ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS

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M22B32/054

A DISSERTATION SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF CIVIL AND ENVIRONMENTAL ENGINEERING OF UGANDA CHRISTIAN UNIVERSITY

February, 2026

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ABSTRACT

This study assesses the suitability of sisal fibre as reinforcement in woodcrete blocks while maintaining low density. Traditional concrete blocks have high density and dead loaded, which increases structural demand, member size and cost. Woodcrete, produced by mixing cement with sawdust, is lighter but suffers from low strength and microcracking. A 1:2 cement–sawdust mix was reinforced with sisal fibre at 0%, 0.5%, 1.0%, 1.5% and 2.0% by weight of cement. To increase the compatibility with the cement matrix, sawdust and fibre were treated in 15% NaOH and then washed and dried. Tensile strength, compressive strength, water absorption and density were tested. At 28 days, the 1.5% fibre mix increased compressive strength from 2.64 to 3.67 MPa (~39%) and tensile strength from 0.91 to 1.08 MPa (~19%), both statistically significant, while water absorption remained acceptable and stayed below 1500 kg/m^3. Thus, 1.5% sisal-reinforced woodcrete provides lightweight, stronger blocks suitable for non-load-bearing, low-cost housing.

DECLARATION

I, ZOZO MUSOLE JONATHAN, hereby declare that this research project entitled "ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS" is my original work and has not been submitted to any other institution for the award of a degree or any other academic qualification. I further declare that the research was conducted in an ethical manner, and that all sources of information used have been duly acknowledged and referenced in accordance with accepted academic standards.

Signed:___________________

Date:_____________________

APPROVAL

This is to certify that this research and design project by ZOZO MUSOLE JONATHAN has been carried out under my supervision and is now approved for submission to the Faculty of Engineering, Design and Technology, Uganda Christian University, in partial fulfilment of the requirements for the award of a Bachelor of Science in Civil and Environmental Engineering.

Name of Supervisor: Mr. Zzigwa Marvin

Signature: ____________________________

Date: _______________________________

DEDICATION

I dedicate this research project to my family, those who have been there for me since the beginning, constantly supporting, with prayers and encouragement. Their sacrifices and faith in me have made all of this possible.

I also dedicate this work to my lecturers and supervisors, whose guidance, patience and commitment to excellence have shaped my understanding of civil and environmental engineering.

ACKNOWLEDGEMENT

I want to express my sincere gratitude to the Almighty God who gave me the gift of life, strength and wisdom that have sustained me throughout this research and my entire academic journey. His grace has followed me through all the obstacles.

I am deeply grateful to my supervisor, Mr. Zzigwa Marvin, for his constructive guidance, patience and support. His remarks, correction had a lot of positive influence over this project.

Finally, I would like to say my heartfelt thankfulness to my family because of unshaken love, prayers, and financial and moral support. This has been made possible and motivated by their sacrifices, encouragement and constant belief in me.

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LIST OF ACRONYMS AND ABBREVIATONS

ASTM	American Society for Testing and Materials
BS	British Standard
Kg	Kilogram
kg/m^3	Kilogram per meter cubed
kN	Kilonewtons
mm	millimeter
µm	micrometer
MPa	Mega Pascals

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

Construction industry is being put under pressure to offer more housing without over exploiting natural resources. The conventional techniques of building that mainly involve the use of thick concrete and masonry usually lead to excessive consumption of materials and overbearing structural loads. This raises the cost of construction and the environmental footprint by increasing energy consumption and consumption of resources. In order to overcome them there is increased concern in using new materials and techniques that are safe, durable, and more sustainable. This has resulted in the replacement of heavy materials with light ones around the world.

Lightweight materials that have a density less than 2000 kg/m^3, are considered to be light in weight and can be used to minimize permanent loads of a building. With these materials, engineers are able to construct smaller portions, require fewer reinforcements, and reduce the costs and amount of material consumed, which makes construction more efficient and friendly to the environment (Kulbhushan et al., 2018). A number of lightweight technologies are currently deployed into construction that have varying strengths and densities. An example of such materials is hempcrete, which is very light with a 300-900 kg/m3, but compresses poorly with a mean of 0.2-0.5 MPa and a peak of 1.2 MPa when compacted (Asghari and Memari, 2014). The density of structural lightweight aggregate concrete is 1,120-1,920 kg/m3 as well as compressive strengths are approximately 17 Mpa (Holm and Ries, 2007). AAC blocks weigh less (400–

800 kg/m3) and have a strength of 27 MPa. Foamcrete is 400-1600kg/m3 with 7 day strengths of about 1-10 Mpa with different mixes.

Woodcrete and papercrete are also under research. They are usually 800-1200 kg/m3 in density, with compressive strengths of 0.6-3.89MPA of woodcrete and 1-3MPa of papercrete. Although not yet standardized, they are said to be ultra-light and have potentials of sustainable construction (Hornby, 2020).

Lightweight materials are significant since normal masonry, which includes solid concrete blocks, impose dead load to the buildings. This puts pressure on foundations, beams, and columns, which may need larger sections and additional reinforcement, increasing costs and consumption of more materials (Sultan et al., 2023). These loads may be minimized by substituting heavy materials with lightweight ones to ensure that the structures become efficient but with no effect on safety.

Lightweight materials are however new but on the spotlight in Uganda. Proposals have researched papercrete bricks, rice husk composite, and straw fiber-reinforced concrete especially in low-cost housing and in projects that are environment-friendly. In East Africa, these materials are increasingly becoming popular in the quest to adopt sustainable and resource efficient buildings.

Lightweight materials are gaining popularity as the construction sector tries to find a more sustainable and cost-effective way of doing things. These materials will reduce the structural loads, decrease the construction cost and also decrease the environmental impact. Of all the possible variants, those materials that can be made of recycled materials or locally obtained ones are receiving some interest as a possible approach to green buildings and low-cost housing.

Woodcrete blocks consist of cement mixed with wood waste such as sawdust, shavings or chips to produce a light and insulating block (Aigbomian, 2013). Recycled wood consumes less embodied energy, generates less CO2 than standard concrete, and is made by using locally sourced devices which promotes sustainable construction.
Woodcrete should be treated so that it becomes durable. The untreated wood- cement composites may lose strength with time, and the application of cement or lime on the wood enables the material to retain its compressive strength (Khelifi et al., 2022).
Woodcrete offers an average performance in terms of structure, sustainability, and cost-effectiveness and therefore is appropriate in low-cost housing construction, particularly in fast-growing economies such as Uganda (Fadiel et al., 2022).
Woodcrete is not yet popular even after the benefits it has. It has less mechanical strength compared to other lightweight materials like structural lightweight concrete (Dias *et al.*, 2022). This is mostly because of high porosity, low bonding at the wood-cement interface, and the inherent property of wood to absorb moisture, which may induce micro-cracking and change in dimensions. To eliminate these shortcomings, researchers recommend the strengthening of the woodcrete with fibers to increase durability (Aigbomian and Fan, 2013).

Fiber reinforcement is normally a construction material applied to enhance performance of materials. Natural fibers like sisal, bamboo, jute have been successfully used as also synthetic fibers like steel and plastic. Sisal, specifically, is a high tensile strength material (350840 Mpa), medium stiffening material (938 Gpa), low density (1.331.45 g/cm 3), and low water uptake, which is extremely fitting to reinforce lightweight composites (Bichang A *et al*., 2022; Z and El, 2021).

Adding fibers such as sisal to woodcrete will provide an effective method of making the material stronger without losing its lightweight and sustainability properties. Given the appropriate treatment and reinforcement, the woodcrete can be a relatively cheap yet stable and sustainable material that can be used to build low-cost housing and sustainable construction in Uganda and in the East African region in general.

1.1.1 PROBLEM STATEMENT

Many buildings experience structural challenges due to excessive permanent loads, which increase the demand on foundations, beams, and columns and driveup construction costs. Some of the most significant contributors are concrete blocks which are commonly used in masonry and with 1800 kg/m^3 or higher density for a block. The weight of the construction materials is thus of much concern, particularly in affordable housing, with the lighter weight of materials being able to reduce dead loads, a smaller structural element, and lower costs.

Woodcrete blocks have the potential to be lightweight construction units although the weaknesses in their structure restrict the application of this potential. Water-induced and micro-cracking may be caused by high porosity, poor bonding between cement and wood, and hygroscopic character of wood, which limits their application in load-bearing structure (Aigbomian, 2013).

A potential solution to these constraints is fiber reinforcement. Natural fiber is silal fiber, which is characterized by high tensile strength (350840 Mpa), moderate stiffness (9-38 Gpa), and comparatively low density (1.331.45 g/cm 3) (Bichang'A et al., 2022). It is strong, does not absorb as much water as most other natural fibers do, and facilitates high mechanical interlock with the cement matrix (Z & El, 2021; Anas et al., 2022).

This research therefore aims to investigate the use of sisal fiber as reinforcement in woodcrete blocks, assessing its effect on mechanical performance and evaluating its potential for broader structural applications.

1.1.2 MAIN OBJECTIVE

To assess the suitability of using sisal fibre as a reinforcement in woodcrete blocks.

1.1.3 SPECIFIC OBJECTIVES

1. To determine the physical and mechanical properties of sisal fibre relevant to woodcrete production.
2. To determine the optimum sisal fibre content for producing stable, workable, and strong woodcrete blocks.
3. To determine the effect of sisal fibre on the micro-cracking, strength of woodcrete blocks.

1.1.4 RESEARCH QUESTIONS

- What are the key mechanical and physical properties of sisal fiber, and how do they influence woodcrete?
- What optimum amount of sisal fiber that is required to obtain a woodcrete block unit?
- What effect of sisal fiber on the microcracking in the woodcrete block?

1.1.5 JUSTIFICATION

Researchers have inquired about the incorporation of natural fibers as cement reinforcement in cement-based composites in order to find sustainable and economical cement reinforcement materials. These fibers have the potential to enhance the mechanical characteristics of lightweight materials such as woodcrete without negative impact on the environment and elimination of the need to use synthetic reinforcements.

Agarave sisalana fiber, or sisal, has found some use in this as it was discovered to have the required mechanical strength as well as be chemical compatible with cementitious materials. It is strong tensile, low density, and surface is fibrous, which enables favorable mechanical bonding with the cement matrix (Silva et al., 2020). It consists of a large quantity of cellulose, which is hydrophilic and the hydroxyl (–OH) groups of the fiber improve adhesion to polar products like cement paste. This tight bonding on fibers-matrices is crucial in porous composite materials such as woodcrete, where porous materials can crack because of the weak bonding between its interfaces (Anas et al., 2022).

Sisal fiber also holds less water than many other natural fibers and this facilitates internal curing and slow release of moisture during cement hydration. In this process, the constant creation of calcium silicate hydrate (C-S-H) enhances the structure of the matrix and compressive properties (Silva *et al.*, 2020). Moreover, alkali solutions, i.e., NaOH, are used to treat sisal fibers, eliminating hemicellulose and making their surfaces rougher which contributes to their longer durability and the ability to bond with the cement matrix.

1.1.6 SIGNIFICANCE

The paper contributes to the existing knowledge on the use of woodcrete as a construction material in Uganda, especially when it is reinforced with sisal fiber. The research enhances sustainable and resource-efficient construction through the use of wood waste like sawdust which are underutilized in the country. The results may be used to inform the choice of materials in building affordable and sustainable housing projects as well as promote adoption of intelligent building techniques utilizing the available materials in the surrounding environment.

Moreover, the development of woodcrete technology will contribute to the minimization of construction waste, which is one of the objectives of Vision 2040 of sustainable development in Uganda (National Planning Authority, 2020). The outcomes of the research should be useful to the policymakers and the construction industry as it will provide an alternative to the traditional lightweight materials, reduce the effects on the environment, and enhance the performance of the building components.

1.1.7 SCOPE OF THE STUDY

1.1.7.1 GEOGRAPHICAL SCOPE

The sisal fibres were sourced from Ngora in Eastern Uganda and sawdust was acquired from Uganda Industrial Research Institute, Namanve

Figure 1.1 Sample of the Sisal Fiber Untreated

1.1.7.2 CONTENT SCOPE

The research will investigate woodcrete blocks and how their mechanical performance can be improved through the addition of sisal fiber. It will evaluate the physical and structural properties of sisal fiber, determine the optimal fiber content, and examine the effect of fiber reinforcement on the strength, durability, and overall behavior of woodcrete. The study also aims to provide practical insights into enhancing lightweight, sustainable building materials using natural fibers for low-cost and environmentally friendly construction.

1.1.7.3 TIME SCOPE

The research study was carried out from July 2025 to November 2025.

CHAPTER TWO: LITERATURE REVIEW

2.1 CONCRETE BLOCKS

A concrete block is a construction product produced by mixing cemet, aggregates and water. The mixture is cast in a reusable mold or 'form' which is then cured in a controlled environment, transported to the construction site and put or lifted into place. A precast concrete block is primarily used as a building material in the construction of walls in building structures and are sometimes called a Concrete Masonry Unit (CMU). The production process for precast concrete blocks is performed on ground level, which helps with safety throughout a project. There is greater control of the quality of materials and workmanship in a precast plant rather than on a construction site. Financially, the forms used in a precast plant may be reused hundreds to thousands of times before they have to be replaced, which allow the cost of formwork per unit to be lower than for site-cast production (Allen, 2009). Concrete blocks come in various shapes and sizes and can be solid or hollow. 39cm x 19cm x (30cm or 20 cm or 10cm) or 2-inch, 4-inch, 6-inch, 8-inch, 10-inch, and 12- inch unit configurations are the most popular concrete block sizes (Kamal, 2022).

The most important mechanical property of concrete blocks is the compressive strength and usually the minimum compressive strength of 7 MPa is required for load-bearing walls (Neville, 2011).

2.1.1 Types of concrete blocks

There are two types of concrete blocks:

- Solid concrete blocks
- Hollow concrete blocks

2.1.1.1 Solid Concrete Blocks:

Solid concrete blocks, which are highly heavyweight and formed by aggregate, are primarily utilized in construction projects. They're sturdy and give structures a lot of solidities. These solid blocks are ideal for large-scale projects such as force-bearing walls.

2.1.1.2 Hollow Concrete Blocks:

In masonry construction, hollow concrete blocks are typically employed. It reduces labor costs on the job site while also speeding up the construction process and saving cement and steel. These blocks reduce the natural weight of masonry structures while also improving physical wall qualities like noise and thermal insulation.

Hollow concrete blocks come in various shapes, sizes, and designs, depending on the shape, needs, and design.

2.1.1.3 Concrete stretcher blocks:

Concrete stretcher blocks are also employed at the masonry's corners. Concrete stretcher blocks commonly use hollow concrete blocks. The parallel length of concrete stretcher blocks is put parallel to the face.

2.1.1.4 Concrete corner blocks:

Concrete corner blocks are utilized at the masonry's corners and the ends of windows and doors. One block corner is plain, while the other has a stretcher design. Concrete corner blocks are placed so that one end of the plane is exposed to the exterior and secured with the stretcher block.

2.1.1.5 Lintel blocks:

Lintel blocks are joined together to form lintel beams. These beams provide structural support by distributing loads from above the beam to the walls on both entry sides. They’re also prefabricated and made of pre- stressed concrete.

2.1.1.6 Concrete Pillar Blocks:

Since both corners are plain, concrete pillar blocks are also known as double corner blocks. As a result, they’re commonly employed when two corners are visible. As the name implies, concrete pillar blocks are commonly used in pillars and piers.

2.1.1.7 Frogged Brick Blocks:

The top surface of this sort of block has a frog section and a header and stretcher. Frog aids in the retention of mortar and forming a strong bond with another brick.

2.1.1.8 Concrete Bricks:

Concrete bricks are small rectangular symmetric blocks that create a rigid wall. These bricks have greater compressive strength than normal clay bricks and have less water absorption property than clay bricks. Concrete bricks are generally made of cement, sand, a little fly ash, etc. These blocks are generally used in facades fences due to their beautiful and modern aesthetic look.

2.2 WOODCRETE

Woodcrete is a composite material developed by mixing wood waste such as sawdust, wood shavings or wood chips into a cementitious matrix to produce a lighter and eco-friendly alternative to conventional concrete. It has gained attention as a sustainable solution to the growing problem of timber and sawmill waste as it contributes to green and sustainable construction by lowering construction costs and reducing landfill waste

(Abdullah et al., 2019). The inclusion of wood in the concrete mix reduces the overall density of the composite as it makes it suitable for non-load-bearing applications such as partition walls, thermal insulation panels and paving units. Studies have shown that woodcrete has favorable thermal and acoustic insulation properties due to the porous nature of the wood particles which trap air and reduce heat and sound transmission (Ajay et al., 2020). Despite all of these advantages, woodcrete has major weaknesses in mechanical strength. A number of researches also suggest that the use of wood waste instead of fine aggregates is likely to decrease compressive and tensile strength, with values that tend to be lower than 5 MPa in the event of more than 20-30% of wood content (Alomayri et al., 2014). This is because it has been found to be resulting due to low interfacial bonding between the hydrophilic wood particles and the cement matrix that results into internal voids and high porosity. Moreover, hygroscopic property of wood leads to absorbed water of the composite and this can tend to often lead to shrinkage, weakening, and dimensional variation over time (Djamaluddin et al., 2019). Physical integrity of woodcrete may also depend on the type and size of wood utilized, treatment and conditions of curing.

