OPEN ACCESS
Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) |ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://scholarsmepub.com/sjet/

Original Research Article

Investigation on Production of Light Weight High Tensile Strength Concrete Using Sugarcane Bagasse Fiber

Abreham Desta
Faculty of Civil and Environmental Engineering, Construction Engineering and Management Chair, Jimma University, School of Graduate Studies, Jimma Institute of Technology, Jimma, Ethiopia

***Corresponding author:** Abreham Desta
| **Received:** 17.03.2019 | **Accepted:** 25.03.2019 | **Published:** 31.03.2019
DOI:10.21276/sjeat.2019.4.3.5

Abstract

Concrete, the most common construction material which has less tension capacity. And, a light weight concrete has many application in construction industry now a days due to its provision of less dead load, improvement for seismic structural response, suitability for transporting, and handling economically. Reinforcing material such as natural fiber, can be used to increase crack control and ductility by reducing the tendency of brittleness of concrete. The objective of this study was to evaluate the density, and tensile strength with its correlation with compressive strength of normal weight and lightweight concrete produced when incorporating with sugarcane bagasse fiber. The study has great significance in developing new advanced concrete product which has reduced density and high ductility with reduced crack. Furthermore, the usage of sugarcane in construction can reduce of environmental pollution. Sugarcane fibers extracted from bagasse by manually was used in volume fraction of 0%, 0.5%, 1.0%, and 1.5% in terms of weight of cement in mix with average fiber length of 25mm. In this study, lightweight aggregate (scoria) was used by replacing the normal weight aggregate by 50% and semi-lightweight concrete achieved. In order to obtain the output of the objective of the study, total of 48 cubes, 48 beams, and 48 cylinder specimens was prepared, and the tests performed on 7th and 28th days curing period. As result of the testing showed that the increase of fiber decreased the unit weight of concrete with light weight aggregate, but it is not uniform for normal weight concrete. The optimum value containing addition of sugarcane bagasse fiber is 0.5% due to flexural and split tensile strength with a little impact on compressive strength. Therefore, the use of sugarcane fiber in concrete is suitable for addition that do not exceed 0.5% of the concrete mixture.
Keywords: Lightweight High Tensile Strength Concrete, Sugarcane Bagasse Fiber, Unit weight, Tensile strength.

Acronyms

ACI - American Concrete Institute
ASTM - American Standard Testing Materials
BS- British Standard
CSA- Central Statistics Agency
ESISC- Ethiopian Sugar Industry Support Center Share Company
FRC - Fiber Reinforced Concrete
GFRC- Glass Fiber Reinforced Concrete
HSHDC- High Strength High Ductile Concrete
LWAC- Lightweight Aggregate Concrete
LWC- Light Weight Concrete
LWHTSC- Light Weight High Tensile Strength Concrete
NFRC - Natural Fiber Reinforced Concrete
NWC- Normal Weight Concrete
OPC- Ordinary Portland cement
PA - Polyamides
PE – Polyethylene
PES- Polyester
PNF- Processed Natural Fibers
PNFRC- Processed Natural Fiber Reinforced Concretes
PP- Polypropylene
PVA- Polyvinyl Acetate
SBF- Sugarcane Bagasse Fiber
SFRC- Steel-Fiber-Reinforced Concrete
SNF- Synthetic Fibers
UNF- Unprocessed Natural Fibers

INTRODUCTION

Background of the Study

Recently, world construction industry broadly and popularly uses concrete as structural material to build various infrastructures. With regard to its increased demand from construction sectors, now it requires environmental concern to produce it. Worldwide, over ten billion tons of concrete are being produced each year which get worse of forecasting its future production [1]. Since for the last three decades, significant progression and development has been made in the field of concrete technology. It has been the time for the introduction of mineral additives (supplementary cementitious material) such as pulverized-fuel ash (PFA), silica fume, ground granulated blast furnace slag (GGBS) as well as chemical admixtures such as superplasticizer (water reducing agent), air-entertainer, retarder, etc. and different kinds of fibers such as steel, synthetic and carbon [2].

Normal strength concrete (NSC) was firstly introduced in the early 1900 [3]. Later on, high performance concrete (HPC) was developed in the 1950 [4]. In the mid 1990's, one of the astonishing developments in the field of concrete technology was made by introduction of ultra-high performance fiber reinforced concrete (UHP-FRC) by Richard and Cheyrezy, which is more commonly known as ultra-high performance „ductile" concrete (UHPdC) or reactive powder concrete (RPC) [5].

Also, today concrete industry is the largest consumer of other natural resources such as water, sand, gravel, and crushed rock, Indeed, the volume of depletion of natural resources and production of CO2 is very large while it requires maximum industrial energy consumption correspondingly.

To overcome the negative effects of environment, the artificial aggregates like fly ash, ground granulated blast furnace slag, and expanded clay can be utilized to produce an environmentally friendly lightweight concrete [1].

Meanwhile, lightweight concrete are commonly used in precast and prestressed components. It is achieved by using of light weight aggregates like volcanic slag, crushed light weight brick, pumice scoria, etc., and can be also produced by applying of a foaming agents in a concrete mix [6]. Light weight concrete offers design flexibility and substantial cost savings by providing less dead load, improves seismic structural response, better fire rating, decreased storey height, smaller size structural members, lower foundation cost, and less reinforcing steel concrete has low density that leads to reduced dead load, and lower transport and handling cost. In addition, it also has a good thermal conductivity. However, lightweight concrete has low compression and flexural strength compared to normal weight concrete [7].

Hence, the application of fiber in production of light weight concrete reduces the weakness of the product that related to resisting compressive stress, and it specially improves the tensile strength. Additionally, incorporating of fiber reduces the cost of product by substituting the nominal materials.

Nowadays natural fibers are very fast replacing the traditional manmade fibers as reinforcements they have several advantages over manmade fibers, which include; plant fibers are renewable and their availability is more.

The result of sugarcane harvest is usually used for the manufacture of sugar by extracting liquid or liquid contained in the stalks of sugarcane so that the fiber and the contents are separated and as a result, that produces waste that is known as bagasse. Untreated well bagasse will be solid waste and causing pollution as well as damaging the healthy environment. But, it is easily obtained and widely used as an ingredient for the manufacture of a product, such as the manufacture of particleboards, furniture, polymer blending substance and can be utilized as additional alternative materials to improve the strength of cement composition [8, 9]. So, it's general perception that consumption of sugarcane bagasse fiber in concrete influences the physical properties like density and water absorption, and mechanical characteristics including flexural, split and compressive strengths.

Statement of the problem

At present, the construction industry and its sectors of the world have high and limitless demands for using concrete material to build various infrastructures. So, this relies on great concern about the environment impact to produce the concrete which balances the demand of it. As the matter of fact, beyond to its production, cement reaction in concrete manufacturing also contributes about five percent of annual global carbon dioxide emission [10].

Cement is essential material for making concrete. Consumption of high amount of cement in concrete increases the compressive and relatively the weight considering other mix materials, but it is highly week to resist when subjected to tensile load. And, in developing countries it is another challenges to convince with the cost of material to make concrete material.

To overcome such problems, it is time to look for other alternative materials like recycled concrete wastes, slags, fly ashes from different organic wastes and natural vegetable fibers to produce environmentally friendly, low cost, and lightweight concrete. Since there is an increase in bagasse waste in the country, it can be easily applicable.

Research Questions

- What is the density of concrete made using sugarcane bagasse fiber?
- What is the influence of the incorporation of different percentage of bagasse fiber on the flexural and split tensile strength of the concrete?

- What is the correlation of compressive strength with flexural and split tensile strength of concrete that resulted due to adding of the sugarcane bagasse fiber?

OBJECTIVES

General Objectives

The main aim of this study was to investigate the possibility of producing lightweight high tensile strength concrete (LWHTS) by incorporating varying amount of sugarcane bagasse fiber.

Specific Objectives

- To determine the unit weight /density of concrete made with bagasse fiber with respect to conventional concrete.
- To evaluate the influence of different percentage of bagasse fiber on flexural and splitting tensile strength of the hardened cast of both lightweight and normal weight concrete.
- To assess the compressive strength correlation with flexural and split tensile strength of concrete due to adding of the sugarcane bagasse fiber.

Significance of the study

The application of short length fiber can enhance the ability to resist tensile cracks, improves the energy absorption of concrete and increases the ductility in the manner before ultimate depletion.

The lightweight concrete is the better option for the replacement of conventional concrete since it is a light weight which helps in economizing the structural design by reducing dead load of structures, and minimizes the cost of the product.

So, the study on this paper encourages developing the new concrete product with increased strength to weight ratio comparatively to normal concrete.

It provides the way to implement the sustainable practices for concrete construction industry by utilizing natural waste material (bagasse), and using bagasse minimizes the negative impact through limiting the emission of gases.

Scope and Limitation

This research was conducted using of materials available in local market of Jimma town, and others possibly near to Jimma zone. It basically concerned on the effect of incorporating of bagasse fiber on unit weight, flexural and split tensile strength of both lightweight and normal weight concrete. Further, the correlation of compressive strength versus flexural and split tensile strength was carried out.

A sample mix for light weight concrete was used 50% of lightweight aggregate (scoria) to minimize its adverse water absorption, and decrease in strength of concrete. Considering the balling effect on mix and degrade of workability, the maximum amount of sugarcane bagasse fiber was restricted to 1.5% volume fraction in terms of weight of cement and the average fiber length was 25mm.

RELATED LITERATURE REVIEW

Fiber in Concrete Construction

Background

Fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortal and straw in mud bricks. In the early 1900s, asbestos fibers were used in concrete. In the 1950s, the concept of composite materials came into being and fiber reinforced concrete was one of the topics of interest. Once the health risks associated with asbestos were discovered, there was a need to find a replacement for the substance in concrete and other building materials. By the 1960s, steel, glass (GFRC), and synthetic fibers such as polypropylene fibers were used in concrete [11].

Fiber Reinforced Concrete

Fiber reinforced concrete is a composite material containing fiber in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously depend upon the efficient transfer of stress between matrix and the fibers, which is largely depend on the type of fiber, fiber geometry, fiber content and distribution of the fibers. Fiber reinforced concrete (FRC) has been recognized for a long as a material with potential which extends the versatility of concrete as a construction material, by providing an effective method of overcoming its intrinsic brittleness [12]. Generally, concrete containing a hydraulic cement, water, fine and coarse aggregate and discontinuous discrete fibers is called fiber-reinforced concrete (FRC). Fibers of various shapes and sizes produced from steel, synthetics, glass, and natural materials can be used.

According to [9] investigation regarding to the feasibility of fiber using with cement, the effect of two bagasse fiber loads (4, 10 w%), three levels of calcium chloride as facilitator (5, 7.5 and 10% per dry weight of cement) and two different types of port land cement (type II and V) on physical and mechanical properties of specimens those were tested. The result indicated that the best conditions reported for flexural strength, modulus of elasticity, internal bond and minimum thickness swelling were 4% fiber, 7.5% calcium chloride and type II cement [9].

As Nuruddin, M. F *et al.*, realized about polyvinyl acetate (PVA), which is one of synthetic fibers of aspect ratio up to 90 are better in terms of compressive strength. The coarser type PVA fibers provide good workability and results in least problems of workability in the concrete in the presence of coarse aggregates and hence provides compressive strength comparable to concrete without fibers. In comparison with control concrete without PVA fiber splitting tensile strength of concrete is increasing with the increase in the aspect ratio up to 90 with fiber which infers that increase in aspect ratio and volume fraction of fibers gives higher splitting tensile strength. And, with PVA fibers of other aspect ratio, the flexural strength has been found to be either competitive to control or lesser than control [13].

The previous research conducted on natural fiber reinforced concrete shows addition of coconut fibers clearly increased flexural strength and stiffness of the concrete. The optimum percent fibers from this research was found to be 0.175%. However, adding excessive fibers resulted in reduction of the tensile strength due to bonding issue between fibers and concrete [7].

In the axial compression test, the concrete containing 2% v/w of bamboo presented an increase of 41% over to the standard concrete and 21.6% in relation to the same dosage with sugarcane in a manner corresponding investigation on influence of vegetale fibers on concrete. However, in the flexural tensile test, the concrete with 5% of sugarcane was the one that presented the best result, having an increase of 247% over to the conventional concrete and 7% in relation to the same dosage with bamboo [14].

Based on investigation focused on the influence of curing types and its period on fiber reinforced concrete, the increase of the fiber content from 1 to 6 volume% increased the tensile strength by 92% and the compressive strength by 72%. From the investigation of the different curing regimes and the curing period, it was observed that the 7 days strength of the steam-cured specimens was almost the same as the 90 days strength of the specimens cured under normal conditions [15].

Types of fiber

The both mechanical and geometrical properties of fibers vary and it does have the potential effect on the properties of concrete. Some types of fiber are mainly used to improve the toughness and reduce crack widths, while others are there to reduce plastic shrinkage cracking or to avoid spalling of concrete during fire. Steel fibers have been used for a considerable time, but modern steel fibers have higher slenderness and more complex geometries, and are often made of high-strength steel. Further, synthetic fibers are becoming more attractive as they can provide effective reinforcement comparable to that of steel fibers. Types of synthetic fibers that have been incorporated into cement matrices include: polyethylene (PE), polypropylene (PP), acrylics (PAN), polyvinyl acetate (PVA), polyamides (PA), aramid, polyester (PES), and carbon [12].

Several important terms, definitions, parameters, and features serve to characterize the wide variety of existing fibers; here are some of relevant definitions of terms according to ACI 544, 1996 [16].

- *Aspect Ratio*, which is the ratio of length to diameter (or equivalent diameter for non-circular fibers) of a fiber;
- *Bundled fibers*, which usually are strands consisting of several hundreds or thousands of filaments of micro fibers;
- *chopped strand*, which contains fibers chopped to various lengths;
- *Collated*, which refers to fibers bundled together either by cross-linking or by chemical means;
- *Fibrillated*, referring to continuous networks of fiber, in which the individual fibers have branching fibrils;
- *Filament*, which is a continuous fiber, i.e. one with an aspect ratio approaching infinity;
- *Monofilament*, a large-diameter continuous fiber, generally with a diameter greater than 100 µm;
- *Multifilament*, a yarn consisting of many continuous filaments or strands.

With regard to method of classification of fibers by Naaman, the short fibers used in a concrete can be characterized by different ways based on their source materials, physical and chemical properties, mechanical properties, geometrical manner, and cross-section [17].

1. Based on fiber source they are categorized as;
- natural and organic fibers; cellulose, sisal ,jute , bamboo, bagasse, etc.,
- natural and mineral fibers; asbestos, rock – wool etc.,
- man-made fibers ; steel, titanium, glass, carbon, polymers or synthetic
2. Based on physical/chemical properties they differentiated by their density, surface roughness, chemical stability, non-reactivity with the cement matrix and fire resistance or flammability
3. Based on their mechanical properties we can categorize them according to tensile strength, elastic modulus, stiffness, ductility, elongation to failure, and Surface adhesion property
4. An infinite combination of geometric properties related to the cross sectional shape, length, diameter (or equivalent diameter) and surface deformation can be selected.
5. The cross section of the fiber can be circular, rectangular, diamond, square, triangular, flat, polygonal, or any.

Moreover, in prEN 14889-2:2004 fibers are also to be characterized in classes in accordance with the intended use specially incorporating with concrete, which are:

- Class I; intended primarily to improve the short-term plastic properties of mortar and/or concrete by controlling plastic shrinkage, settlement cracks, and reducing bleeding, but not adversely affecting the long-term properties.

- Class II; intended primarily to improve the durability of mortar and/or concrete by improving abrasion and impact resistance and by reducing damage caused by cycles of freezing and thawing.
- Class III; fibers which primarily increase the residual strength of mortar and/or concrete.
- Class IV; fibers which are primarily used to improve the fire resistance of mortar and/or concrete.

Natural fibers in concrete construction

Any natural fiber such as sisal, banana, bagasse, coir etc. used as reinforcement, gives good result as compared to the man-made fibers such as steel, glass fiber, carbon fiber etc. If we talk about the future of bagasse fibers, are very bright because they are cheaper, lighter and environmentally superior to glass fiber or other synthetic fibers composites in general [18].

Natural reinforcing materials can be obtained at low levels of cost and energy using locally available manpower and technical know-how. Such fibers are used in the manufacture of low fiber content FRC and occasionally have been used in the manufacture of thin sheet high fiber content FRC. These fibers are typically referred to as unprocessed natural fibers (UNF).

However, other natural fibers are available that have been processed to enhance their properties have been used in commercial production for the manufacture of thin-sheet fiber reinforced cement products. These fibers are derived from wood by chemical processes such as the kraft process. Kraft pulp fibers are used in sophisticated manufacturing processes, such as the Hatschek process, to produce thin sheet high fiber content FRC. These fibers are typically referred to as processed natural fibers (PNF) and concretes made from them as processed natural fiber reinforced concretes (PNFRC) [16].

Natural fibers are prospective reinforcing materials and served many useful purposes but the application of materials technology for the utilization of natural fibers as the reinforcement in concrete has only taken place in comparatively recent years. Their basic properties in concretes are improved tensile and bending strength, greater ductility, and greater resistance to cracking and hence improved impact strength and toughness [19]. But, its properties in concrete will be affected by its type, geometry, form, surface, matrix properties, mixing proportion, mixing method, placing, casting and curing techniques.

Table-1: Typical properties of natural fiber Source [16]

Fiber type	Coconut	Sisal	Suger Cane bagasse	Bamboo	Jute	Flax	Elephant grass	Water reed
Fiber length in	2-4	N/A	N/A	N/A	7-12	20	N/A	N/A
Fiber diameter in	0.004-0.016	N/A	0.008-0.016	0.002-0.016	0.004-0.008	N/A	N/A	N/A
Specific gravity	1.12-1.15	N/A	1.2-1.3	1.5	1.02-1.04	N/A	N/A	N/A
Modulus of Elasticity, ksi	2750-3770	1880-3770	2175-2750	4780-5800	3770-4640	14,500	710	750
Ultimate tensile strength, psi	17,400-29000	40,000-82,400	26,650-42,000	50,750-72,500	36,250-50,750	145,000	25,800	10,000
Elongation at break, percent	10-25	3-5	N/A	N/A	1.5-1.9	1.8-2.2	3.6	1.2
Water absorption, percent	130-180	60-70	70-75	40-45	N/A	N/A	N/A	N/A
Note: N/A=properties not readily Available or not applicable.								
Metric Equvalents: 1 in=25.4mm; 1 ksi-100psi=6.895 MPa								

Sugarcane Bagasse Fiber (SBF)

Sugarcane

Sugarcane is a tall perennial tropical grass, which tillers at the base to produce unbranched stems from 2 to 4 m or more tall, and to around 5 cm in diameter. It is cultivated for these thick stems stalks or canes, from which the sugar is extracted [20].

