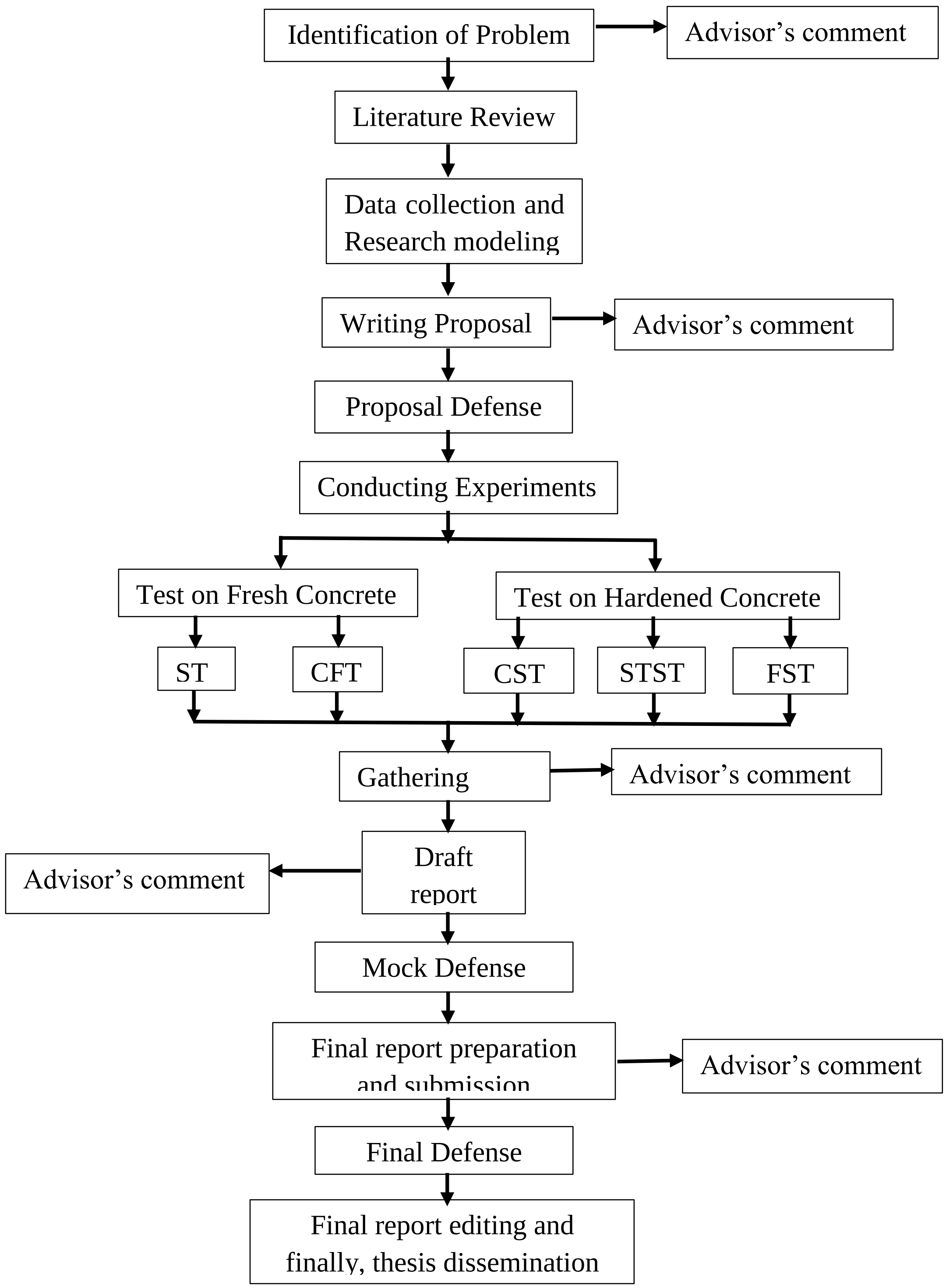

Figure 3.11: Work flow char

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Results and discussions on hybrid of CHA&SCBA and cement blend pastes

4.1.1. Consistency of blended pastes

Cement sets and hardens into a solid mass up on hydration when mixed with water. It binds two or more non-adhesive substance. For various test of cement, neat cement paste of normal (standard) consistency has to be made by mixing the cement with the correct amount of water. It is determined by using vicat apparatus, which measure the resistance of the paste to the penetration of plunger of 300gm released at the surface of the paste.

The determination of the correct amount of water is required for the reason that the rate of hydration and setting of cement are affected by the water cement ratio.

To determine the quantity or parentage of mixing water required for preparing cement paste of standard consistency is done. The detail results of normal consistency of cement are illustrated under Appendix–B, Table B-1.

Table 4.1: Normal consistency of blended pastes containing hybrid CHA&SCBA

S. No	Percentage of replacement	Consistency (%) (ASTM C 187)
1	Control (0%)	29
2	5%	30
3	10%	32
4	15%	33

4.1.2. Setting time of blended pastes

The Ethiopian standard limits the initial setting time of cement not to be less than 45 minutes and the final setting time not to exceed 10 hrs. The results for the setting time in Table 4.2 indicated that addition of hybrid coffee husk ash and sugarcane bagasse ash slow the rate of setting of concrete or retarded the setting; however, this retardation was within limits as specified by the Ethiopian standard. As the hybrid coffee husk ash and sugarcane bagasse ash content increases, the setting time has also showed a trend of increment.

The reason for the increasing in setting time could be the adsorption of water on hybrid of coffee husk ash and sugarcane bagasse ash. The higher the proportion of the hybrid coffee husk ash and sugarcane bagasse ash, the higher was the adsorption of water increasing the normal consistency that in turn slow the rate of setting of concrete or retreaded the setting time of paste.

Table 4.2: Setting time of pastes containing hybrid CHA&SCBA

S. No	Code	Initial setting time (minutes)	Final setting time (minutes)
1	Control	150	270
2	5%	156	277
3	10%	164	287
4	15%	182	308

4.1.3. Chemical properties of hybrid of CHA and SCBA

The hybrid CHA&SCBA was then taken to the Geological Survey center of Ethiopia for the complete silicate analysis and major oxide elements are given in Table 4.3.

Table 4.3: Major and minor oxides of hybrid of CHA and SCBA

Component	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
Hybrid SCBA &CHA	31.32	3.16	1.66	5.86	1.68	16.70	0.08	2.30	0.20	1.52	36.32

As shown in Table 3.4, hybrid CHA&SCBA has found that Al_2O_3, Fe_2O_3, and MgO with in the range as described in Ethiopian standards (ESA, 2013) and it resulted for the formation of compounds like C3S and C3A which are mainly responsible for early strength of concrete. Moreover, the hybrid CHA&SCBA was found to have high alkali content like K_2O (16.70%) implying high potential for alkali-silica reaction when used in concrete with silica reach aggregates.

Addition to that from table 2.1 it was found that, hybrid CHA&SCBA has higher values from some common raw materials of cement. Such as SiO2 of hybrid CHA&SCBA was greater than lime stone, iron ore, bauxite and gypsum. SiO2 of hybrid CHA&SCBA was greater than SiO2 CHA. Al2O3 of hybrid CHA&SCBA was greater than limestone, sand and gypsum. Fe_2O_3 of hybrid CHA&SCBA in similar manner was found higher than gypsum, sandy, and limestone. The same as CaO of hybrid CHA&SCBA was greater than CHA, SCBA, fuel ash, bauxite, sand, shale, iron ore, clay and sandy. This shows that hybrid CHA&SCBA has the required chemical requirement of raw materials for cement productions.

4.2. Sieve Analysis

Sieve analysis was done to determine the fineness modulus of aggregates and the relative amounts of particle sizes distribution of particle in the aggregate using sieve series of square or round openings starting with the large at the top. The sieve was arranged in descending order of size from top to bottom.

The maximum size of the aggregate used was 20mm. For the sieve analysis, the coarse aggregate passing the sieve sizes in between 25mm and 4.75mm sieve according to (ASTMC33/C33M, 2011)sieve size was used. The coarse aggregate grading, upper and lower limits bounds are shown in figure 4.1. The cumulative percentage of passing, percentage retained and the range of requirement as per the specification are briefly tabulated under appendix-A, table A-7.

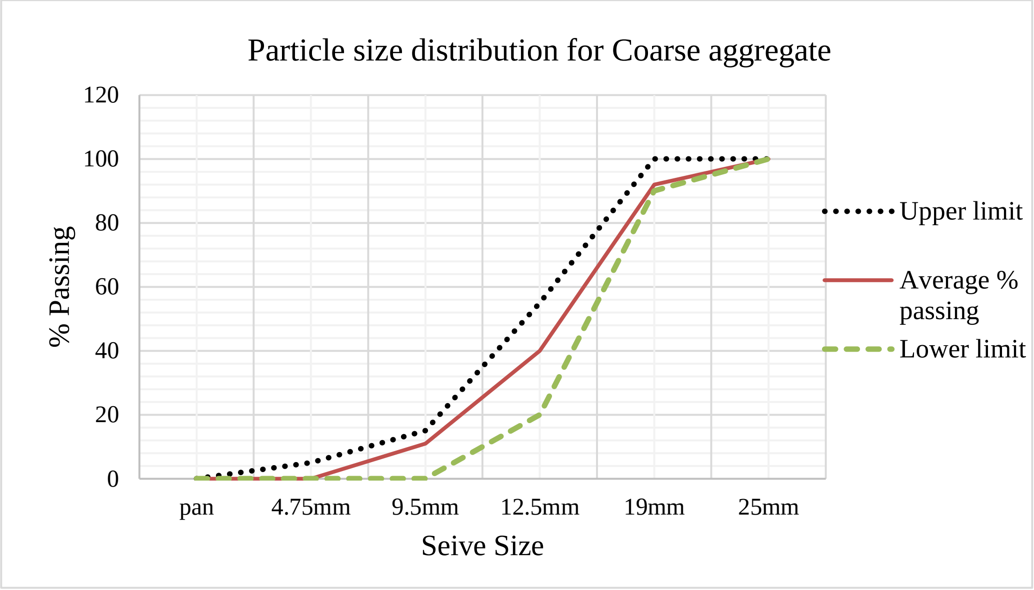

Figure 4.1: Coarse aggregate particle size distribution

Fine aggregate fully passes through 9.5mm sieve size was used. By using the particle size distribution data, the average fineness modulus (uniformity of grading) used for mix design was calculated. The fine aggregate grading, upper and lower limits bounds are shown in figure 4.2 and the detailed cumulative percentage passing, percentage retained, fineness modulus and the requirement range as per (ESC.D3.201, 1990)are shown under Appendix -A, table A-8.

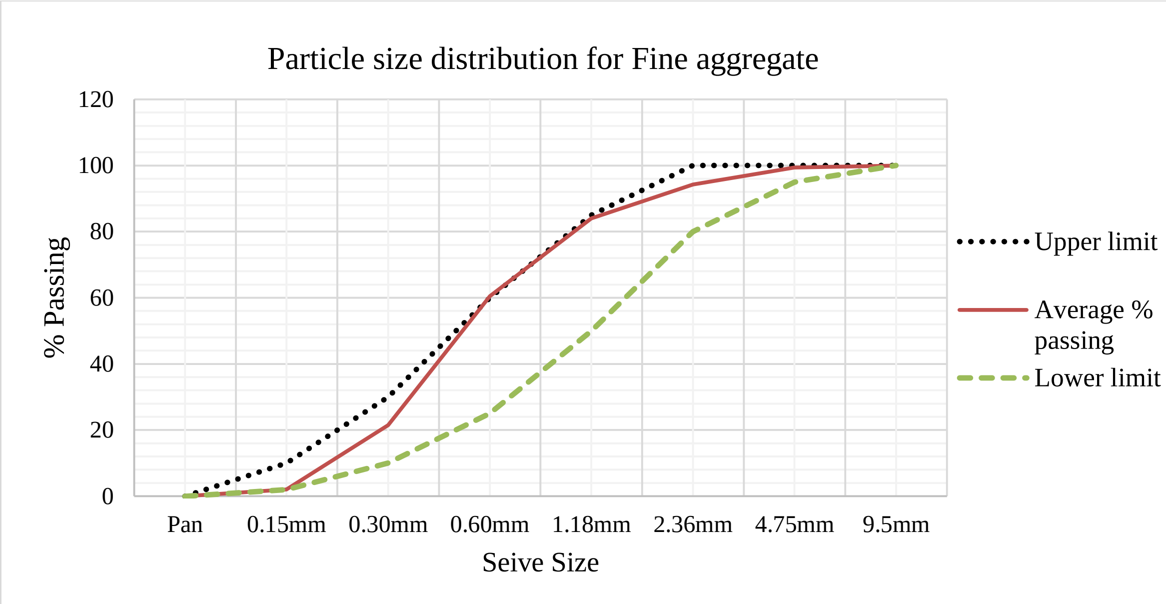

Figure 4.2: Fine aggregate particle size distribution

4.3. Results and discussion on fresh and harden hybrid CHA & SCBA concrete properties

In this part of the thesis, the fresh and hardened hybrid coffee husk ash and sugarcane bagasse ash concrete properties such as workability, mass versus density, compressive strength tests, stress-strain relationship for compressive strength test, split tensile strength test and flexural strength test are presented and analyzed respected to control specimens and relevant standards.

4.3.1. Fresh concrete properties

4.3.1.1. Workability Test

Slump cone test and compaction factor test are done on fresh concrete for knowing the workability of HAC (hybrid ash concrete) discussed as follows. The detail results of slump and compaction factor are illustrated under Appendix–B, Table B-2 and Table B-3.

A. Slump test

The mold for the slump test is in the form of a frustum of a cone, which was placed on top of a rigid and flatten surface. The mold was filled in three equal layers and each layer was tamped 25 times with a tamping rod. Surplus concrete above the top edge of the mold was stroked off with the tamping rod. The cone immediately lifted vertically and the amount by which the concrete sample slumps were measured. The value of the slump obtained from by taking the mean of the distance between the underside of the round tamping bar and the highest, the lowest and medium points on the surface of the slumped concrete sample. Figure 4.3 shows the results of the slump test for the control concretes and the hybrid of coffee husk ash and sugarcane bagasse ash concretes.

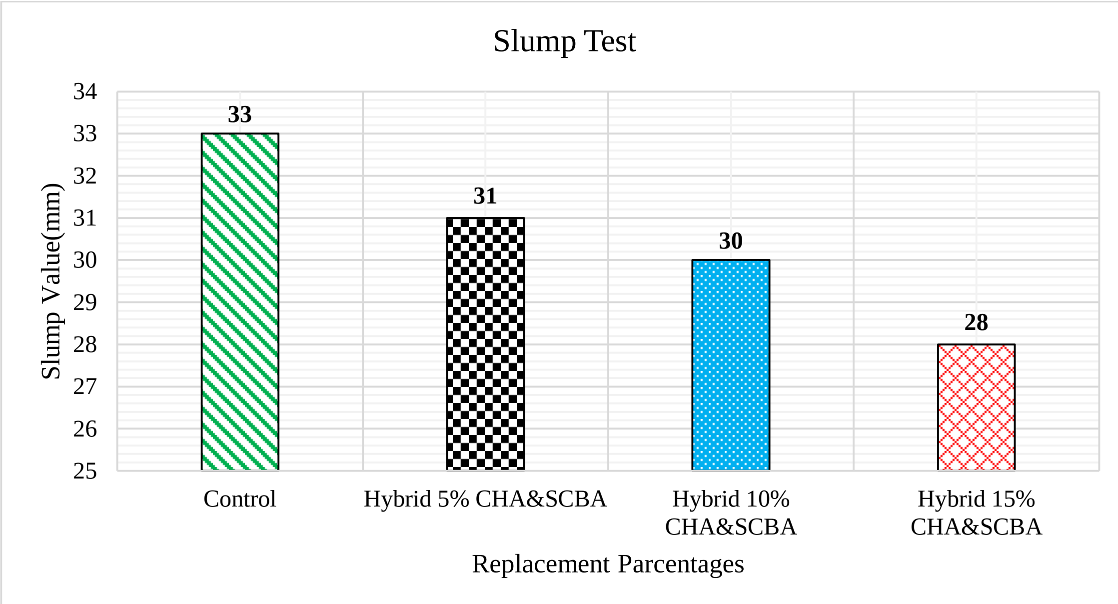

Figure 4.3: Slump taste

As observed from Figure 4.3 the slumps of the concrete containing hybrid of coffee husk ash and sugarcane bagasse ash have shown a reduction as the percentage of ash content increases. In order to get similar slump for the control mix and PPC- hybrid CHA&SCBA concrete, the water content be increased as the hybrid coffee husk ash sugarcane bagasse ash content increases. Table 4.1 (normal consistency), shows that the normal consistency of the blended pastes increased with increase of the hybrid of coffee husk ash and sugarcane bagasse ash, this can also be an indication that in order to get a certain slump, PPC- hybrid of CHA&SCBA blended concretes needs a higher water content than a concrete with no hybrid of coffee husk ash and sugarcane bagasse ash. The possible reason for this was hybrid of coffee husk ash and sugarcane bagasse ash is lower density giving it a higher porosity, resulting in higher water request. In order to get similar slump for the control and PPC- hybrid of CHA&SCBA concrete, the water content be increased as the hybrid of CHA&SCBA content increases. According to (ASTMC143/C143M, 2011) concretes having slumps less than 15 mm may not be adequately plastic and concretes having slumps greater than about 230 mm may not be adequately cohesive for this test to have significance. As a result, since the slump of the study found in the range of 28-33mm, hybrid of CHA&SCBA concrete is good in plastic and cohesive properties. As a result it was found that hybrid of CHA&SCBA concrete will be good to minimize segregation of fresh concrete during placing and consolidating of concrete.

B. Compaction factor test

Compaction factor test is the workability test for concrete conducted in laboratory. The compaction factor is the ratio of weights of partially compacted to fully compacted concrete. The test is used for concrete which have low workability for which slump test is not suitable. It was taken for each concrete mix for this research. The results of compaction factor test is shown in the Figure 4.4.