A study conducted by Aigbomian and Fan (2016) revealed that the best ratio of sawdust to binder was 1:2 to make woodcrete out of different wood species and particle sizes. This ratio was observed to change drastically with the type of sawdust to be used as the compressive strength of the woodcrete. The compressive strength of Hardwood sawdust (beech and oak) was the highest (3.93Mpa) and was followed by softwood (pine and cedar) which was 1.37MPa, and mixed wood at 0.26MPa. The paper has also established that woodcrete made of hardwood was more dense in comparison to softwood-based and mixed woodcrete. Also, particle size influenced strength and density whereby 1mm sawdust particles made stronger and denser blocks than 2mm and 3mm. In addition, the thermal conductivity was attributed to the chemical content of the wood types with the softwood woodcrete having approximately 20 percent lower conductivity than the hardwood. These results explain that sawdust type and size, as well as an appropriate mix ratio, have a great impact on the mechanical and thermal properties of woodcrete (Aigbomian and Fan, 2016).

2.2.1 Fibre use in construction composite materials.

Natural fibers like sisal, coir, jute, flax, banana and hemp have been actively considered as cement-based reinforcements as it is cheap and it is bio-degradable, and enhances mechanical properties. The properties of each type of fibre determine its appropriateness. Coir fibre is also good in toughness and crack control but it possesses low tensile strength (80-250Mpa) and low in stiffness which limits its structural contribution. Jute and banana fibers have good initial strength but they degrade quickly in the alkaline cement matrix and absorb too much water, which can adversely impact durability in the long run (Balan et al., 2017). Hemp fibre is more competent with tensile strength (550900Mpa) but is not as accessible and expensive to process, which is not feasible in places such as Uganda (Fiore et al., 2015).

2.2.2 Plastic Fiber

Plastic fiber is becoming an environmental reinforcement material in concrete especially because of the fact that it helps in recycling of plastic waste including bottles and packaging materials. This will minimize environmental degradation that is caused by improper discarding of plastics.

Plastic fibers are not only used to ensure sustainable construction, but also reduce the total cost of the construction. Studies have indicated that additives of substituting up to 1.5 percent of the cement content with plastic fibers are the most effective. Also, a new system that has use of constant plastic fiber reinforcement has portrayed high bonding strength in between polyethylene terephthalate (PET) fiber and the concrete matrix.

Nevertheless, addition of plastic fibers may decrease compressive strength of concrete. To overcome this limitation, one can use additives like silica fume and metakaolin so that mechanical performance can be enhanced. In spite of an decrease in compressive strength, PET fibers improve tensile and flexural strength of concrete, develop a more ductile mode of failure, and increase the overall cohesion of mix materials.

It is mentioned, too, that the addition of PET fibers can adversely affect the workability of fresh concrete and can even result in spalling. As a result,
the mix design and workability should be changed with the use of plastic fibers.

2.2.3 Natural Fibers

Natural fibers are widely considered promising reinforcements in concrete due to their lightweight, low cost, environmental friendliness, good specific strength and modulus, and absence of health risks. They are also locally available in many regions. Common types include wheat straw, sugarcane fiber, sisal fiber, jute fiber, and bamboo fiber.

2.2.3.1 Wheat Straw Fiber

Wheat Straw Reinforced Concrete (WSRC) has proven to have tremendous advantages in the initial stages of curing especially in paving works. The wheat straw inclusion minimised the severity and quantity of shrinkage cracks. The flexural, tensile and compressive strengths were enhanced even though the slump of the concrete mix reduced. It is also found that the concrete was more ductile and therefore more likely to fail in ductile mode and also the crack width was narrow. The sewing effect of the fiber makes it have improved post-cracking behavior and absorption capacity. The use of wheat straw in concrete also helps to decrease the burning of crop residues and decreases the cost of construction (Khan et al., 2022).

2.2.3.2 Sugarcane Fiber

The thermal stability and mechanical qualities of concrete are increased by the use of sugarcane fiber. It is used as sugarcane bagasse ash (SCBA) which enhances flexural, compressive and tensile strength and minimizes thermal conductivity of the mix. By adding SCBA to concrete, they are made lightweight and thermally stable to 450 o C. Further increase in stiffness and elastic modulus was done with the help of electron beam radiation. Microstructural research showed that voids were considerably reduced and this shows an improved overall performance of the concrete matrix (Khan et al., 2022).

2.2.3.3 Jute Fiber

JTF has proven to be a potential material to be utilized in the reinforcement of concrete because of its sustainability, biodegradability, and non-toxicity nature. JTF addition will decrease the fluidity of fresh concrete due to its high surface area, which enhances the harshness of the mix. Nonetheless, hot treatment of jute fibers with alkali greatly improves the connection between cement paste and fibers, which enhances the performance in terms of mechanical and durability. JTF reinforced concrete boasts of enhanced compressive, split tensile and flexural strength. The maximum compressive strength of 28 days was recorded at a 2% JTF content which was 20% higher than control concrete. Nevertheless, the degree of fiber can decrease the strength and durability owing to the low flowability and the plasticizers are necessary in large amounts. Density, resistance to water absorption, dry shrinkage, and acid resistance are increased in JTF in terms of durability. Nevertheless, very little studies have been done regarding the long- term performance and durability of JTF-reinforced concrete. The review suggests some more research in the field, such as chemical and physical processing of jute fibers, and the addition of pozzolanic substances, such as fly ash or silica fume, to strengthen bonds and overall performance (Ahmad et al., 2022).

2.2.3.4 Bamboo Fiber

Bamboo has been showing good prospects as an efficient and affordable alternative to steel reinforcement in concrete buildings. Special soluble agents including borax-boric acid, vertical soak diffusion, pressurized tank preservation have been observed to contribute greatly to the resistance of bamboo towards attacks by insects. To enhance the durability and bond strength of bamboo in structural application in beams and columns, the advanced treatment methods along with the effective waterproof coating such as bitumen, Sikadur Gel, use of boric-borax acid, and polyester resin are further employed to improve it. Also, mechanical interventions like screws between nodes and hose clamps in the form of shear connectors have been discovered to enhance the bond stress of the bamboo-reinforced concrete (BRC) elements and enhance the load-bearing capacity. Prefabricated panels with a bamboo-reinforcement have significant economic, structural benefits, potentially saving up to 40 percent of costs and cutting weight up to 56 percent of traditional brick walls, possessing an equal or similar compressive strength of 17.6 MPa. However,Flexural bond failure is also an issue, which points to the necessity of additional optimization of bonding performance (Das et al., 2024).

2.2.3.5 Sisal Fiber

Sisal fiber concrete reinforced concrete has got structural applications and can make a compromise to the traditional steel reinforcement that is mostly linked to environmental and health issues. The research has reported that sisal fiber enhances compressive strength, tensile strength, and flexural strength. It is particularly useful in drainage plates and is about 1.85 times cost effective than steel reinforcement. Even though the introduction of sisal fiber decreases the workability of the mix, it raises the initial crack load indicating a high strength. The ideal percentage of cement substitution of ground granulated blast furnace slag (GGBFS) is 20% (Khan et al., 2022). Sisal fibre proves to be one of the most compatible fibers of reinforcing lightweight cementitious materials, such as woodcrete. It has a tensile strength (350-840 Mpa) that is relatively high, exhibits high durability in an alkaline environment following mild alkali treatment and has a rough surface texture enhancing mechanical interlocking between the cement matrix (Anas et al., 2022). Its water permeability is moderate and this means internal curing without causing a major weakening of the matrix and thus allowing easier formation of the calcium silicate hydrate (C-S-H), the material that causes the development of strength in cement composites. Unlike the more brittle or moisture-sensitive types of fibers, sisal is able to retain its structural strength over time and can be found in abundance in East Africa and this makes it a more viable and sustainable material in terms of reinforcement used to improve the mechanical constraints of woodcrete (Uysal et al., 2024).

Chemically modified sisal fibres in cement-based composites show that treatment significantly slows down degradation in alkaline environments, and treated fibres are generally considered capable of providing an effective service life on the order of 10 years or more, according to klerl (2020) In practical masonry applications, the fibres are fully embedded in the cement matrix and further protected by external finishes such as plaster, which limit direct exposure to moisture, oxygen and biological attack; under such interior, non-aggressive conditions, fibres are expected to extend beyond this decade-level estimate (de Klerk et al., 2020; Wei, 2014; Fode et al., 2025).

2.2.4 Fiber optimization

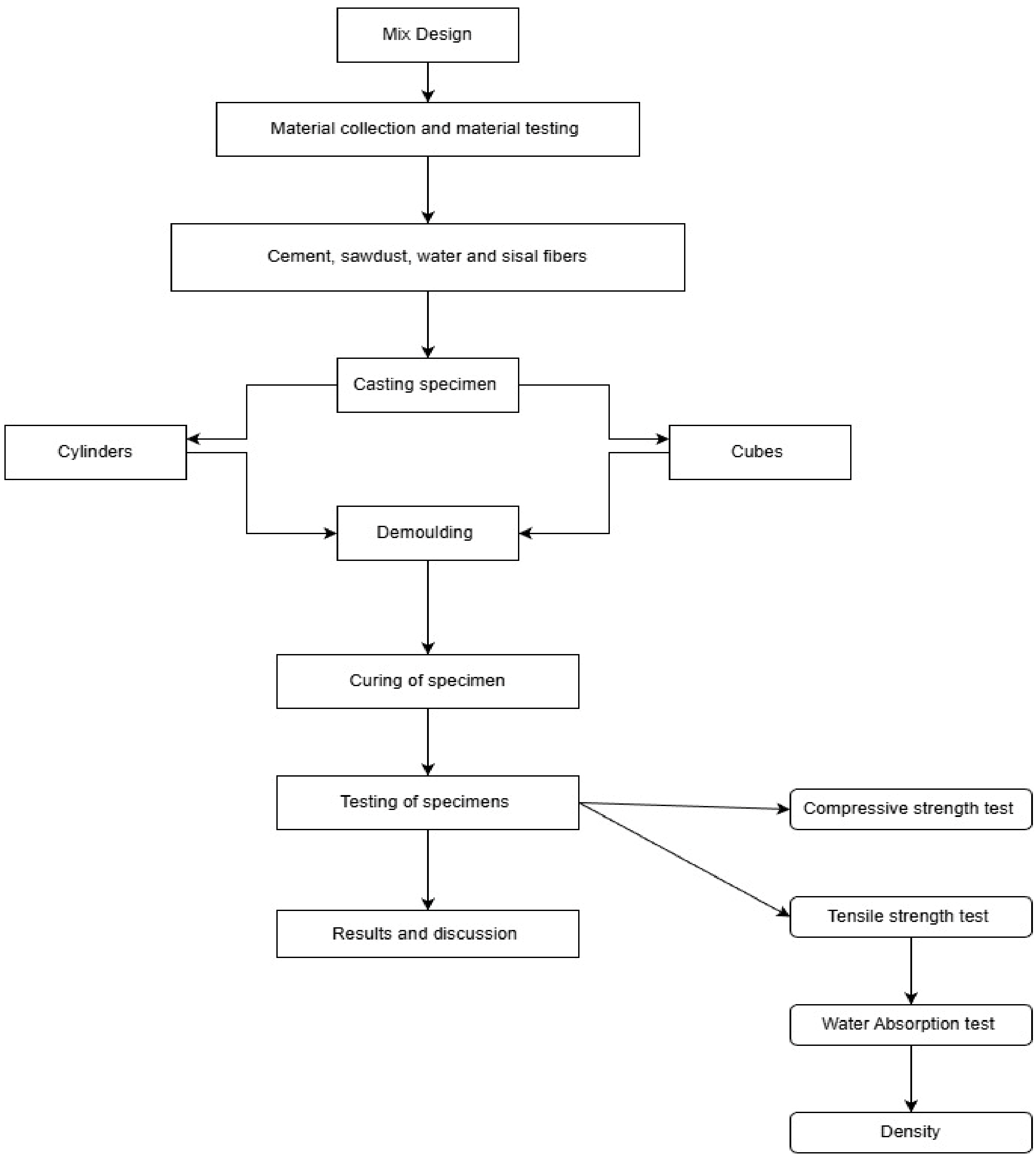
In composite materials, optimization of fibers is done in specific ways depending on the end requirements of the cement matrix. Okeola et al. (2018) conducted an experimental study of sisal fibre reinforced concrete at different fibre doses of 0.5, 1.0, 1.5 and 2.0 % of cement weight and physical and mechanical properties of the mixes that resulted. They claimed that though addition of sisal fibres minimally lowered compressive strength of concrete, it considerably increased split tensile strength and static modulus of elasticity in comparison to control mix, and post cracking behaviour by stopping the propagation of cracks. The authors, however, also noted that workability lowered significantly with the increase in fibre content due to balling of fibre and increased internal friction in the mix, which showed that the dosage of sisal needed to be moderate to allow the mix benefits and realistic workability (Okeola et al., 2018). Some of the ways this is done is by balancing strength gains against workability loss and balancing of cost and benefit. The levels are chosen to maximize structural benefit while maintaining mix quality, ease of placement, and code compliance.

CHAPTER THREE: METHODOLOGY

This chapter includes discussion of procedures, material preparation, methods and the various tests used to meet the specific objectives.

3.1 Research Design.

FLOW CHART



This is the shows and informs how this research will be carried out on. After the submission of the research proposal, intensive literature review will continue up till the end of the research. Preliminary finds are then to be carried out to inform the research methodology. Results will be collected and analyzed to have precise conclusions and recommendations.
The data will be analyzed by quantitative research specifically by carrying out experiments and analyzing the results.

3.1.1 Materials

3.1.1.1 Sawdust

Sawdust was sourced from East African Trading Limited to ensure the use of sawdust derived primarily from hardwood species. Hardwood sawdust is preferred because it has denser, more compact particles that contribute to stronger and more durable woodcrete blocks. Compared to softwood sawdust, which is more porous and tends to retain more moisture, hardwood sawdust offers better dimensional stability and lower shrinkage during curing. It also provides higher mechanical interlocking within the cement matrix, improving the overall compressive and flexural strength of the resulting composite. The choice of supplier was therefore based on consistency, quality, and the ability to provide fine, uniformly graded hardwood sawdust appropriate for experimental research and construction testing.

3.1.1.2 Cement

Cement served as the primary binding material in the formation of woodcrete blocks, providing the necessary cohesion between sawdust and fibres. It is a critical construction material known for its strength, durability, and versatility, enabling it to withstand compressive loads and environmental stress. In this study, ordinary Portland cement (OPC) was selected because of its high availability, cost-effectiveness, and established performance record in structural applications across Uganda.

3.1.1.3 Sisal Fibres

Sisal fibres were obtained from the Uganda Industrial Research Institute (0°20'50.8"N, 32°41'21.7"E), chosen for its reliable processing of natural fibres with controlled quality and uniformity. Sisal was selected due to its biodegradability, high tensile strength, and excellent adhesion characteristics when properly treated. Before application, the fibres underwent alkali treatment to remove lignin and hemicellulose, improving their surface roughness and bonding capacity within the cementitious matrix. This treatment enhances fibre–matrix compatibility, reduces water absorption, and improves tensile load transfer, contributing to the mechanical stability of the woodcrete composite.

3.2 Methods

Determining the mechanical and physical properties sisal fibre in material requirements of woodcrete.

3.2.1 Sisal fiber extraction (ASTM D4151-16)

Sisal fiber was extracted from Badongo in Jinja Uganda and was chosen basing on their maturity. The mature fiber has better mechanical properties like higher tensile strength and durability because it has optimized cellulose and lignin content and composition.

Sisal fiber of about length 700mm was processed by the decortication method using a decorticator machine. This process aims at differentiating the fibrous material from the non-fibrous constituents. This method ensures that the properties of the fiber remain intact to maintain the structural integrity which is crucial for the reinforcement application.

After decortication, the fiber was washed thoroughly with potable water to get rid the residue chlorophyll, waxes and other impurities. The fibers were then be sundried for over 24 hours to remove excess moisture that could affect the mechanical properties during application (Neto et al., 2019). Raw sisal was collected and cut at length of 650 mm to obtain and maintain consistent length of the fibers which will reduce variations in the tests done.

3.2.2 Alkali treatment of sisal fiber (ASTM D518-15)

The sisal fibers of uniform length were treated with an alkali, in this case which will be sodium hydroxide solution. This method is done to modify the chemical and physical structure of natural fiber by removing non-cellulosic components such as lignin, hemicellulose, waxes and also possibly impurities. Removing these components leaves the cellulose fibrils exposed and this improves the mechanical properties of the fiber such as surface morphology, or surface roughness and the tensile strength (Gurunathan et al., 2019). The mechanism of alkaline treatment is that the NaOH solution breaks down the components of the fiber like the ester and glycosides bonds in the lignin and hemicellulose.

The fiber was placed in 15% NaOH solution to enhance the mechanical properties of the fiber and its compatibility in the cement matrix at a temperature of t 100°C for 30 minutes. They will then be washed with distilled water. The treated fiber was then oven dried at a temperature of 29°C to preserve it (Mutumba, 2025).

Figure 3.1 Showing Sisal Fibers in the Sodium Hydroxide Solution

Figure 3.2 Showing Sisal Fibers Being Washed

3.2.3 Mechanical testing using the Tensomaster machine (ASTM D2256)

The mechanical properties of the treated and untreated sisal fibers are to be evaluated using a Automatic Single Yarn Strength Tester machine, a standard apparatus for tensile testing. This machine measures key mechanical parameters such as tensile strength, elongation at break, and breaking force, in compliance with ASTM D2256 for single-Fibre tensile testing.

