ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

INVESTIGATION OF MECHANICAL PROPERTIES OF CONCRETE WITH ASPECT RATIO OF PINEAPPLE LEAF FIBERS.

A Thesis in Structural Engineering

By Tewodros Tilahun

September 29,2023

Addis Ababa

A Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science

The undersigned have examined the thesis entitled '**Investigation of Mechanical Properties of Concrete with Aspect Ratio of Pineapple Leaf Fibers.**' presented by **Tewodros Tilahun**, a candidate for the degree of **Master of Science** and hereby certify that it is worthy of acceptance.

Dr.-Ing. Adil Zekaria		
Advisor	Signature	Date
your Internal Examiners' Name		
Internal Examiner	Signature	Date
your External Examiners' Name		
External Examiner	Signature	Date
Dean of schools' Name		
Chair person	Signature	Date

UNDERTAKING

I certify that research work titled “Investigation of Mechanical Properties of Concrete with Aspect Ratio of Pineapple Leaf Fibers.” is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

Signature _______________

Tewodros Tilahun

ACKNOWLEDGEMENT

First and foremost, I would like to express my gratitude to almighty of God for granting me the strength, determination, and resources to successfully complete this thesis.

I would like to express my deepest gratitude, appreciation and admiration to my advisor, Dr.-Ing. Adil Zekaria, for his `exceptional support, inspiration, guidance, and valuable feedback throughout the thesis. I am inspired by his dedication, commitment and research abilities.

I would like to extend my gratitude and recognition to all the members of the laboratory staff for their invaluable assistance and support.

Furthermore, I would like to express my heartfelt appreciation to my family and friends for their countless words of encouragement and unwavering support.

Last but not least, I want to express my gratitude to all individuals who have provided both direct and indirect support during my research.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials.
ACI	American Concrete Institute
OPC	Ordinary Portland Cement
PALF	Pineapple Leaf Fiber
NaOH	Sodium Hydro oxide
$C_7H_{15}ClO$	Benzoyl Chloride
C.A	Coarse Aggregate
F.A	Fine Aggregate

ABSTRUCT

The paper aims to investigate the influence of incorporating PALF (pineapple leaf fiber) on the mechanical properties of concrete, with a particular focus on the aspect ratio of PALF. This study has to search thoroughly into how varying the aspect ratio of PALF affects the overall performance of concrete as a construction material. The research methodology involves incorporating different aspect ratios of PALF into concrete mixtures, followed by a thorough examination of the resulting mechanical properties. The aspect ratio, which is the ratio of the length to the diameter or width of the PALF fibers, is a critical parameter to study because it can significantly impact the behavior of the composite material. The study will employ various mechanical tests, such as tensile strength, compressive strength and flexural strength, to assess how the different aspect ratios of PALF affect these properties. Additionally, the work will investigate the durability and long-term performance of concrete with PALF reinforcements, considering factors like moisture absorption and aging. Furthermore, the paper will investigate into the implications of the findings for practical applications in the construction industry. Understanding how the aspect ratio of PALF influences concrete's mechanical properties can provide valuable insights for designing sustainable and high-performance concrete composites.

In addition to the investigation of PALF's impact on concrete properties, this research shows the influence of sodium hydroxide (NaOH) treatments on enhancing PALF's properties. These treatments are important to mitigate the hydrophilic nature of the fibers, thereby improving their compatibility with hydrophobic fibers within the concrete matrix. The study systematically analyzes the effects of different concentrations of NaOH on the PALF fibers, specifically Alkali 1 wt., Alkali 2 wt., Alkali 4 wt., and Alkali 8 wt. The concrete samples are subjected to testing at different time intervals: the 7th day (representing the initial stage) and the 28th day (representing the final settling period). Moreover, this investigation is carried out in conjunction with varying aspect ratios of PALF, which include 150, 450, 750, and 1050. the result show that 150 is shown an incremental improvement when compared to the control mix and 450 is the optimum amount of PALF to enhance all three mechanical properties in the other way 1050 aspect ratio showing a significant decrease in strength and the 750 aspect ratio exhibiting a decline compared to the control mix.

Key Words— compressive strength, concrete, flexural strength, split tensile strength, mechanical property, chemical composition, aspect ratio, pineapple leaf fiber (PALF).

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the Study

Concrete, produced mainly with Portland cement, is the most commonly used artificial material in construction. However, it can be brittle and weak in tension while relatively strong in compression. To enhance its tensile properties, fibers are added to create fiber-reinforced concrete. Currently, numerous studies are underway to explore the use of natural fibers as substitutes for synthetic fibers in concrete reinforcement. Natural fibers possess excellent mechanical properties, including high strength, stiffness, and toughness, as well as favorable thermal and acoustic insulation characteristics. These fibers can be obtained from various sources such as plants, animals, and minerals. Commonly used natural fibers in composites include jute, sisal, bamboo, coir, hemp, and flax. These fibers are typically combined with a polymer matrix, such as epoxy or polyester, to form composite materials that exhibit improved mechanical properties compared to the polymer matrix alone.

The use of natural fibers in composites offers several advantages over synthetic fibers. Firstly, natural fibers are renewable resources that can be easily grown and harvested, making them more sustainable than synthetic fibers derived from non-renewable sources. Secondly, natural fibers are biodegradable and have low density, meaning they can easily decompose in the environment through the action of microorganisms. This reduces the environmental impact of composite materials made from natural fibers. Thirdly, natural fibers are cost-effective due to their ready availability and the absence of complex manufacturing processes. As a result, the development of natural fiber composites has gained significant attention in recent years, driven by their cost-effectiveness, sustainability, and improved mechanical properties. The utilization of plant fibers in composites has been extensively studied, with researchers investigating the influence of fiber content, fiber length, and fiber orientation on the mechanical properties of the composite material. Studies have shown that increasing fiber content and length improves the mechanical properties of the composite material. Plant fibers have been proposed as an alternative to synthetic fibers in composites, such as cement paste, mortar, or concrete, to enhance their strength and ductility [1].

When concrete cracks, randomly oriented fibers come into action, arresting the development and propagation of cracks, thereby enhancing the strength and ductility of the material [2]. Pineapple leaf fiber, known for its exceptional mechanical strength and high-quality characteristics, distinguishes itself among various fibers [2]. Pineapple (Ananas Comosus) is the world's third most important tropical fruit, following banana and citrus in significance. Pineapple leaf fiber exhibits superior properties, including high specific strength, rigidity, flexural rigidity, and torsional rigidity, surpassing other fiber types [2]. Previous studies have highlighted epoxy as the most widely employed thermoset material in natural fiber-reinforced composites, although polyester, phenol formaldehyde (PF), and vinyl ester are also commonly used [3-6]. The inclusion of fibers in concrete leads to an increase in the interfacial bonding between aggregates. However, it is important to acknowledge that the presence of fibers can have an impact on the workability of concrete. Specifically, the introduction of fibers may result in fibrillation occurring within the concrete mixture [7-8]. Moreover, the presence of fibers in concrete can also influence the moisture content within the mixture. This is because fibers have the propensity to absorb moisture, which subsequently affects the slump value of the concrete [9].

1.2 Statement of problem

Despite concrete's high compressive strength, it exhibits limited resistance to tensile stresses, which renders it susceptible to brittle failure when subjected to excessive tension. This poses a significant challenge in ensuring the safety and durability of concrete structures, as sudden and unexpected failures can lead to severe consequences. Therefore, there is a critical need to investigate and develop effective strategies to enhance the tensile strength and ductility of concrete, while minimizing crack propagation. This research aims to mitigate the risk of brittle failure and ensure the long-term performance of concrete structures.

The occurrence and propagation of cracks in concrete structures raise significant concerns regarding their long-term durability and performance. Specifically, the width of these cracks holds paramount importance as it directly influences various aspects, including structural integrity, serviceability, and durability.

1.3 Significance of the research

The purpose of this study is to investigate the use of PALF (Pineapple Leaf Fiber) in concrete and determine the aspect ratio that yields optimal mechanical properties, specifically in terms of compressive, tensile, and flexural effects. Additionally, aim to identify the chemical composition percentage by weight that exhibits consistent behavior in enhancing PALF properties and strengthening the material itself. PALF's durability is greatly influenced by these factors.

The incorporation of fibers in concrete not only contributes to its durability but also reinforces its resistance to crack development and propagation. This reinforcement provided by fibers significantly improves the overall strength and ductility of the concrete, rendering it highly resistant to cracking under various loads and environmental conditions.

1.4 Objective of Research

1.4.1 General Objective:

The primary objective of this research is to enhance the tensile strength properties of concrete, thereby improving its resistance to cracking and structural failure.

1.4.2 Specific objective:

To achieve these goals, the research will focus on the following specific objectives:

1. Determine the optimal percentage of chemicals to enhance the strength of PALF fibers. This investigation will involve identifying the precise amount of chemical additives that can effectively improve the reinforcing properties of the fibers, thereby enhancing the overall strength of the concrete.
2. Precisely determine the optimal aspect ratio of PALF, which refers to the length-to-diameter ratio. Through careful optimization of this aspect ratio, the research aims to reinforce the concrete effectively with PALF, leading to improved durability and enhanced performance of the material.
3. Address the issue of moisture-induced clog spalling, characterized by surface degradation and the formation of spalls or cracks due to trapped moisture in the concrete. By minimizing the adverse effects of moisture clog spalling, the research aims to significantly enhance the longevity and reliability of concrete structures. This will ensure their ability to withstand a wide range of environmental conditions while maintaining their structural integrity over an extended period.

   By accomplishing these specific objectives, the research endeavors to provide valuable insights and practical solutions to overcome the limitations and drawbacks associated with conventional concrete. The ultimate aim is to advance the field of construction materials and contribute to the development of more resilient and sustainable infrastructure.

1.5 Scope of the research

Nevertheless, natural fibers in composites present certain drawbacks, primarily due to their limited compatibility with the matrix. Since the fibers are randomly oriented in the concrete, some fibers may contribute to the reinforcement while others may not. This variability poses challenges in accurately predicting the performance of the fibers. Additionally, natural fibers tend to exhibit relatively high moisture absorption, which can have an impact on their properties. To overcome these challenges, chemical treatments are being considered to modify the surface properties of the fibers. However, it is important to note that while chemical treatments can enhance fiber strength, they may also affect the fiber's ability to adhere to the matrix. Consequently, adjustments to the mixture design and finishing practices may be required.

Furthermore, this research specifically focuses on two variables: the chemical composition and the aspect ratio. It is important to note that these variables are not integrated into the current study.

1.6 Organization of the research

The organization of the research is as follows:

Chapter One: Introduction

This chapter serves as a comprehensive introduction to the thesis, offering an in-depth overview of the research topic. It provides essential background information to establish the context and significance of the study. Furthermore, the chapter presents a clear rationale for undertaking the research, highlighting the gaps or limitations in existing knowledge and explaining the need for further investigation. By laying the groundwork in this introductory chapter, the research aims to engage the readers and provide them with a solid understanding of the research objectives and motivations.

Chapter Two: Literature Review

This chapter critically examines the relevant literature on the aspect ratio and chemical composition. It also delves into a detailed discussion on PALF (Pineapple Leaf Fiber) and the testing techniques employed for cube, cylinder, and flexure specimens.

Chapter Three: Methodology

The third chapter outlines the extraction procedure of PALF, as well as the surface treatment methods employed. Furthermore, the materials and methods used in the study are presented, along with the testing procedures.

Chapter Four: Results and Discussions

In this chapter, the results obtained from the research are presented and thoroughly discussed. The findings are analyzed and interpreted in light of the research objectives.

Chapter Five: Conclusions and Recommendations

The final chapter summarizes the key conclusions drawn from the research findings. Additionally, recommendations for future work in the field are provided, highlighting areas that require further investigation and development.

By following this organizational structure, the research aims to present a coherent and comprehensive analysis of the topic, leading to valuable insights and potential avenues for future research.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction

Several researchers have conducted investigations into the impact of pineapple leaf fiber on the mechanical properties of concrete. Pineapple leaf fiber, also known as PALF, serves as a reinforcing material in concrete, aiming to enhance its strength and durability.

2.2 Previous Research Relevant to the Study

2.2.1 Effect of Pineapples leaf fiber on Concrete Properties

A study was conducted to investigate the behavior of pineapple leaf fiber (PALF) In order to achieve the desired strength; a control mix was carefully selected through a process of trial and error. The resulting strengths at 7th days and 28th days were determined and recorded in Table 2.1. The initial mix was designed to have a slump value of 150mm, and the characteristic compressive strength was measured as 34.29 MPa [9].

Table 2.1 Control mix result

Grade of concrete	Mean compressive strength of concrete(MPa)	
	7th	28th
M25	22.81	34.29

In this study, various percentages of pineapple leaf fiber (PALF) were incorporated into the concrete mix, namely 0.05%, 0.10%, 0.15%, 0.20%, and 0.25%. The researcher aimed to determine the impact of PALF on the compressive strength of the concrete.

Initially, the control mix without PALF exhibited a compressive strength of 22.81 MPa after 7 days of curing and 34.29 MPa after 28 days of curing. Subsequently, compressive strength values were obtained for different PALF content levels.

The concrete mixture with a 0.10% PALF addition demonstrated the highest compressive strength at the 7-day mark, measuring 27.31 MPa. This result indicated a notable improvement of 20% compared to the control mix. Similarly, at the 28-day mark, the concrete mixture with a 0.10% PALF addition achieved the peak compressive strength of 40.53 MPa, which represented an 18% increase over the control mix.

These findings provide evidence that the addition of 0.1% pineapple leaf fiber to M25 concrete can effectively replace the need for M30 concrete [9].