The sugar cane stem solid, unbranched stem, roughly circular in cross-section, is clearly differentiated into joints each comprising a node and an internode. The node consists of a lateral bud situated in the axil of the leaf, a band containing root primordial, and a growth ring (see Fig-1). The buds, which can be situated on, or just above, the leaf scar, may be round, small and ad pressed to the stalk, or more prominent and pointed, depending on the variety.

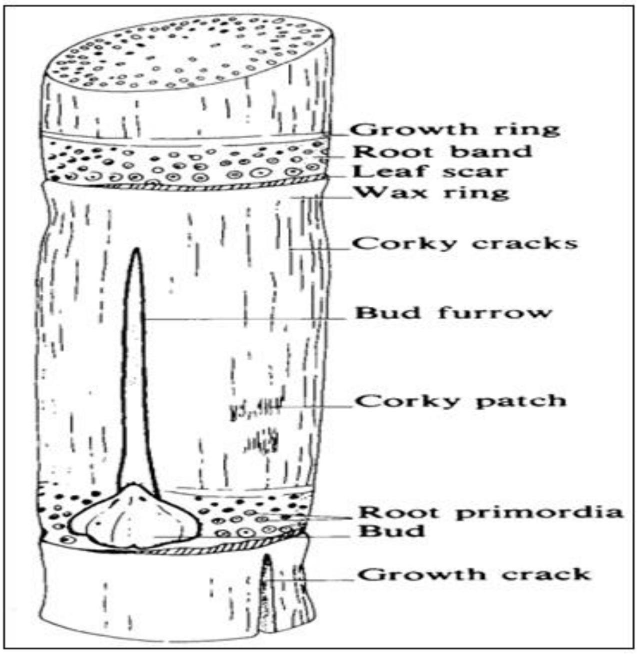

Fig-1: Sugarcane stem and its parts [21]

Generally, the nodes are spaced at intervals of around 15 to 25 cm; but are much closer at the top of the stalk where elongation is taking place. The color and hardness of the stalks vary with the variety, and the stalks can range in diameter from around 2.5 cm to around 5.0 cm. Stalk hardness may also be influenced by the growing conditions. Each stem has a hard, wax-covered rind (epidermis) surrounding a mass of softer tissue (parenchyma) that is interspersed with fibers (vascular bundles).

The wax layer prevents the loss of water from the stalk by evaporation, and the fibrous rind provides strength and rigidity. The fibers are more abundant towards the periphery of the stalk than in the center, so the mechanical structure of the stalk is fundamentally tube-like [20].

Sugarcane Bagasse

Bagasse is bio product of sugar cane which is left after the juice has been extracted for production of sugar. Bagasse fibers are natural fiber products and it biodegrades in 25-65 days. Bagasse fibers are the bast (fiber obtained from plants and used for matting and cord, in particular the inner bark of a lime tree) fiber like as banana fibers. It consists of water, fibers and small amounts of soluble solids and the amount of each of these components may change according to the maturity variety, harvesting and the efficiency of the crushing plant. For each 10 tons of sugarcanes crushed, a sugar factory produced nearly 3 tons of wet bagasse [18, 22]. As it stated in Wikipedia, 2018, it is a heterogeneous material containing around 30-40 percent of "pith" fiber, which is derived from the core of the plant and is mainly parenchyma material, and "bast", "rind", or "stem" fiber, which makes up the balance and is largely derived from sclerenchyma material [22].

Bagasse uses in construction industry

As Ethiopia, there is no detail and further researches have been carried out in the issue related on utilization of sugarcane bagasse for construction purposes. But, based on research performed by FENTA, 2010 there is potential benefit considering particularly about revising the coverage and quality of education demands by the production of pulp and paper locally. The import substitution policy of the government facilitates the local production of raw material for pulp and paper manufacturing. Boosting power generation form 2,000 MW to 8,000 MW, and further to 10,000 MW, shows the governments commitments in the infrastructure and the presence of potential source of energy other than bagasse [The country has more than 45,000 MW hydro, 5,000 MW Geothermal, and 10,000 MW wind electric energy potential (EEPCo, 2009)]. Thus, corresponding to increasing of source of energy improves sugar production from 314.5 thousand tons to 2,250 thousand tons. This further leaves nearly 5.9million tons of bagasse which further has a potential to produce 2.0 million tons of bagasse pulp [23].

Bagasse is mainly used as a burning raw material in the sugar cane mill furnaces, biofuel and raw material for the manufacture of pulp and building materials [22]. Bagasse has low caloric power, which makes this a low efficiency process. Based on data on the Wikipedia, 2018 approximately 9% of bagasse is used in alcohol (ethanol) production.

As Yadav introduced ethanol is a very versatile chemical raw material from which a variety of chemicals can be produced. There exist an excellent opportunity in fabricating bagasse based composites towards a wide array of applications in building and construction such boards and blocks as reconstituted wood, pulp, flooring tiles etc. These pulps are suited for generic printing and writing paper as well as tissue product but it is widely used for boxes and newspaper production. Bagasse fibers are short they result in paper with enhanced printing quality and also improved paper porosity [18].

Besides, bagasse can be utilized for the following general purposes.

a. Paper: - it uses for manufacturing 'paper' which has good opacity, printability and good burning strength.
b. Fiber Board: - It is made from refined or partially refined fibers. Bonding agents or other materials may be incorporated for increasing strength, as well as resistance to moisture, fire or decay. They are usually sold as insulation boards, soft boards and hard boards according to density.
c. Particle Board: - It is produced from small pieces of wood or other lingo cellulosic material impregnated with an organic binder or compressed under heat and pressure. These boards are suitable for furniture preparation. It has been observed that though it is possible to produce very large quantities of particle board from bagasse, no such utilization of bagasse is taking place. One of the reasons responsible for this is that wood waste is available at a considerably lower price than bagasse.
d. Furfural and Acetic Acid: - Furfural has been manufactured traditionally from oat husk in U.S.A. Furfural has a wide market because of its outstanding property as a selective solvent, which can be easily recovered. It can be produced from any fibrous raw material containing pentosans under the action of aqueous acid at higher temperature. Furfural can be further utilized for manufacturing furfliryl alcohol, nylon 66 and xylitol.
e. Alcohol: - Alcohol can also be produced from the bagasse.
f. Activated carbon:-Attempts are made to prepare activated carbon from bagasse.
g. Bagasse ash:-This ash removed from the boilers amounts to be about 0.3% on cane. Bagasse ash is utilized for glass making due to its easiness to grind, and all the main ingredients are already present in the intimate chemical composition.
h. Co-generation:- One of the important uses of bagasse which can really turnaround the sugar co-operatives is that it can be used for the purpose of cogeneration of electricity. After the passing of the Electricity Bill 2003, the power sector has been opened up and the private players can now enter in this field. The sugar co-operatives will be in a position to enter into this sector and produce the electricity. After satisfying their need they can sell the same to the State Electricity Boards at the rate decided by the Electricity Regulatory Commission.

Concerning the concrete construction industry, more researchers oriented with possibility of consumption of bagasse fiber for making cement composites as lightweight wall units, and bagasse ashes as partial replacement of cement in various range in making concrete for structural purposes. As it revealed by [11], bagasse ash can increase the strength of concrete when used up to 10% cement and 30% fine aggregates replacement level. However, the flexural strength of concrete is decrease after certain percentage replacement of sugarcane bagasse ash [11].

According to analysis of Danso on effect of sugarcane bagasse fiber on the strength properties of soil blocks, the addition of fibers to the soil blocks contributed to a reduction in density of the blocks, which could be attributed to the low density of the fiber. This means that when the blocks are used for building houses, the total weight of the structure will be reduced. Thus, the presence of pores inside the blocks resulted on high water absorption rate for fiber reinforced soil blocks. Compressive strength and tensile strength of the reinforced soil blocks increased over the unreinforced soil blocks, and the optimum effectiveness of the enhancement was obtained at 0.5% mass content of the fibers to the soil [24].

The ratio and adhesion behavior of bagasse-SBR-cement matrix played an important role in determining the mechanical properties of the composite product. It was found that composites with 6 % of SBR exhibited the greatest tensile strength with good hardness properties [8, 25-27].

Fig-2: Formation of Bagasse Bio-composite material [28]

Sugarcane Bagasse Fibers (SBF)

Sugarcane bagasse fiber is a cellulosic pith material extracted from bagasse after cane juice is removed during the milling process. The physical properties of natural fibers are mainly determined by the chemical & physical composition, such as structure of fibers' cellulose content, angle of fibrils, cross section and by the degree of polymerization.

Nowadays, natural fibers are very fast replacing the traditional manmade fibers as reinforcements they have several advantages over manmade fibers, which include; plant fibers are renewable and their availability is more or less unlimited, when natural fiber composite were subjected to at the end of their life cycle, to a combustion process or landfill the amount of CO2 released of the fibers is neutral with respect to their assimilated amount during their growth. The abrasive nature is lower which leads to advantages regarding technical material recycling, natural fiber reinforced plastics by using biodegradable polymers as matrix are the most environment friendly materials [20]. Use of bagasse fibers leads to an increase in mechanical properties of composites, due to strong bond between cement particles and fiber surfaces which result in an improvement in bending features of composites [28].

As Yadav investigated, SBF has the following chemical, physical, and mechanical properties [18]. The chemical composition of bagasse plant fibers notes that cellulose is the main constituent of plant fibers followed by hemi-celluloses and lignin interchangeably and pectin respectively. Cellulose is also the reinforcement for lignin, hemi cellulose and Pectin.

Table-2: Chemical composition of bagasse fibers

Cellulose (%)	45-55
Hemi cellulose (%)	20-25
Lignin (%)	18-24
Pectin (%)	0.6-0.8
Ash (%)	1-4
Extractives (%)	1.5-9

Physical properties of bagasse fiber is those of the single cell fibers, and thus the highest aspect ratio will exhibit highest tensile properties provide high surface area which are advantageous for reinforcement purposes.

Table-3: Physical properties of the bagasse fibers

Dia. (µm)	100-340
Length(mm)	8-28
Aspect Ratio(l/d)	76
Moisture content (%)	49

Mechanical properties of bagasse fibers, by which we use fibers as reinforcement for a good mechanical properties of composite materials.

Table-4: Mechanical properties of bagasse fibers

Tensile Strength (Mpa)	180-290
Young's Modulus (Gpa)	15-19
Failure Strain (%)	1-5
Density (Kg/m3)	880-720

In general, there is difference in properties of fibers between varieties as well as between maturity levels and as such no specific trend observed. The properties of sugarcane fibers are closer to the properties of cellulosic coir fibers. Hence, this fiber can be used for making nonwoven mats. The nonwovens can be impregnated in resins for making composites for various applications [30].

Extraction of fiber from sugar cane

Sugarcane bagasse is the residue obtained after extracting the sugarcane juice for sugar or wine. During the processing, the sugarcane stalk is crushed to extract sucrose, and the process produces a large volume of bagasse. The fibers are then extracted from the sugarcane residue; hence, bagasse fiber is easily obtained as a waste product.

The residue left after the extraction of juice called bagasse was collected for extraction of fibers. The soft-core part pith was removed from the bagasse manually to get outer hard rind. The rind was then cut across the length so that the cut portions are free from the nodes.

The samples were then subjected to hot water treatments (material:liquor ratio 1:50) and been stay in hot water at around 90°C for 1hour in order to remove coloring matters and sugar traces. Finally, the samples were then dried under the sunlight [31].

Sugarcane resources and its production in Ethiopia

Ethiopia is endowed with large areas of suitable low lands, rivers and conducive climate for sugar cane growth. The climate and soil types in the country have both proven to be highly conducive for sugar cane growth and productivity. Various pre-feasibility and feasibility studies of sugar projects conducted by the Ethiopian Sugar Industry Support Center Share Company (ESISC) have indicated that many potential sites at the main river basins are suitable for sugar cane plantation. These include 303,500 hectares of already identified suitable net areas in 7 sites. However, the total area developed for the production of sugar cane in the country is only about 8% of the total identified suitable areas.

As the report by the Central Statistics Agency (CSA) of Ethiopia presented, about 29,679.34 hectares of land was under sugar cane in the country, yielding an estimated total of 13,769,813.48 quintals of produce by the peasant holders. But the production is not usually used for industrial purposes. It is noticeably used up in household consumption [32]. This would make Ethiopia a very attractive location for private investors to invest in the production and processing of sugar cane.

ESISC, 2008 report on potential irrigation sites for sugar cane development which concerned with sugar production of Ethiopia shows that there is total of 658,850 hectares and 373,250 hectares gross and net suitable area respectively for the development of sugarcane resources (see Table-5).

Table-5: Potential Irrigation Sites for Sugar Cane Development [33]

Basin	**Site No.**	**Site**	**Water source**	**Gross area**	**Net Suitable area**	**Study level and Remarks**
Awash	1	Angelele Balhamo	Awash	11,000	8,600	Feasibility
	2	Maro Gala	Awash	14,700	6,600	Pre-feasibility
	3	Kasem Kebena	Kasem	17,600	13,600	Pre-feasibility
Blue Nile	4	Arjo Dedesa	Dedesa	139,000	16,800	Pre-feasibility
	5	Anger Valley	Anger	65,500	30,200	Pre-feasibility
	6	Upper Beles	Beles	65,000	55,300	Feasibility
	7	Upper Dinder	Dinder	80,000	58,300	Feasibility
	8	Rahad	Rahad	100,000		*
Tekeze	9	Angereb	Angereb	45,600	38,800	Reconnaissance
	10	Tekeze	Setit	68,550	50,550	Feasibility
Omo Gibe	11	Lower Omo	Omo	58,000	29,000	*
Baro	12	Abob/Ubala	Gilo	46,900	39,400	Reconnaissance
	13	Itang	Baro		21,000	Feasibility
Nile	14	Dabus	Dabus		5,100	
Omo	15	Gojeb	Gojeb	12,000		
Total				**658,850**	**373,250**	

Corresponding to Gain Report, 2015 by USDA Staff on future aims of Ethiopia to Become One of the World's Top 10 Sugar Producers, there will be about 3.27 million MT of sugar production been estimated until year of 2023 from the factory under construction (see table below). Besides, 272,783 ton of bagasse will be obtained, and 95,474 tons of fiber will be extracted [33].

Table-6: Sugar Factories under Construction and their Estimated Production Capacity[33]

Factories	Location	Estimated Production(MT)
Arjo-Dedesa	540km West of Addis	55,200
Kuraz(1-5 factories)	760km South of Addis	1,946,000
Tendaho phase two	600 North of Addis	214,000
Walkaiyt	1200km North of Addis	484,400
Belles(1-3 factories)	576km North of Addis	484,000
Kessem expansion	245km East of Addis	89,800
Total		**3,273,400**

Generally, Ethiopia has a lot of sugar factories both under supplying of the product and while under construction to have increased amount of bagasse.

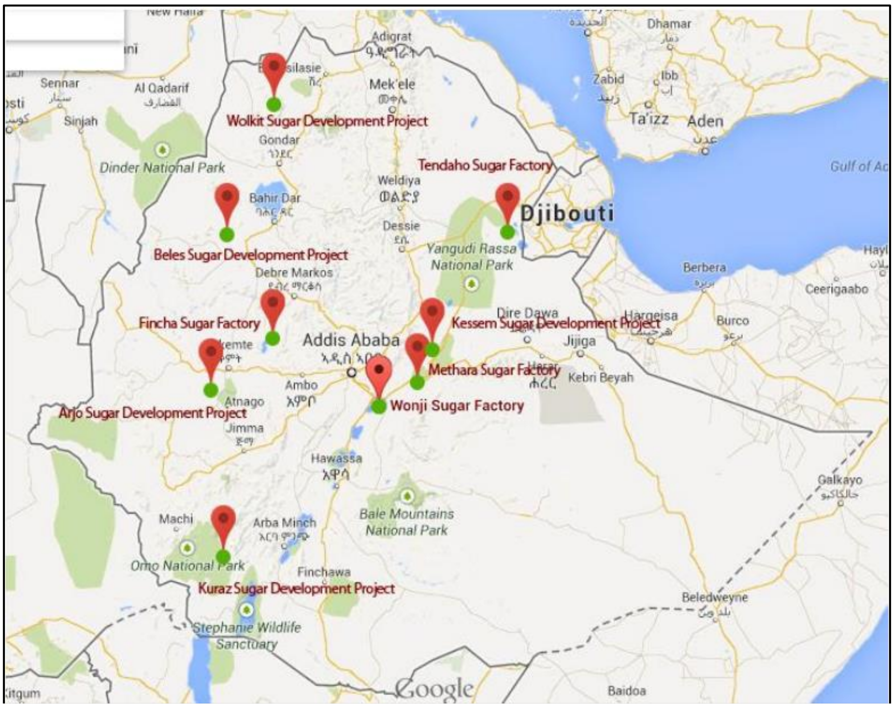

Fig-3: Location of sugar factories in Ethiopia [33]

Light weight concrete for structural purpose

One of the earliest uses of reinforced lightweight concrete was in the construction of ships and barges by the Emergency Fleet Building Corp. of World War I. During the time concrete of the required compressive strength of 5000 psi (34.47 MPa) was obtained with a unit weight of 110 lb/ft 3 (1760 kg/m3) or less, using expanded shale aggregate [34].

Later to post World War II, considerable impetus was given to the development of lightweight concrete when a National Housing Agency survey was conducted on potential use of lightweight concrete for home construction. These studies, and the earlier studies conducted by Richart and Jensen, and others focused attention on the potential structural use of some lightweight aggregate concrete and initiated a renewed interest in lighter weight for building frames, bridge decks, and precast products in the early 1950s. The 42-story Prudential Life Building in Chicago, which incorporated lightweight concrete floors, and the 18-story Statler Hilton Hotel in Dallas, which was designed with a lightweight concrete frame and flat plate floors are some of examples for application of lightweight concrete for structural purposes.