Figure 3.3 Showing A Automatic Single Yarn Strength Tester machine

3.2.3.1 Sample Preparation

Fibre Length: Before testing, the sisal fibers were first sorted and cleaned to remove any visible impurities such as dust and loose particles. Since the individual fibers were shorter than the required testing length, several of them were carefully tied end-to-end to form a continuous strand long enough to fit within the testing machine. Each prepared strand was then cut to a uniform length suitable for the Tensomaster Automatic Single Yarn Strength Tester, which operates with a maximum gauge length of 500 mm, leaving additional length at both ends for secure clamping.

3.2.3.2 Test procedure (ASTM D2256)

The tensile test commences by having the individual sisal strands between the upper and lower grips of the Tensomaster testing machine. Grips are also adjusted such that the fibers are not easily slipped or spoiled during loading and therefore the outcomes will be the real tensile strength of the fibers. A uniaxial tensile force is then applied along the length of the specimen at a controlled rate after anchoring the specimen in place, and in accordance with the ASTM D2256 standard, the time-to-break was approximately 20 ± 3 seconds. The force applied is progressively increased until the fiber snaps and the machine will automatically capture the peak pressure and elongation at the moments of failure.

To ensure accuracy and reliability, three strands of fibers of each set of the treated and un-treated samples are put through testing. The obtained data are subsequently interpreted to calculate the mean tensile strength, elongation and tenacity and are examined to find out the effects of the alkali treatment to the mechanical behavior of the sisal fibers.

3.2.4 Water Absorption Test (ASTM D570)

The hygroscopicity is a physical property of fiber which measures how fibers absorb and retain water, and is determined using water absorption tests. Excessive water absorption may cause fiber swelling, dimensional instability, and reduced durability of woodcrete. In order to know the percentage of absorption, fibers are weighed, immersed in water over a specific period and weighing once more. Reduced water absorption of treated fibers increases their stability and reduces chances of affecting block integrity (Rowell, 2005).

3.2.4.1 Test procedure (ASTM D570)

The sisal fibers were initially dried in the oven at 105 o C and 24 hours so as to eliminate all moisture content. The drying fibers were left to cool down in a conditioning chamber to have room temperature and avoid the rapid absorption of moisture by the air around. The weight of the dry fibers (W1) was then determined with the help of a digital balance and taken note of. The dried fibers were then placed in water and left to dry in 24 hours. After the immersion, the fibers were removed, the surface water was blotted off and the wet mass of the fibers (W2) was obtained and then measured and tabulated. The percentage of water absorption was then determined using the formula:

$$\text{Water Absorption (\%)} = \frac{W_{wet}\text{-}W_{dry}}{W_{dry}} 100$$

Figure 3.4 Showing Sample Immersed in Water

3.2.5 Density / Specific Gravity Measurement (ASTM D3800)

The physical characteristics of mass to volume ratio of the fiber are examined using density determination. Due to the fact that proportions in woodcrete are often calculated based on volume as opposed to weight, the density of treated fibers is important in creating an accurate mix design. A pycnometer or displacement can be used to accurately determine the fiber volume fraction of the composite. Treatment can cause slight changes in the density of the fibers by removing non-cellulosic components, so this data can be utilized to guarantee that the appropriate proportion of mixes is applied to obtain the preferred block density and mechanical behavior.

3.2.5.1 Test procedure (ASTM D3800)

The fibers of sisal were dissolved into minute fragments of about 2 mm in length and sponged in water completely to get rid of any dirt or dust and surface contamination. Oven-drying of the cleaned fibers at 105oC for 24 hours was done in order to dry all the moisture. The fibers were dried and then allowed to cool at a conditioning chamber to achieve room temperature in order to avoid the uptake of moisture. A digital balance then was used to weigh the mass of the dry fibers (M1) and note it.

The volume was then measured by first pouring into a graduated cylinder known volume of water (V1) and recording the level of the water. The dry fibers were observed to be very immersed in the water and the newly-formed water level (V2) was recorded. The volume of the fibers (Vfiber) was obtained using the displacement method as $V_{fiber}=V_2-V_1$.

Finally, the density (ρ) of the sisal fibers was calculated using the formula:

$$\rho = \frac{M1}{Vfiber}$$

3.2.6 Scanning electron microscope (SEM) analysis of sisal fiber (ASTM E986-04)

The determination of the morphological analyses of the treated and untreated sisal fibers was done under a TESCAN VEGA3 Scanning Electron Microscope to ascertain the changes in surface properties and the micro structures of the sisal fibers as a result of the treatment with alkali.

Visualization of the surface morphology, fibre structure, and the impacts of chemical treatments at the micro level is very critical and requires the analysis of the surface, reinforced with SEM that may offer some insights into fibrillation, removal of impurities, and uncovering cellulose fibrils that are highly precious in perspective of reinforcement in composites such as cementituous matrices and concrete (Muthulakshmi et al., 2021).

3.2.6.1 Sample Preparation for SEM

The samples to be used in the SEM imaging were prepared by cutting the sisal fibers into small pieces of about 10-15 mm long. This step was done to make certain that the fibers were inserted in the SEM sample holder, and that they fit well and were uniform and minimized chances of imaging artifacts. Their samples were then washed by the use of the distilled water and ethanol and then dried by air to take away any dust, impurities or moisture that may affect the quality of imaging. To fix the dried samples on aluminum stubs so that they will be in contact with electrical contacts, carbon adhesive tape was used. A very fine gold coating was sputter coated, which enhanced the conductivity of the surface and prevented the charging of electrons during imaging thus resulting in clear and high resolution SEM micrographs.

3.2.6.2 SEM Imaging Procedure

The coated fibers are carefully mounted onto aluminum stubs after sample preparation using conductive carbon adhesive tape to ensure stability and proper electrical conduction within the SEM chamber. The imaging conditions are controlled to achieve optimal visualization of the fiber surface. The accelerating voltage is set to 20 kV, providing high-resolution images while minimizing thermal damage to the sisal fibers. Micrographs are then captured at different magnifications of 20 μm, 50 μm, and 100 μm, allowing the identification of macroscopic impurities, fibrillation effects, and microscopic surface irregularities that may result from the alkali treatment process.

3.3 Experimental Methodology for Woodcrete Blocks

To determine the optimum sisal fibre content for producing stable, workable and strong woodcrete blocks, a structured experimental methodology was adopted. The key aspects of this methodology included:

- Material selection and preparation,
- Mixing and casting of plain woodcrete and sisal fibre–reinforced woodcrete,
- Curing conditions,
- Testing procedures for fresh and hardened properties of both control and fibre-reinforced woodcrete.

These steps were organized to follow the project objectives, so that the behavior of the control woodcrete could be consistently compared with sisal fibre–reinforced woodcrete at different curing ages (7, 14 and 28 days).

3.3.1 Materials used

The main materials used in this study were:

Ordinary Portland Cement (OPC)

Ordinary Portland Cement (OPC) was used as the main binder in all mixes.

Sisal fibres

Sisal fibres were used as natural reinforcement in the woodcrete blocks.

Size of fibres: 15 mm.

Water

Clean, potable water was used for both mixing and curing of the specimens.

Sawdust

Sawdust from a local carpentry workshop was used as the lightweight aggregate in the woodcrete.

3.3.1.1 Preparation of sawdust

Before use, the sawdust was subjected to chemical treatment with a sodium hydroxide ($NaOH$) solution. Alkali treatment of lignocellulosic particles with $NaOH$ is widely used to dissolve sugars and other water-soluble extractives, partially remove hemicellulose and lignin (Aigbomian & Fan, 2014; Alzuhairi et al., 2016).

This treatment was adopted to reduce impurities, minimise biological decay (rotting), and improve the compatibility between the sawdust and the cement matrix, thereby extending the service life of the resulting woodcrete blocks (Aigbomian & Fan, 2014; Alzuhairi et al., 2016).

The sawdust was immersed in a sodium hydroxide solution at a concentration equivalent to 15% of the dry weight of sawdust, thoroughly washed with clean water to remove residual alkali, and then sun-dried for approximately 24 hours before mixing.

3.3.2 Equipment Used

The main equipment used in this study included:

- Standard steel moulds : to cast the different specimen types:
    - 150 × 150 × 150 mm cubes for compressive testing
    - 150 × 200 × 400 mm moulds for block samples
    - 150 mm diameter × 300 mm height cylinders for tensile strength testing
- Universal Testing Machine (UTM): to apply loads for mechanical strength tests.

- Compression Testing Machine: to determine the compressive strength.
- Curing tank (water tank): to immerse and cure the specimens in water for 7, 14 and 28 days.
- Digital weighing balance: to determine the mass of specimens.
- Oven

3.3.3 Mix Design And Proportioning:

Several studies on wood-crete have investigated different cement–sawdust ratios, such as 1:1, 1:2 and 1:3 (cement:sawdust). These ratios are usually adjusted to balance density, strength and workability. Mixes richer in cement (1:1) generally give higher compressive strength and lower water absorption, but become heavier. When the proportion of sawdust is increased the composite becomes lighter and provides better thermal and acoustic insulation, but the compressive strength tends to decrease (Paramasivam et al., 1984; Aigbomian & Fan, 2013; Huseien et al., 2019).

Based on these findings, it showns that mixes where sawdust is 1:2 cement:sawdust, it can produce lightweight blocks with significantly reduced density while still maintaining sufficient (Aigbomian & Fan, 2013; Mangi et al., 2019).

We adopted the 1:2 cement:sawdust ratio by volume therefore as our base woodcrete mix. This proportion was selected to reduce the self-weight of the blocks and enhance their lightweight properties, while keeping enough cement content to bind the treated sawdust and sisal fibres.

Studies on sisal fibre–reinforced cement composites have used different fibre dosages to improve strength and crack control. In many of these works, sisal fibre contents in the range of about 0.5%–2.0% by weight or volume of cement/mix (Okeola et al., 2018; Ahmad et al., 2022; Otieno, 2016). These studies also shows that adding a small to moderate amount of sisal fibre increases tensile and flexural strength and improves crack resistance, but very high fibre contents tend to reduce workability, cause fibre balling and finally reduce strength because of poor compaction and higher void content (Ahmad et al., 2022; Fode et al., 2025).

For this study, sisal fibre was therefore added to the woodcrete at five dosage levels: 0%, 0.5%, 1.0%, 1.5% and 2.0% by weigth of the cement. The 0% mix served as the control, while the 0.5–2.0% mixes allowed to study the effect of gradually increasing fibre content and help the optimum dosage to be identified.

The sisal fibres were cut to an average length of about 15 mm, which lies within the short-fibre range that has shown to be effective for improving mechanical properties in concrete and mortar, using fibre of lengths of 5–15 mm (Mutumba, 2025; Huang et al., 2020) and 10–20 mm (Fode et al., 2025).

3.3.4 Mixing And Casting

For the mixes, the woodcrete was prepared using a 1:2 cement: sawdust ratio by volume. The sisal fibre dosages (0%, 0.5%, 1.0%, 1.5% and 2.0%) were taken as a percentage by weight of cement.

First, the required volumes of cement and treated sawdust were measured to satisfy the 1:2 cement: sawdust proportion. The cement and sawdust were then dry mixed until a uniform color was obtained. This step ensured that the cement was well distributed around the sawdust particles before adding water and fibres.

For the fibre-reinforced mixes, the pre-weighed sisal fibres, calculated as a percentage of the cement weight, were first soaked in water so that they could absorb moisture in advance and would not significantly affect the effective mixing water later. After soaking and draining, the fibres were sprinkled slowly into the mix while mixing continued. This gradual addition helped to distribute the fibres evenly and to reduce fibre balling or clumping.

After the fibres had been incorporated, the mixing water was added gradually while continuous mixing was carried out to obtain a uniform and workable woodcrete mixture. Before casting, all moulds were cleaned and lightly oiled. The fresh woodcrete was then placed into the moulds in layers and compacted by tamping.

Figure 3.5 Showing the Mixing and Casting of the Woodcrete blocks with sisal fibers

Figure 3.6 Showing the Sisal fibers being soaked before incorporation to the mix

3.3.5 Curing Procedures:

After casting, all specimens were kept in their moulds for about 24 hours. After this period, the specimens were demoulded carefully and immediately placed into a curing tank, fully immersed in clean water. The woodcrete specimens were cured for 7, 14 and 28 days, depending on the test age required. At each age, the corresponding set of specimens was removed from the tank.

The main purpose of curing was to provide enough moisture for proper cement hydration and to allow the woodcrete to gain strength with time.

3.3.6 Compressive strength (BS EN 12390-3):

The compressive strength of the woodcrete was determined in accordance with BS EN 12390-3. Cube specimens of 150 × 150 × 150 mm were removed from the curing tank.

Each cube was then placed centrally between the platens of a digital display compression testing machine. The load was applied continuously and without shock at a controlled rate until failure occurred, and the maximum load at failure was recorded from the digital display. The compressive strength was calculated by dividing the maximum load by the loaded cross-sectional area of the cube. Mathematically, the compressive strength was obtained as (BS EN 12390-3, 2009; Neville, 2011):

$$fc = \frac{Pmax}{A}$$

where,

fc = compressive strength (MPa)

Pmax = maximum load at failure (N),

A = loaded cross-sectional area of the cube (mm^2)

Figure 3.7 Showing the block being prepared for Crushing

Figure 3.8 Showing the block after crushing

3.3.7 Tensile strength (BS EN 12390-6):

The tensile strength of the woodcrete was determined in accordance with BS EN 12390-6 using the splitting tensile test. Cylindrical specimens of 150 mm diameter and 300 mm height were removed from the curing tank at different ages (7, 14 and 28 days) and surface-dried. Each specimen was then properly aligned in a Universal Testing Machine to ensure uniform load application from the machine to the sample. A gradual load was applied at a constant rate until failure occurred, and the maximum load at failure was recorded from the machine. The splitting tensile strength was calculated from the recorded failure load using the standard BS EN 12390-6 expression (BS EN 12390-6, 2009; Neville, 2011):

$$ft = \frac{2Pmax}{\pi LD}$$

where,

ft= splitting tensile strength (MPa),

Pmax= maximum load at failure (N),

L = length of the cylinder (mm),

D = diameter of the cylinder (mm).

3.3.8 Water absorption test (ASTM C642-21)

Water absorption of the hardened woodcrete was determined in accordance with ASTM C642-21. After curing, the 150 × 150 × 150 mm cube specimens were removed from the curing tank and placed in an oven at about 105 °C for drying. The specimens were then cooled to room temperature and weighed to obtain the oven-dry mass Wdry.

After oven drying and weighing, the specimens were immersed in water at room temperature for 24 hours to allow saturation. They were then taken out of the water, and weighed again to obtain the saturated surface-dry mass Wssd.

The percentage water absorption was calculated as the increase in mass expressed as a percentage of the oven-dry mass (ASTM C642-21, 2021; Neville, 2011):

$$WA = \frac{\mathrm{Wssd} - \mathrm{Wdry}}{\mathrm{Wdry}} \times 100$$

where

WA= water absorption (%),

Wssd= saturated surface-dry mass of the specimen (g),

Wdry= oven-dry mass of the specimen (g).

3.3.9 Density:

The density of the woodcrete was determined from the mass and volume of the cube specimens. After curing, the 150 × 150 × 150 mm cubes were removed from the curing tank, surface-dried to remove excess water and then weighed using a digital balance to obtain the mass of each specimen. The density of each specimen was then obtained by dividing its mass by the corresponding volume (Neville, 2011):

$$\rho = \frac{W}{V}$$

where

ρ is the density of the specimen,

W is the mass of the specimen,

V is the volume of the specimen.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 INTRODUCTION

This report describes and explains the results of the experimental work carried out on the use of sisal fibre for reinforcing woodcrete. Alkali treatments alter the properties of sisal fibre, affecting, in turn, the suitability of the woodcrete material. Physical properties such as strength, percentage elongation, water absorption, as well as fibre density, form the central focuses of this report. But more importantly, the microscopic changes that occur as a result of treatments provide the essential insights that point towards fibre suitability, compatibility, or the extent of interaction of the fibre with a cement matrix.

The experiments were conducted to establish a scientific basis for the incorporation of natural fibres, specifically sisal, into lightweight concrete materials like woodcrete. With an increasing concern for more environmentally friendly, cost-effective, and sustainable construction materials that can reduce reliance on synthetic and energy-consuming materials, the use of natural fibre composites is on the increase. Being a product derived from the Agave sisalana plant, sisal fibre is renewable, locally found, biodegradable, and ideal for use as reinforcing material in lightweight cement composites, particularly in Uganda where conventional industrial fibre may not be readily accessible.

The primary focus of the analysis carried out in this chapter is to evaluate the behaviour of untreated and chemically treated sisal fibre samples, as well as estimate the extent to which the treatment makes such fibres more suitable for use in construction materials. Alkaline treatments are recognized as fibre surface transformations that remove waxes, lignin, and hemicellulose, thus increasing the fibre's interaction with the cement paste. An understanding of this aspect is critical, as the fibre/paste interface significantly influences load distribution, resistance to cracks, and the strength of the composite material. The laboratory results, therefore, offer valuable information on the improvement of fibre properties through treatments that result in the creation of a strong, stable, and rigid woodcrete composite.

This chapter will begin with the analysis of the tensile strength of sisal fibre before and after treatment, then move on to the analysis of the scanning electron microscope (SEM) results, which indicate changes that occur in the modified fibre samples. After that, the analysis of the water absorption test results, as well as the density test results, will be considered, as this will give further insight into the changes that occur in the fibre's properties. Finally, this chapter will move on to the discussion of the implications that the results may have in terms of their contributions towards sustainable construction practices in Uganda.