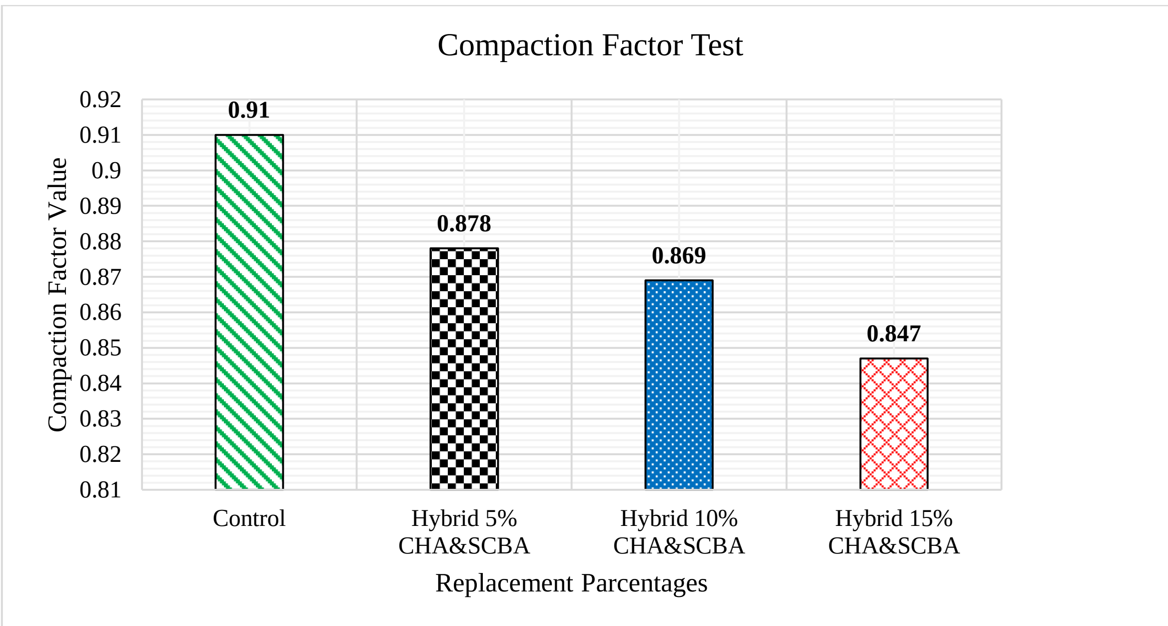

Figure 4.4: Compaction factor test

From Figure 4.4, it was clearly observed that, the compaction factor test result shows decrease for all hybrid of CHA&SCBA concrete as compared to control mix. As the percentage of ash content increases the compaction factor test result decrease. In order to get similar compaction factor value for the control mix and PPC- hybrid CHA&SCBA concrete, the water content be increased as the hybrid coffee husk ash sugarcane bagasse ash content increases.

4.3.2. Hardened Concrete properties

4.3.2.1. Mass versus Density of hardened concrete

The weights and the dimension of the concrete for this research were measured just before testing them. The results for the weight and dimension are given in the appendix C. Unit weights of the concrete were calculated by using the 28 days average unit weight cube and the results are as shown in Table 4.4. The unit weight values used for the analysis of this section were measured from the concrete cubes sample after 28 days of cured in curing tank.

Table 4.4: Mass versus Density of the specimen

Mix. No	Percentage of fiber added	Mass of cube on 28 day in (kg)				Density (Kg/m^3)	Density Reduction (%)
		S-1	S-2	S-3	Avg.		
1	Control	8.18	8.22	8.28	8.23	2469.14	0.0
2	5%	8.12	8.08	8.11	8.10	2416.79	2.12
3	10%	7.96	8.01	7.89	7.95	2383.21	3.48
4	15%	7.43	7.35	7.32	7.37	2183.70	7.12

From the results, it was found out that there were reduction of density while, hybrid of coffee husk ash and sugarcane bagasse ash replacement percentages increases. As shown in Table 4.4 when 5% of hybrid of coffee husk ash and sugarcane bagasse ash added the density of control concrete resulted reduction of density within 2.12% and the reduction continued up to 7.12% was observed when 15% of the cement was replaced hybrid coffee husk ash and sugarcane bagasse ash. Whereas 3.48% reductions were observed for 10% hybrid of coffee husk ash and sugarcane bagasse ash replacement.

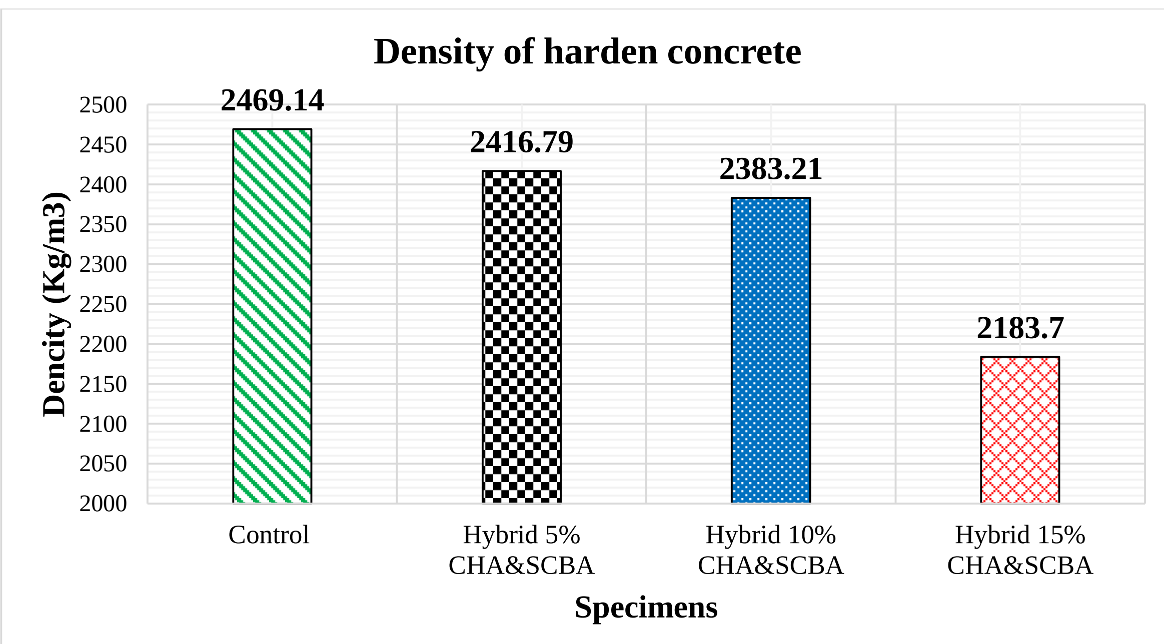

Figure 4.5: Graphical comparison for unit weight values of hybrid CHA&SCBA

Using concrete with a lower density can result in significant benefits in terms of load bearing elements of smaller cross-section and a corresponding reduction in the size of foundations.

This research was conducted for production of normal weight concrete, and the density of the specimens ranges from 2469.14Kg/m^3 to 2383.21 Kg/m^3 (table 4.4) for Control to hybrid10% CHA&SCBA and 2293.33 Kg/m^3 for hybrid15% CHA&SCBA replacement. This showed that 5 and 10 % replacements lies within the range of 2200 Kg/m3 to 2600 Kg/m3 and 15 % replacements was out of the range specified as the density of normal weight concrete by (Neville, 2000).

4.3.2.2. Compressive strength Test

The compressive strength test of concrete is the most common test type for the hardened concrete. To specify the concrete compressive strength, $f_{ck}(t)$, at time t for a number of stages (e.g. demoulding, transfer of prestress) (ESA, 2015).

Where

$$f_{ck}(t) = f_{cm}(t) - 8(MPa) \ldots \ldots . eq\ 4.1 \qquad for\ 3 < t < 28\ days$$

$$f_{ck}(t) = f_{ck} \qquad for\ \geq 28\ days$$

The compressive strength of concrete at an age t depends on the type of cement, temperature and curing conditions. For a mean temperature of 20°C and curing in accordance with EN 12390 the compressive strength of concrete at various ages $f_{cm}(t)$ may be estimated from Expressions (3.1) and (3.2) (ESA, 2015).

$$f_{cm}(t) = \beta_{cc}(t) fcm \ldots \ldots . eq\ 4.2$$

$$\beta_{cc}(t) = \exp\left\{s\left[1 - \left(\frac{28}{t}\right)^{1/2}\right]\right\} \ldots \ldots . eq\ 4.3$$

Where:

$f_{cm}\,(t)$: *is the mean concrete compressive strength at an age of t days*

f_{cm}: *is the mean compressive strength at 28 days*

$\beta_{cc}(t)$: *is a coefficient which depends on the age of the concrete t*

t: *is the age of the concrete in days*

s: *is a coefficient which depends on the type of cement*:

= 0.20 for cement of strength Classes CEM 42.5 R, CEM 52.5 N & CEM 52.5R (Class R)

= 0.25 for cement of strength Classes CEM 32.5 R, CEM 42.5 N (Class N)

= 0.38 for cement of strength Classes CEM 32.5 N (Class S)

For this study Dangote PPC grade 32.5R was used and the value of s =0.25

Where the concrete does not conform with the specification for compressive strength at 28 days the use of Expressions (eq.4.2) and (eq.4.3) is not appropriate.

7th day Concrete Conform the Specification

$$\beta_{cc}(t) = \exp\left\{s\left[1 - \left(\frac{28}{t}\right)^{1/2}\right]\right\}$$

$$s = 0.25\ and$$

$$for\ \ 7^{th}\ day\ t = 7$$

$$\beta_{cc}(7) = \exp\left\{0.25\left[1 - \left(\frac{28}{7}\right)^{1/2}\right]\right\}$$

$$\beta_{cc}(7) = 0.7788$$

$$f_{cm}(t) = \ \beta_{cc}(t)fcm$$

$$fcm\ for\ concrete\ C20/25 = \ 28MPa$$

$$f_{cm}(7) = \ 0.7788 * 28$$

$$f_{cm}(7) = 21.806MPa$$

$$f_{ck}(t) = f_{cm}(t) - 8(MPa)$$

$$for\ 3 < t\ \ < 28\ days$$

$$f_{ck}(7) = 21.806MPa - 8MPa$$

$$f_{ck}(7) = 13.806MPa$$

To convert the 7th day compressive strength of concrete using cylinder to its value by cube 1.25 factor used based on ESEN-2:2015 for C20/25.

$$\boldsymbol{f_{ck,cube} = 1.25 * f_{ck}}$$

$$\boldsymbol{f_{ck,cube}(7) = 1.25 * \ 13.806 \quad f_{ck,cube}(7) = 17.258 MPa}$$

Table 4.5: Compressive strength test result on 7th day

Compressive strength test result on 7th day							
Mix no	percentage of Ash added	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)	$fck, cube\ (7)$	Minimum required $fck, cube\ (7)$	Remark
1	Control	451.11	20.05	0	20.05	17.258	Concrete Conform the Specification
2	5%	462.43	20.55	-2.51	20.55	17.258	Concrete Conform the Specification
3	10%	394.75	17.55	12.49	17.55	17.258	Concrete does not Conform the Specification
4	15%	368.93	16.40	18.22	16.40	17.258	Concrete does not Conform the Specification

14th day Concrete Conform the Specification

$$\beta_{cc}(t) = \exp\left\{s\left[1 - \left(\frac{28}{t}\right)^{1/2}\right]\right\}$$

$$s = 0.25 \ and \ for \ \ 14^{th} \ day \ t = 14$$

$$\beta_{cc}(14) = \exp\left\{0.25\left[1 - \left(\frac{28}{14}\right)^{1/2}\right]\right\} = 0.9016$$

$$f_{cm}(t) = \ \beta_{cc}(t) fcm$$

$$fcm \ for \ concrete \ C20/25 = \ 28MPa$$

$$f_{cm}(14) = 0.9016 * 28$$

$$= 25.2448MPa$$

$$f_{ctm}(14) = 25.2448MPa$$

$$f_{ck}(t) = f_{cm}(t) - 8(MPa) \qquad for\ 3 < t < 28\ days$$

$$f_{ck}(14) = 25.2448MPa - 8MPa = 17.2448MPa$$

To convert the 14th day compressive strength of concrete using cylinder to its value by cube 1.25 factor used based on ESEN-2:2015 for C20/25.

$$\boldsymbol{f_{ck,cube} = 1.25 * f_{ck}}$$

$$\boldsymbol{f_{ck,cube}(14) = 1.25 * 17.2448}$$

$$f_{ck,cube}(14) = 21.556MPa$$

Table 4.6: Compressive strength test result on 14th day

Compressive strength test result on 14th day							
Mix no	percentage of Ash added	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)	$fck, cube$ (14)	Minimum required $fck, cube$ (14)	Remark
1	Control	551.74	24.52	0	24.52	21.556	Concrete Conform the Specification
2	5%	512.13	22.77	7.16	22.77	21.556	Concrete Conform the Specification
3	10%	505.04	22.45	8.45	22.45	21.556	Concrete Conform the Specification
4	15%	436.34	19.40	20.91	19.40	21.556	Concrete does not Conform the Specification

28th day Concrete Conform the Specification

$$\beta_{cc}(t) = \exp\left\{s\left[1 - \left(\frac{28}{t}\right)^{1/2}\right]\right\}$$

$$s = 0.25 \; and$$

$$for \;\; 28^{th} \; day \; t = 28$$

$$\beta_{cc}(28) = \exp\left\{0.25\left[1 - \left(\frac{28}{28}\right)^{1/2}\right]\right\} = 1.0$$

$$\beta_{cc}(28) = 1.0$$

$$f_{cm}(t) = \; \beta_{cc}(t) fcm$$

$$f_{cm} \; for \; concrete \; C20/25 = \; 28MPa$$

$$f_{cm}(28) = \; 1.0 * 28$$

$$f_{cm}(28) = 28MPa$$

$$f_{ck}(t) = f_{cm}(t) - 8(MPa) \qquad for \; 3 < t \; < 28 \; days$$

$$f_{ck}(28) = 28MPa - 8MPa = 20MPa$$

OR

$$f_{ck}(28) = f_{ck} \qquad for \; \geq 28 \; days$$

$$f_{ck} \; for \; concrete \; C20/25 = \; 20MPa$$

To convert the 28th day compressive strength of concrete using cylinder to its value by cube 1.25 factor used based on ESEN-2:2015 for C20/25.

$$\boldsymbol{f_{ck,cube} = 1.25 * f_{ck}}$$

$$\boldsymbol{f_{ck,cube}(28) = 1.25 * \; 20}$$

$$f_{ck,cube}(28) = 25MPa$$

Table 4.7: Compressive strength test result on 28th day

Compressive strength test result on 28th day							
Mix no	percentage of Ash added	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)	$fck, cube$ (28)	Minimum required $fck, cube$ (28)	Remark
1	Control	649.84	28.88	0	28.88	25.00	Concrete Conform the Specification
2	5%	595.63	26.47	8.34	26.47	25.00	Concrete Conform the Specification
3	10%	566.37	25.18	12.82	25.18	25.00	Concrete Conform the Specification
4	15%	473.18	21.04	27.17	21.04	25.00	Concrete does not Conform the Specification

The results of the compressive strength of concrete cubes show that the compressive strengths reduced as the percentage hybrid CHA&SCBA increased, addition of hybrid CHA&SCBA resulted in reduction in concrete compressive strength compared with the control mix. This reduction increased with increasing percentage of ash. Losses in compressive strength of 8.34, 12.82, and 27.17 % were observed when 5, 10 and 15 % of the cement was replaced by an equivalent volume of hybrid coffee husk ash and Sugarcane bagasse ash respectively on the 28th day compressive strength test result. However, the compressive strengths increased as the number of days of curing increased for each percentage hybrid CHA&SCBA replacement.

Table 4.8: Average compressive strength values of concrete summery

Mix No	Percentage of replacement	Average compressive strength in N/mm2			Loss of strength in % due to increasing CHA			Increments of strength due to aging of cubs from 7 to 28 days (%)
		7th day	14th day	28th day	7th day	14th day	28th day	
1	Control	20.05	24.52	28.88	0	0	0	44.04
2	5%	20.55	22.77	26.47	-2.51	7.16	8.34	28.81
3	10%	17.55	22.45	25.18	12.49	8.45	12.82	43.48
4	15%	16.40	19.40	21.04	18.22	20.90	27.17	28.29

As shown in Table 4.9 cube compressive strength on 7th day result the compressive strength of Hybrid 5% CHA&SCBA concrete is greater than the control mix with 2.51% and cube compressive strengths increased from the 7th day to 28th day by average of 36.15 of strength.

The probable reason for decreasing of Hybrid CHA&SCBA concrete compressive strength is due to the high replacement of cement by hybrid coffee husk ash and sugarcane bagasse ash, thus reducing cement content of the mixture, which in turn causes a reduction in the hydration reaction. In addition to this, the high content of hybrid coffee husk ash and sugarcane bagasse ash resulted in a higher water requirement, making the water unavailable for the hydration of the cement. Figure 4.6 shows the trend in compressive strength of the concrete.