Lightweight concrete is the type of concrete that has an in-place unit weight of less than 1840 kg/m3 when compared to that of normal weight concrete which has a density in the range of 2240 to 2400 kg/m3 [7].

Therefore, it is essential to apply of Light Weight Concrete (LWC) in skyscrapers of residential and commercial complexes, as well as office buildings would reduce the overall weight of the buildings, reduce the amount of material used and reduce seismic and wind loads. This is expected to have an effect on the optimization of the structural systems of high rise buildings in terms of energy efficiency and materials savings [35]. As it require a moderate weight foundation correspondingly to mass of upper light structure, it enhances to save costs of structure.

Hence, it achieved in different way and using of light weight aggregate to make it is been best alternative. As Meyer, 2002 revealed, the light weight aggregate concrete (LWAC) is about 25% lighter than normal concrete and, in a design where the dead load is equal to the live load, a saving of 15% in energy intensive steel reinforcement can result. Equal or greater savings are achieved in columns and footings. For long-span bridges, the live load is a minor part of the total load and a reduction in density is translated into reductions in not only mass, but also in section size [36].

Due to its mechanical properties, lightweight concrete is not recommendable to use it for structural purposes. However, as a structural material it should have some specific characteristics to meet the strength and performance requirements for the applications. '*Structural lightweight concrete*-Structural concrete made with lightweight aggregate; the air-dried unit weight at 28 days is usually in the range of 90 to 115 lb/ft3 (1440 to 1850 kg/m3) and the compressive strength is more than 2500 psi (17.2 MPa)' [34].

Materials to produce lightweight concrete

There are various processed and unprocessed lightweight aggregates those can be used to make lightweight concrete considering their influence on unit weight, compressive and tensile strength, time-dependent properties, durability, fire resistance, and other properties of structural lightweight aggregate concrete. Among processed lightweight aggregate rotary kiln expanded shales, clays and slates; sintered shales, clays; and expanded slags are common, and scoria and pumice are typical naturally occurring and unprocessed aggregates.

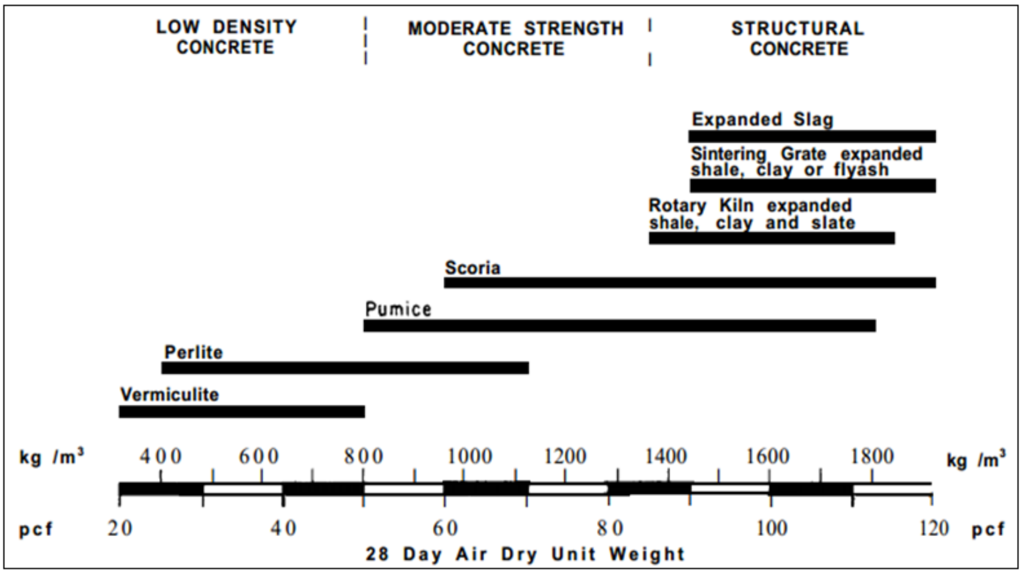

Fig-4: Approximate unit weight and use classification of lightweight aggregate concrete [34]

Nowadays, there are many research works issued with improving use of lightweight aggregates with incorporating various types of fibers to enable it for structural purpose else.

Light weight concrete can be produced by addition of a foaming agent in cement mortar. Depending on study of Singh foaming agent creates a fine cement matrix which has air voids throughout its structure. Thus hardened cellular structure is formed due to aerated cement mortar is produced by the introduction gas into cementations slurry [37].

By the same investigation, he realized that fine powder of Aluminum can be used as air entraining agent mixed with the slurry and reacts with the calcium hydroxide present in slurry, thereby producing hydrogen gas. This hydrogen gas contained in the slurry form cellular structures and thus makes the concrete lighter than the conventional concrete.

According to investigation by [38] concrete with 30% replacement level of limestone dust to normal coarse aggregate which attained 34.99 MPa compressive and 6.39 MPa flexural tensile strength values, satisfies the requirements for a building material to be used in the structural applications [38].

Moreover, the result showed that it is possible to produce a lightweight and satisfied strength concrete by using scoria and pumice as aggregate. It was also seen that, using light weight aggregate in the concrete mixture can reduce the dead load but decreases the concrete strength. Based on Kiliç *et al.*, on the introduction of volcanic scoria and pumice aggregate, it led to a tensile strength reduction of 7-58% when compared to normal concrete with identical cement content [39].

But, as it discovered on the Suitability of Pumice and Scoria Aggregates in Ribbed-Slab Construction, structural scoria lightweight concrete can be produced up to strength of 30 MPa by using locally available well-graded scoria coarse and fine aggregates with cement content of 360 kg/m3 and above which is recognizable to use it for structural purposes. Basic mechanics of reinforced concrete can be used for the design and analysis of ribbed slab systems with Ethiopian scoria aggregates. But, unlike crushed gravel aggregates, the water absorption of pumice and scoria aggregates are significantly affected by weather conditions. Therefore, great care should be exercised during addition of water [40].

To make scoria concrete (SC) with 50% to 100% scoria aggregate (SA) as replacement of coarse crushed gravel aggregate (GA) by volume, a range of slump between 60 and 80 mm would provide satisfactory workability. SC with 50 to 100% SA as replacement of crushed gravel aggregate satisfied the criteria for semi-lightweight structural concrete. SC made with 100% fine and coarse SA satisfies the criteria for lightweight structural concrete [6].

Scoria and Pumice

Pumice and Scoria are pyroclastic rocks. They consist of fragmental volcanic material which has been blown into atmosphere by explosive activity. They are generally produced from volcanoes whose lava has a more viscous type. They have a number of different types, but two major groups may be distinguished. First of all is the material which has been thrown out of the volcano as liquid globules, has solidified in the air and been deposited as solid particles and have small spherical or ellipsoidal cavities which are produced by bubbles of gas trapped during the solidification of the rock. This group may be subdivided into four classes. Two of these are pumice and scoria.

Pumice (P) is a highly vesicular material derived from acidic lavas. It is created when super-heated, highly pressurized rock is violently ejected from volcano, and usually foamy configuration happens because of simultaneous rapid cooling and depressurization that forms bubble by lowering the solubility of gasses that dissolved in the lava. It has a very low density and often floats on water. Pumice is commonly pale in color, ranging from white to green brown or black. In pumice stone, the stone aggregates are having low specific gravity, highly porous material with high water absorption percentage [37]. It widely used to make lightweight concrete or insulative low density cinder blocks. It can be used as additive for cement as pozzolanic material.

Scoria (S) is derived from basic lava that is vesicular, dark colored volcanic rock. It differ from pumice, or another vesicular rock, in having larger and thicker vesicle that means it is denser [39]. In construction, it is widely used in landscaping and drainage works. It can be used for a high temperature insulation. Following Italy, Chile, and Ecuador; Ethiopia is the 4th leading producer of pumice and scoria aggregates in the world.

Fig-5: Pumice- lightweight aggregate [41]

Fig-6: Scoria aggregate [6]

Scoria satisfies the requirements of lightweight aggregate for structural concrete as per ASTM C 330 in terms of its unit weight, specific gravity, gradation, moisture content, water absorption, and other necessary properties that will influences the workability, density, strength, durability and other characteristics of hardened concrete. Following the investigation by [42] on effect of Utilization of Scoria as a partial replacement of coarse aggregate in making lightweight Concrete, to make scoria concrete with 10% to 100% scoria aggregate as replacement of coarse crushed granite aggregate by volume, a range of slump between 40 and 80 mm would provide satisfactory workability. The optimum flexural and split tensile strengths were obtained at 10% of coarse aggregate replacement with values of 4.55 N/mm^2 and 2.31 N/mm^2 respectively. And, water absorption increased with increase in scoria as a replacement to coarse aggregate in concrete that may resulted due to the voids inside which created during its formation [42].

Properties of light weight concrete

Depending upon the source of material, structural grade lightweight concrete can be obtained in a dry weight range of 90 to 115 lb/ft3 (1440 to 1840 kg/m3). Minimum compressive strength at 28^{th} day age, by definition, is 2500 psi (17.24 MPa). Most structural lightweight aggregates are capable of producing concretes with compressive strengths in excess of 5000 psi (34.47 MPa) and, with many of these, concretes can be made with strengths considerably greater than 6000 psi (41.36 MPa) [34].

Despite millions of tiny air filled cells, it is strong and durable. They are excellent in acoustic performance, earthquake resistant, good insulation, workability, long life span due to termite and fire resistance, weather proof and, material savings, low modulus of elasticity (0.5%– 0.75%) than that of the normal concrete and therefore they are more pronounced to deflection. Good environmental impact due to thermal efficiency and thus it makes a major contribution to environmental protection by heating and cooling in buildings. So, it can sustain a long by with resistance cracks and related defects that may result because of thermal impacts. However, light weight concrete cannot be used as reinforced concrete as it has a cellular structure and therefore rusting to steel reinforcement is quite proactive [37].

Because of having large number of voids in the aggregate, lightweight concrete possesses a relatively higher thermal insulating efficiency than the normal weight concrete.

High Tensile Strength Concrete

The deflection and cracking behavior of concrete structure depend on the flexural tensile strength of concrete. Many factors have been shown to influence the flexural tensile strength of concrete, particularly the level of stress, size, age and confinement to concrete flexure member, etc. The concrete members, in general, are of large continuous size and have at least minimum reinforcement introducing a confining effect to the concrete. The confining reinforcement increases ductility and large deflections in structures provide a good warning of failure prior to complete failure of the flexure member and also for efficient use of constructional material, it is desirable to take full advantage of long-term strength gain.

Low tensile strength of concrete is due to the propagation of single internal crack. If the crack restrained locally by extending into another matrix adjacent to it, the initiation of crack is retarded and higher tensile strength of concrete is achieved. This restrained can be achieved by adding small length fibers to concrete. The incorporation of short fiber in concrete matrix changes the large cracking to micro cracks that makes it as acceptable as per as safety and durability perspectives. In addition to increasing the tensile strength, addition of fibers enhances fatigue resistance, energy absorption, toughness, ductility, and durability [12].

Materials to produce high tensile strength concrete

The application of innovative materials in the concrete will improve the strength of concrete in a better manner; one of such innovation is high strength concrete. As Shenbagavalli, *et al*., experimented on light weight high strength concrete, high strength concrete can be achieved by replacing fine aggregate and coarse aggregate by 2% and 4% using equal amount of plastic and glass powder [43].

With regard to study carried out on the development of high strength high ductility concrete, the ultimate tensile stress capacity is governed by the minimum of the peak bridging capacities at various cracks, which is further dependent on the interfacial bond and fiber dispersion using Polyethylene (PE) fiber with diameter of 39 μm, length equals to 12 mm, and volume fraction of 2%, including Microsilica Ground and Silica as mineral additives. The average tensile strain capacity was 3.5% and the average compressive strength of three 2-in. cubes of high strength high ductile concrete (HSHDC) was 160 MPa [44].

The other alternative way to produce high tensile strength corresponding to its tensile strength is through applying of superplasticizer admixture. Thus, high-strength concrete can be achieved with a low water/cementitious ratio and use of superplasticizer to achieve high workability. However, finishability of the concrete was a problem due to loss of effect of the superplasticizer [45].

One of the significant advances in the 20th century was the development of a new generation of highly cementitious based composite material known as Ultra-High Performance „ductile" Concrete (UHPdC) with compressive strength over 150 MPa and flexural strength over 30 MPa and remarkably improvement in durability similar to natural rocks with ingredient of superplasticizer and 40 kg/m3 of Steel Fibers [2].

RESEARCH METHODOLOGY AND MATERIALS

Study Area

The study area of this research was at Oromia regional state in Jimma town, south west Ethiopia which is located 346 Km by road southwest of Addis Ababa. Its geographical coordinates are between 7° 13'-8° 56N latitude and 35°49'-38°38'E longitude with an estimated area of 19,506.24. The experimental test for material as well as concrete was conducted at Jimma University Construction Material Laboratory.

Data requirement

For the experimental analysis of the beams, cubes and cylinders samples were made by the bagasse fiber reinforced lightweight high ductile (tensile strength) concrete, the available universal testing machines were used for evaluating of flexural strength, split tensile strength, and compressive strength.

Research design

This investigation was conducted with experimental works on construction material laboratory setting to determine the influence of sugarcane bagasse fiber on light weight concrete comparatively to normal weight concrete. In order to attain the relative output, it required quantitative approach of the research strategy to have appropriate range in amount of each material considering its quality. The explanation for preparing of the fiber by extracting from bagasse was followed by the descriptive method. And, experimental study was carried out to manipulate the independent variables, and justified for the sugarcane bagasse fibers effects on the lightweight and normal weight concrete in comparative approach. Finally, recommendation was raised based on the approaching experimental results.

Study Variables

Dependent Variable: lightweight high tensile strength concrete with sugarcane bagasse fiber

Independent Variables; Laboratory test results for sample beams, cubes and cylinders for,

- Workability
- Unit weight(density)
- flexural tensile strength
- split tensile strength
- compressive strength

Sampling Technique

The samples that required for this study were prepared in terms of the numbers of Beams, Cubes and Cylinders that used as a representative for the experiment and the numbers of production of LWHTSC with bagasse fiber.

The sampling technique for this research was a non-probability sampling technique which is the purposive method. For material laboratory test, the samples was depends on the types of test requirement and standards. And, size of sample of all aggregates in this study determined by using chute-type mechanical sample splitter method which is dividing of sample as described and beneath the blanket in even amount.

Fig-7: Reducing of fine and coarse aggregate sample using splitter

Based on type of concrete, which means Normal weight concrete(NWC) and Light weight concrete both reinforced by SBF with 25mm of average length, and 0% to1.5% by increasing 0.5% content of fiber in the concrete, the samples in three different specimens were casted for each 7th and 28th day test.

Table-7: Total sample size used

Samples Code	No. of samples for 7th day			No. of samples for 28th day			Total
	Beams	Cubes	Cylinders	Beams	Cubes	Cylinders	
N(0.0, 0.5, 1.0,1.5)	12	12	12	12	12	12	72
L(0.0, 0.5, 1.0, 1.5)	12	12	12	12	12	12	72
Total	24	24	24	24	24	24	144

Where; N stands for Normal weight concrete with 0.0%, 0.5%, 1.0%, and 1.5% of Sugarcane Bagasse Fiber, and L stands for Lightweight concrete with 0.0%, 0.5%, 1.0%, and 1.5% of Sugarcane Bagasse Fiber.

So, the researcher required totally of 48 samples of flexural beam, 48 samples of cube, and 48 samples of cylinder to caste for the reliable result obtained.

Sources of Data

This study focused in both primary and secondary data sources. The primary sources were from the results to be obtained from laboratory experimental works. While, secondary data required for this research was from the reviewed literatures which relates to topic of the study from different journals, book, web site etc.

Materials for this research

Generally, ordinary Portland cement, crushed aggregates, crushed scoria (light weight) aggregate, river sand, and sugarcane bagasse fiber are the materials those were used in this study.

- Cement: - Type of Cement to be used to produce light weight high tensile strength concrete was Dangote Ordinary Portland cement (OPC) whose Cement Grade 42.5R CEM I which is available in market.
- Crushed normal weight aggregate with maximum size of 25mm
- Crushed light weight (scoria) aggregate
- River Sand
- Water: - which is potable water i.e. used as Drinkable water
- Sugarcane bagasse fiber;- after extraction from bagasse

Sources of Materials:

- Cement- local market
- Crushed normal weight aggregate - local market which was produced at Agaro aggregate crushing plant site in Jimma zone.
- Crushed light weight (scoria) aggregate- available in local market around Woliso that sourced from nearby place locally called Qundrus.
- River Sand- from market in Jimma town originated from Worabe.
- Sugarcane bagasse fiber;- it was proposed to obtain it from Arjo Dediessa Sugar Factory, but it was not succeed due to its production in our country was seasonal (December to April per year), and the researcher oriented to extract it manually in local area of Jimma town.

Material properties

The properties of all materials included in this study in terms of description of the type of materials used and their properties that could affect the production of light weight high tensile strength concrete were determined prior to production.

Table-8: Property tests and test methods of material conducted in this study

Property Tests	Test Method
Sieve analysis(sand, crushed aggregate and scoria)	ASTM C136, C33
Unit weight (sand, crushed aggregate, and scoria)	ASTM C29
Silt content(fine aggregate)	ASTM C117
Bulking of sand	IS 2386
specific gravity and absorption (sand, crushed coarse aggregate, scoria)	ASTM C127
Moisture content (crushed coarse aggregate, and fine aggregate)	ASTM C 566

Ordinary Portland Cement, OPC

Dangote Ordinary Portland cement of grade 42.5R CEM I was used throughout this study in the preparation of the concrete mixes. Researcher was reviewed its physical properties from specification of manufacturer (See Table-9).

Table-9: Physical properties of Ordinary Portland Cement [46]

Fineness (passing 0.08mm sieve):	99.6 %
Initial setting time	170 min
Final setting time:	235 min
Compressive strength, MPa(3 days):	26.7
Bending strength, MPa(3 days):	4.9

And, researcher checked its initial and final setting time to be assured on the actual condition of the product in the market. Priorly, the amount of water required to prepare a standard cement paste was determined by using normal consistency test. Three trials were carried out with water to cement ratio of 26% to 33% until the proportional water for mix achieved for a paste that the rod of vicat apparatus settles 10±1 mm below the original surface within 30 seconds. As the result showed, 120 ml of water is preferable to make a standard paste with 0.30 value of water to cement ratio (See Appendix-1).

