ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS :A CASE STUDY IN ADEKOKWOK SUB-COUNTY, LIRA DISTRICT

GOODLUCK JONATHAN EBAL

M22B32/012

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

February, 2026

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

ABSTRACT

In Adekokwok sub-county, Lira district, the compressed earth bricks (CEBs) are subject to crack formation and brittleness due to the high absorption rate (9.55%) and low compressive strength (0.65 MPa). This is due to fine-grained laterite soils with a high silica content used in production. The main objective of this study was to determine the use of sugarcane bagasse ash (SBA) and cement kiln dust (CKD) in compressed earth bricks in Adekokwok sub-county, Lira district. An experimental research approach was the methodology used in this study to determine the mix ratio of CKD and SBA that met the load-bearing requirements according to BS 3921:1985. Bricks were produced using a combination of soil with 2% increments from 0 to 10% for CKD and, in 5% increments from 0 to 25% SBA, to make CEBs of dimensions 205mm by 150mm by 70mm. They were cured for 28 days before undergoing strength and durability tests. The optimal proportion of 6% CKD and 10% SBA achieved a 28-day compressive strength of 5.1 MPa, exceeding the 5.0 MPa strength specified in BS 3921:1985. The 6% CKD + 10% SBA mixture enhanced bulk density values by 22.35% from 1382.09 kgm^{-3} to 1690.93 kgm^{-3}, while decreasing water absorption values by 15.18%. Overall the durability parameters showed an improvement. According to BS 3921:1985, these CEBs are recommended for use in the construction of load-bearing walls as a masonry unit.

DECLARATION

I, EBAL GOODLUCK JONATHAN hereby declare that all the information in this research is not plagiarized and has not been submitted to any other institution of higher learning.

………………………………………………… ………………………………………….

Signature **Date**

APPROVAL

I, declare that this report was done by EBAL GOODLUCK JONATHAN under my supervision and presented to the Faculty of Engineering, Design and Technology of Uganda Christian University in partial fulfillment of the requirements necessary for the Bachelor of Science in Civil and Environmental Engineering degree

Signature; Date;

……………………………………………………… ……………………………………………….

MR. ECONI KENNETH

ACADEMIC PROJECT SUPERVISOR

DEDICATION

This research publication is dedicated in respect and reverence to my beloved family members, who have been unswerving in providing support and motivation towards my academic endeavors. The faith they have in me has been my biggest strength throughout my academic life. This research publication also aims to honor those individuals in my life who have inspired me towards achievement and overcoming obstacles in life.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my academic supervisor, Mr. Econi Kenneth, who guided me in this research through his expert inputs and helpful recommendations. I am also grateful to the research coordinator, Mr. Tayebwa Rodgers, for being with me throughout this research process and ensuring that this research project went well. I would also like to thank all my lecturers in this university for the knowledge and foundation they have imparted in me throughout my academic periods here. Furthermore, I would like to thank all my classmates for being with me in this academic adventure in terms of cooperation and shared inputs. Above all, I thank my family for being with me in this academic venture in terms of support and motivation.