Table 2.2 Compressive Strength

F/C ratio (%)	Compressive Strength(MPa)	
	7th	28th
0	22.81	34.29
0.05	26.01	38.35
0.1	27.31	40.53
0.15	26.15	38.35
0.2	25.72	37.34
0.25	24.84	37.05

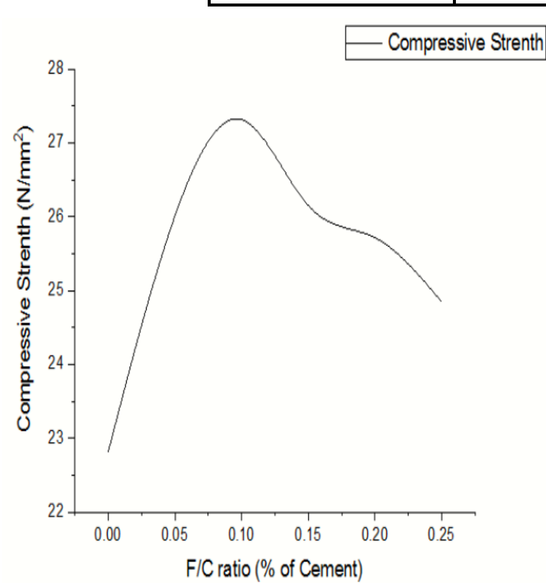


Figure 2.1: 7th Day compressive strength

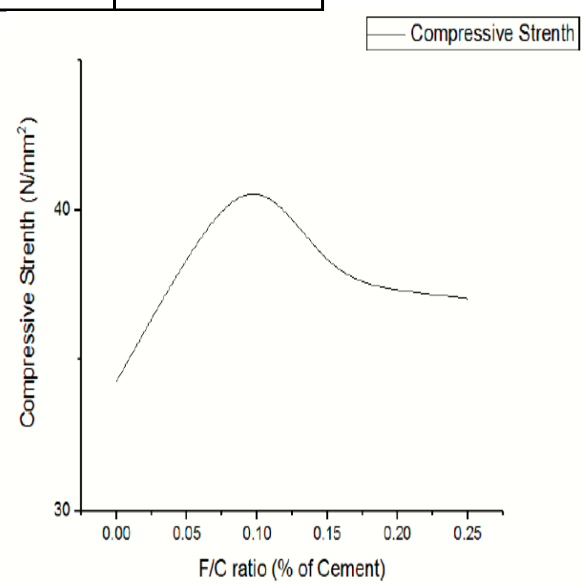


Figure 2.2: 28th Day compressive strength

Based on the analysis of figures 2.1 and 2.2, it is evident that the optimum proportion of pineapple fiber (PALF) in the mix is 0.1%. The compressive strength exhibits an increasing trend up to this proportion, followed by a decline at 0.15% PALF content, which continues to decrease further. Notably, the highest compressive strength values were achieved with a PALF addition of 0.1%, measuring 27.31 MPa after 7th days of curing and 40.53 MPa after 28th days of curing. Considering these test results, the optimal fiber-to-cement (f/c) ratio of 0.1% is selected for fabricating specimens intended for high-temperature testing [9].

The experiment involved conducting tests on 150 × 150 × 150 mm cubes, 300mm length and 150mm diameter cylinder, 100 × 100 × 500 mm beams by incorporating different proportions of PALF into the mixture. Subsequently, were tested after a curing period of 28 days. A total of 10 cubes, cylinder, and beams separately were prepared, with two cubes for each PALF percentage tested (0%, 0.05%, 0.1%, 0.15%, and 0.2%). The test outcomes are presented in Tables, while Figures illustrates the variation in compressive, tensile, flexure strength respectively relative to the different PALF percentages [1].

Table 2.3 Compressive strength of concrete

Percentage of PALF added	Compressive strength (MPa)
0.0%	21.19
0.05%	23.99
0.1%	38.88
0.15%	36.22
0.2%	35.55

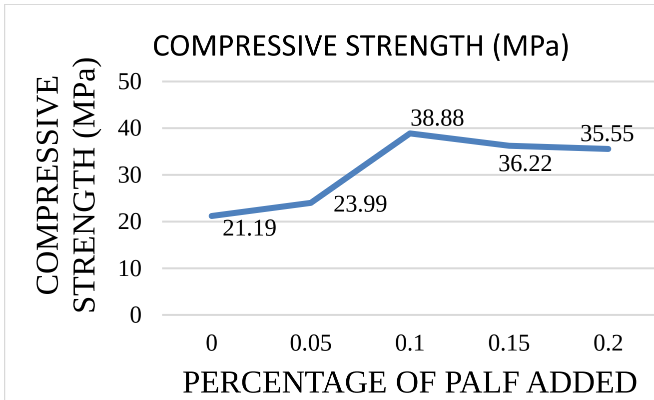


Figure 2.3: Effect of PALF on Compressive Cubes Strength.

Table 2.4 Split Tensile strength of concrete

Percentage of PALF added	Split Tensile strength (MPa)
0.00%	2.96
0.05%	3.6
0.10%	4.45
0.15%	3.53
0.20%	3.53

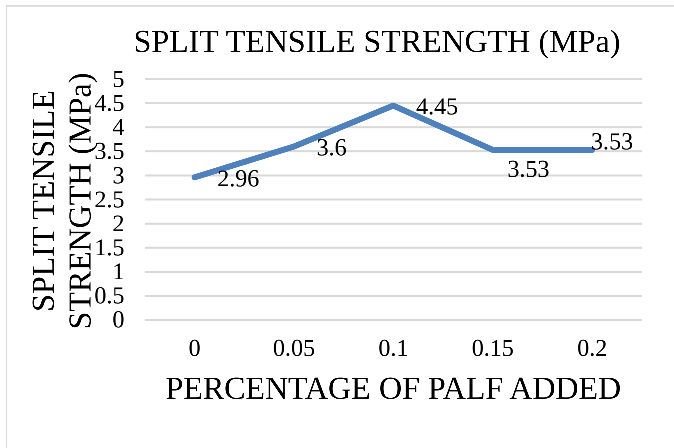


Figure 2. 4: Effect of PALF on Split Tensile of Strength.

Table 2.5 Flexural strength of concrete

Percentage of PALF added	Flexural strength (MPa)
0.00%	4.66
0.05%	5.74
0.10%	6.14
0.15%	5.19
0.20%	4.39

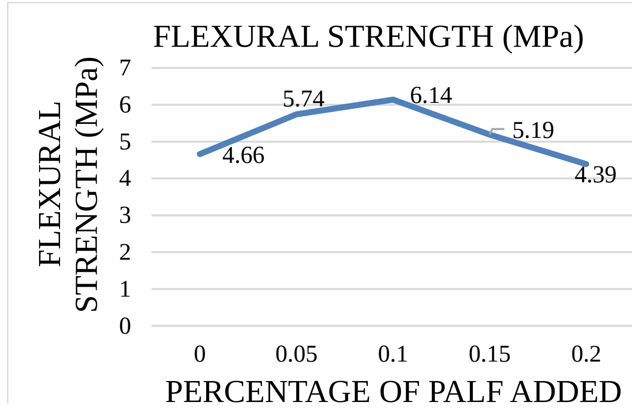


Figure 2.5: Effect of PALF on Flexural Strength of concrete

Based on the conclusive test results, it can be inferred that pineapple fiber (PALF) demonstrates promising potential as an effective fiber reinforcement in concrete. The highest strength achievement was observed when 0.1% PALF, relative to the weight of cement, was incorporated into the concrete matrix. Additionally, this optimal fiber content exhibited an aspect ratio of 450, further emphasizing its advantageous performance [1].

It was studied the experimental study on concrete properties using pineapple leaf fiber. It takes 2 sample on each fiber contents. cubes, split tensile & flexural strength of concrete on top of that he studied that what amount of water-cement ratio are significantly enhance the mechanical properties of strength of concrete The cube specimens were subjected to cube-compressive testing using a compression testing machine in accordance with the IS 416-1964 standard. The testing machine had a capacity of 1000KN. Table 2.6 presents the highest achieved compressive strength for a water-cement ratio of 0.45, while Table 2.7 displays the maximum compressive strength value attained at a fiber-cement ratio of 0.1% after 28 days of curing [10].

Table 2.6 Maximum Compressive strength obtained in water cement ratio of 0.45

S.No	Water Content	Conventional Concrete Compressive Strength (MPa)	
		7 days	28days
1	0.45	20.96	20.3
2	0.5	15.18	16.33
3	0.55	11.476	12.93

Table 2.7 Maximum value of compressive strength obtained at 0.1% of fiber-cement ratio in 28 days.

S.No	Fiber Cement Ratio(%)	28 Days Compressive Strength (MPa)		
		Sample1	Sample2	Average Strength
1	0.05	31.55	31.20	30.80
2	0.1	34.25	34.00	33.80
3	0.15	32.00	31.60	32.75
4	0.2	28.88	27.50	27.65

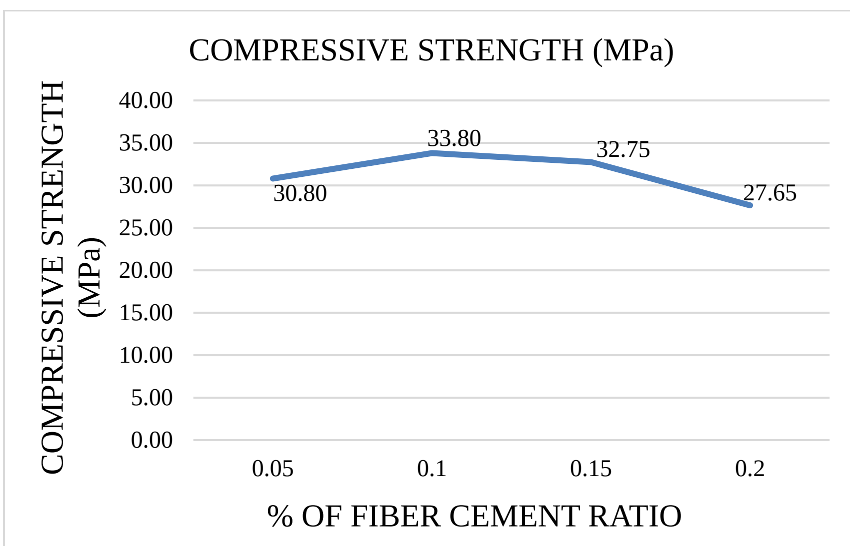


Figure 2.6: Compression strength vs. % of fiber cement

Table 2.8 presents the tabulated results of the flexural strength tests conducted on the concrete beams. Figure 2.7 illustrates the cracked beam that was loaded in the Universal Testing Machine (UTM). The experimental values obtained from the tests have been tabulated and plotted in Figure 2.8 for a comprehensive visual representation.

Figure 2.7: Testing of PALF reinforced beam

Table 2.8 The Average Flexural strength of Concrete

S.No	Fiber Cement Ratio(%)	28 Days Flexural Strength (MPa)		
		Sample1	Sample2	Average Strength
1	0.05	4.50	4.72	4.61
2	0.1	6.73	7.21	6.83
3	0.15	8.90	8.45	8.67
4	0.2	7.44	7.86	7.59

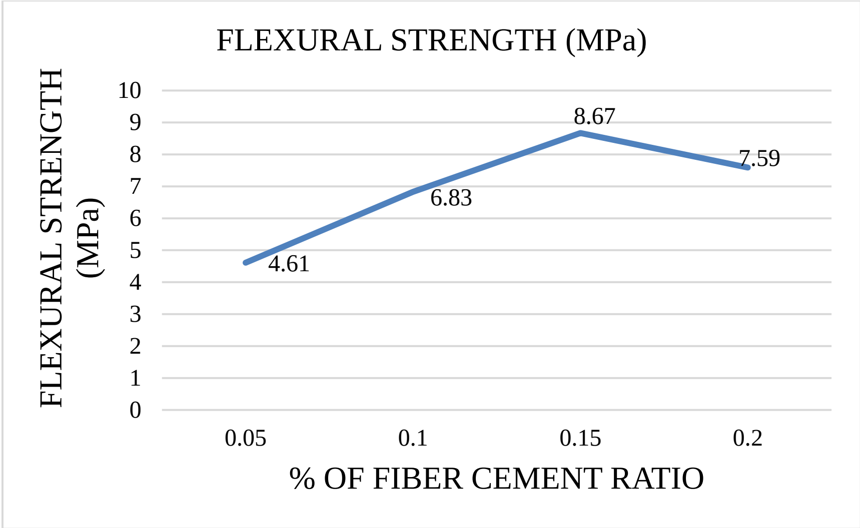


Figure 2.8: Flexural Strength vs. % of fiber cement

Following the standardized procedure, the split-tensile strength tests were conducted on the concrete cylinders. The obtained results have been tabulated in Table 2.9. Additionally, Figure 2.9 displays the cracked beam loaded in the Universal Testing Machine (UTM) during the testing process. The experimental values have been further tabulated and plotted in Figure 2.10 to provide a graphical representation of the data.

Figure 2.9: Testing of PALF reinforced Cylinder

Table 2.9 Tensile strength of the concrete

S.No	Fiber Cement Ratio(%)	28 Days Split Tensile Strength (MPa)		
		Sample1	Sample2	Average Strength
1	0.05	2.48	2.40	2.43
2	0.1	2.90	2.80	2.83
3	0.15	3.35	3.40	3.37
4	0.2	3.20	3.00	3.11

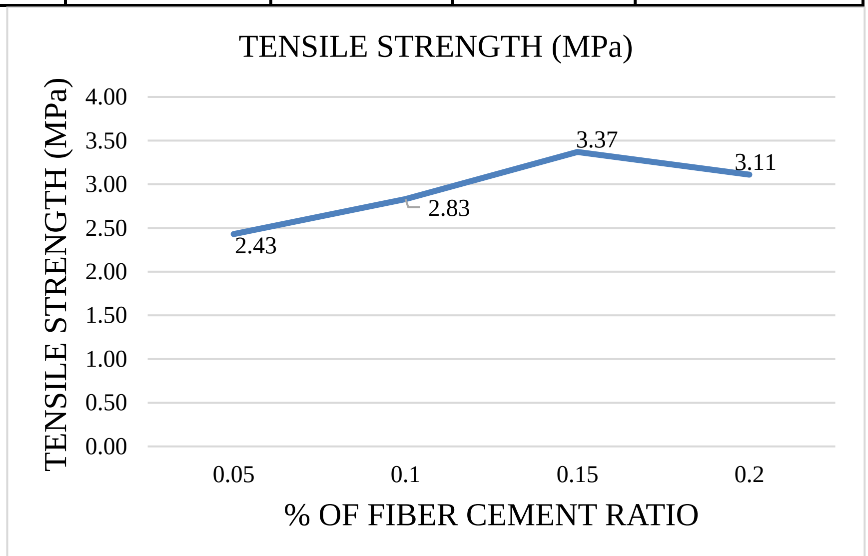
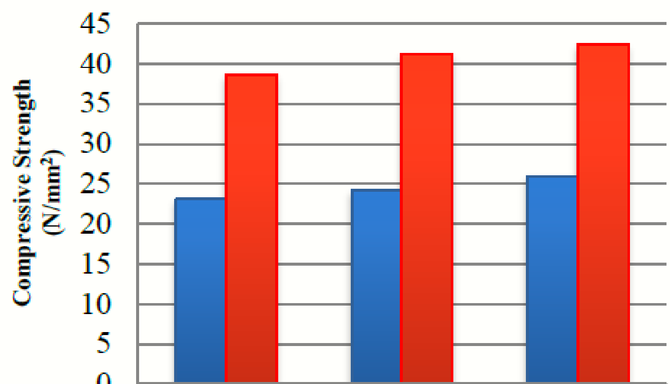


Figure 2.10: Tensile strength vs. % of fiber cement

The addition of PALF fiber at a 0.1% proportion resulted in a significant increase of 30.62% in compressive strength compared to conventional concrete. Moreover, the flexural strength showed a remarkable improvement of 46.858% when compared to conventional concrete. The tensile strength also experienced a notable enhancement of 14.20% with the incorporation of PALF fiber. It is noteworthy that PALF fiber exhibits a hardness ranging between 60-70, contributing to the overall mechanical properties of PALF reinforced concrete surpassing those of conventional concrete. Additionally, the use of PALF as aggregate resulted in lower crushing values compared to conventional aggregate, further indicating its favorable characteristics [10].

