ASSESSING THE SUITABILITY OF USING SISAL FIBER AS A REINFORCEMENT IN WOODCRETE

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ABSTRACT

The conventional concrete blocks in Uganda are not only heavy but also increase the need for larger structural elements which increases the cost making the need for the development of lightweight and eco-friendly and alternatives Woodcrete being one of the materials however, it is weak and susceptible to micro-cracking problems. The main objective of the research is to find out the mechanical and durability improvement of woodcrete when sisal fibers treated with alkali are added in the amount of 0-2% in the 1:2 cement-sawdust matrix. The tests performed in the laboratory included: density, compressive strength, tensile strength and water. At 1.5% fiber content, the best result was reached giving a compressive strength of 3.7 MPa, a tensile strength of 1.08 MPa and a density decrease to 1325.5 kg/m^3, which corresponds to a dead-load reduction of 26.36%. To conclude, sisal fibers particularly at 1.0-1.5% serve as an excellent reinforcement and contribute to the strength, cracking resistance, and durability of woodcrete, which can be used as a very good lightweight material for non-load bearing construction in Uganda.

DECLARATION

I, BABIRYE ESTHER KIRULE hereby declare that this is work originally done by me, it is not plagiarized and has not been submitted to any institution for any award.

BABIRYE ESTHER KIRULE

Signature: ………………….

Date: …………………….

APPROVAL

I Certify that this report is for BABIRYE ESTHER KIRULE and I fully accept that she has been under supervision and submitted to the Faculty of Engineering, Design and Technology of Uganda Christian University in partial fulfilment of the requirements for an award of a Bachelor of Science in Civil and Environmental Engineering.

Signature: …………………….

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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 metre cubed
kN	Kilonewtons
mm	millimeter
µm	micrometer
MPa	Mega Pascals

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

Heavy materials such as standard concrete blocks are some of the elements that contribute to significant dead loads in a structure. Dead loads represent the majority of the forces that building elements must withstand, frequently making up 70–90% of the total load in reinforced concrete constructions (Ghani *et al.*, 2019). The increase in permanent loads leads to a rise in bending moments, shear forces and pressures on foundations, which consequently cause more reinforcement and higher structural costs. According to, a reduction in wall unit materials weight leads to a reduction in these internal forces and thus better structural performance. The unending rise of urban centers has rendered the weight of traditional masonry units a decisive factor not just in these areas but also where structural performance with lower cost is required (Holm *et al.,*2007). Consequently, the removal of permanent loads has become one of the main tactics of modern building. The transition to lightweight construction technologies has been the most effective one among other alternatives (Kulbhushan *et al.,* 2018).

The use of lightweight materials such as hempcrete, autoclaved aerated concrete (AAC), foamcrete and lightweight aggregate concrete has been universal in all building aspects. Hempcrete is extremely light and possesses a variety of compressive strength from 0.2–0.5 MPa and it even attains 1.2 MPa in dense mixes (Asghari *et al.*, 2014). Structural lightweight aggregate concrete has a density range varying from 1,120 to 1,920 kg/m^3 along with compressive strength of nearly 17 MPa (Holm *et al.*, 2007). For AAC density is generally around 400–800 kg/m^3 and the corresponding compressive strength values range between 2–7 MPa. Foamcrete offers a wider spectrum of light building materials with 400–1,600 kg/m^3 density and 1–10 MPa strength depending on the density. These lightweight materials have shown to reduce wall masses by 25-60%, by reduction in density this minimizes demand for large structural elements (Dias et al.,2024).

Amongst the mentioned technologies, woodcrete which is a composite material that is produced by mixing wood waste (sawdust, wood shavings, wood chips) with cement. Depending on the binder type and curing conditions the density ranges from 800-1,200 kg/m^3 and compressive strength range of 0.6–3.89 MPa (Hornby, 2020). Use of woodcrete utilizes the use of wood waste which further enhances the need for smart and green construction that requires use of locally available materials. This technology uses recycled wood waste and this significantly lowers embodied energy and CO_2 emissions one variant reduced net CO_2 compared to conventional concrete. Although untreated composites lose strength over time lime or cement treated sawdust retain their compressive strength after one year and this demonstrates durability under environmental exposure (Khelifi et al., 2022). Therefore, woodcrete is sustainable (low carbon, uses local waste) which makes it cost-effective and durable when properly treated while still delivering moderate structural performance (Fadiel et al., 2022).

In Uganda, the importation of lightweight materials is still quite slow, notwithstanding the fact that quite a number of research works have been carried out on alternatives like papercrete bricks and rice-husk composites. The increasing demand for low-cost housing and eco-friendly materials places woodcrete in a good position for taking it on locally. The fast pace of urbanization in the country has created a challenge for the construction sector of coming up with low cost and sustainability measures at the same time. Woodcrete is a solution that suits Uganda's green construction agenda since it is made from sawdust which is abundantly available in wood-processing firms. Therefore, it becomes both a cost-effective and a feasible option for both small and large developers working with local communities.

Despite the benefits, the use of woodcrete has not been adapted greatly especially in this part of the world and some of the reasons could be because woodcrete exhibits significantly lower mechanical strength compared to other conventional lightweight materials like light weight concrete (Dias et al., 2022). This underlying cause of low strength can be attributed to high porosity and weak interfacial transition zones that result from the mismatch between wood and cement matrix and the hygroscopic behavior of wood which introduces moisture fluctuations causing micro-cracking and dimensional instability. Recommendations like reinforcing woodcrete have been given by researches to enhance the mechanical properties of the material (Aigbomian *et al.*, 2013). Various fibers are used in construction for reinforcement these include natural fibers, steel, bamboo, sisal, jute, plastic, and others (Anas et al., 2022). Different building materials like concrete have been reinforced with a various fiber and this has shown improvement in the compressive strength and decrease in the density. Of the different fibers, sisal is considered best among others for its high tensile strength 350-840 MPa, stiffness 9 - 38 GPa and a relatively low density of 1.33-1.45 g/cm^3 (Bichang'a *et al.,* 2022). It is also very durable and has a lower water uptake compared to most the fibers used. Also, less water uptake compared to the following natural ones makes sisal be more durable when used in cementitious composites. In different parts of the world, sisal is found in various forms of building materials to increase ductility, resistance to cracking, and energy absorption. As for Uganda, which is an abundant source of sisal, the use of it in woodcrete reveals an eco-friendly and sustainable local reinforcement solution. Hence, the idea of utilizing sisal-reinforced woodcrete opens the door to a potential development of lightweight, durable, and inexpensive construction units that can meet the housing demand in Uganda with their excellent qualities.

1.2 PROBLEM STATEMENT

In construction, dead loads increase the size of structural elements leading to the use of more reinforcement and this leads to higher construction costs. These loads also reduce the integrity of the structure. One of the elements that lead to increase of permanent loads are masonry units i.e., concrete blocks which have a density of over 1800 kg/m^3 which means they have great mass. Use of alternative units to have lighter structure is a necessity in construction of low-cost houses. Having lightweight materials as construction units would reduce on permanent loads thus having reduced size of structural elements designed which reduces the cost of construction.

According to literature, woodcrete blocks have shown great potential as light weight building materials although they have structural limitations because of low strength. This is ascribed to the high porosity and weak interfacial transition zones result from the mismatch between wood and cement matrix and the hygroscopic behavior of wood which introduces moisture fluctuations causing micro-cracking and dimensional instability (Aigbomian, 2013). Sawdust cement composite has a low plastic deformation, under low stress it deforms easily due to the compressible sawdust's moisture-sensitive lignocellulosic structure. This quality reflects low rigidity, high porosity and weak fibre-matrix bonding which leads to weak load transfer and early micro cracks.

This limits the blocks application for load bearing construction. To confront this challenge, sisal fibre can be incorporated in the mix. Sisal fiber is a natural fiber known for its high tensile strength ranging from 350 to 840 MPa, stiffness varying broadly between 9 and 38 GPa and density relatively low for a natural fiber at approximately 1.33–1.45 g/cm (Bichang'A *et al.*, 2022). It is also very durable and has a lower water uptake compared to most the fibers used. Studies have shown that sisal fiber contributes to mechanical interlocking with the cement paste and absorbs less water than other natural fibers enhancing the bond strength *(Zziwa et al.*, 2006). Therefore, this research aimed to assess the suitability of using sisal fibre as a reinforcement in woodcrete blocks.

1.3 MAIN OBJECTIVE

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

1.4 OBJECTIVES

1. To determine the physical and mechanical properties of sisal fiber.
2. To find the optimum amount of sisal fiber that is required to obtain a woodcrete block unit.
3. To determine the effect of sisal fiber on the microcracking of the woodcrete block.

1.5 RESEARCH QUESTIONS

1. What are the physical and mechanical properties of sisal fibre?

2. What is the optimum amount of sisal fibre that is required to obtain a woodcrete block unit?

3. What is the effect of sisal fiber on the microcracking of the woodcrete block?

1.6 JUSTIFICATION

Several studies have explored the performance of natural fibers in cementitious composites with sisal fibre emerging as a particularly promising reinforcement material due to its mechanical and chemical characteristics. Sisal is a lignocellulosic fibre derived from Agave sisalana and it exhibits high tensile strength, low density, and has a fibrous surface morphology that supports good mechanical interlocking with cementitious matrices (Silva et al., 2020). Its chemical composition rich in cellulose contributes to a hydrophilic nature due to the presence of hydroxyl (–OH) groups which enhances compatibility with polar materials like cement paste (Anas et al., 2022). In porous composites like woodcrete, where poor interfacial bonding frequently results in cracking, this encourages strong fiber matrix adhesion, an essential characteristic. Additionally, a number of studies have demonstrated that sisal fiber absorbs less water than many other natural fibers, which enhances internal curing and the slow release of moisture during hydration. This supports the continuous formation of calcium silicate hydrate (C-S-H) improving the matrix structure and compressive performance (Silva et al., 2020). Alkali treatment such as with NaOH also improves fibre durability and bonding capacity by removing hemicellulose and enhancing surface roughness.

SIGNIFICANCE

This research contributes to the knowledge base by providing data on the use of reinforced woodcrete blocks as a building material in Uganda. Use of woodcrete would utilize the use of sawdust which is still low in Uganda. This will further enhance the need for smart construction which requires use of locally available materials. This shows potential to inform material selection for affordable, sustainable housing projects in the country. Moreover, promoting woodcrete technology reduces waste generated from aligning with Uganda's Vision 2040 goals for sustainable development (National Planning Authority, 2020).

The findings will benefit policymakers and the construction industry by offering an alternative to lightweight materials, reducing environmental impacts and enhancing material performance for building applications.

1.7 SCOPE OF THE STUDY

1.7.1 Geographical scope

The saw dust will be acquired from Uganda Industrial Research Institute and the sisal fibre will be sourced from Uganda Industrial Research Institute, 0°20'50.8"N 32°41'21.7"E, Uganda.

1.7.2 Content scope

1.7.2.1 To determine the physical and mechanical properties of sisal fibre.

This objective covered the acquisition of sisal fibers Sisal fibers are obtained from Ngora in eastern Uganda, focusing on fibers grown for more than two years due to their higher cellulose content and improved tensile properties. The process of fibre extraction will be alkali (NaOH) treatment and preparation, with justification from literature on how treatment enhances fibre-matrix bonding. The study then helped characterize the fibers through tensile strength testing, water absorption assessment, density determination and spectroscopic and microscopic analyses (SEM) to provide insight into their chemical composition, morphology and suitability as reinforcement material in woodcrete.

1.7.2.2 To find the optimum amount of sisal fibre that is required to obtain a woodcrete block unit.

This objective addressed the mix design development for woodcrete using Ordinary Portland Cement, sawdust from hardwood and water. Mix ratios of 1:1 and 1:2 (cement to sawdust) was evaluated based on precedents in published literature. Incremental additions of sisal fibre (by weight of cement) were introduced across different mix batches to establish the threshold content that maximizes compressive strength and stability without adversely affecting workability or density. Comparisons was drawn from prior studies on fibre dosages in cement composites to justify the chosen ranges. The tests that were carried out are compressive strength, tensile strength, density, water absorption.

1.7.2.3 To determine the effect of sisal fibre on the microcracking of the woodcrete block.

This objective explored the influence of sisal fibre reinforcement on the performance of woodcrete, with a focus on crack mitigation. Standardized compressive strength, water absorption, tensile strength and density tests following the standards were conducted alongside visual and microscopic examinations of crack propagation. The role of fibre bridging and fibre-matrix interaction in reducing microcracking will be highlighted.

1.7.3 Time scope

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

CHAPTER TWO: LITERATURE REVIEW

2.1 Concrete blocks

A concrete block is a building material that is made by mixing together cement, stones, and water. The mixture is poured into a reusable mold or a form which is then cured in a controlled atmosphere, moved to the building site, and either placed or raised into position. A precast concrete block is mainly utilized as a material for the construction of walls of buildings and is sometimes referred to as a Concrete Masonry Unit (CMU). The process of making precast concrete blocks takes place at the ground level which contributes to the safety of the whole project. The industry is stricter about the quality of materials and workmanship in a precast plant than in a construction site. The forms used in a precast plant may be reused one hundred to one thousand times before they need to be replaced, hence the cost of formwork per unit is lower than for site-cast production (Allen, 2009).

Concrete blocks are available in different shapes and sizes and may be either solid or hollow. Dimensions of 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 common sizes of concrete blocks (Kamal, 2022).

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

In Uganda, they are the major players in the building market due to the low price of raw materials and the presence of labor, however, the quality of blocks remains a major challenge. Mwesigwa et al (2021) indicate that more than one-third of blocks checked in Kampala did not comply with the minimum strength standards owing to poor mixing and curing techniques.

