USING SALVAGED STEEL FIBRES FROM WASTE TYRES AS REINFORCEMENT IN UNFIRED EARTH BRICKS

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A FINAL YEAR RESEARCH AND DESIGN PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING OF UGANDA CHRISTIAN UNIVERSITY

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ABSTRACT

This research determined the suitability of using salvaged steel fibers from waste tires as reinforcement in unfired earth bricks. The bricks made in Bugonya village are prone to detrimental cracking and a resulting compressive strength of 3.54 N/mm^2 which makes them unfit for use in works of a permanent nature. To deal with this, soil samples were collected from the village tests done on them and bricks cast with percentages of 4,6 and 8 steel addition. The bricks including controls were tested for water absorption and compressive strength at 7 and 28 days. The results showed that the brick compressive strength and water absorption improved with addition of more steel fibres within the brick matrix. The optimum addition was 8% with a compressive strength of 2.5Mpa and water absorption of 9.6 which all met the design requirements for such a brick. The findings indicate that the fibres can be added to bricks within the village to reinforce the bricks and put-up permanent structures. Further research can be carried out on the effect of varying the lengths of the steel fibres that are added into the brick matrix.

DECLARATION

I Ahabwe Amon, hereby declare that this is my original work, is not plagiarized and has not been submitted to any other institution for any academic award.

Signature:……………………….

Date:………………………………….

AHABWE AMON

S21B32/079

APPROVAL

This final year research project report has been submitted by AHABWE AMON to the department of Engineering and Environment at Uganda Christian University for examination with my approval as the university supervisor.

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MR.TOM MORE MWANJE

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LIST OF ABBREVIATIONS

KG	KILOGRAM
KN	KILONEWTONS
LL	LIQUID LIMIT
LSL	LINEAR SHRINKAGE LIMIT
MM	MILLIMETRE
MPA	MEGA PASACALS
PI	PLASTICITY INDEX
PL	PLASTIC LIMIT

CHAPTER ONE: BACKGROUND AND INTRODUCTION

1.1 INTRODUCTION

Using earth in construction goes back to ancient times. Mud bricks also known as adobe were widely used in areas such as pre-Columbian America and Mesopotamia. Historically, organic fibers for example straw, animal hair to mention but a few were mixed into mud bricks to improve performance and check on the cracking during drying. With advancements in research fields, synthetic and industrial waste materials such as fiber glass have been used to enhance the mechanical properties of bricks with steel fibres showing an interesting potential for study (Hassan M, 2022).

This research study examined mainly two properties that is water absorption. This in particular refers to the brick's ability to absorb and retain moisture. High water absorption can lead to structural weakening, increased weight and reduced durability. The compressive strength is a measure of the bricks' ability to withstand loads without failure. When the bricks made are stronger, it ensures better structural integrity and their use in a variety of applications within the construction industry. The use of salvaged steel fibres aims to improve the above properties and others such as soundness and efflorescence by improving the bonding of the made bricks internally.

The fibres randomly scattered within the brick matrix act as bridges across micro cracks which enables stress distribution more evenly and potentially reduce water ingress through alteration of the material's pore structure (Younsi Z, 2023).

With the increasing emphasis globally on sustainability, waste management and eco-friendly. It is very important to discover innovative ways to repurpose the industrial waste.

For the issue of waste tyres, in Uganda thousands of waste tyres are discarded annually which creates environmental hazards such as landfill overflow, fire risks and breeding grounds for vectors that spread diseases. Salvaging steel fibers from waste tyres reduces on environmental impact while availing an alternative reinforcement material for construction.

The aspect of sustainability in line with building materials is key too since unfired earth bricks are a reliable alternative to the commonly used fired bricks and concrete blocks. They have a low carbon print; energy efficiency and they are affordable for most Ugandans given the financial state of the country. Enhancing their properties with waste steel fibres makes them more viable for construction of superior work more so in low-cost housing areas like villages (Minke G, 2006).

This research study is based on a number of theoretical applications that elaborate how the salvaged steel fibres influence the performance of the unfired earth bricks. Once the fibres are applied, there will be an aspect of fracture mechanics and load distribution because when an external force is applied to material cracks then naturally propagate along the weak points.

The steel fibres help to arrest crack growth by distributing stress across the materials thus enhancing its compressive strength. The other aspect is capillary action and water absorption whereby when water moves through a porous material it does so by capillary action. Inclusion of steel fibres within the brick matrix can alter the internal pore structure which gives rise to a potential of reducing the rate and extent of water absorption (Choi J et al., 2015).

The research also aligns with the principles of sustainability whereby the principles of the circular economy and sustainable construction are incorporated. The tyres can be reused for another purpose without putting an end to their lifecycle within the economy which emphasizes resource efficiency and waste repurposing.

1.2 PROBLEM STATEMENT

Bugonya village in eastern Uganda receives a lot of rainfall due to its location in the thick tropical rainforests area. As a result, the bricks made from unfired earth in this area are susceptible to deterioration when exposed to these adverse weather conditions (I. Alam et al., 2022).

Arising from the low strength characteristics of the soils in the area such as a high moisture content make the bricks made in the end to have a high-water absorption ratio. The compressive strength that the bricks possess is also 3.5N/mm^2 which is quite low compared to the required standard strength of 10N/mm^2 for such bricks (Sanya T, 2021)

The resulting shrinkage is high coupled with a low tensile strength and brittleness.

To boost the potential of unfired earth bricks various stabilization methods have been used in types of mechanical, chemical and physical. However, more research still has to be done especially into the techniques of addition of fibres into the brick matrix. This study aimed at addressing the gaps of strength and water absorption through the addition of steel fibres from waste tyres into the unfired brick matrix.

1.3 OBJECTIVES OF THE STUDY

1.3.1 MAIN OBJECTIVE

To determine the suitability of using salvaged steel fibres from waste tyres as reinforcement in unfired earth bricks.

1.3.2 SPECIFIC OBJECTIVES

1. To determine the physical and mechanical properties of the soil used to make the bricks
2. To determine the effect of steel fibre addition on the compressive strength of the bricks
3. To determine the effect of steel fibre addition on the water absorption and optimum steel fibre content for reinforcement

1.3.3 RESEARCH QUESTIONS

1. What are the physical and mechanical properties of the soil used to make the bricks?
2. What is the effect of steel fibre addition on the compressive strength of the bricks?
3. What is the effect of steel fibre addition on the water absorption of the bricks?
4. What is the optimum steel fibre content required for the brick reinforcement?

1.4 JUSTIFICATION

This research study was carried out to enhance sustainable construction within Bugonya village through the utilization of the available tyre waste. An improvement of the properties of the unfired earth brick shall enable sustainable construction of permanent structures in the area which boosts the livelihood within that community in line with sustainable development goals.

In stabilizing earth structures the use of fiber reinforcement improves the tensile strength, ductility and durability of the stabilized component. Steel has important characteristics that cannot be under looked when it comes to its use as an additive in unfired earth bricks starting with the tensile strength, corrosion resistance and hardenability of its general structure. All these play a key role in its general ability to improve the brick matrix once it is incorporated.

In similar studies where fibres have been incorporated through addition to the structure of the material resistance against abrasion, erosion and shrinkage was to a larger extent enhanced. Decrease in shrinkage was observed as the fibres bridge the soil particles and inhibit crack propagation. The shrinkage was noticed to decrease as more fibre content was added.

Steel fibers have high tensile strength ranging from 800-2000 Mpa which gives them effectiveness in resisting tensile forces once added to the unfired earth bricks. This mechanism boosts the load bearing capacity of the bricks through bridging micro-cracks and distribution of stress throughout the brick (Li et al., 2017). Steel fibres show high stability thermally as they are able to withstand temperatures even above 1000 degrees

Celsius making them fire resistant to boost the safety of the occupants of the units where these unfired bricks are used for construction.