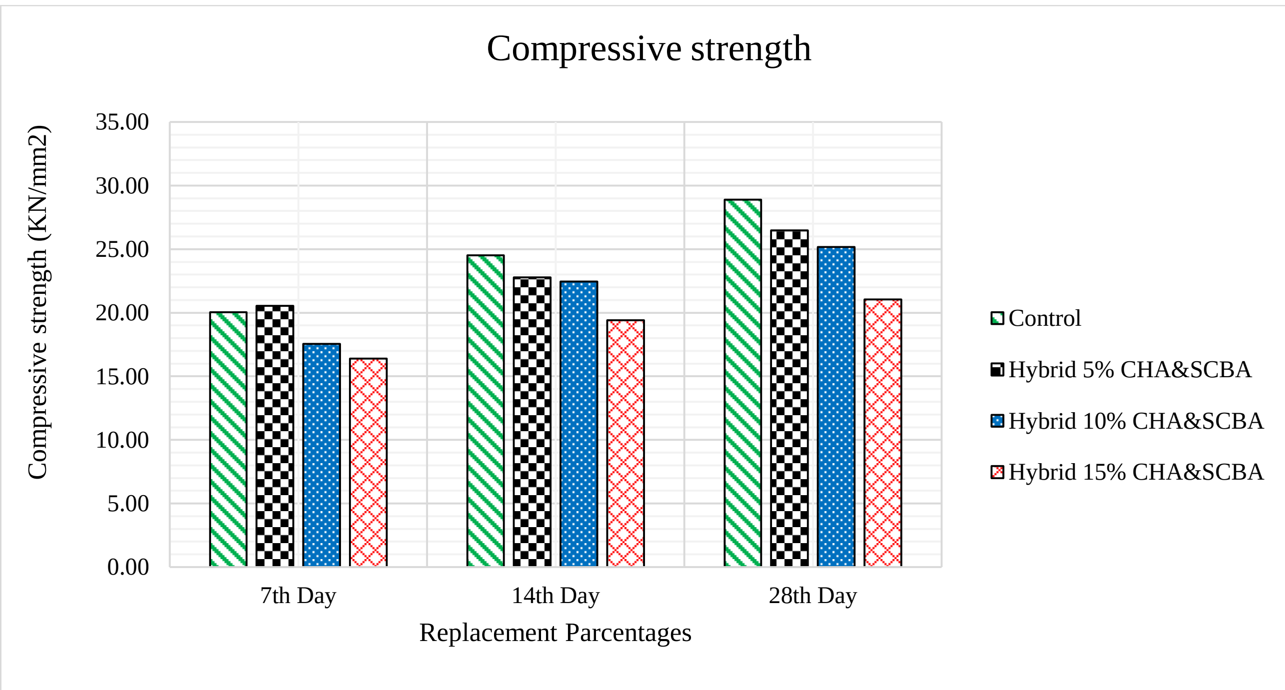

Figure 4.6: Compressive strength of PPC- hybrid CHA&SCBA concrete

Although the compressive strength values have considerably decreased with the addition of hybrid CHA&SCBA as seen in Table 4.8 and Figure 4.6 their values are still in a reasonable range up to 10 % and for 15 % replacement is slightly out of range for targeted grade of concrete C-25.

As shown on figure 4.7 Compressive strength on the 28th day was slightly decreased with an increased hybrid CHA&SCBA; with the range of 8.34% to 27.17% as compared to control mix.

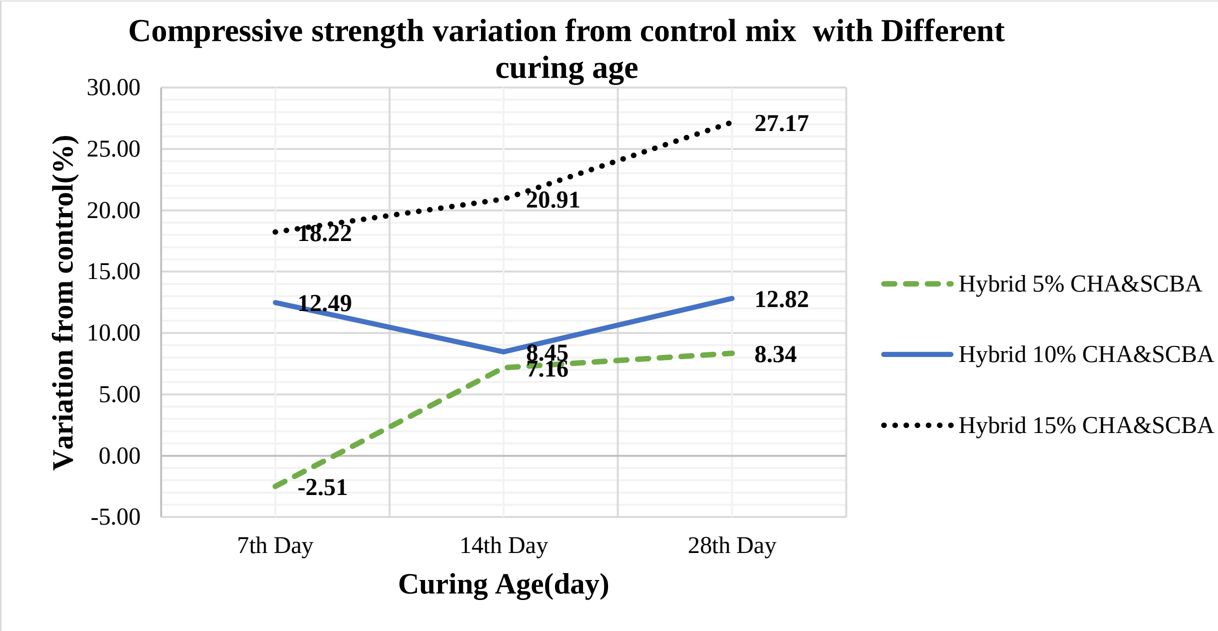

Figure 4.7: Compressive strength Decrement with Different curing age

4.3.2.3. Split tensile strength of the cylinder

The split-cylinder test is a method of determining the tensile strength of concrete in an indirect way. Where the tensile strength is determined as the splitting tensile strength, $f_{ct,sp}$, an approximate value of the axial tensile strength, f_{ct}, may be taken as:

$$f_{ct} = 0.9 f_{ct,sp} \dots \dots \dots .. eq\ 4.4$$

The development of tensile strength with time is strongly influenced by curing and drying conditions as well as by the dimensions of the structural members (ESA, 2015). As a first approximation it may be assumed that the tensile strength f_{ctm} (t) is equal to:

$$f_{ctm}(t) = (\beta_{cc}(t))^{\alpha} . f_{ctm} \dots \dots eq\ 4.5$$

Where $\beta_{cc}(t)$ follows from Expression (3.2)and

$$\alpha = 1\ for\ t < 28$$
$$\alpha = 2/3\ for\ t \geq 28$$

95 % fractile $f_{ctk,0.95} = 1.3 * f_{ctm}$

7th day Concrete Conform the Specification

$$\beta_{cc}(t) = \exp\left\{s\left[1 - \left(\frac{28}{t}\right)^{1/2}\right]\right\}$$

$$s = 0.25 \; and \; for \;\; 7^{th} \; day \; t = 7 \; \alpha = 1$$

$$\beta_{cc}(7) = \exp\left\{0.25\left[1 - \left(\frac{28}{7}\right)^{1/2}\right]\right\} = 0.7788$$

$$f_{ctm}(t) = \; (\beta_{cc}(t))^{\alpha}.f_{ctm}$$

$$f_{ctm}(t) = \; (0.7788)^{1} * 2.2$$

$$f_{ctm}(t) = 1.713$$

$$f_{ctk,0.95} = 1.3 * f_{ctm}$$

$$f_{ctk,0.95} = 1.3 * 1.713$$

$$f_{ctk,0.95} = 2.23 \; for \; 7^{th} \; day$$

Table 4.9: Split tensile strength test result on 7th day

Split tensile strength test result on 7th day								
Mix no	percentage of Ash added	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)	$f_{ct,sp}$	$f_{ct}(7)$	Minimum requirement $f_{ctk}(7)$	Remark
1	Control	82.94	2.65	0	2.65	2.38	2.23	Concrete Conform the Specification
2	5%	78.80	2.51	5.04	2.51	2.62	2.23	Concrete Conform the Specification
3	10%	76.95	2.48	6.17	2.48	2.35	2.23	Concrete Conform the Specification
4	15%	72.28	2.31	12.59	2.31	2.08	2.23	Concrete does not Conform the Specification

14^{h} day Concrete Conform the Specification

$$s = 0.25 \; and \; for \; 14^{th} \; day \; t = 14 \; \alpha = 1$$

$$\beta_{cc}(14) = \exp\left\{0.25\left[1 - \left(\frac{28}{14}\right)^{1/2}\right]\right\}$$

$$\beta_{cc}(14) = 0.9016$$

$$f_{ctm}(t) = (\beta_{cc}(t))^{\alpha}.f_{ctm}$$

$$f_{ctm}(t) = 0.9016^{1} * 2.2$$

$$f_{ctm}(t) = 1.984$$

$$f_{ctk,0.95} = 1.3 * f_{ctm}$$

$$f_{ctk,0.95} = 1.3 * 1.984$$

$$f_{ctk,0.95} = 2.58 \; for \; 14^{th} \; day$$

Table 4.10: Split tensile strength test result on 14^{th} day

Split tensile strength test result on 14^{th} day								
Mix no	percentage of Ash added	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)	$f_{ct,sp}$	$f_{ct}(14)$	Minimum requirement $f_{ctk}(14)$	Remark
1	Control	95.72	3.05	0	3.05	2.74	2.58	Concrete Conform the Specification
2	5%	92.54	2.95	3.06	2.95	2.66	2.58	Concrete Conform the Specification
3	10%	90.01	2.87	5.91	2.87	2.58	2.58	Concrete Conform the Specification
4	15%	76.36	2.44	19.80	2.44	2.20	2.58	Concrete does not Conform the Specification

28th day Concrete Conform the Specification

$$s = 0.25 \ and \ for \ 28^{th} \ day \ t = 14 \ \alpha = 2/3$$

$$\beta_{cc}(28) = \exp\left\{0.25\left[1 - \left(\frac{28}{28}\right)^{1/2}\right]\right\} = 1.0$$

$$f_{ctm}(t) = (\beta_{cc}(t))^{\alpha}.f_{ctm}$$

$$f_{ctm}(t) = 1.0^{2/3} * 2.2$$

$$f_{ctm}(t) = 2.20$$

$$f_{ctk,0.95} = 1.3 * f_{ctm}$$

$$f_{ctk,0.95} = 1.3 * 2.20$$

$$f_{ctk,0.95} = 2.86 \ for \ 28^{th} \ day$$

Table 4.11: Split tensile strength test result on 28th day

Split tensile strength test result on 28th day								
Mix no	percentage of Ash added	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)	$f_{ct,sp}$	$f_{ct}(28)$	Minimum requirement $f_{ctk}(28)$	Remark
1	Control	112.62	3.60	0	3.60	3.24	2.86	Concrete Conform the Specification
2	5%	106.70	3.49	2.87	3.49	3.14	2.86	Concrete Conform the Specification
3	10%	106.30	3.39	5.84	3.39	3.05	2.86	Concrete Conform the Specification
4	15%	84.71	2.70	24.84	2.70	2.43	2.86	Concrete does not Conform the Specification

From Table 4.9, Table 4.10, Table 4.11 and Figure 4.8 a clear relationship was observed between control mix split tensile strength and hybrid of CHA and SCBA content. As hybrid of CHA and SCBA content was increased, the 7th-day, 14th-day and the 28th-day split tensile strength decreased proportionally. However, their values are still in a reasonable range up to 10 % and for 15 % replacement is slightly out of range for targeted grade of concrete C-25 and hybrid of CHA and SCBA Concrete does not conform the Specification.

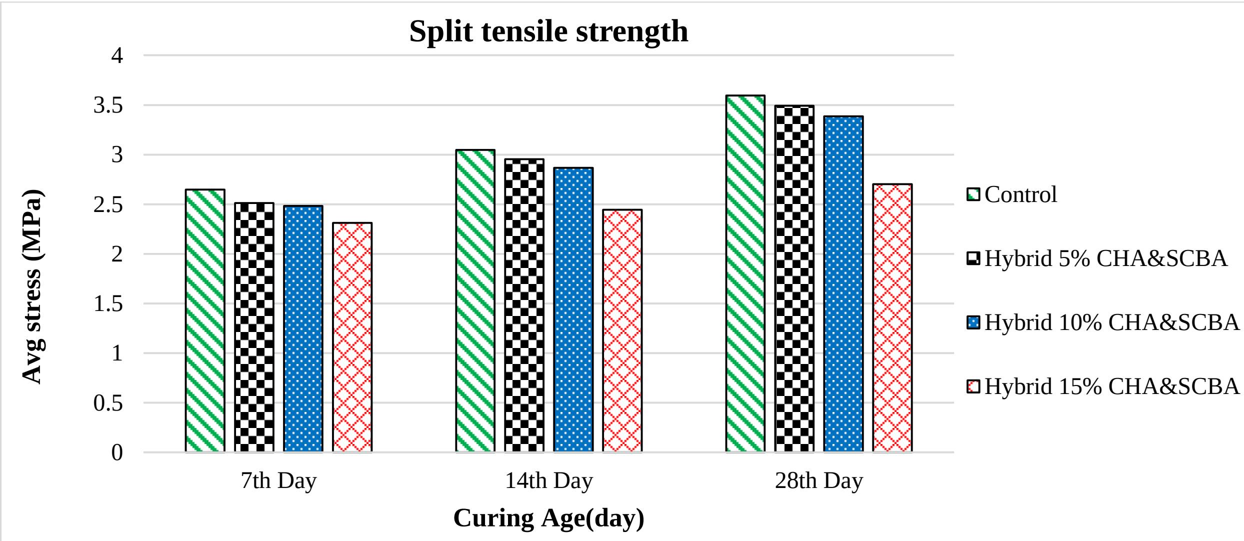

Figure 4.8: Split tensile strength

As shown on figure 4.9 Split tensile strength on the 28th day was slightly decreased with an increased hybrid CHA&SCBA; with the range of 2.87% to 24.84% as compared to control mix.

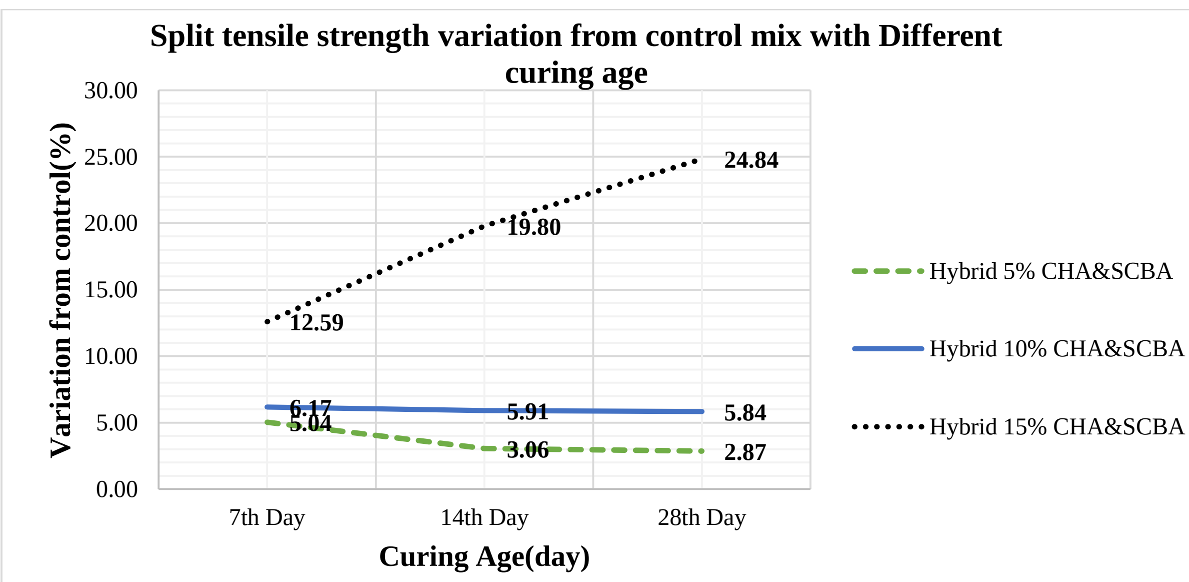

Figure 4.9: Split tensile strength Variation from control mix with Different curing age

4.3.2.4. Flexural/Bending Test

The flexural bending strength is another character that can reflect concrete's tensile capacity and flexural test evaluates the tensile strength of concrete indirectly. Two-point loading flexural tests were conducted experimentally it tests the ability of plain concrete beam to withstand failure in bending. The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa or psi.

The average flexural stresses were calculated from average rupture loads recorded from the testing machine and flexural stresses are determined for each sample. The average flexural strength test results for 7, 14 and 28 days are shown in Figure 4.8. The detail flexural test results are tabulated under appendix-D, Table D-7, Table D-8 and Table D-9.

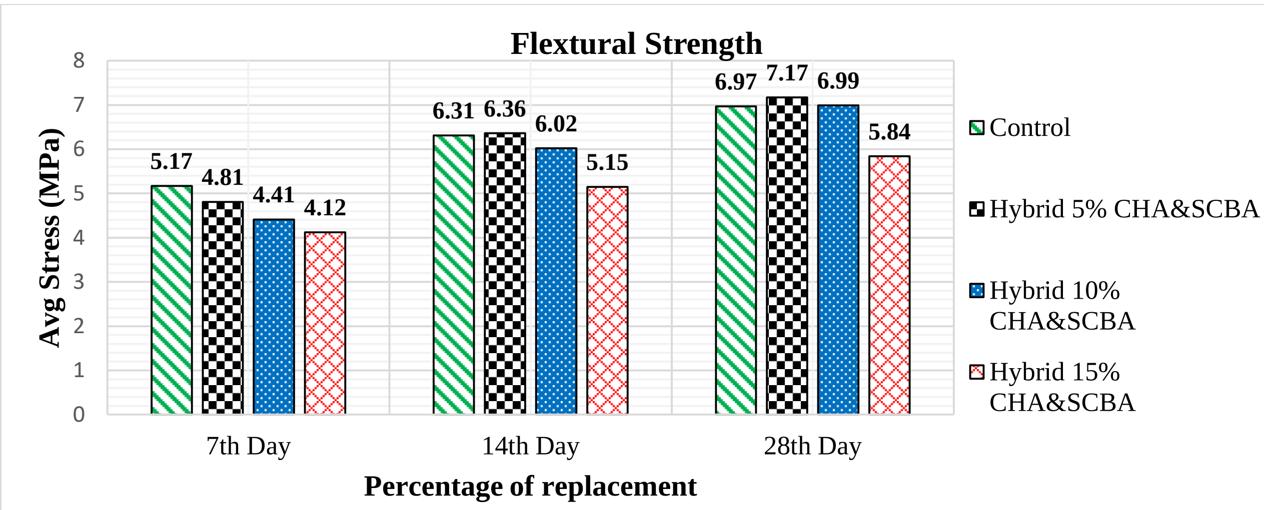

Figure 4.10: Flexural strength test result

From figure 4.10 was clearly observed the flexural strength Control mix and Hybrid coffee husk ash and sugarcane bagasse ash blended concrete result the following discussions was drawn.