Dense and heavy solid concrete blocks have densities that vary between 1,800 and 2,200 kg/m^3. Their compressive strengths frequently vary between 7 MPa and 15 MPa, thus making them particularly ideal for load-bearing applications, such as the aforementioned foundations and walls that resist forces. Nevertheless, due to their bulkiness, they play a major role in the total dead load of buildings, which may, on the other hand, raise foundation costs and also restrain their application in the case of skyscrapers where weight efficiency is paramount (Neville, 2011).

On the other hand, hollow concrete blocks are less heavy and are obtained either by utilizing less aggregate content or by integrating voids in the units. Their density is usually between 1,100 and 1,500 kg/m^3, while the compressive strength lies in the range of 5-12 MPa (Kamal, 2022). The primary use for, hollow concrete blocks is in the construction of partition walls and non-load-bearing structures. The voids, besides making the blocks lighter, provide insulation against noise and heat transfer. Furthermore, the use of hollow blocks also means reduced consumption of cement and steel in construction. Nevertheless, they are fairly susceptible to the entrance of water vapor and hence proper plastering is needed for long-lasting performance (Neville, 2011).

Lightweight blocks are the newest revolution in the quest for to lighten the weight of masonry. The manufacturing process of autoclaved aerated concrete (AAC) blocks entails cement, lime, gypsum, fly ash, and aluminum powder coming together in a mixture. The chemical reactions release a gas that produces a multitude of air pockets, which in turn result in low densities of 500-700 kg/m^3 and compressive strengths of 3-8 MPa (Narayanan *et al.*, 2000). Due to their low density, the walls made of AAC blocks are lighter and better insulators, but their lower strength compared to other types of concrete restricts their use to non-load-bearing or low-rise buildings. In the same way, the making of concrete blocks yields a product that is either comprised of foam or non-foam concrete. her the foaming agents are added to the cement slurry, producing the foam concrete blocks with final densities as low as 400 kg/m^3 and strengths from 1 to 10 MPa (Jones *et al.*, 2005). The main application of concrete blocks is in providing thermal and acoustic insulation, but limited to non-loadbearing on account of the variable strength and the latter of the application being more prone to shrinkage.

The process of manufacturing concrete blocks is very much dependent on the right mixing ratios of each of the components: cement, aggregates, and water. The use of too much water results in the production of weak units with low compressive strength while the use of less water than what is required results in poor quality curing which leads to low durability (Neville, 2011). In the informal sector of Uganda, manual mixing often leads to improper proportions which then produce blocks that fail to meet the minimum strength requirements set by regulations (Mwesigwa et al., 2021). As the saying goes, "the devil is in the details" which in this case means that the quality control has to be very strict and the production method mechanized.

The usage of concrete blocks in construction greatly influences the structural performance mainly through their density and compressive strength. Heavy and firm blocks support greater loads but add significantly to the dead loads while light blocks lower the structure's weight and enhance insulation but demand reinforcement or mixing with stronger materials for durability. Hence, the choice of the type of block needs to consider structural needs, economic viability and eco-friendliness in the particular project setting.

Table 1: Minimum requirements for load-bearing and non-load bearing concrete block

Block	Minimum Compressive Strength	
	Average of 10 Blocks N/mm^2	Individual Block N/mm^2
1	3.5	2.8
2	2.8	2.2

Concrete blocks used in wall construction are subject to the national performance levels established in the Standard Specifications for Building Works (Ministry of Works and Transport, 2013). The specification states that the blocks produced in factories must individually possess the minimum compressive strengths indicated for solid and hollow blocks in Table 1. Type 1 blocks will be required to have an average strength of 3.5 N/mm^2 together with a minimum strength of 2.8 N/mm^2 for single blocks and the same will be the case for Type 2 blocks having the average of 2.8 N/mm^2 and the minimum of 2.2 N/mm^2 to meet the requirements. Where Type 1 is for load bearing loads and Type 2 is for non-load bearing loads.

2.1.1 Lightweight materials

Lightweight materials in construction are generally classified based on their density in comparison to normal concrete. Normal weight concrete typically has a density in the range of 2200–2600 kg/m^3, while lightweight concrete falls within 800–2000 kg/m^3 (Neville, 2012). Materials with a density below 800 kg/m^3 are further categorized as ultra-lightweight concretes, primarily used for insulation rather than structural purposes (ACI, 2014). For example, hempcrete, with a density between 250-500 kg/m^3, is classified as ultra-lightweight, while woodcrete, usually ranging from 600–1200 kg/m^3, falls within the lightweight category. This classification is crucial as it informs the potential structural application of each material, where higher densities are associated with structural strength and lower densities with thermal and acoustic insulation.

2.2 Woodcrete

Woodcrete is one interesting composite material that is made by blending wood waste like sawdust, wood shavings, or wood chips into a cement-based mixture, thus resulting in a lighter and more environment-friendly alternative to the traditional concrete. It is the main reason for the devaluation of timber and sawmill waste as it is a vital contribution to green and sustainable construction by minimizing the costs of construction and reducing landfill waste (Abdullah et al., 2019). Its most important feature is its much lower density, which normally lies in the range of 600 to 1,600 kg/m^3, whereas common concrete density is about 2,300 to 2,400 kg/m^3 (Aigbomian *et al.*, 2013). The initial density reduction is because of the non-wood-like structure of the wood particles, which not only reduces the bulk mass but also gives good thermal insulation. The thermal conductivity of woodcrete is said to be in the range of 0.1–0.4 W/mK, while that of normal concrete is around 1.7 W/mK making it very usable for energy-saving buildings (Fadiel et al., 2022).

On the contrary, in the case of portland concrete, the failure is normally due to the sudden brittle cracking of the cement matrix, whereas the wood composites undergo progressive crushing and pull-out of the wood particles. This gives rise to the phenomenon of better energy dissipation and crack arresting. Da Glória et al (2021) remarked that the wood-bio-concrete elements fortified with long fibers showed better toughness and higher impact resistance as compared to equivalent lightweight concretes. Acoustic absorption capacity of the composite material, which is a result of the porous internal structure, is reported to be higher than that of ordinary concrete; hence, the material is considered suitable for infill walls, partition panels, and acoustic insulation blocks (Fadiel et al., 2022). These thermal, acoustic, and mechanical...

2.2.1 Standards for woodcrete

Currently, there is no general international standard that dictates the mix proportions, performance thresholds, or classification of woodcrete which forces researchers to depend on the testing methods for concrete and masonry. Aigbomian and Fan (2013), for example, evaluated the compressive strength and dimensional stability of sawdust-cement composites through ASTM C39 and ASTM C140 standards. Their study showed that the compressive strength of the blocks with sawdust content of 50% was more than 2.0 MPa.

Therefore, they have taken the minimum requirement given in ASTM C129 for non-load-bearing concrete masonry units, which set strength limits of about 1.4–3.5 MPa according to the unit classification. Similarly, Fadiel et al. (2022) tested woodcrete blocks against the performance criteria of EN 771-3 for aggregate concrete masonry units, and, when the sawdust content was no more than 40%, the density and water-absorption thresholds were found to be within acceptable limits. All these methods demonstrate how researchers are taking existing masonry and concrete standards, in the absence of dedicated regulatory guidelines validating the structural suitability of woodcrete, applying them to woodcrete very well. The dependence on general masonry and concrete testing standards underscores the necessity of a dedicated woodcrete standard that will promote its extensive use and acceptability.

2.2.2 Sawdust particle size in woodcrete

The performance of woodcrete varies a lot depending on the size of sawdust particles used. As per researches, the strength and density of blocks produced out of fine sawdust through a 2 mm sieve are greater than those made with coarse sawdust (Fadiel et al., 2022). On the contrary, the use of particles greater than 5 mm results in highly porous material with low compressive strength, but such materials are still preferred for their excellent thermal insulation properties (Aigbomian *et al.*, 2013). For obtaining uniform grading and for reproduction purposes, sawdust is usually dried in an oven and then sieved with standard ASTM or BS sieves; the 2 mm or 4.75 mm sieve-fraction is then collected for further processing (Okereke, 2015).

2.2.3 Mix ratios for woodcrete

Recent studies have revealed that the performance of woodcrete and sawdust-cement composites is significantly affected by the wood species, binder ratio, and particle size. Aigbomian and Fan (2013) found that beech and oak, among hardwoods, produced woodcrete with the highest strength and density corresponding to 3.93 MPa in compressive strength, while softwoods, on the other hand, produced cedar and pine with only 0.07 to 1.37 MPa. They also indicated that a particle size of 1 mm considerably enhanced the compressive strength related to the better packing of the particles and more efficient stress transfer between the particles and the binder.

They also suggested a ratio of sawdust to binder 1:2 as the optimum for ensuring good bonding and workability. Zziwa et al. (2006) in their research, which strengthens the previous findings, have stated that sawdust-cement composites with proportions of 3:2 and 2:1 sawdust:cement have compressive strengths in the range of 1.61 to 2.21 MPa, the stronger and denser bricks being produced due to the higher cement content. Moreover, they pointed out that moisture exposure could reduce the strength of the composite by as much as 40%, which indicates their vulnerability to wet conditions. All the studies combined the alpha that the mixes with the finest hardwood sawdust and the highest binder content deliver the best mechanical performance, while the high-wood-content mixes provide the insulation at the strength expense.

2.2.4 Fibre reinforcement in wood composites

The use of natural fibres together with cementitious materials is not only a matter of changing the physical properties of the final product but also of increasing toughness, post-crack ductility and better control of cracking. Nevertheless, this latter benefit has not yet been demonstrated in the case of woodcrete; most evidence supports the use of toughened concrete or mortar. Da Gloria and Toledo Filho (2021) established the sandwich panels, consisting of a wood bio-concrete core with cement skins reinforced by sisal fibres and reported a considerable increase in flexural strength, stiffness and energy absorption as compared to panels without reinforcement.

This illustrates the possibility of the combination between bio-aggregates and ligno-cellulosic fibres to work in a composite system. As Jamshaid et al. (2022) did the same, they found that along with jute, sisal, coconut and sugarcane, the best dosages for their application ranged from 0.5% to 3% by weight of cement and that the mechanical performance could be improved up to an optimum of about 2% after which workability was reduced due to fiber clustering.

Rocha et al. (2022) noted that the biggest part of natural-fiber reinforcement research has been done on fibers of lengths between 10 and 40 mm, with 0.5 - 3% being the dosages used, and all these studies have come to one conclusion crack resistance and fracture energy increase even though the paths were very often through reduced workability and increased water absorption. The natural fibers jute, sisal, cotton, and bamboo were used in a blending proportion of about 0.5–1% and for the latter ones the authors Kurpińska et al. (2022) reported that macro strength has risen almost up by 27% and flexural strength has gone up by ±8%. This indicates that the shape and chemical nature of the fiber play a significant role in determining the properties.

The recent studies on flexural toughness of sisal fibers have concluded that if the fibers are correctly treated, they not only yield a huge amount of flexural toughness but also the compressive strength increase at the dosage of 1-2% (Yimer et al., 2023; Fode et al., 2025). Coir and jute-reinforced composites reveal that similar enhancement can be achieved by adding low to medium dosage of fiber (Veerappan et al., 2024). Therefore, it can be said that such treatments along with the use of nylon or an equivalent fiber at low to moderate dosages (≈0.5–2%) and fiber lengths of 10–30 mm are an effective range for improving post-peak behavior being a rational starting point for the design of fiber-reinforced woodcrete, which requires mix-specific experimental validation.

2.2.5 Sensitivity in woodcrete manufacturing

The manufacturing process of wood-cement composites, also known as woodcrete, is extremely sensitive due to the fact that sawdust contains a lot of different organic materials that may vary greatly in quality and quantity. These variations in the chemical composition and compatibility with cement lead to large differences in the final product. Researches over time have confirmed that wood particles which have not been treated release extractives (such as sugars, resins and lignin derivatives) that slow down the process of cement hydration, thus producing low strength or delayed setting, especially if the most course of sawdust is used (Brahmia et al., 2020). One of the main drawbacks to this issue is the necessity for sawdust pre-treatment which is very commonly recommended, for instance, alkaline or water-based extraction, sometimes in combination with chemical admixtures. It has become a common practice to conduct such pre-treatments for the wood particles as it greatly increases the compatibility of the wood with cement, results in higher density and better mechanical performance Rocho et al., 2021).

The addition of the pretreated sawdust composites has been reported to be able to achieve an increase in compressive strength of up to 50% at moderate levels of sawdust substitution compared to the untreated mixes (Sumarno et al., 2023).

Pre-treatment and key manufacturing controls are also very important in determining the quality of the final product: proper control of the sawdust grading (particle size), moisture content measurement and adjustment, following a consistent mixing sequence, and mechanical mixing that is thorough enough to disperse wood particles and any fibers evenly, as well as uniform compaction during casting to ensure repeatability and minimize voids or weak zones, all these are very critical. If such controls are not respected, the produced woodcrete will have a very high variability in density, strength and durability, which will result in a great difficulty of coming up with a structurally design that is reproducible. Given such sensitivities, it is advisable that every woodcrete mixture undergoes experimental validation taking into consideration the local sawdust source, pre-treatment and mixing.

2.3 Fibre use in construction composite materials.

Natural fibers including are widely studied as sustainable reinforcement in cementitious matrices because they improve post-crack behavior, toughness and flexural/tensile response. Although they commonly reduce fresh-workability and may reduce compressive strength above an optimum dosage which necessitates making the mixes carefully. (Ahmad, 2022).