TABLE OF CONTENTS

TABLE OF CONTENTS vi

CHAPTER ONE: INTRODUCTION 1

1.1 BACKGROUND...1

1.2 PROBLEM STATEMENT 2

1.3 MAIN OBJECTIVE...3

1.3.1 SPECIFIC OBJECTIVES...3

1.3.2 RESEARCH QUESTIONS...3

1.4 GEOGRAPHICAL SCOPE 3

1.5 JUSTIFICATION 4

1.6 SIGNIFICANCE OF THIS STUDY 5

CHAPTER TWO: LITERATURE REVIEW 6

2.1 TO DETERMINE THE PHYSICAL, MECHANICAL AND CHEMICAL PROPERTIES OF THE EARTH SOIL, CKD, AND SBA. 6

2.1.1 EARTH SOIL 6

2.1.2 CEMENT KILN DUST (CKD)...7

2.1.3 CEMENT KILN DUST IN SOIL STABILIZATION 8

2.1.4 SUGARCANE BAGASSE ASH IN CONCRETE 8

2.1.5 SYNTHESIS OF SILICA POWDER FROM SUGARCANE BAGASSE ASH.............9

2.1.6 SUGARCANE IN THE ENVIRONMENT 9

2.1.7 SPECIES OF SUGARCANE GROWN AT KAKIRA SUGARWORKS LIMITED....... 10

2.1.8 STABILIZATION OF PAVEMENT SUBGRADE WITH SBA AND LIME 12

2.1.9 Cement kiln dust on the mechanical, thermal and durability properties of compressed earth blocks 12

2.1.10 SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS 14

CHAPTER THREE: METHODOLOGY 16
3.1 MATERIALS AND METHODS 16
3.1.1 EARTH SOIL 16
3.1.2 SUGARCANE BAGASSE ASH (SBA) 16
3.1.3 CEMENT KILN DUST (CKD) 17
3.2 METHODS OF STUDY 18
3.3 DETERMINATION OF THE PHYSICAL, MECHANICAL, AND CHEMICAL PROPERTIES OF THE EARTH SOIL, CKD, AND SBA 18
3.3.1 DETERMINATION OF THE PHYSICAL, MECHANICAL AND CHEMICAL PROPERTIES OF EARTH SOIL 18
3.3.2 DETERMINATION OF THE PHYSICAL AND CHEMICAL PROPERTIES OF SBA .. 23
3.3.3 DETERMINATION OF THE PHYSICAL AND CHEMICAL PROPERTIES OF CKD . 26
3.3.4 DETERMINATION OF THE MIX RATIO OF SBA AND CKD IN COMPRESSED EARTH BRICKS 29
3.3.5 DETERMINATION OF THE PERFORMANCE OF COMPRESSED EARTH BRICKS WITH SBA AND CKD. 30
CHAPTER FOUR: RESULTS AND DISCUSSIONS 34
4.1 INTRODUCTION 34
4.2 Physical, mechanical, and chemical properties of the earth soil, CKD, AND SBA 35
4.2.1 EARTH SOIL PROPERTIES 35
4.2.2 CEMENT KILN DUST PROPERTIES 41
4.2.3 SUGARCANE BAGASSE ASH PROPERTIES 44
4.2.4 SPECIFIC GRAVITY OF SBA 46
4.2.5 OPTIMAL MIX OF CKD-SOIL COMPOSITE 49
4.2.6 OPTIMAL MIX OF SCEBS WITH CKD AND SBA 55

4.2.7 PERFORMANCE OF THE FINAL BRICK PRODUCTS (10% SBA & 6% CKD) 62
4.3 MIX DESIGN AND DRAWING 64
4.3.1 Mix design 64
4.3.2 Findings 66
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS 67
5.1 CONCLUSION 67
5.2 RECOMMENDATION 67
REFERENCES 69
APPENDIX: A SUMMARY OF LABARATORY TEST RESULTS 74
7.1 PHYSICAL, MECHANICAL, AND CHEMICAL PROPERTIES OF THE EARTH SOIL, CKD, AND SBA 74
7.1.1 EARTH SOIL 74
7.1.2 CKD 75
7.1.3 SBA 76
7.1.4 PERFORMANCE OF FINAL BRICK PRODUCT 76
APPENDIX B: SAMPLES AND LAB TESTS SCANS 77
APPENDIX C: DESIGN DRAWING OF THE FINAL BRICK PRODUCT 120

LIST OF FIGURES

Figure 1: A graph showing the percentage passing of laterite soils from Adekokwok Sub-county, Lira district. 35

Figure 2: A graph showing the percentage passing against sieve size of a particle size test done in CKD, Hima Cement, Namanve 41

Figure 3: A graph of the percentage passing against the sieve size of SBA from Kakira Sugar Works Limited........ 44