The flexure strength of concrete increased as the age of curing date increased.

The positive percentage of variations from the control mix is observed for hybrid 5%CHA&SCBA, hybrid 10%CHA&SCBA and hybrid 15%CHA&SCBA from the 7^{th} day test result, hybrid 10%CHA&SCBA and hybrid 15% CHA&SCBA from 14^{th} and hybrid 15%CHA&SCBA from 28^{th} day test result.

The optimum flexural strength 7.17 MPa was obtained for hybrid 5% CHA&SCBA from 28^{th} day result.

The result shows maximum reduction in flexural strength from control mix is observed on the three days result when cement is replaced by 15% of hybrid of coffee husk ash and sugarcane bagasse ash.

In general the flexural strength of hybrid of CHA&SCBA concrete for 10% and 5% on the 28th result almost equal with control mix and their variation is negative.

4.3.2.5. Stress - Strain Relationship for Compressive Strength Test Result

Stress-strain is the most important property of material it represents the relationship between the material internal stress caused by applied force and the corresponding strain derived from the deformation of the material. The property is unique for each material and is usually expressed graphically through a stress-strain curve.

To determine the strain for each stress which were gained using dial gauge ESEN-2:2015 was used (ESA, 2015).

The relation between $\boldsymbol{\sigma_c}$ and $\boldsymbol{\varepsilon_c}$ (compressive stress and shortening strain) for short term uniaxial loading is described by the equation 4.6:

$$\frac{\sigma_c}{f_{cm}} = \frac{k\eta - \eta^2}{1 + (k-2)\eta} \ldots\ldots\ldots\ldots\ldots eq\ 4.6$$

$$where\ \eta = \frac{\varepsilon_c}{\varepsilon_{c1}}$$

$$\varepsilon_{c1}\ is\ the\ strain\ at\ peak\ stress$$

$$k = \frac{E_{cm} * |\varepsilon_{c1}|}{f_{cm}} \ldots\ldots\ldots\ldots\ldots\ldots eq\ 4.7$$

$$\frac{\sigma_c}{f_{cm}} = \frac{k\eta - \eta^2}{1 + (k-2)\eta}\ and\ k = \frac{E_{cm} * |\varepsilon_{c1}|}{f_{cm}}$$

$$\frac{\sigma_c}{f_{cm}} = \frac{\frac{E_{cm} * |\varepsilon_{c1}|}{f_{cm}}\eta - \eta^2}{1 + \left(\frac{E_{cm} * |\varepsilon_{c1}|}{f_{cm}} - 2\right)\eta}$$

$$and\ \eta = \frac{\varepsilon_c}{\varepsilon_{c1}}$$

$$\frac{\sigma_c}{f_{cm}} = \frac{\frac{E_{cm} * |\varepsilon_{c1}|}{f_{cm}} \frac{\varepsilon_c}{\varepsilon_{c1}} - (\frac{\varepsilon_c}{\varepsilon_{c1}})^2}{1 + (\frac{E_{cm} * |\varepsilon_{c1}|}{f_{cm}} - 2) \frac{\varepsilon_c}{\varepsilon_{c1}}}$$

$$solving\ for\ the\ above\ equation$$

$$\frac{\sigma_c}{f_{cm}} * \left(1 + \left(\frac{E_{cm} * |\varepsilon_{c1}|}{f_{cm}} - 2\right) \frac{\varepsilon_c}{\varepsilon_{c1}}\right) = \frac{E_{cm} * |\varepsilon_{c1}|}{f_{cm}} \frac{\varepsilon_c}{\varepsilon_{c1}} - (\frac{\varepsilon_c}{\varepsilon_{c1}})^2$$

$$\frac{\sigma_c}{f_{cm}} + \frac{\sigma_c}{f_{cm}} * \frac{E_{cm} * |\varepsilon_{c1}|}{f_{cm}} * \frac{\varepsilon_c}{\varepsilon_{c1}} - 2 * \frac{\sigma_c}{f_{cm}} * \frac{\varepsilon_c}{\varepsilon_{c1}} + \frac{{\varepsilon_c}^2}{{\varepsilon_{c1}}^2} - \frac{E_{cm} * \varepsilon_c}{f_{cm}} = 0$$

$$\frac{1}{{\varepsilon_{c1}}^2} * {\varepsilon_c}^2 + \varepsilon_c * \left(\frac{\sigma_c E_{cm}}{{f_{cm}}^2} - \frac{E_{cm}}{f_{cm}} - 2 * \frac{\sigma_c}{f_{cm}\varepsilon_{c1}}\right) + \frac{\sigma_c}{f_{cm}} = 0$$

$$\frac{1}{{\varepsilon_{c1}}^2} * {\varepsilon_c}^2 + \varepsilon_c * \left(\frac{E_{cm}}{f_{cm}} \left(\frac{\sigma_c}{f_{cm}} - 1\right) - 2 * \frac{\sigma_c}{f_{cm}\varepsilon_{c1}}\right) + \frac{\sigma_c}{f_{cm}} = 0 \ldots\ldots..eq\ 4.8$$

$$now\ it\ is\ in\ the\ form\ of\ qadratic\ equation\ ax^2 + bx + c$$

$$a = \frac{1}{{\varepsilon_{c1}}^2} \quad b = \frac{E_{cm}}{f_{cm}} \left(\frac{\sigma_c}{f_{cm}} - 1\right) - 2 * \frac{\sigma_c}{f_{cm}\varepsilon_{c1}} \quad and\ c = \frac{\sigma_c}{f_{cm}}$$

By using equation 4.6 the value of strain for each corresponding stress determined by scilab-5.5.1. The averaged value of compressive stress and averaged value of strain for the four experimental group samples with the 7th, 14th and 28th day resulted in table 4.12. The detailed cube stress -strain relation for 7th, 14th and 28th day test are listed under appendix.

Table 4.12: Average compressive stress and strain at peak load

7th Day Average compressive stress and strain at peak load				
Mix No	Percentage of replacement	Average Peak load (KN)	Average compressive strength in Mpa	Avg strain
1	Control	451.11	20.05	0.001901
2	5%	462.34	20.55	0.001911
3	10%	394.747	17.55	0.001851
4	15%	368.93	16.40	0.001828

14th Day Average compressive stress and strain at peak load				
1	Control	551.74	24.52	0.0019904
2	5%	512.13	22.77	0.0019554
3	10%	505.04	22.45	0.0019490
4	15%	436.34	19.40	0.001888
28th Day Average compressive stress and strain at peak load				
1	Control	647.22	28.88	0.0020621
2	5%	595.63	26.47	0.00202352
3	10%	566.37	25.18	0.0020029
4	15%	473.18	21.04	0.0019208

The results show that from 7th day test result the maximum average strain obtained at 20.55MPa compressive strength is 0.001911 when cement is replaced by 5% hybrid coffee husk ash and sugarcane bagasse ash, from 14th day test result the maximum average strain obtained at 24.52MPa compressive strength is 0.0019904 for control mix concrete and from 28th day test result the maximum average strain obtained at 28.88MPa compressive strength is 0.0020621 for control mix concrete.

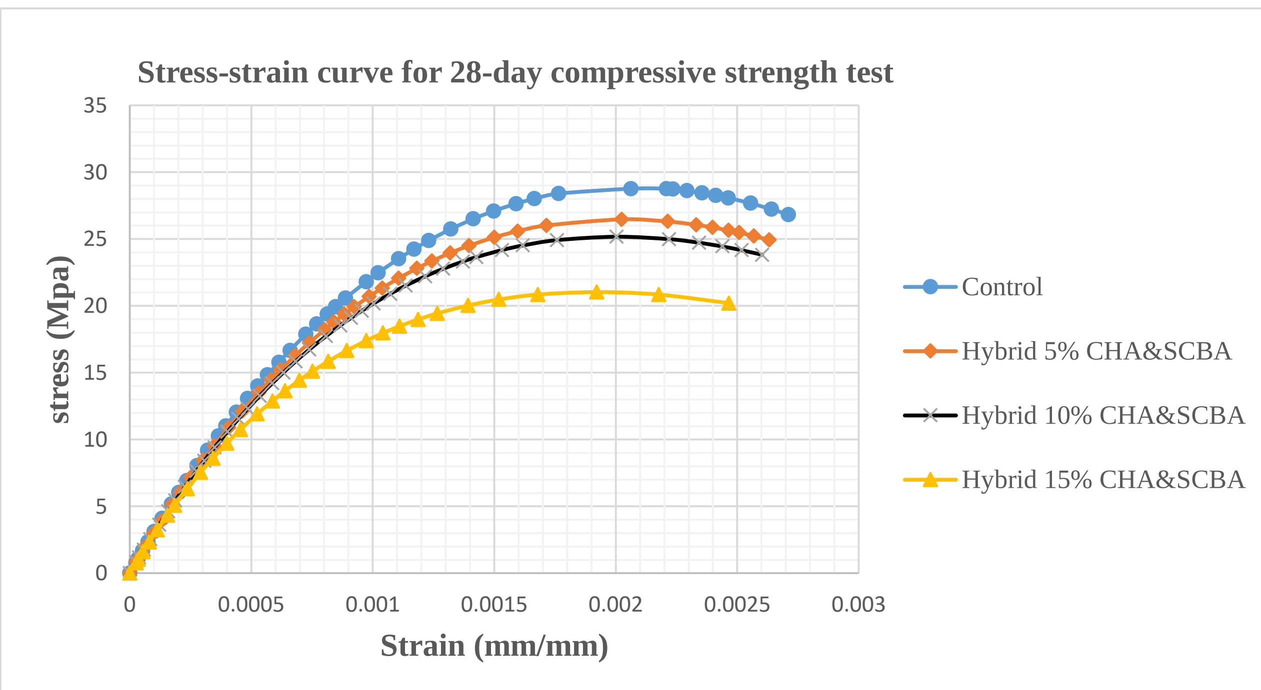

Figure 4.11: Stress-strain curve for 28-day compressive strength test

The average stress and strains are calculated for all mixes shown in the Appendix D, Table D-1, Table D-2 and Table D-3. The Stress-strain curve for 28-day compressive strength test is drawn for hybrid 5% CHA&SCBA, hybrid 10% CHA&SCBA and hybrid 15% CHA&SCBA graph for each mix for comparison with control. Figure 4.11 illustrate peak compressive stress and the corresponding strain for 28th days test result. The detailed cube stress -strain relation for 7th, 14th and 28th day test and stress-strain curve are listed under appendix E, F and G respectively.

From the above stress-strain curve the following observations are drawn.
As the date of curing increases the average compressive strength and strain of concrete increases.

From the curve for all mixes the compressive stress and the corresponding strain are directly proportional to some extent and all the graphs are over lapped. This shows the elastic range of concrete.

Once the ultimate load is reached, the load carrying capacity (ductile properties of concrete) is changed for each mix based the parentage of hybrid ash replacement and percentage variation.
After the point of ultimate load, the duration of strain up to the point of rupture for hybrid coffee husk ash and sugarcane bagasse ash concrete is less than the point of failure of control.

A minimum average stress and average strain was recorded by the time cement is replaced by hybrid of 15% coffee husk ash and sugarcane bagasse ash was added.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The research aimed to study the strength characteristics of concrete using by different proportioning values of 0%, 5%, 10%, and 15%, hybrid of coffee husk ash and sugarcane bagasse ash as partial replacement of cement. Furthermore, to achieve the aim of this study the researcher collected related literature and conducted different tests of materials and specimens to determine the effects of using hybrid of coffee husk ash and sugarcane bagasse ash on concrete strength. Therefore, based on the findings of the study the following conclusions are drawn:

Higher replacements of cement by hybrid coffee husk ash and sugarcane bagasse ash resulted in higher normal consistency (implying higher water demand for certain workability) and longer setting time. The workability of concrete containing combination of coffee husk ash and sugarcane bagasse ash slightly decrease as the combination of coffee husk ash and sugarcane bagasse ash content increases which is due to the higher water demand of coffee husk ash and sugarcane bagasse ash.

The compressive strength increased with curing period and decreases with increased amount of hybrid coffee husk ash and sugarcane bagasse ash. For this hybrid coffee husk ash and sugarcane bagasse ash concrete, the test results show that the addition of hybrid coffee husk ash and sugarcane bagasse ash in a significant reduction in concrete compressive strength compared with the control concrete. This reduction increased with increasing percentage of hybrid coffee husk ash and sugarcane bagasse ash. Losses in compressive strength ranging from 8.34 to 27.17% were observed at 28^{th} day of curing for 5% and 15% replacements respectively but strength development of hybrid coffee husk ash and sugarcane bagasse ash concrete increased with age.

Split tensile strength on the 28^{th} day was slightly decreasing with an increase in hybrid coffee husk ash and sugarcane bagasse ash; with the range of 2.87% to 24.84% for the content of 5% to 15% hybrid coffee husk ash and sugarcane bagasse ash as compared to the control mix. In contrast, percentage of variation is decreased with curing period is increased when cement is partially replaced by hybrid 5% and 10% CHA&SCBA as compared to the control mix and for 15% cement replacement by hybrid of coffee husk ash and sugarcane bagasse ash the result is vice versa; the percentage of variation is increased with curing period is increased.

The Flexural strength increased with curing period and decreases with increased amount of hybrid coffee husk ash and sugarcane bagasse ash on the 7th day. On 28th day percentage of variation of hybrid CHA&SCBA concrete compared to the control mix is -2.79% and -0.21% for 5% and 10% cement replacement and the result was showed that flexural strength of hybrid CHA&SCBA concrete was increased up to 10% cement replacement on 28th day.

From Compressive Strength stress-strain curve as the date of curing increases the average compressive strength and strain of concrete increases. Once the ultimate load was reached, the load carrying capacity (ductile properties of concrete) the duration of strain up to the point of rupture for hybrid coffee husk ash and sugarcane bagasse ash concrete was less than the point of failure of control mix.

Therefore, the investigation of this study has found out that replacement of Portland Pozzolana cement by hybrid coffee husk ash and sugarcane bagasse ash from up to 10% results were reasonable range in compressive strength, split tensile strength and flexural strength for targeted grade of concrete C-20/25. Therefore, 10 % of hybrid coffee husk ash and sugarcane bagasse ash replacement is the optimum ratio for C-20/25 concrete.

5.2. Recommendation

Based on the findings of this research, the following recommendations are forwarded:
The hybrid coffee husk ash and sugarcane bagasse ash as investigated in this study can be used as a cement replacing material up to 10 % within reasonable range in compressive strength, split tensile strength and flexural strength for targeted grade of concrete. Therefore concerned bodies like coffee pulpler, Sugar factory, cement industries, Ethiopian construction and chemicals institution and government entities should be made aware about this potential cement replacing material and promote its standardized production and usage.

The sugar factory, coffee pulpler and cement factories in collaboration with higher education institution in the country should work together and establish a research team to study further the usage of hybrid coffee husk ash and sugarcane bagasse ash as cement replacement material.

The use of local materials like hybrid coffee husk ash and sugarcane bagasse ash as pozzolans should be encouraged in concrete production.

For further study

Other researchers can use the findings of this study as a reference to validate, improve and dig out other properties of concrete. Hence, some of the focus areas for future study are:

Further studies on concrete plasticity variables for concrete containing hybrid coffee husk ash and sugarcane bagasse ash to validate the experimental results by numerical method using finite element software.

Further studies on validation of this the experimental results by numerical method using finite element software.

Study on improving the mechanical properties of concrete containing hybrid coffee husk ash and sugarcane bagasse ash using different additive.

The test results in this study were based on results taken after 7^{th}, 14^{th} and 28^{th} days of standard curing of the test samples. The long-term effects of hybrid CHA&SCBA concrete needs to be studied to find out the relevant properties associated with the age of the concrete.

For further Jimma University Institute of Technology should deliver additional testing machines to evaluate the performance of concrete for wider applications. These machines are like strain gauge, biaxial testing machine, equipment used to find out complete silicate analysis, and testing machine to determine durability of the concrete. If the university provides those listed machines, another researcher can study the areas mentioned for further study.

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APPENDICES

APPENDIX-A Physical properties of materials

A-1 Specific gravity and Water absorption test for aggregates.

Specific gravity is the ratio between the weight of the substance and that of the same volume of water. It helps for design of concrete mix and calculating void content in aggregate. The water absorption value is the difference in weight between the saturated surface dry aggregate and oven dry sample expressed as percentage of dry weight of aggregate. Knowing the water absorption value of aggregate was helped to calculate the total water to be added to the concrete mix. The following procedures are the steps in which the physical properties of coarse aggregate and fine aggregates are determined in laboratory as per (Abebe, 2002).

Coarse aggregates

Step 1- rejecting materials passing 4.75mm sieve and using sample splitter 2 Kgs sample of aggregate measured and washed to remove fine particles

Step 2- using basket with sample immersed in distilled water for 24 hours at constant temperature

Step 3 – the basket placed at 50mm of water above the top of the basket and the entrapped air is removed by lifting the basket 25mm above the base of the tank by allowing to drop25 times at one drop per second

Step 4- after 24hour jolt and weight the basket with sample in water then remove sample from water allowed to drain then the empty basket placed in water jolted 25 times and weight in water

Step 5- the sample aggregate surface dried by cloth and weight then placed in an oven for 24 hours

Step 6 -after 24 hours the sample removed from oven and cooled for one hour and finally the dried sample weighted. Using the following formula, the specific gravity and absorption capacity calculated for coarse aggregate tabulated on table A-1

$$Apparent\ specific\ gravity\ = \frac{M_D}{M_D - M_W}$$

$$Bulk\ specific\ gravity\ = \frac{M_D}{M_{SSD} - M_W} Oven\ dry$$

$$Bulk\ specific\ gravity\ = \frac{M_D}{-M_W} Saturated\ surface\ dry$$

$$Percentage\ of\ water\ Absorption\ = \frac{(M_{SSD} - M_D) * 100}{M_D}$$

$$Weight\ of\ aggregate\ in\ water\ W_W = (W_a - W_B)$$

Where

MW Weight in water of the saturated aggregate

MSSD Weight in air of the saturated surface dry aggregate

MD Weight in air of oven dried aggregate

SSD Saturated surface dry

Table A - 1 Specific gravity and water absorption of coarse aggregate

Description	Trial1	Trial2	Trial3	Average
M_W=Weight in water of saturated aggregate (Kg)	1.296	1.297	1.298	
M_{SSD}=Weight in air of saturated surface dry(Kg)	2.011	2.009	2.010	
M_D=Weight in air of oven dried aggregate(Kg)	1.992	1.991	1.993	
Bulk specific gravity=$M_D/(M_{SSD}-M_W)$	2.786	2.796	2.799	2.79
Bulk specific gravity (sat.sur.dry basis) =$M_{SSD}/(M_{SSD}-M_W)$	2.813	2.822	2.823	2.82
Apparent specific gravity=$M_D/(M_D-M_W)$	2.862	2.869	2.868	2.87
Absorption capacity (%)	0.95	0.90	0.85	0.90%

Fine aggregate

Step 1- A sample of 500g fine aggregate which is at free-flowing condition without moisture measured and placed into the pycnometer then filled up with water 90 % capacity of the pycnometer.