Both manual and automatic vicat apparatus were used to determine the setting time of Dangote OPC of Grade 42.5R CEM I according to ASTM C191 standards. The cement paste was prepared carefully by using 85% water that has given normal consistence. The time at which water was first added was taken, and the next time in minutes when the initial set needle penetrated the paste to a depth of 25mm below the upper edge of the ring that held the paste was recorded as initial setting time. Further, the researcher estimated the final setting time by using the equation;

Final setting time (in minutes) = 90+ 1.2*(initial setting time)……………………..Equation1
Based on result of experiment, the initial setting time and final setting time of Dangote OPC of Grade 42.5R CEM I were 137.5 min and 255 min respectively when manual vicat apparatus used. Meanwhile, 119.47 min and 233.37 min were obtained as initial setting time and final setting time respectively when automatic vicat apparatus used (See Appendix-1). Both results are nearest to the value pointed on the specification of manufacturer.

Fig-7: Checking the normal consistency, and setting time by using manual and automatic vicat apparatus

TEST ON AGGREGATE

Coarse aggregate(both normal weight and light weight)

It was essential to determine the bulk specific gravity, water absorption capacity (%), unit weight (kg/m3), moisture content, and fineness modulus of both normal weight and light weight coarse aggregates. The researcher was carried out this activity by using sieve analysis conforming to ASTM C136, C33, and other available apparatus. Based on the result recorded, both normal weight and lightweight aggregate meets their requirements according to ASTM standard.

Thus, excess amount of fines in coarse aggregates been removed by sieving through 4.75mm sieve to confirm as per requirements. And, fines which contain many impurities and could be results in strength loss in the concrete checked and departed. Accordingly, the following result in properties of coarse aggregate obtained.

Table-10: Physical properties of coarse aggregate

Aggregates	Unit weight(Kg/m^3)	Sieve analysis (Fineness Modulus)	Moisture content (%)	Bulk specific gravity	Bulk specific gravity(in SSD)	Apparent specific gravity	Absorption capacity of water (%)
Gravel	1,726	7.49	0.76	2.66	2.69	2.75	1.26
Scoria	844	7.39	6.4	1.51	1.78	2.10	18.30

Fine Aggregate

The fine aggregate used in this study was sourced from Worabe river basin. So, the researcher needed to focus on its silt content according to ASTM C117. As it carried out, the fine aggregate used for this study resulted 3.5% of the weight of sand, and bulking of sand yielded 25 in percentage. And, the other requirements of properties including Specific Gravity compacted density Fineness Modulus, and moisture content was carried out according to the test method of ASTM as follow:

Table-11: Physical properties of fine aggregate

Aggregates	Unit weight(Kg/m^3)	Sieve analysis (Fineness Modulus)	Moisture content (%)	Bulk specific gravity	Bulk specific gravity(in SSD)	Apparent specific gravity	Absorption capacity of water (%)
Sand	1,565	3.05	2.0	2.47	2.50	1.55	1.53

Water

Water is an important ingredient of concrete as it actively participates in chemical reactions with cement. Clean potable water conforming to IS 456 – 2000 was used for the preparation of concrete mixture which is fresh, odor less and tasteless, free from organic matter of any type.

Sugarcane bagasse fiber

Researcher reviewed related literatures from previous investigation about the properties of bagasse fiber, to determine its influence in production of concrete. So, the maximum mixing volume fraction of fibers in in this study was restricted to 1.5% with aspect ratio *l/df* of 113.6 in order to avoid the balling effect on concrete during mixing and its significant influence in workability of fresh concrete.

- Diameter = 100-340 µm, in average = $\frac{100+340}{2}$ = 220 µm
- Length =10- 40 mm, in average = $\frac{10+40}{2}$ = 25 mm

So, the aspect ratio = *l/df* = $\frac{25}{0.22}$ = 113.6

Extraction of bagasse fiber

The bagasse to extract the fiber for this research work was proposed to be obtained from Arjo Dediessa Sugar Factory, which is the residue left after separating of juice for production of sugar. But it was not succeed due to its production in our country was seasonal (December to April per year), and obliged to extract it manually in local area.

So, the researcher followed the steps below to derive the required sugarcane bagasse fiber.
Step 1: The solid sugarcane was collected from Jimma town, Mendera Koci peasant holders with consideration of its suitability and maturity to be used to extract fiber.
Step 2: The sugarcane stalk was crushed manually using locally available tools to extract sucrose, and to have enough volume of bagasse. During this process, the stalk was cut across the length so that the cut portions were free from the nodes.
Step 3: The fibers were then extracted from the bagasse easily. The residue left after the extraction of juice called bagasse was collected for extraction of fibers. The soft-core part pith was removed from the bagasse manually to get outer hard rind.
Step 4: The rind was then cut across the length to the require length using sharp knife to use it in concrete mix. The average length was 25 mm.
Step 5: The samples were then subjected to hot water treatments and been stay in hot water at around 90°C for 1hour in order to remove coloring matters and sugar traces. Finally, samples were then dried under the sunlight.

Fig-8: The method of extraction of fiber from sugarcane the researcher used

Hence, there was basic difference between extraction of fiber from bagasse produced by factory of sugar and locally prepared.

Based on observation of researcher to decomposed bagasse, and respond of interviewed technician at Arjo Didesa sugar factory during a time to obtain bagasse sample which was not succeed due to out of date of production, showed that:

- There are four steps in corresponding crushing mills that grains sugarcane stalks to extract juices, and the node of sugarcane also crushed without separation in the same way which varies it from the method that researcher used to extract it for this study.
- Through these phases of separating juices from bagasse, obviously there is high level of reduction

of sucrose from fiber even if the researcher treated the fiber in hot water for 1 hour to situate it.

- And also as it is observed, the bagasse output from sugar factory in Arjo was finer than the sample prepared manually in local area to extract fiber from it.

But, both of the method needs additional manual works to separate the fiber from piths or soft part of the bagasse.

Mixing proportion

There are different mix design methods based on cubical specimen compressive strength resistance such as, C-25, C-30 and C-40 in terms of capacity to hold a load of 25MPa, 30MPa and 40MPa respectively. Among, C-25 mix design was used in this study which has known first estimate mix proportion of 1:2:3 by the weight of ordinary Portland cement, river sand, coarse aggregate with water to cement ratio of 0.5. The adjustment for amount of fine aggregate taken by computing both mass and volume basis of proportioning method. And, the light weight aggregate incorporation was 50% of NWA to make light weight concrete. Addition of BSF was range from 0% to 1.5% increasing 0.5%.

And the researcher was followed American Concrete Institution method of mix design procedure to obtain the relevant mix proportion of both normal weight concrete and lightweight concrete reinforced with bagasse fiber, as it is recommended practice for selecting proportions of concrete and most widely used. So, ACI mix design primarily focuses on water/cement ratio taking concern of the maximum size and grading of the aggregates. The prerequisite for the application of the method is the determination of the specific gravity and absorption capacity of the aggregates to be used.

Based on experimental investigation on material properties, the researcher obtained the following results that conducted with request to mix proportion.

- Fineness modulus of selected fine aggregate = 3.05
- Unit weight of dry rodded coarse aggregates =1726kg/m^3
- Specific gravity of coarse and fine aggregate in saturated surface dry condition is 2.69 and 2.50 respectively
- Absorption characteristic of both coarse and fine aggregate is 1.26%and 1.53% respectively. Whereas free surface moisture in sand and coarse Aggregate 2.00% and 0.76% respectively
- Specific gravity of ordinary Portland cement (from specification of product) =3.15

The procedure to be followed in designing a concrete mix is detailed below:

Mix-1: For normal weight concrete

Step-1: Choice of Slump

The recommend slump for concretes consolidated by vibration was considered as 20 - 100mm and air content 2%.

Step-2: Choice of Maximum Size of Aggregate

Maximum size of coarse aggregate was 20mm.

Step-3: Estimation of Mixing Water and Air Content

The approximate mixing water required was selected from tables of ACI for desired workability and maximum size of aggregate was 200 kg/m3.

Step-4: Selection of Water/ Cement Ratio

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 0.6 for strength requirement of 25MPa concrete strength. The minimum amount of water-cement ratio taken was 0.5

Step-5: Calculation of Cement Content

The cement content was calculated from the water content and the water/cement ratio required for durability or strength.

Cement content $=\frac{200}{0.5} = 400$ Kg/m^3

Step-6: Estimation of Coarse Aggregate Content

From ACI for maximum size of 20mm coarse aggregate and fineness modulus of sand 3.05, the dry rodded bulk volume of coarse aggregate is 0.60 per unit volume of concrete.

The weight of coarse aggregate = 0.60 x 1726Kg/m3=1035.6 kg/m^3

Step-7: Estimation of Fine Aggregate Content

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

Weight of fine Aggregate =2355-(200+400+1035.6) = 719.4 Kg/m^3

Based on absolute volume considering the specific gravity of aggregates,

Item No	Ingredient	Weight (Kg/m^3)	Absolute volume
1	Cement	400	0.127
2	Water	200	0.2
3	Gravel	1035.6	0.385
4	Air		0.02
		Total	0.732

Therefore, absolute volume of fine aggregate =1-0.732= 0.268

Weight of fine aggregate =0.268 x 2.50 x 1000= 670.0 Kg/m^3

So, based on result from mass basis and volume basis for determining the weight of fine aggregate, the maximum value 719.4 Kg/m^3 was used. And the proportion of mix was:

Ingredients quantity	Cement	Sand	gravel	water
(kg/m^3)	400	719.4	1035.6	200
Ratio	1	1.8	2.6	0.5
One bag cement	50 Kg	90	130	25Kg

Step-8: Adjustments for Aggregate Moisture:

Fine aggregate has surface moisture of 2.00%.

Weight of fine aggregates = (719.4+0.02 x 719.4) Kg/m^3= 733.8Kg/m^3

Coarse aggregate has surface moisture of 0.76%

Weight of normal coarse aggregates = (1035.6+0.0076 x 1035.6) Kg/m^3 = 1043.47Kg/m3

Fine aggregate and Coarse aggregate absorbs 1.53% and 1.26% of water respectively.

Adjust the amount of water based on moisture content.

The required mixing water=200-719.4(0.02-0.0153)-1035.6(0.0076-0.0126) = 201.8Kg/m3

Step-9: Final design proportion

Ingredients quantity	Cement	sand	gravel	water
(kg/m3)	400	733.8	1043.47	201.8
Ratio	1	1.83	2.61	0.504
One bag cement	50 Kg	91.5	130.5	25.22

Amount of bagasse required;

Based on above mix proportion resulted for 1 m^3 mass density of concrete 400 Kg weight of cement used. And researcher uses 0.5%, 1.0%, 1.5% of bagasse fiber in terms of weight of cement:

- For 0.5%: $\frac{0.5}{100}\ x$ weight of cement = $\frac{0.5}{100}\ x\ 400$ = 2 Kg/m^3
- For 1.0%: 2 x 2 Kg/m^3 = 4 Kg/m^3
- For 1.5%: 3 x 2 Kg/m^3 = 6 Kg/m^3 used for both lightweight concrete and normal weight concrete.

Mix-2: For lightweight concrete

There is no definite method of mix design to determine the relative proportion of ingredients for replacement of lightweight aggregate in terms of normal weight aggregate to produce lightweight concrete. So, the researcher used the ACI mix design method that the same as detailed on above with some modification based on the properties of lightweight coarse aggregate (scoria).

Based on laboratory result, scoria has the following properties:

- Unit weight of scoria = 844 Kg/m^3
- Lightweight aggregate(Scoria) absorbs about 18.3%, and has surface moisture of 6.4 %
- The specific gravity and absorption of lightweight aggregate(Scoria) is 1.78 and 18.3% respectively
- According to ACI 211.2, average air entrained due to lightweight coarse aggregate is 6%. As the scoria replaces normal weight aggregate, the estimation for air content in mix is equals to 4%

Procedures

All the other steps (1-6) are the same to above way until computing the weight of fine aggregate in the absolute basis.

From ACI table for maximum size of 20mm coarse aggregate and fineness modulus of sand 3.05, the dry rodded bulk volume of coarse aggregate is 0.60 per unit volume of concrete.

The weight of lightweight coarse aggregate = 0.60*844Kg/m3=506.4 kg/m^3

Step-7: Estimation of Fine Aggregate Content: Due to volume basis, in case of 50% replacement of scoria to normal weight coarse aggregate

The weight of normal weight aggregate = 0.5*1035.6 =517.8 Kg/m^3

The weight of scoria = 506.4*0.5 = 253.2 Kg/m^3

Item No	Ingredient	Weight (Kg/m^3)	Absolute volume
1	Cement	400	0.127
2	Water	200	0.200
3	Gravel	517.8	0.1925
4	Scoria	253.2	0.142
5	Air		0.040
		Total	0.7015

Therefore, absolute volume of fine aggregate =1-0.7015 = 0.2985

Weight of fine aggregate =0.2985 x 2.50 x 1000= 746.25 Kg/m^3

Step-8: Adjustments for Aggregate Moisture:

- Fine aggregate has surface moisture of 2.00%.
- Weight of fine aggregates = (746.25+0.02 x 746.25) Kg/m^3= 761.175Kg/m^3
- Normal weight coarse aggregate has surface moisture of 0.76% and that of Scoria has 6.4 %
- Weight of normal weight coarse aggregates = (517.8+0.0076 x 517.8) Kg/m^3 = 521.735Kg/m^3
- Weight of lightweight coarse aggregates = (253.2+0.064 x 253.2) Kg/m^3 = 269.4 Kg/m^3
- Fine aggregate and Coarse aggregate absorbs 1.53% and 1.26% of water respectively. And lightweight aggregate absorbs about 18.3%.
- Adjust the amount of water based on moisture content
- The required mixing water = 200-746.25(0.02-0.0153) - 517.8 (0.0076-0.0126) – 253.2(0.064 -0.183) =229.21 Kg/m^3

Step-9: Final design proportion for lightweight concrete

Ingredients quantity		Cement	sand	gravel	scoria	water
(kg/m^3)		400	761.175	521.735	269.4	229.21
Ratio		1	1.903	1.304	0.673	0.573
One bag cement		50 Kg	95.15 Kg	65.2Kg	33.65Kg	28.65Kg

So, the researcher used the following summarized setup of mix proportion based on number and category of the mix;

Table-12: Summary of mix proportions for each mix

Mix no.	Mix ID	Water (Kg)	Cement(Kg)	Sand(Kg)	Gravel (Kg)	Scoria (Kg)	SBF (Kg)	W/C
1	N 0.0	25.22	50	91.5	130.5	-	0	0.5
2	N 0.5	25.22	50	91.5	130.5	-	0.25	0.5
3	N 1.0	25.22	50	91.5	130.5	-	0.5	0.5
4	N 1.5	25.22	50	91.5	130.5	-	0.75	0.5
5	L 0.0	28.65	50	95.15	65.2	33.65	0	0.5
6	L 0.5	28.65	50	95.15	65.2	33.65	0.25	0.5
7	L 1.0	28.65	50	95.15	65.2	33.65	0.5	0.5
8	L 1.5	28.65	50	95.15	65.2	33.65	0.75	0.5

Table-13: Description of the mixes

Mix no.	Mix ID	Description
1	N 0.0	Normal weight concrete without Sugarcane Bagasse Fiber
2	N 0.5	Normal weight concrete with 0.5 % Sugarcane Bagasse Fiber
3	N 1.0	Normal weight concrete with 1.0 % Sugarcane Bagasse Fiber
4	N 1.5	Normal weight concrete with 1.5 % Sugarcane Bagasse Fiber
5	L 0.0	Lightweight concrete without Sugarcane Bagasse Fiber
6	L 0.5	Lightweight concrete with 0.5 % Sugarcane Bagasse Fiber
7	L 1.0	Lightweight concrete with 1.0 % Sugarcane Bagasse Fiber
8	L 1.5	Lightweight concrete with 1.5 % Sugarcane Bagasse Fiber

Mixing and Casting of the concrete

The mixing procedure of concrete that the researcher followed for this investigation was the same to that of conventional concrete which using of cement mixer. Firstly, cement, sand, both normal and lightweight coarse aggregates, water, and the bagasse fiber was measured and prepared. Then, the mixer started running the drum pointing toward the sky at about 45^o above horizontal. Half of both sand and gravel measured and poured sequentially. After the small amount of water added, and the drum allowed to mix for two minutes. All the required amount of cement poured, and the remaining amount of sand and gravel followed to be mixed within allowed 2 minutes. Finally, considering the consistency of mix the remaining water added in some amount gradually. And when the mix been uniform, the steel plate moved in to position under drum to pour the concrete mix.

Fig-9: Mix setup using concrete mixer

After the mix properly prepared, all the moulds made of cast iron was used to prepare the specimens of size 150 x 150 x150 mm for cubes, 100 x 100 x 500mm beams and cylinders of 150mm diameter and 200mm long. During the placing of concrete in the moulds, the moulds were placed on the appropriate way and compacted properly. After 24 hours, the casted samples were removed from the moulds, and then date of casting and curing period were written on the concrete samples and immediately submerged in to water for curing purposes in the prepared curing tank. After 7^{th} and 28^{th} days of curing, the specimens taken out and tests were conducted using the cube crushing test, split tensile test, and the two-point bending test.

Test on Fresh Concrete (Workability)

Workability is the ease of freshly mixed concrete can be transport, place, compact and finish which can be controlled by the amount of water and mineral admixtures (water reducers). There are test methods that are used to determine the workability of concrete like slump cone test, flow table test, compaction factor test.

Slump Test

The Slump test is an empirical test that measures the workability of fresh concrete. It measures the consistency for specifically prepared fresh concrete batch. The slump test result shows a slump of the behavior of compacted inverted cone of concrete under the action of gravity.

The test was carried out using a mold known as a slump cone as per ASTM C- 143 specifications. The cone was filled with freshly prepared concrete in three stages; each time tamped 25 times using a rod of standard dimensions. At the end of the third stage, concrete was struck off flush at the top of the mold. The mold then carefully lifted vertically upwards, so as not to disturb the concrete cone. The concrete was subsided, and the subsidence is termed as slump, and it was measured from the top of the slump cone apparatus to the top of concrete.