Figure 4: A graph showing the compressive strength of CEBs with varying amounts of CKD 50

Figure 5: A graph showing the Water absorption of CEBs with varying amounts of CKD after 28 days 54

Figure 6: A graph showing the compressive strength of brick samples of 6% CKD with varying amounts of SBA 59

Figure 7: A graph showing the water absorption of CKD-Soil CEBs with varying amounts of SBA........ 61

Figure 8: An image of the soil, SBA, and CKD in batching portions........ 77

Figure 9: An image of the compression test on brick samples 77

Figure 10: An image of the Particle Size Distribution test........ 77

Figure 11: An image of a brick sample with 20% SBA & 6% CKD being weighed...... 77

Figure 12: An image of the block drop test in progress 78

Figure 13: An image of the final brick product with 10% SBA & 6% CKD 78

LIST OF TABLES.

Table 1: A table showing the observations and deductions of efflorescence tests in CEBs 30

Table 2: A table showing the required particle size (%) for soil to make SCEBs against the Sample soil's particle size distribution 36

Table 3: A table showing the chemical compositions for the earth soil from Adekokwok, Sub-county, Lira district 40

Table 4: A table showing the chemical composition of CKD from Hima Cement, Namanve 43

Table 5: A table showing specific gravity results of SBA from Kakira Sugar Works Limited, Jinja 47

Table 6: A table showing the chemical suitability of SBA from Kakira Sugar Works Limited, Jinja according to ASTM C618 48

Table 7: A table showing the batching portions for a soil-CKD composite with varying percentages of CKD 49

Table 8: A table showing the water absorption and the percentage changes of water absorption of soil-CKD with varying percentages of CKD 53

Table 9: A table showing the batching portions of brick samples with 6% CKD, soil and varying percentages of SBA 56

Table 10: A table showing the average compressive strength and the percent increments with varying amounts of SBA 57

Table 11: A table showing a summary of the lab results for earth soil, Adekokwok sub-county, Lira district 74

Table 12: A table showing a summary of the lab results for Cement Kiln Dust, Namanve Industrial Area... 75

Table 13: A table showing a summary of the lab results for SBA, Kakira Sugar Works 76

Table 14: A table showing a summary of the lab results for brick products 76

LIST OF ACRONYMS AND ABBREVIATIONS

SBA	-	Sugarcane Bagasse Ash
CKD	-	Cement Kiln Dust
w/w	-	weight of solute per weight of total mixture
PL	-	Plastic Limit
LL	-	Liquid Limit
PI	-	Plastic Index
Mm	-	millimeter
CEB	-	Compressed Earth Brick
ASTM	-	American Society for Testing and Materials
ARSO	-	African Standardization Organization
BS	-	British Standard
G_S	-	Specific Gravity
C-S-H	-	Calcium Silicate Hydrate
C-A-H	-	Calcium Aluminate Hydrate
Δ	-	change

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

Over the last few years, Stabilized Earth Bricks (SEBs) have gained substantial interest as a more sustainable option compared to traditional fired bricks, mainly owing to their lower carbon emissions (Nnadi *et al.,* 2024). Nevertheless, the use of SEBs is still limited, especially in rural communities, where the high cost involved in using traditional stabilizers like cement makes fired bricks a more cost-effective option (Wang, 2025). Production of fired bricks typically involves kilns that use firewood from surrounding forests, a process that not only accelerates deforestation but also increases greenhouse gas emissions.

Although Stabilized Earth Blocks (SEBs) show environmental benefits compared to conventionally fired bricks, they are not entirely free of environmental concerns. The use of common stabilizers, namely cement, involves high energy consumption during the production process and produces byproducts such as Cement Kiln Dust (CKD), which is an environmental risk if not effectively handled. To reduce the environmental burden of cement production and encourage the use of industrial byproducts, research efforts have focused on incorporating waste materials, such as CKD, into the construction process.