The salvaged steel fibres do not undergo significant shrinkage due to changes in moisture since they are chemically inert which ensures long term dimensional of the earth bricks. Studies show that dispersed fibers reduce capillary action which reduces the overall water absorption rate of the brick by obstruction continuous pore channels. In extraction of the steel fibres there are some residual rubber particles attached to them. These particles possess water repelling characteristics which further enhances their resistance to water absorption (Ghernouti et al., 2010). Unlike the traditional fired bricks whose making process requires use of high temperature kilns, the unfired earth bricks reinforced with steel fibers cut out the need for the energy intensive firing while still achieving improved mechanical performance. This results in lower carbon emissions and reduced energy consumption (Morel et al., 2020).

Using salvaged steel fibers also aligns with the circular economy principles, reducing reliance on new steel production and the minimization of industrial waste. Every ton of recycled steel saves approximately 1.5 tons of iron ore, 0.5 tons of coal and 40% of the water required for steel making (World Steel Association, 2022). This makes the reuse of steel fibers an economically and environmentally friendly alternative.

1.5 GEOGRAPHICAL SCOPE

The research study was carried out in Bugonya village in Gadumiire sub-county in Kaliro district 33°29’ 15’’

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews the conceptual knowledge based on which the research study was carried out noting the key findings from the review of material by other researchers in this similar field.

2.2 PHYSICAL AND MECHANIC PROPERTIES OF SOIL FOR BRICK MAKING

The quality of unfired earth bricks very much so depends on the composition and properties of soil used to produce them. The understanding of these properties is crucial since they directly influence the durability, strength and water absorption of the bricks. Soil typically has components such as sand, silt, clay and organic materials with varying proportions impacting the overall general brick performance (Gouvenec & Allix, 2010).

2.3 SOIL COMPOSITION AND CLASSIFICATION

Soil classification is an essential step in determining the suitability of a selected material for brick making. The most commonly used classification systems are the Unified Classification System (USCS) and the AASHTO classification system which categorize soils based on their particle size distribution and plasticity (Bhat et al.,2017).

Generally, clay soils are preferred for brick making due to their finer particles that enhance binding properties though they are also highly prone to shrinkage during drying which leads to potential cracking (Khatri, 2019).

Silt and sand content can improve workability though might reduce the compressive strength once they dominate the mix (Kumar& Prasad, 2018). A balance between these components is key to production of bricks with adequate strength and minimal cracking upon drying.

2.4 GEOTECHNICAL SOIL PROPERTIES

The two critical geotechnical properties that influence the performance of bricks are the plasticity index and shrinkage limit. The plasticity index (PI) measures the range of water content within which the soil remains workable. Soils with high PI that is clays tend to be more plastic and easier to mold but they also retain moisture longer which increases water absorption (Prusty & Mishra, 2016).

Soils with low PI on the other hand tend to have lower shrinkage though they may not form solid bricks without proper additives (Adhikary et al., 2020).

The shrinkage limit measures the extent to which the soil can reduce in volume as it dries up. High shrinkage can cause cracks in bricks leading to a reduction in structural integrity (Mendez et al., 2013). Proper soil stabilization techniques for example use of lime or cement can reduce shrinkage and improve overall brick strength.

2.5 STRENGTH AND DURABILITY CHARACTERISTICS

The compressive strength of unfired earth bricks is a key factor for their use in load bearing structures. The strength is primarily determined by the amount of clay and the compaction degree (Sartori et al., 2014). Bricks that are well compacted made from high clay content soil generally exhibit higher compressive strength though they have a setback of being more prone to water absorption if not properly treated (Smyth & Tindall, 2005)

For unfired earth bricks, durability is another key aspect especially in areas with high rainfall and moisture exposure. Excessive water absorption can lead to mortar failure or brick surface erosion. Hence increasing moisture resistance is very key for extending the lifespan of earth brick structures (Hernandez & Rodriguez, 2016). Several studies have explored natural fiber reinforcement and other additives such as cement to enhance brick durability and reduce water absorption (Gavilan et al., 2018).

2.6 SOIL STABILIZATION AND REINFORCEMENT

The techniques used to improve brick performance include chemical stabilization for example lime and addition of fibers such as synthetic fibers.

Research has shown that lime stabilization helps reduce water absorption and increases compressive strength (Pfeiffer et al., 2017). However, the use of cement in earth bricks can reduce their environmental benefits such as cement production which is energy intensive and generates significant carbon dioxide (Sagahfi & Yousefi, 2013).

However, natural fibers like straw or hemp offer an eco-friendlier option though their contribution to strength and water resistance is typically less significant than that of synthetic fibers or steel fibers (Minke, 2006). The addition of steel fibers especially from salvaged materials like waste tyres is a relatively recent innovation aimed at improving both compressive strength and water resistance (Li et al., 2017). These fibers have proven to enhance the tensile strength of the earth bricks and offer greater resistance to cracking and moisture absorption (Choi et al., 2015).

2.7 CHALLENGES IN SOIL-BASED BRICK PRODUCTION

As earth bricks offer environmental benefits, their limitations in performance in line with water absorption and strength remain a challenge. The sensitivity to moisture and low load bearing capacity restrict their use in rainy buildings (El-Hassan et al., 2019). This limitation highlights the need for effective environmentally friendly capable of long-term durability of the bricks. The use of salvaged steel fibers holds potential in addressing both strength and moisture related issues offering a reliable solution for communities.

2.8 COMPRESSIVE STRENGTH OF EARTH BRICKS

The compressive strength of unfired earth bricks is a critical property that determines their load-bearing capacity and structural reliability. Traditionally, earth bricks rely on compaction and natural cohesion of clay and silt particles to attain strength. However, their mechanical performance is inferior compared to fired bricks or concrete blocks (Minke, 2006). One way to improve their strength is by incorporating reinforcement materials such as natural, synthetic or metallic fibers. Among these, salvaged steel fibers from waste tyres have gained interest due to their high tensile strength, durability and crack-bridging ability (Li et al., 2017).

2.9 LOAD DISTRIBUTION AND CRACK RESISTANCE

Steel fibers primarily enhance compressive strength by bridging micro cracks and redistributing stress throughout the material. During the compression, earth bricks tend to develop internal fractures due to the weak bonding between soil particles. The addition of steel fibers helps resist crack propagation, thereby improving the overall load-bearing capacity of the bricks (Choi et al., 2015).

In addition, steel fibers act as loading transferring elements increasing shear resistance within the brick matrix. Research has shown that fiber-reinforced earth bricks exhibit a 20-40% increase in compressive strength compared to unreinforced bricks depending on the fiber dosage, aspect ratio and soil composition (Sarkar et al., 2021).

2.10 FIBER CONTENT INFLUENCE AND ASPECT RATIO ON STRENGTH

Fiber content

Studies indicate that an optimum steel fiber content exists beyond which further additions reduce workability and increase voids leading to strength reduction (Ghavami et al., 1999). A 0.5-2.0% fiber volume fraction is typically used in soil-based composites with peak compressive strength improvements observed around 1.0-1.5% (Sarkar et al., 2021).

Length to diameter ratio

Higher aspect ratios improve fiber matrix bonding leading to better stress transfer and crack resistance (Hernandez and Rodriguez, 2016). Aspect ratios between 40 and 80 are generally for maximizing reinforcement benefits in earth (Gavilan et al., 2018).

2.2.3 Comparison with other reinforcement materials

Steel fibers outperform many natural and synthetic fibers in terms of strength enhancement;

Table 1:Fiber performance by type

Material	Compressive strength increase (%)	Durability	Cost	Sustainability
Straw fibers	5-15	Low	Low	High
Hemp fibers	10-20	Moderate	Medium	High
Polypropylene fibers	15-30	High	High	Low
Steel fibers	20-40	Very high	Low	High

2.11 DENSITY AND WORKABILITY

Increasing fiber content generally leads to denser bricks but excessive fiber addition an introduce voids, reducing overall compactness (Adhikary et al., 2020). On the other hand, for workability high fiber dosages reduce workability making it harder to mix and compact the bricks. However proper fiber distribution techniques for example pre-mixing can improve uniformity (Li et al., 2017).

2.12 EXPERIMENTAL FINDINGS

Case study 1: Effect of steel fibers on compressive strength (Li et al., 2017)

From a brick that's not reinforced of 2.5Mpa and on addition of 1.5% steel fibers, the strength shot up to 3.8MpPa which is a 52% increase.