These natural fibers such as sisal, coir, jute, flax, banana and hemp have been increasingly explored due to their low cost, biodegradability and ability to improve mechanical performance. Each fibre type has unique characteristics influencing its suitability. Coir fibre offers excellent toughness and crack control though it has low tensile strength (80–250 MPa) and poor stiffness causing a limit to its structural contribution. Jute and banana fibers show promising initial strength but their rapid degradation in the alkaline cement matrix and high-water absorption can negatively affect long-term durability (Balan et al., 2017). Hemp fibre performs better in terms of tensile strength (550–900 MPa) but its lower availability and higher processing cost make it less practical in regions like Uganda (Fiore et al., 2015).

Sisal-specific studies report mixed results on its performance, many authors observe improved toughness and improved flexural/tensile strength with small additions of sisal while compressive strength often increases up to a low-moderate content and then falls as fibre content further increases. Reported optimum ranges for sisal in cementitious matrices typically lie between 0.25% and 3.0% (by weight of cement) but values depend strongly on fibre length, treatment and matrix composition. (Ahmad, 2022).

2.3.1 Plastic fiber

Plastic fiber has emerged as an environmentally friendly reinforcement material in concrete, particularly due to its role in recycling plastic waste such as bottles and packaging materials. This helps reduce environmental degradation caused by improper plastic disposal.

Using plastic fibers not only promotes sustainable construction but also lowers overall construction costs. Research has shown that replacing up to 1.5% of cement content with plastic fibers provides optimal performance. Additionally, a novel arrangement involving continuous plastic fiber reinforcement has demonstrated high bonding strength between polyethylene terephthalate (PET) fibers and the concrete matrix.

However, incorporating plastic fibers can reduce the compressive strength of concrete. To counter this drawback, additives such as silica fume and metakaolin can be used to improve mechanical performance. Despite the reduction in compressive strength, PET fibers enhance the tensile and flexural strength of concrete, contribute to a more ductile failure mode, and improve the overall cohesion of materials within the mix.

It is also noted that the inclusion of PET fibers may negatively impact the workability of fresh concrete and can sometimes lead to spalling. As a result, proper mix design and workability adjustments are necessary when plastic fibers are used.

2.3.2 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.

2.3.2.1 Wheat straw fiber

Wheat Straw Reinforced Concrete (WSRC) has demonstrated significant benefits at early curing stages, particularly in pavement applications. The inclusion of wheat straw reduced the severity and number of shrinkage cracks. While the slump of the concrete mix decreased, flexural, tensile, and compressive strengths improved. Additionally, the concrete exhibited increased ductility, resulting in ductile failure and reduced crack width. The fiber's sewing effect contributes to better post-cracking behavior and absorption capacity. Using wheat straw in concrete also reduces crop residue burning and lowers construction costs (Khan et al., 2022).

2.3.2.2 Sugarcane fiber

Sugarcane fiber enhances the thermal stability and mechanical properties of concrete. When used as sugarcane bagasse ash (SCBA), it increases flexural, compressive, and tensile strength while reducing the thermal conductivity of the mix. Concrete incorporating SCBA becomes lightweight and thermally stable up to 450 °C. Additional improvements in stiffness and elastic modulus were achieved through electron beam radiation. Microstructural analysis revealed a significant reduction in voids, indicating better overall performance of the concrete matrix (Khan et al., 2022).

2.3.2.3 Jute fiber

Natural jute fiber (JTF) has been touted as a green, compostable, and safe material for concrete reinforcement. Cement matrix with the addition of JTF will have a new concrete of less consistency because of JTF's large surface area which also leads to the mix's harshness. But the hot alkali treatment of jute fibers very much increases the interfacial bond between fibers and cement paste and hence, leads to the improvement of mechanical and durability properties. The reinforcement of JTF concrete gave rise to enhanced compressive, split tensile, and flexural strengths. At 28 days, the maximum compressive strength was recorded at 2% JTF content, which is a 20% rise over control concrete.

However, the increase in fiber content has the potential to be detrimental to strength and durability because of reduced flow ability, which necessitates the use of super plasticizers at the higher dosages. JTF excels in terms of durability since it not only enhances concrete's density but also its resistance to water absorption, dry shrinkage, and acid attack. But still, only a small number of studies have been conducted regarding the long-term durability of JTF-reinforced concrete. There is a strong recommendation for further scientific investigations including the chemical and physical treatment of jute fiber and incorporation of pozzolanic materials like fly ash or silica fume not only to enhance bonding but also to exert control overall (Ahmad et al., 2022).

2.3.2.4 Bamboo fiber

Bamboo has emerged as a green and productive option to steel reinforcement in the construction of concrete structures. Conventional means of treatment such as borax-boric acid solutions, vertical soak diffusion and pressurized tank preservation have been successful in giving bamboo an insect attack resistance equal to that of treated wood. Advanced techniques and effective waterproof coatings like bitumen, Sikadur Gel, boric-borax acid and polyester resin have been reported to enhance further the bamboo's durability and bond strength for structural applications in beams and columns. Additionally, mechanical improvements such as screws placed between nodes and hose clamps used as shear connectors have been suggested to increase the bond stress and thus the load-bearing capacity of bamboo-reinforced concrete (BRC) elements.

The development of bamboo-reinforced prefabricated panels has not only been a great economic and structural benefit but also resulted in a cost-saving of 40% and weight reduction of 56% at the most when compared with the traditional brick walls while maintaining the same compressive strength of 17.6 MPa. However, the downside is that debonding failure under flexural loads is still an unresolved issue that needs further refinement of the bonding effectiveness (Das et al., 2024).

2.3.2.5 Sisal fiber

The reinforcement of concrete with sisal fiber is not only suitable but also a good alternative to conventional steel which is the main reason for environmental and health issues. With the help of studies, it has been proven that sisal fiber enhances compressive, tensile, and flexural strengths. It is especially useful in drainage plates and its cost is about 1.85 times less than steel reinforcement. However, the introduction of sisal fiber leads to the reduction of the mix's workability, but an increase in the initial crack load is observed which signifies greater strength. Khan et al. (2020) found that foamed concrete with sisal reinforcement showed better resistance to cracking and stability in dimension. To reduce the negatives such as high porosity and poor workability methods like alkali soaking, latex coating, or perlite blending are usually suggested.

They not only increase the fiber-matrix bond but also lower the moisture uptake by up to 65%, thus allowing the composite to be more stable over time (Mdpi, 2022). The properties of sisal fiber make it suitable for reinforcing woodcrete in overcoming the drawbacks.

This natural fiber is biodegradable and is still nowadays used in the traditional ways such as products made out of ropes, mats, carpets, and baskets. The idea to use it as a construction material for reinforcement has recently been attempted. It stands out due to its exceptional tensile strength, low price and good bonding with cement. The composition of sisal fiber includes cellulose, lignin and hemicellulose which are mainly responsible for the unique properties of the fiber. The fiber is treated with alkali to get rid of the surface impurities and this consequently enhances its compatibility with the mix. The literature has it that Sisal improves the ability of the cement matrix to resist cracking when added to concrete which is vital in enhancing the mechanical properties of the whole mix.

To improve performance, these various natural and synthetic materials are increasingly being used in cementitious materials in modern construction. Sisal fiber is one of the most compatible fibers among them for reinforcing lightweight cementitious materials like woodcrete. Besides, it has very high tensile strength (350 to 840 MPa) and good durability in alkaline environments after mild alkali treatment and its rough surface texture is responsible for the above property which promotes the mechanical interlocking with the cement matrix (Anas et al., 2022). Its water absorption being moderate is a boon for internal curing since matrix is not weakened to a great extent and more effective formation of calcium silicate hydrate (C-S-H), the binder responsible for strength development in cement composites, takes place. Unlike the fibers that are more brittle or moisture-sensitive, sisal over the years maintains its structural integrity and is also available in East Africa which makes it a more practical and sustainable reinforcement material option for counteracting the mechanical limitations of woodcrete (Uysal et al., 2024).

2.3.3 Fiber optimization

The optimization of fibre in cementitious composites is a process that needs to be optimized according to the performance requirements of the material to be produced, especially the strength enhancement versus workability loss. Overdosing of fibre tends to make the composite less flowable and more susceptible to fibre clumping, whereas low and moderate amounts of fibers usually increase the strength of the composite and its toughness, control of the cracks and behavior after the peak load. Ahmad et al. (2022) indicates that the maximum mechanical performance of natural fibers is usually found at the dosages of 0.5% to 2% based on cement weight, beyond which the workability gets worse and strength improvements are less.

This is also true with the observations mentioned above and taking into account the additional variability brought about by sawdust in woodcrete, it is justifiable to have an experimental matrix with sisal fibre dosages of 0.25%, 0.5%, 1%, and 2% in cement and fibre lengths of 10-20mm. These are the ranges that are usually employed in natural-fibre cement composites and they are likely to provide measurable increases in toughness and crack resistance without exceed the limit of mix workability that is considered acceptable (Rocha et al., 2022; Fode et al., 2025).

2.3.4 Aspect ratio

The ratio of the length of the fibre to its diameter is known as the aspect ratio and it's a very important factor that determines how effective the reinforcement in cement composites will be. Sisal fibers having moderate aspect ratios (AR 60–100) give better performance in terms of crack bridging, tensile strength and ductility, because of their pull-out resistance and better fibre-matrix bond. On the other hand, very high aspect ratios lead to decreased workability and might result in fibre balling. Fibers that are employed in the production of cement composites usually have an aspect ratio of 30–100 which is the range namely optimal for the processes of crack bridging and load transfer in brittle matrices.

Research also points out that natural fibers in cement composites generally can be found with an aspect ratio of 30 to 100 (Fibre Reinforced Cement Composites, 2018). The very same aspect ratio ranges between 40 and 80 have been put forward by the industry as the benchmarks to attain remarkable concrete dispersion alongside reinforcement efficiency.

CHAPTER THREE: METHODOLOGY

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

Research Design.

This shows and informs how this research will be carried out on.

After the submission of the research proposal, intensive literature review continued up till the end of the research. Preliminary findings were carried out to inform the research methodology. Results were collected and analyzed to have precise conclusions and recommendations.

The data was analyzed by quantitative research specifically by carrying out experiments and analyzing the results.

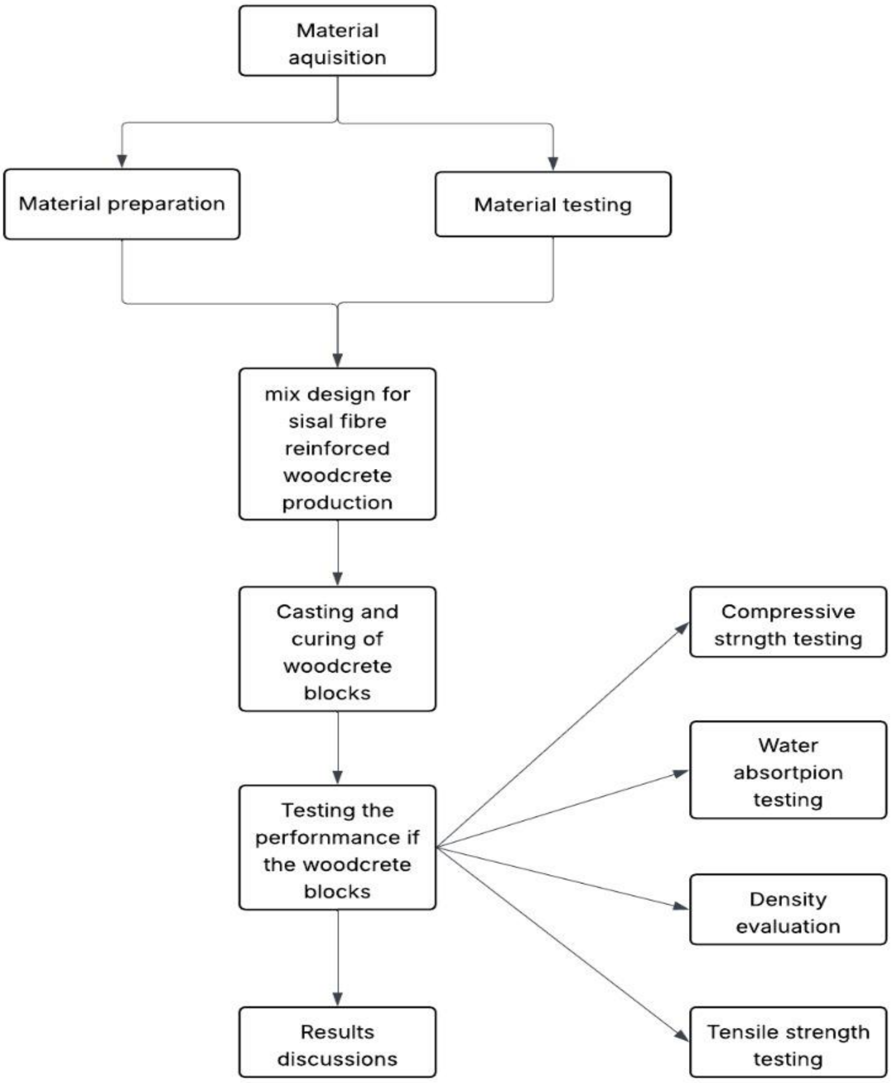


Figure 1: Research design

3.1 Preparations of samples

3.1.1 Cement

CEM I (Ordinary Portland Cement) was chosen as the cement type for this project due to its high availability, and its compressive strength of 42.5N is usually taken to be a filter with a minimum strength of 42.5 MPa at 28 days. This study adopted the CEM I 42.5 designation and this value indicates that the cement reaches a compressive strength of 42.5 MPa after curing for 28 days, which is appropriate for both structural and non-structural applications (Hewlett *et al.*, 2019). It was available in 50 kg bags. Finding a perfect w/c ratio is a necessary step to the end of the project as it would allow to set the strength requirement without losing ease of handling and placement; thus, a ratio of 0.6 was used in this project.