4.2 Mechanical and Physical Properties of Sisal Fiber

4.2.1 Mechanical Testing of Sisal Fibers

Table 4.1 and Table 4.2 show the tensile properties of untreated and treated sisal fibers respectively. The results clearly indicate that alkali treatment significantly enhanced the mechanical performance of the fiber.

Table 4.1 Tensile Properties of Untreated Sisal Fiber Samples

Tests	Breaking Force (N)	Elongation (mm)	RKM (g/tex)	Breaking Work (gf·cm)	Breaking Time (s)
1	3.91	4.05	4.61	92.47	0.49
2	1.26	2.10	1.49	17.15	0.25
3	4.51	4.05	5.33	96.56	0.49
Average	**3.23**	**3.40**	**3.81**	**68.73**	**0.41**

Table 4.2 Tensile Properties of Treated Sisal Fiber Samples

Tests	Breaking Force (N)	Elongation (mm)	RKM (g/tex)	Breaking Work (gf·cm)	Breaking Time (s)
1	16.24	8.55	36.31	674.49	1.03
2	13.71	8.25	30.66	603.00	0.99
3	17.13	9.15	38.32	773.83	1.10
Average	**15.69**	**8.65**	**35.10**	**683.77**	**1.04**

Figure 4.1 illustrates the variation in breaking force between untreated and treated sisal fibres. From the results, the average breaking force of untreated fibres was 3.23N, while that of treated fibres rose sharply to 15.69N. This represents an increase of nearly 387%.

A t-test was performed that compared the treated sisal fiber and untreated sisal fiber. The fibers that were treated showed a much higher tensile strength as compared to the untreated ones. The t-value calculated was 8.72, which is more than t-critical value 2.78 at 95% confidence level. The p-value, which was 0.00096, is smaller than 0.05. This indicates that the tensile strength of the treated fiber and the untreated fiber are significantly different. This shows that treatment greatly improved the tensile strength of the sisal fibres.

The increase in breaking force indicates the removal of surface impurities (waxes, lignin, and hemicellulose) on NaOH treatment. As a result, there is a more compact fiber structure. It also proves to be capable of sustaining higher tensile loads.

Furthermore, this treatment process improves interfacial bonding as a result of fibre surface roughening. Using this as a reinforcement causes frictional resistance in the cement matrix due to its roughness. This also decreases the slippage of the fibre.

These studies support the results from Silva et al. (2020) and Bichang'A et al. (2022) regarding the tensile improvement taking place through modification of the crystallinity of fibres and alignment of microfibrils.

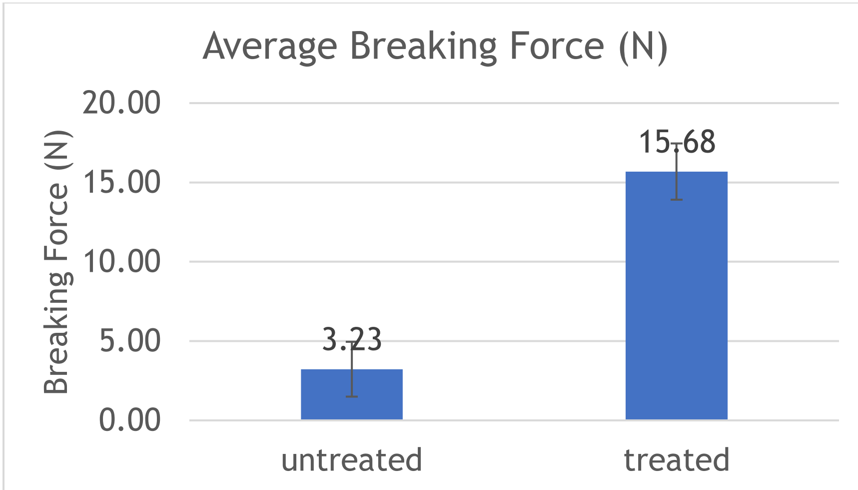


Figure 4.1 Comparison of Breaking Force for Untreated and Treated Sisal Fibres

4.2.2 Water Absorption

Table 4.3 Water Absorption Results of Treated and Untreated Sisal Fibers

S/N	Untreated Samples (absorption in %)	Treated Samples (absorption in %)
1	219	180
2	303	265
3	261	254
Average	**261**	**233**

The results show that treated fibers absorbed less water than untreated ones, 233% compared to 261%, indicating about 11% reduction in water uptake.

4.2.2.1 Discussion:

Due to the removal of hemicellulose which has a high affinity for water, there is a decrease in water absorption. Due to removing these hydroxyl groups they cannot bond to water, thus the moisture content of the fiber is reduced. As a result, the fiber's dimensional stability increases and minimizes the swelling or shrinkage upon being immersed into cement paste. While water absorption may slightly diminish, however, the independent t-test of treated and untreated sisal fibers show that it is statistically insignificant. The t-value of -0.78 is smaller than the t-critical of 2.78. As a result, the ability of the fibers to absorb water does not alter significantly after alkali treatment.

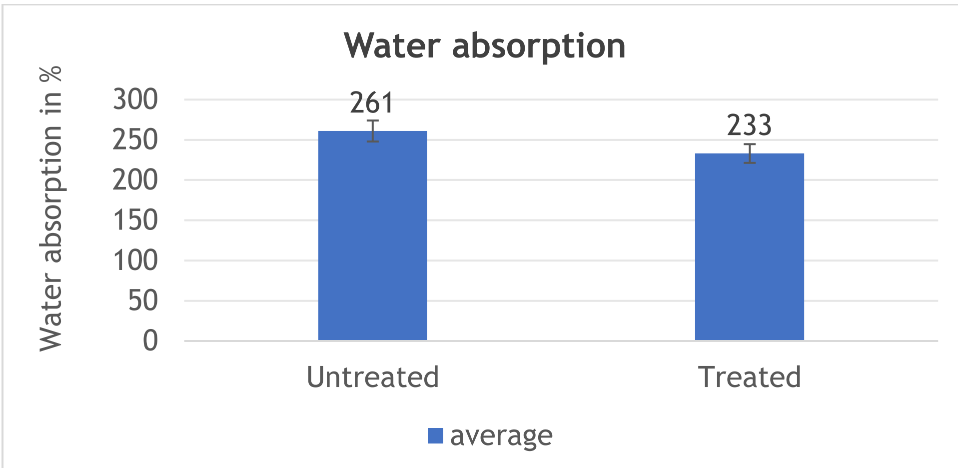


Figure 4.2 Comparison of Water Absorption for Untreated and Treated Sisal Fibres

4.2.3 Density

Table 4.4 Density Results of Treated and Untreated Sisal Fibers

S/N	**Untreated Samples (Density in g/cm³)**	**Treated Samples (Density in g/cm³)**
1	1.45	1.52
2	1.47	1.50
3	1.45	1.51
Average	**1.46**	**1.51**

4.2.3.1 Discussion:

The density of treated fibers (1.51 g/cm 3) was a bit higher than that of the untreated ones (1.46 g/cm 3). This increment may be attributed to the elimination of low-density substance like hemicellulose and lignin to give rise to a condensed crystalline structure of cellulose. The enhanced density increases the mechanical strength of the fiber and its ability to endure deformation due to stress.

Denser fibers when included in the woodcrete mix, contribute in better packing, less porosity and even distribution of stress. The marginal increase in density is also associated with the increase in tensile strength and in load-carrying capability, which implies that the treatment procedure has a positive effect on the microstructure of sisal fiber and its macro-characteristics.

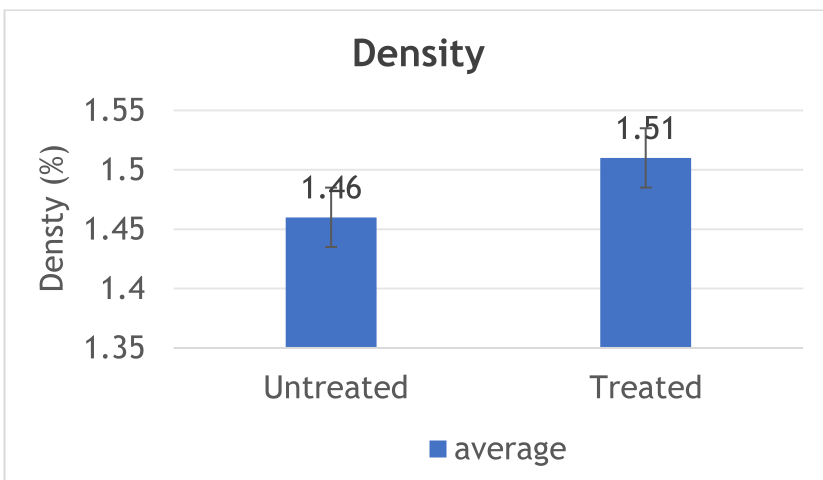


Figure 4.3 Comparison of Density for Untreated and Treated Sisal Fibres

4.2.4 Scanning Electron Microscope (SEM) Analysis

The microstructural examination of the sisal fibres was carried out using a Scanning Electron Microscope (SEM) at ×500 magnification to observe the surface characteristics before and after alkali treatment. The results, shown in Figure 4.4 and Figure 4.6, reveal distinct morphological changes between untreated and treated fibres, confirming the effect of the NaOH treatment on fibre surface composition and texture.

4.2.4.1 Untreated Sisal Fibers:

The SEM micrograph of the untreated sisal fibre Figure 4.4 indicates an smooth, compact and wax-covered surface. The external coat presents few visible cracks or fibrils, which can be meaning that there are non-cellulosic materials like lignin, waxes and hemicellulose that cover the cellulose microfibrils.

Little deposits and film-like layers are visible, which indicates contamination by natural plant debris and processing dust. This morphological structure is indicative of a chemically inert and comparatively low hydrophobic fibre surface that restricts the binding capacity with a cement matrix in composites.

Due to such a smooth outer coating, the transfer of stress between the fibre and matrix during loading of the composite would, therefore, be poor resulting in premature fibre pull-out or debonding.

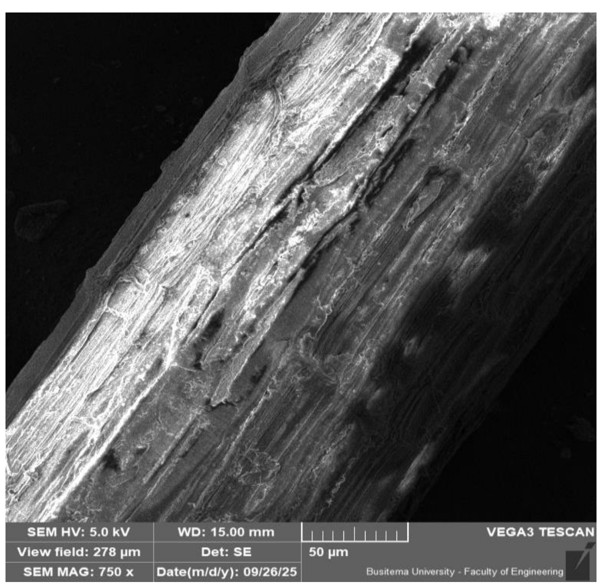


Figure 4.4 Showing SEM Micrograph of Untreated Sisal Fibre (×50 Magnification)

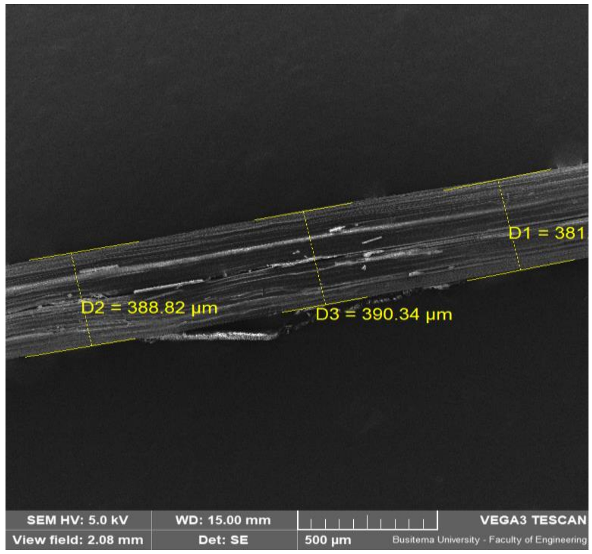


Figure 4.5 Showing SEM Micrograph of Untreated Sisal Fibre (×500 Magnification)

4.2.4.2 Treated Sisal Fibers:

Figure 4.6 of the SEM images of the alkali-treated sisal fibre reveals from the treatment that the surface is rough, irregular and highly fibrillated, unlike the untreated sample. The NaOH treatment successfully removed amorphous materials, particularly lignin and hemicellulose, resulting in the exposure of the inner cellulose microfibrils.

The fibre length is characterized with a set of grooves, ridges and micro-voids which increase the total surface area of the fibre. The edges of the fibre also get open and torn, with much evidence of fibrillation. The physical properties of fibre are also changed leading to strengthening of the mechanical interlocking and wetting when embedded in the cement matrix. The cleaner and more porous surface also increases the fibre's surface energy, making it more compatible with hydrophilic cementitious materials.

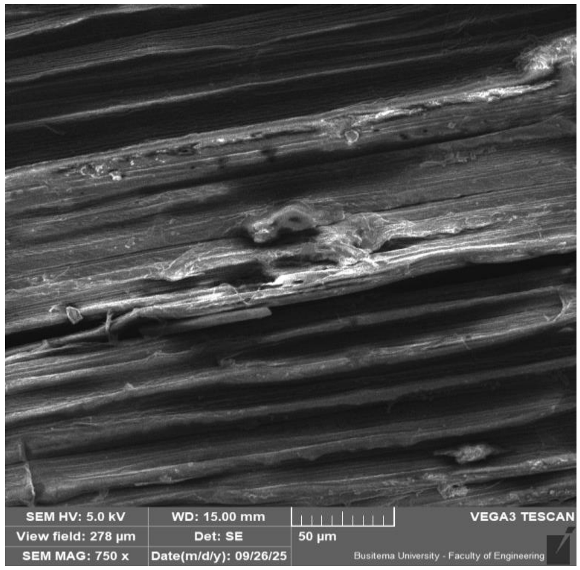


Figure 4.6 Showing SEM Micrograph of Treated Sisal Fibre (×50 Magnification)

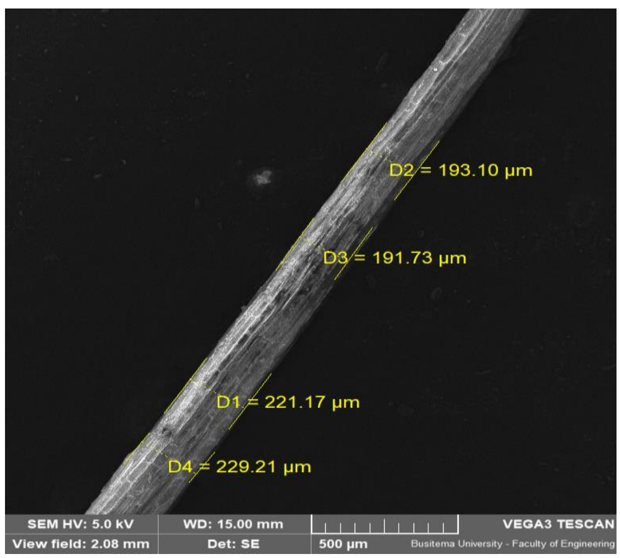


Figure 4.7 Showing SEM Micrograph of Treated Sisal Fibre (×500 Magnification)

4.2.4.3 Discussion of SEM Analysis

The SEM micrographs clearly reveal the morphological transformation of sisal fibres after alkali treatment. The untreated fibre shows a compact, waxy surface covered with non-cellulosic materials such as lignin and hemicellulose, which mask the cellulose microfibrils and give the fibre a smooth appearance. This coating acts as a barrier, that limit the adhesion between the fibre and cement matrix and restrict mechanical interlocking.

In contrast, the treated fibre exhibits a rough, fibrillated, and porous surface with visible grooves and ridges. The removal of surface impurities exposes the cellulose structure, resulting in a cleaner and more textured fibre that can bond more effectively within the composite matrix.

In addition to the surface morphology, the SEM measurements reveal a significant reduction in fibre diameter following treatment. The untreated fibre recorded an average diameter of about 386 μm, while the treated fibre averaged 208 μm, representing roughly a 46% reduction. The thinner and denser cellulose core left behind possesses higher stiffness and strength.

The combined effects of diameter reduction and fibrillation directly explain the improved tensile performance of treated fibres observed in mechanical testing. A rougher, thinner fibre provides better mechanical anchorage, reduces fibre pull-out, and enhances load distribution across the composite.

The SEM evidence therefore confirms that NaOH treatment not only modifies surface texture but also refines the internal fibre structure, making treated sisal fibres more effective reinforcement materials for lightweight composites such as woodcrete.

4.3 Mechanical test results and discussion of woodcrete blocks

4.3.1 Data analysis of mechanical properties of woodcrete blocks

This section presents the mechanical and physical test results of woodcrete blocks cast with and without sisal fibres at different fibre contents. The woodcrete mixes were prepared using a 1:2 cement:sawdust ratio and sisal fibre dosages of 0%, 0.5%, 1.0%, 1.5% and 2.0%.

The blocks were tested for compressive strength, splitting tensile strength, water absorption and density. The results are analysed, presented, interpreted and discussed in relation to the objectives of the study.