Case study 2: Experimental study on fiber reinforced soil bricks (Choi at al., 2015)

From a brick that's not reinforced of 2.8Mpa and on addition of 1% steel fibers, the strength increased to 3.6Mpa which is a 29% increase.

2.13 OPTIMUM CONTENT AND MATERIAL BEHAVIOR

For unfired earth bricks, water absorption is an important concern since its presence in excess weakens the structural integrity of the brick which causes deterioration over time. The addition of steel fibers more so from waste tires has shown capacity in modifying water absorption characteristics accompanied by boosting mechanical performance. The determination of optimum fiber content is quite key for balancing strength, durability and moisture resistance (Li et al., 2017)

2.14 WATER ABSORPTION IN EARTH BRICKS

Unfired earth bricks absorb water due to their porous microstructure that is affected by the soil's particle size distribution, the clay to silt ratio, presence of micro cracks and the degree of compaction (Hernandez & Rodriguez, 2016). On exposure to water, earth bricks swell and soften due to soil expansion, there is loss of strength due to weakening of interparticle bonds and micro crack propagation that leads to structural failure (Smyth & Tindall, 2005).

Steel fibers can reduce water absorption by enhancing the interlocking effect between soil particles and voids minimization which limit water penetration. However excessive fiber content can introduce additional voids (Gavilan et al., 2018).

2.15 FIBER CONTENT EFFECT ON MOISTURE RESISTANCE

Studies indicate that addition of 0.5% to 2% steel fibers by volume faction can reduce water absorption in earth bricks by 15-40% (Adhikary et al., 2020). Although, beyond a certain threshold typically 1.5 to 2% excessive fiber addition creates non uniform distribution which increases porosity that could lead to higher water uptake.

2.16 MICROSTRUCTURAL MODIFICATIONS

At low fiber content (0.5-1%) the fibers effectively fill micro cracks and reduce capillary pores which improves water resistance. At optimal fiber content (1-1.5%), the fibers enhance bonding between soil particles reducing water penetration without compromising workability. At excessive fiber content (>1.5%), fibers can agglomerate creating voids that increase overall porosity making the bricks more susceptible to water absorption (Kumar & Prasad, 2018).

Scanning Electron Microscopy studies reveal that steel fibers help densify the matrix at optimal dosages though at higher concentrations they disrupt soil cohesion allowing water to infiltrate through larger gaps (Lie at al., 2017).

2.17 OPTIMIZATION OF STEEL FIBER CONTENT

Experimental research identifies that optimum steel fiber content for balancing strength falls between 1-1.5% by volume fraction.

Table 2: Variation of fiber percentages

Steel fiber content (% by volume)	Compressive strength increase (%) (+)	Water absorption Reduction (%) (-)	Workability
0 (control)	Baseline	Baseline	High
0.5	12	15	Good
1	22	28	Optimal
1.5	35	40	Moderate
2	25	20	Low
2.5	10	10	Poor

Results Analysis

1-1.5% steel fibers offer the best balance between strength and water resistance. Beyond 1.5%, an increase in fiber induced voids negatively impact moisture resistance.

2.18 COMPARISON WITH OTHER ADDITIVES

Steel fibers outperform several other natural and synthetic additives in improving both mechanical and moisture resistant properties.

Table 3: Effects of different fiber types

Material	Effect on Strength	Effect on water absorption (reduction)	Environmental impact
Hemp fibers	Moderate increase	Moderate	Low impact
Lime stabilization	High increase	High	High carbon dioxide emissions
Polypropylene	Good increase	Moderate	Non-biodegradable
Steel fibers (1-1.5%)	Very High increase	Significant	Recycled material

Steel fibers provide superior mechanical enhancement while maintaining a lower environmental footprint making them a promising reinforcement strategy.

2.19 LONG TERM DURABILITY

The long-term performance of steel fiber reinforced earth bricks in rainy environments has been studied with key observations noted. Fiber treated bricks maintain structural integrity even after wet dry cycles (Hernandez & Rodriguez, 2016). In comparison to unreinforced bricks, steel-fiber reinforced bricks show 30-50% less degradation in water exposure tests over a 6-month period (Gavilan et al., 2018).

Corrosion studies indicate that salvaged steel fibers retain effectiveness over time due to the alkaline nature of soil which provides some protection against rusting (Saghafi & Yousefi, 2013).

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

This chapter outlines the procedures, methods and approaches to achieve the suitability of incorporating salvaged steel fibers into unfired earth bricks.

3.2 MATERIALS USED IN THE RESEARCH

3.2.1 STEEL FIBRES

The steel fibers were acquired from Kalerwe in Kampala, Central Region, Uganda where six rings of car tyre size 205mm width. The rings were split open and straightened then cut into portions of equidistant 5mm. They were cut into these lengths using a cutting disk at the Stirling metal workshop.

The cut pieces were then separated manually by hand with protective gloves into individual units that could easily be measured by weight and added into the bricks after which they were kept in a clean dry place in plastic containers. By the end of the research only two of the acquired rings had been used and the rest of the material was stored for future use.

3.2.2 SOIL FOR BRICK MAKING

The samples were acquired from Bugonya village in Kaliro district from one of the bricks making hubs at coordinates of 33 29' 15'' East. They were dug out by hand hoes and transported in sacks with a separate sample for natural moisture content kept in an airtight bag to ensure accuracy of those results. At the laboratory premises it was riffled and spread out and air-dried for 48 hours. The organic matter or other foreign constituents were eliminated before the soil was used in the brick casting.

3.3 EQUIPMENT USED

Two molds of dimensions 200*100*90 (mm) made of wood were used alongside a soft plywood piece for exerting some pressure to slide the bricks cast out of the mold. A hand rammer was also made to compact the mix homogenously within the molds to prevent voids within the brick matrix. Machines for carrying out lab tests for example determination of compressive strength, soil grading to mention but a few were acquired from the Stirling laboratory.

The water used for the brick mixing was acquired from the Stirling lab water tap, spades and protective gear such as gloves were used to mix the steel fibers within the different weighted soil samples for brick making.

3.4 OBJECTIVE 1

This objective aimed at determining the properties of the soils used to make the bricks in Bugonya village and it covered soil classification, determination of Atterberg limits and natural moisture content of the soil.

3.4.1 SIEVE ANALYSIS

This test was done to assess the proportions of sand, silt and clay in the soil sample because they directly influence the workability, strength and water absorption properties of the bricks.

Equipment used

1. Standard sieve set with sieve sizes 0.075, 0.425, 2.00, 4.75 (mm) which separated the soil sample into the different grades
2. Weighing balance for accurate mass measurement

3. Brush and spatula used to clean the sieves

Procedure

The sample was air-dried for 48 hours to prevent moisture from affecting particle separation. Clumps within the soil were broken.

500g of the soil were weighed and recorded as the initial dry mass (Wo).

Sieving Process

The sieves were stack in descending order with the largest openings at the top. The soil sample was poured in the top sieve and shaking was done through the sieve series for a period of 10 minutes at a similar average hand shaking speed.

Retained Soil

Each sieve was removed from the series and the soil retained on it was weighed. These masses retained were weighed to obtain the percentage retained and percentage passing.

The cumulative percentage through each sieve was calculated and a plot of particle size distribution curve was done using Ms. Excel software suite.

3.4.2 ATTERBERG LIMITS

These tests were done to understand the plasticity and the workability of the soil used for making the unfired earth bricks. The limits mainly defined the moisture content at which soil changes from solid to plastic and then furthermore from plastic to liquid.

LIQUID LIMIT DETERMINATION (LL)

Equipment used

1. Casagrande apparatus
2. Grooving tool

3. Weighing balance
4. Spatula
5. Moisture cans
6. Oven (maintained the temperature at 105 degrees Celsius for drying)

Procedure

A sample of 250g of air-dried soil that passed via the 0.425mm sieve was mixed with water to form a paste.

The soil was then spread into the Casagrande cup and a grooving tool was used to cut 2mm width at the bottom and 11mm at the top.

The brass cup was then lifted and dropped at 2 drops per second with the number of blows counted for the groove to close by 13mm.