3.1.2 Sisal fiber

3.1.2.1 Fiber Extraction. (ASTM D4151-16)

Mature sisal plant leaves (2-3 years) were harvested at their highest maturity. Decortication was performed immediately after cutting as the high moisture content of the leaves makes prompt processing absolutely necessary.

Afterwards, the sisal fibers obtained after decortication and initial washing were spread on the ground for natural drying being turned regularly to ensure there was no hot spot created by the sun and also protecting them from rainfall and excessive direct sun. Over-drying fibers can lead to gobbling of fungal attack and coloration, which causes a reduction of their mechanical quality and marketable grade (Diniz, 2021).

The fibers were then brushed to remove the remaining pulp, dust and short fibers, which also aligns the fiber bundles, thus improve smoothness (Barasa et al., 2021). The dried and brushed fibers were graded based on length, color, and cleanliness. High-grade sisal fiber is usually creamy white to light yellow in appearance and free of residual pulp. After grading, the fibers were compressed into bales using simple hand-presses and then placed in a dry and well-ventilated storage area (Kawongolo et al).

3.1.2.2 Treatment (ASTM D518-15)

After extraction, the sisal fibers were treated. The fiber was cut in very long bundles to ensure compatibility with the machine's maximum gauge length of 500 mm. Pre-

washing and mechanical removal of coarse pulp improves uniform chemical penetration and reduces the volume of alkali consumed. (Bekele et al., 2023).
The preparation of 15% NaOH solution was done for the alkali treatment and the treatment was carried out. For 1 liter of working solution 50g technical NaOH pellets were into approximately 1 liter of clean tap water while stirring to allow the solution. The moderate alkali level is usually used because it improves adhesion while preserving cellulose (de Vilhena et al, 2024).

The fibers were immersed so they are freely suspended at temperature, 100 °C immersion for 30 minutes. This is widely used and reported to improve tenacity and interfacial bonding without obvious cellulose damage.
During immersion, the fibers were gently agitated by manually swirling every 15 minutes to avoid local concentration pockets and to promote uniform delignification. After the target immersion time, the alkali was decanted and fibers washed repeatedly with distilled water until the rinse water reached neutral by a pH meter. Proper rinsing is critical or else residual NaOH will continue to damage fibers and impair end-use performance. Then the fibers were left to dry in shade. (Diniz et al., 2021).

The treatment of sisal fibers was performed following ISO 22157:2019 (natural fiber preparation and conditioning procedures). The primary aim of this treatment was to get rid of impurities, lessen the content of lignin and hemicellulose and enhance the fiber-matrix interfacial bonding for the application of the fibers in lightweight concrete composites. The alkalization treatment was also done to improve the roughness of the fiber surface and to make it more compatible with the hydrophilic cement matrix.

Required Equipment

- Stainless steel alkali-resistant treatment bath
- Hot plate
- Bench-mounted fiber comb/defibrator
- Laboratory glass beakers, stirring rod
- Digital balance

Procedure

1. The extracted fibers were manually cleaned and combed to get rid of the pulp.
2. The fibers were then cut into 500 mm bundles.
3. A 15% sodium hydroxide (NaOH) solution was made by dissolving 50 g of technical-grade NaOH pellets in about 1 L of clean water while stirring until completely dissolved.
4. A digital thermostat was used to heat the solution to 100 °C.
5. The fibers were placed in the hot NaOH solution while they were hanging freely in the treatment bath.
6. They remained at 100 °C for 30 minutes with gentle manual stirring.

Alkali (NaOH) treatment of sisal fibre is an agent for the improvement of the fibre-matrix bond, strengthening the woodcrete composite and making it more durable. The treatment not only removes the surface impurities including lignin, hemicellulose, waxes and pectins but also increases surface roughness and exposes cellulose microfibrils resulting in better mechanical interlocking and interfacial adhesion with cement paste (Castoldi et al., 2022). The research also reports that treated sisal fibers demonstrate less water uptake and lesser hydrophilicity, which translates into better dimensional stability and lesser susceptibility to moisture damage in cement composites (Yimer et al., 2023). Consequently, sisal-reinforced composites possess higher tensile and flexural strength, better crack-bridging capacity, and longer durability than untreated fibre composites, thereby making the alkali-treated sisal fibre technically suitable for the reinforcement of woodcrete blocks used for structural improvement.

Figure 2: Treatment of sisal fibers

3.1.3 Saw dust

The sawdust was obtained from a reputable sawmill in UIRI in Namanve Industrial Area. The material collected was free from contaminants such as bark, resin, or chemicals, as these can adversely affect the properties.

The collected sawdust was spread in a well-ventilated area under shade to prevent exposure to direct sunlight for 24–48 hours, to reduce moisture content.

The sawdust which was obtained from the milling of Musizi (Maesopsis eminii), a common hardwood species in Uganda, and other hardwoods too. Generally, hardwoods are the most preferred types of wood for sawdust production because of their lower resin content, higher density, and better dimensional stability over softwoods. Such properties enhance not only the compatibility of the cement paste but also the segregation of the mixture decreased.

3.1.3.1 Treatment

The saw dust was treated with an alkali, 20% NaOH solution. The sawdust was immersed in it for 2 hours as indicated by research, to achieve the desired chemical changes without compromising the structural integrity of the sawdust (Zulhanif et al., 2022).

The sawdust was thoroughly washed with distilled water to remove excess NaOH and dissolved organic materials. This step is essential to neutralize the alkaline solution and to prevent any residual NaOH from affecting the subsequent processing steps.

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

3.2.1 Mechanical testing using the tensomaster machine (ASTM D2256)

The mechanical properties of the treated and untreated sisal fibers were evaluated using a Tensomaster universal testing 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 D3822/D3822M-14 for single-fibre tensile testing.

3.2.1.1 Test procedure

The tensile properties of sisal fibers that was treated and of that that did not undergo treatment were evaluated according to ASTM D3822/D3822M-14. The mechanical performance of sisal fibers was determined by tensile strength, elongation at break, tensile load at failure, and young's modulus measurements, which were the main target of the current test. Thus, the chemical treatment effects on the fibrous mechanical properties were evaluated comparatively.

Equipment used

- Tensomater Universal testing machine
- Fibre gripping clamps

Test Procedure

1. Testing of the sisal fibres (both treated and untreated) was done after they had been conditioned to room temperature and moisture content (22–27 °C).
2. Single fibres were arranged and cut to the necessary gauge length (typically 20–50 mm, depending on the machine configuration).
3. The length of the gauge was verified using a digital calliper.
4. The fibre was put between the upper and lower clamps of the Tensomaster UTM.
5. Special fibre grips were used in the tests to avoid slippage, uneven stress distribution, or fibre damage during the tests.
6. A unidirectional tensile load was applied at a constant strain rate of 2 mm/min.
7. The force was continuously increased till the fibre broke.
8. Each test was automatically recorded by the Tensomaster machine via breaking load, elongation at break, stress-strain characteristics, and tensile strength.
9. Three sisal fibers were taken from each category (treated and untreated) for testing.

10. Mean values were computed to ensure that the results were statistically reliable and to assess the impact of alkali treatment on mechanical performance.

Figure 3: Tensomaster machine for tensile strength testing

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

The SEM morphologic analysis of sisal fibers considered as well as not treated was done according to ASTM E986-04. The SEM analysis aimed at the surface morphology as well as the microstructural changes of sisal fibers after alkali treatment. The SEM technique has the potential of showing: fibrillation and fiber splitting, impurities and surface waxes removed, cellulose fibrils exposed, micro-cracks or treatment-induced defects, all which are essential in determining the fiber’s compatibility and mechanical interlocking potential in cementitious composites.

3.2.2.1 Sample Preparation for SEM

- Sisal fibers were cut into short segments of around 10 mm each to fit properly in the SEM sample holder.

- The fibers were cleaned with compressed air blowing to get rid of the debris, dust, and loose particles which would cause distortion in micrographs.
- A thin layer of carbon coating was deposited on the fibers by a sputter coater to improve the electrical conductivity and also to avoid charging under the electron beam.
- After coating, the fibers were attached to aluminum SEM stubs by using conductive carbon adhesive tape to make sure that there was stable electrical grounding inside the SEM chamber.

Procedure

1. Mounted fibre samples were introduced to the SEM vacuum chamber where they were secured for imaging.
2. The accelerating voltage was advanced to 20 kV, a combination that not only provided high-resolution pictures of the surface but also allowed the natural fibers to be less subjected to damage from heat or the electron beam.
3. The imaging parameters (working distance, spot size, vacuum mode) were changed in order to achieve maximum clarity and depth of field.
4. All fibre samples were photographed using the magnifications of 20 μm, 50 μm, and 100 μm.
5. Fibre images were all stored for further comparison between treated and untreated fibers to assess the morphological effect of the alkali treatment.

3.2.6 Water absorption test (ASTM D570)

Water absorption testing determines the physical property of fiber hygroscopicity, i.e., the ability of fibers to absorb and retain water. Excessive water uptake can cause fiber swelling, dimensional instability, and reduced durability of woodcrete. In this test, fibers were weighed, immersed in water for a defined period, and reweighed to calculate absorption percentage. Treated fibers with lower water absorption are more stable and less likely to negatively impact block integrity (Rowell, 2005).

The features of water absorption of sisal fibers were defined in compliance with ASTM D570-98. The test aimed to inform the hygroscopicity of the treated and untreated sisal fibers their capability of taking up and holding water. Knowledge of water uptake is of utmost importance since excessive absorption may result in: fiber expansion, changes in shape, interlocking of fiber and matrix becoming weaker and composite materials like woodcrete or lightweight concrete losing their life.

Procedure

1. Sisal fibers were oven-dried at 60 °C for 24 hours (optional step depends on moisture content) before weighing.
2. The dry fibres were then to cool down to room temperature, and the digital scale was used for weighing.
3. The weight taken was considered the initial dry weight (W_0).
4. The fibers were transferred into a glass with distilled water, making sure that the entire volume was under water.
5. The samples were left under water for the stipulated time (normally 24 hours)
6. In this process, the tweezers were the means used to get the fibers out of the water after the water had been pushed down.
7. Though, the excess moisture was not underestimated as the filter paper was gently used for blotting up the surplus surface water.
8. The re-weighing of the fibers gave the wet weight of the fibers (W_1) immediately.

9. The water absorption percentage was calculated by means of the following formula:
10. The water absorption values were compared first in order to know the moisture uptake effect of alkali treatment.
11. Less absorption values of the treated fibres also led to the conclusion that these fibres were made more dimensionally stable and thus more suitable for composite reinforcement. The formula was used to calculate the water absorption.

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

Figure 4: Testing for density of the sisal fibers

3.2.7 Density (ASTM D3800)

The density of both the treated and untreated sisal fibers was determined using ASTM D792-13. The main aim of this test was to get the mass-to-volume ratio (density) of sisal fibres, which is a very important factor for precise woodcrete and lightweight-concrete mix design. Although alkali treatment can very slightly lower the fiber density since it operates through the removal of hemicellulose, lignin, and extractives thus, density measurement was carried out on both the treated as well as the untreated fibers.

Procedure

1. The sisal fibres were cut into approximated pieces of 2 mm size to facilitate precise measurement of displacement.
2. These pieces were then rinsed several times with distilled water in order to eliminate completely dust and dirt and the other contaminants which might be on the surface.
3. The fibres which had been cleaned were they placed in an oven set at 105 °C for a period of 24 hours in order to ensure that all the moisture content is removed.
4. Subsequently, the dried fibres were conditioned in a chamber where the temperature was controlled so as to bring them to room temperature without allowing moisture absorption.
5. After the cooling process, the dried fibres were weighed on a digital scale.
6. The dry mass (M_1) was determined as this weight.
7. The volume (V_1) of water that initially was marked in the graduated cylinder was noted down.
8. The fibres were completely soaked in the water with the help of tweezers.
9. The water level (V_2) which was higher than before was again noted down.
10. The volume of the fibre (V_fibre) was computed by subtracting the initial volume (V_1) from the new volume (V_2):
11. The density of sisal fibres was computed using the following equation:

12. The density values of the treated fibres were compared with those of untreated fibres in order to examine the influence of alkaline treatment on fibre composition and their suitability for composite mix design.
13. The volume of the fibers (Vfiber) was obtained using the displacement method as $V_{fiber}=V_2-V_1$.
14. Finally, the density (ρ) of the sisal fibers was calculated using the formula:

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

3.3 Finding the optimum amount of sisal fibre that is required to obtain a woodcrete block unit.

3.3.1 Mix design

For the project, as we are following the measurements of the cube molds and the number of samples, it is estimated that it will require the following quantities of cement: carried out 3 tests, water absorption, compressive strength and tensile strength in triplicates with weights 2.480 kg of cement and 2.960 kg of sawdust mixed with 2.2 L of water, corresponding to a water-cement ratio of about 0.9 for every batch.

The woodcrete block was made by mixing cement and sawdust in a ratio of 1:2 by volume. This particular ratio was selected after several trial mixes (including an initial mix of 1:1) revealed that the 1:1 ratio was not economical as it consumed too much cement for a slight increase in strength, while the 1:2 ratio provided a good mix of unit weight reduction, workability and strength.

Sisal was added at dosages of 0%, 0.5%, 1.0%, 1.5% and 2.0% based on the weight of cement. These dosages were determined from the literature on natural fibre-reinforced cementitious composites, where the usual range of 0.5-2.0% for optimum contents is very effective in bridging cracks without making the mix too unworkable. The approximately 15 mm long fibers were cut to size, which provided them with a length to diameter aspect ratio of 60-100, a range acknowledged as being effective for crack control and toughness in fiber-reinforced cement.