2 – Using rod the air bubbles are eliminated with adjusted temperature and the water level of pycnometer filled up to its calibrated capacity.

Step 3- The total weight of the pycnometer, sample and water recorded.

$$C = 0.9976V_a + 500 + w$$

Where

C –Weight of pycnometer filled with sample plus water

Va– Volume of water added to pycnometer

W - Weight of the pycnometer empty

Step 4 – Oven dried the aggregate removed from pycnometer at 105±5°Cfor an hour then cooled and measured

$$B = 0.9976V + W$$

$Where$

$B - Weight\ of\ flask\ filled\ with\ water$

$V - Volume\ of\ flask$

$W - Weight\ of\ the\ flask$

$$Bulk\ specific\ gravity = \frac{A}{B + 500 - C}$$

$$Bulk\ specific\ gravity = \frac{500}{B + 500 - C}\ \text{(saturated surface dry basis)}$$

$$Apparent\ specific\ gravity = \frac{A}{B + A - C}$$

$$Absorption = \frac{(500 - A) * 100}{A}$$

Where

A – Weight of oven dried sample

B – Weight of pycnometer filled with water

Table A- 2 Specific gravity and water absorption of fine aggregate

Description	Trial1	Trial2	Trial3	Average
Weight of saturated & surface dry sand (gm)	500	500	500	
Weight of pycnometer + sample + water (C) (gm)	1852	1853	1841	
Weight of pycnometer +water (B) (gm)	1553	1551	1550	
Weight of oven dry sand (A) (gm)	495.5	491	494	
Bulk specific gravity=A/(B+500-C)	2.47	2.480	2.36	2.44
Bulk specific gravity (sat.sur.dry basis)=500/(B+500-C)	2.488	2.525	2.392	2.47
Apparent specific gravity=A/(B+A-C)	2.522	2.598	2.433	2.52
Absorption capacity(%)=((500-A)/A)*100	0.9	1.8	1.2	1.32

Unit weight of aggregate

Table A-3 Unit weight for coarse Aggregate

	Result(coarse Aggregate)	Volume(m^3)=0.010		
Sample	mass of cylinder (Kg)	Mass of sample (Kg)	Mass of cylinder and sample(Kg)	Unit weight(Kg/m^3)
1	1.6770	16.763	18.440	1676.3
2	1.6770	16.768	18.445	1676.8
3	1.6770	16.763	18.440	1676.3
Average				**1676.5**

Table A-4 Unit weight for fine Aggregate

Fine Aggregate (Chewaka)		V= 0.005 m^3		
Sample	mass of cylinder(Kg)	Mass of sample(Kg)	Mass of cylinder and sample(Kg)	Unit weight(Kg/m^3)
1	1.051	7.949	9	1590
2	1.051	7.759	8.81	1552
3	1.051	7.959	9.01	1592
Average				**1578**

Table A-5 Total moisture content for coarse aggregate

S. No	Description		Sample	
		1	2	3
1	Weight of original sample ,A (Kg)	2.0	2.0	2.0
2	Weight of oven dried sample B ,(Kg)	1.992	1.992	1.990
3	Moisture content(%)=(A-B/A)*100	0.4	0.4	0.5
Average				**0.4**

Table A-6 Total moisture content for fine aggregate

S. No	Description	Sample		
		1	2	3
1	Weight of original sample ,A,(Kg)	0.5	0.5	0.5
2	Oven dried mass ,B,(Kg)	0.4975	0.4975	0.4975
3	Moisture content in %=((A-B)/B)*100	0.5	0.5	0.5
Average				**0.5**

Particle Size distribution test for coarse and fine aggregate

TableA-7 Particle size distribution for Coarse aggregates

Sieve Size, mm	Mass retained (gm)				% Retained	% cumulative retained	% Passing	ASTM Spec Range
	Trial 1	Trial 2	Trial 3	Avg.				
25	0	0	0	0	0	0	100	100
19	790	780	804	791	8	8	92	90-100
12.50	5315	5210	5250	5258	53	60	40	20-55
9.50	2790	2850	2790	2810	28	89	11	0-15
4.75	1100	1150	1135	1128	11	100	0	0-5
pan	5	9	19	11	0	100	0	
TOTAL	10000	9999	9998	9999		356.77		

Table A-8 Particle size distribution for fine aggregates

Sieve Size,mm	Mass retained (gm)				% Retained	% cumulative retain	% Passing	ESC.D3 Spec Range
	Trial 1	Trial 2	Trial 3	Avg.				
9.5	0	0	0	0	0	0	100	0
4.75	10	14	13	12	0.62	0.62	99.38	95-100
2.36	110	100	98	103	5.13	5.75	94.25	80-100
1.18	208	212	197	206	10.28	16.03	83.97	50-85
0.60	485	446	479	470	23.50	39.53	60.47	25-60
0.30	814	769	756	780	38.98	78.51	21.49	10~30
0.15	357	441	438	412	20.59	99.10	2.00	2~ 10
pan	16	19	15	17	0.83	99.93	0	
TOTAL	2000	2000	1996	1999		240		

$$Fineness\ Modulus = (\Sigma\ Cumulative\ Percentage\ Retained)/100$$

$$FM = (0.62 + 5.13 + 10.28 + 23.50 + 39.98 + 20.59 + 0.83\ )/100 = 2.4$$

APPENDIX-B Normal consistency of cement, CFT and ST Results on Fresh concrete

Table B-1 Normal consistency of blended pastes containing hybrid CHA&SCBA

Trial	Percentage of replacement	Cement quantity (g)	Water quantity	Ash quantity (g)	W/C	Penetration depth	%age of water for normal consistency
1	Control	400	112	0	0.28	8	28
2		400	116	0	0.29	9	29
3		400	124	0	0.31	11	31
1	5%	380	116	20	0.29	8	29
2		380	120	20	0.30	10	30
1	10%	360	124	40	0.31	7	31
2		360	128	40	0.32	9	32
1	15%	340	128	60	0.32	8	32
2		340	132	60	0.33	9	33

Table B-1 Slump Test

Mix No.	Percentage of ash added	Replaced PPC (%)	Observed Slump (mm)
1	Control	0	33
2	5%	5	31
3	10%	10	30
4	15%	15	28

Table B-2 Compaction factor

Compaction factor test				
Mix. No	Percentage of ash added	Partially compacted mass(g)	Fully Compacted mass(g)	Compaction factor
1	Control	13451	14772	0.910
2	5%	12887	14672	0.878
3	10%	12516	14411	0.869
4	15%	12109	14289	0.847

APPENDIX-C Mass and density of the specimens

Table C-1 Mass and density of cube on 7th Day

Mix. No	Percentage of ash added	Mass of cylinder cube on 7th Day				Density (kg/m3)
		S-1	S-2	S-3	Avg	
1	Control	8.18	8.22	8.28	8.23	2437.53
2	5%	8.12	8.08	8.11	8.10	2400.99
3	10%	7.96	8.01	7.89	7.95	2356.54
4	15%	7.63	7.67	7.72	7.67	2272.59

Table C-2 Mass and density of cube on 14th Day

Mix. No	Percentage of ash added	Mass of cylinder cube on 14th Day				Density (kg/m3)
		S-1	S-2	S-3	Avg	
1	Control	8.31	8.19	8.26	8.25	2445.43
2	5%	8.13	8.06	8.17	8.12	2405.93
3	10%	8.06	7.93	8.11	8.03	2380.25
4	15%	7.61	7.80	7.72	7.71	2284.44

Table C-3 Mass and density of cube on 28th Day

Mix. No	Percentage of ash added	Mass of cylinder cube on 28th Day				Density (kg/m3)
		S-1	S-2	S-3	Avg	
1	Control	8.34	8.29	8.37	8.33	2469.14
2	5%	8.16	8.09	8.22	8.16	2416.79
3	10%	8.03	8.12	7.98	8.04	2383.21
4	15%	7.62	7.60	8.01	7.74	2293.33

Table C-4 Mass and density of cylinder on 7th Day

Mix. No	Percentage of ash added	Mass of cylinder on 7th day				Density (kg/m3)
		S-1	S-2	S-3	Avg	
1	Control	3.785	3.804	3.798	3.80	2416.08
2	5%	3.773	3.697	3.761	3.74	2382.98
3	10%	3.754	3.721	3.663	3.71	2363.25
4	15%	3.697	3.687	3.703	3.70	2352.43

Table C-5 Mass and density of cylinder on 14th Day

Mix. No	Percentage of ash added	Mass of cylinder on 14th day				Density (kg/m3)
		S-1	S-2	S-3	Avg	
1	Control	3.828	3.763	3.831	3.81	2423.51
2	5%	3.811	3.881	3.782	3.82	2434.54
3	10%	3.785	3.774	3.792	3.78	2408.44
4	15%	3.779	3.8	3.699	3.76	2392.96

Table C-6 Mass and density of cylinder on 28th Day

Mix. No	Percentage of ash added	Mass of cylinder on 28th day				Density (kg/m3)
		S-1	S-2	S-3	Avg	
1	Control	3.898	3.839	3.815	3.85	2451.09
2	5%	3.834	3.81	3.785	3.81	2424.99
3	10%	3.815	3.747	3.824	3.80	2415.87
4	15%	3.763	3.795	3.724	3.76	2393.80

Table C-7 Mass and density of beam on 7th Day

Mix. No	Percentage of ash added	Mass of Beam on 7th day				Density (kg/m3)
		S-1	S-2	S-3	Avg	
1	Control	12.931	12.848	14.361	13.38	2676.00
2	5%	12.773	13.649	11.587	12.67	2533.93
3	10%	14.001	11.062	12.112	12.39	2478.33
4	15%	12.61	12.32	13.702	12.88	2575.47

Table C-8 Mass and density of beam on 14th Day

Mix. No	Percentage of ash added	Mass of Beam on 7th day				Density (kg/m3)
		S-1	S-2	S-3	Avg	
1	Control	14.667	12.983	12.388	13.35	2669.20
2	5%	13.201	13.623	11.658	12.83	2565.47
3	10%	12.887	12.953	11.753	12.53	2506.20
4	15%	10.936	11.61	13.081	11.88	2375.13

Table C-9 Mass and density of beam on 28th Day

Mix. No	Percentage of ash added	Mass of Beam on 7th day				Density (kg/m3)
		S-1	S-2	S-3	Avg	
1	Control	13.663	14.012	12.998	13.56	2711.53
2	5%	12.137	13.466	13.27	12.96	2591.53
3	10%	12.615	12.137	13.625	12.79	2558.47
4	15%	12.209	11.887	13.052	12.38	2476.53

APPENDIX-D Hardened concrete test results

Table D-1 Average Compressive stress and strain for 7^{th} day test results

Compressive stress test result on 7^{th} day						
Mix. No	Percentage of ash added	Sample	Peak load (kN)	Compressive stress (MPa)	Avg compressive strength	Avg strain
1	Control	1	461.9	20.53	20.05	0.001901
		2	435.94	19.38		
		3	455.5	20.24		
2	5%	1	469.6	20.87	20.55	0.001911
		2	455.44	20.25		
		3	462.26	20.54		
3	10%	1	396.14	17.61	17.55	0.001851
		2	393.19	17.48		
		3	394.91	17.55		
4	15%	1	364.87	16.22	16.40	0.001828
		2	382.3	16.99		
		3	359.63	15.98		

Table D-2 Average Compressive stress and strain for 14^{th} day test results

Compressive stress test result on 14^{th} day						
Mix. No	Percentage of ash added	Sample	Peak load (kN)	Compressive stress (MPa)	Avg compressive strength	Avg strain
1	Control	1	549.36	24.42	24.52	0.0019904
		2	580.55	25.8		
		3	525.3	23.35		
2	5%	1	529.36	23.54	22.77	0.0019554
		2	506.5	22.51		
		3	500.54	22.25		
3	10%	1	517.72	23.01	22.45	0.0019490
		2	498.92	22.18		
		3	498.48	22.16		
4	15%	1	445.59	19.81	19.40	0.001888
		2	442	19.65		
		3	421.43	18.73		

Table D-3 Average Compressive stress and strain for 28th day test results

Compressive stress test result on 28th day						
Mix. No	Percentage of ash added	Sample	Peak load (kN)	Compressive stress (MPa)	Avg compressive strength	Avg strain
1	Control	1	618.46	30.44	28.88	0.0020621
		2	646.31	28.72		
		3	684.74	27.49		
2	5%	1	594.19	26.41	26.47	0.00202352
		2	610.62	27.14		
		3	582.08	25.87		
3	10%	1	590.17	26.24	25.18	0.0020029
		2	545.27	24.25		
		3	563.66	25.05		
4	15%	1	461.4	20.51	21.04	0.0019208
		2	486.81	21.64		
		3	471.32	20.96		

Table D-4 Split tensile strength on 7th day

Split tensile strength test result on 7th day							
Mix. No	Percentage of ash added	Sample	Peak load (kN)	Split tensile stress (MPa)	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)
1	Control	1	81.87	2.62	82.94	2.65	0
		2	80.66	2.57			
		3	86.3	2.75			
2	5%	1	79.69	2.54	78.80	2.51	5.04
		2	81.37	2.59			
		3	75.33	2.41			
3	10%	1	74.98	2.49	76.95	2.48	6.17
		2	79.83	2.54			
		3	76.03	2.42			
4	15%	1	75.3	2.43	72.28	2.31	12.59
		2	69.18	2.21			
		3	72.36	2.3			

Table D-5 Split tensile strength on 14th day

Split tensile strength test result on 14th day							
Mix. No	Percentage of ash added	Sample	Peak load (kN)	Split tensile stress (MPa)	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)
1	Control	1	91.03	2.90	95.72	3.05	0
		2	102.36	3.26			
		3	93.76	2.98			
2	5%	1	90.16	2.87	92.54	2.95	3.06
		2	91.18	2.92			
		3	96.27	3.07			
3	10%	1	89.08	2.84	90.01	2.87	5.91
		2	92.99	2.96			
		3	87.96	2.8			
4	15%	1	74.22	2.36	76.36	2.44	19.80
		2	81.05	2.6			
		3	73.8	2.37			

Table D-6 Split tensile strength on 28th day

Split tensile strength test result on 28th day							
Mix. No	Percentage of ash added	Sample	Peak load (kN)	Split tensile stress (MPa)	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)
1	Control	1	107.59	3.43	112.62	3.60	0
		2	120.87	3.87			
		3	109.41	3.49			
2	5%	1	112.59	3.62	106.70	3.49	2.87
		2	103.84	3.32			
		3	103.68	3.54			
3	10%	1	106.51	3.39	106.30	3.39	5.84
		2	103.68	3.31			
		3	108.7	3.46			
4	15%	1	84.5	2.7	84.71	2.70	24.84
		2	81.88	2.62			
		3	87.75	2.79			

Flexural strength test result on 7th, 14th and 28th Day

Table D-7 Flexural strength 7th day test results

Flexural strength test results on 7th day							
Mix. No	Percentage of ash added	Sample	Peak load (kN)	Corresponding flexural stress (MPa)	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)
1	Control	1	18.50	5.55	17.22	5.17	_
		2	14.85	4.46			
		3	18.32	5.50			
2	5%	1	16.00	4.80	16.05	4.81	6.82
		2	15.83	4.75			
		3	16.31	4.89			
3	10%	1	14.36	4.31	14.70	4.41	14.63
		2	15.03	4.51			
		3	14.72	4.41			
4	15%	1	14.13	4.24	13.73	4.12	20.25
		2	12.79	3.84			
		3	14.28	4.28			

Table D-8 Flexural strength 14th day test results

Flexural strength test results on 14th day							
Mix. No	Percentage of ash added	Sample	Peak load (kN)	Corresponding flexural stress (MPa)	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)
1	Control	1	21.74	6.52	21.03	6.31	_
		2	21.07	6.32			
		3	20.27	6.08			
2	5%	1	21.52	6.46	21.19	6.36	-0.77
		2	20.62	6.19			
		3	21.42	6.43			
3	10%	1	19.83	5.95	20.07	6.02	4.55
		2	20.12	6.04			
		3	20.26	6.08			
4	15%	1	18.18	5.45	17.16	5.15	18.37
		2	16.56	4.97			
		3	16.75	5.03			

Table D-9 Flexural strength 28th day test results

Flexural strength test results on 28th day							
Mix. No	Percentage of ash added	Sample	Peak load (kN)	Corresponding flexural stress (MPa)	Avg Peak load (kN)	Avg stress (MPa)	Variation from control (%)
1	Control	1	22.93	6.88	23.24	6.97	–
		2	25.01	7.50			
		3	21.77	6.53			
2	5%	1	23.01	6.90	23.88	7.17	-2.79
		2	25.09	7.53			
		3	23.56	7.07			
3	10%	1	22.08	6.63	23.28	6.99	-0.21
		2	23.76	7.13			
		3	24.01	7.20			
4	15%	1	19.83	5.95	19.46	5.84	16.24
		2	17.20	5.16			
		3	21.35	6.41			