A sample from the closed groove was removed and its moisture content determined by oven drying. The procedure was then repeated at different moisture contents with the number of blows being recorded each time.

A curve was then plotted of moisture content (%) against number of blows on a log scale. The liquid limit was determined as the moisture content at 25 blows.

DETERMINATION OF PLASTIC LIMIT (PL)

Equipment used

1. Rolling board
2. Weighing balance
3. Spatula
4. Moisture cans and ovens

Procedure

20g of air-dried soil passing the 0.425 mm sieve were mixed with water to form a plastic ball.

The soil was then rolled into 3mm diameter threads on the rolling board and the rolling continued until the soil thread crumbled.

The crumbled soil particles were then collected and their moisture content determined by oven drying. The determined moisture content at which the moisture started crumbling was determined as the plastic limit.

PLASTICITY INDEX

This value was attained by getting the difference between the liquid limit value and the plastic limit value

Table 4: PI results INTERPRETATION

Plasticity Index (PI)	Soil Type	Suitability for Bricks
PI < 10%	Low plasticity	Poor may require additives
10% < PI < 25%	Moderate plasticity	Ideal for brick making
PI > 25%	High plasticity	Excessive shrinkage risk

3.4.3 NATURAL MOISTURE CONTENT

This the amount of water present in a soil sample before drying. It is expressed as a percentage of the dry soil mass which is key towards understanding the compaction behavior and shrinkage in making of earth bricks.

Equipment used

I. Weighing balance

II. Moisture cans

III. Drying oven

IV. Desiccator

V. Spatula

Procedure

250g of undisturbed soil were collected from the area of study and stored in a sealed plastic bag to prevent moisture loss before testing.

The soil sample was then placed in a clean and dry moisture can and the total weight recorded (W1).

The sample was then placed in an oven at 105 degrees Celsius for a period of 24 hours. Precaution was taken to ensure that the correct temperature was set to remove only water and not organics.

The moisture can was then withdrawn from the oven and cooled in a desiccator. The total weight of the can and the dry soil was recorded (W2).

The natural moisture content of the soil was then calculated using the formula below

$$\boldsymbol{NMC = \frac{W1 - W2}{W2 - W0} \times 100}$$ **EQN 1**

Where:

W1 = Weight of the wet soil + can

W2 = Weight of dry soil + can

Wo = Weight of empty can

Table 5:Moisture content interpretation

NMC (%)	Soil Condition	Effect on brick Production
< 5%	Very dry soil	Difficult to mold, require addition of water
5 – 15%	Moderately moist soil	Suitable for molding
➢ 20%	Very wet soil	High Shrinkage risk

3.5 OBJECTIVE 2

The effects of salvaged steel fiber addition on the compressive strength and water absorption of the unfired earth bricks were tested and were essential for assessment of the structural integrity and durability of the bricks.

3.5.1 COMPRESSIVE STRENGTH TEST

This test was done by subjecting the reinforced unfired earth bricks to an axial compressive load until failure.

Equipment used

1. Compression Testing Machine
2. Ruler
3. Weighing balance
4. Capping materials (Wood sheets were used to ensure balance under the machine and even load distribution)

Procedure

The bricks of the varying steel fiber addition percentages that is 4,6 and 8% were prepared and cured under controlled conditions for 28 days. The compressive strength was tested at maturity of 7 and 28 days with the results compiled for comparison.

Measuring brick dimensions. Based on the known dimensions of the cast bricks, the cross-sectional area of the bricks was obtained

$$A = W * H \qquad \textbf{EQN 2}$$

Loading the brick onto the CTM. The bricks were placed centrally in turns under the machine ensuring that the load faces were flat and parallel to distribute load evenly. Gradually the machine was used to apply a compressive load and the failure load (F) when the brick cracked was recorded.

The compressive strength (Mpa) was then determined using the formula:

$$\mathbf{CS = \frac{F}{A}} \qquad \textbf{EQN 3}$$

Where: CS – compressive strength (Mpa)

F-Maximum failure load (N)

A-Cross sectional area of the brick (mm^2)

3.5.2 WATER ABSORPTION TEST

This was done to determine the water absorption capacity in the controls and the bricks with steel fibers added.

Equipment used

1. Weighing balance
2. Water tank
3. Cleaning cloth

Procedure

The bricks were oven dried at 105 degrees for 24 hours and the mass of the dry brick recorded W1. The bricks for the different percentages were then submerged completely in water for 24 hours.

After the 24 hours, the bricks were removed with excess water wiped off before they were weighed. The wet brick mass was recorded as W2.

The water absorption as a percentage was then calculated using the formula

$$\boldsymbol{WA = \frac{W2 - W1}{W1} \times 100} \qquad \textbf{EQN 4}$$

Where WA Water Absorption (%)

W1- Dry weight of the brick (g)

W2 – Wet weight of the brick (g)

3.6 OBJECTIVE 3

Majorly under this, there was results compiling and analysis to identify the ideal steel fiber percentage that maximizes compressive strength, water resistance and soundness. Using software to draw graphs and result curves the compressive strength test, water absorption test and soundness test were analyzed.

The fiber content selected as optimum had to satisfy the following:

- ✓ Provide the highest compressive strength
- ✓ Reduce water absorption significantly compared to other percentages added
- ✓ Exhibit minimal mass loss and cracking in soundness test

CHAPTER 4: RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter covers the findings on the experimental tests carried out for the mechanical performance, durability and general effectiveness of reinforcing unfired earth bricks with steel fibers extracted from waste tyres. Key parameters were analyzed such as compressive strength, flexural strength, water absorption density and soil properties of the earth used to make the bricks.

4.2 SOIL CHARACTERIZATION

The following subsections show the key soil properties including the natural moisture, sieve analysis, Atterberg limits and maximum dry density along with their implications for brick performance.

4.2.1 Optimum Moisture Content

It represents the amount of water present in the soil in its undisturbed state which directly influences compaction, plasticity and drying behavior of the bricks.

The optimum moisture content is 25.5

From the graph, the optimum moisture content of the soil is 25.5 which is high and indicates increased plasticity of the soil sample. Though on drying, this pauses a higher risk of shrinkage and drying (Perrot et al., 2025). For such instances, air drying the soil or adding sand to reduce plasticity may be necessary.

The optimal moisture content falls within the range of 10-20% ensuring good workability and low shrinkage (Janpetch N et al., 2024). The moisture content between 5%-10%

makes bonding poor resulting into production of weak bricks not fit for superior permanent work (Kruesen K et al., 2024). Above 25%, the soils absorb excessive water which causes deformations and prolonged drying.

4.2.2 Sieve analysis and particle size distribution

The grading modulus was 0.16

The test was done to establish the particle size distribution of the earth used to makes the bricks. This test illustrates whether the soil has mainly gravel, sand, clay or silt particles.

The soil sample was made up of a mix of fine range to medium with sizes between 0.075mm and 6.3mm. This implies that most of the sample's particles are finer since the higher cumulative passing percentages were for the smaller sieves. The dominance of finer particles such as clay or silt is very important in the brick matrix since it improves the bonding between particles which for the case a higher clayey-silt is observed.

The plasticity makes it easy for the brick to be molded and gain the required shape. From the general analysis of the sieve analysis of the soils, the soils are poorly graded with a narrow range of particle sizes and a grading modulus of 0.16 which poses a danger of being prone to erosion and settling since the soil's stability. The results indicated that the soils need stabilization to produce better bricks that ae more reliable for superior structure construction.

4.2.3 Atterberg Limits

Liquid limit

This the water content at which the soil changes from a plastic state to a liquid state (I. Shah, 2023). From analysis, the soils have a high liquid limit of 56.6 which is quite above the normal plasticity range for soils of 30 to 50. This can be attributed to smaller particles and higher surface areas that support high water retention.

Due to the high plasticity and high swelling potential, on exposure to loads this causes deformation which put up a need to reduce the water absorption properties. The recommended plasticity index should be less than 20 however for these soils it was 28.2 which is much higher implying the bricks cast are highly prone to disintegration which called for stabilization. The shrinkage limit by definition is the water content at which a soil does not continue to change in volume as it continues to dry.