The selected fibre length of 15 mm provided the best compromise between workability and mechanical performance in the woodcrete mix. For this experiment, the sisal fibers were measured having an average diameter of 0.25 mm and was cut to a length of 15 mm, thus giving an aspect ratio of 60, which is fully in line with the range defined for reinforcement in cementitious composites (Fibre Reinforced Cement Composites, 2018).

Mixing Procedure

1. For each mix, in order to maintain the 1:2 (cement: sawdust) ratio, the required amounts of cement and treated sawdust were taken.
2. The corresponding masses of these volumes were calculated by using the assumed densities
3. A clean mixing tray was used to place the cement and sawdust. The dry mixing of the two materials was conducted until a uniform color and texture were produced cement was evenly distributed around the sawdust particles.
4. In the case of fibre-reinforced mixes, the sisal fibers were weighed beforehand according to the required dosage (0.5, 1.0, 1.5, 2.0% by weight of cement).

5. The fibers were briefly soaked in water and then drained. This process lessens the inclination of dry fibers to later absorb mixing water, thereby helping to keep the intended effective water-binder ratio and reducing the loss of workability.
6. The pre-soaked and drained fibers were intermittently sprinkled into the cement-sawdust mixture while mixing was done continuously. This gradual addition was for the purpose of preventing fibre balling and at the same time encouraging the even distribution of fibers throughout the matrix.
7. Water of good quality was added little by little while the mixture was being continuously turned until a woodcrete mix that could be easily handled and was cohesive was obtained. The consistency aimed at was such that the mix was just wet enough to be clamped together when squeezed by hand, demonstrating adequate cohesion without segregation

Figure 5: Mixing and casting of a block unit

3.3.3 Casting and Compaction of Cubes

Mold preparation

150 x 150 x 150 mm cube molds (for compressive strength, water absorption, and density) and 100 × 200 mm cylinder moulds (for tensile strength) were slightly oiled with form oil to avoid sticking. The new woodcrete mixture was put into the cube molds in three layers that were approximately equal in weight. A standard steel tamping rod was used to compact each layer. The top of each cube was made smooth with a steel trowel. The identification of each specimen was shown by its mix ID, fibre content and the specific test that it was meant for.

Demolding and Curing

The specimens (cubes and cylinders) were kept in the moulds for about 24 hours to ensure that sufficient initial set was achieved.

Then, they were very carefully demolded so as not to cause any damage to the edges and corners. They were then immediately put into a curing tank and completely submerged in clean water. For curing until the specified ages for the test (7,14 and 28 days).

The curing practice made sure that the moisture which was required for the hydration of cement was supplied consistently leading to the strength development that was similar to the one in the case of the comparison between different fiber dosages, thus, making it more reliable.

3.4 Determining the effect of sisal fiber on the microcracking and dimension stability of the woodcrete block.

3.3.1 Compressive Strength Test (BS EN 12390-3)

The compressive strength of the control sample was assessed, and subsequently the woodcrete blocks combined with sisal fibre. This test shows the contribution of the sisal fibre incorporation to the load capacity and cracking resistance under compressive stress. Use of fibre boosts ductility fibre and reduces the chance of brittle failure by cracking and redistributing stress.

Required equipment: Universal Testing Machine (UTM), steel platens

Procedure

1. A cube measuring 150 millimeters on all sides was surface-dried and put in the middle of the UTM steel platens.
2. A vertical compressive load was slowly imposed at a rate of 0.5-1.0 MPa/s till the point of failure.
3. The UTM recorded the highest failure load and the compressive strength was calculated as maximum failure stress per unit area.
4. The test was done three times for each percentage of fiber used (0%, 0.5%, 1.0%, 1.5%, 2.0%). The formula was usedto calculate compressive strength.

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

where,

fc = compressive strength (MPa)

Pmax = maximum load at failure (N),

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

Figure 6: Block under a UTM for compressive test

3.3.2 Water Absorption (ASTM C642-21)

The water absorption and density of the woodcrete blocks was determined. This test evaluates the influence of sisal fibre on the permeability and compactness of the composite. Water absorption directly affects durability, as increased porosity facilitates moisture ingress and promotes microcrack development (Khalid et al., 2022).

Required equipment: Analytical balance, drying oven, water tank, absorbent cloth

Procedure

1. Each cube was oven-dried at 105 ± 5°C for 24 hours and its dry mass W1 recorded.
2. The specimen was immersed in water for 24 hours and its saturated surface-dry mass W2 was recorded.
3. Tests were done in triplicates for each fibre percentage. And the following formula was used to determine the density.

$$WA = \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{W1}} \times 100$$

where,

WA= water absorption (%),

W2= saturated surface-dry mass of the specimen (g),

W1= oven-dry mass of the specimen (g)

3.3.3 Tensile strength (ASTM C642-21)

Required equipment: UTM, cylindrical moulds (100 × 200 mm), steel bearing strips

Procedure

1. The surface of the cylinder was dried and it was then horizontally placed between the UTM platens with steel bearing strips on the top and bottom.
2. The load was applied gradually across the cylinder diameter until a longitudinal split occurred.
3. The maximum load at failure was noted.
4. Each fiber percentage was tested three times. And the formula was used to determine the tensile strength.

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

where,

ft= splitting tensile strength (MPa),

Pmax= maximum load at failure (N),

L = length of the cylinder (mm),

D = diameter of the cylinder (mm).

3.3.4 Density

Required equipment: Drying oven, weighing balance, ruler/caliper

Procedure

All cubes were dried in the oven at 105 degrees Celsius to constant weight and the weight of dried samples was noted down.

Density was found out from the formula:

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

where

ρ is the density of the specimen,

W is the mass of the specimen,

V is the volume of the specimen.

Figure 7: An oven drier used for drying specimen

CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter shows and discusses the research findings from the results obtained after the addition of sisal fiber to the mix of woodcrete. The studies were carried out in triplicates in order to get consistency and accuracy in the results obtained. The data was analyzed to clearly identify the effect of the fibers at different percentage addition to the mechanical properties of woodcrete firstly by understanding the physical properties of sisal fiber as a material introduced to the mix and then fully checking the change when put to the mix of woodcrete.

4.1 Mechanical and physical testing of the sisal fiber.

The results highlight a significant change on mechanical properties of sisal fiber which is attributed to the alkali treatment. Further discussions were carried out to find out the influence of this treatment on woodcrete.

Table 2: Mechanical properties of treated and untreated sisal fiber

Sisal fiber average diameter = 0.25 mm					
Mechanical property	Breaking Force (N)	Elongation (mm)	RKM (g/tex)	Breaking work (mJ)	Time to break (s)
Before treatment	3.23	3.40	123.88	6.73	0.41
After treatment	15.69	8.65	318.80	67.05	1.04

4.1.1 Breaking force

The maximum force that a fiber can bear before breaking is known as the breaking force. The breaking force increased after and this is explained by the cellulose fibrils being exposed and aligned as non-cellulosic materials like lignin and hemicellulose were removed. Cellulose fibrils are known to be the main load-bearing components of natural fibers, meaning they greatly increase tensile strength (Manimaran et al. 2021). The fiber's strength under action was indicated by a breaking force of 15.69N. This figure represented both the overall structural integrity and the strength of the cellulose microfibrils in the fiber (Okafor et al., 2022).

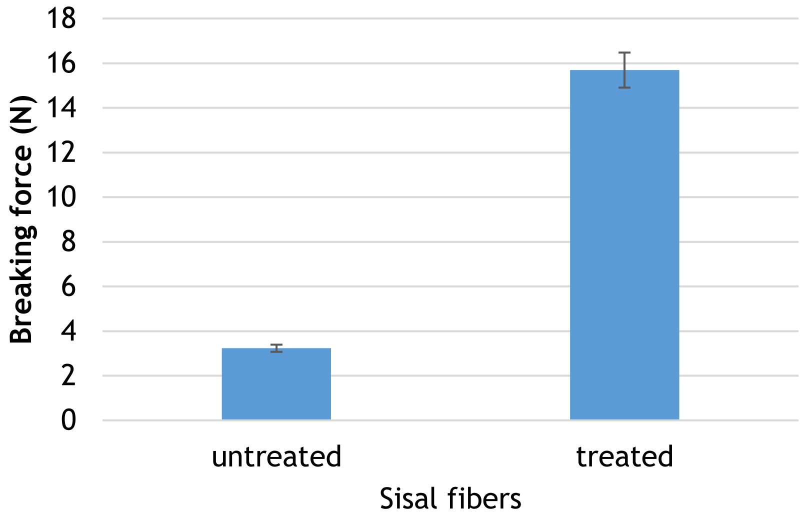


Figure 8: Comparison of breaking force between untreated and treated sisal fibers.

4.1.2 Elongation

Elongation refers to the power of the fiber to absorb energy and then get slightly deformed before it breaks. This is a positive attribute since it accounts for the partial resistance of the fibers to breaking (Manimaran et al., 2021). The elongation increased for about 60% after treatment which this shows a moderate increase. The reason for this improvement is that the removal of the lignin allowed the fiber to soften and thus deform more before breaking (Saba et al., 2020). The elongation of 8.65 mm shows that the fibers have a moderate degree of ductility. It is reported that high elongation was an indicator of increased fiber's ability to bridge cracks in concrete which in turn had the effect of enhancing the toughness and durability of the composite (Okafor et al., 2022).

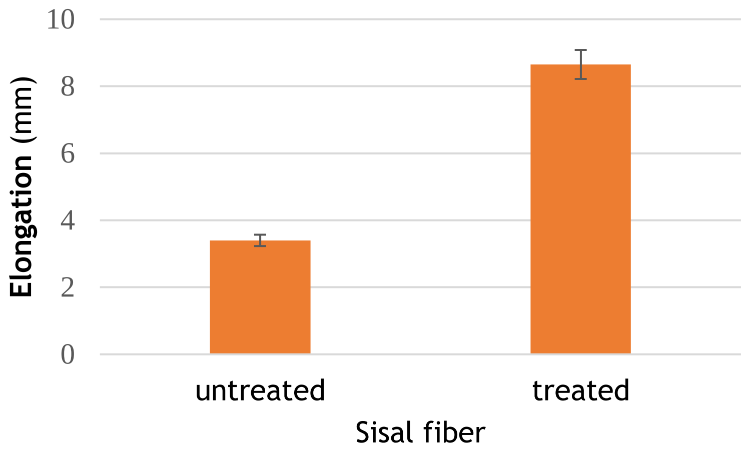


Figure 9: Elongation variation between untreated and treated sisal fiber.

4.1.3 Fiber strength RKM-Resistance per kilometer

RKM stands for the ratio of the efficiency and ability of the fiber to bear tensile loads to its weight. The percentage increase of 61% shows that RKM denotes a huge improvement in the strength-to-weight ratio of the fiber. The use of alkali treatment for non-structural components removal leads to a decrease in the fibers' mass while having its strength concentrated (Manimaran et al., 2021). An RKM of 318.80 g/tex were showing, according to previous studies, the lightweight qualities of sisal fiber making it suitable for cellular concrete applications (Saba et al., 2020).

4.1.4 Breaking work

Breaking work is the energy the fiber absorbs before breaking and it is measured as a product of force and elongation. Showing an increase in the breaking work. The enhanced surface roughness and fibrillation due to treatment improve energy dissipation under tensile loading (Saba et al.,2020). Breaking work of 67.05mJ indicated the fiber's capacity to absorb and dissipate energy underload. Thus, high breaking work indicates the effectiveness of fiber to absorb impact energy reducing the likelihood of brittle failure (Gurunathan et al., 2019).

4.2 Water Absorption

Table 3: Water absorption comparison of treated and untreated sisal fiber.

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, indicating about 11% reduction in water uptake.

The decrease in water absorption after alkali treatment occurs due to the partial removal of hemicellulose, which is highly hydrophilic. This removal reduces the number of hydroxyl groups available to bond with water molecules, resulting in lower moisture retention. Consequently, the dimensional stability of the fibers improves, minimizing swelling or shrinkage when embedded in cement paste. Although there is a slight reduction in water absorption, the independent t-test comparing treated and untreated sisal fibers shows that the difference is not statistically significant. The t-value is –0.78, which is less than the t-critical value of 2.78. Therefore, the alkali treatment does not cause a noticeable change in the fibers' water absorption capacity.

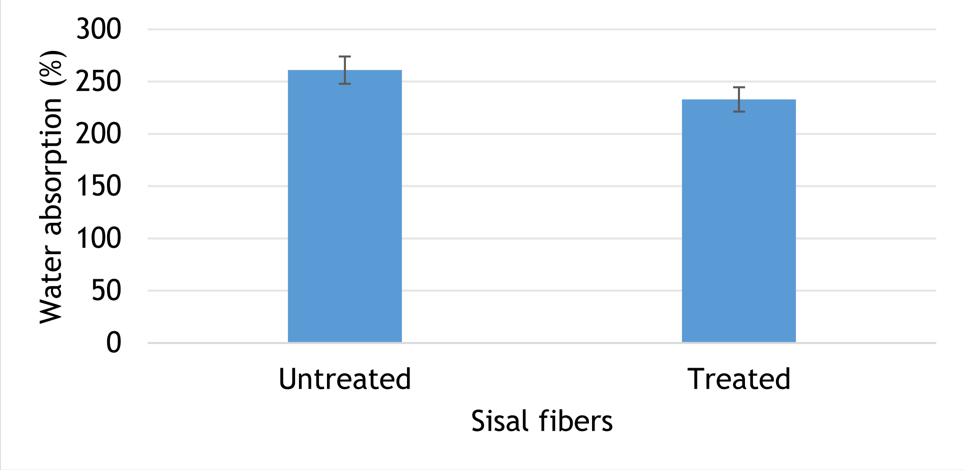


Figure 10: water absorption of the untreated and treated sisal fiber

4.3 Density of the fibers

Table 4: Density of the sisal fiber sample before and after treatment.