The researcher observed in Figure 2.11 that the compressive strength test on the 28th day demonstrated an increasing trend. Notably, there was a notable enhancement in compressive strength for specimens containing PALF fibers. Specifically, the specimens with 5mm PALF fibers exhibited a 6.7% increase in compressive strength compared to the control mix. Similarly, the specimens with 15mm PALF fibers showed a significant improvement of 9.75% in compressive strength relative to the control mix. These findings highlight the positive impact of PALF fibers on the compressive strength of the concrete [11].



	MPF 0	MPF 5	MPF 15
7 Day	23.11	24.22	26
28 Day	38.67	41.26	42.44

Figure 2.11: Comparison of Compressive Strength of test specimens.

2.3 Effect of Alkaline treatment on the characteristics of pineapple leaves fiber.

In recent studies, researchers have put few series treatments and chemical treatments used at enhancing the surface properties of fibers and its matrices. Among these approaches, surface modification treatments such as acetylation, coupling agents, polymer grafting, and mercerization have been proposed. Alkaline and peroxide treatments are currently the common surface modifications.

The objective of the study was to assess the effects of different concentrations of sodium hydroxide (NaOH) during alkali treatment on the chemical, thermal stability, and morphology of pineapple leaf fiber (PALF). This research aimed to identify the optimum conditions for each treatment to enhance the compatibility between the PALF and matrix, ultimately leading to the production of high-quality bio composites [12].

The treatment process involved several steps, including peroxide treatment, modification with maleic anhydrous, and acetylation. However, for the pre-treatment of PALF, alkali treatment using NaOH was considered a preferable method due to its ease of use and cost-effectiveness.

To determine the most suitable concentration of NaOH, PALF analysis was conducted on both untreated fibers and fibers treated with different concentrations of NaOH, namely Alkali 1 wt.%, Alkali 2 wt.%, Alkali 4 wt.%, and Alkali 8 wt.%. Additionally, the moisture content of PALF was measured and is presented in the table below.

Overall, this study aimed to establish the optimal conditions for the treatment of PALF to achieve maximum compatibility between the fiber and matrix, facilitating the production of bio composites with enhanced properties.

Table 2.10 The moisture content of untreated and treated PALF

PALF Sample	Moisture content (dry basis)
Untreated	16.36%
Alkali 1 wt.%	15.54%
Alkali 2 wt.%	12.89%
Alkali 4 wt.%	12.84%
Alkali 8 wt.%	10.41%

Scanning electron microscopy (SEM) was employed to examine the surface morphology of both untreated and alkali-treated pineapple leaf fiber (PALF) samples. Prior to the SEM analysis, a thin gold coating was applied to the samples using a vacuum sputter coater to enhance their conductivity and improve the quality of the resulting images [12]. Figure 2.12 illustrates the morphological differences between the untreated PALF and various alkali-treated samples. Figures 2.12(b-e) specifically depict the distinct morphologies observed in the alkali-treated PALF. Notably, Figure 2.12(e) exhibits a fascinating structure where the PALF treated with 8 wt.% alkali at room temperature showcases the formation of skeletal string-like microfibril bundles.

This analysis using SEM provides valuable visual insights into the structural changes occurring in PALF due to alkali treatment, highlighting the development of unique fiber characteristics.

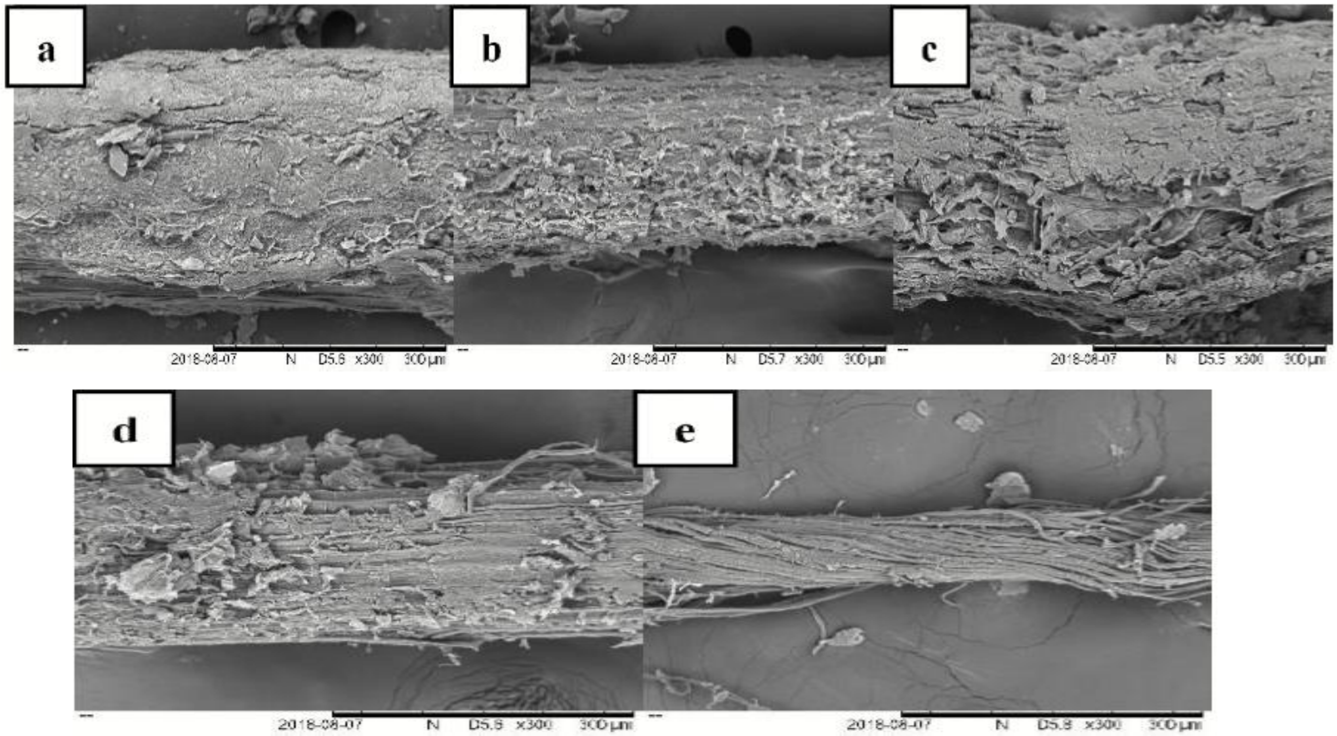


Figure 2.12: SEM image of (a) Untreated, (b) Alkali 1 wt.%, (c) Alkali 2 wt.%, (d) Alkali 4 wt.%, (e) Alkali 8 wt.% PALF under magnification of ×300.

In order to assess the strength of the PALF/PP bio composite, mechanical property tests were conducted. Figure 2.13 illustrates the results of the tensile strength evaluation for the bio- composite with different treatment conditions, specifically at a 30wt% PALF loading [12].

The highest tensile strength was observed in the bio composite sample treated with 8wt.% alkali (Alkali 8wt.%), which yielded a strength of 116.17 MPa. This was followed by the bio composite samples treated with 4wt.% alkali (Alkali 4wt.%) and 2wt.% alkali (Alkali 2wt.%), which exhibited tensile strengths of 99.85 MPa and 90.56 MPa, respectively.

These results indicate that a higher concentration of NaOH during alkali treatment leads to a greater removal of hemicellulose and lignin from the surface of PALF. This removal process disrupts the hydrogen bonding network and increases the roughness of the fiber surface, thereby enhancing physical interlocking within the bio composite. The alkali-treated PALF, particularly with 8wt.% alkali treatment, demonstrates a more organized structure.

In summary, the mechanical property tests demonstrate that the PALF/PP bio composite treated with higher concentrations of NaOH exhibits improved tensile strength. The removal of hemicellulose and lignin, along with increased surface roughness and physical interlocking, contribute to the enhanced performance of the bio composite.

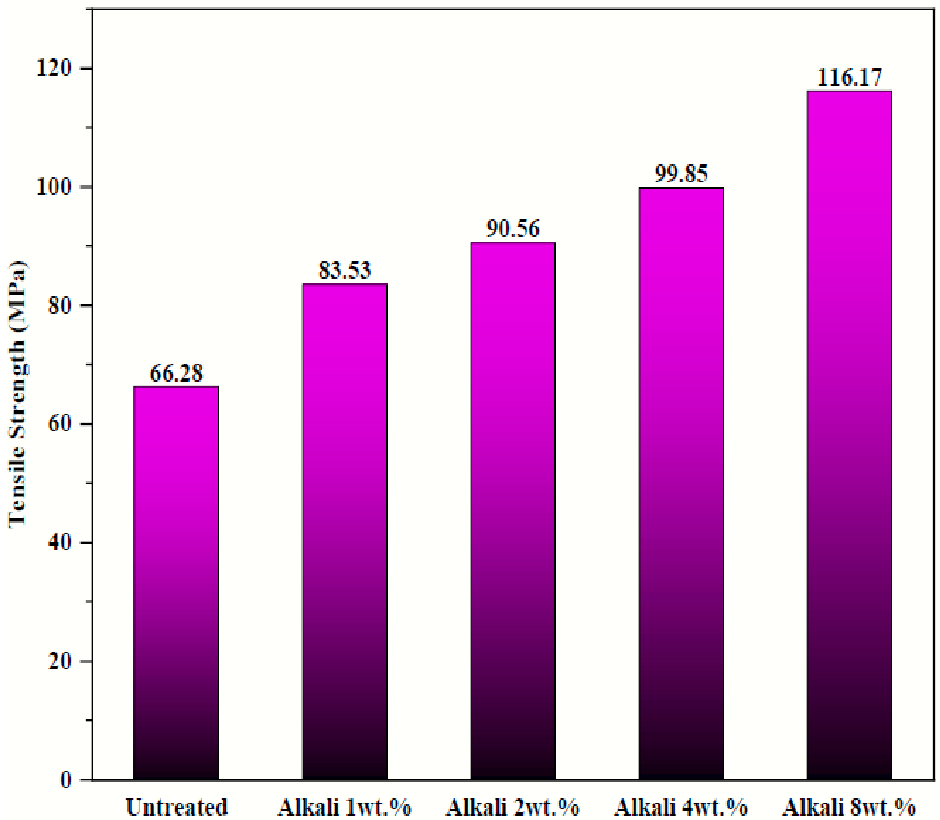


Figure 2.13: Summary of the mechanical analysis for PALF/PP bio-composite

CHAPTER THREE

3. MATERIALS AND METHODOLOGY

3.1 Introduction

This chapter provides an overview of material types and properties, sample preparations, experimental procedures, extraction process of fiber and test setups used in the study. All laboratory tests were conducted at Addis Ababa Institute of Technology (AAiT) Building Material Laboratory. The material preparations, tests, and detailed experimental setup adhered to strict requirements defined in ASTM standards and specifications. The following sections will present a comprehensive description of these processes, ensuring transparency and accuracy in the process.

3.2 Materials

The materials used for this research includes cement, fine aggregate, coarse aggregate, water, pineapple leaf fiber (PALF) and sodium hydroxide (NaOH).

3.2.1 Cement

For the purposes of this study, Ordinary Portland cement was used, which was readily obtainable from the local market. The specific cement type employed was Type-1 Dangote with a CEM 42.5R grade and a relative density of 3.15g/cm3. A comprehensive analysis of the cement's physical properties has been conducted in Table 3.1 Shown on Appendix A.

Table 3.1 Physical properties of cement

<table>
<tr><th>Item No.</th><th colspan="2">Description</th><th>Test result</th></tr>
<tr><td>1</td><td colspan="2">Fineness of cement (cm²/gm)</td><td>2850</td></tr>
<tr><td>2</td><td colspan="2">Specific gravity</td><td>3.15</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Normal consistency test</td><td>Water to Cement Ratio (%)</td><td>27</td></tr>
<tr><td>Water (gm)</td><td>135</td></tr>
<tr><td>Penetration (mm)</td><td>10</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Setting time</td><td>Initial setting time (min)</td><td>75</td></tr>
<tr><td>Final setting time (min)</td><td>290</td></tr>
</table>

3.2.2 Aggregate

The term "aggregate" incorporates both fine and coarse aggregates, constituting approximately three-quarters of the total volume of concrete. To ensure consistency and eliminate potential variations, the same source was utilized for the supply of aggregates throughout the study. Rigorous laboratory tests, including assessments of bulk density, specific gravity, and moisture content, were conducted on the aggregate to ensure compliance with concrete work specifications. As part of this process, the aggregate undertake a thorough washing procedure to eliminate impurities such as silt and dust that could compromise the quality. Subsequently, the aggregate was carefully stored in plastic bags to maintain its moisture content until the time of mixing.

3.2.2.1 Fine Aggregate

In this research, a fine aggregate characterized by its ability to pass through a 4.75mm sieve was employed as a small-size filler material in the concrete mixture. The laboratory tests conducted to assess the physical properties of the fine aggregates have been compiled and presented in Table 3.2. and Table 3.3 respectively [13] for more description on properties of fine aggregate has been conducted on Appendix B.