From the graph, the shrinkage limit is 13.5 which is quite higher than the tenth percentile of the normal shrinkage values signaling a need for stabilization.

The liquid limit was 56.7, plastic limit was 27.1 and a plasticity index of 29.6%

4.2.4 Maximum Dry Density

This refers to the dry density of a soil once compacted to the highest density with a defined amount of force at its optimum moisture content (Eko M, 2023). This test was done to assess the ability of the soil to support loads without excessive deformation which greatly had an impact on the compressive strength of the bricks that had to be made.

The maximum dry density of 1.557 g/cm^3 acquired falls within the range (1.4-1.8) g/cm^3 that is the acceptable range for general uses for earth in construction for example earth fills. This qualified the soil sample to be ideal for load bearing masonry applications.

4.3 BRICK TESTS

4.3.1 Compressive strength

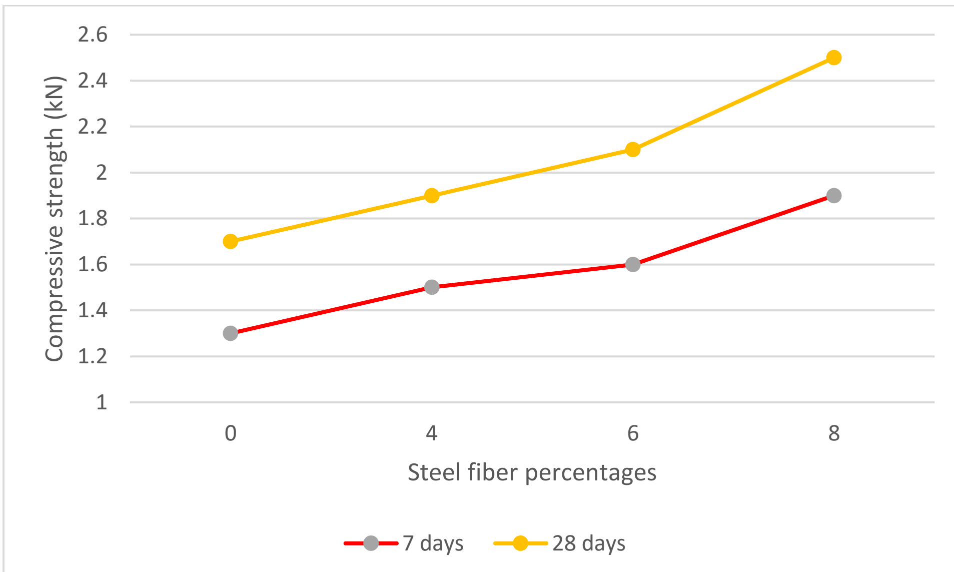


Figure 1:Variation of compressive strength

Explanation for the trend of results

The significant increase in compressive strength at 6% and at 8% steel fiber concentration can be attributed to the effect of the steel fibers on the material's microstructure. The steel fibers act as springs and absorb a great deal of plastic energy (Shantanu P, 2022).

The steel fibers furthermore resist deformation without full disintegration hence increasing the compressive strength of the bricks. The high aspect ratio of the steel fibers that is 20:1 contributed to the formation of a strong and stable network of interlocking particles in the material which caused an increase in the compressive strength. For more clarity, a high aspect ratio means that the fibers have a long, thin shape with a much greater length than its width or thickness (Sanya T, 2021).

4.3.2 Water absorption

A graph showing Water Absorption against Steel Fiber Percentages

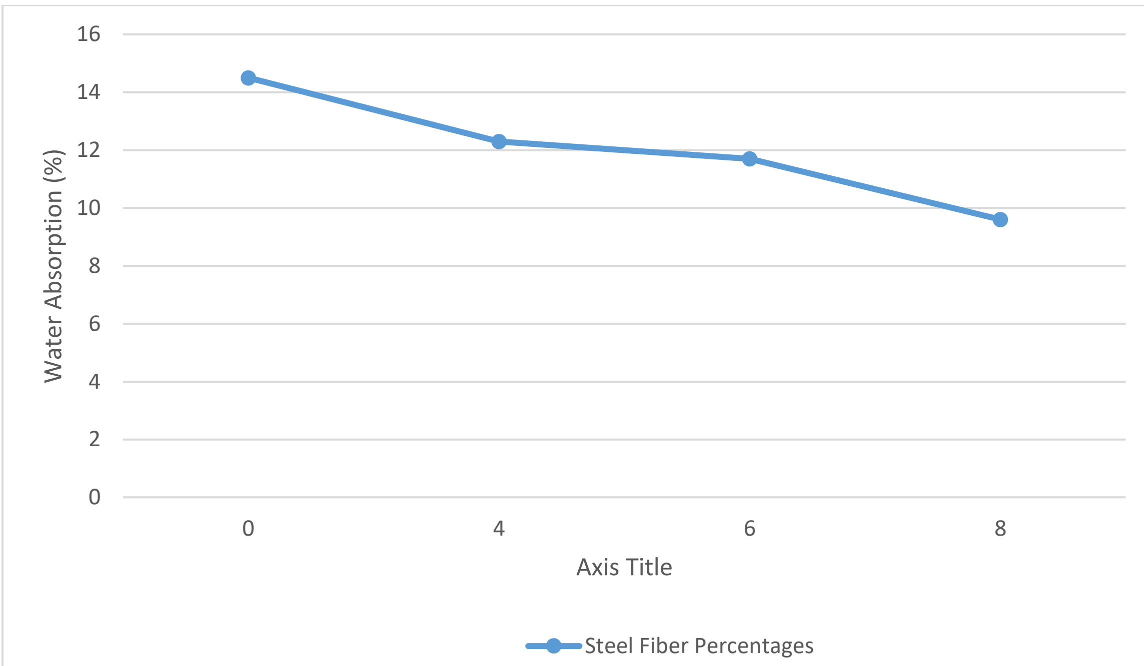
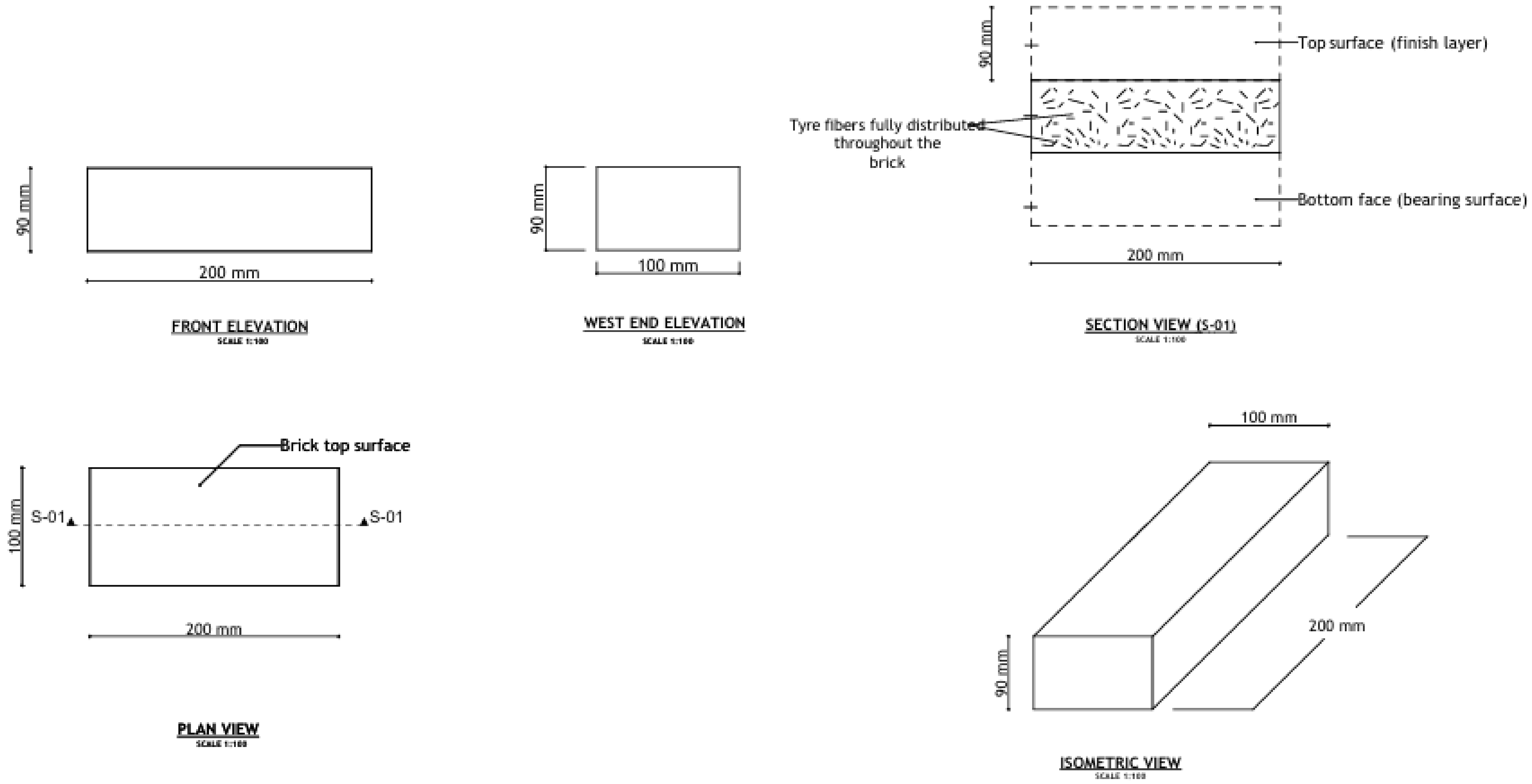