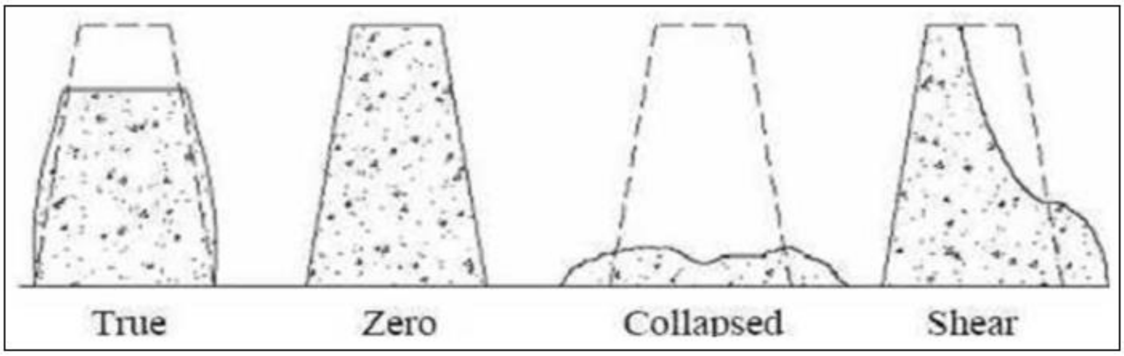

Fig-10: Different types of slump failure [47]

Fig-11: Measuring the workability using slump

Compaction factor test

Compaction factor test is the other method to measure the workability of concrete more accurately. It is better to check low workability which is below 25 mm slump when the slump test is less reliable. The test requires measurement of weight of partially and fully compacted weight to fully compacted weight according to B.S 1881: PART 2 1970, which is always less than one in value.

Fig-12: Measuring the workability using compaction factor apparatus

The apparatus of compaction factor test including two hoppers and cylinder was oiled on the inner surface to prevent

adhesion of mix. Then, mass of the empty cylinder was measured and recorded as M_1.

After fixing the base with in alignment at central point of the hopper, cylinder covered with steel floats. Using the hand scoop, the upper hopper gently and loosely filled with fresh mix of concrete. The trap door was then opened and the concrete released to the next hopper below. The float on cylinder removed and the trap door of second hopper opened immediately that the concrete to fall in to cylinder. When the concrete fell in to cylinder, the excess was removed by cutting off level from top of the cylinder using trowel. After outside of the cylinder swept and cleaned, the mass of cylinder with partially compacted concrete mix measured and recorded as M_2.

Finally empty cylinder filled with fresh concrete and was compacted by using hand ramming of each layer to obtain full compaction. The mass of cylinder with compacted concrete was measured and recorded as $\mathbf{M_3}$. Then, the compaction factor was calculated by the formula;

$$\text{Compaction factor} = \frac{weight\ of\ partially\ compacted\ concrete}{weight\ of\ fully\ compacted\ concrete} = \frac{M2-M1}{M3-M1} \ldots \text{Equation 2}$$

Test on hardened concrete

Standards to test concrete have varying method in different countries. The researcher was used the following standards of ASTM considering the availability of apparatus and test machine in concrete material laboratory of Jimma institute of technology.

Table-14: Standard Test Method for both hardened LWC and NWC reinforced by SBF

Property Tests	Standard Test Method
Unit weight	ASTM C 138M-17
Flexural tensile strength	ASTM C 078
Split tensile strength	ASTM C496M-17
Compressive strength	ASTM C 469/ ASTM C109M-16

Unit weight

Unit weight is the density of a specific unit of material which equals to the ratio of mass to the volume it will occupy. So, the density of light weight high tensile strength concrete was determined by measuring the mass of the cast per the volume of specimens in terms of cube. It varies depending on amount and weight of ingredients (basically coarse and fine aggregate), the amount of air entrained, degree of compaction else.

Fig-13: Measuring the mass of cube for determination of unit weight (density) of hardened concrete

$$\text{Density,} = \frac{\text{mass,m(kg)}}{\text{volume,v (m3)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 3}$$

Flexural tensile strength

Flexural tensile strength is performed to evaluate the maximum bending capacity of hardened concrete. It checks the ability of plain concrete beam to withstand failure in bending. It was applied in accordance to ASTM C 42. A sample of both normal weight and lightweight concrete beams of standard size of 100 x 100x 500mm was loaded at one third points from supports (see Fig-7). The results from the flexural strength test obtained in the form of the maximum load due to which a beam made for each fiber content batch mixed i.e. 0%, 0.5%, 1.0%, and 1.5% fiber amount failed under bending compression. Based on the mode of crack, there are different computation method to determine the modulus rapture under two-point loading. So, special care has been taken to ensure that the load was applied at the specified dimension.

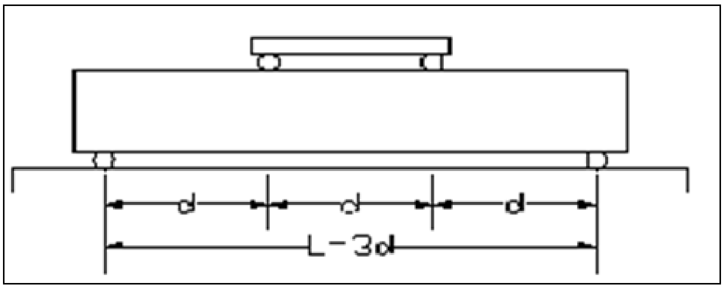

Fig-14: The two-point loading of a beam specimen for flexural strength test

Fig-15: Mode of failure occurred on beam with and without fiber

And, the flexural strength of concrete was calculated as;

a) If failure occurs in the middle third of the span;

$Ft = \frac{PL}{bd^2}$ …………………………………… Equation 4

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

$Ft = \frac{3PA}{bd^2}$ ……………………………Equation 5

Where,
P = the Maximum load, N
L = the span of the beam, mm
d = depth of the beam, mm
b = breadth of the beam, mm
A = the distance between line of fraction and the nearest support measured along the centerline of the bottom surface of beam.

Split Tensile Strength

The splitting tensile test was another method that researcher used to measure the tensile strength in concretes and therefore signifying the relative tensile stress of the fibers. The standard cylindrical concrete specimen placed horizontally between the loading surfaces of the Compression Testing. The compression load was then applied uniformly along the length of the cylinder the failure of the cylinder along the vertical diameter. Two bearing strips of nominal 3mm thick plywood, which is about 25mm wide and length slightly longer than the specimen was provided between the specimen and the loading surface that at upper and lower bearing blocks of the testing machine to ensure uniform distribution of the applied load and thus preventing high magnitude of compressive loads near the points of application. The maximum load at which failure occurred was recorded for the different concrete specimens made.

Fig-16: Cracks of cylinder occurred under horizontal loading

Hence, the split tensile strength of specimen recorded computed by using the following equation.

Split tensile strength, $Fct = \frac{2P}{\pi Ld}$……………………… Equation 6

Where,
P = the Maximum load, N
L = the length of line of contact of the cylinder, mm and
d = the diameter of the cylinder, mm.

Compressive Strength

Compressive strength of concrete is the capacity of concrete to withstand loads tending to reduce size until fractured or attained its limits. It is the stress obtained by ratio of force applied to the specific area of the sample which resists, and usually conducted experimentally by a means of compressive test using universal testing machine.

This test was carried out on the 150 x150 x 150mm cube specimen at the laboratory according to ASTM C 469. The casted specimens were tested by compression testing machine at 7^{th} and 28^{th} days of curing. They were taken out from curing tank and excess of water wiped off and then placed on the bearing surface of the compression machine with the smooth surface facing the front. The loads then applied gradually till the specimen failed and the maximum result was recorded.

Fig-17: Cracks of cube under loading

Hence, the compressive strength of specimen recorded computed by using the equation;

$$f c = \frac{P}{b*d} = \frac{P}{150*150}$$ ……………. Equation 7

Where,
fc = Compressive stress,
P = Failure Load, N
b = width of cube, mm and
d = depth of cube, mm

RESULTS AND DISCUSSIONS

This part of paper focuses on the discussion of experimental results obtained concerning the physical properties of material which used for this study. And, the effect of sugarcane bagasse fiber on unit weight, flexural and split tensile strength, and compressive strength of both normal weight and lightweight concrete was analyzed based on test results recorded with all consideration of objectives of the study.

Particle size distribution (Sieve analysis)

According to the result of experiment on the sieve analysis performed, the coarser size aggregate was fully passed sieve size 37.7 mm (1 ½ in) and retained on size of 4.75 mm (No. 4). The grading of coarse aggregate on each sieve, its upper and lower limit bounds are shown below in Fig-18.

Table-15: Sieve analysis of normal weight coarse aggregate (Gravel)

Sieve Size (mm)	Weight retained (Trial -1)	Weight retained (Trial -2)	Average Weight retained	% retained	Cumulative % retained	Cumulative % passing
37.5	0	0	0	0	0	100
*28	510	520	515	10.30	10.30	89.70
20	2080	2260	2170	43.40	53.70	46.30
*12.5	1780	1575	1677.5	33.55	87.25	12.75
9.5	455	465	460	9.20	96.45	3.55
4.75	165	175	170	3.40	99.85	0.15
2.36	10	5	7.5	0.15	100	
*Pan						

Table-16: Sieve analysis of lightweight coarse aggregate (Scoria)

Sieve Size (mm)	Weight retained	% retained	Cumulative % retained	Cumulative % passing
37.5	0	0	0	100
*28	830	16.60	16.60	83.4
20	1705	34.10	50.70	49.3
*12.5	1250	25.00	75.70	24.3
9.5	685	13.70	89.40	10.60
4.75	495	9.90	99.30	0.70
2.36	35	0.70	100	
*Pan				

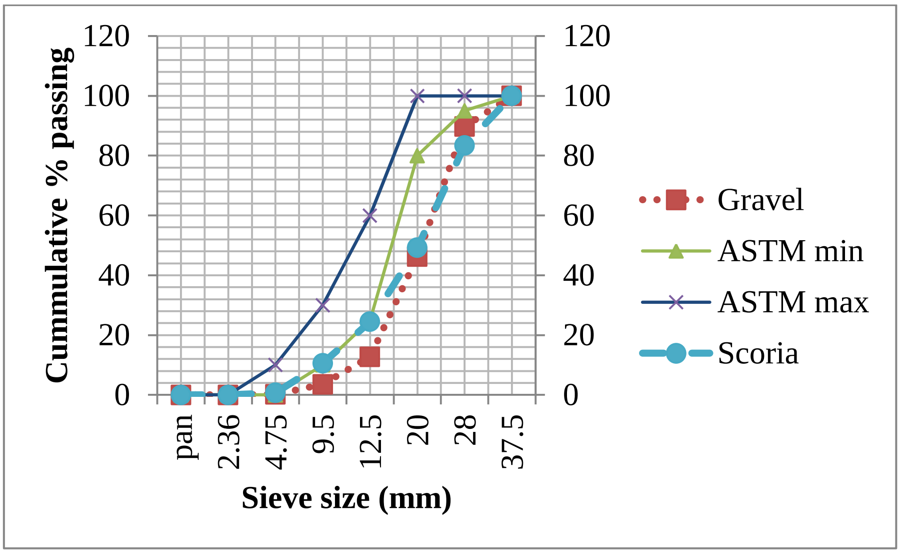

Fig-18: Particle distribution curve for coarse aggregates

The fine aggregate used in study entirely passed the 9.5mm and almost the 4.75mm sieve size which met the requirement of standard. According to ASTM C33 fine aggregates should have fineness modules between 2.3 and 3.1; the sand used has fineness modules of 3.05, this means it is all most within the ASTM limits and the cumulative percentage passes was within the interval as shown on Fig-19.

Table-17: Sieve analysis of fine aggregate (sand)

Sieve Size	Weight retained (Trial -1)	Weight retained (Trial -2)	Average Weight retained	% retained	Cumulative % retained	Cumulative % passing
*9.5mm	0	0	0	0	0	100
4.75mm	65	55	60	3	3	95.75
2.36mm	225	205	215	10.75	13.75	83.25
1.18mm	345	310	327.5	16.375	30.135	66.12
600μm	745	760	752.5	37.625	67.75	26
300μm	470	495	482.5	24.125	91.87	7.25
150μm	130	150	140	7.00	98.87	1.13
*Pan	20	25	22.5	1.13	100	0

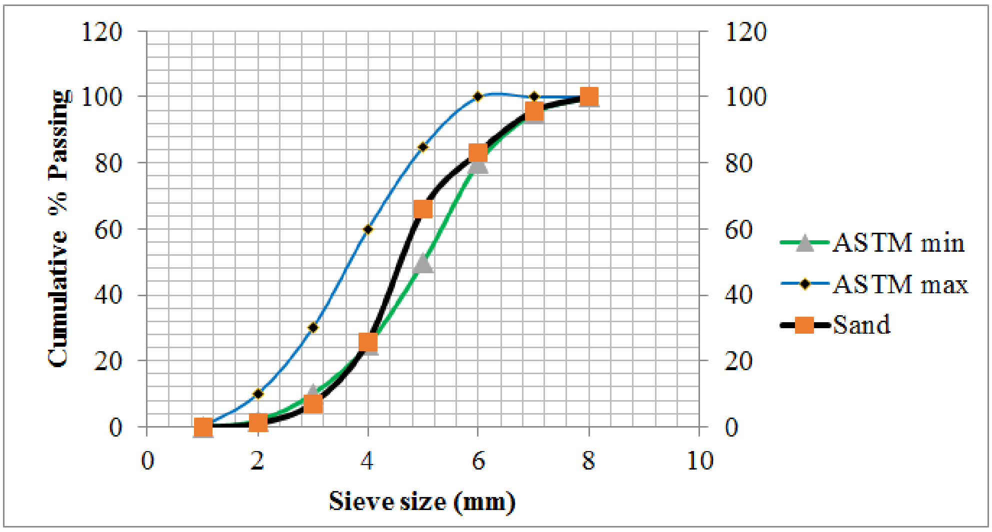

Fig-19: Particle distribution curve for fine aggregates

Workability test of fresh concrete

As explained in the methodology part, researcher used both slump tests and compaction factor test in order to configure the workability and consistency of fresh concrete.

Table-18: Results of slump, and compaction factor of fresh concrete

Sample Code	Slump (in Avg.)	variation with control	Compaction factor	variation of compaction factor from control value
N0.0	76.5	0.00	0.912	0.00
N0.5	66.5	-13.07	0.886	-2.85
N1.0	61	-20.26	0.847	-7.13
N1.5	57	-25.49	0.825	-9.54
L 0.0	41	-46.41	0.834	-8.55
L 0.5	24	-68.63	0.792	-13.16
L 1.0	20.5	-73.20	0.741	-18.75
L 1.5	16.5	-78.43	0.728	-20.18

Based on the result obtained, the slump of both normal weight and lightweight concrete decreased when the amount fiber increased in the mix. The control mix (mixes without fiber) met the estimated slump which is 76.5 mm for normal weight concrete and 41 mm for lightweight concrete. Due to adding of fiber it downs to 57mm for NWC and 16.5 mm for LWC (See Fig-20). The reason for decline of workability of the mix is absorption capacity of scoria in lightweight concrete and sugarcane bagasse fiber used.

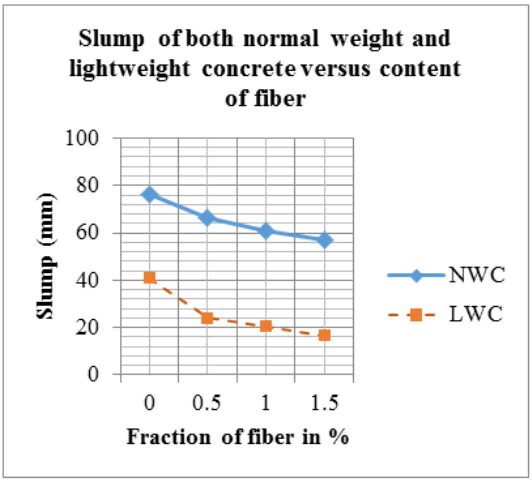

Fig-20: Slump versus amount of fiber

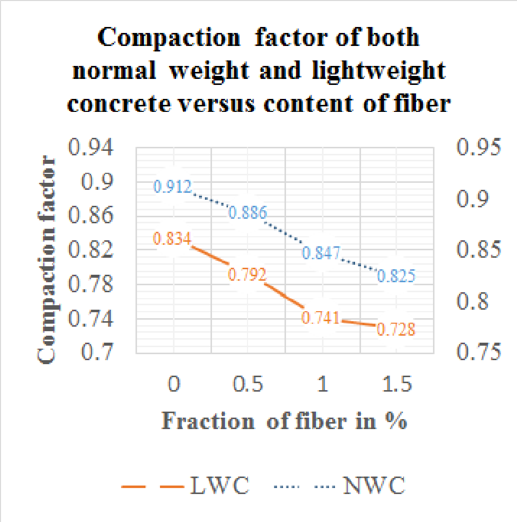

Fig-21: Compaction factor versus amount of fiber

As the result of variation of compaction factor of both concretes with respect to the control sample showed, workability of the fresh mix off influenced due to addition of bagasse fiber and incorporation of scoria as partial replacement of coarse aggregate to make light weight concrete else. The concrete outcome 0.912 of compaction factor, and decreased to 0.825 with variation of 9.54% when 1.5% of bagasse fiber added. This indicates the addition of bagasse fiber decreases the degree of workability of normal weight concrete mix from medium to low. Based on result obtained, lightweight fresh mix without bagasse marked 0.834 of compaction factor which has dry consistency. Meanwhile, very low degree of workability attained for a mix contain 50% of scoria aggregate with 1.5% of bagasse fiber.

Table-19: Limits of degree of workability and consistence

Degree of workability	Consistency	Slump (mm)	Compaction factor
Extremely very low	Moist earth	0	0.65 - 0.70
Very low	Very dry	0-25	0.7 – 0.8
Low	Dry	25-50	0.8 – 0.85
Medium	Plastic	50-100	0.85 – 0.95
High	Semi – fluid	100-175	0.95 – 1

Generally, as it was shown in compaction factor test, workability and consistency of fresh concrete decreases when the amount of fiber in mix increases.