Table 3.2 properties of fine aggregate

No	Test description		Test result
1	Silt content		1%
2	Moisture content		1%
3	Absorption capacity		2%
4	Fineness modulus		2.48
5	Unit weight		1481.8 kg/m^3
6	Specific gravity	Bulk	2.48 g/cm^3
		Bulk (SSD)	2.54 g/cm^3
		Apparent	2.62 g/cm^3

Table 3.3 particle size distribution of fine aggregate

Sieve Size	weight retained	Individual retained	Cummulative passing	Cummulative Retained	ASTM C33 Standard Passing Range
(mm)	(g)	(%)	(%)	(%)	(%)
9.5	5.2	0	100	0	100
4.75	40.7	4.5	95.5	4.5	95-100
2.36	30.5	6.1	89.4	10.6	80-100
1.18	48.8	9.76	79.64	20.36	50-85
0.6	101.7	20.34	59.3	40.7	25-60
0.3	195.4	39.08	20.22	79.78	5-30
0.15	62.7	12.54	7.68	92.32	0-10
pan	15	7.68	0	100	0-0.3[A,B]
Total	500			248.26	

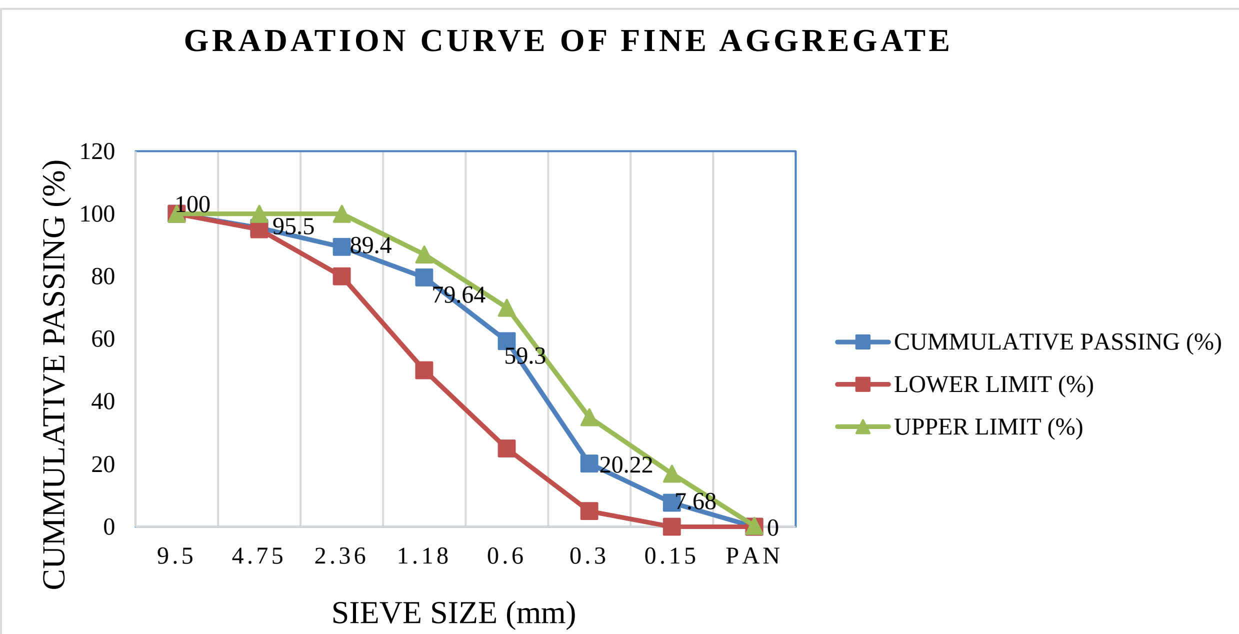


Figure 3. 1: Gradation curve of fine aggregate

The fine aggregate used in this study, which initially had a silt content of 7.44%, underwent a washing process to reduce the silt content to 1%. By using this method the fine aggregate met the specifications according to ASTM C-33-01.

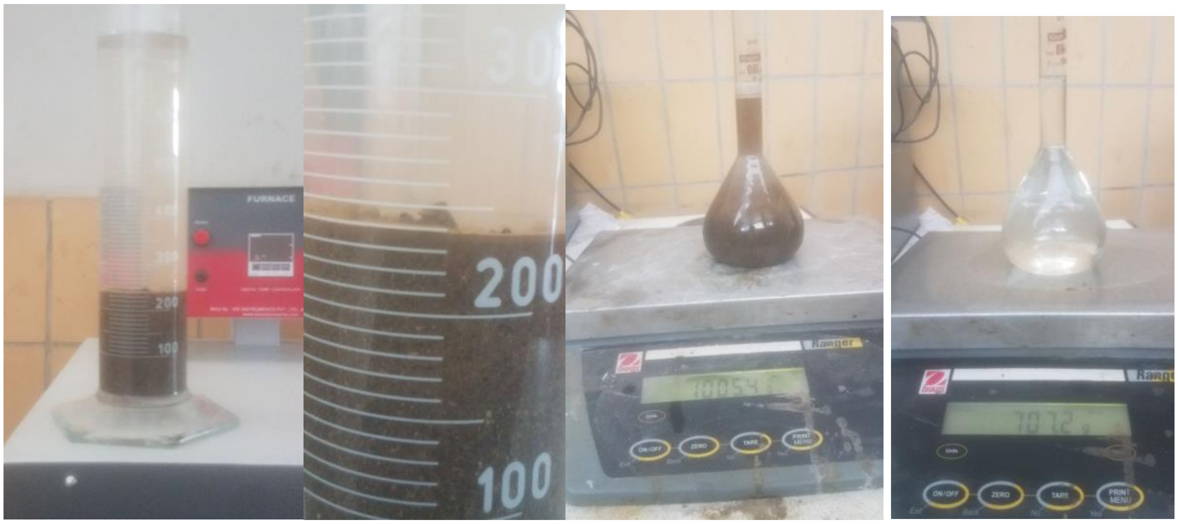


Figure 3.2: Silt content and specific gravity of fine aggregate

3.2.2.2 Coarse Aggregate

For this research, locally sourced basaltic crushed rock coarse aggregate was employed as the primary material. Four different sizes of coarse aggregates were used: 9.5mm, 12.5mm, 19mm, and 25mm. The laboratory test results for these aggregates are presented in Table 3.4 and Table 3.5, providing a summary of their respective physical properties [13] for more description on properties of coarse aggregate has been conducted on Appendix C.

Table 3.4 physical properties of coarse aggregate

No	Test description		Test result
1.	Moisture content		4%
2.	Absorption capacity		2.56%
3.	Fineness modulus		3.35
4.	Unit weight		1547.9 kg/m^3
5.	Specific gravity	Bulk	2.43
		Bulk (SSD)	2.49
		Apparent	2.59

Table 3.5 particle size distribution of coarse aggregate

sieve size	**weight retained**	**Individual retained**	**Cummulative passing**	**Cummulative Retained**	**ASTM C33 Standard Passing Range**
(mm)	(g)	(%)	(%)	(%)	(%)
25	0	0	100	0	95-100
19.5	655.95	13.119	86.881	13.119	-
12.5	2001.4	40.028	46.853	53.147	25-60
9.5	1160.9	23.218	23.635	76.365	-
4.75	568.5	15.5	8.135	91.865	0-10
pan	613.25	8.135	0	100	0
Total	5000	100		335	

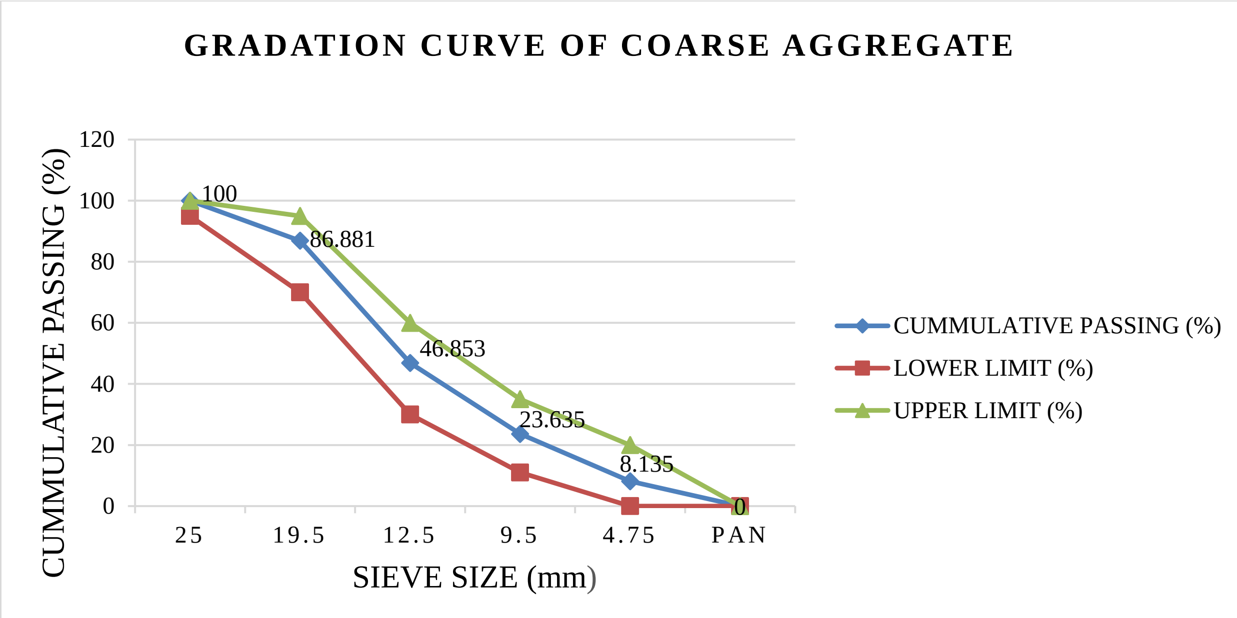


Figure 3.3: Gradation curve of coarse aggregate

3.2.3 Water

Water is a crucial component in the formation and performance of concrete. When water is mixed with cement, it undergoes a chemical reaction called hydration. This hydration process forms a strong and durable matrix that binds the aggregates (such as sand and gravel) together, creating the solid material we know as concrete. Here's why water is essential for concrete:

1. Hydration: Cement is the primary binding agent in concrete, and water activates its chemical properties, initiating the hydration process. During hydration, the cement particles react with water, forming calcium silicate hydrate (C-S-H) and other compounds that provide concrete with its strength and rigidity.
2. Workability: The right amount of water is crucial for the workability of concrete, which refers to its ability to be mixed, placed, and compacted without segregation or bleeding. Adequate workability allows for smooth pouring and proper placement, ensuring that concrete fills the formwork evenly.
3. Strength development: The hydration process continues over time, and the concrete gains strength as the chemical reactions progress. Controlling the amount of water during mixing is essential for achieving the desired concrete strength. Too much water can lead to weaker concrete, while too little water can result in incomplete hydration and reduced strength.

4. Durability: Properly hydrated concrete is more resistant to wear, weathering, and external stresses. The chemical bonds formed during hydration create a dense and strong material that can withstand various environmental conditions and mechanical forces.
5. Volume stability: Water helps in controlling the shrinkage of concrete as it cures. During the early stages of hydration, concrete may experience some initial shrinkage, but later, the formation of hydration products counteracts this effect, leading to a more stable volume.
6. Curing: After concrete is placed, it needs to be cured to maintain adequate moisture levels for the hydration process to continue. Proper curing ensures the concrete reaches its full potential strength and durability.
7. It is also used in washing the sand and the aggregate to reduce the silt content.

While water is essential for concrete, it is crucial to strike the right balance. The water-cement ratio (the amount of water relative to the amount of cement) should be carefully controlled during mixing. An excessive water-cement ratio can lead to several issues, such as decreased strength, increased permeability, and a higher likelihood of cracking. Therefore, it is vital to follow proper concrete mix design and construction practices to achieve the desired performance and longevity of the concrete structure. The water used for this research was tap water sourced from the water supply pipe of the construction material laboratory at Addis Ababa Institute of Technology.

3.2.4 Pineapple Leaf Fiber

In the entire world, pineapple has a large amount of quantity's and the third most important tropical fruits, following banana and citrus in significance. Specifically, it is the famous fruit around in the West Country India. They have been used a lot of things in pineapple one of the major things are they take by using there leafs they extract fibers by the function of extraction machine and by using this fibers with mixing concrete has be get a good performance on the mechanical properties of concrete.

In Ethiopia, particularly in the Southern Nations, Nationalities, and Peoples' Region (SNNP), there is a significant quantity of pineapple fruit. Through my own research, it was observed that 60% of the Pineapple Leaf Fiber (PALF) generated in this region is recycled, while the remaining 40% is classified as waste material. For the purposes of this study, the pineapple leaf fibers were collected from the Sidamo Zone, specifically in the area of Kebado, Located between Choko and Dilla.

3.2.4.1 PALF Extraction Process

The traditional extraction method of Pineapple Leaf Fiber (PALF) are adopted because of there is no easily obtaining extraction machine.it involved the use of a knife as the bladed material, During the extraction process, fibers will be separated from the cementing substances like pectin or lignin, as well as from wax, resin, fats, and other carbohydrates as shown in Table 3.6 [13] Appendix D shows in detail.

Table 3.6 Ingredients of Pineapple Leaf Fiber

Composition	%
Cellulose	69.5 - 79.5
Pentose	17 - 17.8
Lignin	4 - 4.7
Pectin	1 - 1.2
(protein, organic acid, wax dll)	Balance

For doing a 0.1% by mass concentration of PALF it needed a total of 500 g of PALF was used for all the samples.

To determine the diameter of a single PALF, both Analog and Digital Calipers were employed for measurement.

For assessing the strength of PALF, 60 individual fibers were extracted and taken for Testometric universal testing machine equipped with 50N capacity load cell at the place of Horizon Addis Tire. The sample length was taken to 200 mm, and the cross-head displacement rate was set to 500 mm/min.

3.2.5 Sodium hydro oxide (NaOH)

Most chemicals have been used to enhance the mechanical properties of leaf fibers, with treatments involving either sodium hydroxide (NaOH) or benzoyl chloride (C_7H_5ClO). This treatment process leads to a reduction in the material's hydrophilic nature. While in the other way, improving its compatibility with hydrophobic fibers within the matrix.

For this specific research Sodium hydroxide is chosen rather than benzoyl chloride due to its extensive availability in the market. on top of that, there are two types of forms on sodium hydroxide obtainable, and for this research, the preferred choice is the more abundant form are plenty types of forms, and it is a better characteristic of chemical of NaOH compared to the other form flour types of NaOH.

Each fiber was then soaked with a different percentage of a chemical (NaOH) solution, b/c of it will increase the mechanical properties of the fiber and will improve the adhesion between the fiber surface and polymer matrix by reducing the water absorption of the composites specifically 0%, 5%, 8%, 11%, 14%, and 17%. The results of these strength tests were recorded and organized in Table 3.7 according to the table we see that 11% are more efficient percent with enhancement of tensile strength and elastic modulus regarding others percentage of NaOH.