Sample	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**

The density of treated fibers was denser than that of untreated fibers by a little margin. The increase in density is justified since the low-density components like hemicellulose and lignin are removed leading to a more compact and crystalline cellulose structure. The density improvement provides the fibre with greater mechanical strength and its ability to deform under force is reduced.

Denser fibers when mixed with a composite, contribute to the reversal of porosity, better packing and more uniform distribution of the stress. The slight increase in density has a connection with higher tensile strength and better load-carrying capacity, thus the treatment process is said to positively influence the microstructure as well as the bulk properties of the sisal fiber

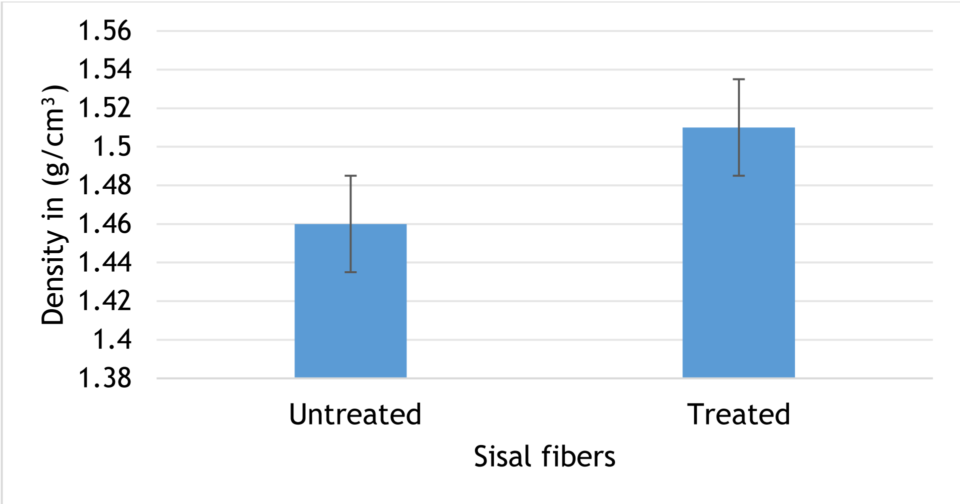


Figure 11: Comparison of density of untreated and treated sisal fibers

4.4 Scanning Electron Microscope (SEM) Analysis

The Scanning Electron Microscope (SEM) was used at a magnification of ×500 for the microstructural examination of the sisal fibers to test the surface characteristics before and after alkali treatment. The outcomes were indicated through the electron micrographs and they showed evidently diverse morphological features of the fibre in the untreated and treated states. Thus, the NaOH treatment was confirmed to affect the composition and texture of the fibre surface.

4.4.1 Untreated sisal fibers.

The scanning electron microscopy (SEM) image of the untreated sisal fiber depicted in the figure illustrates a surface that is similar to being smooth, compact and waxy. The outer layer is almost devoid of cracks and fibrils showing the presence of non-cellulosic substances such as lignin, waxes and hemicellulose that mask the cellulose microfibrils. The appearance of tiny deposits and layers that are like a film indicates contamination from natural plant residues and processing dust. The whole morphology indicates a fibre surface that is not chemically reactive and is very hydrophobic which could prevent the cement matrix from bonding when incorporated in composites.

The presence of the smooth outer coating would lead to poor stress transfer between the fibre and the matrix during the loading of the composite and the early fibre pull-out or debonding would result.

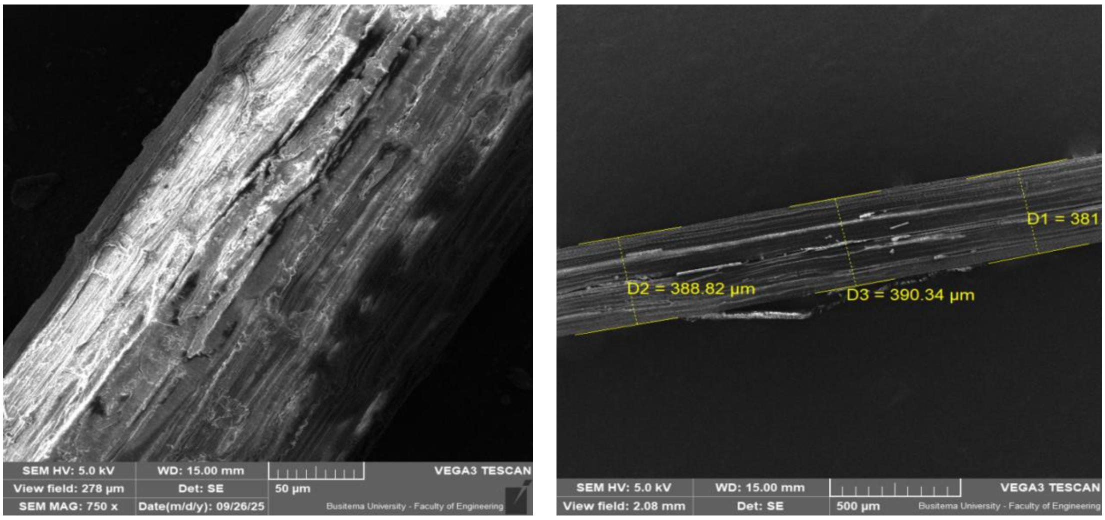


Figure 12: The surface texture of the fiber and the diameter for untreated fiber.

4.4.2 Treated sisal fibers.

The SEM image of the alkali-treated sisal fiber reveals a surface that is very different from the untreated fiber through its roughness, irregularity and extreme fibrillation. Particularly, the NaOH treatment was effective in removing the amorphous materials, lignin and hemicellulose that it has allowed to the exposure of the cellulose microfibrils inside.

The fiber length shows a lot of grooves, ridges and micro-voids which are the reason for the rough surface with larger area. The fiber edges appear to be looser and more split thus indicating very clearly the process of fibrillation. The physical transformations mentioned above magnify the effects of mechanical interlocking and wetting during the embedding of the fiber in the cement matrix. A fiber with a cleaner and more porous surface will have a higher surface energy and thus be more compatible with hydrophilic cementitious materials.

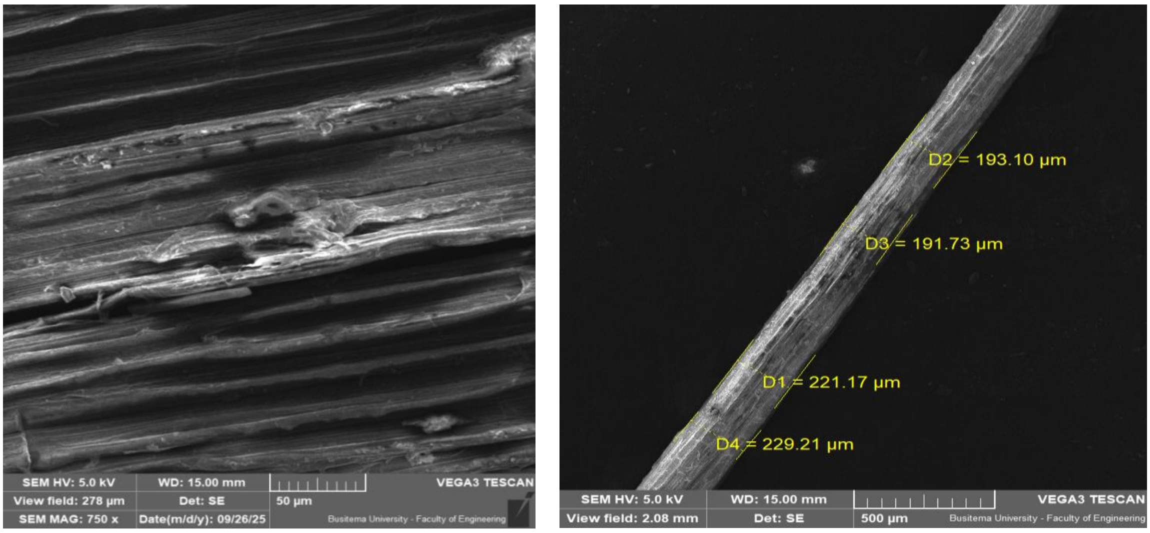


Figure 13: Rough surface and reduced diameter of treated fiber.

The SEM micrographs clearly reveal the morphological transformation of sisal fibers 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 fibers 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 micrographs depicted distinctly the morphological transition of sisal fibers due to alkali treatment. The fibers not subjected to treatment exhibited a dense and waxy surface that was not only smooth but also seemed to be made up of non-cellulosic materials which were lignin and hemicellulose among others. This surface layer or coating actually acted as a barrier that limited the bonding between the fibre and cement matrix and even restricted the mechanical interlocking.

On the other hand, the fibre that was treated showed a surface that was rough, fibrillated, and porous with grooves and ridges being clearly discernible. The cellulose structure which had been previously hidden was unmasked thereby making the fibre feel smoother and look rougher. The newly exposed fibre, being more textured, could bond within the composite matrix more effectively. Besides the morphology of the fiber surface, the SEM measurements depicted a notable drop in fiber diameter due to the treatment. The untreated fiber had an average diameter of around 386 μm, in contrast, the treated fiber showed an average diameter of 208 μm which is roughly a 46% reduction. The cellulose core that was leftover is thinner and more compact than the original but it has more than enough stiffness and strength.

The combination of the diameter reduction and fibrillation gives a clear picture of the improved tensile performance of treated fibers, which was one of the outcomes of mechanical testing. A rough, thin fiber would mean better mechanical anchoring, thus reducing fiber pull-out, and an even distribution of load 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.

4.5 Woodcrete performance

4.5.1 Density results

The density results emphasized that the woodcrete remains under the lightweight materials category even after the addition of the fibers at all the different percentages. They increased gradually showing that addition of fiber contributes to the density of the block. The table shows density of the control sample and fibre reinforced woodcrete at different percentages. Employing the standard density of normal concrete, which is 1800 kg/m^3, as a reference point, the density calculated for the newly created woodcrete composite reached 1325.5 kg/m^3, thus resulting in a reduction of density by 474.5 kg/m^3. This highly significant decrease in density is in the order of 26.36% when normal-weight concrete is taken as the reference. The considerable reduction of the density of the produced composite indicates the successful use of a combination of both sawdust and sisal in an environmentally sustainable cement-composite for the structure that is not only lightweight but also has larger applications by virtue of its reduced dead load on the structure and material efficiency.

Table 5: Density of the sample at varying fiber % addition

Sample	Density (kg/m^3)
Control sample	1254
0.5%	1270
1%	1298
1.5%	1319
2%	1388

For percentage reduction of the total weight of a structure if woodcrete block is used as an infill block instead of a concrete block.

Original value = 1800 kg/m^3

New value = 1800 – 1325.5

= 474.5 kg/m^3

Percentage reduction = 474.5/18000×100

= 26.36%

Therefore, the density 1325.5 kg/m3 represents about a reduction pf 26.4%

4.5.2 Compressive strength results

These results show how woodcrete performed under compressive loading at the different curing ages (7, 14 and 28 days). The inclusion of the fiber is compared to the control sample and also to the standards of building units.

Table 6: Compressive strength of the sample at different % fiber addition

Sample	At 7 days	At 14 days	At 28 days
Control sample	1.7	2.3	2.6
0.5%	2.3	3.1	3.5
1%	2.3	3.1	3.6
1.5%	2.4	3.2	3.7
2%	2.4	3.1	3.6

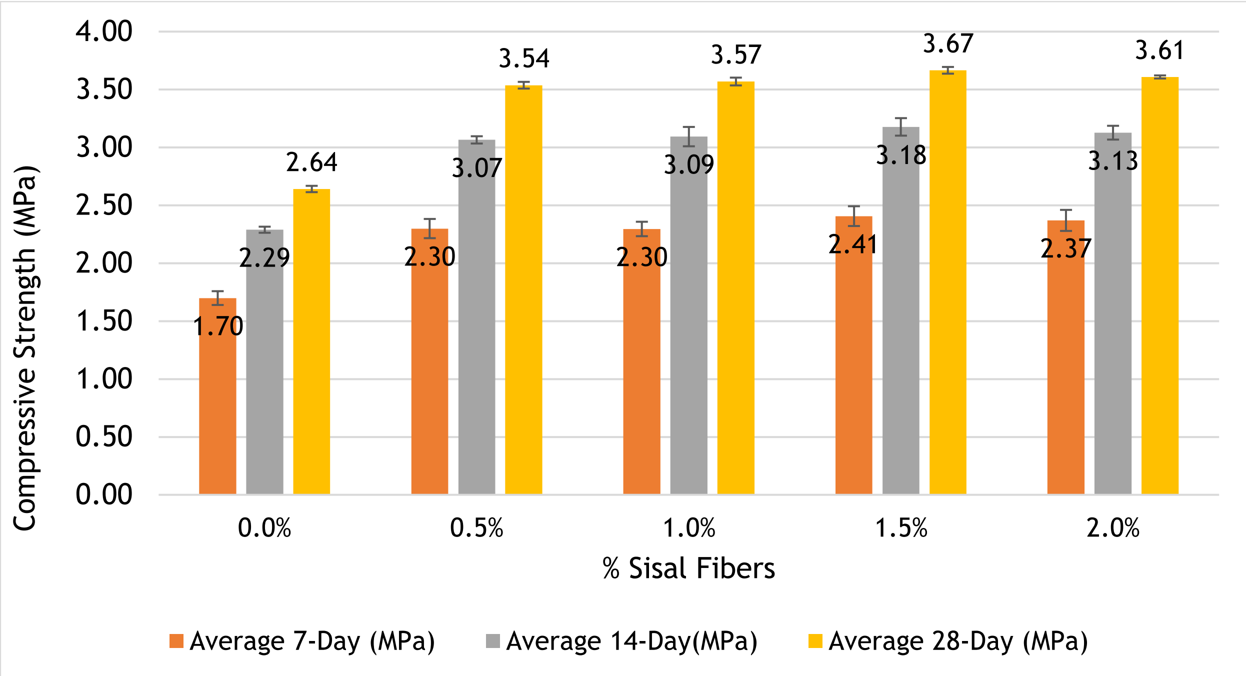


Figure 14: Compressive strength of the sample at different % fiber addition

The increase to the compressive strength can be explained by the fiber matrix interaction where fibers bridged gaps, limiting crack formation and improving the capacity of the woodcrete to carry load. Among the ratios that were tested, 1.5% showed the highest compressive strength of 3.7 MPa, making it the optimum ratio. From the standards where minimum compressive strength for average of a concrete block is 2.5 MPa for type 2 blocks, this shows that woodcrete reinforced with fiber stands a great chance of utilization for non-load bearing walls.