Figure 2: Variation of water absorption

Explanation for the results trend

The water absorption of the bricks reduces with increase in steel fiber percentages added since the fibers are hydrophobic and do not absorb water easily. The steel fibers also bridge the cracks and fill voids that would otherwise accommodate water within the soil matrix.

Addition of steel fibers increased the cohesion among the soil particles which reduced the water absorption as the particles bonded more together closing out that would otherwise harbor moisture.



0. MASONRY UNIT 1:100

PROJECT: USING STEEL FIBERS FROM WASTE TYRES AS REINGFORCEMENT IN UNFIRED EARTH BRICKS

DRAWING TITLE: NEW BRICK MASONRY UNIT

AUTHOR: AHABWE AMON & MULONDO YOAB

REG. NUMBER: S21B32/070 & S21B32/102

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This research investigated the reinforcement of unfired earth bricks using steel fibers from waste tires with the study focused on analyzing the soil properties, particle size distribution and the impact of the fiber addition on mechanical performance of the bricks. The compressive strength of the bricks increased from 1.7Mpa to 2.5Mpa after addition of steel fibers which implies that fiber reinforcement enhanced the load bearing capacity of the bricks by improving the internal bonding and crack resistance.

The water absorption rate decreased from 14.5% to 9.6% which showed an improvement in the bricks' resistance to moisture entry. This reduction suggested that steel fiber reinforcement contributed to a denser microstructure reducing the porosity. The sieve analysis results showed that the soil had a suitable particle size distribution for brick making however the presence of excessive fine particles such as silt and clay could lead to shrinkage issues which were mitigated by the steel fibers.

5.2 RECOMMENDATIONS

Optimization of fiber length. Further research should look into the varying of the lengths of the steel fibers added to the bricks to determine the optimal length that maximizes strength and minimizes shrinkage.

Long term durability research. Further research should look into the long-term performance of fiber reinforced earth bricks under the real-life conditions in the area of study.

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APPENDIX A: PHOTOS OF MATERIAL PREPARATION AND TESTING

Figure 3: Rammer for compaction

Figure 4: Mortar ready for molding

Figure 5:Grinder for cutting

Figure 6: Separation of fibers into singular units

Figure 7:Earth compacted in mold

Figure 8:Sample before mixing

Figure 9:Cast bricks

Figure 10:Steel fibers of 5mm length

Figure 11: Weighing sample for

accuracy

APPENDIX B: PHOTOS OF ORIGINAL LABORATORY RESULTS

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AHABWE AMON & MULONDO YOAB	Stirling

PROJECT:	ASSESSING THE USE OF STEEL FIBRES FROM USED TYRES IN UNFIRED EARTH BRICKS				
Test Reference No.	Lab. Reference No.		Date Sampled	Date Tested	Technician
SOURCE	BUGONYA VILLAGE GADUMIRE SUBCOUNTY KALIRO DISTRICT		23/Jan/25	26/Jan/25	Lab team
Material description:	NEAT DARK BROWN		Natural moisture (%) :	11.0	

TEST DATA

Weight of rammer (Kg)	No. of blows per layer	No of layers	Height of drop (mm)	Diameter of mould(mm)	Volume of mould (cm^3)
4.5	62	5	457	152	2,260

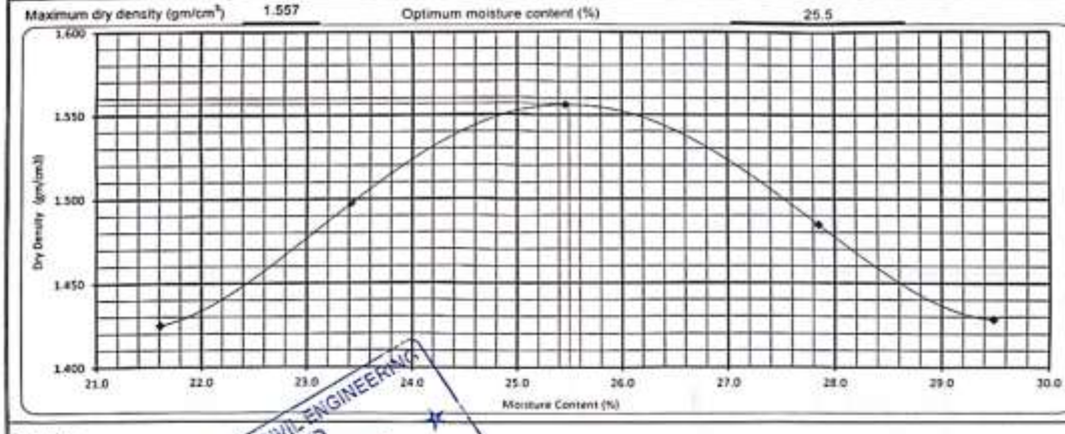
MOISTURE CONTENT DATA

Test No.		1	2	3	4	5
Tin No.		A	A	A	A	A
Water Added	cm^3	160	260	360	460	560
Mass of Compacted soil + mould	gm	8,791	9,052	9,287	9,164	9,055
Mass of Mould	gm	4,875	4,875	4,875	4,875	4,875
Mass of Compacted soil	gm	3916	4177	4412	4289	4180
Volume of mould	cm^3	2,260	2,260	2,260	2,260	2,260
Wet density of soil	g/cm^3	1.733	1.848	1.952	1.898	1.850

DATA FOR PROCTOR CURVE

Container No.		PI	HP	AT	DAD	KCR
Mass of wet soil + Container	gm	1,158.0	1,188.0	1,199.0	1,005.0	1,941.0
Mass of dry soil + container	gm	973.0	991.0	980.0	812.0	1,596.0
Mass of container	gm	117.0	150.0	120.0	119.0	426.0
Mass of water added	gm	185	197	219	193	345
Mass of dry soil	gm	856	841	860	693	1170
Moisture content	%	21.6	23.4	25.5	27.8	29.5
Dry density	g/cm^3	1.425	1.497	1.556	1.484	1.428

Maximum dry density (gm/cm^3) 1.557 Optimum moisture content (%) 25.5



Remarks:

FOR TESTING LAB	FOR STUDENTS
Lab Technician	

STIRLING CIVIL ENGINEERING LTD

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AMON AND YOAB	Stirling

PROJECT:	**ASSESSING THE USE OF STEEL FIBRES FROM USED TYRES IN UNFIRED EARTH BRICKS**

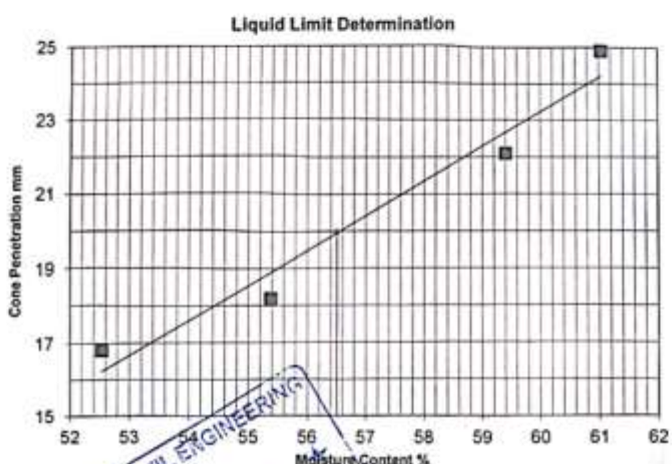
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Material description:	0		Technician:	Lab Team
mix	)NYA VILLAGE GADUMIRE SUBCOUNTY KALIRO DIS		Sample Date	23/Jan/2025
Test method	BS 1377: Part 2, 1990:4.3/4.4		Test Date	27/Jan/2025
LAYER	0			
Depth:	0			

PLASTIC LIMIT	Test No.	KK	OG		Average
Mass of wet soil + container (g)		34.1	33.25		33.675
Mass of dry soil + container (g)		31.59	30.74		31.165
Mass of container (g)		22.26	21.4		21.83
Mass of moisture (g)		2.51	2.5		2.51
Mass of dry soil (g)		9.33	9.34		9.335
Moisture content %		26.9	26.9		26.9
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		16.8	18.2	22.1	24.9
penetration (mm)		16.8	18.2	22.1	24.9
AVERAGE		16.8	18.2	22.1	24.9
Container No.		AX	AO	PI46	A3
Mass of wet soil + container (g)		61.47	61.82	27.80	60.28
Mass of dry soil + container (g)		42.75	42.30	20.09	40.07
Mass of container (g)		7.12	7.05	7.11	6.96
Mass of moisture (g)		18.72	19.52	7.71	20.21
Mass of dry soil (g)		35.63	35.25	12.98	33.11
Moisture content (%)		52.5	55.4	59.4	61.0
AVERAGE		52.5	55.4	59.4	61.0



Liquid limit (%)	56.5
Plastic limit (%)	26.9
Plasticity Index (%)	29.6
Linear shrinkage	
Trough No.	R
Trough length (cm)	14.0
Specimen length (cm)	11.9
L.shringage =	2.1
% L.shrinkage =	15.0

Remarks:

TESTING LAB		STUDENTS
Materials Engineer.		____________
Lab Technician		____________

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INSTITUTION	STUDENTS	TESTING LAB
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PROJECT: ASSESSING THE USE OF STEEL FIBRES FROM USED TYRES IN UNFIRED EARTH BRICKS

ATTERBERG LIMITS

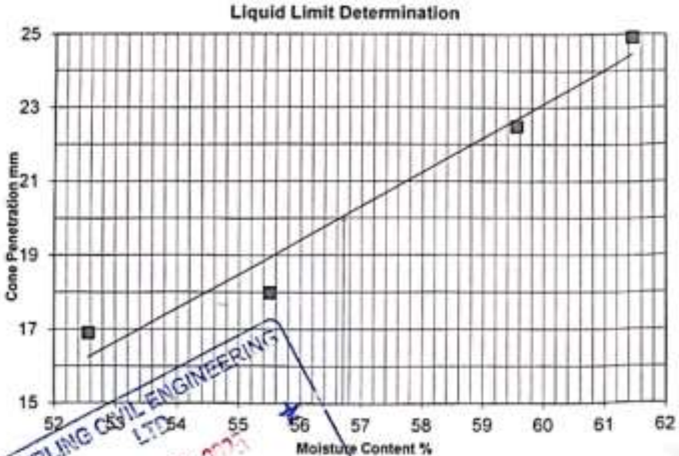
Liquid limit (cone penotrometer) and plastic limit

Material description:	0	Technician:	Lab Team
mix	)NYA VILLAGE GADUMIRE SUBCOUNTY KALIRO DIS	Sample Date	23/Jan/2025
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	27/Jan/2025
LAYER	0		
Depth:	0		

PLASTIC LIMIT	Test No.	P4	BA		Average
Mass of wet soil + container (g)		33.02	36.93		34.975
Mass of dry soil + container (g)		30.8	33.99		32.395
Mass of container (g)		22.64	23.12		22.88
Mass of moisture (g)		2.22	2.9		2.58
Mass of dry soil (g)		8.16	10.87		9.515
Moisture content %		27.2	27.0		27.1
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		16.9	18	22.5	24.9
penetration (mm)		16.9	18.0	22.5	24.9
AVERAGE		16.9	18.0	22.5	24.9
Container No.		A6	A5	PI45	PI20
Mass of wet soil + container (g)		63.49	63.91	44.66	58.18
Mass of dry soil + container (g)		43.98	43.58	30.60	40.45
Mass of container (g)		6.86	6.95	6.99	11.60
Mass of moisture (g)		19.51	20.33	14.06	17.73
Mass of dry soil (g)		37.12	36.63	23.61	28.85
Moisture content (%)		52.6	55.5	59.6	61.5
AVERAGE		52.6	55.5	59.6	61.5

Liquid Limit Determination



Liquid limit (%)	56.7
Plastic limit (%)	27.1
Plasticity Index (%)	29.6
Linear shrinkage	
Trough No.	R
Trough length (cm)	14.0
Specimen length (cm)	11.9
L shringage =	2.1
% L.shrinkage =	15.0

Remarks:

TESTING LAB		STUDENTS
Materials Engineer		
Lab Technician		

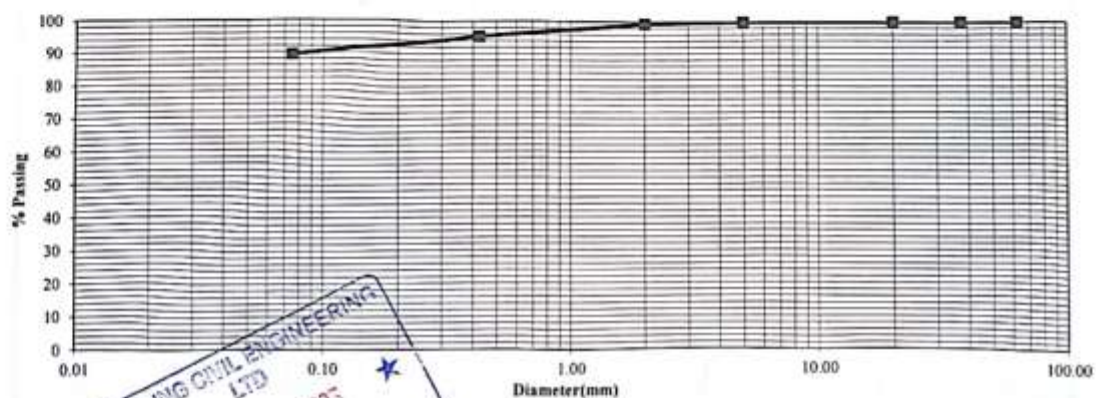
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AHABWE AMON & MULONDO YOAB	Stirling

PROJECT : ASSESSING THE USE OF STEEL FIBRES FROM USED TYRES IN UNFIRED EARTH BRICKS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	BUGONYA VILLAGE GADUMIRE SUBCOUNTY KALIRO DISTRICT	Dry wt. of sample before washing: (g)		2357.6
Depth: (m)		Dry wt. of sample after washing: (g)		254.4
Material description:	NEAT DARK BROWN	Date Sampled:	Date Tested:	Technician
		23/Jan/2025	26/Jan/2025	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)		
63.0	0.0	0	100		
37.5	0.0	0.0	100		
20.0	0.0	0.0	100		
5.0	2.9	0.1	100		
2.00	13.6	0.6	99		
0.425	92.6	3.9	95		
0.075	142.8	6.1	89		
Total fines	2105.7	89.3			
Bottom Pan	2.5				
Extracted fines	2103.2				
Total sample	2357.6				
Grading Modulus		0.16			