4.3.2 The compressive strength (BS EN 12390-3)

The compressive strength of the woodcrete cubes was determined according to BS EN 12390-3 with 150 x 150 x 150 mm cubes using the compression testing machine. Three cubes samples were tested and an average compressive strength was computed for the different percentage of sisal fiber content (0%, 0.5%, 1%, 1.5% and 2%). The compressive strength of each specimen was determined as the maximum load at failure over the loaded cross-sectional area of the cube:

$$fc = \frac{Pmax}{A}$$

where

fc is the compressive strength (MPa),

Pmax is the maximum load at failure (N),

A is the loaded cross-sectional area of the cube (mm^2).

To determine the impact of the addition of sisal fibre, an independent t -test was conducted on the control mix (0% sisal) and the optimum mix (1.5% sisal fibre) at 28 days. The p-value (0.000078) received is lower than 0.05, confirming that the difference between the mean compressive strength of the two mixes is statistically significant, and the effect of adding sisal fibre, on compressive strength of the woodcrete is not a mere accidental change of the data.

4.3.2.1 Data presentation:

Table 4.5 Presents The Average Compressive Strengths Of The Woodcrete Cubes At 7, 14 And 28 Days For The Different Sisal Fibre Contents

% Sisal	Sample	7-Day Strength (MPa)	Average 7-Day (MPa)	14-Day Strength (MPa)	Average 14-Day(MPa)	28-Day Strength (MPa)	Average 28-Day (MPa)
	S1	1.76		2.32		2.63	
0%	S2	1.65	1.70	2.28	2.29	2.62	2.64
	S3	1.68		2.27		2.67	
	S1	2.37		3.08		3.54	
0.50%	S2	2.32	2.30	3.03	3.07	3.56	3.54
	S3	2.21		3.09		3.51	
	S1	2.25		3.11		3.57	
1%	S2	2.27	2.30	3.17	3.09	3.60	3.57
	S3	2.37		3.00		3.53	
	S1	2.31		3.23		3.67	
1.50%	S2	2.47	2.41	3.21	3.18	3.69	3.67
	S3	2.44		3.09		3.64	
	S1	2.42		3.07		3.61	
2%	S2	2.26	2.37	3.13	3.13	3.60	3.61
	S3	2.43		3.19		3.62	

4.3.2.2 Interpretation of results

The findings indicate that all mixes have increased compressive strength with the different ages of curing, as it is expected from cement-based composites. The lowest compressive strength was recorded in control mix (0% sisal) at all the three ages.

The 28-day mix of the 1.5 percent sisal fibre had the highest average compressive strength, about 3.67 MPa, which is by far greater than the average compressive strength of the control mix. This reinforces the fact that the compressive strength of the woodcrete is improved greatly on introducing sisal fibre into it.

This is further supported by the t-test value ($p = 0.000078 < 0.05$) which indicates that there is a statistically significant difference between 0% to 1.5% sisal.

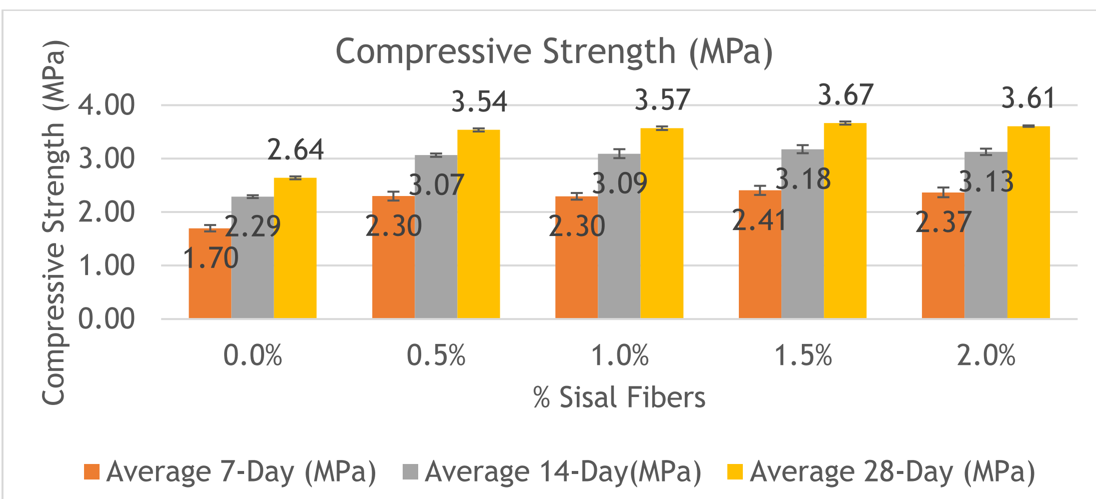


Figure 4.8 A Bar Graph Showing The Average Compressive Strengths Of Samples

4.3.2.3 Compressive strength results discussion:

The observed increase in compressive strength in the fibre-reinforced mixes can be attributed to the way sisal fibres improve the resistance of the woodcrete matrix under compressive stress. As the load increases, the cement-sawdust matrix begins to develop internal microcracks and local crushing zones. The sisal fibres, acting as discrete micro-reinforcements, restrain lateral deformation, bridge microcracks and help to keep crushed zones from spreading quickly. This delays the coalescence of microcracks into major cracks, enhances the integrity of the load-carrying skeleton and results in higher peak compressive strength and a less brittle failure mode (Silva et al., 2020; Rashad, 2018; Ahmad et al., 2022).

The strength tends to decline slightly on increasing the fibre content to 2.0 %, and this can be attributed to decreased workability or entanglement of fibres with increased of the presences of voids, which lead to weak spots in the material (Fode et al., 2025; Huang et al., 2020; Ahmad et al., 2022).

With the 28 days mean compressive strength of the 1.5% sisal woodcrete blocks (3.67MPa), it shows to be higher then the minimum average compressive strength of 2.8MPa required for concrete blocks in Uganda Ministry of Works Standard Specifications for Building Works (MoWT, 2021).

In addition, in comparison to the concrete British concrete block standard BS 6073-1, lightweight concrete blocks have a compressive strength in the range of about 2.8 - 3.5 MPa. At 1.5%, our block tends to slightly pass that range (BS 6073-1, 1981).

These results indicate that addition of sisal fibre improves the compressive behaviour of woodcrete blocks with 1.5% sisal showing as the best fibre content in this study. When this dosage is used, the blocks are still lightweight but attain able compressive strength to support non-load-bearing purposes.

4.3.3 Tensile Strength (BS EN 12390-6)

4.3.3.1 Data analysis

The tensile strength of the woodcrete was determined by conducting a splitting tensile test as per BS EN 12390-6. A total of three cylindrical specimens of each fibre content (0%, 0.5%, 1.0%, 1.5% and 2.0) and each curing age (7, 14 and 28 days) were tested and the mean tensile strength was obtained in each set.

The tensile strength splitting strength of any particular specimen was determined as the maximum load at the failure point by the standard expression:

$$ft = \frac{2Pmax}{\pi LD}$$

where,

ft= splitting tensile strength (MPa),

Pmax= maximum load at failure (N),

L = length of the cylinder (mm),

D = diameter of the cylinder (mm).

To determine the impact of the addition of sisal fibre, a t-test was conducted to compare the control mix (0% sisal fibre) and the mix containing 1.5% sisal fibres at 28 days. 1.5% was chosen as the proportion as it gave a highest average tensile strength for the fibre-reinforced mixes. In conclusion, the p-value obtained under this test was 0.000078 which is lower than the significance level of 0.05 implying that there is a significant difference in mean tensile strength at different fibre contents: fiber content of 1.5% and fiber content of 0%.

4.3.3.2 Data presentation

Table 4.6 Average splitting tensile strength of woodcrete at different curing ages

% Sisal	Sample	7-Day Strength (MPa)	Average 7-Day (MPa)	14-Day Strength (MPa)	Average 14-Day (MPa)	28-Day Strength (MPa)	Average 28-Day (MPa)
	S1	0.553		0.758		0.892	
0%	S2	0.571	0.56	0.764	0.76	0.921	0.91
	S3	0.569		0.748		0.903	
	S1	0.67		0.865		1.081	
0.50%	S2	0.64	0.65	0.907	0.88	1.067	1.06
	S3	0.65		0.876		1.031	
	S1	0.626		0.867		1.044	
1%	S2	0.679	0.65	0.916	0.89	1.078	1.06
	S3	0.658		0.88		1.061	
	S1	0.676		0.928		1.091	
1.50%	S2	0.641	0.67	0.887	0.89	1.069	1.08
	S3	0.682		0.866		1.083	
	S1	0.63		0.846		1.057	
2%	S2	0.665	0.64	0.913	0.88	1.074	1.06
	S3	0.631		0.873		1.051	

4.3.3.3 Interpretation of results

The findings indicate that all mixes, between 7 and 28 days of curing, had higher tensile strength as the age of curing increased, as it is expected for the case with cement-based composites. In the control mixture (0% fibre) the mean tensile strength increased at 7 days (approximately 0.56 MPa) to 28 days (approximately 0.91MPa). Tensile strength was increased with the addition of sisal fibres at all ages, and fibre-reinforced mixes (0.5- 2.0%) were always better than the control.

The maximum average tensile strength of 1.08Mpa was achieved at the 28 days with the sisal fibre content of 1.5%, relative to the 0.91Mpa of the control, which is about 19 percent more tensile strength level.

There was an increase in tensile strength (approximately 1.06 Mpa) with the mixes of 0.5, 1.0, and 1.5 percent fibre. This trend shows that tensile strength rises with dosage of fibre to approximately 1.5 per cent, beyond which there is a beginning of a slight deacrese. The result of the t-test of p = 0.000078 (Less than 0.05) shows that the difference between 0% and 1.5% of sisal at 28 days is significant statistically meaning that the improvement cannot be attributed to random variation alone but is a real effect of the fibre reinforcement.

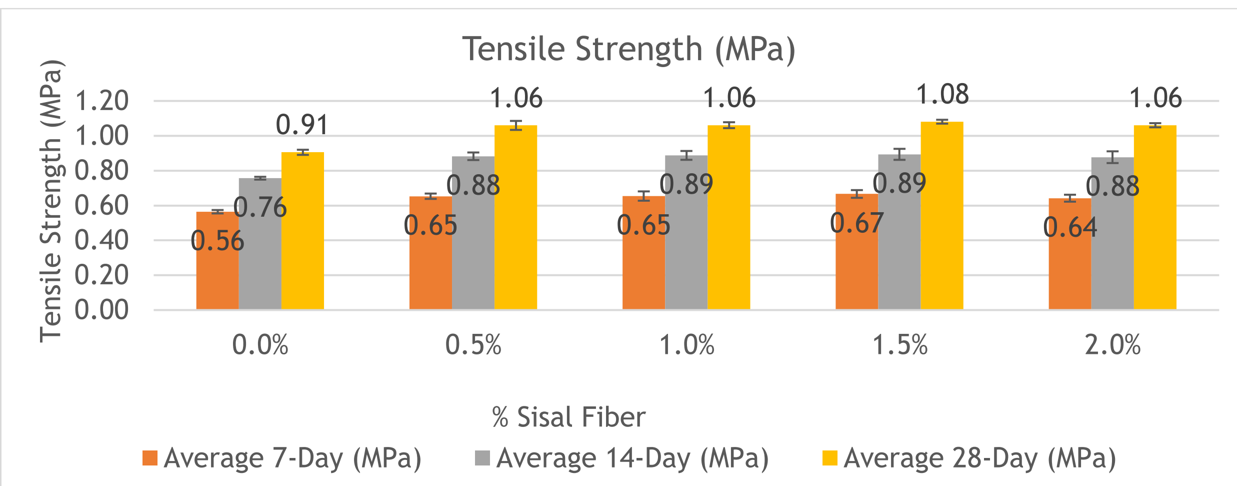


Figure 4.9 A Bar Graph Showing The Average Tensile Strengths Of Samples

4.3.3.4 Tensile Strength Results Discussion

The overall tensile strength increment in the fibre-reinforce mixes can be associated to presence of sisal fibres as micro- reinforcement in the woodcrete matrix. under tension of sisal fibres:

- Bridge microcracks which occur in the cement-sawdust matrix,
- Retard crack initiation and propagation

that in combination raise tensile resistance and lower brittleness of the composite and in consistency with other sisal-reinforced cement-based materials (Okeola et al., 2018; Ahmad et al., 2022).

In the study, the increase in 28-day tensile strength from the plain mix to the 1.5% sisal mix (≈19% improvement, up to about 1.08 MPa) shows that the fibres are actively controlling microcracking in the woodcrete. The higher tensile resistance means the matrix can withstand greater internal tensile stresses before cracking, and once microcracks start to form, the fibres bridge them and limit their opening. This results in finer, better-distributed cracks instead of wide, localised ones, so the material maintains its integrity for longer under load. The measured gain in tensile strength at 1.5% is direct evidence that microcrack initiation and growth have been restrained by the sisal fibre network in the woodcrete matrix.

At about 1.5% fibre, the fibres are seen to be enough in quantity and well dispersed to offer effective crack bridging without severing serious workability and compaction issues. It results into superior internal confinement and tensile strength. As the fibre content is increased to 2.0, the tensile strength after 28 days no longer improves and at this level it is approximately 1.06Mpa, which is very slightly lower than the 1.5% mix.

This tendency is generally linked to decreased workability, fibre entanglement and increased void levels in high doses of fibre that create weakly bound areas and prevent further increment of strength (Fode et al., 2025; Huang et al., 2020; Ahmad et al., 2022).

In comparison with British practice, BS EN 772-6 only specifies the test method and not a minimum tensile strength, but dense concrete blocks in the UK usually have splitting tensile strengths of about 0.20–0.50 MPa. The 1.5% sisal woodcrete mix, with a 28-day tensile strength of about 1.08 MPa, is therefore more than twice the upper end of this range, showing a very good tensile performance compared to conventional concrete masonry units.

In comparison with the british practice, BS EN 772-6, where dense concrete blocks in UK usually have splitting tensile strengths of about 0.20 – 0.50MPa, the 1.5% sisal woodcrete mix, with 1.08MPa is higher than the range, showing a good tensile performance.

4.3.4 Water absorption

4.3.4.1 Data analysis

Water absorption was determined as a percentage increase in mass after 24h immersion, as already described in the methodology (ASTM C642-21). For each mix (0%, 0.5%, 1.0%, 1.5% and 2.0% sisal), three cubes were tested and the average water absorption was calculated.

An independent t-test between 0% and 1.5% sisal, our optimum, and gave a p-value of 0.22 (> 0.05), indicating that the difference in mean absorption between these two mixes is not statistically significant at the 5% level.

4.3.4.2 Data presentation

Table 4.7 Average Water Absorption Of Woodcrete For Different Percentage Of Sisal Fiber

% Sisal	**dry weight(g)**	**wet weight(g)**	**weight gain(g)**	**% Absorption**	**AVERAGE ABSORPTION**
0%	4035.2	4255.6	220.4	5.18	4.40
	4103.0	4277.5	174.5	4.08	
	4072.5	4239.8	167.3	3.95	
0.50%	4099.7	4317.2	217.5	5.04	5.00
	4110.2	4339.5	229.3	5.28	
	4085.3	4285.3	200	4.67	
1%	4183.8	4402.1	218.3	4.96	3.94
	4295.0	4423.9	128.9	2.91	
	4213.5	4386.1	172.6	3.94	
1.50%	4310.0	4480.6	170.6	3.81	3.68
	4320.5	4503.0	182.5	4.05	
	4295.8	4437.3	141.5	3.19	
2%	4551.1	4710.0	158.9	3.37	3.55
	4565.0	4732.6	167.6	3.54	
	4514.2	4689.6	175.4	3.74	

4.3.4.3 **Interpretation And Discussion**

Water absorption values for all mixes lie between about 3.5% and 5.0%, which are well below the commonly used limit of 7% for concrete masonry units tested in accordance with BS EN 772-11 type procedures, satisfying the typical masonry block requirements in terms of water absorption.

Compared to the control (4.40%), the mix with 0.5% sisal shows a slight increase in absorption (about +14%), but as the fibre content increases further, absorption decreases: by roughly 10% lower at 1.0%, 16% lower at 1.5%, and nearly 19% lower at 2.0% relative to the control. This reduction can be attributed to improved fibre–matrix bonding, which limits the formation of interconnected voids and refines the pore structure of the woodcrete. Similar observations were reported by Rashad (2018), who noted that the inclusion of natural fibres in concrete improves matrix densification and consequently reduces permeability.

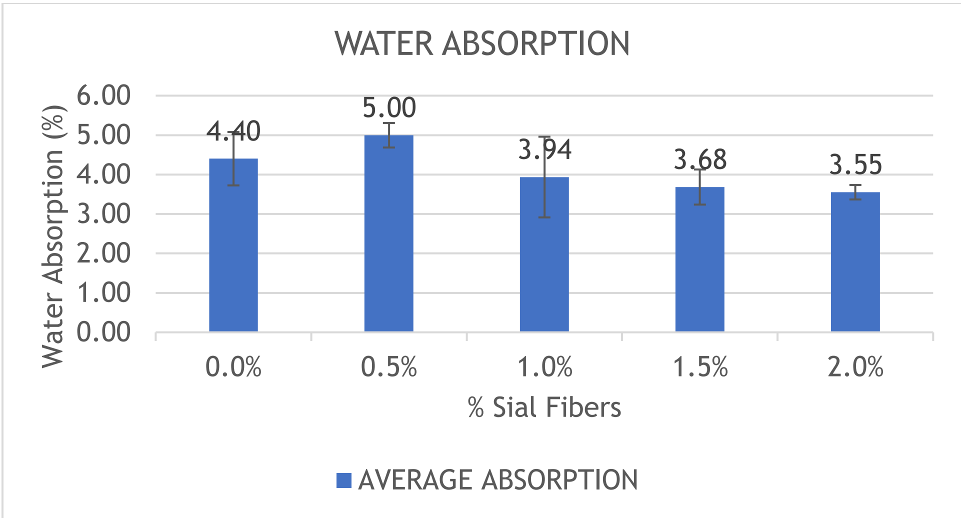


Figure 4.10 A Bar Graph Showing Water Absorption Percentages Of Different Sisal Fiber Content

4.3.4.4 Density:

4.3.4.5 Data analysis

The density of the woodcrete was determined from the mass and volume of the 150 × 150 × 150 mm cube specimens. After curing at 28 days, the cubes were removed from the curing tank, weighed on a digital balance, and the density of each specimen, with 0%, 0.5%, 1.0%, 1.5% and 2.0% sisal, was computed by dividing its mass by the corresponding volume (Neville, 2011).