Table 3.7 Physical Properties of Pineapple Leaf Fiber

Chemical percentage of PALF (%)	Length (mm)	Diameter(µm)	Relative Density (g/cm3)	Braking Force (N)	Tensile Strength (MPa)	Braking Strain (%)	Elastic Modulus (Gpa)
0	30	70	1.34 - 1.4	0.78	203	3.09	6.57
5	30	70	1.34 - 1.4	0.80	207.98	2.66	7.82
8	30	70	1.34 - 1.4	0.86	223.58	2.61	8.57
11	30	70	1.34 - 1.4	0.95	246.98	2.41	10.25
14	30	70	1.34 - 1.4	0.94	244.38	2.55	9.58
17	30	70	1.34 - 1.4	0.91	236.58	2.59	9.13

Figure 3.4: Diameter of PALF Using Caliper

Figure 3.5: Testometric universal testing machine

After taking the optimum amount of NaOH, the material had to undergo a process known as retting, and specifically, water retting or tank retting was chosen for its ability to produce a more uniform and superior quality fiber.in spite of, water retting are good for the strength of fiber it shall need replaced by a fresh water by some time of interval.

Figure 3.6: Soaking and retting extracting Pineapple leaf fibers

The fibers were chopped using a scissor to a different aspect ratio (length to diameter) of 150, 450, 750, and 1050 respectively with 0.1% fiber contents by mass were prepared for the experiment.

Figure 3.7: fiber Chopping

3.3 Methodology

3.3.1 Mix design

In this study, I aim to investigate and evaluate the properties and performance of a specific material intended for use in concrete production. The selection of suitable materials for concrete plays a critical role in determining the final characteristics of the concrete mix, such as compressive strength, cylindrical strength, flexural strength, workability and durability.

The mix design was conducted the following standard procedures outlined in ACI 211.1-91 [14]. The specified concrete grade was C-25. The quantities of each ingredient are summarized in Table 3.8, and a comprehensive calculation can be found in Appendix E.

Table 3.8 Quantity of Materials Required for C-25 concrete

Quantities in kg/m^3						
Mix No.	**Cement**	**Sand**	**Coarse aggregate**	**Water**	**PALF @ 0.1%**	**Aspect ratio**
1	360.00	920.00	1120.00	154.00	0	0
2	360.00	920.00	1120.00	154.00	0.12	150
3	360.00	920.00	1120.00	154.00	0.12	450
4	360.00	920.00	1120.00	154.00	0.12	750
5	360.00	920.00	1120.00	154.00	0.12	1050

3.3.2 Concrete mix

In the laboratory, all the concrete mixes were prepared using the mixer shown in Figure 3.8, with the ingredients prepared and ready for mixing. The concrete test specimens were made and cured following the standards specified in ASTM C192 [15].

Figure 3.8: PALF with concrete in mixer

The mixing process involved the following steps: First, the coarse aggregate was added to the mixer, followed by the cement and then the fine aggregate. The materials were dry blended, and two-thirds of the measured water were added, along with two-thirds of the fibers. Mixing continued for an additional minute. Subsequently, the remaining water was added, and the ingredients were thoroughly mixed until a uniform consistency was achieved.

The workability of each fresh concrete mix was assessed by measuring the slump, following the guidelines according to ASTM C-143 [16].

Figure 3.9: measuring slump of fresh concrete mix

Before to being cast into the molds, the freshly mixed concrete undertake a slump test using a cone, with each batch compacted in three rounds to assess its workability. The inner surface of the mold were coated with Machine oil. Subsequently, the concrete was poured into the prepared molds, and a vibrator was employed to eliminate trapped air from the mixture, resulting in a more densely packed and leveled end product as illustrated on Figures 3.10.

Figure 3.10: Concrete Specimen after cast

3.3.3 Testing methods

Various testing methods can be applied to assess the mechanical properties of concrete. This study specifically conducted tests for compressive strength, splitting tensile strength, and flexural strength test

3.3.3.1 Compressive Strength Test

Upon the curing period completed for the concrete specimens, they were removed from the curing water tank and undertake surface drying prior to testing. The testing procedure adhered to the guidelines according to ASTM C39 [17]. The specimens were initially weighed and subjected to testing using the Universal Testing machine at both 7^{th} and 28^{th} day time intervals. Loading was applied gradually, with a loading rate of 0.28 MPa/sec, until the point of failure was reached, when the machine capacity reached up to a 3000KN.

For each concrete mix, three cubes were tested to assess the compressive strength at both 7^{th} and 28^{th} days, Additionally, three samples were tested for each mix to individually investigate the impacts of different aspect ratio of PALF with concrete at a 7^{th} and 28^{th} days of concrete age. A total of 30 cube samples, each measuring 100mm×100mm×100mm, were cast for this testing.

Figure 3.11 show the compressive strength testing machine and the prepared setup for the test. Detailed outcomes of the compressive strength test are provided in Appendix G.

Figure 3.11: Compressive Strength Test Setup

3.3.3.2 Splitting Tensile Strength Test

The purpose of the splitting tensile strength test is to determine the tensile strength of concrete along its length of the splitting side of cylinder. This method involves applying a diametric compressive force along the length of a cylindrical concrete specimen at a controlled loading rate of 0.017 MPa/sec, continuing until failure ensues (ASTM C-496-71) [18].

For this particular study, a set of 30 cylindrical samples was prepared. Each mix contains three samples, with the cylinders measuring 100mm in diameter and 200mm in height. The samples undertake testing at both the 7th and 28th day. The subsequent equation can interpret the calculation of splitting tensile strength.

$T = {}^{2P}/_{\pi dl}$, Where T– Splitting Tensile Strength (MPa)

P – Maximum applied load (N)

d – Diameter of cylindrical specimen (mm)

l – Length of cylindrical specimen (mm)

Figure 3.12: Splitting Tensile Strength Test Setup

3.3.3.4 Flexural Strength Test

This test serves the purpose of determining the tensile strength of the concrete and the ability of concrete to withstand bending forces. It is also known as the modulus of rupture test or the bending test. This test is crucial in assessing the behavior of concrete when subjected to bending or flexural stresses The test provides valuable information about the concrete's ability to distribute loads, resist cracking, and withstand external forces that can cause bending The testing procedure adhered to the standards set forth in ASTM C 78 – 94 [19]. The flexural strength denotes the highest stress experienced within the material at the point of yield.

Concrete was cast into a mold designed as a beam member, featuring dimensions of 100 mm in width, 100 mm in height, and 500 mm in length. A total of 30 samples were prepared for this testing. In cases where the fracture initiates on the tension surface within the middle third of the span length, the modulus of rupture can be calculated using the following method:

$R = PL/bd^2$, Where R– Modulus of rupture, (psi or MPa),

P – Maximum applied load indicated by the testing machine, (lbf, or N),

b – Average width of specimen, (in., or mm), at the fracture,

d – Average depth of specimen, (in., or mm), at the fracture

Figure 3.13: Flexural Strength Test Setup

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Introduction

This chapter is dedicated to a detailed and exhaustive exploration of the outcomes derived from the laboratory-based experiments. The primary focus lies in carefully elaborating upon the results that have been acquired from experiments conducted at different aspect ratios: 0, 150, 450, 750, and 1050. Furthermore, the chapter rigorously undertakes a comprehensive analysis, drawing comparisons and conducting evaluations of the test results from the assessment of cubes, cylinders, and flexural tests.

This chapter exclusively focuses on the discussion of two distinct aspects: the initial development of concrete strength over time and the eventual attainment of final strength in concrete over time.

4.2 Hardened Concrete Properties

In order to examine the mechanical characteristics of concrete with normal strength, tests were conducted to measure its compressive, flexure and splitting tensile strengths at both the 7th and 28th days.

4.2.1 Compressive Strength of Concrete

The compressive strength tests were conducted in laboratory a mean value was calculated for both the control mix and the specimens with varying aspect ratios. These tests were carried out after the specimens had been properly cured for both 7th and 28th days. Detailed results of the compressive strength tests can be found in Appendix F. The average results are shown in Figure 4.1 and Figure 4.2 respectively.

It includes all samples, considering various aspect ratios, including the control mix at 150, 450, 750, and 1050.

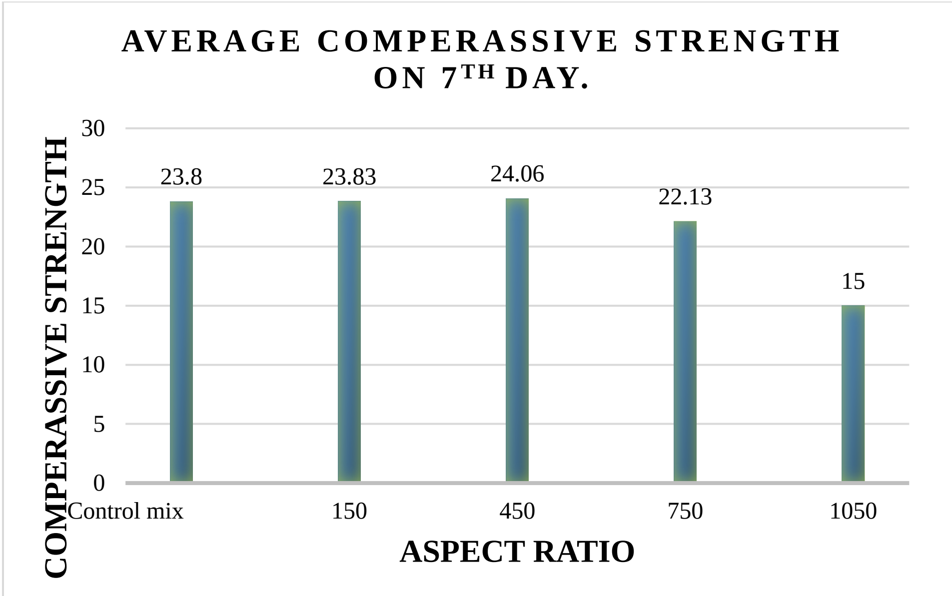


Figure 4.1: 7th day cube compressive strength

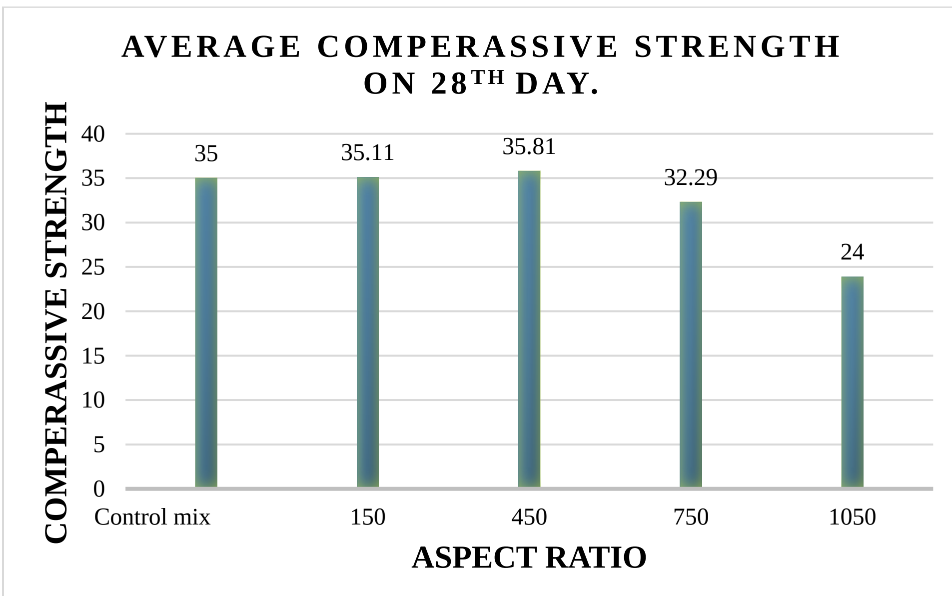


Figure 4.2: 28th day cube compressive strength

There is a visual representation, on the graph, which displays data related to aspect ratios and their effects on various Time. And when compared to a control mix (which serves as a baseline or reference), all tested aspect ratios resulted in some form of enhancement and some form of aspect ratios are dehancement.

On the aspect ratio of 150 on the 7th and 28th days, we observe that the control mix achieves cube compressive strengths of 23.8 and 35 MPa, respectively. For the same time points, the 150 aspect ratio yields slightly improved results with strengths of 23.83 MPa (a 0.12% increase) on the 7th day and 35.11 MPa (a 0.3% increase) on the 28th day.

Moving on to the 450 aspect ratio, it outperforms the control mix significantly. On the 7th day, it achieves a cube compressive strength of 24.06 MPa (a 1.09% improvement), and on the 28th day, it reaches 35.81 MPa (a remarkable 2.31% improvement).

In contrast, the 750 aspect ratio demonstrates a decrease in cube compressive strength compared to the control mix. On the 7th day, it records a strength of 22.13 MPa (a reduction of 7.01%), and on the 28th day, it registers 32.29 MPa (a reduction of 7.74%).

Finally, the 1050 aspect ratio exhibits a substantial reduction in cube compressive strength at both time points. On the 7th day, it drops to 15 MPa (a decrease of 36.9%), and on the 28th day, it falls to 24 MPa (a decrease of 31.49%).

In summary, when analyzing cube compressive strength, the aspect ratios of 450 and 150 show improvements over the control mix, whereas the aspect ratios of 750 and 1050 result in reductions. It asserts that, among all the tested aspect ratios, the one with a value of 450 is the most effective in achieving the highest levels of cube compressive strength. This is observed both at an early stage (7th day) and at the final setting time (28th day). Essentially, the 450 aspect ratio produced the best results in terms of these crucial material properties.

To provide an overview, the sentence conveys that after conducting experiments and analyzing the data presented in the graph, it was found that while all aspect ratios showed improvement compared to the control mix, the aspect ratio of 450 stood out as the most effective in enhancing cube compressive strength at both early and final stages of setting.

4.2.2 Splitting tensile strength of concrete

Splitting tensile strength tests were performed in the laboratory, and mean values were determined for both the control mix and specimens with different aspect ratios. These tests were conducted after the specimens had undergone proper curing for both 7 and 28 days. It can get summarized results of the Splitting tensile strength tests in Appendix G. Figure 4.3 and Figure 4.4 display the average results, encompassing all samples, including those with various aspect ratios as well as the control mix at 150, 450, 750, and 1050.

