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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Effect of Enset Fiber Length On Mechanical Properties of Concrete

By

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This is to certify that the thesis prepared by Yohans Negash, entitled “Effect of Enset Fiber Length on Mechanical Properties of Concrete” is submitted in partial fulfillment of the requirements for the Degree of Master of Science (Structure), complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

In light of the fact that natural fibers are used, since many centuries for different purpose at the beginning of civilization. They have been used for ropes, toughening of pots etc. Considering global environmental warming problems, research and innovation in natural fiber reinforced concrete has been rising rapidly at present. Interest is warranted due to the advantage of natural fiber compared to others, such as synthetic fiber, which includes low environmental impact and low cost and support their potential across a wide range of applications.

Natural fibers are categorized in to two. Those are natural inorganic fibers like carbon Asbestos and so on and the other are the natural organic fibers likes coconut, palm, kenaf, jute, sisal, Enset, pine, sugarcane, bamboo etc. The natural fibers are investigated by a lot of particular researchers as construction materials that could be used in cement paste/mortar/concrete. Much effort has long been made to improve their mechanical performance in order to expand fiber capacities and applications. The present work is carried out to evaluate the compressive, tensile as well as flexural strength of concrete using enset fibers.

Fiber length is the essential factor that influences the properties of fiber reinforced concrete. Hence the prediction of effective fiber length becomes important. Results on compressive strength, split tensile strength and flexural strength of concrete samples for quite a number of combinations are analyzed with the use of different fiber length. Fibers used with length of 10mm, 15mm and 20mm with constant percentage of 1.5% by weight had been used for the work. Natural fiber reinforced concrete is suitable for low-cost construction, which is very desirable for developing countries. Normal C -20 mixes was used for the study. It is observed that enset fiber length can affect significantly the mechanical properties of concrete.

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List of Abbreviations

AAiT	Addis Ababa Institute of Technology
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
ASCE	American's Society of Civil Engineers
EFRC	Enset Fiber Reinforced Concrete
SFRC	Steel Fibers Reinforced Concretes
SNFRC	Synthetic Fiber Reinforced Concrete
GFRC	Glass Fibers Reinforced Concretes
NFRC	Natural Fibers Reinforced Concretes
C – 20	Concrete Grade with characteristic strength of 20MPa by 28th day
CA	Coarse Aggregate
FA	Fine Aggregate
FM	Fineness Modulus
FRC	Fiber Reinforced Concrete
FRI	Fiber Reinforcing Index
M1	Mix without Enset Fiber
M2	Mix with 10mm Enset fiber length
M3	Mix with 15mm Enset fiber length
M4	Mix with 20mm Enset fiber length
OPC	Ordinary Portland cement
OD	Oven Dry condition
SSD	Saturated-Surface-Dry condition
SNNP	South Nation Nationalities and People
FRP	Fiber Reinforced Polymer
ETIDI	Ethiopian's Textile Industry Development Institute

Contents

Chapter One

1. Introduction

1.1 General

Fiber Reinforced Concrete (FRC) is a concrete containing fibrous materials which will increase its structural integrity. It's containing short, uniformly allocated and randomly oriented discrete fibers.

The predominant aim of the usage of fibers in concrete is that they are capable of improving the mechanical properties such as fracture toughness, impact, tension, fatigue, thermal shock, spalling and much more. Fibers are small discrete reinforcing inputs produced from various materials like steel, glass, carbon and natural sources in various shapes and sizes. Plain concrete takes two crucial drawbacks as a structural material. They behave in brittle or semi brittle fashion and possess a very low tensile strength. It has a low special modulus, minimal ductility and little resistance to cracking compared to other construction materials.

Concrete, on the other hand, is a brittle material with high compressive strength, susceptible to strain for which reinforcement is given. Fibers had been used in concrete as reinforcement and strengthening component as they are effective in strengthening the concrete under tension as well as withstanding the spread of cracks. The influence of enset fibers length on the strength of concrete is taken as the core objective of this experimental study.

Studies have shown that the addition of natural fiber in a concrete matrix's improve all the mechanical properties of concrete, in particular compressive strength, tensile strength, flexural strength, and toughness. The resulting material possesses higher tensile strength, consolidated response and higher ductility.

Performance of concrete is evaluated from mechanical properties which encompass compressive strength, tensile strength, flexural strength and modulus of elasticity with the aid of adding ultimate fiber length. In this study, the mechanical characteristics of concrete like compressive strength, tensile strength and flexural strength will examine by adding different Enset Fiber length.

1.2 Statements of the Problem

Before environmental era emerges synthetic fibers were being used to provide a concrete good tensile strength as reinforcement. But, presently the world is looking for eco-friendly construction materials with environment friendly price and extensive abundances.

Enset fiber is low cost eco-friendly product and is abundantly available and convenient to transport. It is broadly being used traditionally as a natural choice for ropes, carpets, apparel and other reinforcement materials.

More than one fifth of the populations of Ethiopia rely on enset. The application of enset has preceded research in regarding with nutritionals and socio – cultural values as well as Some health benefits**.** And therefore the potential use of enset and its fiber for engineering purpose cannot yet be predicted with reasonable accuracy. There are certain factors which inhibit us from harnessing it; lack of technologists, lack of awareness, lack of instruments and frequent laboratory investigations.

As a consequence, important issues related to designs and constructions of enset Fibers reinforced concretes for different structures are not adequately addressed in building codes including ES-EN. Structural designers are unable to take the full advantage of enset fiber because of insufficient information. There is lack of less expensive but durable building materials for the construction of low cost, low energy consumption and environmental friendly housing.

The main factor that influences the characteristics of fiber-reinforced concrete is fiber length. Therefore, thesis on effect of enset fiber length is needed to provide designers and researchers with additional information on the identifying effective fiber length to enhance mechanical properties of enset fiber reinforced concrete. This study is important for it provides some investigations for mechanical properties of fibers reinforced concretes such as, compressive strength, splitting tensile strength and flexural strength with varying enset fiber length.

1.3 Significance of the Research

The paper is intended to investigate the potential use of effective enset fiber length in concrete production. For the sake of enhancing the mechanical features of plain concrete, enset fiber serves as reinforcement. In doing so, enset fiber will enhance plain concrete to be resistant to tensile cracks, bending and fracture. Thus it's important to extend the concept of effective enset fiber length addition into the conventional reinforced concrete as it saves percentage of reinforcement bars used in steel reinforced concrete production. Therefore by specifying the effective Enset fiber length we can improve the mechanical characteristics of concrete like, compressive, flexural strength and split tensile strength and then by doing additional investigations on enset fiber reinforced concrete we can use the improved concrete for different structures especially for low- cost construction.

1.4 Objectives of Research

1.4.1 General Objective

To study the effect of enset fiber length on mechanical property of concrete, namely flexural strength, compressive strength and splitting tensile strength.

1.4.2 Specific Objectives

- ✓ To study the potential use of enset fiber length in affecting the properties of fresh concrete that is slump test which carried out to obtain the workability and consistency by considering the higher flow values were obtained with the increase of mix workability and improving hardened concrete like ,compressive ,splitting tensile strength and flexural Strength.

- ✓ To quantify the effective enset Fiber length on the properties of freshly mixed concrete and hardened concrete.

- ✓ To compare and contrast enset fiber reinforced concrete with plain concrete in regarding different fiber length addition with basic characteristic of mechanical properties; like compressive strength, flexural strength and split tensile strength.

1.5 Scope of the Research

The experiments in this particular study were performed using enset fiber. As enset fibers reinforced concrete is a reliable materials that used in practice for the development of structural elements in rural construction in Ethiopia with a constant water cement ratio of 0.59, this particular study is also limited to investigating mechanical properties of concrete mixes with enset fiber length variation for a concrete grade designated as C-20.

1.6 Organization of the research

The organization of this research paper is as follows. Chapter one provides a general introduction to the thesis with a brief content of the background information, statement of the Problem, research scope and significance of the study. Chapter 2 discusses the literature review on the effect and applications of fibers in concrete. Chapter 3 covers materials used and test methods during the experimental process. Chapter 4 covers the test results of the laboratory experiments and discussion on the results; Chapter 5 provides conclusion and recommendations for further investigation.

Chapter Two

2. Literature Review

2.1 Introduction

Based on the terminology adopted by the American's Concrete Institute (ACI) committee 544, there are four categories of fiber reinforced concrete particularly

1) Steel Fibers Reinforced Concrete (SFRC),

2) Glass Fibers Reinforced concrete (GFRC),

3) Synthetic Fibers Reinforced Concrete (SNFRC) and

4) Natural Fibers Reinforced Concrete (NFRC).

Natural fibers are fibers that are found in nature. Natural fibers can be classified as organic or in-organic fibers. Natural organic fibers are fibers that are obtains from either plant or animal sources. The majority of useful natural textile fibers are plant derived with the notable exceptions of wool and silk fibers. Natural-inorganic fibers are discontinuous short fibers widely used to reinforce concrete. Many natural reinforcing materials can be obtained at low levels of cost and energy using locally available manpower and technical know-how.

Natural fibers are prospective reinforcing materials and their use until now has been more traditional than technical. They have long 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. The distinctive properties of natural fiber reinforced concretes are improved compressive, tensile and bending strength, greater ductility, and greater resistance to cracking and hence improved impact strength and toughness.

Natural fibers reinforced concrete highly fascinated designers by their several advantages such as low weight, low cost, high availability, easy productivity, their friendly to environment and high specific mechanical performance. Natural fibers confirm advanced mechanical properties like stiffness, flexibility and modulus composite to glass fibers. Their availability, renewability, low density, and price as well as acceptable mechanical properties make natural fibers more attractive ecological alternative to glass, carbon and manmade fibers.

The natural fibers have been tried as reinforcement for concrete matrices typically to produce less costly skinny factors for use in housing schemes. For their production, vegetable fibers need only a low industrialization diploma and in an equal weight assessment of the most common synthetic reinforcing fibers, the energy needed for their manufacture is small and the cost of manufacturing these composites is therefore also low. In addition, the importance of vegetable fiber in cement matrices requires solely a small wide variety of skilled personnel in the construction industry.

Fiber reinforced concretes (FRC) are concrete containing fibrous material which will increase its structural integrity. It consists of quick discrete fibers that are uniformly disbursed and randomly oriented. Fibers encompass synthetic fibers, glass fibers, natural fibers and steel fibers. The character of fiber reinforced concrete changes with varying concretes, orientation, densities, geometries, fiber materials and distribution.