APPENDIX-E Stress versus strain relationship of cube test on 7 day

Table E-1 -Stress versus strain of cube test on 7th day for control

Stress versus strain of cube test on 7th day for control								
Load (KN)			Area,mm²	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
17	21	19	22500	0.756	0.933	0.844	0.844	0.0000282
25	29	22	22500	1.111	1.289	0.978	1.126	0.0000379
37	42	39	22500	1.644	1.867	1.733	1.748	0.0000596
46	73	58	22500	2.044	3.244	2.578	2.622	0.0000913
57	89	73	22500	2.533	3.956	3.244	3.244	0.0001146
73	120	90	22500	3.244	5.333	4.000	4.193	0.0001516
89	140	120	22500	3.956	6.222	5.333	5.170	0.0001916
106	180	153	22500	4.711	8.000	6.800	6.504	0.0002498
125	198	169	22500	5.556	8.800	7.511	7.289	0.0002862
138	211	176	22500	6.133	9.378	7.822	7.778	0.0003098
167	235	200	22500	7.422	10.444	8.889	8.919	0.0003677
188	250	222	22500	8.356	11.111	9.867	9.778	0.0004144
200	278	248	22500	8.889	12.356	11.022	10.756	0.0004713
221	290	265	22500	9.822	12.889	11.778	11.496	0.0005174
242	304	280	22500	10.756	13.511	12.444	12.237	0.0005665
266	312	302	22500	11.822	13.867	13.422	13.037	0.0006234
280	330	310	22500	12.444	14.667	13.778	13.630	0.0006687
294	355	332	22500	13.067	15.778	14.756	14.533	0.0007435
300	363	349	22500	13.333	16.133	15.511	14.993	0.0007849
310	385	364	22500	13.778	17.111	16.178	15.689	0.0008526
327	399	386	22500	14.533	17.733	17.156	16.474	0.0009382
339	408	410	22500	15.067	18.133	18.222	17.141	0.0010210
355	421	421	22500	15.778	18.711	18.711	17.733	0.0011052
367	432	430	22500	16.311	19.200	19.111	18.207	0.0011829
394	443	439	22500	17.511	19.689	19.511	18.904	0.0013229
419	452	448	22500	18.622	20.089	19.911	19.541	0.0015057
435.94	461.9	455.5	22500	19.375	20.529	20.244	20.05	0.0019010
431	445	434	22500	19.156	19.778	19.289	19.407	0.0023966
424	422	434	22500	18.844	18.756	19.289	18.963	0.0025567
413	411	421	22500	18.356	18.267	18.711	18.444	0.0027110
403	405	409	22500	17.911	18.000	18.178	18.030	0.0028195

Table E-2 Stress versus strain of cube test on 7th day for Hybrid 5% CHA&SCBA

Stress versus strain of cube test on 7th day for Hybrid 5% CHA&SCBA								
Load (KN)			Area,mm^2	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
17	20	18	22500	0.75556	0.88889	0.8	0.815	0.0000271
26	33	34	22500	1.15556	1.46667	1.51111	1.378	0.0000464
34	40	36	22500	1.51111	1.77778	1.6	1.630	0.0000552
42	65	44	22500	1.86667	2.88889	1.95556	2.237	0.0000767
76	85	73	22500	3.37778	3.77778	3.24444	3.467	0.0001223
94	100	89	22500	4.17778	4.44444	3.95556	4.193	0.0001504
112	130	106	22500	4.97778	5.77778	4.71111	5.156	0.0001894
126	150	132	22500	5.6	6.66667	5.86667	6.044	0.000227
153	175	141	22500	6.8	7.77778	6.26667	6.948	0.0002672
165	195	158	22500	7.33333	8.66667	7.02222	7.674	0.0003011
187	215	197	22500	8.31111	9.55556	8.75556	8.874	0.0003603
192	253	226	22500	8.53333	11.2444	10.0444	9.941	0.000417
213	267	245	22500	9.46667	11.8667	10.8889	10.741	0.0004624
232	293	264	22500	10.3111	13.0222	11.7333	11.689	0.0005198
246	310	287	22500	10.9333	13.7778	12.7556	12.489	0.0005718
258	320	314	22500	11.4667	14.2222	13.9556	13.215	0.0006222
279	338	318	22500	12.4	15.0222	14.1333	13.852	0.0006694
286	347	325	22500	12.7111	15.4222	14.4444	14.193	0.000696
304	359	339	22500	13.5111	15.9556	15.0667	14.844	0.0007495
320	366	362	22500	14.2222	16.2667	16.0889	15.526	0.0008102
355	377	376	22500	15.7778	16.7556	16.7111	16.415	0.0008982
371	387	389	22500	16.4889	17.2	17.2889	16.993	0.0009622
395	397	401	22500	17.5556	17.6444	17.8222	17.674	0.0010468
404	403	411	22500	17.9556	17.9111	18.2667	18.044	0.001098
410	410	419	22500	18.2222	18.2222	18.6222	18.356	0.001145
420	414	423	22500	18.6667	18.4	18.8	18.622	0.0011884
429	419	430	22500	19.0667	18.6222	19.1111	18.933	0.001244
439	423	436	22500	19.5111	18.8	19.3778	19.230	0.0013033
445	428	441	22500	19.7778	19.0222	19.6	19.467	0.0013564
454	432	449	22500	20.1778	19.2	19.9556	19.778	0.0014376
460	438	453	22500	20.4444	19.4667	20.1333	20.015	0.0015129
465	441	456	22500	20.6667	19.6	20.2667	20.178	0.0015763
467	447	459	22500	20.7556	19.8667	20.4	20.341	0.0016575

468	451	460	22500	20.8	20.0444	20.4444	20.430	0.0017174
469.26	455.5	462.26	22500	20.856	20.2444	20.5449	20.548	0.001911
468	454	458	22500	20.8	20.1778	20.3556	20.444	0.0021015
467	449	457	22500	20.7556	19.9556	20.3111	20.341	0.0021809
460	442	453	22500	20.4444	19.6444	20.1333	20.074	0.0023249
455	437	451	22500	20.2222	19.4222	20.0444	19.896	0.0024001
446		448	22500	19.8222		19.9111	19.867	0.0024662
445			22500	19.7778			19.778	0.0025364
440			22500	19.5556			19.556	0.0026048

Table E-3 Stress versus strain of cube test on 7th day for Hybrid 10% CHA&SCBA

Stress versus strain of cube test on 7th day for Hybrid 10% CHA&SCBA								
Load (KN)			Area,mm^2	Stress,Mpa				
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	Strain
0	0	0	22500	0	0	0	0	0
20	5	5	22500	0.88889	0.22222	0.22222	0.444	0.0000153
24	14	26	22500	1.06667	0.62222	1.15556	0.948	0.000033
49	35	41	22500	2.17778	1.55556	1.82222	1.852	0.0000662
56	49	63	22500	2.48889	2.17778	2.8	2.489	0.0000906
102	65	90	22500	4.53333	2.88889	4	3.807	0.0001441
117	83	104	22500	5.2	3.68889	4.62222	4.504	0.0001743
138	116	122	22500	6.13333	5.15556	5.42222	5.570	0.0002232
152	135	138	22500	6.75556	6	6.13333	6.296	0.0002586
165	147	155	22500	7.33333	6.53333	6.88889	6.919	0.0002906
199	156	179	22500	8.84444	6.93333	7.95556	7.911	0.0003449
219	172	195	22500	9.73333	7.64444	8.66667	8.681	0.0003902
236	198	226	22500	10.4889	8.8	10.0444	9.778	0.0004605
253	212	245	22500	11.2444	9.42222	10.8889	10.519	0.0005124
269	225	277	22500	11.9556	10	12.3111	11.422	0.0005817
281	241	289	22500	12.4889	10.7111	12.8444	12.015	0.0006315
316	266	302	22500	14.0444	11.8222	13.4222	13.096	0.0007332
333	293	316	22500	14.8	13.0222	14.0444	13.956	0.0008275
345	312	325	22500	15.3333	13.8667	14.4444	14.548	0.0009018
355	328	333	22500	15.7778	14.5778	14.8	15.052	0.0009732
368	340	344	22500	16.3556	15.1111	15.2889	15.585	0.0010599
372	353	354	22500	16.5333	15.6889	15.7333	15.985	0.0011353
377	363	360	22500	16.7556	16.1333	16	16.296	0.0012027
384	369	370	22500	17.0667	16.4	16.4444	16.637	0.0012896
388	373	378	22500	17.2444	16.5778	16.8	16.874	0.001362

390	375	385	22500	17.3333	16.6667	17.1111	17.037	0.0014209
392	383	389	22500	17.4222	17.0222	17.2889	17.244	0.0015139
393	387	392	22500	17.4667	17.2	17.4222	17.363	0.0015846
394	391	393	22500	17.5111	17.3778	17.4667	17.452	0.001656
396.14	393.19	394.91	22500	17.6062	17.4751	17.5516	17.544	0.001851
395	391	394	22500	17.5556	17.3778	17.5111	17.481	0.0020234
394	390	394	22500	17.5111	17.3333	17.5111	17.452	0.0020574
392	385	394	22500	17.4222	17.1111	17.5111	17.348	0.002151
389	380	394	22500	17.2889	16.8889	17.5111	17.230	0.0022326
388	378		22500	17.2444	16.8		17.022	0.0023179
383	372		22500	17.0222	16.5333		16.778	0.0024512
374	367		22500	16.6222	16.3111		16.467	0.0025127
	361		22500		16.0444		16.044	0.0026137

Table E-4 -Stress versus strain of cube test on 7th day for Hybrid 15% CHA&SCBA

Stress versus strain of cube test on 7th day for Hybrid 15% CHA&SCBA								
Load (KN)			Area,mm^2	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
19	16	13	22500	0.84444	0.71111	0.57778	0.711	0.0000251
26	23	21	22500	1.15556	1.02222	0.93333	1.037	0.000037
39	41	37	22500	1.73333	1.82222	1.64444	1.733	0.0000631
49	52	49	22500	2.17778	2.31111	2.17778	2.222	0.0000822
65	63	87	22500	2.88889	2.8	3.86667	3.185	0.0001215
79	76	92	22500	3.51111	3.37778	4.08889	3.659	0.0001419
97	106	109	22500	4.31111	4.71111	4.84444	4.622	0.0001854
100	119	126	22500	4.44444	5.28889	5.6	5.111	0.0002087
115	123	139	22500	5.11111	5.46667	6.17778	5.585	0.0002322
127	148	152	22500	5.64444	6.57778	6.75556	6.326	0.0002707
144	158	163	22500	6.4	7.02222	7.24444	6.889	0.0003016
165	173	178	22500	7.33333	7.68889	7.91111	7.644	0.0003456
175	186	192	22500	7.77778	8.26667	8.53333	8.193	0.0003796
189	192	201	22500	8.4	8.53333	8.93333	8.622	0.0004075
200	201	213	22500	8.88889	8.93333	9.46667	9.096	0.0004398
210	213	221	22500	9.33333	9.46667	9.82222	9.541	0.0004717
224	226	236	22500	9.95556	10.0444	10.4889	10.163	0.0005191
234	236	248	22500	10.4	10.4889	11.0222	10.637	0.0005578
247	247	259	22500	10.9778	10.9778	11.5111	11.156	0.0006031
258	256	261	22500	11.4667	11.3778	11.6	11.481	0.0006331

265	273	272	22500	11.7778	12.1333	12.0889	12.000	0.0006844
277	290	284	22500	12.3111	12.8889	12.6222	12.607	0.0007502
289	307	295	22500	12.8444	13.6444	13.1111	13.200	0.0008223
299	322	312	22500	13.2889	14.3111	13.8667	13.822	0.0009086
310	338	324	22500	13.7778	15.0222	14.4	14.400	0.0010025
317	356	332	22500	14.0889	15.8222	14.7556	14.889	0.001097
325	367	339	22500	14.4444	16.3111	15.0667	15.274	0.0011862
342	375	348	22500	15.2	16.6667	15.4667	15.778	0.0013377
358	380	353	22500	15.9111	16.8889	15.6889	16.163	0.001516
364.87	382.3	359.63	22500	16.2164	16.9911	15.9836	16.397	0.001828
363	380	357	22500	16.1333	16.8889	15.8667	16.296	0.0020524
362	375	356	22500	16.0889	16.6667	15.8222	16.193	0.0021488
361	371	351	22500	16.0444	16.4889	15.6	16.044	0.0022548
360	361		22500	16	16.0444		16.022	0.0023251
359	359		22500	15.9556	15.9556		15.956	0.0023957
358	351		22500	15.9111	15.6		15.756	0.0024674
	346		22500		15.3778		15.378	0.0025265

APPENDIX-F Stress versus strain relationship of cube test on 14th day

Table F-1 -Stress versus strain of cube test on 14th day for control

Stress versus strain of cube test on 14th day for control								
Load (KN)			Area,mm²	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
21	24	17	22500	0.933333	1.066667	0.755556	0.919	0.0000297
34	33	29	22500	1.511111	1.466667	1.288889	1.422	0.0000463
49	48	38	22500	2.177778	2.133333	1.688889	2.000	0.0000657
60	61	58	22500	2.666667	2.711111	2.577778	2.652	0.000088
78	81	76	22500	3.466667	3.6	3.377778	3.481	0.0001171
100	99	97	22500	4.444444	4.4	4.311111	4.385	0.0001499
123	113	111	22500	5.466667	5.022222	4.933333	5.141	0.000178
133	139	126	22500	5.911111	6.177778	5.6	5.896	0.0002069
155	160	148	22500	6.888889	7.111111	6.577778	6.859	0.000245
174	179	172	22500	7.733333	7.955556	7.644444	7.778	0.0002828
196	201	194	22500	8.711111	8.933333	8.622222	8.756	0.0003246
211	215	207	22500	9.377778	9.555556	9.2	9.378	0.0003521
231	228	230	22500	10.26667	10.13333	10.22222	10.207	0.00039
246	252	252	22500	10.93333	11.2	11.2	11.111	0.0004331
264	275	265	22500	11.73333	12.22222	11.77778	11.911	0.0004729
281	293	276	22500	12.48889	13.02222	12.26667	12.593	0.0005082
301	309	295	22500	13.37778	13.73333	13.11111	13.407	0.0005521
316	330	310	22500	14.04444	14.66667	13.77778	14.163	0.0005948
342	354	329	22500	15.2	15.73333	14.62222	15.185	0.0006559
358	369	343	22500	15.91111	16.4	15.24444	15.852	0.0006981
370	388	354	22500	16.44444	17.24444	15.73333	16.474	0.0007394
378	400	366	22500	16.8	17.77778	16.26667	16.948	0.0007722
394	415	379	22500	17.51111	18.44444	16.84444	17.600	0.0008196
415	436	400	22500	18.44444	19.37778	17.77778	18.533	0.0008925
422	453	415	22500	18.75556	20.13333	18.44444	19.111	0.0009412
442	474	434	22500	19.64444	21.06667	19.28889	20.000	0.0010228
465	485	446	22500	20.66667	21.55556	19.82222	20.681	0.0010921
473	500	456	22500	21.02222	22.22222	20.26667	21.170	0.0011464
484	516	468	22500	21.51111	22.93333	20.8	21.748	0.001217
493	530	476	22500	21.91111	23.55556	21.15556	22.207	0.0012794
502	539	490	22500	22.31111	23.95556	21.77778	22.681	0.0013518
514	553	498	22500	22.84444	24.57778	22.13333	23.185	0.0014414

521	561	505	22500	23.15556	24.93333	22.44444	23.511	0.0015099
535	572	513	22500	23.77778	25.42222	22.8	24.000	0.0016411
541	577	519	22500	24.04444	25.64444	23.06667	24.252	0.0017373
549.36	580.55	525.30	22500	24.41616	25.80222	23.34667	24.522	0.0019904
546	578	524	22500	24.26667	25.68889	23.28889	24.415	0.0021549
537	574	519	22500	23.86667	25.51111	23.06667	24.148	0.0023039
531	570	510	22500	23.6	25.33333	22.66667	23.867	0.0024094
528	568	497	22500	23.46667	25.24444	22.08889	23.600	0.0024911
525	547	487	22500	23.33333	24.31111	21.64444	23.096	0.0026199
519	544	481	22500	23.06667	24.17778	21.37778	22.874	0.0026699
511	539	473	22500	22.71111	23.95556	21.02222	22.563	0.0027351

Table F-2 -Stress versus strain of cube test on 14th day for Hybrid 5% CHA&SCBA

Stress versus strain of cube test on 14th day for Hybrid 5% CHA&SCBA								
Load (KN)			Area,mm^2	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0.000	0
18	17	19	22500	0.8	0.75556	0.84444	0.800	0.0000261
21	19	23	22500	0.93333	0.84444	1.02222	0.933	0.0000306
28	32	34	22500	1.24444	1.42222	1.51111	1.393	0.000046
44	39	48	22500	1.95556	1.73333	2.13333	1.941	0.0000647
52	45	56	22500	2.31111	2	2.48889	2.267	0.0000761
78	67	72	22500	3.46667	2.97778	3.2	3.215	0.0001098
110	78	91	22500	4.88889	3.46667	4.04444	4.133	0.0001437
125	95	103	22500	5.55556	4.22222	4.57778	4.785	0.0001685
144	114	121	22500	6.4	5.06667	5.37778	5.615	0.0002011
156	126	139	22500	6.93333	5.6	6.17778	6.237	0.0002263
168	139	158	22500	7.46667	6.17778	7.02222	6.889	0.0002535
182	144	178	22500	8.08889	6.4	7.91111	7.467	0.0002782
207	158	190	22500	9.2	7.02222	8.44444	8.222	0.0003117
234	175	207	22500	10.4	7.77778	9.2	9.126	0.0003534
250	197	226	22500	11.1111	8.75556	10.0444	9.970	0.0003942
265	213	245	22500	11.7778	9.46667	10.8889	10.711	0.0004315
281	228	271	22500	12.4889	10.1333	12.0444	11.556	0.0004762
310	244	296	22500	13.7778	10.8444	13.1556	12.593	0.0005343
324	258	319	22500	14.4	11.4667	14.1778	13.348	0.0005792
338	287	342	22500	15.0222	12.7556	15.2	14.326	0.0006412
351	297	355	22500	15.6	13.2	15.7778	14.859	0.000677