With a p-value of 0.0000015 (< 0.05) from the t-test, the mean compressive strength at 1.5% sisal fiber content is significantly higher than that at 0%. This indicates that increasing the sisal fiber percentage to 1.5% has a statistically significant positive effect on compressive strength.

4.5.3 Tensile strength

The table summarizes the tensile strength results for the different mix ratios of fiber. The data shows how addition of fiber enhances the tensile strength of the woodcrete block.

Table 7: Average tensile strength at different curing days

Sample	At 7 days	At 14 days	At 28 days
Control sample	0.56	0.76	0.91
0.5%	0.65	0.76	1.06
1%	0.65	0.89	1.06
1.5%	0.67	0.89	1.08
2%	0.64	0.88	1.06

The results of the tensile strength testing show a uniform increase when the woodcrete mixture is made with 1.5% sisal fibre. The control specimens displayed tensile strengths of 0.56 MPa, 0.76 MPa, and 0.91 MPa for the ages of 7, 14, and 28 days respectively. On the flip side, the 1.5% fibre samples had 0.67 MPa, 0.89 MPa, and 1.08 MPa for the same time intervals of curing. This enhancement is a reflection of the natural fibers' main function in cement-based composites, which is to restrict microcrack growth and foster tensile load distribution.

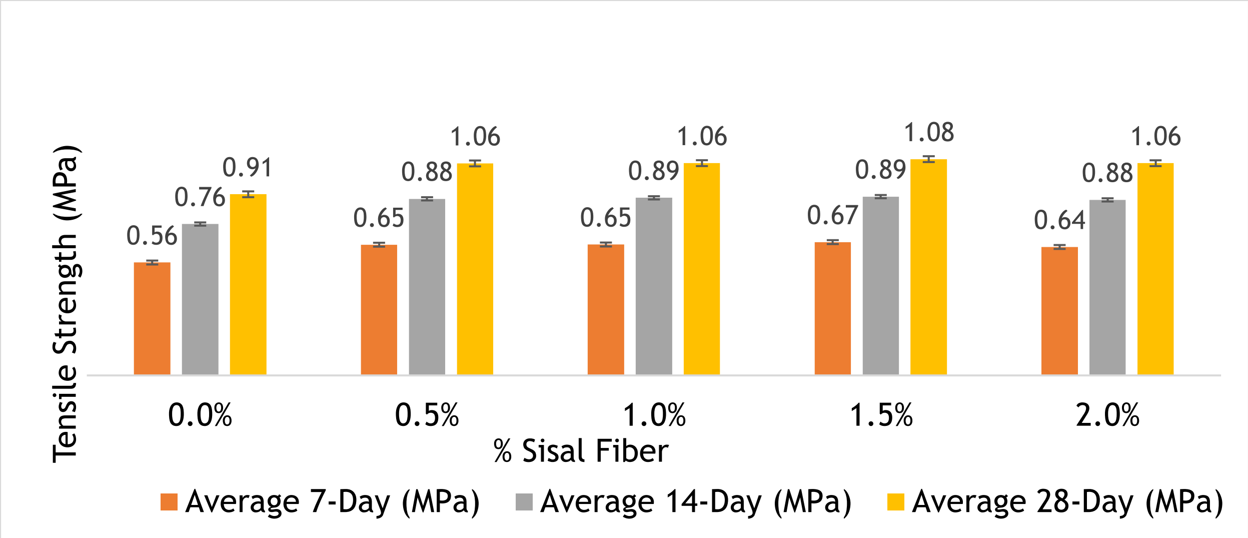


Figure 15:Tensile strength of the sample at different % fiber addition

The t-test results conducted for the 28-day tests gave a p-value of 0.000078, which is much less than the significance level of 0.05 thus, confirming the increase in tensile strength at 1.5% fibre content is not only statistically significant but also practically significant. The research published indicates the typical tensile strengths for lightweight masonry materials to be in the range of 0.8–1.5 MPa. The tensile strength of 1.08 MPa gained by the inclusion of 1.5% fibre, is not only within the range of the strength of the material but also points out the crack resistance sufficiency of the material for non-load bearing and partition wall systems. Hence the tensile behaviour of fibre-reinforced woodcrete is not only acceptable but also better than the control mix.

4.5.4 Water absorption

Table 8: water absorption at different fiber % replacement

Sample	Water absorption (%)
Control sample	4.40
0.5%	5.00
1%	3.94
1.5%	3.68
2%	3.55

The rise in addition of the sisal fibre led to the drop in water absorption. The slight reduction implying that adding fibre lowers the woodcrete matrix's permeability more or less, probably because of better internal packing and smaller microcrack continuity. Standards are set and give clear benchmark limits for water absorption of masonry units, acceptable water absorption values for concrete and clay masonry usually vary below 10-15%, it depends on the unit density. The range of water absorption values reported in this study (3.68–4.40%) is below the limits set by standards. This means that the fibre-reinforced woodcrete blocks have very good resistance to moisture penetration and are well within the international guidelines.

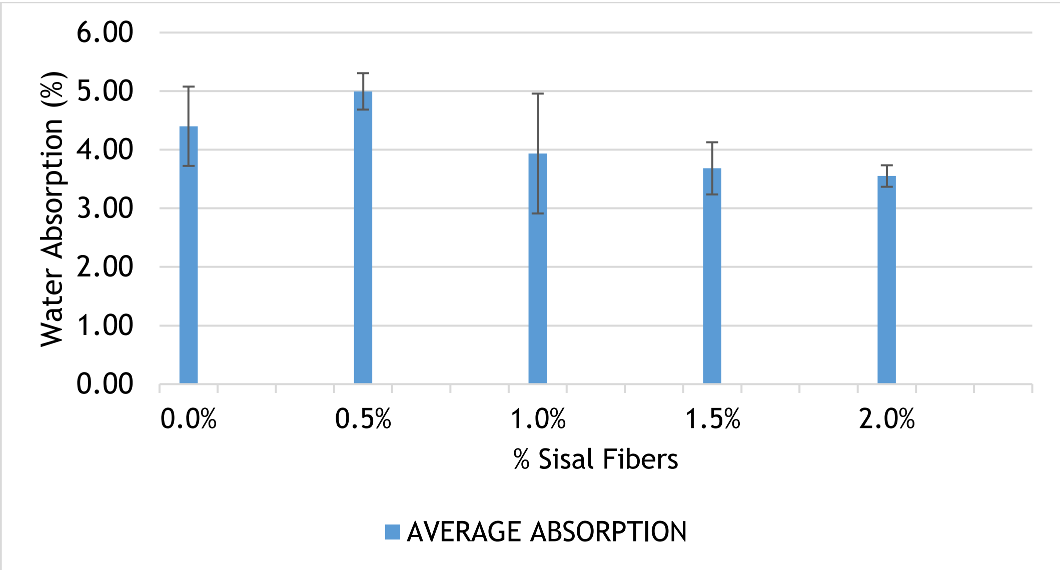
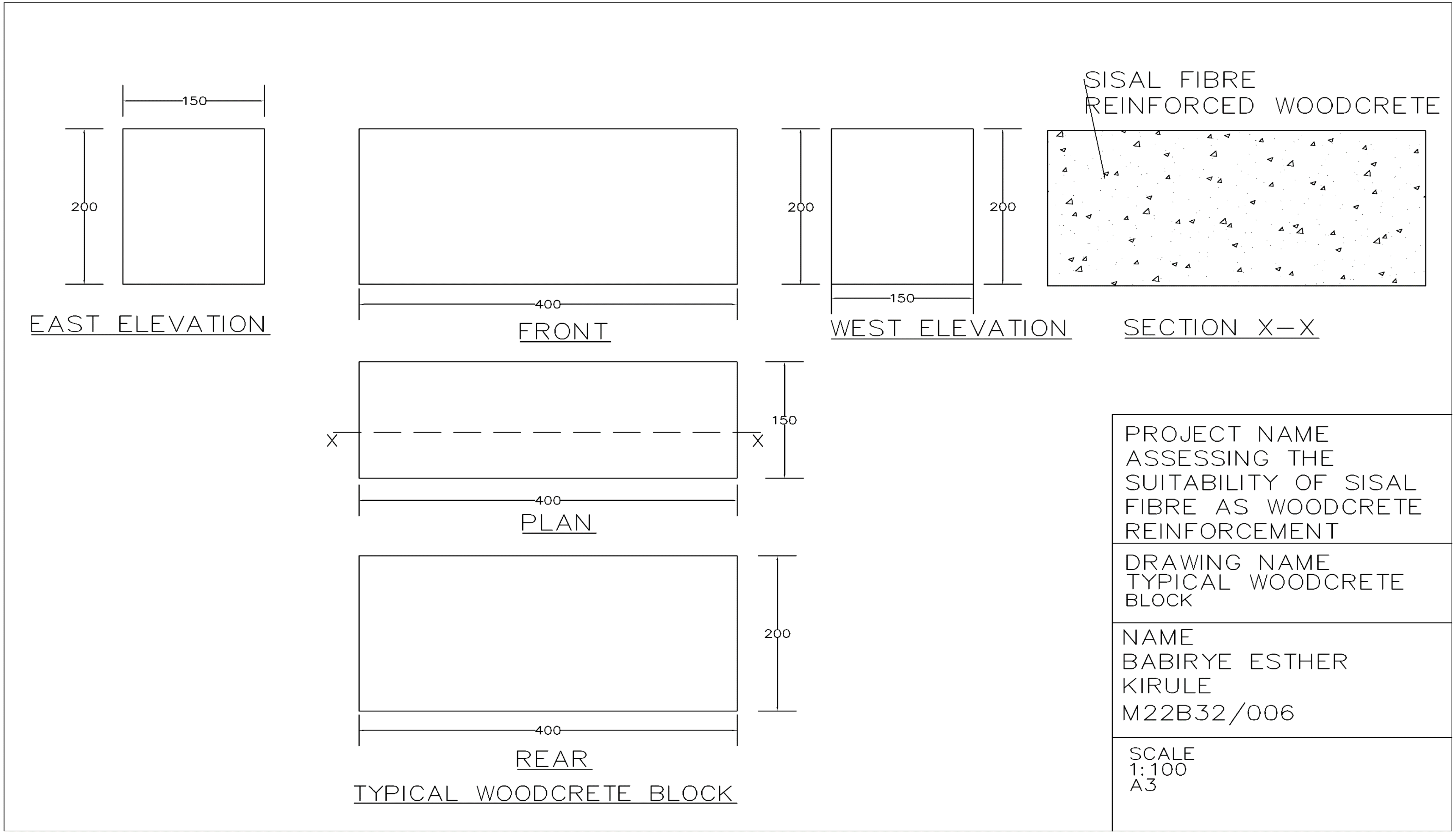


Figure 16: Water absorption of the sample at different % fiber addition

The paired t-test yielded a p-value of 0.222 (> 0.05), indicating that the observed reduction is not statistically significant and cannot be conclusively attributed to the fibre addition alone.


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
NAME
BABIRYE ESTHER KIRULE
M22B32/006
SCALE
1:100
A3

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study set out to develop and evaluate a lightweight, eco-friendly woodcrete composite using cement, sawdust, and sisal fibers, with the core objective of determining the optimum fibre content that enhances mechanical strength, reduces density, and improves durability without compromising workability or structural integrity. Based on the experimental results, all objectives were successfully achieved.

The incorporation of sisal fibre significantly influenced the physical and mechanical behavior of the woodcrete blocks. Density values decreased consistently with fibre addition due to the inherently low density of natural fibers and sawdust, confirming the suitability of the composite for lightweight construction applications. The observed average density reduction of approximately 25–28% compared to conventional concrete aligns with reported behavior of natural fibre-modified composites.

Compressive strength results showed an initial improvement with fibre addition, peaking between 1.0% and 1.5% fibre content, after which the strength declined at 2.0% due to fibre agglomeration and increased void content. This trend confirms that moderate fibre content enhances stress redistribution and crack bridging, improving load-bearing capacity, while excessive fibre addition disrupts matrix continuity and reduces compaction efficiency.

Tensile strength results followed a similar trend, with fibre-reinforced samples outperforming the control due to improved ductility, increased post-crack resistance, and better energy absorption. Water absorption tests revealed that sisal treatment (alkali treatment) reduced hydrophilicity, leading to lower absorption rates in treated-fibre mixes. This improved durability by limiting moisture ingress and reducing pore connectivity.

SEM analysis further confirmed the mechanical results by showing improved fibre-matrix interfacial bonding in treated fibers, removal of surface impurities, and exposure of cellulose microfibrils that enhance adhesion. Treated fibers displayed fewer voids and better mechanical interlocking with the cement matrix, which directly supported the improved strength values at optimum dosage.