Historically, lots effort has been spent enhancing the behavior of concrete structures. flexural, compressive, shear strength, ductility, and other properties have been the focal point of many researchers who have examined concretes with delivered steel and other materials to improve the behavior of concrete. The idea of including fibers to enhance brittle material behavior is ancient. For example, mesopotamians used straw to improve sun baked bricks. This ancient technology is nevertheless used to enhance concrete characteristics. The present day improvement of fiber strengthened concrete happening in the early sixties.

2.2 Enset Plant

Enset ventricosum is a monocarp perennial crop, located under the same genus Enset and have close similarity with the domesticated banana. It has the capacity to face up to drought condition and use as a substantial food item for many hundreds of thousands of people in Ethiopia. (Brandt et al. 1997). Records show that Enset has been cultivated for over 10,000 years in Ethiopia. It is renewable and eco-friendly, as it consumes nitrogen which may want to be a part of huge effort to prevent air pollution.

This plant grows and reaches its maximum strength in simply few years. A fiber of enset is a natural organic fiber which serves to make stronger concrete materials and improves tensile energy of a concrete. Under tensile loading, concrete is fundamentally brittle.

Enset (Enset ventricosum) is a multipurpose crop that offers a variety of products such as food, forage, medicine, rituals, soil protection and construction. The different uses are attributed to the existence of different Enset varieties (Yemane Tsehaye and Fassil Kebebew, 2006). Enset is distributed in the wild throughout much of central, eastern and southern Africa.

It is however, recognized to have been cultivated (Simmonds, 1958; Taye Bizuneh et al. 1967), domesticated (Brandt, 1996) and installed in Ethiopia, the farming gadget (Ehret, 1979). Around one-fifth of the Ethiopian population currently depends on this crop.

In many parts of the heavily populated south, enset ventricosum is a traditional staple crop on which more than twenty million people in the southern part of Ethiopia rely as a staple and co-staple food source (Dereje2012).

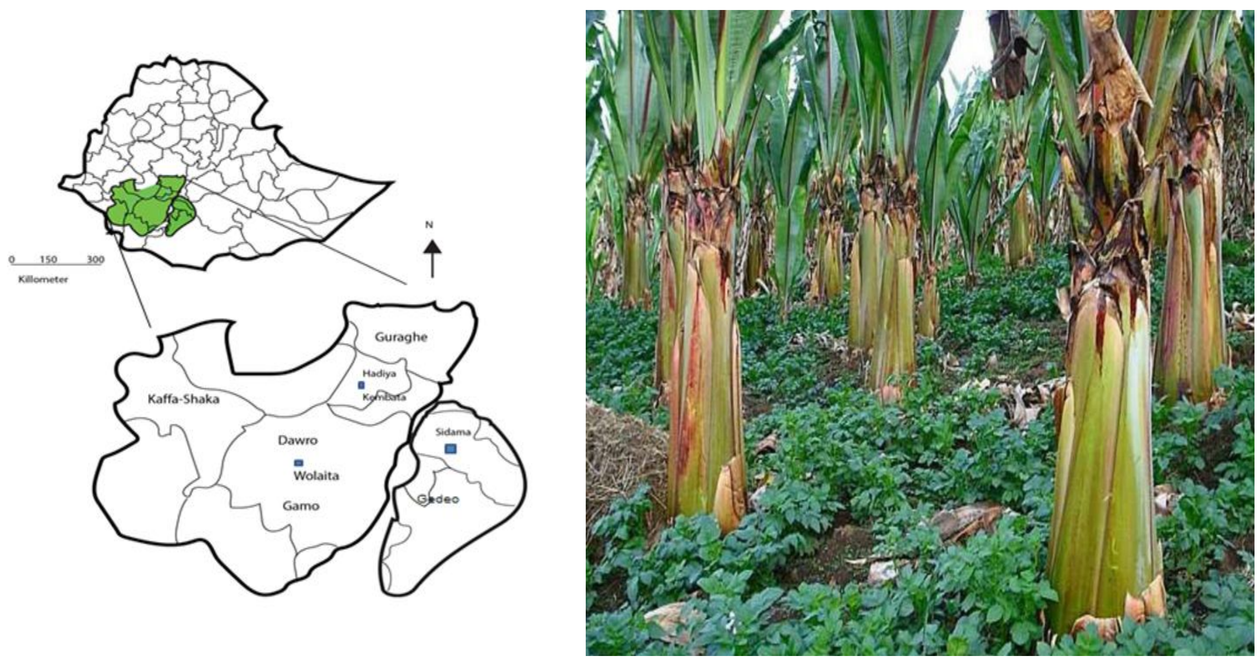

Figure 2. 1 Enset plant and map of Ethiopia showing the southwestern part of the main Enset rising geographical areas.

Natural fibers also abound in large quantities in developing countries, for example in Nigeria; there are research works where the performance of natural fibers in concrete have been investigated exploiting the advantage of the economical and abundant availability of materials such as Kenaf fiber (Hibiscus cannabinus L.), akwara, palm nut fiber and bamboo strips, (Akubueze et al., 2014; Okafor, 1988; Salau et al., 2012; Udoeyo et al., 2011; Uzomaka, 1976).

Mechanical properties of concretes should be expanded through reinforcement with randomly oriented quick discrete fibers, which stop and manipulate initiation, propagation or coalescence of cracks. Fiber reinforced concrete can continue to maintain tremendous hundreds even at deflections exceeding fracture deflections of plain concrete. Fibers reinforcement concretes construction is more competitively priced than conventional construction. In addition to cost reduction, it has different beneficial properties such as greater stiffness, higher ductility, lightweight, low repair costs, and higher post-cracking and dynamic behavior.

Fibers are thread like materials which should be used for exceptional purposes. Fibers produced by way of plant life (vegetable, leaves and wood), animals and geological procedures are acknowledged as natural fibers. In order to increase its strength properties, researchers have used plant fibers as an alternative source of steel and/or artificial fibers to be used in composites (such as cement paste and/or concrete). These plant fibers, herein referred as natural fibers, include coir, sisal, jute, Hibiscus cannabinus, eucalyptus grandis pulp, malva, kenafbast, bamboo, pineapple leaf, ramie bast, abaca leaf, sansevieria leaf, hemp, vakka, date, sugarcane,flax,, palm, cotton and banana.

Natural fibers are inexpensive and domestically handy in many countries. So their use as a development fabric for growing properties of composites costs a very little (almost nothing when in contrast to the total fee of the composites). Their use will lead to growth that is sustainable. Because of their versatility, another advantage can also consist of the handy use/handling of fibers, because the issue occurs when a high proportion of fibers is to be used as in the case of steel fibers. But a technique for casting needs to be invented for the use of very excessive percentages of fibers. For many civil engineering applications, including roofing tiles, corrugated slabs, basic slab panels, boards and mortar, etc., volume fraction and fiber content material are two terminologies used to express the amounts of fibers in a given composite reinforced composite.

Natural fibers as reinforcement in composites have been studied by many researchers only for non-structural members. Natural fibers are good alternative at lower cost and promote sustainable development. Earthquakes have caused mass destruction of buildings because of non-engineered constructions. These observations emphasize the need for new techniques for economical and safe housing in earthquake prone rural areas. Natural fiber reinforced concrete structures may be one solution.

Enset fiber is exceptionally durable and requires low maintenance with minimum wear and tear. Enset is one of the most promising natural fibers. An effort to diversify and encourage the use of Enset fibers for construction is to be made in this study.

2.3 Previous Works Related to Fiber Reinforced Concrete

This part of the study reviews the findings of the previous research works carried out on fiber reinforced concrete. The materials used in the review are mainly published works found relevant to this investigation which are useful in pointing out the direction to adopt for this thesis and clearly revealing the gap in knowledge which this research will fill for the advancement and full exploitation of EFRC in practice. The review also assists in the selection of variables and the effectiveness of method of investigation adopted in this thesis work.

Jitendra D. Dalvi, Uttam B. Kalwane, Pallavi Pasnur studied on the effects of fiber length and percentage of Sisal on strength of concrete. For each combination the samples are casted in C 20 mix. The researchers conclude that the maximum compressive strength is observed at 1% fiber with length of 15mm which is 69.27 % more than the average compressive strength without fiber. The maximum tensile strength is at 1.5% fiber with 15mm length, which is 29.14% more than the concrete strength without fiber. The maximum flexural strength is at 1.5% fiber with length of 15mm which is 87.71% more than the concrete strength without fiber.

Č. Mizera, D. Herák, P. Hrabě, M. Müller, A. Kabutey presented the research on the effects of length of false banana fiber on mechanical behavior under tensile loading. The researcher concludes that fiber with a length of 10 mm exhibited the best mechanical properties and also the smallest variance. The presented models of mechanical behavior hopefully provided background information for further research focused on the enset fiber application.

Kelly & Tyson, 1965 presented a research on use of natural fibers to enhance tensile strength of the concretes. During the tensile loading stage of the composite materials in order to fiber to be broken, fiber should have higher length than the critical length. Therefore fiber length is also important factor which can affect the mechanical performance of the composites. With the addition of coir fibers compressive strength did reduce severely by 20% to 75%. With the increasing in fiber length, compressive strength was also observed to decrease.

Pramasivan et al. (1984), gave recommendations (about fibre length and volume fraction of coconut fibres) for the production of coconut fibre reinforced corrugated slabs along with the casting technique. Tests for flexural strength, thermal and acoustic properties were performed. For producing slabs with a flexural strength of 22 MPa, a volume fraction of 3%, a fibre length of 25 mm and a casting pressure of 1.5 atm were recommended. The thermal conductivity and sound absorption coefficient for low frequency were acceptable.

According to the previous study (Mansur and Aziz 1982; Chakraborty et al. 2013; Meddaha and Bencheikh 2009; Bezerra et al. 2004), when combining natural fibers to create composites, a range of difficulties are encountered. Meddaha and Bencheikh (2009), for example, mentioned that inhomogeneous fiber distribution produces bulk and surface flaws. The concentration of stress on these vulnerabilities will intensify.

Chakraborty et al. (2013) also stated that the use of natural fibers in the FRC could not be prevented from agglomerating. The amount of fibers that can be applied to a mix is limited by the "balling" tendency (Mansur and Aziz 1982), in which the fibers often intermesh and form fiber balls that are important for separation. The fibre balling results in an inefficient and separated mix that creates a concrete that is highly brittle and honeycombed. As a consequence, the concrete composite causes a surprising drop in power. It can be inferred from the above elucidation that the fiber length and mixing play a vital role in the perfection of fiber-reinforced concrete composite mechanical properties.