Properties of hardened concrete

In this part, there are three types of tests carried out on 144 concrete samples which 72 samples are prepared for normal concrete and another 72 samples are prepared for lightweight concrete. Both of the samples were conducted flexural and split tensile strength, and compressive strength tests other than checking of the unit weight.

Unit weight (density) of hardened concrete

Due to this study, researcher obtained the mass of each specimens of concrete to compute the dry density of both NWC and LWC. But, typically cube was used to describe the result (see Table-19), and further density in terms of beams and cylinders are shown in Appendix-2.

Table-20: Unit weight of the samples in terms of cube specimen

Sample code	7th day					28th day				
	Weight of cube(Kg)				Dry density (Kg/m^3)	Weight of cube(Kg)				Dry density (Kg/m^3)
	1	2	3	Avg.		1	2	3	Avg.	
N0.0	8.34	8.28	8.17	8.26	2447.41	8.32	8.35	8.20	8.29	2456.00
N0.5	8.17	8.26	8.14	8.19	2425.68	8.22	8.22	8.33	8.26	2446.52
N1.0	8.41	8.38	8.28	8.35	2475.06	8.36	8.23	8.34	8.31	2463.11
N1.5	8.05	7.98	8.11	8.04	2382.72	8.40	8.36	8.38	8.38	2483.56
L 0.0	7.46	7.37	7.26	7.36	2181.23	7.47	7.39	7.36	7.41	2194.57
L 0.5	7.45	7.26	7.29	7.33	2171.85	7.35	7.31	7.30	7.32	2168.89
L 1.0	7.32	7.27	7.36	7.31	2166.91	7.25	7.32	7.28	7.28	2158.02
L 1.5	7.07	7.16	6.96	7.06	2091.36	7.24	7.28	7.26	7.26	2151.11

The density of sugarcane bagasse fiber reinforced normal weight concrete measured in this research indicates that there is variation on the density of concrete related with the increase in percentage of fiber. The maximum density achieved was 2475.06 Kg/m^3 for concrete with 1.0% of SBF after 7th day curing period and 2483.56 Kg/m^3 for concrete incorporated 1.5% of SBF at 28th day cure. While, the minimum density been 2382.72 Kg/m^3 for concrete with 1.5% SBF at 7th day and 2446.52 Kg/m3 for 0.5% SBF added concrete of 28th day curing period. Generally, the unit weight of NWC meets the requirement of ASTM standards practically, and additions of SBF vary the result not uniformly.

Meanwhile, the unit weight requirement for lightweight concrete according to ASTM shows it should be less than 1840 Kg/m^3, and the normal weight concrete should yields 2400 Kg/m^3. Based on plain (without fiber) LWC, the density was 2181.23 Kg/m^3 at 7th day and 2194.57 Kg/m^3 at 28 day curing age, which indicates it is Semi-Lightweight Concrete. And, due to increasing of amount of SBF the density of LWC decreases in both curing periods, And downs up to 2091.36 Kg/m^3 during 7th day and 2151.11 Kg/m^3 at 28th day curing for lightweight concrete with 1.5% of sugarcane bagasse fiber.

Flexural tensile strength of concrete

The results of flexural test on concrete expressed as a modulus of rupture which denotes as (MR) in MPa or psi. The flexural test on both normal weight and lightweight concrete conducted using the two points loading as it explained at methodology part. The result consists of the 7th day and 28th day for flexure test of both NWC and LWC with 0.0%, 0.5%, 1.0%, and 1.5% of sugarcane bagasse fiber as shown in Table-20.

Table-21: Flexural tensile strength of SBF reinforced concrete (both NWC and LWC)

Sample	Result of 7th day				Result of 28th day			
	Avg. Load (KN)	Modulus of Rapture (MPa)	Variation from control (%)	Standard deviation (σ)	Avg. Load (KN)	Modulus of Rapture (MPa)	Variation from control (%)	Standard deviation (σ)
N0.0	18.34	5.50	0.00	0.50	27.21	8.16	0.00	1.10
N0.5	21.42	6.43	16.83	2.05	27.93	8.38	2.62	1.46
N1.0	16.24	4.87	-11.42	0.54	25.11	7.53	-7.74	0.05
N1.5	13.31	3.99	-27.44	2.01	19.77	5.93	-27.34	2.62
L0.0	15.79	4.74	0.00	0.56	21.94	6.58	0.00	0.49
L0.5	18.49	5.55	17.09	1.91	24.37	7.31	11.11	1.71
L1.0	14.13	4.24	-10.51	0.27	21.56	6.47	-1.73	0.30
L1.5	10.24	3.07	-35.14	2.21	15.97	4.79	-27.19	2.49

The control sample of normal weight concrete containing 0.0% sugarcane recorded a reading of 5.50MPa tensile strength as shown in Fig-22. For samples containing 0.5% additive showed higher readings than the control sample that was 6.43 MPa for the curing 7 days. The sample containing 1.0% and 1.5% sugarcane bagasse fiber decreased in the strength in 11.42% and 27.44% variation to control respectively. For the 28-day flexural tensile the strength, the sample containing 0.5% sugarcane fiber showed an increase about 2.26% variation in tensile strength which was 8.38 MPa when compared to concrete without SBF that was 8.16 MPa. The concrete with 1.0% tended to lesser reading to 7.53 MPa, and that of concrete with 1.5% was the lower reading of flexural tensile strength for normal weight concrete which has 27.34% decreased variation value with respect to control. This indicates that the sample with 0.5% has reached a stage of maturity in giving more strength and it also possible to increase other properties of concrete like durability and cracking resistance towards concrete.

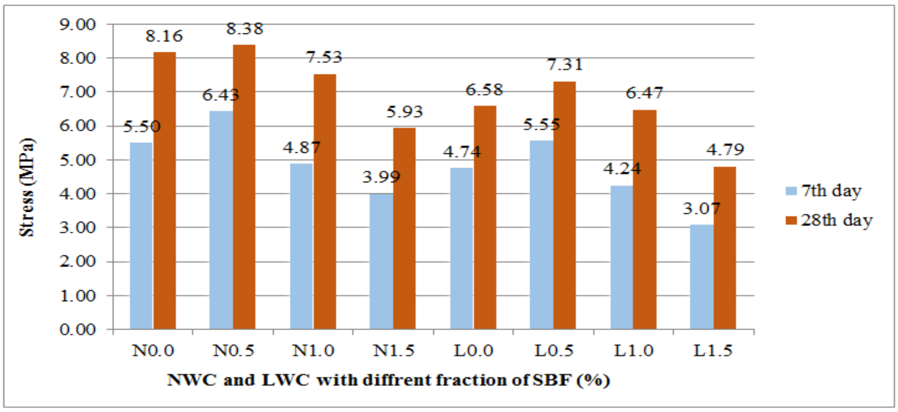

Fig-22: Flexural tensile strength of both NWC and LWC reinforced with SBF

Meanwhile, the lightweight concrete for control specimen was 4.74MPa. However, the 0.5% of addition of sugarcane bagasse gives maximum tensile strength at 7 days as compared to control, 1.0% and 1.5% addition of fiber sugarcane bagasse which was 5.55MPa that increased in 16.83% variation from control at 7^{th} day curing. Concrete with 1.0%, and 1.5% SBF decreased by the value of 4.24MPa and 3.07 MPa respectively. At 28 day a LWC without SBF was 6.58 MPa, and concrete with 0.5% increased to 7.31 MPa in 11.11% variation. But, the increase of fraction of fiber to 1.0% slightly decreased the strength to 6.47 MPa in 1.73% variation with respect to control concrete. And that of 1.5% SBF incorporated concrete reduced to 4.79MPa. Incorporating of sugarcane bagasse fiber tends to reduce the tensile strength. A decreased of tensile is observed with the increase of fiber proportion of the concrete for 28 days.

The fiber properties control the strength behavior of concrete that contains fibers. Fibers with higher tensile strength transfer more tensile stress from a cracked zone to the fibers. The tensile strength of fiber used in this research work is significant to create bridge stress between fiber and concrete matrix during tensile test.

Split tensile strength of concrete

It is the well-known indirect test, in which compressive line load is applied along the opposite generators with the cylinder axis being horizontal between the compression platens. Due to compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter. The result of each samples of NWC and LWC with varying percentage of sugarcane bagasse fiber are shown in Table-21.

Table-22: Result of split tensile strength of both NWC and LWC with varying percentage of SBF

Sample	7th day				28th day			
	Avg. Load (KN)	Avg. Stress (MPa)	Variation from control (%)	Standard deviation (σ)	Avg. Load (KN)	Avg. Stress (MPa)	Variation from control (%)	Standard deviation (σ)
N0.0	83.33	2.65	0.00	1.21	124.87	3.97	0.00	5.51
N0.5	91.77	2.92	10.12	5.42	126.87	4.04	1.60	6.51
N1.0	80.00	2.55	-4.00	0.46	106.47	3.39	-14.74	3.69
N1.5	68.67	2.19	-17.60	6.13	97.20	3.09	-22.16	8.33
L0.0	66.00	2.10	0.00	1.58	84.33	2.68	0.00	1.58
L0.5	69.33	2.21	5.05	3.25	88.00	2.80	4.35	3.42
L1.0	61.67	1.96	-6.57	0.58	76.67	2.44	-9.09	2.25
L1.5	54.33	1.73	-17.68	4.25	75.67	2.41	-10.28	2.75

For normal weight concrete containing 0% SBF resulted of 2.65MPa split tensile strength as shown in Fig-23. Among the samples, concrete containing 0.5% additive showed increased readings than the control sample in 10.12% variation that was 6.43 MPa at 7 days age. The concrete containing 1.0% sugarcane bagasse fiber decreased slightly to 2.55 MPa, and 2.19MPa was recorded for normal weight concrete with 1.5% of SBF. The split tensile strength at 28^{th} day curing period for plain concrete recorded 3.97 MPa. The sample containing 0.5% of SBF increased value in 1.60% variations in terms of control in tensile strength which was 4.04 MPa. But, concrete with 1.0% decreased the reading to 3.39 MPa, and that of concrete with 1.5% was the lower reading of split tensile strength for normal weight concrete which was 3.09 MPa.

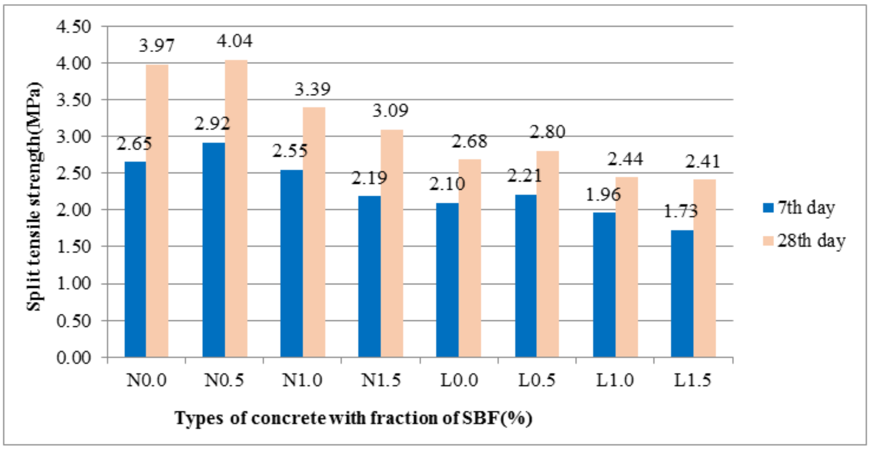

Fig-23: The split tensile strength of both NWC and LWC with varying of SBF

Meanwhile, the 7th day split tensile strength of lightweight concrete for control specimen was 2.10MPa. However, the 0.5% of addition of sugarcane bagasse recorded high tensile strength at 7 days as compared to control, 1.0% and 1.5% addition of fiber sugarcane bagasse which was 2.21MPa that increased in 5.05% variation from control at 7th day curing. Concrete with 1.0%, and 1.5% SBF lowered to the value of 1.96MPa and 1.73 MPa respectively. The split tensile strength at 28 day a LWC with 0.0% SBF was 2.68 MPa, and concrete with 0.5% increased to 2.80MPa in 4.35% variation with regard to control sample. Further, the increase of fiber to 1.0% decreased the strength to 2.44 MPa in 9.09% variation with respect to control concrete. And that of 1.5% SBF incorporated concrete reduced to 2.41MPa.

Generally, the result indicates that the incorporation of 0.5% of sugarcane bagasse fiber in both NWC and LWC increases the tensile strength in either of 7th and 28th day age of concrete when compared to concrete without SBF. And, the SBF in 0.5% fraction influences better of lightweight concrete at 28 days. Contrarily, the increase of such fiber beyond 0.5% decreases the tensile strength in both concrete which aged 7 and 28 days.

Compressive strength of concrete

The composite material, such as natural (organic) vegetable fiber in concrete tends to have less compressive strength and higher tensile strength.

So, the result recorded in this study in terms of cube specimens for both 7th and 28th day curing period of NWC and LWC with incorporation of SBF in different fraction as shown in Table-22.

Table-23: Result of compressive strength of both NWC and LWC with varying percentage of SBF

Sample code	Result of 7th day				Result of 28th day			
	Avg. Load (KN)	Avg. Stress (MPa)	Variation from control (%)	Standard deviation (σ)	Avg. Load (KN)	Avg. Stress (MPa)	Variation from control (%)	Standard deviation (σ)
N0.0	641.40	28.51	0.00	3.39	775.17	34.45	0.00	1.97
N0.5	527.09	23.43	-17.83	0.85	726.58	32.29	-6.25	0.90
N1.0	454.65	20.21	-29.13	0.76	685.96	30.49	-11.49	0.01
N1.5	332.39	14.77	-48.18	3.48	556.95	24.75	-28.14	2.87
L0.0	403.17	17.92	0.00	1.28	514.17	22.86	0.00	1.66
L0.5	391.65	17.41	-2.85	1.02	502.73	22.34	-2.27	1.40
L1.0	310.50	13.80	-22.98	0.78	384.39	17.08	-25.28	1.23
L1.5	277.07	12.31	-31.27	1.52	356.78	15.86	-30.65	1.84

According to Fig-24 on the 7 day result of normal weight concrete, control sample of containing 0% sugarcane recorded a reading of 28.51MPa compressive strength. Samples containing 0.5%, 1.0% and 1.5% additive of SBF showed lesser reading compared to concrete without SBF at 7 days. The sample containing 0.5% of sugarcane fiber representing 23.43 MPa, and 1.0% sugarcane reinforced NWC decreased to 20.12 MPa. Sample containing 1.5% sugarcane representing has lowest compressive strength for 7 days curing that was 14.77 MPa. Meanwhile, compressive strength of concrete for curing period of 28 days after the cube was produced. Based on the figure, the sample containing 0.0% sugarcane fiber recorded a reading of compressive strength is 34.45 MPa. For samples containing 0.5% additive showed compressive strength 32.29 MPa meanwhile sample containing 1.0% recorded compressive strength 30.49 MPa. For sample 1.5% additive recorded the lowest compressive strength of concrete for samples 28 days that is 24.75 MPa that has 28.14% variation from control sample. As it is explained in literature part, the lower compressive strength of fibrous mixtures might be attributed to the presence of fiber bundle (high percentage of fiber) during mixing. These might attributed the voids due to the addition of high percentage of fiber and the existence of a weak interfacial bonds among the fiber and concrete matrix.

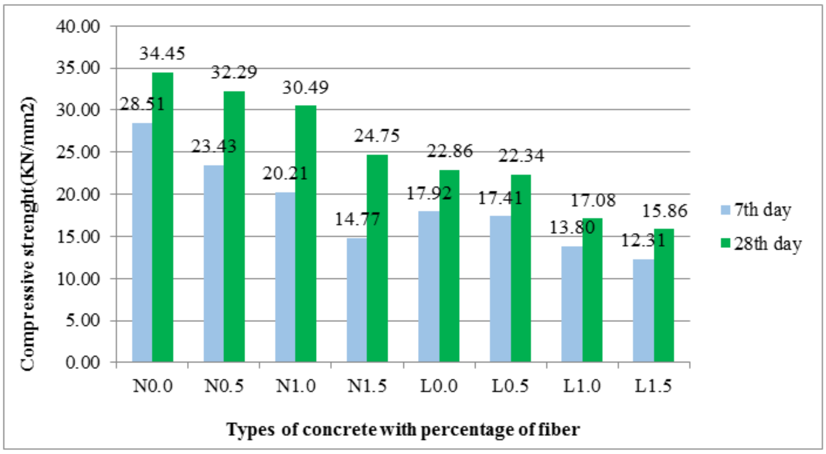

Fig-24: Compressive Strength of Concrete with Sugarcane Fiber

As the result of compression test of lightweight concrete, the control sample that containing 0% of sugarcane bagasse was 17.92MPa at 7 day age. Samples containing 0.5% bagasse slightly decreased about 2.85% variation in compressive strength with respect to control which was 17.41MPa. Meanwhile, the value of compressive strength for samples containing 1.0% and 1.5% recorded decline values compared to sample control which were 13.80MPa and 12.31MPa after curing 7 days.

Meanwhile, the result compressive strength of the light weight concrete for 28 days, the control sample obtained value 22.86MPa. The sample containing 0.5% sugarcane bagasse recorded reduced slightly in 2.27% variation of control which is 22.34MPa. And, the samples containing 1.5% sugarcane bagasse showed the lowest value which is 15.86MPa.

Correlation of compressive strength versus tensile strength of concrete

Based on test result of experiment of this study, sugarcane bagasse fiber has little impact on the compressive strength of either of normal weight concrete and lightweight concrete. Thus, increase of fiber inversely decreased the compressive strength of concrete. This might be due to the organic nature and bundle of bagasse to have good matrix bond with cementing material. However, the flexural and split tensile strength of concrete were increased at 0.5% SBF and decreased after certain addition of fiber.

Correlation of compressive strength versus flexural tensile strength due to using of bagasse fiber in concrete;

As it mentioned above, the variation of strengths to control sample, at 7th day age declination of both compressive and flexural tensile strength of normal weight concrete after increment of fiber from 0.5% to 1.0% and 1.5% was simultaneous.