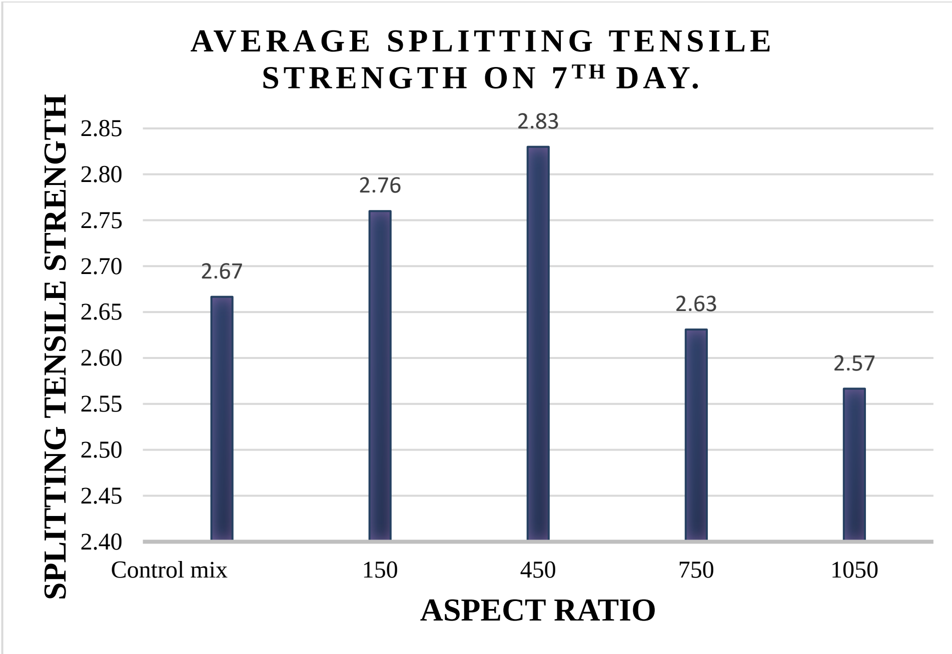


Figure 4.3: 7th day Splitting tensile strength

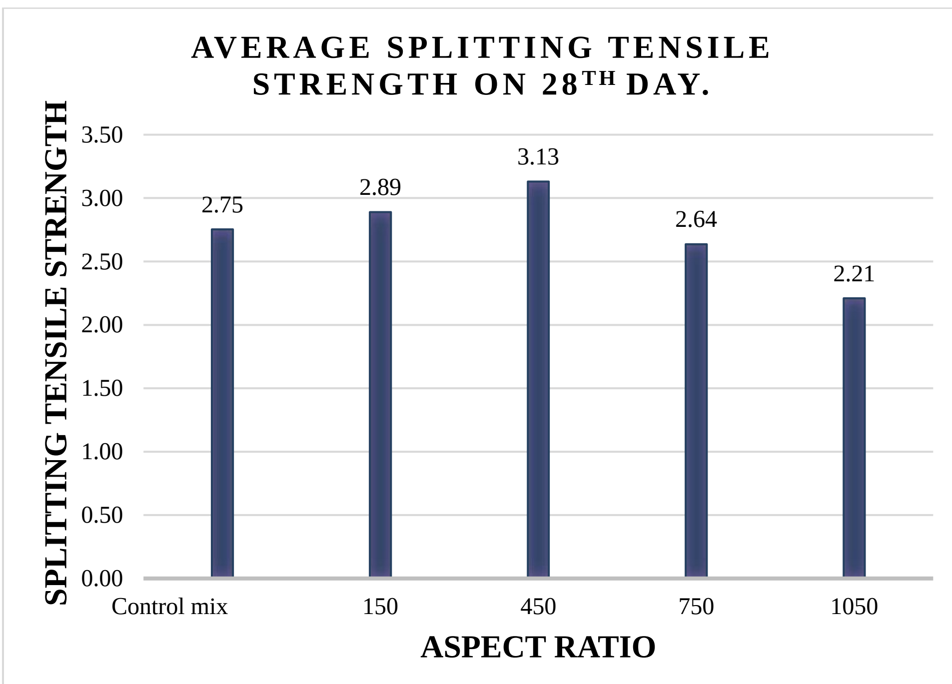


Figure 4.4: 28th day Splitting tensile strength

The graph shows to presents data regarding aspect ratios and their impacts over time. When compared to a control mix, which serves as a baseline or reference, it becomes noticeable that all tested aspect ratios exhibited either enhancements or reductions in performance.

When examining the aspect ratio of 150 on the 7^{th} and 28^{th} days, it is apparent that the control mix attains Splitting tensile strengths of 2.67 and 2.75 MPa, respectively. Conversely, for the same time intervals, the 150 aspect ratio demonstrates marginal enhancements, with strengths of 2.76 MPa (a 3.37% rise) on the 7^{th} day and 2.89 MPa (a 5% increase) on the 28^{th} day.

When we Focusing on the 450-aspect ratio, it notably increases the performance of the control mix. Specifically, on the 7^{th} day, it attains a Splitting tensile strength of 2.83 MPa, marking a 5.99% improvement, while on the 28^{th} day, it achieves an impressive 3.13 MPa, indicating a remarkable 13.81% enhancement.

Conversely, the 750 aspect ratio exhibits a decline in splitting tensile strength when compared to the control mix. Specifically, on the 7^{th} day, it registers a strength of 2.63 MPa, reflecting a reduction of 1.49%, and on the 28^{th} day, it records 2.64 MPa, indicating a decrease of 4%.

Lastly, the 1050 aspect ratio demonstrates a significant decrease in splitting tensile strength at both time points. On the 7^{th} day, it descends to 2.57 MPa, representing a substantial decrease of 3.75%, and on the 28^{th} day, it diminishes to 2.21 MPa, indicating a notable reduction of 19.63%.

To summarize, when assessing Splitting tensile strength, the aspect ratios of 450 and 150 exhibit enhancements compared to the control mix, while the aspect ratios of 750 and 1050 lead to reductions.

To conclude, the sentence communicates that following experiments and an analysis of the graphed data, it became evident that although all aspect ratios exhibited improvements compared to the control mix, the 450-aspect ratio emerged as the most effective in enhancing Splitting tensile strength during both the early and final setting stages.

4.2.3 Flexural strength test analysis

In the laboratory, we conducted flexural tensile strength tests on specimens with various aspect ratios as well as a control mix. These tests were carried out following proper curing for both 7 and 28 days. Appendix F contains summarized results for these tests. Figure 4.5 and Figure 4.6 showcase the average results for all samples, including those with different aspect ratios, as well as the control mix at 150, 450, 750, and 1050.

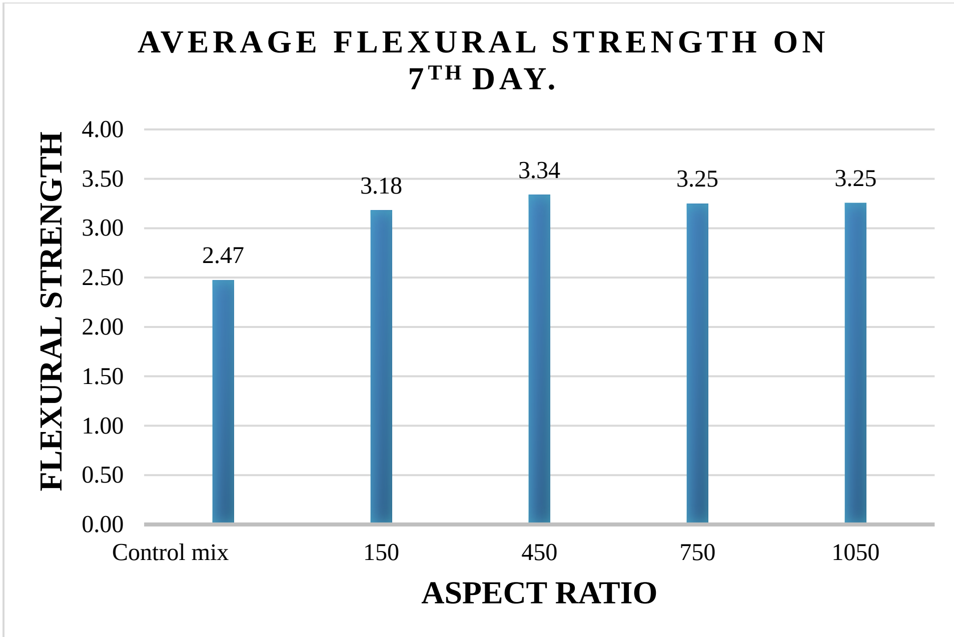


Figure 4.5: 7th day flexural strength

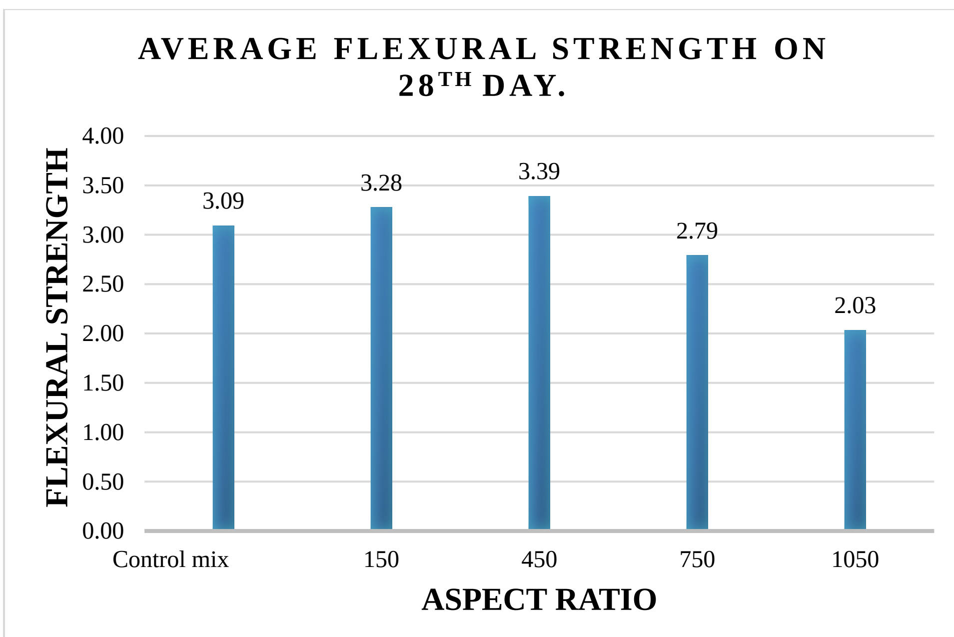


Figure 4.6: 28th day flexural strength

The graph illustrates the relationship between aspect ratios and their effects over time. In comparison to a control mix, which serves as the baseline or reference point, it is shown that all tested aspect ratios displayed either improvements or decreases in performance.

Upon examining the aspect ratio of 150 on both the 7th and 28th days, it is visible that the control mix achieves flexural strengths of 2.47 MPa and 3.09 MPa, respectively. In contrast, during the same time frames, the aspect ratio of 150 exhibits slight improvements, with strengths of 3.18 MPa (reflecting a 28.7% increase) on the 7th day and 3.28 MPa (a 6.15% increase) on the 28th day.

When we become to the 450 aspect ratio, it becomes shown that it significantly enhance the performance of the control mix. To be more specific, on the 7th day, it achieves a flexural strength of 3.34 MPa, representing a notable 35.2% improvement. On the 28th day, this aspect ratio performs even more impressively, reaching a remarkable 3.39 MPa, indicating a substantial enhancement of 9.7%.

On the same as, the 750-aspect ratio demonstrates a increase in flexural strength when contrasted with the control mix. In particular, on the 7th day, it records a strength of 3.25 MPa, signifying a increase of 31.5%, however on the 28th day, it registers 2.79 MPa, indicating a 9.7% reduction.

Finally, the 1050 aspect ratio reveals a notable incline in flexural strength at only 7th day time intervals. Specifically, on the 7th day, it enhance to 3.25 MPa, marking a substantial increase from control mix of 31.5%, on contrary by the 28th day, it decline to 2.05 MPa, indicating a significant reduction of 33.65%.

In summary, when evaluating flexural strength, it becomes certainly that the aspect ratios of 450 and 150 demonstrate improvements in contrast to the control mix. Conversely, the aspect ratios of 750 and 1050 result in reductions on the 28th day concrete test.

In conclusion, after conducting experiments and analyzing the graphed data, it became clear that while all aspect ratios showed improvements compared to the control mix, the 450 aspect ratio proved to be the most effective in enhancing flexural strength during both the initial and final setting stages.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- ✓ The alkali treatment with a 11% concentration of NaOH resulted in a greater removal of hemicellulose and lignin from the surface of PALF, leading to an enhanced physical interlocking within the bio composite
- ✓ The control mix achieves cube compressive strengths of 23.8 MPa on the 7th day and 35 MPa on the 28th day, while the 150 aspect ratio yields slightly improved results on all tests cube compressive strength, splitting tensile strength and flexural strength at both initial and setting time date.
- ✓ After conducting the experiments and analyzing the graphed data. It was found that PALF has a great role in the mechanical properties of concrete. it became clear that while all aspect ratios showed improvements compared to the control mix, the 450 aspect ratio emphasize proved to be the most effective in enhancing flexural strength and compressive strength during both the initial and final setting stages.
- ✓ In contrast, on 750 aspect ratio yields slightly descend results on all tests cube compressive strength, splitting tensile strength and flexural strength at both initial and setting time date.
- ✓ The 1050 aspect ratio exhibited a substantial reduction in all tests cube compressive strength, splitting tensile strength and flexural strength at both time points.

5.2 Recommendation

The following points are needed further studies regarding this specific research

- ✓ The mechanical properties of concrete with a Bundle PALF according to their aspect ratio in addition to this, the optimum study amount of bundle PALF will enhance the mechanical properties of concrete.
- ✓ The mechanical properties of concrete are affected by the twisting effect of PALF based on their aspect ratio. Furthermore, conducting an optimal study on the quantity of PALF can lead to improvements in the concrete's mechanical properties.
- ✓ The mechanical properties of concrete regarding to different chemical combustion on PALF with aspect ratio of PALF.
- ✓ The mechanical properties of concrete regarding Concrete with the aspect ratio of PALF on impact resistance.

REFERENCE

[1] Hisana KP, Mohammed Suhail Parathodika, Ajeesh K "Experimental Study on Pineapple Leaf Fiber Reinforced Concrete", International Journal of Scientific & Engineering Research Volume 10, Issue 5, May-2019 ISSN 2229-5518.

[2] Santosh Kumar D S, Praveen B A, Kiran Aithal S, U N Kempaiah. "Development of Pineapple Leaf Fiber Reinforced Epoxy Resin Composites", International Research Journal of Engineering and Technology, Volume: 02 Issue: 03, June-2015.

[3] R. Roselin, Dr. M.S. Ravikumar. "Experimental Investigation on Pineapple Fiber Reinforced Cement Concrete", International Journal of Civil Engineering and Technology (IJCIET), Volume 9, Issue 6, June 2018, pp.1479–1484.