Rami H. Haddad and Ahmed M. Asteyate (2001) discovered an interesting way of predicting the role of artificial fibers length such as polypropylene and nylon fibers in delaying metal corrosion cracks and enhancing the bond with concrete. Different lengths of polypropylene and nylon fibers with more than a few volumes had been combined with concrete. Pullout tests and corrosion study were performed and they have been concluded that both the fibers contributed extra in delaying the corrosion and improving the bond strength. Moreover it used to be pointed out that polypropylene fibers played extra big role than nylon fiber in the enhancement of bond.

- ❖ Based on the literature review, one can see that there is limited number of studies that address the influence of basic parameters, such as
  - ✓ Fiber volume fraction and fiber length, on both physical and mechanical characteristics of EFRC,
  - ✓ The quantitative relationship between mechanical properties of different Enset fiber lengths. and
  - ✓ The early shrinkage cracking resistance with varying enset fiber length in Fiber reinforced concrete. Accordingly, the objective of this investigation is to study the effect of the fundamental parameter which is enset Fiber length on the mechanical behavior of EFRC as compared with that of plain concrete.

- ❖ Therefore, this study aims at identifying the reasonable enset fiber length which could significantly enhance the plain concrete mechanical properties. Fundamental mechanical properties of enset fiber reinforced concrete such as compressive strength, flexural strength, splitting tensile strength, are studied.

Chapter Three

3. Material and Methods

3.1 Introduction

Concrete is a construction substance consisting of cement, sand as fine aggregate, crushed rock as coarse aggregate, water and admixture. It's obvious that, concrete can be produced through mixing of concrete ingredients, but the important point to bear in mind is producing acceptable concrete quality with a reasonable economy. To produce acceptable quality, it's important to make physical characteristic tests on concrete making materials before any concrete experiments are carried out. So, this chapter elaborates concrete making material uses for the research and their physical test results conducted from the experiment, mix design and proportioning, concrete production process and concrete mechanical properties.

3.2 Materials Used for the Experiment

3.2.1 Cement

Cement is a construction material with adhesive and cohesive properties that make it capable of linking two or more materials into a solid mass together. Cement from different sources may have different properties which in turn will influence properties of concrete mix. Ordinary portland cement is designed for a general use of construction work throughout the world. From locally produced cements Dangote ordinary portland cement was used in this specific research conforming to the specifications of ASTM C150.

3.2.2 Fine aggregate

In this specific research work, local river sand was used as fine aggregate. Physical properties of fine aggregates like specific gravity and absorption capacity (ASTM C 128), fineness modulus and Sieve analysis (ASTM C 136), silt content and moisture content (ASTM C 566) are determined.

3.2.3 Coarse aggregate

Basaltic crushed rock was used as coarse aggregate in sample preparation for this specific experimental study. The maximum aggregate sizes of coarse aggregate is 19 mm. Physical property of coarse aggregate; like specific gravity and absorptions capacity (ASTM C 127), moisture content (ASTM C 566) , fineness modulus and sieve analysis (ASTM C136) are determined.

3.2.4 Water

Water is an important constituent in concrete. It chemically reacts with cement to produce the desired properties of concrete. Mixing water is an amount of water that falls in contact with cement, impacts concrete slump, and is used to assess the ratio of concrete mixtures to water to cement materials.

3.2.5 Enset fiber

Enset plants for this study were collected from SNNP region, Gurage Zone, a place called Agena. The fibers are extracted from enset plant by hand and dried in sunlight for 12 hours until all the moisture is removed from the fiber.

3.2.5.1 Extraction Process of Enset Fiber

The extraction of the fiber was not taken place as the main objective. Rather it is a byproduct. The main reason for extraction process is during the search for food. The processes are discussed as follows according to my observation under collecting the fiber.

- ✓ Cut the enset plant which is ready for the food process, from the ground level.
- ✓ Cut the outer two layers of the plant into smaller pieces.
- ✓ Attach the smaller piece on an inclined plane wood and hold it with right leg.
- ✓ Between the right leg and the inclined plane wood, scrap it with a tool made from wood to obtain the fiber. The one which is left on the inclined plane will be the fiber and the one which is left on the ground will be the food.

Figure 3. 1 Extraction process of enset fiber

Figure 3. 2 The extracted enset fiber

The absorption capacity was measured by conventional method and the diameter is taken from literatures. The Average Tensile Strength of 30 randomly selected samples of Enset fiber is tested by a tensile strength tester with collaboration of Ethiopian Textile Industry Development

Institute (ETIDI).Then the results were recorded by grouping in to five groups. The Result is summarized in table 3.1 below and Appendix B.

Table 3. 1 Physical properties of enset fiber

Diameter (mm)	Absorption Capacity (%)	Average Tensile Strength (MPa)
0.2	1.1	172.61

The collected fibers length was chopped in to smaller pieces of about 10mm, 15mm and 20 mm in length.

Figure 3. 3 Manual chopping of enset fiber into smaller pieces

3.3 Methodologies

All constituent materials used in producing concrete samples have been prepared and their respective physical properties were performed to approve their appropriateness. Constituent materials for normal grade concrete designated as C-20 concrete proportioned using ACI (American Concrete Institute) mix design method. Samples for flexural strength tests, split tensile strength test and compressive strength test were casted, demoulded, cured with ponding and tested on their respective dates.

3.3.1 Materials preparation

Ordinary portland cements supplied from Dangote cement factory has been used for this specific research throughout the whole experiment. The cement is produced as per CEM-I-42.5 grade. Aggregate samples have been prepared in accordance with the test requirements; and hence river sand samples were collected from suppliers; basaltic crushed stone samples were also collected from manufacturers. It is very important to obtain the right type and quality of aggregates on site. They should be clean, hard, strong, and durable and graded in size to achieve utmost economy from the paste. Therefore, to judge the quality and physical characteristics of the aggregates, physical tests were conducted for both fine and coarse ingredients.

Enset fibers in this specific research were examined to have a length 10, 15, and 20mm after measuring representative samples with help of rulers. The fiber was chopped into smaller size by scissor.

3.3.2 Testing constituent materials

Aggregates are one of the key components of concrete. It is not possible to compromise the correct form and consistency of aggregates when producing concrete. They have a significant effect on the properties of both freshly mixed and hardened concrete.

Aggregate needs to be standardized because concrete strength and quality depends on physical properties, mechanical properties and chemical composition of the parent aggregate making materials. All physical tests conducted for both fine and coarse aggregates are discussed in the following sessions and briefly on appendix A. River sand and crushed gravel found in Ethiopia were used in this study. All aggregate were conditioned in the laboratory environment for 24 hrs and the moisture content was adjusted to compensate for the absorption capacity of the aggregate before mixing. Both the fine and coarse aggregate met the standard gradation requirements according to ASTM Standard.

3.3.2.1 Tests for coarse aggregates

In this specific research, basaltic crushed rock aggregates having nominal maximum size of 19 mm were made use of through blending in order to keep gradation in the range specified on ASTM standard. Physical property tests; like gradation, specific gravity, water absorption, moisture content and unit weight of the aggregates were conducted.

Figure 3.4 below shows gradation curve for coarse aggregate used in the thesis in comparison to the minimum and maximum quantities of coarse aggregates on each series of sieves specified in ASTM Standard.

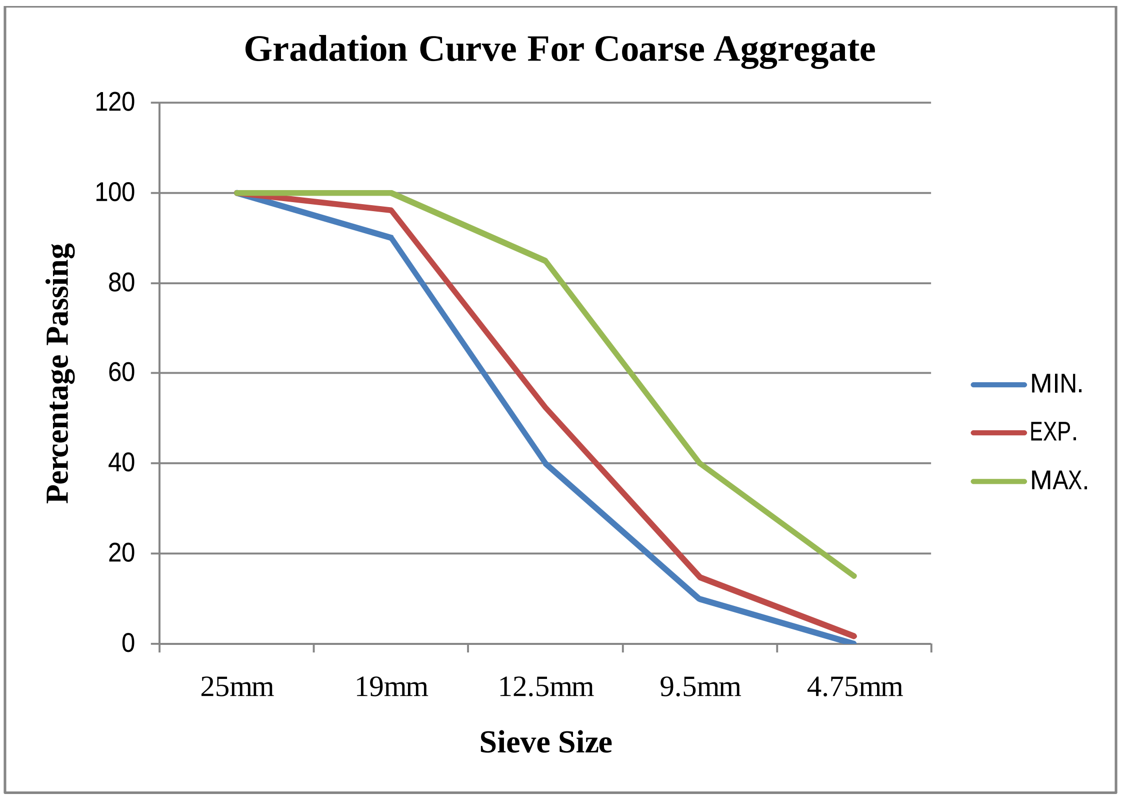

Figure 3.4 Gradation curve for coarse aggregate

Test Result

Table 3. 2 Particle size distribution for coarse aggregate

Sieve Size (mm)	Weight of Sieve (gm)	Weight of Sieve and Retained (gm)	Weight Retained (gm)	Percentage Retained (gm)	Cumulative Retained (gm)	Cumulative Passing (gm)
25	1210	1210	0	0	0	100
19	1280	1475	195	3.9	3.9	96.1
12.5	1160	3355	2195	43.9	47.8	52.2
9.5	1163	3033	1870	37.4	85.2	14.8
4.75	1170	1822	652	13.04	98.24	1.76
Pan	735	823	88	1.76	-	-
				Total	235.14	

Table 3. 3 Coarse aggregate's physical properties

Type	Moisture Content (%)	Specific Gravity	Absorption Capacity(%)	Bulk Unit Weight ($\frac{g}{m^3}$)
Coarse Aggregate	1.94	2.81	1.86	1610.33

The detail physical test for coarse aggregates is given in appendix A1 of this paper.