Overall, the study confirms that sisal-reinforced woodcrete is a viable lightweight composite, with optimum fibre content around 1.0–1.5%, balancing strength, density reduction, and durability. The results demonstrate that treated sisal fibers can significantly enhance block performance and provide a sustainable alternative to traditional aggregates.

The main goal of this research was to produce and assess the properties of a novel and eco-friendly woodcrete composite containing sisal fibre. To do this, the materials were characterized by their densities, mechanical strengths, water absorption, and microstructure during laboratory tests. The results revealed that all the aims of the research were fulfilled, and it is obvious that woodcrete strengthened by sisal has a practical use in Uganda for non-load-bearing construction.

The technologist worked determining the first goal pertaining to the impact of sisal fibre on the density of woodcrete. The findings indicated a considerable decrease of the material density in comparison to the conventional concrete. By referring to the density of 1800 kg/m^3 and the average density of 1325.5 kg/m^3 that was measured, the composite had a reduction of 474.5 kg/m^3 which means a decrease of 26.36% in dead loads. This reduction has a great impact on the structural design because lighter walling units reduce the pressure on the foundation, need less reinforcement, and thus become more cost-efficient. The study thus points out that the new material made of wood and silica meets the requirement of reduced permanent loads in the case of masonry construction.

The second aim was to analyze the improvements in mechanical strength. The addition of animal hair brought about an increase in compressive strength that reached a maximum at 1.5% sisal content. At this point, the blocks had 3.7 MPa which was a minimum for non-load-bearing masonry units in Uganda (range of 2.5 to 3.5 MPa). Tensile strength was also increased and the control value was changed to 1.08 MPa showing better crack initiation and propagation resistance. In masonry, microcracking commonly starts with tensile stresses due to shrinkage, temperature changes, and loads during the service. The tensile strength improvement is a strong indication that the sisal fibers have successfully closed microcracks, slowed down crack propagation, and improved crack growth and overall behavior during cracking. The uniform distribution of the fibers provided reinforcement and consequently, the tensile stresses were transferred more effectively across the matrix. Therefore, the research has indicated that the inclusion of sisal fiber has a major impact in stopping microcracking, which is one of the greatest weaknesses of untreated woodcrete.

The composite had good water absorption and dimensional stability because the connectivity of pores was limited and the pathways for moisture were reduced due to the cleaned, smoother fibre surfaces and the microfibril exposure that was observed in the SEM micrographs. The third objective took durability into account through water absorption and SEM analysis. The treated sisal fibers led to reduced water absorption due to better fiber-matrix bonding, which was supported by the cleaner, smoother fiber surfaces and the microfibril exposure seen in the SEM micrographs.

Thus, the composite meets the durability standards for lightweight masonry in humid Ugandan conditions. It is, therefore, concluded that the 1.0-1.5% of sisal fiber is the most suitable one giving the best combination of strength, density reduction, and durability. The material at this dosage presents better tensile and compressive performance, lesser water absorption, more than 26% decrease in dead loads, and higher resistance to microcracking. This corroborates that sisal-reinforced woodcrete is a feasible, eco-friendly, and locally suitable alternative for non-load-bearing construction in Uganda, hence the issue raised in the research has been effectively solved.

5.2 Recommendations

1. This research accomplished its primary goals although a number of significant issues were not addressed. The long-term durability characters like sulphate attack, carbonation, chloride ingress and freeze-thaw resistance were not looked into. Another issue is that the thermal and acoustic performance which are the main benefits of wood-based composites was not measured either.

And also, the research was limited to non-load-bearing blocks thus, the load-bearing capacity of reinforced woodcrete was not explored.

2. Future studies should look into the combination of different types of reinforcement such as banana or papyrus fibres and pozzolanic additives such as fly ash, metakaolin, or nano-silica for improvement in performance. Large-scale models of panels could be made for testing their characteristics in normal conditions, and Life Cycle Assessment would be done to measure the reduction of the environmental burden in quantitative terms.
3. Woodcrete that has been reinforced by sisal is a good candidate for use in the housing sector because it has lower density and cheaper price. The lighter blocks are advantageous to the buildings' performance in case of earthquakes and at the same time the addition of sawdust and sisal fulfills and strengthens Uganda's sustainability and circular economy aspirations. Besides, the local production's decentralization can result in the formation of jobs in sawmills, workshops and community enterprises.

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APPENDICES

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**

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/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**

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

UGANDA INDUSTRIAL RESEARCH INSTITUTE
25 SEP 2025
UIRI P.O. BOX 7086, KAMPALA

Prepared by

Tukashaba Annitah 25/09/20

Namiiro Moureen 25/09/2025.

UGANDA INDUSTRIAL RESEARCH INSTITUTE.,
Kampala Business Park - Namanve
P.O Box 7086,
Kampala.,UGANDA

TensoMaster Version 3.1.5 MAG beyond quality

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	

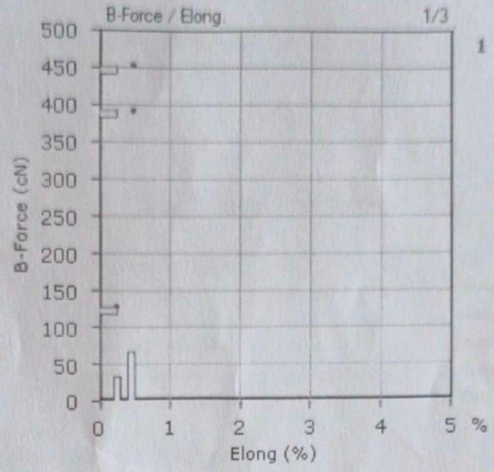
Weak Places : BF = 0, BE = 0, BF+BE = 0

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

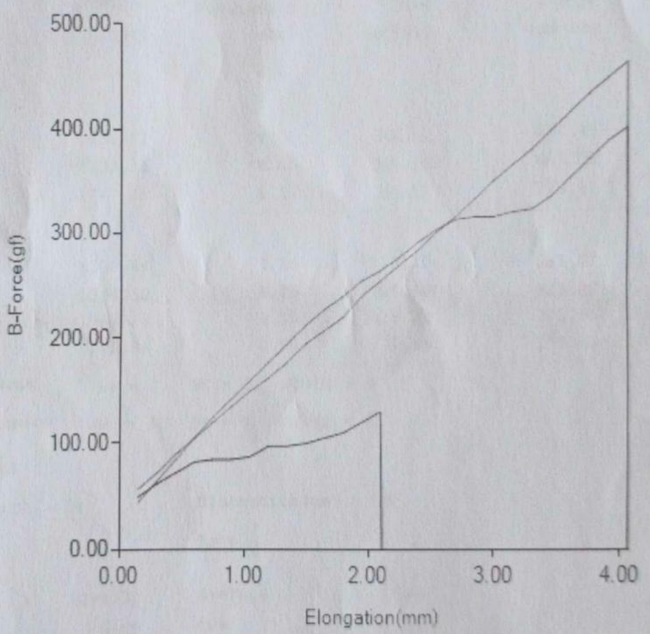
*** - Out Lier Results :**

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

UGANDA INDUSTRIAL RESEARCH ... 25 SEP 2025 ... KAMPALA in One



FE Curve



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2_ SEP 2025
P.O. BOX 7086, KAMPALA

Prepared By

Approved By

24-Sep-2025 | 12:33:02 pm

UGANDA INDUSTRIAL RESEARCH INSTITUTE.,
Kampala Business Park - Namanve
P.O Box 7086,
Kampala.,UGANDA

TensoMaster
Version 3.1.5

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

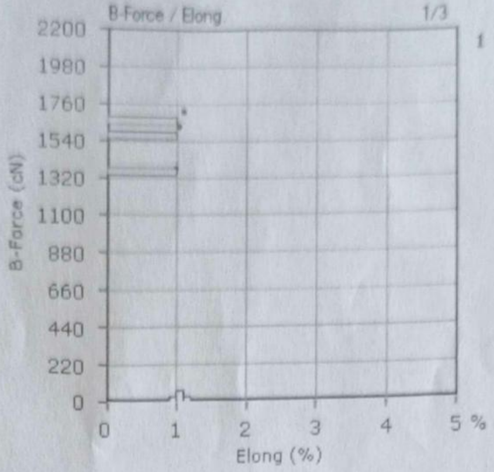
Strong Places : BF = 0, BE = 0, BF+BE = 0

* - Out Lier Results :

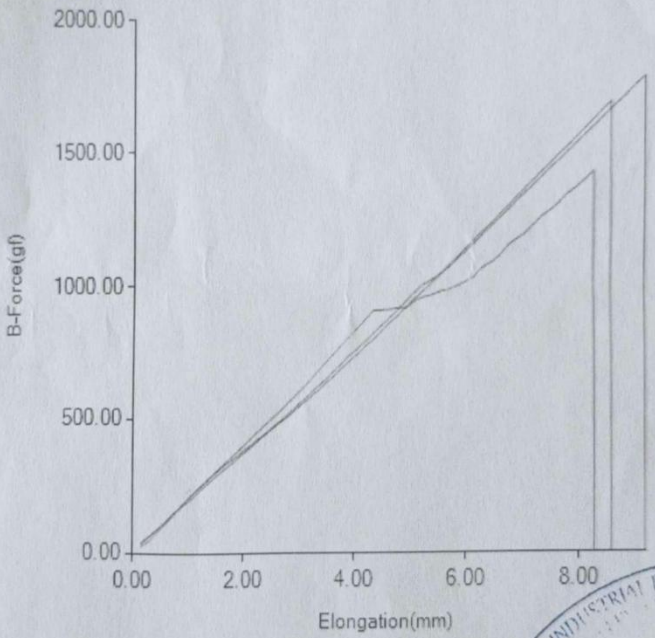
B-Force(gf) - 1%		Elongation(mm) - 1%	
Total :	1	Total :	2
Average :	1398.32	Average :	8.40
CV% :	0.00	CV% :	2.53

UGANDA INDUSTRIAL RESEARCH
2_ SEP 2025
UIRI
P.O. BOX 7086, KAMPALA

One



FE Curve



UGANDA INDUSTRIAL RESEARCH

2[illegible] SEP 2025

Prepared By

Approved By

24-Sep-2025 | 01:49:04 pm

Page 2 of 2

TERZAGHI'S Soils & Materials Lab

Document No:	TZG/CCS/TF-20
Revision No.	: 00
Revision Date	: 6th /09/2021
Approved by	: MD

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/m^3	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 also smooth without honeycombs

N/A- not available

TERZAGHI'S SOILS & MATERIALS LAB LTD
20 NOV 2025
P. O. Box 860003, Kampala
info@terzaghislab.com
Block 109, Plot 225, Kireka

Checked by
Laboratory Engineer

Approved by
Technical Manager

Document No: TZG/CCS/TF-20
Revision No. : 00
Revision Date : 6th /09/2021
Approved by : MD

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 (%)		0.5		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
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 also smooth without honeycombs

N/A- not available

Checked by

Laboratory Engineer

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Technical Manager

Document No: TZG/CCS/TF-20
Revision No. : 00
Revision Date : 6th /09/2021
Approved by : MD

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/m^3	Maximum Load (KN)	Compressive Strength (MPa)	Average Compressive Strength
C1-1	22-Oct-25	29-Oct-25	7	150 x 150 x 150	4.337	1285	50.67	2.25	2.3
C1-2				150 x 150 x 150	4.385	1299	51.03	2.27	
C1-3				150 x 150 x 150	4.334	1284	53.26	2.37	
C1-4	22-Oct-25	5-Nov-25	14	150 x 150 x 150	4.380	1298	69.95	3.11	3.1
C1-5				150 x 150 x 150	4.411	1307	71.28	3.17	
C1-6				150 x 150 x 150	4.369	1294	67.57	3.00	
C1-7	22-Oct-25	19-Nov-25	28	150 x 150 x 150	4.402	1304	80.41	3.57	3.6
C1-8				150 x 150 x 150	4.424	1311	81.00	3.60	
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

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Soils & Materials Lab

Document No:	TZG/CCS/TF-20
Revision No.	: 00
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Approved by	: MD

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/m^3	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
Laboratory Engineer

TERZAGHI'S SOILS & MATERIALS LAB LTD
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TERZAGHI'S Soils & Materials Lab

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Revision No. : 00
Revision Date : 6th /09/2021
Approved by : MD

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/m³**	**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

Checked by

Laboratory Engineer

TERZAGHI'S SOILS & MATERIALS LAB LTD
20 NOV 2025
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TERZAGHI'S Soils & Materials Lab

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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				150 x 300	3930	78.00	0.55	
S2	22-Oct-25	29-Oct-25	7	150 x 300	4062	80.10	0.57	0.6
S3				150 x 300	4072	78.90	0.56	
S1				150 x 300	5102	106.00	0.75	
S2	22-Oct-25	5-Nov-25	14	150 x 300	5241	107.80	0.76	0.8
S3				150 x 300	5191	106.40	0.75	
S1				150 x 300	5964	125.60	0.89	
S2	22-Oct-25	19-Nov-25	28	150 x 300	5979	130.60	0.92	0.9
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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Revision No.	: 00
Revision Date	: 6th /09/2021
Approved by	: MD

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

TERZAGHI'S SOILS & MATERIALS LAB LTD
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Laboratory Engineer

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Technical Manager

TERZAGHI'S
Soils & Materials Lab

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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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20 NOV 2025
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TERZAGHI'S Soils & Materials Lab

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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 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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TERZAGHI'S Soils & Materials Lab

Document No: TZG/CCS/TF-20
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Revision Date : 6th /09/2021
Approved by : MD

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