[4] Riya Johnson, Amritha E. k. "Experimental Study on Pineapple Leaf Fiber Reinforced RCC Beams", International Journal of Engineering Research and General Science Volume 6, Issue 3, May-June, 2018.

[5] M. S. Sreekala, M. G. Kumaran, Seena Joseph, Maya Jacob, Sabu Thomas, "Oil palm fiber reinforced phenol formaldehyde composites" Influence of fiber surface modifications on the mechanical performance, Applied Composite Materials 7 (2000) 295-329.

[6] A.R. Mohamed, S.M. Sapuan and A. Khalina, "Selected properties of hand-laid and compression molded vinyl ester and pineapple leaf fiber (PALF)- reinforce vinyl ester composites", IJMME 5 (2010) 68-73.

[7] Hadipramana J, Samad A A A, Zaidi A M A, Mohammad N and Ali N "Contribution of Polypropylene fiber in improving strength of foamed concrete", Adv. Mater. Res. 626 762–768.

[8] Blazy J and Blazy R 2021 "Polypropylene fiber reinforced concrete and its application in creating architectural forms of public spaces", Case Stud. Constr. Mater. 14 e00549

[9] Linto Mathew and Dr. Mathews M. Paul "Mechanical Properties of Pineapple Fiber Reinforced Concrete Subjected to High Temperature", GRD Journal for Engineering | Volume 2 | Issue 5 | April 2017 ISSN: 2455-5703.

[10] R. Abirami, D.S.Vijayan and Sijo Joseph John, Aldrin Albert, Alfred Koshy Alex "Experimental Study on Concrete Properties Using Pineapple Leaf fiber", International

Journal of Advanced Research in Engineering and Technology (IJARET) Volume 11, Issue 6, June 2020, pp. 913-920, Article ID: IJARET_11_06_082.

[11] Aboo Jacob, Aiswarya J, Anakha M, Boniface Francis and Amrutha Raman "Behaviour of Concrete by using Pineapple Leaf Fibre", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Published by, www.ijert.org ICART - 2022 Conference Proceedings.

[12] S. Gnanasekaran, N.I.A.A. Nordin, M.M.M Hamidi and J.H. Shariffuddin "Effect of Alkaline treatment on the characteristics of pineapple leaves fiber and PALF/PP bio composite", Journal of Mechanical Engineering and Science (JMES) VOL. 15, ISSUE 4, 8518 – 8528 DOI: https://doi.org/10.15282/jmes.15.4.2021.05.0671.

[13] Fadil Azhar Ekoputra, Sulistijono, Ika Ismail "Effect a Chemical Treatment of Pineapple Leaf Fiber (PALF) for Mechanical Properties as a Reinforced Composite Matrix Polyesters", Material and Metallurgical Engineering, Institute Technology Kalimantan, Soekarno-Hatta KM. 15 Balikpapan Utara, Balikpapan 76127, Indonesia.

[14] A.C., 1991. Standard Practice for Selecting Proportions for Normal Heavyweight, and Mass Concrete (ACI 211.1-91) Reapproved 1997.

[15] ASTM, C., 192/C 192M–02. 2002. Standard practice for making and curing concrete test specimens in the laboratory. West Conshohocken (PA): ASTM International.

[16] ASTM, C., 143/C-143 M, 2000. Standard Test Method for Slump of Hydraulic-Cement Concrete.

[17] ASTM, C., 39/C 39M-03, 2003. Standard test method for compressive strength of cylindrical concrete specimens.

[18] ASTM C 496, 1996. Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.

[19] ASTM, C., 2000. C 78-94. Standard test method for flexural strength of concrete (using simple beam with third-point loading). American Society for Testing and Materials, Philadelphia, p.3.

APPENDIX

Appendix A- Tests for Cement

Appendix B- Tests for Fine Aggregate

Appendix C- Tests for Coarse Aggregate

Appendix D- Properties of Pineapple leaf fiber

Appendix E- Mix Design

Appendix F- Test Results for Compressive, Splitting Tensile and Flexural Strength of Concrete

Appendix G- Pictures

Appendix A- Tests for Cement

Item No.	Description		Test result
1	Fineness of cement (cm^2/gm)		2850
2	Specific gravity		3.15
3	Normal consistency test	Water to Cement Ratio (%)	27
		Water (gm)	135
		Penetration (mm)	10
4	Setting time	Initial setting time (min)	75
		Final setting time (min)	290

Appendix B- Tests for Fine Aggregate

B-1: Sieve analysis results of fine aggregate

Sieve Size	weight retained	Individual retained	Cummulative passing	Cummulative Retained	ASTM C33 Standard Passing Range
(mm)	(g)	(%)	(%)	(%)	(%)
9.5	5.2	0	100	0	100
4.75	40.7	4.5	95.5	4.5	95-100
2.36	30.5	6.1	89.4	10.6	80-100
1.18	48.8	9.76	79.64	20.36	50-85
0.6	101.7	20.34	59.3	40.7	25-60
0.3	195.4	39.08	20.22	79.78	5-30
0.15	62.7	12.54	7.68	92.32	0-10
pan	15	7.68	0	100	0-0.3[A,B]
Total	500			248.26	

B-2: Physical properties of fine aggregate

No	Test description		Test result
1	Silt content		1%
2	Moisture content		1%
3	Absorption capacity		2%
4	Fineness modulus		2.48
5	Unit weight		1481.8 kg/m^3
6	Specific gravity	Bulk	2.48 g/cm^3
		Bulk (SSD)	2.54 g/cm^3
		Apparent	2.62 g/cm^3

FM (Fineness modulus) =$\sum \text{CUMMULATIVE RETAIEND CAORSER}(\%)/100$

$$FM=\frac{248.26}{100} = 2.48$$`

B-3: Moisture content of the fine aggregate

Weight of original sample= 500g

Weight of container= 33g

Weight of original Sample+ weight of container = 533g

Weight of oven-dry sample = 495g

Moisture content =$\frac{\text{original sample weight} - \text{weight of oven dry}}{\text{weight of oven dry}}$ X 100%

$$= \frac{(500 - 495)}{495} \text{ X } 100\% = 1.01\%$$

B-4: Unit weight of the fine aggregate

Weight of measure + content = 14.003Kg

Weight of measure = 3.304 Kg

Net weight of aggregate = (weight of measure + content) – weight of measure

= 14.003 Kg – 3.304 Kg =10.669 Kg

Volume of equipment = $\frac{\pi d^2}{4}$ X h

d=0.205m and h=0.217m

Volume of equipment = $\frac{\pi \text{ x } 0.205^2}{4}$ X 0.217 =0.0072 m^3

Unit weight of fine aggregate = $\frac{\text{Net weight of aggregate}}{\text{Volume of equipment}} = \frac{10.669\ Kg}{0.0072\ m^3}$ = 1481.8 Kg/m^3

B-5: Specific gravity and absorption capacity for fine aggregate

Weight of original sample (A) = 500 g

Weight of water + weight of pycnometer (B) = 707.2 g

Weight of sample + water + pycnometer (C) = 1010 g

Weight of oven dry sample (D) = 490 g

Bulk specific gravity = $\frac{D}{B+A-C} = \frac{490}{707.2+500-1010} = 2.48$ g/cm3

Bulk specific gravity (SSD basis) = $\frac{A}{B+A-C} = \frac{500}{707.2+500-1010} = 2.54$ g/cm3

Apparent specific gravity = $\frac{D}{B+D-C} = \frac{490}{707.2+490-1010} = 2.62$ g/cm3

Absorption capacity = $\frac{A-D}{D} = \frac{500-490}{500}$ X $100\% = 2\%$

B-6: Silt content of the fine aggregate

Silt content (%) = $\frac{\text{amount of silit cotent}}{\text{clean sand}}$ X $100\% = \frac{0.3\ \text{mm}}{30\ \text{mm}}$ X $100\% = 1\%$

Appendix C- Tests for Coarse Aggregate

C-1: Sieve analysis results of coarse aggregate

sieve size	weight retained	Individual retained	Cummulative passing	Cummulative Retained	ASTM C33 Standard Passing Range
(mm)	(g)	(%)	(%)	(%)	(%)
25	0	0	100	0	95-100
19.5	655.95	13.119	86.881	13.119	-
12.5	2001.4	40.028	46.853	53.147	25-60
9.5	1160.9	23.218	23.635	76.365	-
4.75	568.5	15.5	8.135	91.865	0-10
pan	613.25	8.135	0	100	0
Total	5000	100		334.5	

C-2: Physical properties of coarse aggregate

No	Test description		Test result
1.	Moisture content		4%
2.	Absorption capacity		2.56%
3.	Fineness modulus		3.35
4.	Unit weight		1547.9 kg/m^3
5.	Specific gravity	Bulk	2.43
		Bulk (SSD)	2.49
		Apparent	2.59

FM (Fineness modulus) =$\sum \text{CUMMULATIVE RETAIEND CAORSER}(\%)/100$

$$FM=\frac{334.5}{100} = 3.35$$

C-3: Moisture content of the coarse aggregate

Weight of original sample= 2000g

Weight of container= 33g

Weight of original Sample+ weight of container = 2033g

Weight of oven-dry sample = 1923g

$$\text{Moisture content} = \frac{\text{original sample weight} - \text{weight of oven dry}}{\text{weight of oven dry}} \text{ X } 100\%$$

$$= \frac{(2000 - 1923)}{1923} \text{ X } 100\% = 4\%$$

C-4: Unit weight of coarse aggregate

Weight of measure + content = 25.73Kg

Weight of measure = 4.845 Kg

Net weight of aggregate = (weight of measure + content) – weight of measure

= 25.73Kg - 4.845 Kg =20.885 Kg

$$\text{Volume of equipment} = \frac{\pi d^2}{4} \text{ X h}$$

d=0.25m and h=0.275m

Volume of equipment = $\frac{\pi \text{ x } 0.25^2}{4}$ X 0.275 =0.0135 m^3

Unit weight of fine aggregate = $\frac{\text{Net weight of aggregate}}{\text{Volume of equipment}} = \frac{20.885\ Kg}{0.0135\ m^3}$ = 1547.9 Kg/m^3

C-5: Specific gravity for coarse aggregate

Weight of oven dried aggregate in air (A) = 4885 g

Weight of S.S.D aggregate in air (B) = 5010 g

Weight of S.S.D aggregate in water (C) = 2998 g

Bulk specific gravity = $\frac{A}{B-C} = \frac{4885}{5010-2998} = 2.43$ g/cm3

Bulk specific gravity (SSD basis) = $\frac{B}{B-C} = \frac{5010}{5010-2998} = 2.49$ g/cm3

Apparent specific gravity = $\frac{A}{A-C} = \frac{4885}{4885-2998} = 2.59$ g/cm3

Absorption capacity = $\frac{B-A}{A} = \frac{5010-4885}{4885}$ X $100\% = 2.56\%$

Appendix D- Properties of pineapple leaf fiber

D-1: Ingredient of pineapple leaf fiber

Composition	%
Cellulose	69.5 - 79.5
Pentose	17 - 17.8
Lignin	4 - 4.7
Pectin	1 - 1.2
(protein, organic acid ,wax dll)	Balance

D-2: Physical properties of pineapple leaf fiber

It conducts 60 samples to determine the optimum amount of NaOH chemical to enhance the mechanical properties of pineapple leaf fiber using Testometeric universal machine.

Chemical percentage of PALF (%)	samples	Length (mm)	Diameter(μm)	Relative Density (g/cm3)	Braking Force (N)	Tensile Strength (MPa)	Braking Strain (%)	Elastic Modulus (Gpa)
0	1	30	70	1.34	0.75	194.98	2.94	6.20
	2	30	70	1.36	0.76	197.58	2.84	6.17
	3	30	70	1.40	0.74	192.38	2.61	6.13
	4	30	70	1.38	0.79	205.38	3.20	6.50
	5	30	70	1.38	0.79	205.38	3.10	6.48
	6	30	70	1.37	0.78	202.78	3.20	6.50
	7	30	70	1.34	0.81	210.58	3.40	7.36
	8	30	70	1.35	0.78	202.78	3.10	6.48
	9	30	70	1.35	0.82	213.18	3.45	7.40
	10	30	70	1.40	0.78	202.78	3.10	6.48
	AVERAGE				0.79	202.78	3.09	6.57
5	1	30	70	1.34	0.77	200.18	2.94	8.40
	2	30	70	1.36	0.78	202.78	2.84	7.40
	3	30	70	1.40	0.74	192.38	2.61	8.50
	4	30	70	1.38	0.79	205.38	2.40	7.20
	5	30	70	1.38	0.81	210.58	2.50	7.50
	6	30	70	1.37	0.84	218.38	2.20	7.60
	7	30	70	1.34	0.83	215.78	2.26	8.51
	8	30	70	1.35	0.78	202.78	3.10	8.40
	9	30	70	1.35	0.82	213.18	2.80	7.20
	10	30	70	1.40	0.84	218.38	2.90	7.40
	AVERAGE				0.80	207.98	2.66	7.811
8	1	30	70	1.34	0.88	228.78	2.80	8.40
	2	30	70	1.36	0.89	231.38	2.84	8.40
	3	30	70	1.40	0.89	231.38	2.61	8.55
	4	30	70	1.38	0.85	220.98	2.40	8.40
	5	30	70	1.38	0.84	218.38	2.50	8.56
	6	30	70	1.37	0.84	218.38	2.20	8.64
	7	30	70	1.34	0.85	220.98	2.26	8.61
	8	30	70	1.35	0.88	228.78	2.80	8.67

	9	30	70	1.35	0.84	218.38	2.80	8.69
	10	30	70	1.40	0.84	218.38	2.84	8.78
	AVERAGE				0.86	223.58	2.61	8.57
11	1	30	70	1.34	0.96	249.58	2.80	10.80
	2	30	70	1.36	0.94	244.38	2.84	10.91
	3	30	70	1.40	0.99	257.38	2.61	10.81
	4	30	70	1.38	0.97	252.18	2.11	10.75
	5	30	70	1.38	0.97	252.18	2.10	9.20
	6	30	70	1.37	0.94	244.38	2.10	9.40
	7	30	70	1.34	0.96	249.58	2.56	9.80
	8	30	70	1.35	0.90	233.98	2.33	9.75
	9	30	70	1.35	0.88	228.78	2.30	10.68
	10	30	70	1.40	0.99	257.38	2.31	10.40
	AVERAGE				0.95	246.98	2.41	10.25
14	1	30	70	1.34	0.93	241.78	2.45	9.20
	2	30	70	1.36	0.94	244.38	2.47	9.10
	3	30	70	1.40	0.98	254.78	2.63	9.60
	4	30	70	1.38	0.96	249.58	2.62	9.68
	5	30	70	1.38	0.96	249.58	2.62	9.20
	6	30	70	1.37	0.95	246.98	2.59	9.40
	7	30	70	1.34	0.92	239.18	2.56	9.80
	8	30	70	1.35	0.90	233.98	2.57	9.76
	9	30	70	1.35	0.88	228.78	2.30	9.86
	10	30	70	1.40	0.98	254.78	2.64	10.20
	AVERAGE				0.94	244.38	2.55	9.58
17	1	30	70	1.34	0.87	226.18	2.52	9.20
	2	30	70	1.36	0.89	231.38	2.54	9.10
	3	30	70	1.40	0.97	252.18	2.63	9.60
	4	30	70	1.38	0.95	246.98	2.62	8.40
	5	30	70	1.38	0.94	244.38	2.62	8.60
	6	30	70	1.37	0.92	239.18	2.68	8.60
	7	30	70	1.34	0.87	226.18	2.56	8.60
	8	30	70	1.35	0.86	223.58	2.57	9.76

	9	30	70	1.35	0.86	223.58	2.48	9.86
	10	30	70	1.40	0.97	252.18	2.64	9.30
	AVERAGE				0.91	236.58	2.59	9.102

Appendix E- Concrete mix design

The mix design is accomplished as per ACI 211.1-91 standard procedures. The mix design is specified to concrete C-25.