3.3.2.2 Tests for fine aggregates

River Sand was used in order to keep gradation in the range specified on ASTM Standard. physical property tests; like silt content, gradation, specific gravity, water absorption, moisture content of the fine aggregates were conducted.

Figure 3.5 below shows gradation curve for fine aggregate used in the thesis in comparison to the minimum and maximum quantities of fine aggregates on series of sieves specified in the ASTM Standard.

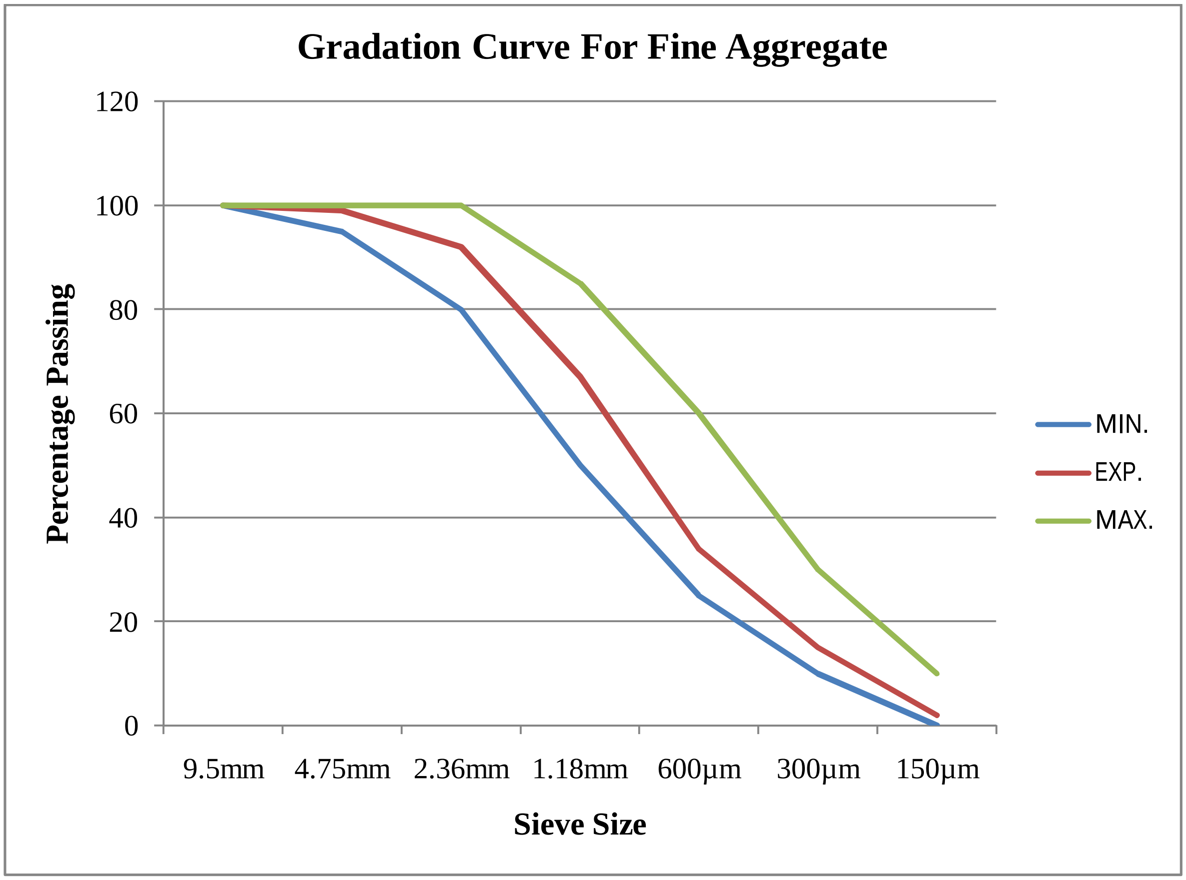

Figure 3. 5 Gradation curve for fine aggregate

Test Result

Table 3. 4 Particle size distribution for fine aggregate

Sieve Size (mm)	Weight of Sieve (gm)	Weight of Sieve and Retained (gm)	Weight Retained (gm)	Percentage Retained (gm)	Cumulative Retained (gm)	Cumulative Passing (gm)
9.5	515	515	0	0	0	100
4.75	425	430	5	1	1	99
2.36	390	425	35	7	8	92
1.18	375	500	125	25	33	67
0.6	325	490	165	33	66	34
0.3	310	405	95	19	85	15
0.15	285	350	65	13	98	2
Pan	240	250	10	2	-	-
				Total	291	

Calculation

Fineness Modulus (F.M) = $\frac{\sum \text{Cumulative retained}}{100} = \frac{291}{100}$ = 2.91

Table 3. 5 Physical properties of fine aggregate

Type	Silt Content(%)	Moisture Content(%)	Specific Gravity	Absorption Capacity(%)
Fine Aggregate	3.44	2.88	2.4	1.79

The detail physical test for fine aggregates is given in appendix A2 of this paper.

3.4 Experimental methods

To evaluate the effect of enset fiber length on the concrete strength, a number of tests are conducted. According to the condition of the concrete when it is being tested, these tests can be grouped into two categories:

1. Fresh concrete tests

2. Hardened concrete tests.

Fresh concrete property tests evaluate the following properties of concrete: slump and unit weight. Three basic mechanical properties at different ages were conducted for the hardened concrete state obtained from the mix designs: compressive strength, flexural strength, and splitting tensile strength.

3.4.1 Mix proportions

The objective of concrete mixing proportion is to determine the most economical and practical combination of readily available materials that will satisfy the performance requirement under a particular condition of use.

The mix proportioning was carried out by following the ACI mix proportion process for this experimental work. The proportions of the concrete mix are typically expressed on the basis of the ingredients' mass per unit volume. The proportioning of concrete by the method of absolute volume requires the measurement of the volume of each ingredient and its contribution to the concrete output of $1m^3$.Volumes are subsequently converted to design weights. These conversions to weights are accomplished by taking the known volumes of ingredients and multiplying by the specific gravities of ingredients and again multiplying by the density of water.

In this specific research mix design of enset fibers reinforced concrete with determined ratios of cement, sand, water, coarse aggregate and enset fiber were proportioned for C20 concrete grade.

The concrete mix design has been carried out for various proportions as per ACI 318 Standard and arrived at final mix proportion. A total of four concrete mixtures were investigated in this study. One mixture consisted of a control mixture without enset fiber the other three mixtures were made by modifying the control mixture with the addition of 10mm, 15mm and 20mm chopped Enset fibers with constant 1.5% fiber volume to it.

Table 3. 6 Mix proportioning

Mix Code	Enset Fiber length(mm)	For $1m^3$ of Concrete				
		Cement (kg)	Water (kg)	Sand (kg)	Coarse Aggregate(kg)	Enset Fiber(kg)
M_0	Normal Mix	317	198	824	967	-
M_1	10mm	312	197	812	952.5	20.1
M_2	15mm	312	197	812	952.5	20.1
M_3	20mm	312	197	812	952.5	20.1

3.4.2 Workability test

The workability of the fresh concrete is a key attribute that determines the quality of a potential hardened form of the concrete. The term workability describes the capability of fresh material to be well handled and flow into the formwork or around the particular area of the structure where it is required. The slump test was performed following the procedures of ASTM C 143"Slump of hydraulic cement concrete". The inverted slump cone used for this test is shown in Figure below.

Figure 3.6 Workability Test Using Slump

3.4.3 Unit weight of concrete

The unit weight was done as per the procedures of ASTMC 138 “Standard test method for density (unit weight), yield, and air content (gravimetric) of concrete “.

3.4.4 Compressive strength test

According to British Standards Institute (2009c), compressive strength of test specimens of hardened concrete are determined using cube, cylinder or core meeting the specified requirements, whereby the specimens are loaded to failure in a compression testing machine.

In this Specific thesis, The specimens for compressive strength test, with 10mm, 15mm and 20mm Enset fibers length was casted and cured in a water bath until they were tested. In order to gain information on the rate of compressive strength gain with age, compressive strength tests were conducted at 7, 14 and 28 days for all concrete mixes. In each category three cubes was tested and their average was reported. The load was applied at a rate of 0.3MPa.When the given percentage of load after failure was attained, the control automatically stops. Then the ultimate load was recorded. The compressive strength was calculated by dividing the ultimate load by the cross sectional area of the specimen.

Figure 3. 7 Compressive strength testing

3.4.5 Flexural strength test

One indicator of concrete's tensile strength is flexural strength. It is a measure of the amount of stress or force that can be withstood by a beam or slab against bending failures. The flexural strength is expressed as modulus of rupture in (MPa) and is determined by standard test methods ASTM C 78 “Standard method of test for flexural strength of concrete (Using simple beam with two - point loading)” or ASTM C 293 (center-point loading). Beam samples having 10cm x 10cm x 50cm sizes were tested after 7, 14 and 28 days of curing according to ASTM C 78 (Two-point loading) standard test methods in this specific thesis.

In each category three beams was tested and their average was reported. The flexural strength calculation is as follows.

Flexural strength (Mpa) = $\frac{P\times L}{b\times d^2}$,

Where, P = Failure load,

L = Centre to centre distance between the support = 400 mm,

b = width of specimen=100 mm,

d = depth of specimen= 100 mm.