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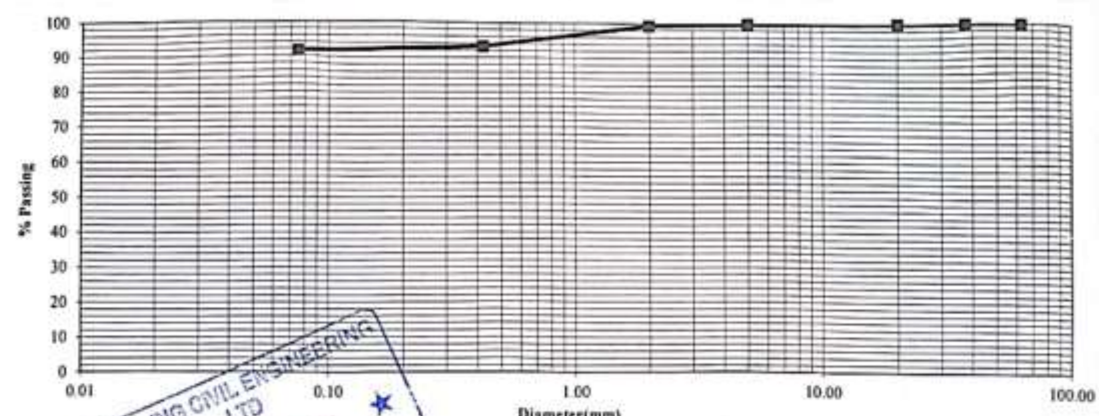
PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:			Lab. Refernece No.:		
Location :(km)	BUGONYA VILLAGE GADUMIRE SUBCOUNTY KALIRO DISTRICT		Dry wt. of sample before washing: (g)		2211.4
Depth: (m)			Dry wt. of sample after washing: (g)		185.4
Material description:	NEAT DARK BROWN		Date Sampled:	Date Tested:	Technician
			23/Jan/2025	26/Jan/2025	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)		
63.0	0.0	0	100		
37.5	0.0	0.0	100		
20.0	0.0	0.0	100		
5.0	2.6	0.1	100		
2.00	10.7	0.5	99		
0.425	136.5	6.2	93		
0.075	34.6	1.6	92		
Total fines	2027.0	91.7			
Bottom Pan	1.0				
Extracted fines	2026.0				
Total sample	2211.4				
Grading Modulus		0.16			



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FOR STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
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PROJECT: ASSESSING THE USE OF STEEL FIBRES FROM USED TYRES IN UNFIRED EARTH BRICKS

SUMMARY OF TEST RESULTS FOR NEAT MATERIAL AT BUGONYA VILLAGE GADUMIRE SUBCOUNTY KALIRO DISTRICT

LOCATION	BLENDED %	SAMPLING DATE	GRADING								ATTERBERG LIMITS				MDD			CBR		CBR SWELL	
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC				62	AVERAGE
BUGONYA VILLAGE GADUMIRE SUBCOUNTY KALIRO DISTRICT	NEAT DARK BROWN	23/01/2025	100	100	100	100	99	93	92	0.16	56.7	27.1	29.6	15.0	1.557	25.5		5.5		1.50	1.50
			100	100	100	100	99	95	89	0.16	56.5	26.9	29.6	15.0	-	-	-	-	-	-	
			100	100	100	99.88	99.35	94.3	90.49	0.16	56.6	27.0	29.6	15.0	1.557	25.5		6		1.50	1.50
	AVERAGE		100	100	100	100	99	94	90	0.159	56.6	26.9	29.6	15.0	1.557	25.5		5.5		1.50	1.50

FOR LAB

Lab Technician

STIRLING CIVIL ENGINEERING LTD
Materials Engineer
P.O. BOX 796, KAMPALA (U)

FOR STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AHABWE AMON & MULONDO YOAB	Stirling

PROJECT ASSESSING THE USE OF STEEL FIBRES FROM USED TYRES IN UNFIRED EARTH BRICKS

SUMMARY OF WATER ABSOPTION RESULTS

LOCATION: MUKONO LAB

STRUCTURE: BRICKS

SSD WGHT	OVEN DRY	WATER ABSORPTION %
	NEAT	
4266	2758	15.1
4085	2690	14.0
AVERAGE		14.5
	4% STEEL	
3766	2566	12.0
4164	2914	12.5
AVERAGE		12.3
	6% STEEL	
3997	2786	12.1
3971	2850	11.2
AVERAGE		11.7
	8% STEEL	
3896	2850	10.5
3852	2986	8.7
AVERAGE		9.6

TESTING LAB

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

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PROJECT	ASSESSING THE USE OF STEEL FIBRES FROM USED TYRES IN UNFIRED EARTH BRICKS	

COMPRESSIVE STRENGTHS FOR BRICKS

LOCATION: MUKONO LAB	BRICKS	TECHNICIAN	Stirling lab
STRUCTURE:		SAMPLE No.	
		Date Casted:	28/Jan/25
		Date Crushed:	6/Jan/25

CASTING DATE	CRUSHING DATE	WT OF CUBES (gm)	DIMENSION (mm)	DENSITY KG/M^3	AGE	CRUSHING LOAD(KN)	ULTIMATE COMP. STRENGTH (Mpa)	AVERAGE STRENGTH(Mpa)
6% STEEL								
6/Jan/25	13/Jan/25	2711	200 X100X 90	1.506	7	30	1.5	1.6
	13/Jan/25	2785	200 X100X 90	1.547		32	1.6	
	3/Feb/25	2856	200 X100X 90	1.587	28	40	2.0	2.1
	3/Feb/25	2789	200 X100X 90	1.549		38	1.9	
	3/Feb/25	2924	200 X100X 90	1.624		45	2.3	
8% STEEL								
6/Jan/25	13/Jan/25	2911	200 X100X 90	1.617	7	35	1.8	1.9
	13/Jan/25	2855	200 X100X 90	1.586		40	2.0	
	3/Feb/25	3022	200 X100X 90	1.679	28	47	2.4	2.5
	3/Feb/25	2989	200 X100X 90	1.661		55	2.8	
	3/Feb/25	2788	200 X100X 90	1.549		50	2.5	

FOR TESTING LAB

LAB TECHNICIAN

STIRLING CIVIL ENGINEERING LTD
MATERIALS ENGINEER
P.O. BOX ... KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AHABWE AMON & MULONDO YOAB	Stirling

PROJECT	ASSESSING THE USE OF STEEL FIBRES FROM USED TYRES IN UNFIRED EARTH BRICKS

COMPRESSIVE STRENGS FOR BRICKS

LOCATION: MUKONO LAB	BRICKS	TECHNICIAN	Stirling lab
STRUCTURE:		SAMPLE No.	
		Date Casted:	16/Dec/24
		Date Crushed:	6/Jan/25

CASTING DATE	CRUSHING DATE	WT OF CUBES (gm)	DIMENSION (mm)	DENSITY KG/M^3	AGE	CRUSHING LOAD(KN)	ULTIMATE COMP. STRENGTH (Mpa)	AVERAGE STRENGTH(Mpa)
NEAT								
6/Jan/25	13/Jan/25	2799	200 X100X 90	1.555	7	25	1.3	1.3
	13/Jan/25	2782	200 X100X 90	1.546		25	1.3	
	3/Feb/25	3011	200 X100X 90	1.673	28	30	1.5	1.7
	3/Feb/25	2856	200 X100X 90	1.587		35	1.8	
	3/Feb/25	2789	200 X100X 90	1.549		35	1.8	
4% STEEL								
6/Jan/25	13/Jan/25	2799	200 X100X 90	1.555	7	28	1.4	1.5
	13/Jan/25	2781	200 X100X 90	1.545		30	1.5	
	3/Feb/25	2952	200 X100X 90	1.640	28	35	1.8	1.9
	3/Feb/25	2635	200 X100X 90	1.464		38	1.9	
	3/Feb/25	2789	200 X100X 90	1.549		39	2.0	

FOR TESTING LAB

LAB TECHNICIAN

STIRLING CIVIL ENGINEERING LTD
MATERIALS ENGINEER
P. O. BOX ... KAMPALA (U)