This study explores the use of CKD in combination with Sugarcane Bagasse Ash (SBA), a pozzolanic industrial by-product from the sugarcane processing industry, rich in silica content, to improve the engineering properties in Compressed Earth Bricks (CEBs).

1.2 PROBLEM STATEMENT

In Adekokwok sub-county, Lira district, the compressed earth bricks (CEBs) are subject to crack formation and brittleness due to the high absorption rate and low compressive strength. Field investigations further revealed that the locally made bricks exhibited an average compressive strength and water absorption of 0.63 N/mm^2 and 9.55% respectively. According to BS 3921:1985, the compressive strength doesn't meet the load bearing requirement for masonry units.

Besides the constraints associated with the soil, the dependence on firebricks is environmentally problematic in the following way: the production of firebricks in the region relies strongly on firewood, thereby hastening the rate of vegetation loss due to the burning of wood to fuel the fire in the kilns to produce the firebricks. Current studies indicate the loss of natural forests in the Republic of Uganda to be estimated at 31.9 kilowatt hours per annum by the year 2024, or approximately 15.8 metric tons of CO_2 emissions (Tjebane *et al.*, 2023).

Therefore, this study aims to assess the use of Sugarcane Bagasse Ash (SBA) and Cement Kiln Dust (CKD) as a stabilizer in Compressed Earth Bricks (CEB).

1.3 MAIN OBJECTIVE

To assess the use of Sugarcane Bagasse Ash (SBA) and Cement Kiln Dust (CKD) in Compressed Earth Bricks in Adekokwok sub-county, Lira district.

1.3.1 SPECIFIC OBJECTIVES

i. To determine the physical, mechanical and chemical properties of the earth soil, CKD, and SBA.
ii. To determine the optimal mix ratio of SBA and CKD in compressed earth bricks.
iii. To determine the performance of compressed earth bricks with SBA and CKD.

1.3.2 RESEARCH QUESTIONS

1. What are the physical, mechanical and chemical properties of the earth soil, SBA, and CKD used to make bricks in Adekokwok sub-county, Lira District?
2. What is the optimal mix ratio of SBA and CKD?
3. What is the performance of Compressed Earth Bricks with SBA and CKD?

1.4 GEOGRAPHICAL SCOPE

Adekokwok sub-county is in Lira district in Northern Uganda.

1.5 JUSTIFICATION

Calcium Kiln Dust (CKD), a byproduct in producing cement clinker, shows some promise as a stabilizer, but due to its rough texture and lack of calcium silicate, it is unable to form enough Calcium Silicate gel (Ghavami et al., 2021). Hence, the introduction of Sugar Bagasse Ash (SBA), which is rich in silica content (53.1% w/w) when synthesized. The highest silica content in SBA is achieved by heating at 600°C for 3 hours with 91.57% Hydrochloric Solution (Megawati et al., 2018).

The presence of silica ions from the SBA and Calcium ions from the CKD, when hydrated, can produce Calcium Silicate Hydrate gel (C-S-H) as follows;

Calcium Oxide is hydrated to form Calcium Hydroxide, which is a reactive alkaline. The reactive calcium hydroxide is then hydrated in the presence of silica ions from SBA to form the Calcium Silicate Hydrate that has binding properties as shown.

$3Ca\ (OH)_2 + 2(SiO_2) \rightarrow 3CaO.2(SiO_2).3(H_2O)$

The calcium hydroxide can react with Aluminum Oxide in soil when hydrated to form C-A-H gel that increases the density of the soil. This property stabilizes the soil as shown below;

$3Ca\ (OH)_2 + Al_2O_3 + 6H_2O \rightarrow 3CaO.Al_2O_3.6H_2O$

The presence of Calcium Silicate Hydrate acts as a binder that increases the density of the CEB by filling the voids in the soil. This improves the compressive strength and lowers brittleness of the CEB (Arif *et al.*, 2025).