Figure 3.8 Flexural strength testing

3.4.5 Splitting Tensile test

A technique for assessing the tensile strength of concrete is the fracturing tensile strength test on concrete cylinders. The concrete is very poor in tension due to its brittle nature and is not designed to withstand direct tension. The concrete develops cracks when subjected to tensile forces. Thus it is important to measure the tensile strength of concrete by finding the load at which the concrete members will crack. Split tensile strength of cylindrical samples having 30cm height and 15cm diameter were tested after 7,14 and 28 days of curing in accordance with ASTM C496 standard testing methods.

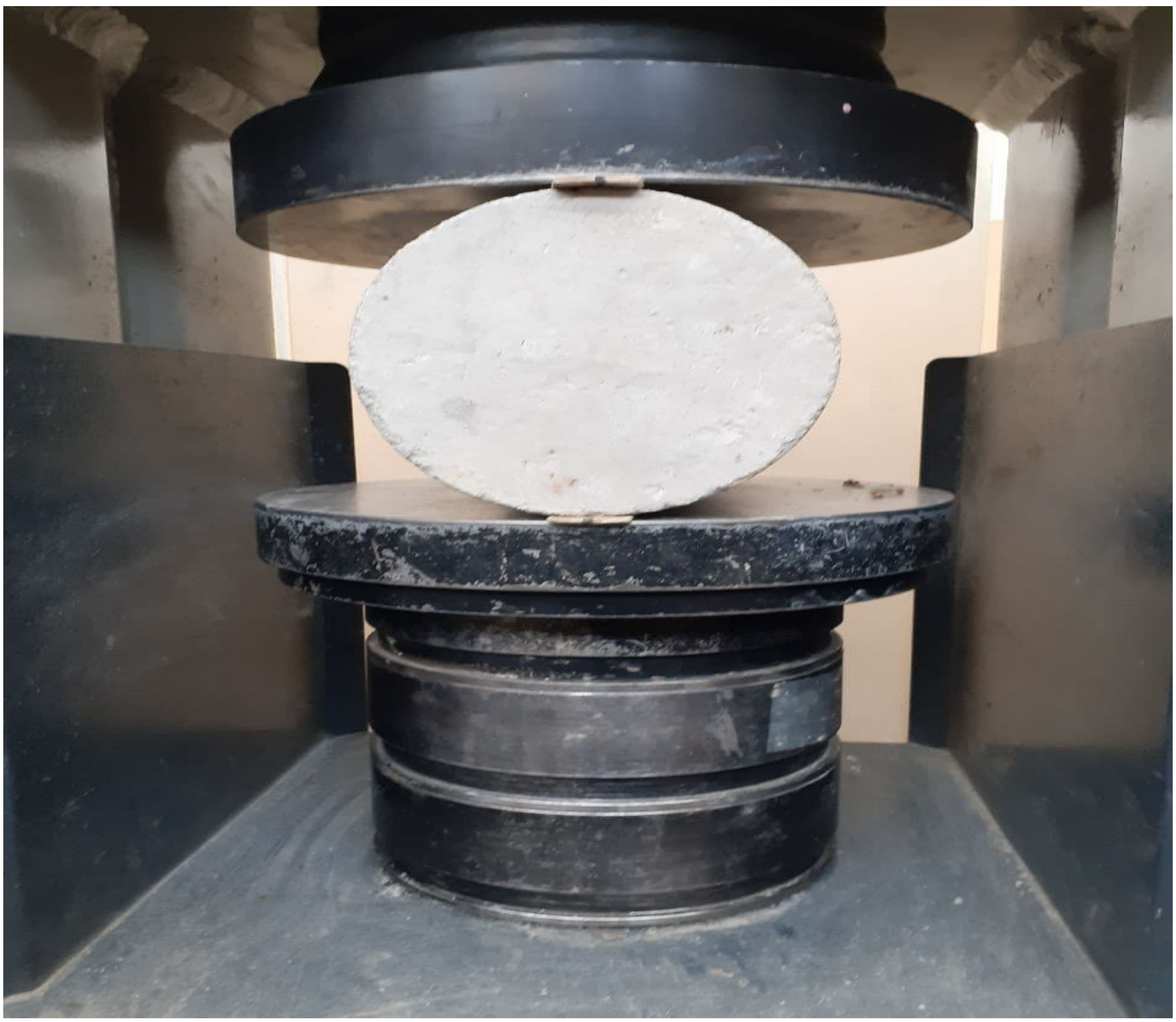

Figure 3. 9 Splitting Tensile Strength Testing

Chapter Four

4. Test Results and Discussions

4.1 Test Result

4.1.1 Fresh concrete properties

Among the fresh concrete properties slump test and fresh concrete unit weight tests are investigated for each concrete mixture incorporating normal and addition of 10mm, 15mm and 20mm length of Enset fiber by weight of concrete. Table 4.1 below shows slump and fresh concrete densities for each mix.

Table 4. 1 Slump and Fresh Concrete density test result

Mix Code	Slump(mm)	Density ($\frac{kg}{m^3}$)
M_0	38	2369.3
M_1	20	2355.1
M_2	15	2353.5
M_3	10	2350.7

4.1.2 Compressive strength

Three 150mm sized cube samples were tested for Normal mix and for each length of Enset fiber addition in this specific thesis. The results of the compressive strength tests at three different specimen ages (7 days, 14 days and 28 days) and the percentage increment of fiber added mix from that of normal mix are listed in Table 4.2, and illustrated in Figure 4.1.

Table 4. 2 Compressive strength results of concrete specimens

Code	Fiber Length (mm)	Compressive Strength (MPa)					
		7th day	Percentage increment	14th day	Percentage increment	28th day	Percentage increment
M_0	Normal mix	11.1		20.2		21.5	
M_1	10mm	14.7	32.4%	25.3	25.2%	31.2	45.11%
M_2	15mm	12.9	16.2%	24.9	18.3%	26.9	25.11%
M_3	20mm	12.2	9.99%	21.5	6.4%	24.3	13%

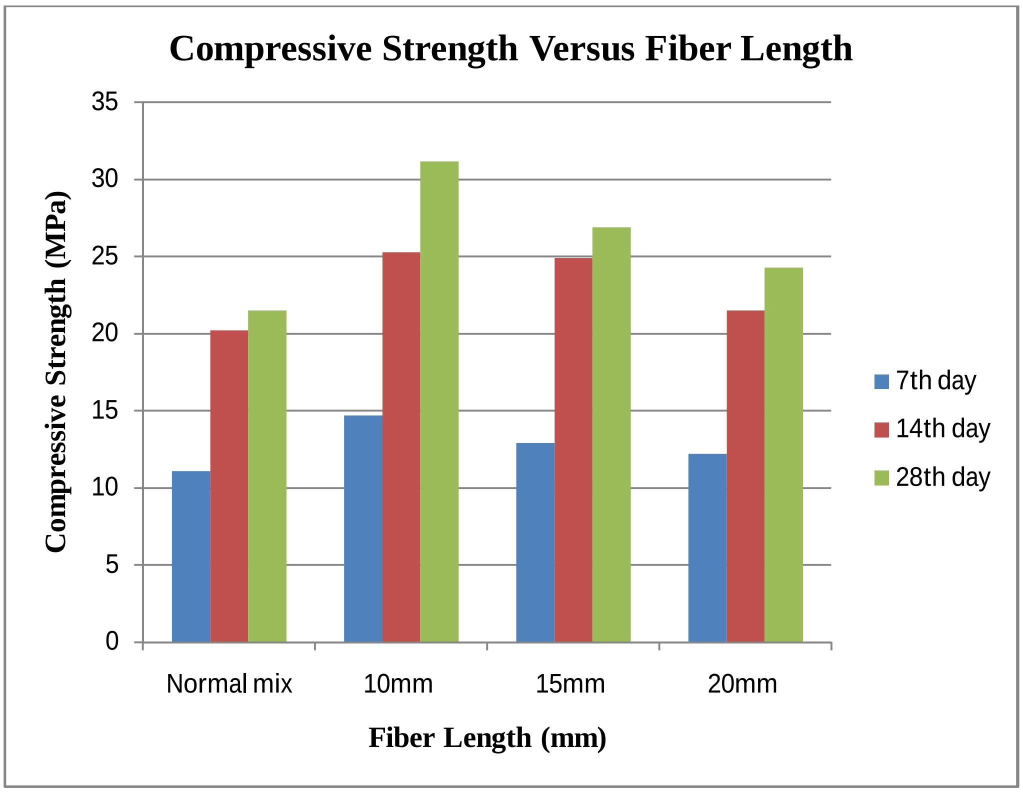

Figure 4.1 Variation of Compressive Strength with Fiber Length

It is to be noted from the above results that, for all the combinations of enset, the compressive strength is found to be greater than that of the normal concrete after 7, 14 and 28 days curing. From the obtained results that, compressive strengths for 10mm length Enset insertion are seen to be maximumfor7, 14and 28 days strength results.

4.1.3 Flexural strength test

The results of the flexural strength tests at three different specimen ages (7 days, 14 days and 28 days) and the percentage increment of fiber added mix from that of normal mix are listed in

Table 4.3 and illustrated in figure 3.10. For the sake of testing three prismatic samples each for different length addition of enset fiber by fiber length variation of concrete namely; 10mm, 15mm and 20mm were tested with third-point loading in accordance with ASTM C78 standard.