An independent t-test comparing the 28-day densities of the 0% and 1.5% mixes gave a p-value of 0.0023 (< 0.05), indicating that the increase in density at 1.5% sisal is statistically significant.

4.3.4.6 Data presentation

Table 4.8 Average Density Of Woodcrete For Different Percentage Of Sisal Fiber

% Sisal	Weight of cube (g)	Density (Kg/m3)	Average Density (Kg/m3)
	4255.6	1260.919	
0%	4277.5	1267.407	1261.52
	4239.8	1256.237	
	4317.2	1279.170	
0.50%	4339.5	1285.778	1278.22
	4285.3	1269.719	
	4402.1	1304.326	
1%	4423.9	1310.785	1304.90
	4386.1	1299.585	
	4480.6	1327.585	
1.50%	4503	1334.222	1325.52
	4437.3	1314.756	
	4710	1395.556	
2%	4732.6	1402.252	1395.77
	4689.6	1389.511	

4.3.4.6.1 Interpretation and discussion

The results show a gradual increase in density with sisal fibre content. The average density rises from about 1261.5 kg/m³ at 0% to about 1325.5 kg/m³ at 1.5% sisal, an increase of roughly 5%, and to about 1395.8 kg/m³ at 2.0% sisal, an increase of 10–11% relative to the control. This trend suggests that the presence of sisal fibres, combined with improved internal confinement of the cement–sawdust matrix, leads to a slightly denser material, possibly due to better packing and partial reduction of larger voids. Although the density increases with higher fibre doses, all values remain below the 1500 kg/m³ limit for lightweight concrete masonry units specified in BS EN 771-3 and the compared to the ≥1800–2200 kg/m³ density of solid concrete blocks the is a reduction of about 26.36%. This shows that the blocks retain their lightweight character while still gaining strength.

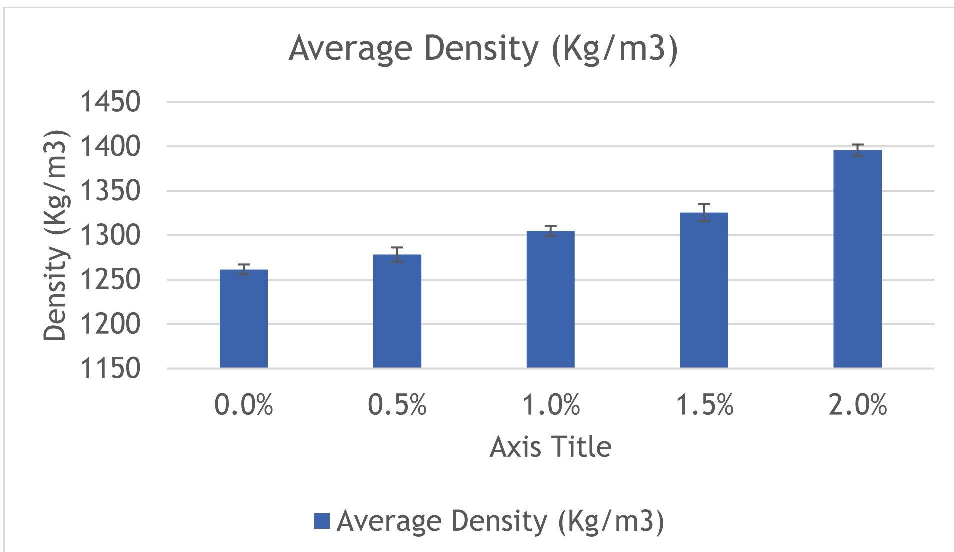


Figure 4.11 A Bar Graph Showing Density Percentages Of Different Sisal Fiber Content

4.3.5 Significant observations of the research study

This study addressed the suitability of sisal fibre-reinforced woodcrete as a lightweight masonry material by first studying the characteristics of the fibres and then defining the behaviour of the woodcrete blocks in compressive strength, splitting tensile strength, water absorption and density. The overall results can be summarized into two parts namely the influence of alkali treatment on sisal fibres and the influence of sisal fibre content on the performance of woodcrete blocks.

NaOH treatment at fibre level was effective in improving the mechanical behaviour of sisal. The treated fibres had significantly increased breaking than the untreated fibres, which are stronger and stiffer reinforcement materials. The fibres became less water-absorbing following treatment and the density of the fibre appeared to be slightly smaller indicating a more compact arrangement of the inner structure with fewer pores. The observations of SEM supported the fact that alkali treatment eliminated the surface impurities, waxes and hemicellulose, decreased fibre diameter and gave the surface a rougher appearance with visible microfibrils. This increase of strength and reduction of water absorption and a better surface texture reveals that treated sisal fibres will be capable of forming a stronger mechanical and chemical bond with cement based matrices.

At composite level, it was observed that when sisal fibre was introduced to woodcrete, improvements in mechanical properties were always witnessed. All fibre reinforced mixes had higher compressive strength of the woodcrete blocks than the control (0% sisal) at the 7, 14 and 28 days. They recorded the maximum 28-day average compressive strength about 3.6Mpa at 1.5 % sisal fibre implying that this is an amplification of 39% on the control mix. The statistical analysis of independent t-test between 0 and 1.5% sisal introduced into the experiment proved such an increase in strength is significant meaning that the improvement is not due to random variation but is actually caused by the reinforcing action of fibres. The behaviour at 2.0 % fibre content reveals a minor decrease in strength indicating an empirical optimum in the 1.5 percent range that the fibres improve load transfer without leading to severe workability or compaction issues. The tensile strength splitting pattern was the same. The tensile strength of the control mix was around 28 days of approximately 0.91 Mpa when compared to the fibre reinforced mixes, 1.5% sisal mix had a tensile strength of approximately 1.08 Mpa. This shows that sisal fibres are a good reinforcement at the micro level by being in tension, that fills the microcracks, postponing the crack propagation, and improving the post-cracking behaviour of the woodcrete. Once again, no further improvement was found by adding more fibre to 2.0% and this is in line with the entanglement of fibre and higher voids at a very high dosage.

Regarding the remaining properties, water absorption and density were also positive. All mixes had a water absorption ranging between 3.5% to 5.0% with 1.5 and 2.0% sisal having it slightly lower than the control. All values are within the normal level of masonry unit of concrete, which means that the microstructure is rather compact and closed to permeability. Density of the blocks rose slightly with fibre content, between 1260 kg/m3 at 0% sisal to between 1325 kg/m3 at 1.5% and 1396 kg/m3 at 2.0%. Even with this increase, all of the mixes were below 1500 kg/m3, so the blocks still qualify as lightweight concrete masonry units.

4.4 DESIGN OF SISAL REINFORCED-WOODCRETE BLOCKS

This section describes the proposed design of the sisal fibre-reinforced woodcrete block. The aim is to translate the optimized mix (1:2 cement:sawdust with 1.5 percent sisal fibres by weight of cement) into a viable masonry unit which can be utilized in the lightweight partition and infill walls, and while lowering the self-weight compare to the traditional solid concrete block.

Geometry and size of block

For it to be compatible with the standard rectangular solid block common for modular masonry practice in Uganda, the dimensions of the proposed sisal fibre reinforced woodcrete block are as follows:

- Length: 400mm
- Height: 150mm
- Width: 200mm

These dimensions correspond to common masonry module sizes, and it is not difficult to fit the block into the existing wall designs, bond, and opening details. The 400 mm length gives a convenient modular length on the wall, the 150 mm height which gives a reasonable number of courses.

4.4.1 Internal structure and layout of materials.

The block is conceived as a fully solid woodcrete unit, with no voids or hollow cores. The internal material arrangement is as follows:

- Woodcrete matrix: cement matrix is made using Ordinary Portland Cement (OPC) and treated sawdust in a 1:2 cement:sawdust ratio by volume.

- For each batch, 2.480 kg of cement and 2.960 kg of sawdust were mixed with 2.2 L of water, corresponding to a water–cement ratio of about 0.9. This relatively high water–cement ratio was used to provide enough workability for the woodcrete, taking into account the high water absorption of the sawdust and the presence of sisal fibres in the mix.
- Sisal fibres: short, randomly distributed sisal fibres of 15 mm length, that was added in at 1.5% weight of cement which was identified as the optimum dosage from the test results.

The fibres are spread all over the block volume, which serves as the micro-reinforcement within the cement–sawdust matrix.

Functional role and application

The planned block is mainly meant to have the following purposes:

- Non-load-bearing partition walls,
- Infill panels in framed structures,

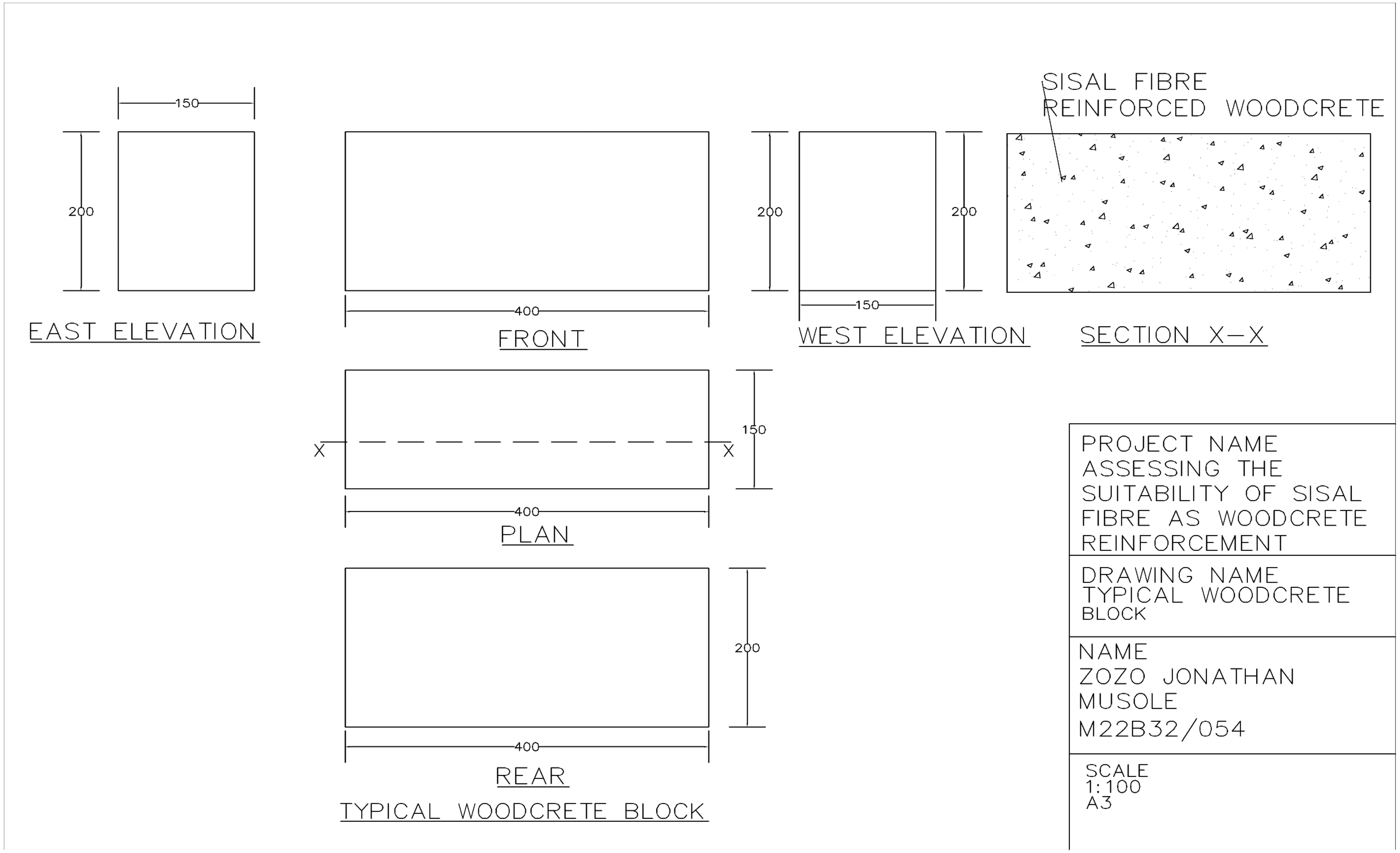
Other applications where light weight and thermal insulation are desired, while only moderate compressive strength is required.

Based on the results of the experiment, the sisal fibre-reinforced woodcrete with 1.5% fibre contents recorded:

- A 28-day compressive strength of about 3.6 MPa, and
- A dry density in the range of approximately 1.08 t/m^3,

Which confirms that the material acts as a lightweight masonry unit, but still achieves and exceeds the minimum strength requirements of non-load-bearing walls. The selected block geometry thus combines:

- Reduced self-weight, which lowers dead loads on slabs and foundations;
- Sufficient compressive capacity for partition and light duty load transfer; and
- Improved crack control and toughness due to the presence of sisal fibres in the woodcrete matrix.


150
200
EAST ELEVATION
400
FRONT
200
200
150
WEST ELEVATION
SISAL FIBRE
REINFORCED WOODCRETE
SECTION X–X
X
X
150
400
PLAN
200
400
REAR
TYPICAL WOODCRETE BLOCK
PROJECT NAME
ASSESSING THE SUITABILITY OF SISAL FIBRE AS WOODCRETE REINFORCEMENT
DRAWING NAME
TYPICAL WOODCRETE BLOCK
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CHAPITRE FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study assessed the suitability of using sisal fibre as a reinforcement in woodcrete blocks produced with a 1:2 cement:sawdust mix, by first studying the fibres themselves and then the mechanical and physical properties of woodcrete blocks reinforced with sisal fibre ranging from 0% to 2.0% of cement weight. The first part of this conclusion discusses the behaviour of sisal fibre and therefore addresses Objective 1, while the second part focuses on the optimum fibre content, block performance and lightweight criteria, thereby addressing Objectives 2 and 3.

With respect to Objective 1, the laboratory tests on untreated and alkali-treated sisal fibres showed that sodium hydroxide (NaOH) treatment significantly improves the mechanical performance and surface condition of the fibre. Tensile tests based on single-fibre measurements indicated a sharp increase in breaking force after treatment, rising to about 1600 gf, which corresponds to an increase of nearly 387% compared with the untreated fibres; a t-test gave a t-value of about 8.72, greater than the critical value at the 5% significance level, with a very low p-value, confirming that the difference in tensile strength between treated and untreated fibres is statistically significant. This improvement is linked to the removal of hemicellulose, lignin, waxes and other weak surface impurities, leaving a denser, more crystalline cellulose structure with higher stiffness and load-carrying capacity. Water absorption tests showed that treated fibres absorb less water than untreated ones, indicating better dimensional stability and reduced risk of swelling and shrinkage when embedded in the cement–sawdust matrix, while density results showed a slight increase after treatment, consistent with the removal of low-density components and the formation of a more compact fibre structure. Microstructural observations under SEM supported these findings: untreated fibres exhibited a relatively smooth, waxy, impurity-covered surface, which limits mechanical interlock with cement paste, whereas treated fibres developed a rough, fibrillated surface with grooves, ridges and exposed microfibrils and a reduced diameter, a morphology that favours strong mechanical anchorage and more efficient stress transfer across the fibre–matrix interface. Overall, these results show that alkali-treated sisal fibre possesses the tensile strength, reduced water uptake, appropriate density and favourable surface morphology required for effective reinforcement in woodcrete, fully addressing the first objective of the study.

Regarding Objectives 2 and 3, woodcrete blocks were produced with a 1:2 cement:sawdust ratio and sisal fibre dosages of 0%, 0.5%, 1.0%, 1.5% and 2.0% by weight of cement. For the woodcrete blocks, both compressive and splitting tensile strength increased with the addition of sisal fibre up to the 1.5% content. At 28 days, the average compressive strength rose from about 2.64 MPa (0% fibre) to about 3.67 MPa at 1.5% sisal, while splitting tensile strength increased from about 0.91 MPa to about 1.08 MPa over the same range. Statistical tests confirmed that the improvements between 0% and 1.5% mixes are significant at the 5% level. Beyond 1.5%, strengths tended to plateau or decline slightly at 2.0% fibre, mainly due to reduced workability, fibre entanglement and increased voids, indicating that 1.5% sisal is the optimum dosage for balancing improved strength with acceptable workability and compaction. The goal relating to the effect of sisal fibre on micro-cracking and overall strength behaviour was addressed through both microstructural evidence and block performance. SEM results indicated that alkali-treated fibres develop a rough, fibrillated surface capable of strong mechanical interlock, while the block tests showed that fibres act as discrete micro-reinforcements that bridge microcracks, delay crack initiation and propagation, and improve stress redistribution within the cement–sawdust matrix. This crack-bridging action explains the higher compressive and tensile strengths, as well as the less brittle failure mode observed in the fibre-reinforced mixes.