1.6 SIGNIFICANCE OF THIS STUDY

This study addresses the engineering problem in Adekokwok Sub-county, Lira District, where compressed earth bricks are exibit low compressive strength according to BS, strength issues, and moisture sensitivity. By exploring the use of Sugarcane Bagasse Ash (SBA) or Cement Kiln Dust (CKD) that could potentially serve the role of the stabilizer, the paper develops new knowledge on how the concerned soil could react with the by-product.

This study investigates the pozzolanic reactions that take place between the calcium-based CKD and the silica-based SBA, yielding the evolution of gel materials like Calcium Silicate Hydrate (C-S-H) and Calcium Aluminate Hydrate (C-A-H). Knowledge of this reaction explains the relevance of the study, which offers insight into the effective use of alternative soil stabilizers for modifying soil structure, reducing the possibility of shrink-swelling, and increasing the strength of the bricks which aims to provide a masonry unit that meets load bearing requirements and makes use of waste materials that would otherwise contribute to environmental degradation if poorly disposed.

Overall, the study contributes to the existing literature by assessing the new combination of the stabilizer and showing the potential it holds for improving the strength of the compressed earth bricks.

CHAPTER TWO: LITERATURE REVIEW

2.1 TO DETERMINE THE PHYSICAL, MECHANICAL AND CHEMICAL PROPERTIES OF THE EARTH SOIL, CKD, AND SBA.

2.1.1 EARTH SOIL

Earth soil is one of the oldest and most abundant natural building materials used in the construction of houses, roads, and other civil infrastructure works. It primarily consists of mineral particles such as clay, silt, and sand, mixed with organic matter and varying levels of moisture. The physical and chemical properties of the soil such as particle size distribution, plasticity, specific gravity, and mineral composition greatly influence its suitability for use in brickmaking and other construction applications (Mumpembe *et al.*, 2020).

The suitability of earth soil for compressed earth brick (CEB) production is largely dependent on its grading and mineral composition. Well-graded soils that contain appropriate proportions of sand, silt, and clay tend to exhibit better compaction characteristics and greater stability when used for brickmaking. According to the African Standard WD-ARS 1333:2018, an ideal soil for CEB production should contain 50–70% sand, 15–30% silt, and 5–15% clay. Deviations from these proportions may result in cracking, brittleness, or poor structural performance of the bricks (Compressed stabilized earth blocks-Requirements, production and construction, 2018; Heath *et al.*, 2004).

In Adekokwok Sub-County, Lira District, studies have shown that the local soils possess a high silica content ranging between 90% and 92.5%, which contributes to their brittleness and tendency to crack due to high moisture absorption rates (Mumpembe *et al.*, 2021). These soils also exhibit high plasticity, with liquid limits averaging around 45.3% and plastic indices of approximately 21.6%, indicating significant shrink–swell potential. The free swell index of about 28.1% confirms that the soils are expansive in nature and require stabilization to improve their performance in brick production (Saidou *et al.*, 2025; Singh *et al.*, 2008).

The interaction of these oxides with calcium-based stabilizers enhances the formation of Calcium Silicate Hydrate (C-S-H) and Calcium Aluminate Hydrate (C-A-H) gels, which act as binding agents within the soil matrix. These compounds increase the density and compressive strength of the stabilized earth bricks while reducing shrinkage and water absorption (Arif *et al.*, 2025). Therefore, understanding the physical and chemical characteristics of local earth soils is crucial in determining their potential for sustainable and high-strength CEB production, particularly when utilizing industrial by-products as stabilizers.

2.1.2 CEMENT KILN DUST (CKD)

Cement Kiln dust is a byproduct in the production of cement that takes the form of fine-grained particulate matter consisting of dry oxidized particles from electrostatic precipitators during the formation of cement clinker (Siddique, 2006). CKD can be reintroduced into the clinker production cycle, but that is dependent on the alkali and chloride concentration necessary for the cement in production (Maslehuddin *et al.*, 2008).