Table 4. 3 Flexural strength results of concrete specimens

Code	Fiber Length (mm)	Flexural Strength (MPa)					
		7th day	Percentage increment	14th day	Percentage increment	28th day	Percentage increment
M_0	Normal mix	1.86		2.50		3.11	
M_1	10mm	1.92	31.5%	3.21	28.4%	3.97	27.65%
M_2	15mm	2.60	78.08%	3.81	52.4%	4.7	51.12%
M_3	20mm	1.90	30.13%	2.71	8.4%	3.5	12.5%

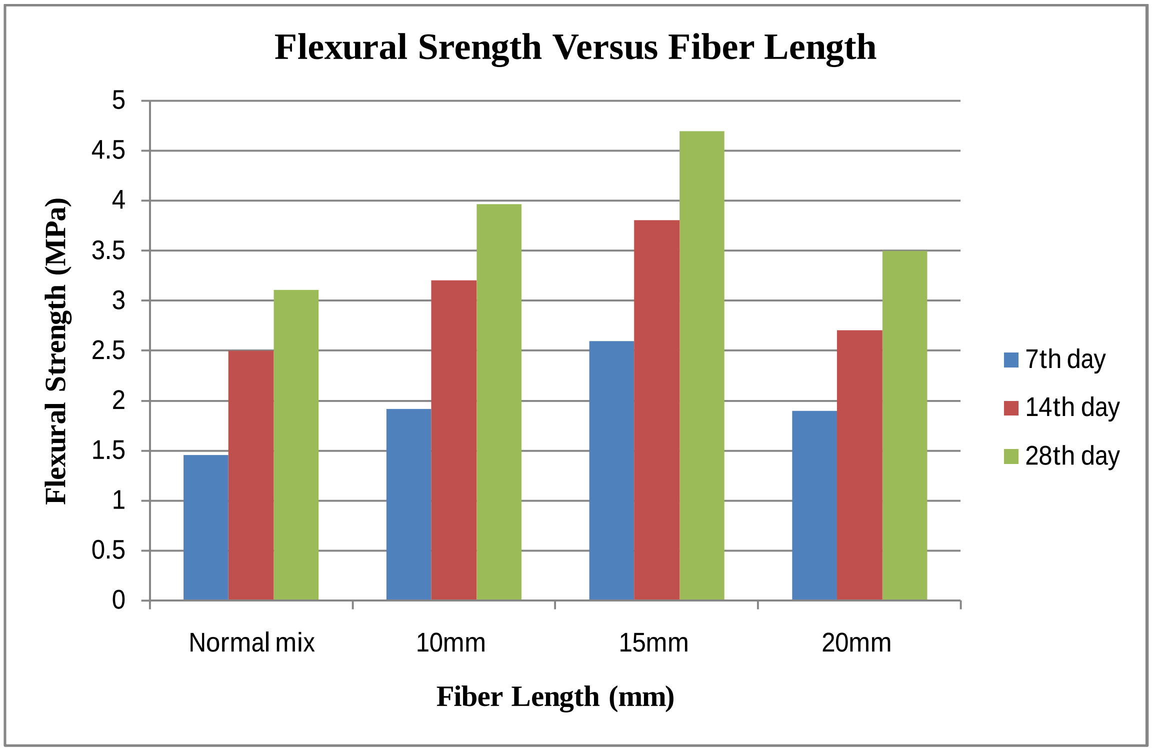

Figure 4.2 Variation of flexural strength with fiber length

From the previous obtained flexural strength results , for all the combinations of Enset, the flexural strength is found to be greater than that of the normal concrete after 7, 14 and 28 days curing. From the obtained results that, flexural strengths for 15mm length of Enset insertion are seen to be maximum for 7, 14and 28 days strength results.

4.1.4 Split tensile strength test

The splitting tensile strength test is an indirect tension test for concrete. It is carried out on a standard cylindrical specimen, tested on its side in diametric compression. In split tensile strength testing, length of enset fiber addition namely; 10mm, 15mm and 20mm was undertaken. Three cylindrical samples were tested for each length addition of enset fiber. Then the average Split tensile strength is recorded and listed below as a table and figure.

Splitting tensile test results are given in table 4.4 below and relationship between the Enset fiber length and corresponding concrete tensile split strength with respect to the control concrete are shown in Figure 4.3.

Table 4.4 Splitting tensile strength results of concrete specimens

Code	Fiber Length (mm)	Splitting tensile Strength (Mpa)					
		7 days	Percentage increment	14 days	Percentage increment	28 days	Percentage increment
M_0	Normal mix	1.27		2.15		2.45	
M_1	10mm	1.71	34.6%	2.87	33.4%	3.11	34.6%
M_2	15mm	2.10	65.3%	3.24	50.69%	3.51	43.2%
M_3	20mm	1.78	40.15%	2.44	13.48%	2.97	21.22%

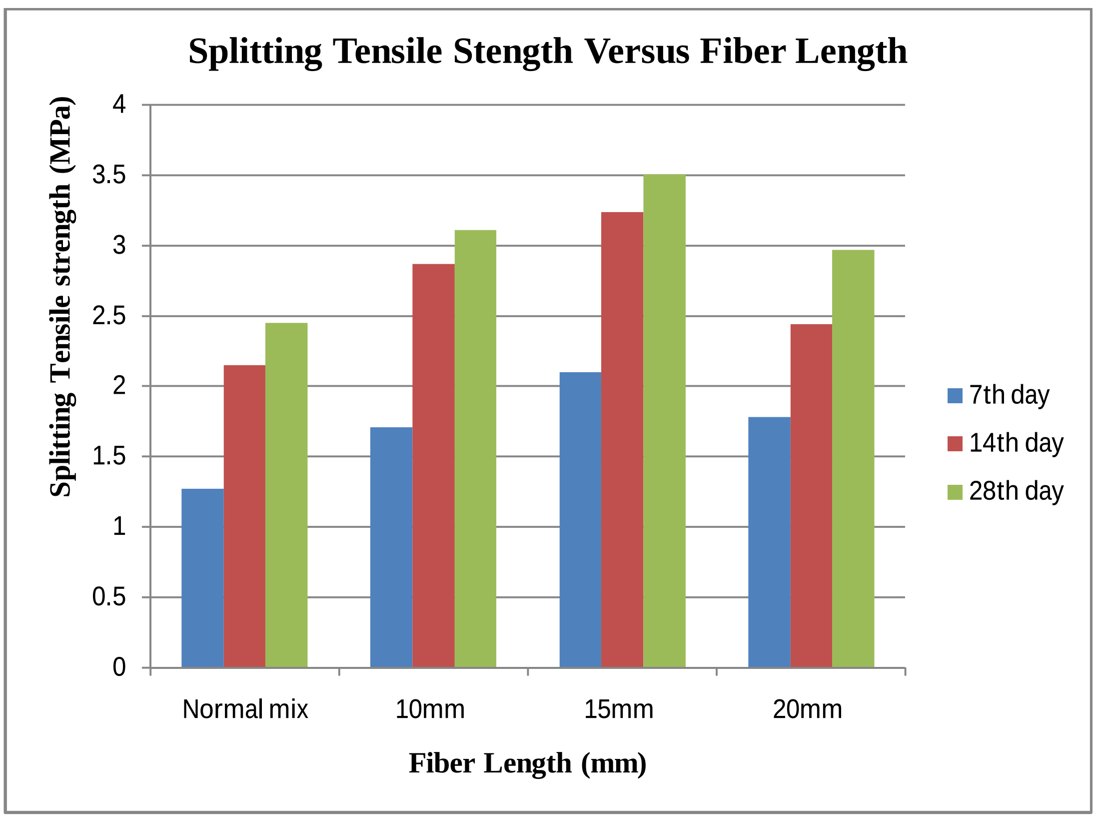

Figure 4.3 Split tensile strength variance with fiber length

- From the above obtained results , for all the combinations of Enset, the splitting tensile strength is found to be greater than that of the normal concrete after 7, 14 and 28 days curing. From the obtained results, tensile strengths for 15mm length Enset insertion are seen to be maximum for 7, 14and 28 days strength results.

4.2 Discussions

4.2.1 Effect of enset fiber length on the workability of concrete

Its workability is known to be the ease with which fresh concrete can be shaped, molded, and compacted without segregation. It is a freshly mixed concrete property that shows the amount of internal work required to overcome the internal tension between the concrete's individual constituents. The effect of fiber length on concrete workability in this study is negligible. There was a decrease in the downturn in all. Fiber reinforced concrete mix relative to standard concrete mix. This decrease in concrete workability was due to the presence of fibers in the mix that tend to lump, ball, and absorb some of the free water required for lubrication and paste formation. There is also the occurrence of poor adhesion between fibers and the matrix. Therefore, the mix required more efforts to compact.

4.2.2 Discussion on compressive strength

The compression-loaded plain concrete specimens experienced a highly unstable failure mode, while the fiber-reinforced concrete displayed a more robust nature. It can be checked from the outcome that the impact on the strength level of the enset fiber length has a deleterious effect.
In addition, in contrast to the shorter ones, this effect turns out to be more important for the long fibers. Short Fibers are also higher in number and therefore, much closer together; In the short fiber reinforced composites, there are more in volumes, which can contribute more bonding between fibers or between fiber and cement matrix. The long enset fiber length will block the bonding between fibers and cement matrix that significantly contribute to the lower strength. Thus, short fibers enhance the compressive strength of concrete more than longer Fibers.

4.2.3 Discussion on Flexural strength

For bridging discrete macro-cracks at higher loads, long fibers are required and the volume fraction of long fibers can be much smaller than the volume fraction of short fibers. However, In this current study, the greatest flexural strength was obtained for the length of enset fiber samples is at15mm length.

In addition, long fibers are more effective in delaying crack propagation and offer more resistance to being pulled out due to better bonding characteristics. Similarly longer fibers tend to orient along the length of the specimen due to the boundary effects in random generation. Therefore, the number of fibers across the crack plane is relative to the direction of applied load increases for longer fibers. But in this study the flexural strength is decreased at 20mm fiber length since fiber balling was observed during mix. Therefore for flexural strength of Enset Fiber reinforced concrete is better if the fiber length is not exceeding beyond the optimum fiber length which is 15 mm.

4.2.4 Discussion on splitting tensile strength

The result shows that enset fibers length has an effect to enhance the splitting tensile strength of concrete, but up to a limit. The split tensile strength of EFRC at each fiber length increases up to 15mm length before declining. The improvement in splitting tensile strength is the ability of effective fiber length to bridge across possible cracks and impact more ductility in the concrete as the specimens with short enset fiber length didn’t break into pieces, as seen in normal concrete without fiber specimens and specimen with longer fiber addition.

Chapter Five

5. Conclusions and Recommendations

Based on the experimental program conducted on mechanical characteristics of enset fiber reinforced concrete (EFRC) regarding laboratory investigations of concrete mechanical properties, namely compressive strength, flexural strength and split tensile strength; conclusions are drawn and recommendations are forwarded on the effect of enset fiber length addition in concrete strength.