In terms of service properties, density and water absorption remained within acceptable limits for lightweight masonry. Block densities between about 1260 and 1400 kg/m^3 are below the 1500 kg/m^3 upper limit typically adopted for lightweight concrete units, confirming that the blocks retain their lightweight character. Water absorption values between roughly 3.5% and 5.0% are comfortably below the commonly used 7% limit for concrete masonry units. The 1.5% sisal woodcrete blocks not only satisfy these physical requirements but also exceed the minimum average compressive strength of 2.8 MPa specified in the Uganda Ministry of Works Standard Specifications for Building Works and slightly surpass the 2.8–3.5 MPa range quoted for British lightweight concrete blocks. Their splitting tensile strength (≈1.08 MPa) is more than twice the typical range reported for conventional dense concrete blocks.

Overall, the research demonstrates that woodcrete blocks reinforced with 1.5% sisal fibre provide a lightweight, structurally adequate and sustainable alternative to conventional concrete blocks for non-load-bearing walls. The combination of improved compressive and tensile behaviour, controlled density, acceptable water absorption, and the use of locally available waste sawdust and natural fibres supports the wider adoption of sisal-reinforced woodcrete in affordable and environmentally friendly construction.

5.2 RECOMMENDATIONS

- **Long-term durability study:** Further research is needed to assess the long-term properties of sisal reinforced woodcrete in real service conditions which may involve drying-wetting cycles, shrinkage and creep, carbonation and potential biodegradation (fungi, termites, etc.).
- **Fibre geometry and dosage optimisation:** Investigate the impact of length (i.e. 10, 20, 30 mm), diameter and aspect ratio in addition to perform a more detailed optimisation of fibre content.
- **Supplementary cementitious materials (SCMs):** Future studies should assess incorporating pozzolanic materials (fly ash, rice-husk ash, calcined clay or volcanic pozzolana) to partially replace cement to reduce costs and CO_2 emissions and assess strength, durability and microstructural impact.

REFERENCES:

- Ahmad, J., Arbili, M. M., Majdi, A., Althoey, F., Deifalla, A. F., & Rahmawati, C. (2022). Performance of concrete reinforced with jute fibers (natural fibers): A review. Journal of Engineered Fibers and Fabrics.
- Aigbomian, E. P. (2013). Development of Wood-Crete building material.
- Aigbomian, E. P., & Fan, M. (2013). Development of Wood-Crete from hardwood and softwood sawdust. The Open Construction and Building Technology Journal, 7(1), 108–117. https://doi.org/10.2174/1874836801307010108
- Aigbomian, E. P., & Fan, M. (2013). Development of Wood-Crete building materials from sawdust and waste paper. Construction and Building Materials, 40, 361–366.
- Aigbomian, E. P., & Fan, M. (2014). Development of wood-crete from treated sawdust. Construction and Building Materials, 52, 353–360. https://doi.org/10.1016/j.conbuildmat.2013.11.025
- Alabduljabbar, H., Huseien, G. F., Sam, A. R. M., et al. (2020). Engineering properties of waste sawdust-based lightweight alkali-activated concrete: Experimental assessment and numerical prediction. Materials, 13(23), 5490.
- Alzuhairi, M. H., Shabbeb, K. M., & Alsaedy, S. A. H. (2016). Heat and chemical treatments for sawdust/UPE composites. Engineering and Technology Journal, 34(8A), 4261–4272. https://doi.org/10.30684/etj.34.8A.13

- Anas, M., Khan, M., Bilal, H., Jadoon, S., & Khan, M. N. (2022). Fiber reinforced concrete: A review. Engineering Proceedings, 22(1), 1–7. https://doi.org/10.3390/engproc2022022003
- Asghari, N., & Memari, A. M. (2014). Fundamental properties of hempcrete. Oxford Studies in Metaphysics, 8, 78–104.
- ASTM C642-21. (2021). Standard test method for density, absorption, and voids in hardened concrete. ASTM International, West Conshohocken, PA, USA.
- Bichang'A, D. O., Aramide, F. O., Oladele, I. O., & Alabi, O. O. (2022). A review on the parameters affecting the mechanical, physical, and thermal properties of natural/synthetic fibre hybrid reinforced polymer composites. Advances in Materials Science and Engineering, 2022. https://doi.org/10.1155/2022/7024099
- BS 6073-1. (1981). Precast concrete masonry units – Specification for precast concrete masonry units. British Standards Institution, London.
- BS EN 772-11. (2011). Methods of test for masonry units – Part 11: Determination of water absorption of aggregate concrete, autoclaved aerated concrete, manufactured stone and natural stone masonry units due to capillary action and the initial rate of water absorption of clay masonry units. British Standards Institution, London.
- BS EN 12390-3. (2009). Testing hardened concrete – Part 3: Compressive strength of test specimens. British Standards Institution, London.

- BS EN 12390-6. (2009). Testing hardened concrete – Part 6: Tensile splitting strength of test specimens. British Standards Institution, London.
- Das, I. P., Kini, P. G., & Prashant, S. (2024). A systematic literature review of bamboo as reinforcement in concrete. Journal of Building Engineering.
- Dias, S., Tadeu, A., Almeida, J., Humbert, P., António, J., de Brito, J., & Pinhão, P. (2022). Physical, mechanical, and durability properties of concrete containing wood chips and sawdust: An experimental approach. Buildings, 12(8). https://doi.org/10.3390/buildings12081277
- Fadiel, A. A. M., Abu-Lebdeh, T., & Petrescu, F. I. T. (2022). Assessment of woodcrete using destructive and non-destructive test methods. Materials, 15(9). https://doi.org/10.3390/ma15093066
- Fode, T. A., et al. (2025). Effects of different lengths and doses of raw and treated sisal fibers on cement-based composites. Scientific Reports, 15, 1–15.
- Holm, T. A., & Ries, J. P. (2007). Chapter 6: Physical properties of structural lightweight concrete. In Reference Manual for the Properties and Applications of Expanded Shale, Clay and Slate Lightweight Aggregate (pp. 6–3–6–36).
- Hornby, R. (2020). A review of alternative building materials in comparison to CMU: Hempcrete, Woodcrete, Papercrete (pp. 1–16). University of Arizona.
- Khelifi, W., Bencedira, S., Azab, M., Riaz, M. S., Abdallah, M., Baki, Z. A., Krauklis, A. E., & Aouissi, H. A. (2022). Conservation environments' effect on the compressive strength behaviour of wood–concrete composites. Materials, 15(10). https://doi.org/10.3390/ma15103572

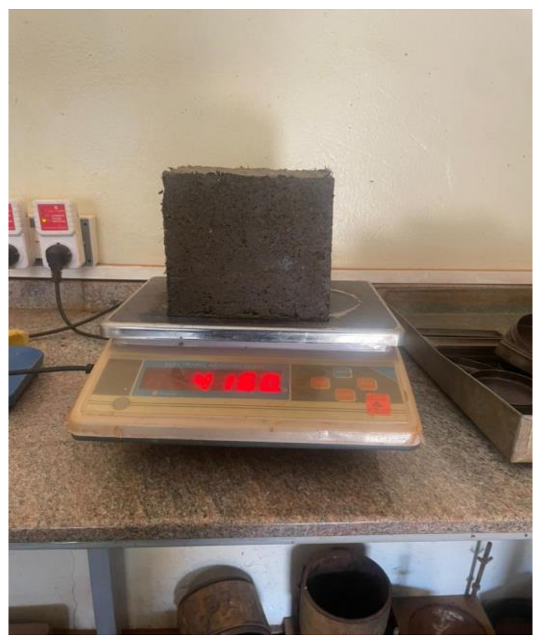
- Kulbhushan, K., Verma, S. K., Chaudhary, R., Ahamad, S., Gupta, S., & Chaurasia, S. R. (2018). A contextual analysis of the advantages by using lightweight concrete blocks as substitution of bricks. International Research Journal of Engineering and Technology (IRJET), 5(2), 926–931. https://www.irjet.net/archives/V5/i2/IRJET-V5I2200.pdf
- Mangi, S. A., Jamaluddin, N., Siddiqui, Z., Memon, S. A., & Ibrahim, M. H. W. (2019). Utilization of sawdust in concrete masonry blocks: A review. Journal of Building Construction and Planning Research, 7(2), 1–17.
- MoWT. (2013). Standard Specifications for Building Works, Part 1: Architectural, Structural and General Works. Ministry of Works and Transport, Republic of Uganda.
- Neville, A. M. (2011). Properties of concrete (5th ed.). Pearson Education Limited.
- Paramasivam, P., & Loke, Y. O. (1980). Study of sawdust concrete. International Journal of Cement Composites and Lightweight Concrete, 2(1), 57–61.
- Rashad, A. M. (2018). A comprehensive overview of the effect of using agricultural and industrial wastes on the properties of green concrete. Construction and Building Materials, 190, 125–141.
- Silva, R. V., de Brito, J., & Dhir, R. K. (2020). Performance of natural fiber-reinforced concrete. Journal of Cleaner Production, 249, 119385.
- Sultan, H. K., Abbas, B. J., Al Khuzaie, H. M. A., & Alsheakayree, T. K. Q. (2023). Designing high strength concrete grade T-beams at the lowest possible cost.

Mathematical Modelling of Engineering Problems, 10(4), 1369–1376. https://doi.org/10.18280/mmep.100431

- Z, S., & El, R. (2021). Identification of the physical and mechanical properties of composite materials.

APPENDICES

APPENDIX A: PICTURES SHOWCASING THE DIFFERENT PROJECT ACTIVITIES TAKING PLACE




Zhejiang Tugong

APPENDIX B: LABORATORY DATA AND RESULTS

TERZAGHI'S Soils & Materials Lab

Document No:	TZG/CCS/TF-20
Revision No.	: 00
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CONCRETE CUBE COMPRESSIVE STRENGTH TEST CERTIFICATE

Project	ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS		
Client:	ZOZO MUSOLE JONATHAN AND ESTHER KIRULE	**Date received:**	22-10-25
Location/ Chainage:	N/A	**Technician:**	FM

Reference Method: BS 1881 - Part 102 & 116

	SISAL FIBRE (%)		**0**		**Compaction Method**		N/A		
Cube No.	**Casting Date**	**Testing Date**	**Age (Days)**	**Cube Dimensions (LxWxH), (mm)**	**Mass of cube (Kg)**	**Density Kg/m³**	**Maximum Load (KN)**	**Compressive Strength (MPa)**	**Average Compressive Strength**
C00-1	22-Oct-25	29-Oct-25	7	150 x 150 x 150	4.190	1241	39.71	1.76	1.7
C00-2				150 x 150 x 150	4.225	1252	37.10	1.65	
C00-3				150 x 150 x 150	4.190	1241	37.87	1.68	
C00-4	22-Oct-25	5-Nov-25	14	150 x 150 x 150	4.234	1254	52.18	2.32	2.3
C00-5				150 x 150 x 150	4.260	1262	51.26	2.28	
C00-6				150 x 150 x 150	4.223	1251	51.08	2.27	
C00-7	22-Oct-25	19-Nov-25	28	150 x 150 x 150	4.256	1261	59.27	2.63	2.6
C00-8				150 x 150 x 150	4.278	1267	58.90	2.62	
C00-9				150 x 150 x 150	4.238	1256	60.10	2.67	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were [illegible]combs

N/A- not available

Checked by
Laboratory Engineer

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Project	ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS		
Client:	ZOZO MUSOLE JONATHAN AND ESTHER KIRULE	Date received:	22-10-25
Location/ Chainage:	N/A	Technician:	FM

Reference Method: BS 1881 - Part 102 & 116

	SISAL FIBRE (%)		0.5		Compaction Method		N/A		
Cube No.	Casting Date	Testing Date	Age (Days)	Cubes Dimensions (LxWxH), (mm)	Mass of cube (Kg)	Density Kg/m^3	Maximum Load (KN)	Compressive Strength (MPa)	Average Compressive Strength
C0.5-1	22-Oct-25	29-Oct-25	7	150 x 150 x 150	4.252	1260	53.37	2.37	2.3
C0.5-2				150 x 150 x 150	4.271	1265	52.12	2.32	
C0.5-3				150 x 150 x 150	4.225	1252	49.70	2.21	
C0.5-4	22-Oct-25	5-Nov-25	14	150 x 150 x 150	4.296	1273	69.30	3.08	3.1
C0.5-5				150 x 150 x 150	4.317	1279	68.15	3.03	
C0.5-6				150 x 150 x 150	4.265	1264	69.44	3.09	
C0.5-7	22-Oct-25	19-Nov-25	28	150 x 150 x 150	4.317	1279	79.65	3.54	3.5
C0.5-8				150 x 150 x 150	4.340	1286	80.20	3.56	
C0.5-9				150 x 150 x 150	4.285	1270	78.90	3.51	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were smooth without honeycombs

N/A- not available

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CONCRETE CUBE COMPRESSIVE STRENGTH TEST CERTIFICATE

Project	ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS		
Client:	ZOZO MUSOLE JONATHAN AND ESTHER KIRULE	Date received:	22-10-25
Location/ Chainage:	N/A	Technician:	FM

Reference Method: BS 1881 - Part 102 & 116

	SISAL FIBRE (%)			1	Compaction Method		N/A		
Cube No.	**Casting Date**	**Testing Date**	**Age (Days)**	**Cubes Dimensions (LxWxH), (mm)**	**Mass of cube (Kg)**	**Density Kg/m³**	**Maximum Load (KN)**	**Compressive Strength (MPa)**	**Average Compressive Strength**
C1-1				150 x 150 x 150	4.337	1285	50.67	2.25	
C1-2	22-Oct-25	29-Oct-25	7	150 x 150 x 150	4.385	1299	51.03	2.27	2.3
C1-3				150 x 150 x 150	4.334	1284	53.26	2.37	
C1-4				150 x 150 x 150	4.380	1298	69.95	3.11	
C1-5	22-Oct-25	5-Nov-25	14	150 x 150 x 150	4.411	1307	71.28	3.17	3.1
C1-6				150 x 150 x 150	4.369	1294	67.57	3.00	
C1-7				150 x 150 x 150	4.402	1304	80.41	3.57	
C1-8	22-Oct-25	19-Nov-25	28	150 x 150 x 150	4.424	1311	81.00	3.60	3.6
C1-9				150 x 150 x 150	4.386	1300	79.50	3.53	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were also smooth without honeycombs

N/A- not available

Checked by
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CONCRETE CUBE COMPRESSIVE STRENGTH TEST CERTIFICATE

Project ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS

Client: ZOZO MUSOLE JONATHAN AND ESTHER KIRULE | **Date received:** 22-10-25

Location/ Chainage: N/A | **Technician:** FM

Reference Method: BS 1881 - Part 102 & 116

	SISAL FIBRE (%)		1.5		Compaction Method		N/A		
Cube No.	**Casting Date**	**Testing Date**	**Age (Days)**	**Cubes Dimensions (LxWxH), (mm)**	**Mass of cube (Kg)**	**Density Kg/m³**	**Maximum Load (KN)**	**Compressive Strength (MPa)**	**Average Compressive Strength**
C1.5-1	22-Oct-25	29-Oct-25	7	150 x 150 x 150	4.429	1312	51.99	2.31	2.4
C1.5-2				150 x 150 x 150	4.448	1318	55.67	2.47	
C1.5-3				150 x 150 x 150	4.395	1302	54.79	2.44	
C1.5-4	22-Oct-25	5-Nov-25	14	150 x 150 x 150	4.464	1323	72.65	3.23	3.2
C1.5-5				150 x 150 x 150	4.485	1329	72.27	3.21	
C1.5-6				150 x 150 x 150	4.423	1311	69.53	3.09	
C1.5-7	22-Oct-25	19-Nov-25	28	150 x 150 x 150	4.481	1328	82.54	3.67	3.7
C1.5-8				150 x 150 x 150	4.503	1334	83.10	3.69	
C1.5-9				150 x 150 x 150	4.437	1315	81.80	3.64	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were also smooth without honeycombs

N/A- not available

Checked by
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CONCRETE CUBE COMPRESSIVE STRENGTH TEST CERTIFICATE

Project	ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS		
Client:	ZOZO MUSOLE JONATHAN AND ESTHER KIRULE	**Date received:**	22-10-25
Location/ Chainage:	N/A	**Technician:**	FM

Reference Method: BS 1881 - Part 102 & 116

	SISAL FIBRE (%)		2		**Compaction Method**		N/A		
Cube No.	**Casting Date**	**Testing Date**	**Age (Days)**	**Cubes Dimensions (LxWxH), (mm)**	**Mass of cube (Kg)**	**Density Kg/m^3**	**Maximum Load (KN)**	**Compressive Strength (MPa)**	**Average Compressive Strength**
C2.0-1	22-Oct-25	29-Oct-25	7	150 x 150 x 150	4.662	1381	54.38	2.42	2.4
C2.0-2				150 x 150 x 150	4.682	1387	50.96	2.26	
C2.0-3				150 x 150 x 150	4.603	1364	54.96	2.44	
C2.0-4	22-Oct-25	5-Nov-25	14	150 x 150 x 150	4.694	1391	69.00	3.07	3.1
C2.0-5				150 x 150 x 150	4.716	1397	70.40	3.13	
C2.0-6				150 x 150 x 150	4.661	1381	71.68	3.19	
C2.0-7	22-Oct-25	19-Nov-25	28	150 x 150 x 150	4.710	1396	81.17	3.61	3.6
C2.0-8				150 x 150 x 150	4.733	1402	80.90	3.60	
C2.0-9				150 x 150 x 150	4.690	1390	81.50	3.62	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were also smooth without honeycombs