As the researcher checked their linear relationship (Pearson), the correlation of compressive strength with respect to flexural tensile strength at 7th day curing period of concrete resulted r= 0.7786. This indicates the moderate to strong positive linear relationship between the compressive strength and flexural tensile strength. In the same way, r valued 0.8465 for a linear relation of the variables at 28th day, which indicates there is also a moderate to strong positive linear relation between compressive and flexural tensile strength of concrete when bagasse fiber incorporated.

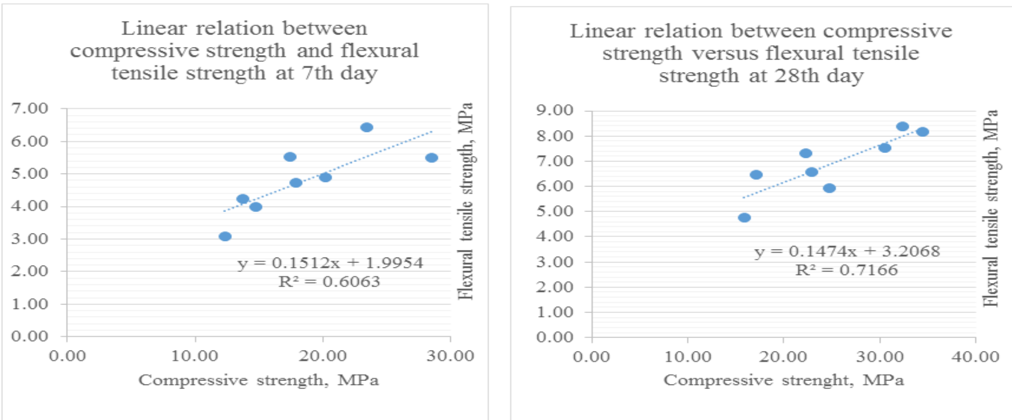

Fig-25: Linear relation between compressive strength and flexural tensile strength bagasse reinforced concrete at 7th and 28th curing period

Correlation of compressive strength versus split tensile strength due to using of bagasse fiber in concrete;

From Fig-26, the points fell close to the line which shows the addition of bagasse by increasing the fraction beyond 0.5% increases the reduction of split tensile strength strongly the same to that of compressive strength of concrete. The Pearson r is 0.8662 and 0.9657 for the correlation between compressive and split tensile strengths of the concrete at 7th and 28th day respectively. This indicates there is a strong linear relationship between the compressive strength and split tensile strength of concrete due to addition of bagasse fiber which implies that when the compressive strength decreases due to addition of sugarcane bagasse fiber, the split tensile strength also decreases.

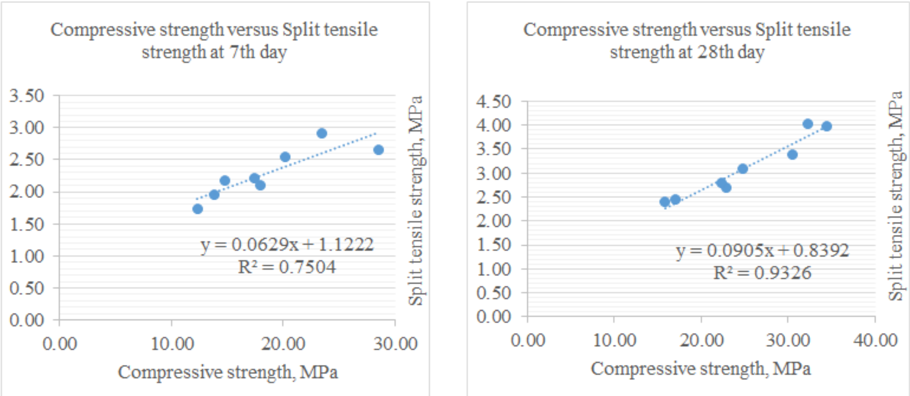

Fig-26: Linear relation between compressive strength and split tensile strength bagasse reinforced concrete at 7th and 28th day curing period.

Appendix-1: Laboratory test results of material physical properties

1. Normal consistency and Setting time of cement

a. Normal consistency test

Sample of cement = 400gm

Trial-1
Weight of cement taken(C) =400 gm.
Weight of water for desired penetration (W) = 120 ml
Initial reading = 107 mm
Final reading (after 30 sec) = 116 mm
Normal consistency depth = 116-107 = 9 mm

Trial-2
Weight of cement taken(C) =400 gm.
Weight of water for desired penetration (W) = 132 ml
Initial reading = 111 mm
Final reading (after 30 sec) = 122mm
Normal consistency depth = 111-122= 11 mm

Recording of observation

Trial	Weight of cement , C(g)	Quantity of water added, W(ml)	W/C ratio	Penetration depth(mm)
1	400	120	0.3	9
2	400	132	0.33	11

P1 = (W/C) * 100 = 0.3*100 = 30, 26<30<33 Ok!
P2 = 0.33 * 100 = 33

So, it is better to use 85% of 120 ml to determine setting time of this cement.

b. Setting time test of Dangote OPC grade 42.5R CEM I

Sample of cement is 300 gm.

Using manual Vicat apparatus

Weight of cement used = 300 gm.
Amount of water used = 0.85*120 = 102 ml
T1 = 3:25 am (just water reacted with cement)
T2 = 5:25 am (at 27 mm penetration)

Vicat time of setting = $[\left(\frac{H-E}{C-D}\right) * (C-25)] + E$
Time in minutes of last penetration (E) = 120
Time in minutes of first penetration (E) = 15

Penetration reading at time (C) = 27 mm
Penetration reading at time (D) = 39 mm

Vicat time of setting; = $[\left(\frac{15-120}{C27-39}\right) * (27-25)] + 120$ = 137.5 min

Final setting time estimated as;
Final setting time (in minutes) = 90 +1.2(Initial setting time = 90 +1.2*(137.5) = 255 min

Using automatic Vicat apparatus
Weight of cement used = 300 gm.
Amount of water used = 0.85*120 = 102 ml
Time in minutes of last penetration (E) = 140
Time in minutes of first penetration (E) = 10
Penetration reading at time (C) = 22.3 mm
Penetration reading at time (D) = 39.4 mm

Vicat time of setting = $[\left(\frac{10-140}{22.3-39.4}\right) * (22.3-25)] + 140$ = 119.47 min

Final setting time estimated as;
Final setting time (in minutes) = 90 +1.2(Initial setting time) = 90 +1.2*(119.47) = 233.37 min

2. Unit weight of aggregates
a. Fine aggregate(sand)
Weight of sample with object (A) = 8.885 Kg
Weight of object (B) = 1.06Kg
Volume of Object (C) = 0.005 m3
Unit weight of sand= $\frac{A-B}{C} = \frac{8.885-1.06}{0.005}$ = 1,565 Kg/m3

b. Coarse aggregate
Weight of sample with object (A) = 18.955 Kg
Weight of object (B) = 1.69Kg
Volume of Object (C) = 0.01 m3

Unit weight of coarse aggregate = $\frac{A-B}{C} = \frac{18.955-1.69}{0.01}$= 1726 Kg/m3

c. Lightweight coarse aggregate(scoria)
Weight of sample with object (A) = 10.130 Kg
Weight of object (B) = 1.69Kg
Volume of Object (C) = 0.01 m3

Unit weight of scoria = $\frac{A-B}{C} = \frac{10.130-1.69}{0.01}$ = 844 Kg/m3

3. Silt content of sand
Weight of sample with silt (A) = 1000 gm.
Weight of clean sample after washed by water (B) = 965 gm.
Silt content = $\frac{A-B}{A} = \frac{1000-965}{1000}$ = 3.5%

4. Moisture content of aggregates
a. Fine aggregate(sand)
Weight of original sample = 500 gm.
Weight of oven-dry sample= 490 gm.
% of moisture content=$\frac{500-490}{490}$ x100 = 2%

b. Coarse aggregate
Weight of original sample= 2000 gm.
Weight of oven-dry sample= 1985 gm.

% of moisture content= $\frac{2000-1985}{1985}$ x100 = 0.76%

c. Lightweight coarse aggregate(scoria)
Weight of original sample= 2000 gm.
Weight of oven-dry sample= 1880 gm.
% of moisture content= $\frac{2000-1880}{1880}$ x100 = 6.4%

5. Bulking of sand
Sample size = 500 ml
V1 = Damp/moist sand taken = 0.75x500ml = 375 ml
V2 = fully saturated volume of sand = 300 ml
% Bulking = $\frac{V1-V2}{V2}$ x100 = $\frac{375-300}{300}$ x100 = 25%
Bulking factor= $\frac{V1}{V2}=\frac{375}{300}$ = 1.25

6. Sieve Analysis of Aggregate
a. Sieve analysis of fine aggregate
Sample size = 2000 gm.

Sieve Size	Weight retained (Trial -1)	Weight retained (Trial -2)	Average Weight retained	% retained	Cumulative % retained	Cumulative % passing
*9.5mm	0	0	0	0	0	100
4.75mm	65	55	60	3	3	95.75
2.36mm	225	205	215	10.75	13.75	83.25
1.18mm	345	310	327.5	16.375	30.135	66.12
600µm	745	760	752.5	37.625	67.75	26
300µm	470	495	482.5	24.125	91.87	7.25
150µm	130	150	140	7.00	98.87	1.13
*Pan	20	25	22.5	1.13	100	0
Total	2000	2000	2000	100	305.2	

Fineness modulus = $\frac{305.2}{100}$ = 3.05

b. Sieve analysis of coarse aggregate
Sample size = 5000 gm.

Sieve Size	Weight retained (Trial -1)	Weight retained (Trial -2)	Average Weight retained	% retained	Cumulative % retained	Cumulative % passing
37.5 mm	0	0	0	0	0	100
*28 mm	510	520	515	10.30	10.30	89.70
20 mm	2080	2260	2170	43.40	53.70	46.30
*12.5 mm	1780	1575	1677.5	33.55	87.25	12.75
9.5mm	455	465	460	9.20	96.45	3.55
4.75mm	165	175	170	3.40	99.85	0.15
2.36mm	10	5	7.5	0.15	100	
1.18mm	0	0	0	0	100	
600µm	0	0	0	0	100	
300µm	0	0	0	0	100	
150µm	0	0	0	0	100	
*Pan	0	0	0	0	100	
Total	5000	5000	5000	100	749.3	

Fineness modulus of coarse aggregate, FM = $\frac{749.3}{100}$ = 7.49

c. Sieve analysis of lightweight coarse aggregate(scoria)
Sample size = 5000 gm.

Sieve Size	Weight retained	% retained	Cumulative % retained	Cumulative % passing
37.5 mm	0	0	0	100
*28 mm	830	16.60	16.60	83.4
20mm	1705	34.10	50.70	49.3
*12.5 mm	1250	25.00	75.70	24.5
9.5mm	530	10.60	86.30	13.70
4.75mm	685	13.70	100	
2.36mm	0	0	100	
1.18mm	0	0	100	
600µm	0	0	100	
300µm	0	0	100	
150µm	0	0	100	
*Pan	0	0	100	
Total	5000	100	753.6	

Fineness modulus of Scoria, FM $=\frac{753.3}{100}$ = 7.53

7. Specific Gravity and Water absorption capacity of fine aggregate

Sample-1

A=Weight of oven-dry sample in air = 0.495 Kg

B = weight of pycnometer filled with water = 1.555 Kg

C = weight of pycnometer with sample and water to calibration mark = 1.860 Kg

- Bulk specific gravity = A/(B+500-C) = $\frac{495}{1555+500-1860} = 2.54$
- Bulk specific gravity (Saturated Surface Dry basis) = 500/(B+500-C) $= \frac{500}{1555+500-1860} = 2.56$
- Apparent specific gravity = A/(B+A-C) = $\frac{495}{1555+495-1860} = 2.60$
- Absorption capacity of fine aggregate= $\frac{500-A}{A} x\ 100 \quad = \frac{500-495}{495} x\ 100 = 1.01\ \%$

Sample-2

A=Weight of oven-dry sample in air = 0.490 Kg

B = weight of pycnometer filled with water = 1.555 Kg

C = weight of pycnometer with sample and water to calibration mark = 1.850 Kg

- Bulk specific gravity = A/(B+500-C) = $\frac{490}{1555+500-1850} = 2.39$
- Bulk specific gravity (Saturated Surface Dry basis) = 500/(B+500-C) $= \frac{500}{1555+500-1850} = 2.44$
- Apparent specific gravity = A/(B+A-C) = $\frac{490}{1555+490-1850} = 2.51$
- Absorption capacity of fine aggregate= $\frac{500-A}{A} x\ 100 = \frac{500-490}{490} x\ 100 = 2.04\ \%$

Average result of Specific Gravity and Water absorption capacity of fine aggregate

- Bulk specific gravity = $\frac{2.54+2.39}{2}$ = 2.47
- Bulk specific gravity (Saturated Surface Dry basis) = $\frac{2.56+2.44}{2}$ = 2.50
- Apparent specific gravity = $\frac{2.60+2.51}{2}$ = 2.55
- Absorption capacity of fine aggregate= $\frac{1.01+2.04}{2}$ = 1.53%

8. Specific Gravity and Water absorption capacity of coarse aggregate

a. Normal weight coarse aggregate

A=Weight of oven-dry sample in air = 1.980 Kg

B= Weight of saturated surface dry sample = 2.005 Kg

C = weight of saturated sample in water = 1.260 Kg (soaking weight with basket deduct weight of basket)

- Bulk specific gravity = A/(B-C) = $\frac{1980}{2005-1.260} = 2.66$
- Bulk specific gravity (Saturated Surface Dry basis) = B/(B-C) = $\frac{2005}{2005-1260} = 2.69$

- Apparent specific gravity = A/(A-C) = $\frac{1980}{1980-1260} = 2.75$
- Absorption capacity of fine aggregate= $\frac{B-A}{A} x\ 100 = \frac{2005-1980}{1980} x\ 100 = 1.26\ \%$

b. Light weight coarse aggregate (Scoria)
A=Weight of oven-dry sample in air = 1.885 Kg
B= Weight of saturated surface dry sample = 2.230 Kg
C = weight of saturated sample in water = 0.980 Kg (soaking weight with basket deduct weight of basket)

- Bulk specific gravity = A/(B-C) = $\frac{1885}{2230-980} = 1.51$
- Bulk specific gravity (Saturated Surface Dry basis) = B/(B-C) = $\frac{2230}{2230-980} = 1.78$
- Apparent specific gravity = A/(A-C) = $\frac{1885}{1885-980} = 2.10$
- Absorption capacity of fine aggregate= $\frac{B-A}{A} x\ 100 = \frac{2230-1885}{1885} x\ 100 = 18.3\ \%$

Appendix-2: Experimental result of Physical and Mechanical properties of concrete

1. Unit weight of concrete

a. In terms of cube specimen

Sample code	7th day mass of cube				dry density
	s1	s2	s3	average	
N0.0	8.34	8.28	8.17	8.26	2447.41
N0.5	8.17	8.26	8.14	8.19	2425.68
N1.0	8.41	8.38	8.28	8.35	2475.06
N1.5	8.05	7.98	8.11	8.04	2382.72
L0.0	7.46	7.37	7.26	7.36	2181.23
L0.5	7.45	7.26	7.29	7.33	2171.85
L1.0	7.32	7.27	7.36	7.31	2166.91
N0.0	7.07	7.16	6.96	7.06	2091.36

Sample code	28th day mass of cube				dry density
	s1	s2	s3	average	
N0.0	8.32	8.35	8.20	8.29	2456.00
N0.5	8.22	8.22	8.33	8.26	2446.52
N1.0	8.36	8.23	8.34	8.31	2463.11
N1.5	8.40	8.36	8.38	8.38	2483.56
L0.0	7.47	7.39	7.36	7.41	2194.57
L0.5	7.35	7.31	7.30	7.32	2168.89
L1.0	7.25	7.32	7.28	7.28	2158.02
N0.0	7.24	7.28	7.26	7.26	2151.11

b. In terms of beam specimen

Sample code	7th day mass of beam				dry density
	s1	s2	s3	average	
N0.0	13.34	12.24	11.85	12.48	2495.33
N0.5	12.65	12.25	12.76	12.55	2509.73
N1.0	11.67	11.66	11.81	11.71	2342.73
N1.5	12.22	11.96	11.86	12.01	2402.93
L0.0	11.10	11.18	11.10	11.13	2225.00
L0.5	10.64	10.50	10.81	10.65	2130.00
L1.0	10.55	10.34	10.42	10.43	2086.60
N0.0	10.86	10.61	10.51	10.66	2131.87

Sample code	28th day mass of beam specimen				dry density
	s1	s2	s3	average	
N0.0	12.45	12.74	12.85	12.68	2535.80
N0.5	12.42	12.18	12.65	12.42	2483.31
N1.0	12.25	13.40	12.09	12.58	2516.27
N1.5	13.26	12.11	12.47	12.61	2522.28
L0.0	11.51	11.46	11.29	11.42	2283.57
L0.5	10.58	10.73	11.04	10.79	2157.16
L1.0	11.28	10.80	10.97	11.02	2203.08
N0.0	11.34	10.73	10.60	10.89	2178.17

c. In term of cylinder specimen

Sample code	7th day mass of cylinder				dry density
	s1	s2	s3	average	
N0.0	3.99	3.97	3.92	3.96	2423.33
N0.5	3.99	4.14	3.84	3.99	2441.70
N1.0	3.89	3.86	4.06	3.94	2409.04
N1.5	4.03	4.07	3.98	4.02	2463.12
L0.0	3.53	3.35	3.46	3.45	2109.06
L0.5	3.65	3.47	3.41	3.51	2146.81
L1.0	3.47	3.38	3.38	3.41	2085.59
N0.0	3.30	3.41	3.30	3.33	2040.70

Sample code	28th day mass of cylinder				dry density
	s1	s2	s3	average	
N0.0	4.11	3.92	3.93	3.99	2441.08
N0.5	3.87	4.03	3.91	3.93	2408.64
N1.0	4.04	3.97	3.98	4.00	2445.98
N1.5	3.99	4.03	3.91	3.98	2434.55
L0.0	3.38	3.53	3.44	3.45	2112.94
L0.5	3.52	3.37	3.56	3.49	2133.75
L1.0	3.42	3.48	3.40	3.43	2102.33
N0.0	3.41	3.51	3.54	3.49	2135.18