5.1 Conclusions

1. The effect of enset fiber length did not strongly affect the workability of the fresh concrete that even if as the length increased, the workability is decreased.
2. The insertion of enset fiber at different length has significantly altered the compressive strength of concrete. Among all enset fiber reinforced concrete specimens, the specimens with lower length of enset fiber produced the higher compressive strength value. In the short fiber reinforced concrete, there are more volumes, which can contribute more bonding between fibers or between fiber and cement matrix. The long enset fiber length will block the bonding between fibers and cement matrix that significantly contribute to the lower strength.
3. With the variation of fiber length, it is seen that, the maximum tensile strength has occurred with addition of 15mm fiber length. Since effect of fiber length on Tensile strength is expressed as the ability of effective fiber length to bridge across possible cracks and impact more ductility in the concrete.
4. Long fibers are needed to bridge discrete macro-cracks at higher loads; and the volume fraction of long fibers can be much smaller than the volume fraction of short fibers. However, In this current study, the greatest flexural strength was obtained for the length of enset fiber samples is at15mm length.
5. In general, based on this study 15mm fiber length is selected as an effective length to enhance the mechanical properties of concrete

5.2 Recommendations

1. More laboratory investigations and tests ought to be performed to study on the other mechanical characteristics of enset fiber reinforced concrete with distinctive grades of concrete for the impact of fiber length.
2. The combination of fibers might also have a tendency to provide greater efficient mechanical properties of structure. Other investigation can be carried out through by combination of different kinds of fibers in the concrete mix.
3. Durability of enset fiber reinforced concrete should be studied.
4. The effect of enset fiber length on plastic shrinkage should be further studied.
5. It is highly recommended for the construction companies involved in the current construction industry to be very familiar in supporting different researches and adopt the use of fiber length especially natural fibers which are more economical and eco-friendly than the other fibers for an improved concrete strength production.
6. Primarily, traditional Enset fiber extraction and reducing techniques do have problems; be it in quality, accuracy and efficiency. To resolve these problems, it is strongly recommended to enhance a new method of acquiring Enset fibers with mechanical machines that extract and prepares Enset fibers with a desired quality, accuracy and efficiency.

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Appendix

Appendix A: Test for Constituent Material

Appendix A1: Physical Test for Coarse Aggregate

i) Moisture content of coarse aggregates:

Moisture content of coarse aggregate samples has to be determined as it affects workability and water-cement ratio in the mix design. A design water-cement ratio is usually specified based on the assumption that aggregates are inert (neither absorbs nor gives water to the mixture) and hence aggregates from different sources do not comply with this assumption of water cement ratio.

To determine moisture content, 2000 g coarse aggregate sample was weighed and oven dried for about 24hrs at a temperature of 105 c^o-110 c^o. The sample was removed from the oven and placed on desiccators for about an hour in order to cool without absorbing water from the atmosphere. The sample was then weighed (oven dry weight). Moisture content of the coarse aggregate in this case was calculated to be 1.94%.

Test Results:

A = 2000 g Where: A = weight of original sample [g]

B = 1960 gB = weight of oven dry sample [g]

Calculation

W = Moisture content (%) = $(\frac{A-B}{B}) \times 100$

$$= (\frac{2000-1962}{1962}) \times 100 = 1.94\%$$

ii) Sieve analysis

Sieve analysis is a procedure for the determination of the particle size distribution of aggregates using a series of square or round openings sieves starting with the largest opening at the top. Samples were prepared for particle size distribution in such a way that crushed basaltic stones with 19mm nominal maximum sizes were blended to keep graduation requirement within the range specified on ASTM Standard for grading coarse aggregates. The fineness modulus for this coarse aggregate sample was found to be 2.35%.

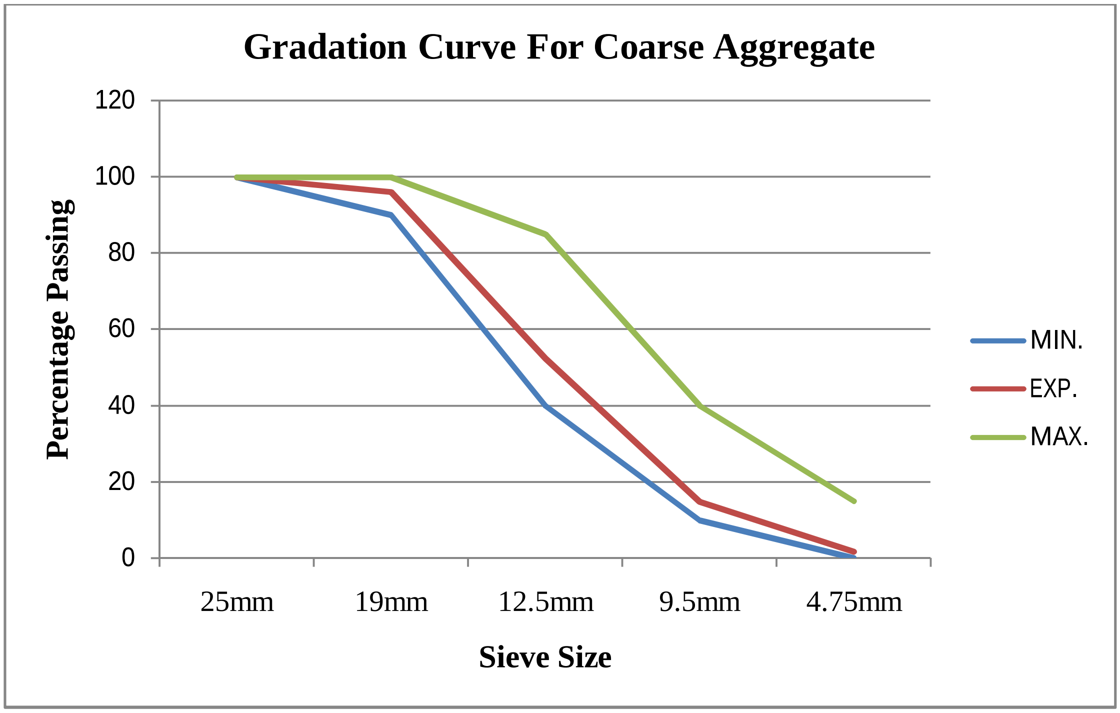


Figure Gradation Curve for Coarse Aggregate

<u>Test Result</u>

Table Particle Size Distribution for Coarse Aggregate

Sieve Size (mm)	Weight of Sieve (gm)	Weight of Sieve and Retained (gm)	Weight Retained (gm)	Percentage Retained (gm)	Cumulative Retained (gm)	Cumulative Passing (gm)
25	1210	1210	0	0	0	100
19	1280	1475	195	3.9	3.9	96.1
12.5	1160	3355	2195	43.9	47.8	52.2
9.5	1163	3033	1870	37.4	85.2	14.8
4.75	1170	1822	652	13.04	98.24	1.76
Pan	735	823	88	1.76	-	-
				Total	235.14	

Calculation

Fineness Modulus (F.M) = $\frac{\sum \text{Cumulative Retained}}{100}$

$= \frac{235.14}{100}$ = 2.35

iii) Specific gravity and absorption capacity

Specific gravity is the ratio between the density of the substance and the density of the reference substance, which is normally water; similarly, it is the ratio between the mass of the substance and the mass of the water for the same given volume. Absorption is the process by which water is drawn into and tends to fill the permeable pores in a porous solid body. An approximate coarse aggregate Sample of 5kg was acquired, by using quartering from the mass sample.

Measured quantities:

A = 4941 g Where: A = weight of oven-dry sample in air, [g]

B = 5033 g B = weight of saturated – surface – dry sample in air, [g]

C = 3243 g C = weight of saturated sample in water, [g]

Table below shown below summarizes the test results for bulk specific gravity, bulk specific gravity (SSD), apparent specific gravity and absorption capacity of coarse aggregates.

Table Specific Gravities and Absorption Capacity of Coarse aggregate

	Specific Gravity (OD)	Bulk Specific Gravity (SSD)	Apparent Specific Gravity	Absorption Capacity (%)
Calculation	$\frac{A}{B-C}$	$\frac{B}{B-C}$	$\frac{A}{A-C}$	$(\frac{B-A}{A}) \times 100$
Result	2.76	2.81	2.9	1.86

iv) Unit weight of coarse aggregates

The unit weight reflects the amount that the graded aggregate can occupy in concrete and contains both the solid aggregate particles and the voids between them. The unit weight is simply determined by filling a container of known volume and measuring it.Oven-dried coarse aggregate samples were used in this specific test. This method is applicable to maximum aggregate size of 40mm. Table below below shows dry rodded unit weight calculation of coarse aggregate used in this specific research.

Table Unit weight Determination for coarse aggregates

	Weight of Container (g)	Weight of Sample &Container (g)	Inside diameter of Container (mm)	Inside height of Container (mm)	Volume of Container (m^3)	Unit weight of coarse aggregate ($\frac{g}{m^3}$)
Calculation	-	-	-	-	V= $\frac{\pi D^2 h}{4}$	$\frac{27451 - 4842}{0.01404}$
Result	4842	27451	255	275	0.01404	1610.33

Appendix A2: Physical Test Fine Aggregate

i) Silt Content

The distinction between silt & clay can't be based on particle size because both are microscopic having sizes finer than No. 200 (0.075mm) sieve and hence the significant physical properties of the two materials are related only indirectly to the size of particles. The objective of this test is to determine these fine particle contents from the mass sand sample.

<u>Test results:</u>

A = 10ml Where: A = amount of silt deposited above the sand

B = 290ml B = amount of clean sand

<u>Calculation</u>**:**

Silt content (%) = $\frac{A}{B} \times 100 = \frac{10}{290} \times 100 = 3.44\ \% < 6\ \%$ OK!

Based on the Ethiopian Standard,(Abebe Dinku, "Construction Materials Laboratory Manual" Faculty of Technology, AAU, Department of Civil Engineering: June 2002) if the silt content of the sand is more than 6% it is recommended either to wash or to reject the sand.

ii) Moisture content

To determine the moisture content, 500g fine aggregate sample was weighed and oven dried for about 24hrs to remove moisture contained in the sample with a temperature of 105 oC-110 oC. The sample was then removed from the oven and placed on a desiccators for about an hour in order to cool without absorbing water from the atmosphere. The sample was then weighed (oven dry weight). Moisture content of the fine aggregate in this specific research was calculated to be 2.88%.

<u>Test Results:</u>

A = 500 g Where: A = weight of original sample [g]

B = 486gB = weight of oven dry sample [g]

<u>Calculation</u>

W = Moisture content (%) = $\left(\frac{A-B}{B}\right) \times 100 = \left(\frac{500-486}{486}\right) \times 100 = 2.88\%$

iii) Sieve analysis

Samples were prepared for particle size distribution in such a way that river sand with 4.75 mm nominal maximum sizes was prepared in accordance with the gradation requirement specified in the ASTM Standard for the grading of fine aggregates.