365	329	362	22500	16.2222	14.6222	16.0889	15.644	0.0007328
378	344	371	22500	16.8	15.2889	16.4889	16.193	0.0007742
396	357	380	22500	17.6	15.8667	16.8889	16.785	0.0008215
417	375	392	22500	18.5333	16.6667	17.4222	17.541	0.0008864
442	399	408	22500	19.6444	17.7333	18.1333	18.504	0.0009783
462	417	416	22500	20.5333	18.5333	18.4889	19.185	0.0010514
475	430	429	22500	21.1111	19.1111	19.0667	19.763	0.0011204
487	444	436	22500	21.6444	19.7333	19.3778	20.252	0.0011852
497	460	441	22500	22.0889	20.4444	19.6	20.711	0.0012532
505	473	453	22500	22.4444	21.0222	20.1333	21.200	0.0013362
513	484	466	22500	22.8	21.5111	20.7111	21.674	0.0014323
516	492	473	22500	22.9333	21.8667	21.0222	21.941	0.0014971
521	497	487	22500	23.1556	22.0889	21.6444	22.296	0.0016047
524	501	494	22500	23.2889	22.2667	21.9556	22.504	0.0016902
527	505	498	22500	23.4222	22.4444	22.1333	22.667	0.0017886
529.36	506.5	500.54	22500	23.5271	22.5111	22.2462	22.761	0.0019554
522	504	499	22500	23.2	22.4	22.1778	22.593	0.002183
516	501	498	22500	22.9333	22.2667	22.1333	22.444	0.0022667
509	500	492	22500	22.6222	22.2222	21.8667	22.237	0.0023569
501	486		22500	22.2667	21.6		21.933	0.0024753
	478		22500		21.2444		21.244	0.0026164

Table F-3 -Stress versus strain of cube test on 14th day for Hybrid 10% CHA&SCBA

Stress versus strain of cube test on 14th day for Hybrid 10% CHA&SCBA								
Load (KN)			Area,mm²	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
17	19	19	22500	0.75556	0.84444	0.84444	0.815	0.0000267
19	26	21	22500	0.84444	1.15556	0.93333	0.978	0.0000321
25	38	39	22500	1.11111	1.68889	1.73333	1.511	0.0000501
30	45	44	22500	1.33333	2	1.95556	1.763	0.0000588
56	49	55	22500	2.48889	2.17778	2.44444	2.370	0.0000799
74	70	68	22500	3.28889	3.11111	3.02222	3.141	0.0001075
88	84	89	22500	3.91111	3.73333	3.95556	3.867	0.0001539
110	106	114	22500	4.88889	4.71111	5.06667	4.889	0.0001733
125	121	126	22500	5.55556	5.37778	5.6	5.511	0.0001979
139	133	139	22500	6.17778	5.91111	6.17778	6.089	0.0002214
156	156	154	22500	6.93333	6.93333	6.84444	6.904	0.0002555

167	170	170	22500	7.42222	7.55556	7.55556	7.511	0.0002819
188	188	197	22500	8.35556	8.35556	8.75556	8.489	0.000326
210	213	225	22500	9.33333	9.46667	10	9.600	0.0003789
218	227	252	22500	9.68889	10.0889	11.2	10.326	0.0004153
239	248	287	22500	10.6222	11.0222	12.7556	11.467	0.0004757
256	273	305	22500	11.3778	12.1333	13.5556	12.356	0.0005259
288	297	331	22500	12.8	13.2	14.7111	13.570	0.0005997
293	314	344	22500	13.0222	13.9556	15.2889	14.089	0.0006333
325	343	354	22500	14.4444	15.2444	15.7333	15.141	0.000706
356	368	368	22500	15.8222	16.3556	16.3556	16.178	0.0007848
369	376	380	22500	16.4	16.7111	16.8889	16.667	0.0008249
381	389	394	22500	16.9333	17.2889	17.5111	17.244	0.0008752
394	409	405	22500	17.5111	18.1778	18	17.896	0.0009364
410	414	411	22500	18.2222	18.4	18.2667	18.296	0.0009767
426	427	421	22500	18.9333	18.9778	18.7111	18.874	0.0010395
444	434	428	22500	19.7333	19.2889	19.0222	19.348	0.0010958
458	441	436	22500	20.3556	19.6	19.3778	19.778	0.0011515
463	448	442	22500	20.5778	19.9111	19.6444	20.044	0.0011887
476	455	452	22500	21.1556	20.2222	20.0889	20.489	0.0012569
479	466	463	22500	21.2889	20.7111	20.5778	20.859	0.0013207
489	475	472	22500	21.7333	21.1111	20.9778	21.274	0.0014035
499	484	485	22500	22.1778	21.5111	21.5556	21.748	0.0015217
506	488	489	22500	22.4889	21.6889	21.7333	21.970	0.0015928
513	491	492	22500	22.8	21.8222	21.8667	22.163	0.0016711
515	494	494	22500	22.8889	21.9556	21.9556	22.267	0.0017258
516	496	497	22500	22.9333	22.0444	22.0889	22.356	0.0017879
517.72	498.92	498.48	22500	23.0098	22.1742	22.1547	22.446	0.001949
517	494	497	22500	22.9778	21.9556	22.0889	22.341	0.0021287
516	490	494	22500	22.9333	21.7778	21.9556	22.222	0.0022111
515	492	488	22500	22.8889	21.8667	21.6889	22.148	0.0022519
514	487	470	22500	22.8444	21.6444	20.8889	21.793	0.0024023
		466	22500			20.7111	20.711	0.0025003

Table F-4 -Stress versus strain of cube test on 14th day for Hybrid 15% CHA&SCBA

Stress versus strain of cube test on 14th day for Hybrid 15% CHA&SCBA								
Load (KN)			Area,mm^2	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
16	17	19	22500	0.71111	0.75556	0.84444	0.770	0.0000259

24	23	24	22500	1.06667	1.02222	1.06667	1.052	0.0000357
32	30	32	22500	1.42222	1.33333	1.42222	1.393	0.0000476
39	41	39	22500	1.73333	1.82222	1.73333	1.763	0.0000608
46	46	49	22500	2.04444	2.04444	2.17778	2.089	0.0000726
55	57	58	22500	2.44444	2.53333	2.57778	2.519	0.0000885
64	67	71	22500	2.84444	2.97778	3.15556	2.993	0.0001064
79	81	83	22500	3.51111	3.6	3.68889	3.600	0.00013
97	99	96	22500	4.31111	4.4	4.26667	4.326	0.0001592
110	113	109	22500	4.88889	5.02222	4.84444	4.919	0.0001839
124	125	121	22500	5.51111	5.55556	5.37778	5.481	0.0001839
145	139	134	22500	6.44444	6.17778	5.95556	6.193	0.0002399
169	156	148	22500	7.51111	6.93333	6.57778	7.007	0.0002781
189	177	169	22500	8.4	7.86667	7.51111	7.926	0.0003236
217	198	184	22500	9.64444	8.8	8.17778	8.874	0.0003736
238	217	201	22500	10.5778	9.64444	8.93333	9.719	0.0004212
255	231	218	22500	11.3333	10.2667	9.68889	10.430	0.0004638
277	246	236	22500	12.3111	10.9333	10.4889	11.244	0.0005145
294	264	258	22500	13.0667	11.7333	11.4667	12.089	0.000574
326	288	279	22500	14.4889	12.8	12.4	13.230	0.0006607
345	307	296	22500	15.3333	13.6444	13.1556	14.044	0.0007299
360	325	304	22500	16	14.4444	13.5111	14.652	0.0007864
375	347	319	22500	16.6667	15.4222	14.1778	15.422	0.0008655
388	353	331	22500	17.2444	15.6889	14.7111	15.881	0.0009176
410	366	348	22500	18.2222	16.2667	15.4667	16.652	0.0010162
417	379	356	22500	18.5333	16.8444	15.8222	17.067	0.0010767
426	387	364	22500	18.9333	17.2	16.1778	17.437	0.0011366
432	396	379	22500	19.2	17.6	16.8444	17.881	0.0012185
437	413	384	22500	19.4222	18.3556	17.0667	18.281	0.0013057
441	422	394	22500	19.6	18.7556	17.5111	18.622	0.0013959
442	431	411	22500	19.6444	19.1556	18.2667	19.022	0.0015379
443	439	418	22500	19.6889	19.5111	18.5778	19.259	0.0016702
445.59	442.00	421.43	22500	19.804	19.6444	18.7302	19.393	0.001888
442	437	417	22500	19.6444	19.4222	18.5333	19.200	0.0021642
435	431	411	22500	19.3333	19.1556	18.2667	18.919	0.0023245
432		403	22500	19.2		17.9111	18.556	0.002428

APPENDIX-G Stress versus strain relationship of cube test on 28th day

Table G-1 -Stress versus strain of cube test on 28th day for control

Stress versus strain of cube test on 28th day for control								
Load (KN)			Area,mm^2	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
19	17	17	22500	0.84444	0.75556	0.75556	0.785	0.0000246
25	20	28	22500	1.11111	0.88889	1.24444	1.081	0.000034
40	34	39	22500	1.77778	1.51111	1.73333	1.674	0.0000531
58	45	56	22500	2.57778	2	2.48889	2.356	0.0000753
71	68	72	22500	3.15556	3.02222	3.2	3.126	0.0001008
92	89	95	22500	4.08889	3.95556	4.22222	4.089	0.0001334
118	114	117	22500	5.24444	5.06667	5.2	5.170	0.0001709
145	130	133	22500	6.44444	5.77778	5.91111	6.044	0.0002021
156	148	164	22500	6.93333	6.57778	7.28889	6.933	0.0002345
182	174	188	22500	8.08889	7.73333	8.35556	8.059	0.0002768
208	202	210	22500	9.24444	8.97778	9.33333	9.185	0.0003205
230	228	236	22500	10.2222	10.1333	10.4889	10.281	0.0003646
248	243	253	22500	11.0222	10.8	11.2444	11.022	0.0003952
274	271	268	22500	12.1778	12.0444	11.9111	12.044	0.0004389
289	297	296	22500	12.8444	13.2	13.1556	13.067	0.0004841
310	312	323	22500	13.7778	13.8667	14.3556	14.000	0.000527
331	325	345	22500	14.7111	14.4444	15.3333	14.830	0.0005665
354	347	364	22500	15.7333	15.4222	16.1778	15.778	0.0006134
372	365	388	22500	16.5333	16.2222	17.2444	16.667	0.0006592
402	387	417	22500	17.8667	17.2	18.5333	17.867	0.0007242
421	404	434	22500	18.7111	17.9556	19.2889	18.652	0.000769
435	417	457	22500	19.3333	18.5333	20.3111	19.393	0.0008132
445	430	470	22500	19.7778	19.1111	20.8889	19.926	0.0008462
463	438	488	22500	20.5778	19.4667	21.6889	20.578	0.0008882
488	471	513	22500	21.6889	20.9333	22.8	21.807	0.0009727
496	488	533	22500	22.0444	21.6889	23.6889	22.474	0.0010222
520	510	558	22500	23.1111	22.6667	24.8	23.526	0.0011064
541	525	571	22500	24.0444	23.3333	25.3778	24.252	0.00117
556	536	588	22500	24.7111	23.8222	26.1333	24.889	0.0012306
580	551	607	22500	25.7778	24.4889	26.9778	25.748	0.0013215
605	560	624	22500	26.8889	24.8889	27.7333	26.504	0.0014134
618	577	634	22500	27.4667	25.6444	28.1778	27.096	0.0014972
629	586	651	22500	27.9556	26.0444	28.9333	27.644	0.0015894

637	594	660	22500	28.3111	26.4	29.3333	28.015	0.0016649
641	603	673	22500	28.4889	26.8	29.9111	28.400	0.0017645
646.31	610.62	684.74	22500	28.7249	27.1387	30.4329	28.77	0.0020621
644	615	683	22500	28.6222	27.3333	30.3556	28.770	0.0022081
642	617	680	22500	28.5333	27.4222	30.2222	28.726	0.0022351
638	618	675	22500	28.3556	27.4667	30	28.607	0.0022932
632	617	671	22500	28.0889	27.4222	29.8222	28.444	0.0023551
628	616	664	22500	27.9111	27.3778	29.5111	28.267	0.0024106
624	610	661	22500	27.7333	27.1111	29.3778	28.074	0.0024628
611	600	657	22500	27.1556	26.6667	29.2	27.674	0.0025546
601	585	652	22500	26.7111	26	28.9778	27.230	0.0026408
589	573	649	22500	26.1778	25.4667	28.8444	26.830	0.0027095

Table G-2 -Stress versus strain of cube test on 28th day for Hybrid 5% CHA&SCBA

Stress versus strain of cube test on 28th day for Hybrid 5% CHA&SCBA								
Load (KN)			Area,mm^2	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
20	18	19	22500	0.88889	0.8	0.84444	0.844	0.0000269
27	23	24	22500	1.2	1.02222	1.06667	1.096	0.000035
49	40	46	22500	2.17778	1.77778	2.04444	2.000	0.0000647
73	63	68	22500	3.24444	2.8	3.02222	3.022	0.0000992
92	85	87	22500	4.08889	3.77778	3.86667	3.911	0.00013
118	118	114	22500	5.24444	5.24444	5.06667	5.185	0.0001757
142	136	129	22500	6.31111	6.04444	5.73333	6.030	0.000207
166	166	152	22500	7.37778	7.37778	6.75556	7.170	0.0002506
203	184	183	22500	9.02222	8.17778	8.13333	8.444	0.0003014
231	204	209	22500	10.2667	9.06667	9.28889	9.541	0.0003471
264	234	238	22500	11.7333	10.4	10.5778	10.904	0.0004066
303	252	265	22500	13.4667	11.2	11.7778	12.148	0.0004639
332	277	303	22500	14.7556	12.3111	13.4667	13.511	0.0005305
358	294	326	22500	15.9111	13.0667	14.4889	14.489	0.0005811
376	309	342	22500	16.7111	13.7333	15.2	15.215	0.0006203
398	335	365	22500	17.6889	14.8889	16.2222	16.267	0.0006801
423	356	384	22500	18.8	15.8222	17.0667	17.230	0.0007382
446	375	409	22500	19.8222	16.6667	18.1778	18.222	0.0008021
453	388	427	22500	20.1333	17.2444	18.9778	18.785	0.0008405
464	408	436	22500	20.6222	18.1333	19.3778	19.378	0.0008827
471	426	448	22500	20.9333	18.9333	19.9111	19.926	0.0009237
486	452	459	22500	21.6	20.0889	20.4	20.696	0.0009849

497	475	468	22500	22.0889	21.1111	20.8	21.333	0.0010392
519	488	482	22500	23.0667	21.6889	21.4222	22.059	0.0011062
530	513	496	22500	23.5556	22.8	22.0444	22.800	0.0011814
542	525	509	22500	24.0889	23.3333	22.6222	23.348	0.0012428
551	549	517	22500	24.4889	24.4	22.9778	23.956	0.0013185
562	560	532	22500	24.9778	24.8889	23.6444	24.504	0.0013961
571	578	547	22500	25.3778	25.6889	24.3111	25.126	0.0015003
580	588	559	22500	25.7778	26.1333	24.8444	25.585	0.0015957
586	599	571	22500	26.0444	26.6222	25.3778	26.015	0.001714
594.19	610.62	582.08	22500	26.4084	27.1387	25.8702	26.472	0.0020235
589	609	578	22500	26.1778	27.0667	25.6889	26.311	0.0022135
580	608	571	22500	25.7778	27.0222	25.3778	26.059	0.0023315
577	607	562	22500	25.6444	26.9778	24.9778	25.867	0.0023983
564	594		22500	25.0667	26.4		25.733	0.0024642
553	589		22500	24.5778	26.1778		25.378	0.0025072
549	572		22500	24.4	25.4222		24.911	0.0025673
557			22500	24.7556			24.756	0.0026316

Table G-3 -Stress versus strain of cube test on 28th day for Hybrid 10% CHA&SCBA

Stress versus strain of cube test on 28th day for Hybrid 10% CHA&SCBA								
Load (KN)			Area,mm^2	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
18	17	20	22500	0.8	0.75556	0.88889	0.815	0.0000262
27	26	27	22500	1.2	1.15556	1.2	1.185	0.0000382
43	40	36	22500	1.91111	1.77778	1.6	1.763	0.0000574
61	57	54	22500	2.71111	2.53333	2.4	2.548	0.0000839
82	83	79	22500	3.64444	3.68889	3.51111	3.615	0.0001211
111	106	96	22500	4.93333	4.71111	4.26667	4.637	0.0001579
127	119	121	22500	5.64444	5.28889	5.37778	5.437	0.0001877
149	143	144	22500	6.62222	6.35556	6.4	6.459	0.0002269
176	171	169	22500	7.82222	7.6	7.51111	7.644	0.0002743
197	188	183	22500	8.75556	8.35556	8.13333	8.415	0.0003063
226	209	200	22500	10.0444	9.28889	8.88889	9.407	0.000349
251	240	223	22500	11.1556	10.6667	9.91111	10.578	0.0004018
278	259	242	22500	12.3556	11.5111	10.7556	11.541	0.0004474
299	276	256	22500	13.2889	12.2667	11.3778	12.311	0.0004854
318	298	279	22500	14.1333	13.2444	12.4	13.259	0.0005344
342	320	297	22500	15.2	14.2222	13.2	14.207	0.0005859
365	337	311	22500	16.2222	14.9778	13.8222	15.007	0.0006316