2. Flexural tensile strength

Sample code	Result of 7th days flexural tensile strength test						
	S-1	S-2	S-3	Avg peak load (kN)	Avg. Stress(MPa)	Variation from control (%)	Standard deviation (σ)
N0.0	17.82	18.74	18.45	18.34	5.50	0.00	0.50
N0.5	22.22	22.23	19.82	21.42	6.43	16.83	2.05
N1.0	15.17	17.34	16.22	16.24	4.87	-11.42	0.54
N1.5	12.625	13.07	14.23	13.31	3.99	-27.44	2.01
L0.0	15.27	16.48	15.63	15.79	4.74	0.00	0.56
L0.5	18.325	18.75	18.4	18.49	5.55	17.09	1.91
L1.0	14.835	14.19	13.38	14.13	4.24	-10.51	0.27
L1.5	9.345	10.97	10.42	10.24	3.07	-35.14	2.21

Sample code	Result of 28th days flexural tensile strength test						
	S-1	S-2	S-3	Avg peak load (kN)	Avg. Stress(MPa)	Variation from control (%)	Standard deviation (σ)
N0.0	26.62	26.39	28.63	27.21	8.16	0.00	1.10
N0.5	28.235	27.125	28.42	27.93	8.38	2.62	1.46
N1.0	25.435	24.265	25.63	25.11	7.53	-7.74	0.05
N1.5	19.805	19.45	20.07	19.77	5.93	-27.34	2.62
L0.0	21.96	22.01	21.84	21.94	6.58	0.00	0.49
L0.5	23.37	25.295	24.46	24.37	7.31	11.11	1.71
L1.0	20.59	22.295	21.79	21.56	6.47	-1.73	0.30
L1.5	14.89	17.075	15.95	15.97	4.79	-27.19	2.49

3. Spilt tensile strength

Sample code	Result of 7th days Split tensile strength test						
	S-1	S-2	S-3	Avg peak load (kN)	Avg. Stress(MPa)	Variation from control (%)	Standard deviation (σ)
N0.0	87	85	78	83.33	2.65	0.00	1.21
N0.5	84	92	99.3	91.77	2.92	10.12	5.42
N1.0	79	85	76	80.00	2.55	-4.00	0.46
N1.5	72	65	69	68.67	2.19	-17.60	6.13
L0.0	60	67	71	66.00	2.10	0.00	1.58
L0.5	65	75	68	69.33	2.21	5.05	3.25
L1.0	62	59	64	61.67	1.96	-6.57	0.58
L1.5	55	50	58	54.33	1.73	-17.68	4.25

Sample code	Result of 28th days Split tensile strength test						
	S-1	S-2	S-3	Avg peak load (kN)	Avg. Stress(MPa)	Variation from control (%)	Standard deviation (σ)
N0.0	124.3	119	131.3	124.87	3.97	0.00	5.51
N0.5	133.5	123.2	123.9	126.87	4.04	1.60	6.51
N1.0	109.5	105.2	104.7	106.47	3.39	-14.74	3.69
N1.5	101.8	90	99.8	97.20	3.09	-22.16	8.33
L0.0	81	87	85	84.33	2.68	0.00	1.58
L0.5	85	90	89	88.00	2.80	4.35	3.42
L1.0	70	78	82	76.67	2.44	-9.09	2.25
L1.5	80	72	75	75.67	2.41	-10.28	2.75

4. Compressive strength

Sample code	Result of 7th days compressive strength in terms of cube						
	S-1	S-2	S-3	Avg. Load (KN)	Avg. Stress(MPa)	Variation from control (%)	Standard deviation (σ)
N0.0	641.30	693.90	589.00	641.40	28.51	0.00	3.39
N0.5	566.32	499.48	515.48	527.09	23.43	-17.83	0.85
N1.0	469.36	511.64	382.95	454.65	20.21	-29.13	0.76
N1.5	328.28	315.44	353.46	332.39	14.77	-48.18	3.48
L0.0	390.90	388.20	430.40	403.17	17.92	0.00	1.28
L0.5	376.43	399.16	399.37	391.65	17.41	-2.85	1.02
L1.0	303.53	318.16	309.82	310.50	13.80	-22.98	0.78
L1.5	264.62	274.54	292.06	277.07	12.31	-31.27	1.52

Sample code	Result of 28th days compressive strength in terms of cube						
	S-1	S-2	S-3	Avg. Load (KN)	Avg. Stress(MPa)	Variation from control (%)	Standard deviation (σ)
N0.0	782.20	798.80	744.50	775.17	34.45	0.00	1.97
N0.5	723.16	766.58	690.00	726.58	32.29	-6.25	0.90
N1.0	697.06	733.96	626.86	685.96	30.49	-11.49	0.01
N1.5	486.68	653.84	530.32	556.95	24.75	-28.14	2.87
L0.0	559.30	474.20	509.00	514.17	22.86	0.00	1.66
L0.5	446.18	500.84	561.16	502.73	22.34	-2.27	1.40
L1.0	358.22	407.04	387.92	384.39	17.08	-25.28	1.23
L1.5	360.00	367.22	343.12	356.78	15.86	-30.65	1.84

Appendix-3: Photo gallery captured during laboratory works

a) Measuring unit weight of coarse aggregate setting time


b) Preparation of cement sample to check


c) Test to check bulking of sand


d) Measuring fully saturated weight of coarse aggregate

e) Filling water to determine the weight normal consistence

f) Measuring amount of water for of picnometer filled with water

g) Preparing of cement paste and cylinder

h) Moulds prepared to cast cube

i) Working with slump cone to check the workability of fresh concrete

j) Partially compacted concrete mix to check the samples

k) Measuring the dry mass of compaction factor

CONCLUSION

Based on the analysis of data and discussion that has been carried out, it was shown that sugarcane bagasse fibers can be used as concrete reinforcing material. After the completion of testing and analysis based on the objectives outlined for this study, the following conclusions can be derived:-

- Workability of the fresh mix of both NWC and LWC decreased from its control mix due to addition of sugarcane bagasse fiber. NWC without SBF recorded average of 76.5 mm slump, and 0.912 of compaction factor which is medium range in limit of degree of compaction. Due to addition of increasing amount of fiber it reduced to low range, and dry in consistency. Incorporation of scoria in half of coarse aggregate also adversely decreased it up to 16.5 mm in slump and 0.728 of compaction factor when 1.5% of SBF added.
- The unit weight of control sample of NWC meets the requirements of ASTM standard and the SBF influences it but not uniformly. The dry density of concrete entitled as light weight was 2194.5 kg/m^3 which is between the range of 2400 kg/m^3 for NWC and 1840 kg/m^3 for LWC. Hence, the concrete containing 50% replacement of coarse aggregate was semi-light weight concrete. And, the increase of fiber decreased the unit weight of concrete with light weight aggregate.
- Addition of bagasse fibers increased the flexural tensile strength of both concretes in 2.62% for NWC and 11.11% for semi-LWC from their control samples at 0.5% of SBF in 28^{th} day age of curing. During the test its failure shown effective mode of crack.
- Spilt tensile strength of the normal weight and semi-lightweight concrete also increased when 0.5% amount of sugarcane fiber added. Hence, optimum split tensile strength of the concrete with sugarcane fiber based on this study is at 0.5 % of SBF. When the sugarcane fiber keeps increasing, the tensile strength of the both concretes was reduced.
- Incorporation of SBF in both concrete was decreased the compressive strength of sample. But, the impact of 0.5% of SBF compressive strength is not more significant that the result is not far more from strength of concrete control. And, it has moderate to strong positive linear relation with both flexural and split tensile strength.

Overall, the optimum value of sugarcane fiber is 0.5% in terms of weight of cement in mix which is effective in modifying the tensile strength of concrete with a little impact on compressive strength.

RECOMMENDATION

Standing on the conclusion deducted above, the following recommendations were made for the further activities;

- Using of scoria as in-all lightweight aggregate to make structural lightweight concrete should be considered for further research work due to its high availability in our country.
- The additional investigation in influence of bagasse fiber from output of sugarcane factories to use as concrete reinforcing material should be conducted to identify the difference that may occur from extraction of fiber the researcher used for this study. The influence of bagasse fiber at varying fraction that $0 < 0.5 < 1$ percentage in terms of weight of cement should also be checked.
- The other method of extraction of fiber from bagasse should be developed with chemical treatments to improve its impact on compressive strength.
- Further, additional physical properties such as water absorption, and shrinkage; chemical resistance, thermal resistance, and durability should be evaluated with consideration of the age of concrete beyond 28^{th} day.

ACKNOWLEDGEMENT

First of all I would like to thank the almighty God for giving me the strength to walk unpaved way to reach this point in life. I would like to express my respectful thanks to my major advisor Ing Elmer C.Agon (Ass. Prof), and Co-advisor Ing. Lucy Feleke for all their encouragement, guiding me through my work, and indicating the best alternative way to perceive of my works. I would like to give my deepest gratitude to all others for their help, moral and material support, and true friendship with regard to this thesis works.

REFERENCES

9. Meyer, C. (2004). Concrete materials and sustainable development in the USA. *Structural engineering international*, *14*(3), 203-207.
10. Nematollahi, B., Saifulnaz, R. M., Jaafar, M. S., & Voo, Y. L. (2012). A review on ultra high performance'ductile'concrete (UHPdC) technology. *International journal of civil and structural engineering*, *2*(3), 994.
11. Lambert, P. (2002). *Cement and Concrete History and Development*.
12. Voo, Y. L., & Foster, S. J. (2009). *Reactive powder concrete: analysis and design of RPC girders* (Vol. 364). Saarbrücken, Germany: Lambert Academic Publishing.
13. Richard, P., & Cheyrezy, M. H. (1994). Reactive Powder Concretes With High Ductility and 200

800 Mpa Compressive Strength. *ACI Special Publication*, 144(1): 507-518.
14. Hossain, K. M. A. (2006). Blended cement and lightweight concrete using scoria: mix design, strength, durability and heat insulation characteristics. *International Journal of Physical Sciences*, *1*(1), 5-16.
15. Hardjasaputra, H., Ng, G., Urgessa, G., Lesmana, G., & Sidharta, S. (2017). Performance of lightweight natural-fiber reinforced concrete. In *MATEC Web of Conferences* (Vol. 138, p. 01009). EDP Sciences.
16. Bilba, K., Arsène, M. A., & Ouensanga, A. (2003). Sugar cane bagasse fibre reinforced cement composites. Part I. Influence of the botanical components of bagasse on the setting of bagasse/cement composite. *Cement and concrete composites*, *25*(1), 91-96.
17. Varshoee, A., Nasiri, H., Kargarfard, A., Hoseinzadeh, A., & Ezati, E. (2012). Investigating Cement-Bagasse Fiber Composite Properties. *World Applied Sciences Journal*, 16(5): 744-747.
18. Andrew, R. M. (2018). *Global CO2 emissions from cement production.* Earth Systen Science Data, 10: 195-217.
19. Olutoge, F., Ofuyatan, O., Rachael, A., & Opaluwa, E. (2015). Strength Characteristics of Concrete Reinforced With Sugar Cane Bagasse Fibre. *Journal of Mechanical and Civil Engineering*, 12(3): 68-71.
20. Löfgren, I. (2005). *Fibre-reinforced Concrete for Industrial Construction-a fracture mechanics approach to material testing and structural analysis*. Chalmers University of Technology.
21. Nuruddin, M. F., Khan, S. U., Shafiq, N., & Ayub, T. (2014). Strength development of high-strength ductile concrete incorporating Metakaolin and PVA fibers. *The Scientific World Journal*, *2014*.
22. Ferreira, C. R., Tavares, S. S., Ferreira, B. H. M., Fernandes, A. M., Fonseca, S. J. G., Oliveira, C. A. D. S., ... & Gouveia, L. L. D. A. (2017). Comparative Study About Mechanical Properties of Strutural Standard Concrete and Concrete with Addition of Vegetable Fibers. *Materials Research*, *20*, 102-107.
23. Paschalis, S., & Lampropoulos, A. (2017). Fiber content and curing time effect on the tensile characteristics of ultra high performance fiber reinforced concrete. *Structural Concrete*, *18*(4), 577-588.
24. ACI-Committee. (2002). *Report on Fiber Reinforced Concrete*, ACI-544.1R-96, Editor. American Concrete Institute. 57-66.
25. Naaman, A. E. (2003). Engineered steel fibers with optimal properties for reinforcement of cement composites. *Journal of advanced concrete technology*, *1*(3), 241-252.
26. Yadav, S., Gupta, G., & Bhatnagar, R. (2015). A review on composition and properties of bagasse fibers. *International Journal of Scientific & Engineering Research*, *6*(5), 143-147.
27. Sivaraja, M., Velmani, N., & Pillai, M. S. (2010). Study on durability of natural fibre concrete composites using mechanical strength and microstructural properties. *Bulletin of Materials Science*, *33*(6), 719-729.
28. Ellis, R., James, G., Merry,B., Weekes, D., Yates., B., Digges, P., Forber, G., Todd, M., Berding, N., Cox, M., Hogarth, M., Bailey, R., Leslie, G., & James Irvine, J. (2004). *Sugarcane*. Second Edition ed. Blackwell Science.
29. Artschwager, E. (1948). *Vegetative characteristics of some wild forms of Saccharum and related grasses* (No. 951). Department of Agriculture.
30. Wikipedia contributors. 2018, M.B.I.W., The Free Encyclopedia. Retrieved 06:44, May 5, 2018, from https://en.wikipedia.org/w/index.php?title=Bagasse&oldid=831858676.
31. Fenta, D. T. (2010). *The economic significance of using bagasse as a source of raw material for pulp manufacturing: a case of Ethiopia* (Doctoral dissertation).
32. Danso, H., Martinson, D. B., Ali, M., & Williams, J. B. (2015, June). Effects of sugarcane bagasse fibre on the strength properties of soil blocks. In *First International Conference on Bio-Based Building Materials*.
33. Verma, D., Gope, P. C., Maheshwari, M. K., & Sharma, R. K. (2012). Bagasse fiber composites-A review. *J. Mater. Environ. Sci*, *3*(6), 1079-1092.
34. Patel, D., & Patel, V. M. (2015). Application of sugarcane bagasse fibres as concrete composites for rigid pavement. *Indian J. Res*, *4*(4), 4-5.
35. Subramonian, S., Ali, A., Amran, M., Sivakumar, L. D., Salleh, S., & Rajaizam, A. (2016). Effect of fiber loading on the mechanical properties of bagasse fiber–reinforced polypropylene composites. *Advances in Mechanical Engineering*, *8*(8), 1687814016664258.
36. Balaji, A., Karthikeyan, B., & Raj, C. S. (2014). Bagasse fiber–the future biocomposite material: a review. *International Journal of Cemtech Research*, *7*(1), 223-233.
37. The Mechanical Properties Of Sugarcane Bagasse And Its Reinforced Epoxy Resin Composite.
38. Asagekar, S. D., & Joshi, V. K. (2014). Characteristics of sugarcane fibres. *Indian Journal of Fibre & Textile Research*, 39: 180-184.
39. Collier, B. J., Collier, J. R., Agarwal, P., & Lo, Y. W. (1992). Extraction and evaluation of fibers from sugar cane. *Textile Research Journal*, *62*(12), 741-748.
40. Addis, A. (2016). The Federal Democratic Republic Of Ethiopia Central Statistical Agency, C., *Area And Production Of Major Crops*, in *Agricultural Sample Survey, Volume I*, S. Bulletin, Editor.

41. Staff, U. (2015). Ethiopia Aims to Become One of the World's Top 10 Sugar Producers, in Gain Report.
42. ACI-Committee. (1999). *Guide for Structural Lightweight Aggregate Concrete*, ACI-213R-87, Editor. American Concrete Institute.
43. Lee, H. S., Ismail, M., Woo, Y. J., Min, T. B., & Choi, H. K. (2014). Fundamental study on the development of structural lightweight concrete by using normal coarse aggregate and foaming agent. *materials*, *7*(6), 4536-4554.
44. Meyer, K. E., & Kahn, L. F. (2002). Lightweight concrete reduces weight and increases span length of pretensioned concrete bridge girders. *PCI journal*, *47*(1), 68-76.
45. Singh, N. T. (2016). Effective uses of Light Weight Concrete. *Journal of Civil Engineering and Environmental Technology*, 3(3): 208-211.
46. Kitouni, S., & Houari, H. (2013). Lightweight concrete with Algerian limestone dust: Part I: Study on 30% replacement to normal aggregate at early age. *Cerâmica*, *59*(352), 600-608.
47. Kılıç, A., Ati, C. D., Teymen, A., Karahan, O., & Arı, K. (2009). The effects of scoria and pumice aggregates on the strengths and unit weights of lightweight concrete. *Scientific Research and Essay*, 4(10): 961-965.
48. Yohannes, M. (2015). Investigation on the Suitability of Pumice and Scoria Aggregates in Ribbed-Slab Construction. *Journal of Civil Engineering Research*, 5(4): 75-82.
49. Venkatesh, B., & Krishna, B. V. (2015). A Study on the Mechanical Properties of Light Weight Concrete by Replacing Course Aggregate with (Pumice) and Cement with (Fly Ash). *International Journal of Engineering Research & Technology (IJERT*), 4(8).
50. Abubakar, A., & Duna, S. (2017). Utilization of Scoria as Aggregate in Lightweight Concrete. *International Journal of Engineering Research*, 6(1): 34-37.
51. Shenbagavalli, M., Jenitha, G., & Pandi, S. S. A. (2018). Experimental Study On Light Weight High Strength Concrete. *Indian Journal of Science and Research*, 17(2): 175-179.
52. Ranade, R., Stults, M. D., Li, V. C., Rushing, T. S., Ronth, J., & Heard, W. F. (2011). Development of high strength high ductility concrete. in *2nd International RILEM Conference on Strain Hardening Cementitious Composites*. Rio de Janeiro, Brazil.
53. Naik, T. R. (1992). *Performance Of High-Strength Concrete Incorporating Mineral By-ProductS*. in *Progress Seminar at the ACI*. Washington, D.C.
54. Da Lian Tianrui Cement Co., L. *Dangote Construction Material 42.5 Cement*. 2018; Available from: http://trgroup.en.alibaba.com/product/60378489121-802361923/Dangote_construction_material_42_5_cement.html.
55. Keno, A. (2017). *Experimental Evaluation of bamboo as fibers in concrete*, in *Structural Engineering*. Jimma University.