Fineness modulus for this fine aggregate sample came to be 2.91%. The sand sample used in this specific research was tested to have a particle size distribution within the range of the ASTM Standard for the grading of fine aggregate. Thus it satisfies the gradation requirement.

A detailed gradation test results for fine aggregates in comparison with the requirements set in the ASTM Standard for grading of fine aggregate using ranges of percentage passing through each sieve openings were presented in figure below.

Figure below shows gradation curve for fine aggregate used in the research in comparison to the minimum and maximum quantities of fine aggregates on series of sieves specified in the ASTM Standard.

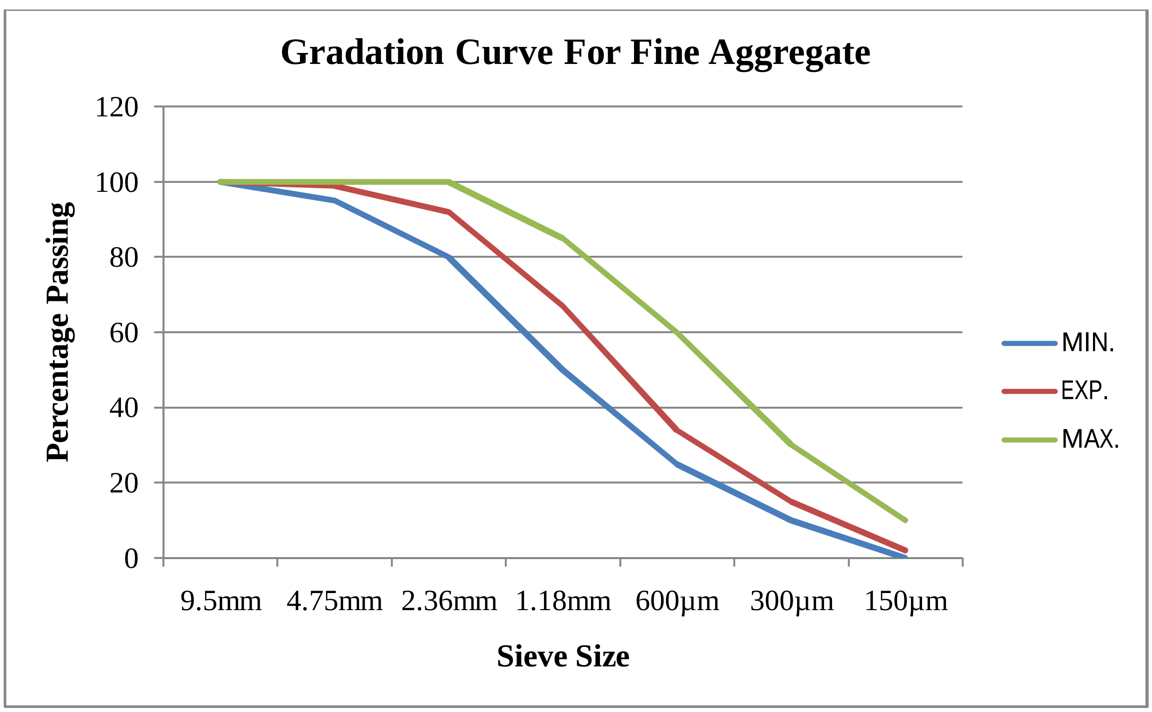


Figure Gradation Curve for Fine Aggregate

Test Result

Table Particle Size Distribution for Fine Aggregate

Sieve Size (mm)	Weight of Sieve (gm)	Weight of Sieve and Retained (gm)	Weight Retained (gm)	Percentage Retained (gm)	Cumulative Retained (gm)	Cumulative Passing (gm)
9.5	515	515	0	0	0	100
4.75	425	430	5	1	1	99
2.36	390	425	35	7	8	92
1.18	375	500	125	25	33	67
0.6	325	490	165	33	66	34
0.3	310	405	95	19	85	15
0.15	285	350	65	13	98	2
Pan	240	250	10	2	-	-
				Total	291	

Calculation

Fineness Modulus (F.M) = $\frac{\sum \text{Cumulative Retained}}{100} = \frac{291}{100}$ = 2.91

iv) Specific gravity and absorption capacity

The objective of this test is to determine bulk and apparent specific gravity, and absorption capacity of the fine aggregates. Approximately 500g of the fine aggregate sample from the availed mass of the total was taken by using a method of sample splitter.

Measured quantities:

S = 500 g Where: S =Weight of Sample.

B = 705g B = weight of pycnometer filled with water to calibration mark.

C = 997.1g A = Weight of oven dry sample.

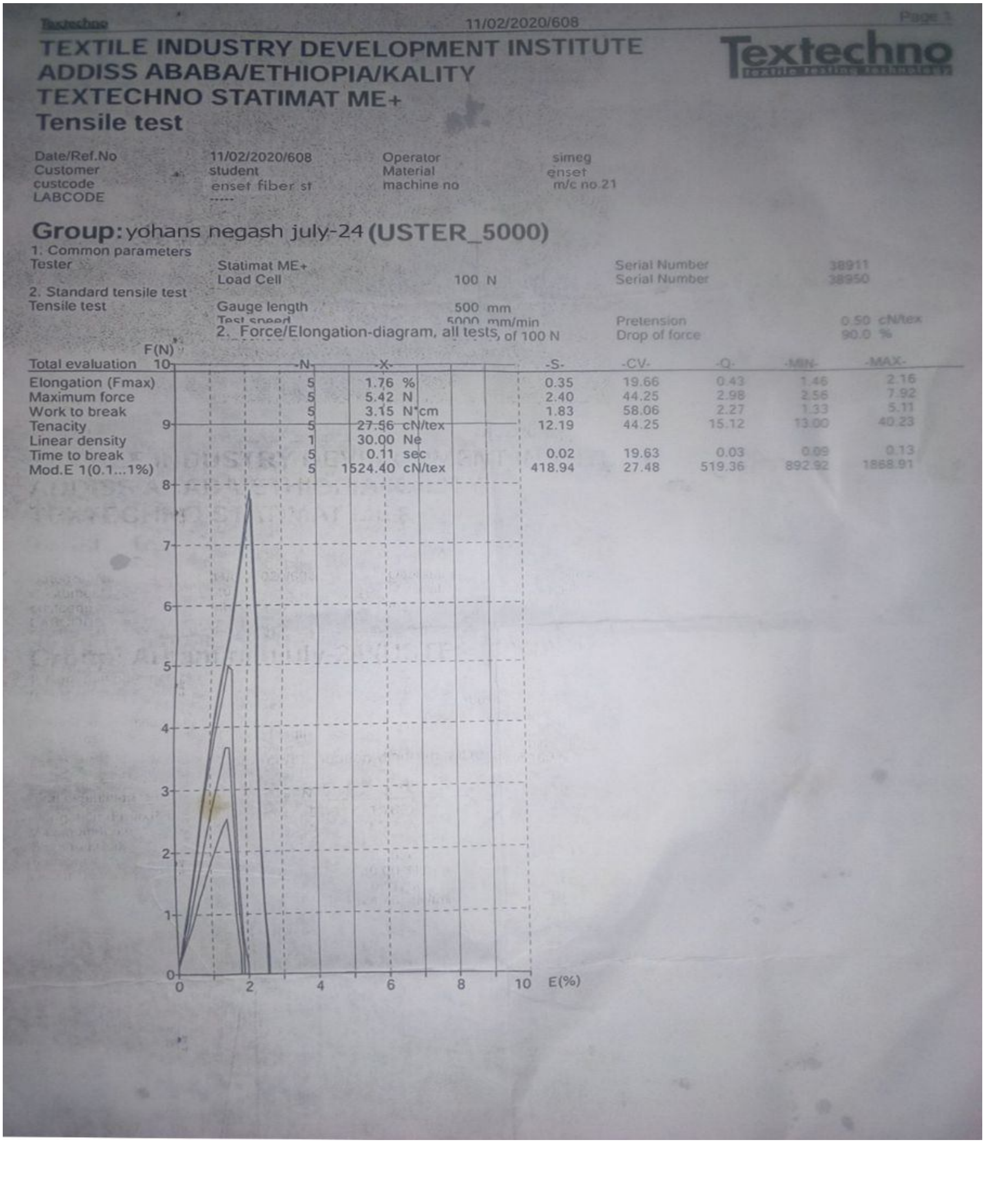
A = 491.2 g C = weight of pycnometer filled with sample & water to calibration mark.

Table shown below summarizes the test results for bulk specific gravity, bulk specific gravity (SSD basis), apparent specific gravity and absorption capacity of fine aggregates.

Table Specific Gravities and Absorption capacity of Fine Aggregates

	Specific Gravity (OD)	Bulk Specific Gravity (SSD)	Apparent Specific Gravity	Absorption Capacity (%)
Calculation	$\frac{A}{B + S - C}$	$\frac{S}{B + S - C}$	$\frac{A}{B + A - C}$	$(\frac{S - A}{A}) \times 100$
Result	2.36	2.40	2.47	1.79

Appendix B: Tensile strength test of Enset fiber



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TEXTILE INDUSTRY DEVELOPMENT INSTITUTE
ADDISS ABABA/ETHIOPIA/KALITY
TEXTECHNO STATIMAT ME+
Tensile test

Date/Ref.No	11/02/2020/608	Operator	simeg
Customer	student	Material	enset
custcode	enset fiber st	machine no	m/c no 21
LABCODE	-----		

Group: yohans negash july-24 (USTER_5000)

1. Common parameters

Tester	Statimat ME+		Serial Number	38911
	Load Cell	100 N	Serial Number	38950

2. Standard tensile test

Tensile test	Gauge length	500 mm		
	Test speed	5000 mm/min	Pretension	0.50 cN/tex
			Drop of force	90.0 %

2. Force/Elongation-diagram, all tests, of 100 N

Total evaluation	-N-	-X-	-S-	-CV-	-Q-	-MIN-	-MAX-
Elongation (Fmax)	5	1.76 %	0.35	19.66	0.43	1.46	2.16
Maximum force	5	5.42 N	2.40	44.25	2.98	2.56	7.92
Work to break	5	3.15 N*cm	1.83	58.06	2.27	1.33	5.11
Tenacity	5	27.56 cN/tex	12.19	44.25	15.12	13.00	40.23
Linear density	1	30.00 Ne					
Time to break	5	0.11 sec	0.02	19.63	0.03	0.09	0.13
Mod.E 1(0.1...1%)	5	1524.40 cN/tex	418.94	27.48	519.36	892.92	1868.91