389	355	326	22500	17.2889	15.7778	14.4889	15.852	0.0006825
411	376	343	22500	18.2667	16.7111	15.2444	16.741	0.0007393
433	399	365	22500	19.2444	17.7333	16.2222	17.733	0.0008073
446	417	388	22500	19.8222	18.5333	17.2444	18.533	0.0008664
458	430	401	22500	20.3556	19.1111	17.8222	19.096	0.0009106
467	442	416	22500	20.7556	19.6444	18.4889	19.630	0.0009549
479	454	429	22500	21.2889	20.1778	19.0667	20.178	0.0010031
496	470	445	22500	22.0444	20.8889	19.7778	20.904	0.001072
512	482	458	22500	22.7556	21.4222	20.3556	21.511	0.0011352
527	494	478	22500	23.4222	21.9556	21.2444	22.207	0.0012157
541	502	494	22500	24.0444	22.3111	21.9556	22.770	0.0012891
556	509	509	22500	24.7111	22.6222	22.6222	23.319	0.0013708
563	516	517	22500	25.0222	22.9333	22.9778	23.644	0.0014257
571	524	537	22500	25.3778	23.2889	23.8667	24.178	0.0015321
580	532	543	22500	25.7778	23.6444	24.1333	24.519	0.0016175
586	539	557	22500	26.0444	23.9556	24.7556	24.919	0.0017577
590.17	545.27	563.66	22500	26.2298	24.2342	25.0516	25.172	0.0020029
586	541	560	22500	26.0444	24.0444	24.8889	24.993	0.0022186
578	537	554	22500	25.6889	23.8667	24.6222	24.726	0.0023424
571	531	548	22500	25.3778	23.6	24.3556	24.444	0.0024385
562	526		22500	24.9778	23.3778		24.178	0.0025182
538			22500	23.9111			23.911	0.0026022

Table G-4 -Stress versus strain of cube test on 28th day for Hybrid 15% CHA&SCBA

Stress versus strain of cube test on 28th day for Hybrid 15% CHA&SCBA								
Load (KN)			Area,mm^2	Stress,Mpa				Strain
Samp 1	Samp 2	Samp 3		Samp 1	Samp 2	Samp 3	Avg	
0	0	0	22500	0	0	0	0	0
18	17	18	22500	0.8	0.75556	0.8	0.785	0.000026
27	24	19	22500	1.2	1.06667	0.84444	1.037	0.0000345
41	36	32	22500	1.82222	1.6	1.42222	1.615	0.0000544
57	54	47	22500	2.53333	2.4	2.08889	2.341	0.0000801
81	79	59	22500	3.6	3.51111	2.62222	3.244	0.0001131
104	92	97	22500	4.62222	4.08889	4.31111	4.341	0.0001552
122	108	113	22500	5.42222	4.8	5.02222	5.081	0.0001848
146	123	158	22500	6.48889	5.46667	7.02222	6.326	0.0002371
172	146	191	22500	7.64444	6.48889	8.48889	7.541	0.0002915
189	163	228	22500	8.4	7.24444	10.1333	8.593	0.0003418
212	186	258	22500	9.42222	8.26667	11.4667	9.719	0.0003992
238	204	284	22500	10.5778	9.06667	12.6222	10.756	0.000456

260	219	325	22500	11.5556	9.73333	14.4444	11.911	0.0005243
277	245	348	22500	12.3111	10.8889	15.4667	12.889	0.0005871
298	269	354	22500	13.2444	11.9556	15.7333	13.644	0.0006393
320	288	366	22500	14.2222	12.8	16.2667	14.430	0.0006977
338	307	375	22500	15.0222	13.6444	16.6667	15.111	0.0007523
357	329	384	22500	15.8667	14.6222	17.0667	15.852	0.0008167
377	348	399	22500	16.7556	15.4667	17.7333	16.652	0.0008933
399	367	408	22500	17.7333	16.3111	18.1333	17.393	0.0009729
408	386	419	22500	18.1333	17.1556	18.6222	17.970	0.0010422
417	407	423	22500	18.5333	18.0889	18.8	18.474	0.0011097
426	424	431	22500	18.9333	18.8444	19.1556	18.978	0.0011859
430	438	444	22500	19.1111	19.4667	19.7333	19.437	0.0012656
442	452	458	22500	19.6444	20.0889	20.3556	20.030	0.0013919
454	464	464	22500	20.1778	20.6222	20.6222	20.474	0.0015183
459	479	469	22500	20.4	21.2889	20.8444	20.844	0.0016791
461.4	486.81	471.32	22500	20.5067	21.636	20.9476	21.030	0.0019208
456	481	470	22500	20.2667	21.3778	20.8889	20.844	0.0021768
449	478	469	22500	19.9556	21.2444	20.8444	20.681	0.0022708
441	473	464	22500	19.6	21.0222	20.6222	20.415	0.0023883
		455	22500			20.2222	20.222	0.0024648

APPENDIX-H Stress-strain curves

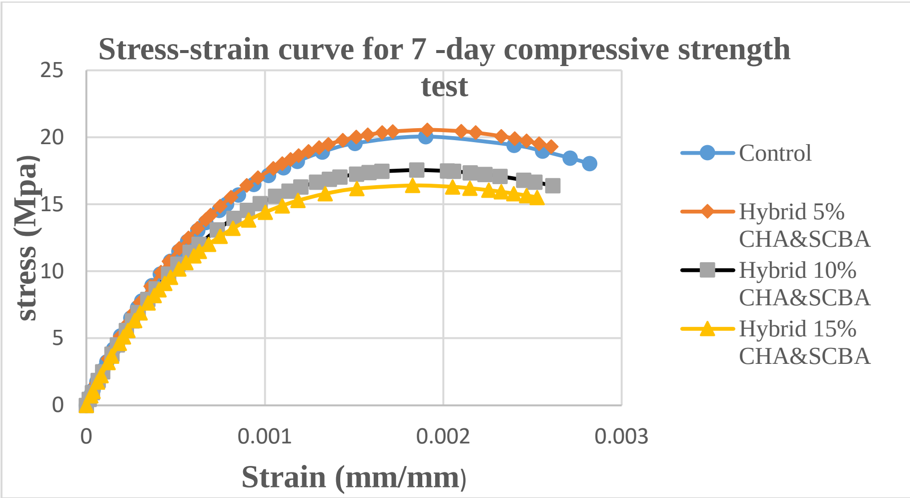

Figure H-1: Stress-strain curve for 7 day

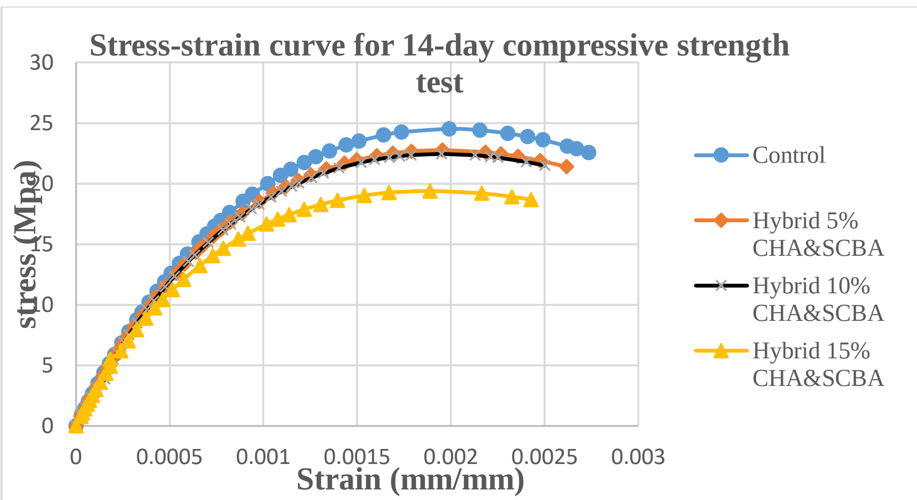

Figure H-2: Stress-strain curve for 14th day

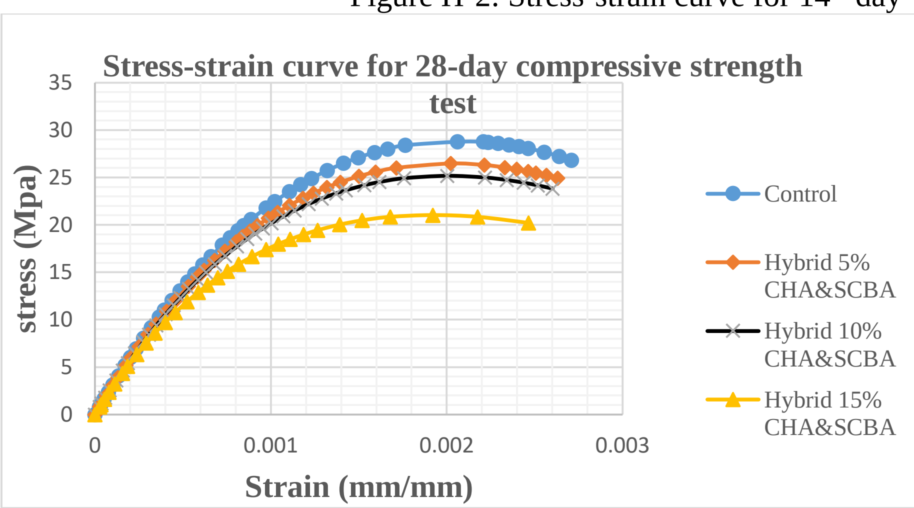

Figure H-3: Stress-strain curve for 28th day

APPENDIX-I Strength and deformation characteristics for concrete

Table H-1 Strength and deformation characteristics for concrete (ESA, 2015).

Strength classes for concrete															Analytical relation / Explanation
f_{ck} (MPa)	12	16	20	25	30	35	40	45	50	55	60	70	80	90	
$f_{ck,cube}$ (MPa)	15	20	25	30	37	45	50	55	60	67	75	85	95	105	
f_{cm} (MPa)	20	24	28	33	38	43	48	53	58	63	68	78	88	98	$f_{cm} = f_{ck} + 8$ (MPa)
f_{ctm} (MPa)	1.6	1.9	2.2	2.6	2.9	3.2	3.5	3.8	4.1	4.2	4.4	4.6	4.8	5.0	$f_{ctm} = 2.12\ln(1+(f_{cm}/10)) \geq$ C50/60
$f_{ctk,0.05}$ (MPa)	1.1	1.3	1.5	1.8	2.0	2.2	2.5	2.7	2.9	3.0	3.1	3.2	3.4	3.5	$f_{ctk,0.05} = 0.7 \times f_{ctm}$ 5 % fractile
$f_{ctk,0.95}$ (MPa)	2.0	2.5	2.9	3.3	3.8	4.2	4.6	4.9	5.3	5.5	5.7	6.0	6.3	6.6	$f_{ctk,0.95} = 1.3 \times f_{ctm}$ 95 % fractile
E_{cm} (GPa)	27	29	30	31	33	34	35	36	37	38	39	41	42	44	$E_{cm} = 22[(f_{cm})/10]^{0.3}$ (f_{cm} in MPa)
ε_{c1} (‰)	1.8	1.9	2.0	2.1	2.2	2.25	2.3	2.4	2.45	2.5	2.6	2.7	2.8	2.8	See Figure 3.2 ε_{c1} (‰) $= 0.7 f_{cm}^{0.31} \leq 2.8$
ε_{cu1} (‰)	3.5									3.2	3.0	2.8	2.8	2.8	See Figure 3.2 for $f_{ck} \geq 50$ MPa ε_{cu1} (‰) $= 2.8 + 27[(98 - f_{cm})/100]^4$
ε_{c2} (‰)	2.0									2.2	2.3	2.4	2.5	2.6	See Figure 3.3 for $f_{ck} \geq 50$ MPa ε_{c2} (‰) $= 2.0 + 0.085[(f_{ck}-50)^{0.53}$
ε_{cu2} (‰)	3.5									3.1	2.9	2.7	2.6	2.6	See Figure 3.3 for $f_{ck} \geq 50$ MPa ε_{cu2} (‰) $= 2.6 + 35[(90 - f_{ck})/100]^4$
n	2.0									1.75	1.6	1.45	1.4	1.4	for $f_{ck} \geq 50$ MPa $n = 1.4 + 23.4\,[(90 - f_{ck})/100]^4$
ε_{c3} (‰)	1.75									1.8	1.9	2.0	2.2	2.3	See Figure 3.4 for $f_{ck} \geq 50$ MPa ε_{c3} (‰) $= 1.75 + 0.55[(f_{ck} - 50)/40]$
ε_{cu3} (‰)	3.5									3.1	2.9	2.7	2.6	2.6	See Figure 3.4 for $f_{ck} \geq 50$ MPa ε_{cu3} (‰) $= 2.6 + 35[(90 - f_{ck})/100]^4$

APPENDIX-J Certificate of calibration

Figure I-1 Certificate of calibration


NATIONAL METROLOGY INSTITUTE
CALIBRATION

…TROLOGY INSTITUTE OF ETHIOPIA
(NMIE)

CERTIFICATE OF CALIBRATION

This calibration certificate documents the traceability to national standards, which realize the units of measurement according to the international system of units

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Addis Ababa, Ethiopia
Tel 251-11- 6517985
Fax 251-11-6459312
e-mail: info@ nmie.net
website: http://www nmie net

Date of Issue: 2018-10-10 Certificate number: OFS-0242 Page 1 of 3

Object		**Compressive Strength Testing Machine**
Manufacturer		**UTEST**
Type / Model		**UTC-6231**
Serial Number	Display	**---**
	Machine	**18/001091674-1-5006**
Customer		**Jimma University Institute of Technology**
Registration no.:		**10-0736**
Number of pages of the certificate		**3**
Date of Calibration:		**2018-09-30**

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Seal Date	Approved By	Calibrated By
2018-10-10	Solomon Asefa	Seid Fentaw

APPENDIX-K Chemical Properties of hybrid CHA&SCBA

	GEOLOGICAL SURVEY OF ETHIOPIA	Doc.Number: GLD/F5.10.2	Version No: 1
	GEOCHEMICAL LABORATORY DIRECTORATE		Page 1 of 1
Document Title:	Complete Silicate Analysis Report	Effective date:	May, 2017

Issue Date: -10/06/2021

Customer Name:-Muliye Tarekegn

Request No:- GLD/RQ/969/21

Report No:- GLD/RN/525/21

Sample type :-Ash

Sample Preparation: - 200 Mesh

Date Submitted :-04/05/2021

Number of Sample:- One(01)

Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides

Analytical Method: $LiBO_2$ FUSION, HF attack, GRAVIMETERIC, COLORIMETRIC and AAS

Collector's code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
MT-21	31.32	3.16	1.66	5.86	1.68	0.56	16.70	0.08	2.30	0.20	1.52	36.32

Note: - This result represent only for the sample submitted to the laboratory.

Analysts	Checked By	Approved By	Quality Control
Lidet Endeshaw			
Yirgalem Abreham	Tizita Zemene	Yohannes Getachew	Gosa Haile
Nigist Fikadu			

APPENDIX-L Photo Gallery

Photo-1 Collecting Sugarcane bagasse ash from Arjo Didessa Sugar factory

Photo-2 Burning CH by Furness in highway laboratory

Photo-3 silt content determination of fine aggregate

Photo-4 Sieve Analysis

Photo-5 Unit weight of fine and coarse aggregate

Photo-6 Specific gravity test for fine and coarse aggregate

Photo-7 Cement Normal Consistency and Setting Time test

Photo-8 Prepared molds

Photo-9 Mix and casting

Photo-10 fresh concrete properties slump test

Photo-11 Fresh Concrete Properties Compaction Factor Test

Photo-12 Demolding and curing Casted specimen

Photo-13 Adjustment and reading dial gauge

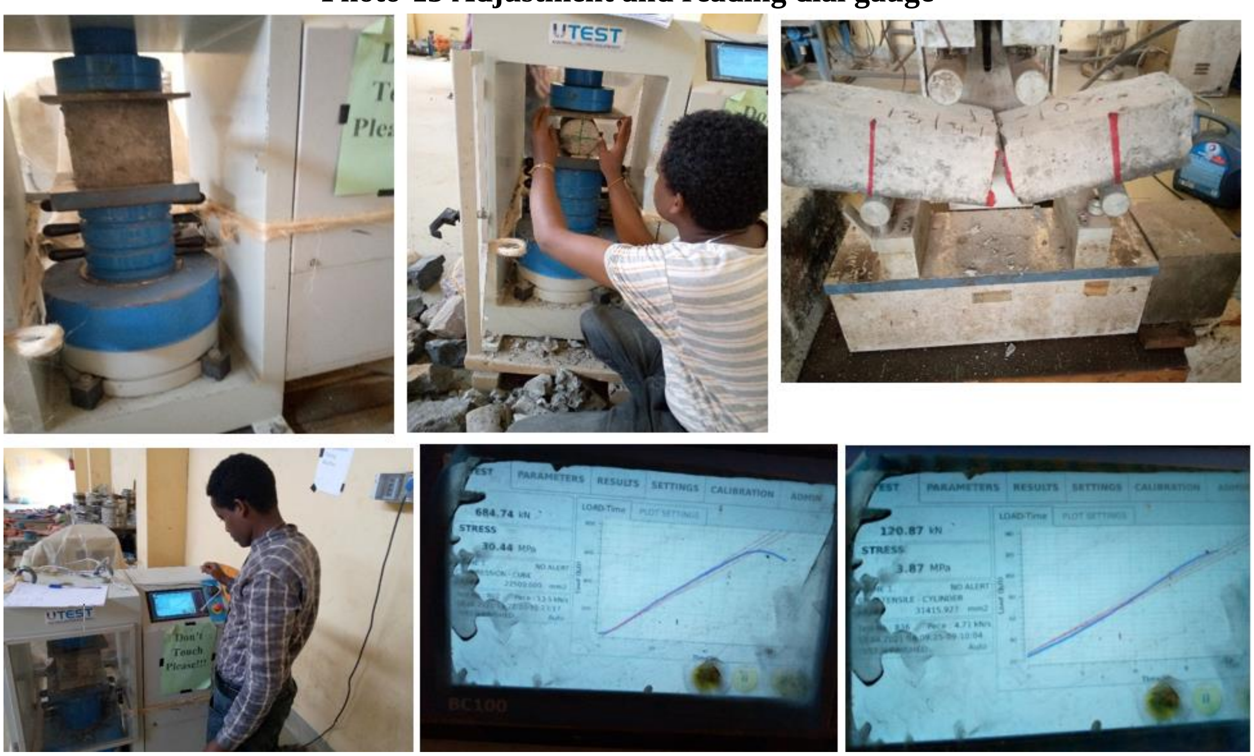

Photo-14 During hardened concrete test