Procedure for Concrete Mix Design of C20/25 Concrete

- ✓ Step 1 -The slump is required to be 75-100mm

According to ACI 211 [14] Table: 6.3.1 (Recommended slumps for various types of construction), the recommended slump to address more frequent constructions is from 25mm to 100mm where maximum slump= 100mm, and minimum slump= 25mm

- ✓ Step 2- Choice of maximum aggregate size

Coarse aggregates =25mm

- ✓ Step 3 - Estimation of Mixing water and Air content

From Table 6.3.3 of ACI 211 [14] standards (Approximate mixing water and air content requirements for different slumps and nominal maximum aggregate of aggregates), considering non-air entrained concrete and for non-air-entrained and slump of 75 mm-100 mm, the water in $1m^3$ of concrete is 128.28kg.

- ✓ Step 4- Selection of Water to Cement ratio (W/C)

The water-cement ratio for non-air-entrained concrete with a strength of 25 MPa is found from Table Al.5.3.4(a) to be 0.36

- ✓ Step 5 - Calculation of Cement content

  $\frac{W}{C}$=0.36 c=$\frac{W}{0.61}$=$\frac{128.28}{0.36}$=360kg/m^3

- ✓ Step 6 Determination of mass of course aggregate: -

The quantity of coarse aggregate is estimated from Table A 1.5.3.6. For a fine aggregate having a fineness modulus of 2.48 and a 25 mm nominal maximum size of coarse aggregate, the table indicates that 0.69 m^3 of coarse aggregate, on a dry-rodded basis, may be used in each cubic meter of concrete. The required dry mass is, therefore, 0.69 x 1547.9 = 1076.92 kg.

- ✓ Step 7 Total mass of concrete

From Table A1.5.3.7.1, the mass of a cubic meter of non-air-entrained concrete made with aggregate having a nominal maximum size of 25 mm is estimated to be 2501.81 kg.

Water (net mixing)	- 154 Kg
Cement	- 360 Kg
Coarse aggregate	- 1076.92 Kg
	Total 1590.92 Kg

The mass of fine aggregate, therefore, is estimated to be 2501.81 – 1590.92 = 910.89 Kg

- ✓ Step 8 Addition of moisture content to fine and coarse aggregate

Tests indicate total moisture of 4 percent in the coarse aggregate and 1 percent in the fine aggregate. the adjusted aggregate masses become

Coarse aggregate (wet) = 1076.92(1.04) = 1120 Kg

Fine aggregates (wet) = 910.89(1.01) = 920 Kg

- ✓ Step 9 moisture content adjustment

If absorption capacity is greater than the moisture content of aggregate, we need to add water up to its moisture capacity.

C.A water = 4% - 2.558%% = 1.442 %

F.A water = 1 % - 2.04 % = -1.04%

Total water required = 128.28+1120(1.442%) +920*(-1.04%)= 154Kg

The estimated ingredients for a meter cube of concrete are, therefore, summarized as follows

N0	Ingredient	Weight (Kg/m^3)
1	Cement	360 Kg
2	Fine aggregate	920 Kg
3	Coarse aggregate	1120 Kg
4	Water	154 Kg

Appendix F-Test Results for Compressive, Splitting Tensile and Flexural Strength of Concrete

F-1: Test Results for Compressive Strength

Aspect ratio	Days	Sample	Cube		
			Weight(g)	Force(KN)	Strength(MPa)
Control mix	7	1	2375.6	238.8	23.88
		2	2377.9	249.5	24.95
		3	2347.8	225.7	22.57
	AVERAGE COMPRESIVE STRENGTH (Mpa)				23.8
150	7	1	2376.2	239.2	23.89
		2	2372.5	245.3	24.5
		3	2324.5	231.07	23.11
	AVERAGE COMPRESIVE STRENGTH (Mpa)				23.83
450	7	1	2367.5	239.9	23.99
		2	2377	248.4	24.84
		3	2360.2	233.37	23.34
	AVERAGE COMPRESIVE STRENGTH (Mpa)				24.06
750	7	1	2339.4	223.3	22.4
		2	2334	218.5	21.9
		3	2336.8	220.98	22.09
	AVERAGE COMPRESIVE STRENGTH (Mpa)				22.13
1050	7	1	2311.1	129	12.9
		2	2335	157.6	15.8
		3	2339.1	162.5	16.3

	AVERAGE COMPRESIVE STRENGTH (Mpa)				15
Result on 28th day					
Control mix	28	1	2350.4	358	35.8
		2	2342	351	35.1
		3	2326.4	341	34.1
	AVERAGE COMPRESIVE STRENGTH (Mpa)				35
150	28	1	2358.4	325.1	32.51
		2	2339.4	355.9	35.59
		3	2362.9	372.4	37.24
	AVERAGE COMPRESIVE STRENGTH (Mpa)				35.11
450	28	1	2352.6	359.7	35.97
		2	2339.5	357.7	35.77
		3	2333.6	356.8	35.68
	AVERAGE COMPRESIVE STRENGTH (Mpa)				35.81
750	28	1	2373.5	347.7	34.7
		2	2351.1	298.9	29.89
		3	2362.28	323.25	32.29
	AVERAGE COMPRESIVE STRENGTH (Mpa)				32.29
1050	28	1	2291.6	263.5	26.35
		2	2273.3	197	19.7
		3	2287	256	25.6
	AVERAGE COMPRESIVE STRENGTH (Mpa)				23.88

F-2: Test Results for Splitting Tensile Strength

Aspect ratio	Days	Sample	Cylinder		
			Weight(g)	Force(KN)	Strength(MPa)
Control mix	7	1	3849	64.1	3.2
		2	3793	41.8	2.09
		3	3792	54.1	2.71
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				2.67
150	7	1	3822	56.3	2.82
		2	3868	54.2	2.71
		3	3851	54.9	2.75
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				2.76
450	7	1	3792	44	2.2
		2	3810	69.2	3.46
		3	3801	56.6	2.83
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				2.83
750	7	1	3749	57.2	2.86
		2	3775	48.4	2.42
		3	3762	52.3	2.61
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				2.63
1050	7	1	3760	61.3	3.08
		2	3832	42.4	2.12
		3	3804	49.9	2.5
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				2.57
Result on 28th day					
Control mix	28	1	3892	56.5	2.83
		2	3750	53.8	2.6
		3	3769	56.5	2.83
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				2.75
150	28	1	3876	67	3.35
		2	3779	48.6	2.43

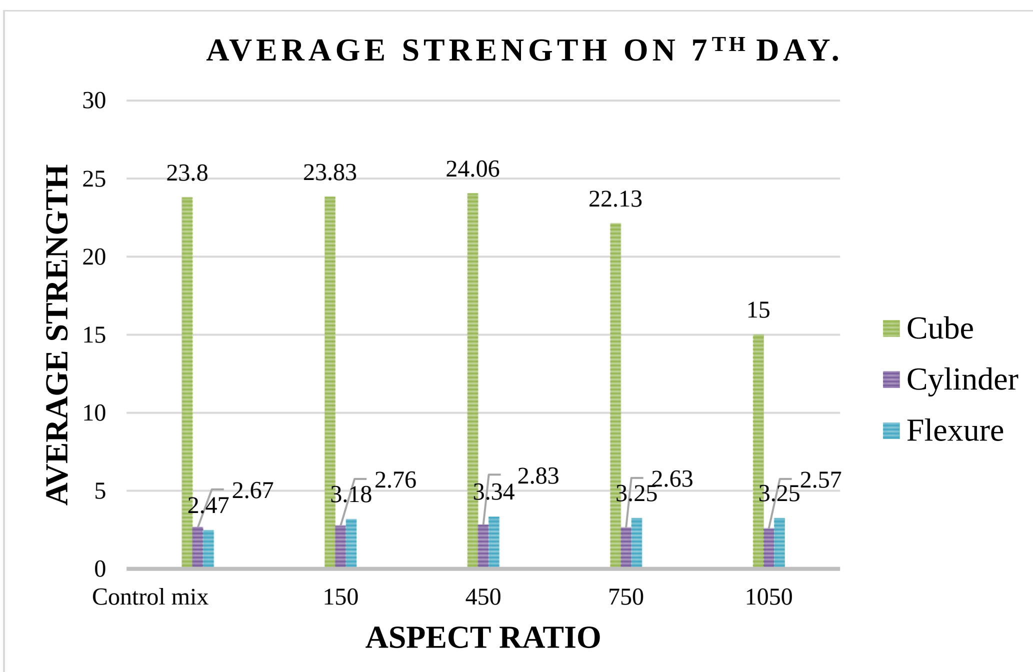
		3	3784	57.8	2.89
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				2.89
450	28	1	3865	66.2	3.4
		2	3797	59.2	3.03
		3	3795	58.4	2.96
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				3.13
750	28	1	3835	49.1	2.46
		2	3825	52.6	2.63
		3	3814	56.5	2.82
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				2.64
1050	28	1	3733	38.4	1.92
		2	3791	49.4	2.47
		3	3778	44.8	2.24
	AVERAGE SPLITTING TENSILE STRENGTH (Mpa)				2.21

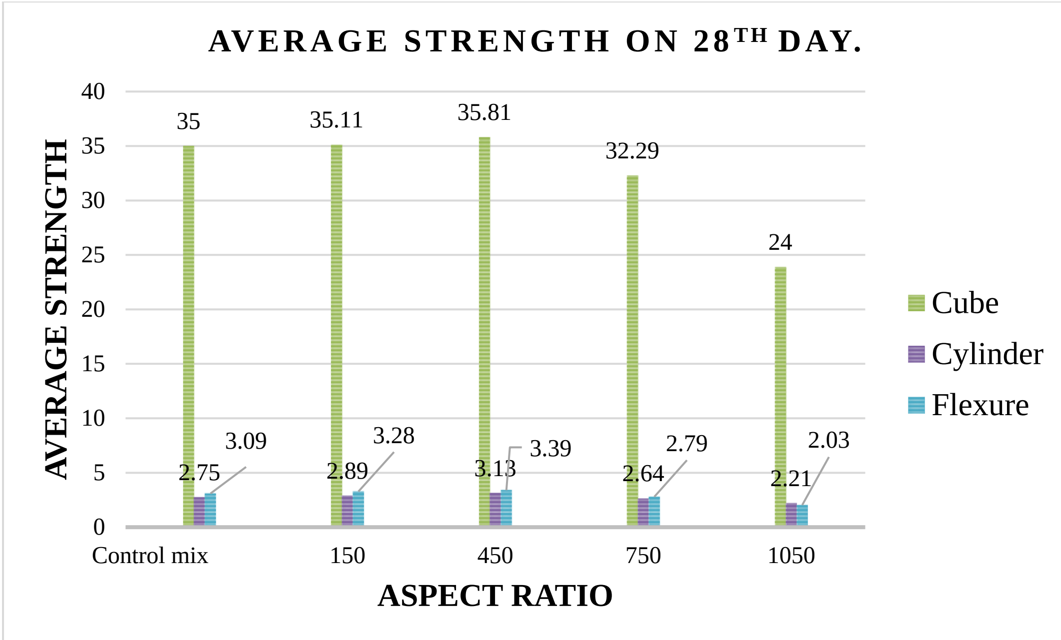
F-3: Test Results for Flexural Strength

Aspect ratio	Days	Sample	Flexure		
			Weight(g)	Force(KN)	Strength(MPa)
Control mix	7	1	11970	4.9	2.07
		2	11859	6.4	2.9
		3	11869	5.5	2.45
	AVERAGE FLEXURAL STRENGTH (Mpa)				2.47
150	7	1	13144	7	3.14
		2	12975	7.2	3.22
		3	13060	7.1	3.18
	AVERAGE FLEXURAL STRENGTH (Mpa)				3.18
450	7	1	13336	8.1	3.61
		2	13322	8.09	3.6
		3	12202	7.29	2.8
	AVERAGE FLEXURAL STRENGTH (Mpa)				3.34
750	7	1	13569	8.2	3.68
		2	13063	6.3	2.85
		3	13283	7.13	3.21
	AVERAGE FLEXURAL STRENGTH (Mpa)				3.25
1050	7	1	13512	8.1	3.64
		2	13789	7.4	3.31
		3	14209	6.34	2.81
	AVERAGE FLEXURAL STRENGTH (Mpa)				3.25
Result on 28th day					
Control mix	28	1	13300	7.2	3.15
		2	12140	6.7	3.02
		3	11854	6.9	3.1
	AVERAGE FLEXURAL STRENGTH (Mpa)				3.09
150	28	1	13278	7.1	3.2

		2	13366	7.5	3.39
		3	13298	7.2	3.24
	AVERAGE FLEXURAL STRENGTH (Mpa)				3.28
450	28	1	13789	8	3.58
		2	13578	7.1	3.2
		3	13683	7.5	3.39
	AVERAGE FLEXURAL STRENGTH (Mpa)				3.39
750	28	1	11810	5.6	2.51
		2	13519	6.7	2.91
		3	13690	6.8	2.95
	AVERAGE FLEXURAL STRENGTH (Mpa)				2.79
1050	28	1	13507	6	2.7
		2	13405	4.2	1.8
		3	13382	3.8	1.6
	AVERAGE FLEXURAL STRENGTH (Mpa)				2.03

Summarizing graph representation





Appendix G- Pictures