N/A- not available

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CONCRETE CUBE COMPRESSIVE STRENGTH TEST CERTIFICATE

Project	ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS		
Client:	ZOZO MUSOLE JONATHAN AND ESTHER KIRULE	Date received:	22-10-25
Location/ Chainage:	N/A	Technician:	FM

Reference Method: BS EN1230-6

	SISAL FIBRE (%)		0		Compaction Method			
Cylinder No.	Casting Date	Testing Date	Age (Days)	Cylinder Dimensions (DxH), (mm)	weight of cylinder (g)	Maximum Load (KN)	tensile Strength (MPa)	Average tensile Strength
S1	22-Oct-25	29-Oct-25	7	150 x 300	3930	78.00	0.55	0.6
S2				150 x 300	4062	80.10	0.57	
S3				150 x 300	4072	78.90	0.56	
S1	22-Oct-25	5-Nov-25	14	150 x 300	5102	106.00	0.75	0.8
S2				150 x 300	5241	107.80	0.76	
S3				150 x 300	5191	106.40	0.75	
S1	22-Oct-25	19-Nov-25	28	150 x 300	5964	125.60	0.89	0.9
S2				150 x 300	5979	130.60	0.92	
S3				150 x 300	5986	126.70	0.90	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were also smooth without honeycombs

N/A- not available

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CONCRETE CUBE COMPRESSIVE STRENGTH TEST CERTIFICATE

Project	ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS		
Client:	ZOZO MUSOLE JONATHAN AND ESTHER KIRULE	**Date received:**	22-10-25
Location/ Chainage:	N/A	**Technician:**	FM

Reference Method: BS EN 12390-6

	SISAL FIBRE (%)		0.5		**Compaction Method**			
Cylinder No.	**Casting Date**	**Testing Date**	**Age (Days)**	**Cylinder Dimensions (DxH), (mm)**	**weight of cylinder (g)**	**Maximum Load (KN)**	**tensile Strength (MPa)**	**Average tensile Strength**
S1	22-Oct-25	29-Oct-25	7	150 x 300	3893	94.30	0.67	0.7
S2				150 x 300	4032	90.10	0.64	
S3				150 x 300	3958	91.90	0.65	
S1	22-Oct-25	5-Nov-25	14	150 x 300	5121	122.80	0.87	0.9
S2				150 x 300	5237	128.00	0.91	
S3				150 x 300	5176	124.60	0.88	
S1	22-Oct-25	19-Nov-25	28	150 x 300	5987	152.30	1.08	1.1
S2				150 x 300	6002	151.30	1.07	
S3				150 x 300	5997	145.90	1.03	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were also smooth without honeycombs

N/A- not available

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CONCRETE CUBE COMPRESSIVE STRENGTH TEST CERTIFICATE

Project ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS

Client: ZOZO MUSOLE JONATHAN AND ESTHER KIRULE | **Date received:** 22-10-25

Location/ Chainage: N/A | **Technician:** FM

Reference Method: BS EN 12390-6

	SISAL FIBRE (%)		1		Compaction Method			
Cylinder No.	**Casting Date**	**Testing Date**	**Age (Days)**	**Cylinder Dimensions (DxH), (mm)**	**weight of cylinder (g)**	**Maximum Load (KN)**	**tensile Strength (MPa)**	**Average tensile Strength**
S1	22-Oct-25	29-Oct-25	7	150 x 300	3965	88.60	0.63	0.7
S2				150 x 300	4023	96.40	0.68	
S3				150 x 300	3970	93.30	0.66	
S1	22-Oct-25	5-Nov-25	14	150 x 300	5145	123.00	0.87	0.9
S2				150 x 300	5216	130.70	0.92	
S3				150 x 300	5193	124.20	0.88	
S1	22-Oct-25	19-Nov-25	28	150 x 300	6009	147.20	1.04	1.1
S2				150 x 300	6022	152.90	1.08	
S3				150 x 300	6016	150.10	1.06	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were also smooth without honeycombs

N/A- not available

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Client:	ZOZO MUSOLE JONATHAN AND ESTHER KIRULE	Date received:	22-10-25
Location/ Chainage:	N/A	Technician:	FM

Reference Method: BS EN 12390-6

	SISAL FIBRE (%)		1.5		Compaction Method			
Cylinder No.	Casting Date	Testing Date	Age (Days)	Cylinder Dimensions (DxH), (mm)	weight of cylinder (g)	Maximum Load (KN)	tensile Strength (MPa)	Average tensile Strength
S1	22-Oct-25	29-Oct-25	7	150 x 300	3975	96.23	0.68	0.7
S2				150 x 300	4010	90.44	0.64	
S3				150 x 300	4042	96.76	0.68	
S1	22-Oct-25	5-Nov-25	14	150 x 300	5181	130.98	0.93	0.9
S2				150 x 300	5245	125.84	0.89	
S3				150 x 300	5203	122.40	0.87	
S1	22-Oct-25	19-Nov-25	28	150 x 300	6026	153.80	1.09	1.1
S2				150 x 300	6040	151.30	1.07	
S3				150 x 300	6044	152.38	1.08	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were also smooth without honeycombs.

N/A- not available

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Client:	ZOZO MUSOLE JONATHAN AND ESTHER KIRULE	**Date received:**	22-10-25
Location/ Chainage:	N/A	**Technician:**	FM

Reference Method: BS EN 12390-6

	SISAL FIBRE (%)		2		**Compaction Method**	N/A		
Cylinder No.	**Casting Date**	**Testing Date**	**Age (Days)**	**Cylinder Dimensions (DxH), (mm)**	**weight of cylinder (g)**	**Maximum Load (KN)**	**tensile Strength (MPa)**	**Average tensile Strength**
S1	22-Oct-25	29-Oct-25	7	150 x 300	3985	89.75	0.63	0.6
S2				150 x 300	4025	95.13	0.67	
S3				150 x 300	4048	89.16	0.63	
S1	22-Oct-25	5-Nov-25	14	150 x 300	5203	120.67	0.85	0.9
S2				150 x 300	5237	128.65	0.91	
S3				150 x 300	5241	123.04	0.87	
S1	22-Oct-25	19-Nov-25	28	150 x 300	6049	150.17	1.06	1.1
S2				150 x 300	6063	151.76	1.07	
S3				150 x 300	6071	148.87	1.05	

Remarks:

1. These results only apply to the samples that were delivered and tested.
2. Cubes were in good shape with the right dimensions, surfaces were also smooth without honeycombs

N/A- not available

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Checked by
Laboratory Engineer

Approved by
Technical Manager

TERZAGHI'S

Soils & Materials Lab

Document No: TZG/CCS/TF-23	
Revision No.	: 01
Revision Date	: 6th/09/2021
Approved by	: MD

Project	ASSESSING THE SUITABILITY OF USING SISAL FIBRE AS A REINFORCEMENT IN WOODCRETE BLOCKS
Client:	ZOZO MUSOLE JONATHAN AND ESTHER KIRULE
Location/ Chainage:	N/A

WATER ABSORPTION

sample ID	age	dimensions	dry weight(g)	wet weight(g)	weight gain(g)	% Absorption	AVERAGE ABSORPTION
C00-10			4035.2	4255.6	220.4	5.18	
C00-11			4103.0	4277.5	174.5	4.08	4.40
C00-12			4072.5	4239.8	167.3	3.95	
C0.5-10			4099.7	4317.2	217.5	5.04	
C0.5-11			4110.2	4339.5	229.3	5.28	5.00
C0.5-12			4085.3	4285.3	200	4.67	
C1.0-10			4183.8	4402.1	218.3	4.96	
C1.0-11	28	150*150*150	4295.0	4423.9	128.9	2.91	3.94
C1.0-12			4213.5	4386.1	172.6	3.94	
C1.5-10			4310.0	4480.6	170.6	3.81	
C1.5-11			4320.5	4503.0	182.5	4.05	3.68
C1.5-12			4295.8	4437.3	141.5	3.19	
C2.0-10			4551.1	4710.0	158.9	3.37	
C2.0-11			4565.0	4732.6	167.6	3.54	3.55
C2.0-12			4514.2	4689.6	175.4	3.74	

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P.O Box 7086,
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Single Yarn Test Report

Test ID	: TM-000275	Material Type	: sisal fibers	RH	: 59.11 %
Department	: TEXTILE	Yarn Spec.	: 86.4/1 Tex	Temperature	: 26.80 °C
Machine No.	: 1	Pre-tension	: 43.20 Grams	Sample(s)	: 1
Lot No.	: -	Gauge Length	: 830 mm	Readings / Sample	: 3
Shift	: General	Test Speed	: 500 mm/min.	Date	: 24-09-2025
Operator	: OSBERT	Clamp Pressure	: 3.69 bar	Time	: 12:15:56 pm

Client/party : samples of sisal fibres
Remarks : ZOZO JONATHAN AND BABIRYE ESTHER
Limits : -

Single Test Results :

Sample:1	Tests	B-Force (gf)	Elongation (mm)	RKM (g/tex)	B-Work (gf*cm)	T- Break (s)
	1	398.46	4.05	4.61	92.47	0.49
	2	*128.69	*2.10	1.49	17.15	0.25
	3	460.32	4.05	5.33	96.56	0.49
	Average	329.16	3.40	3.81	68.73	0.41
	Minimum	128.69	2.10	1.49	17.15	0.25
	Maximum	460.32	4.05	5.33	96.56	0.49
	Range	331.63	1.95	3.84	79.41	

Weak Places : BF = 0, BE = 0, BF+BE = 0
Strong Places : BF = 0, BE = 0, BF+BE = 0

*** - Out Lier Results :**

B-Force(gf) - 1%		Elongation(mm) - 1%	
Total :	1	Total :	1
Average :	128.69	Average :	2.10
CV% :	0.00	CV% :	0.00

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24-Sep-2025 | 12:33:01 pm

LABORATORY ANALYSIS REPORT FOR ZOZO JONATHAN AND BABIRYE ESTHER STUDENTS OF UGANDA CHRISTIAN UNIVERSITY.

Test serial number: T08/2025

Received on: 25/09/2025

Name of client: Zozo Jonathan and Babirye Esther

Sample Description: Samples of treated and untreated sisal fibers were delivered in the Textile, Polymer and Material Technologies Laboratory at UIRI on 19/09/2025.

Test methods used: ASTM D 2256, ASTM D 3800 and ASTM D 570

Date of testing: 22/09/2025- 24/09/2025

Tests carried out

Tensile properties ASTM D 2256, water absorption and density

The samples were subjected to the following tests;

- Breaking force
- Elongation
- RKM
- Breaking work
- Breaking time
- Water absorption

1. Tensile properties of untreated sisal fiber samples

The following test results were obtained for untreated sisal fibres

Tests	Breaking force(gf)	Elongation (mm)	RKM (g/tex)	Breaking work (gf*cm)	Breaking time (s)
1	398.46	4.05	4.61	92.47	0.49
2	128.69	2.10	1.49	17.15	0.25
3	460.32	4.05	5.33	96.56	0.49
Average	**329.16**	**3.40**	**3.81**	**68.73**	**0.41**

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2. Tensile properties of treated sisal fiber samples

The following test results were obtained for treated sisal fibres

Tests	Breaking force(gf)	Elongation (mm)	RKM (g/tex)	Breaking work (gf*cm)	Breaking time (s)
1	1655.71	8.55	36.31	674.49	1.03
2	1398.32	8.25	30.66	603.00	0.99
3	1747.28	9.15	38.32	773.83	1.10
Average	**1600.44**	**8.65**	**35.10**	**683.77**	**1.04**

3. Water absorption results of treated and untreated samples of sisal leaf fibers.

S/N	Untreated samples (absorption in %)	Treated samples (absorption in %)
1	219	180
2	303	265
3	261	254
Average	**261**	**233**

4. Density results of treated and untreated sisal fibers

S/N	Untreated samples (density in g/cm^3)	Treated samples (density in g/cm^3)
1	1.45	1.52
2	1.47	1.50
3	1.45	1.51
Average	**1.46**	**1.51**

Note; A minimum of three (3) sample results was considered for each test as per standard requirement

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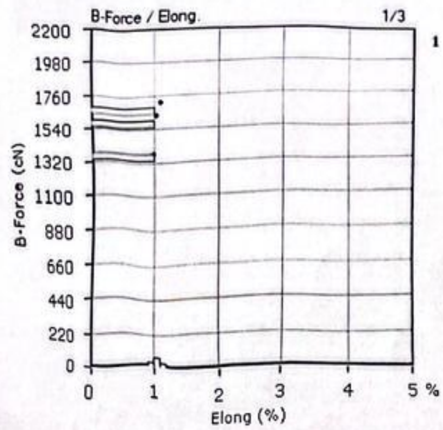
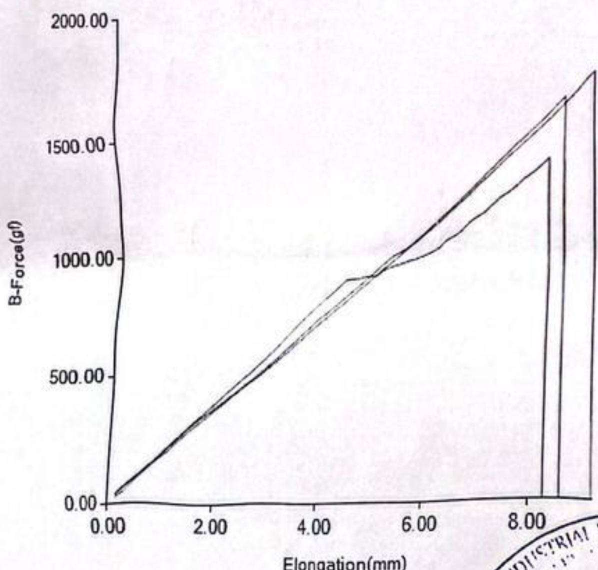
Prepared by

Tukashaba Annitah 25/09/2025

Namiiro Moureen 25/09/2025



FE Curve



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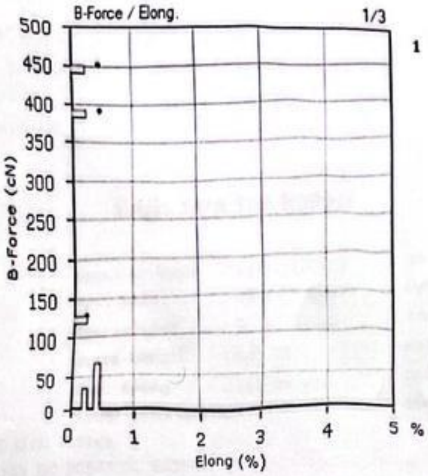

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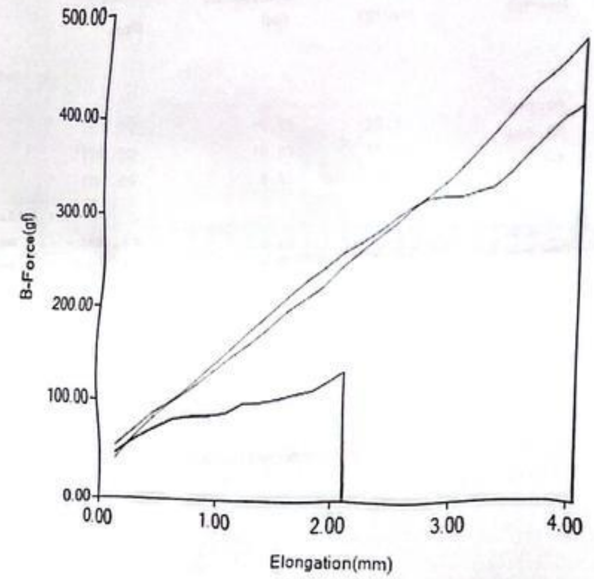

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Single Yarn Test Report

Test ID	: TM-000276	Material Type	: sisal fibers	RH	: 54.26 %
Department	: TEXTILE	Yarn Spec.	: 45.6/1 Tex	Temperature	: 27.50 °C
Machine No.	: 1	Pre-tension	: 22.80 Grams	Sample(s)	: 1
Lot No.	: -	Gauge Length	: 830 mm	Readings / Sample	: 3
Shift	: general	Test Speed	: 500 mm/min.	Date	: 24-09-2025
Operator	: OSBERT	Clamp Pressure	: 4.34 bar	Time	: 01:13:49 pm

Client/party : samples of sisal fibres
Remarks : ZOZO JONATHAN AND BABIRYE ESTHER
Limits : -

		B-Force (gf)	Elongation (mm)	RKM (g/tex)	B-Work (gf*cm)	T- Break (s)
Single Test Results :						
Sample:1	Tests					
	1	1655.71	*8.55	36.31	674.49	1.03
	2	*1398.32	*8.25	30.66	603.00	0.99
	3	1747.28	9.15	38.32	773.83	1.10
Overall Test Results :						
	Average	1600.44	8.65	35.10	683.77	1.04
	Minimum	1398.32	8.25	30.66	603.00	0.99
	Maximum	1747.28	9.15	38.32	773.83	1.10
	Range	348.96	0.90	7.65	170.83	

Weak Places : BF = 0, BE = 0, BF+BE = 0

Strong Places : BF = 0, BE = 0, BF+BE = 0

*** - Out Lier Results :**

B-Force(gf) - 1%			Elongation(mm) - 1%		
Total	:	1	Total	:	2
Average	:	1398.32	Average	:	8.40
CV%	:	0.00	CV%	:	2.53

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