CKD's chemical composition depends on what materials are used to produce the clinker, with the texture attributed to what's contained. Finer CKD normally contains higher concentrations of sulfates and alkalis, and coarser CKD has higher concentrations of free lime (Siddique, 2006).

2.1.3 CEMENT KILN DUST IN SOIL STABILIZATION

CKD contains calcium oxide, aluminum oxide, silicon dioxide, and ferric oxide that, together in the right ratio, can produce cement-like properties (Miller and Azad, 2000). The introduction of cement kiln dust in soil can facilitate the formation of Calcium Aluminate Hydrate gel (C-A-H) that acts as a binder, facilitating agglomeration of the soil. When added in moderation, CKD lowers the plastic Index of the soil and improves the bearing capacity of the soil (Miller *et al.*, 2000).

2.1.4 SUGARCANE BAGASSE ASH IN CONCRETE

Sugarcane Bagasse Ash is a pozzolanic material capable of improving the engineering properties of concrete. When optimally dosed into the concrete mix, SBA lowers the heat of hydration and permeability of the concrete through pozzolanic reactions that increase the strength of the concrete products (Thomas *et al.*, 2021). In the batching process, SBA has also been shown to improve workability in concrete (Jahanzaib *et al.*, 2021).

2.1.5 SYNTHESIS OF SILICA POWDER FROM SUGARCANE BAGASSE ASH

Sugar Bagasse Ash (SBA) is obtained from sugarcane bagasse, which is a fiber material obtained after the juice has been removed from the sugarcane. Through synthesis, sugarcane bagasse can produce silica powder (Megawati *et al.*, 2018).

The synthesis of silica powder from SBA to get the highest silica content is done by heating Sugarcane Bagasse at 600°C for three hours in the presence of 91.57% Hydrochloric solution (Megawati *et al.*, 2018).

$2NaOH + SiO_2 \rightarrow Na_2SiO_3 + H_2O$

$Na_2SiO_3 + 2HCl \rightarrow SiO_2$ (pure silica) $+ H_2O$

2.1.6 SUGARCANE IN THE ENVIRONMENT

Sugarcane can be grouped under various types, mainly depending on the particular use of it to be made thereof, and on the special attributes possessed by its fiber.

Chewing Canes. This is a special type of cane identified by having relatively softer fibers, which, when chewed, tend to stick together, making them relatively ideal for direct human consumption. Besides being consumed raw, these canes can be processed and converted to syrup, which can be utilized for different kinds of food applications. Good examples of such canes include Yellow Gal and Pele's Smoke, which are only singled out from other types by their striking purplish edible leaf, making the whole plant a sight to behold (Jackson *et al.*, 2014).

Syrup Canes. The canes from this variety can be identified by the considerably lower content of sucrose, a factor responsible for its cultivation. They are not cultivated to produce crystallized sugar but mainly for the manufacture of syrup. The most popular types of sugarcane that are cultivated include Louisiana Ribbon, Louisiana Purple, and Louisiana Strip, and these contain distinctive characteristics for the manufacture of syrups (Jackson *et al.*, 2014).

2.1.7 SPECIES OF SUGARCANE GROWN AT KAKIRA SUGARWORKS LIMITED

Kakira Sugar Works Limited in Jinja District, Uganda, is the largest sugar-producing company in East Africa. Its success is based on the production of disease-free and high-yielding sugarcane varieties suited to Lake Victoria basin for agro-climatic conditions. To ensure reliable cane supply, reliable sucrose production, and disease and pest resistance, the company cultivates several cultivars in its estates (Jackson et al., 2014). The major sugarcane varieties planted at Kakira include Co 945, Co 449, Co 421, R83–2089, CB 38–22, and FR 93–761. Each of the varieties has individual agronomic characteristics that are conducive to efficient and sustainable sugar production (Kamusiime *et al.*, 2019). Below are the different species of sugarcane;

Co 945 is a high-yielding variety from the Coimbatore (Co) breeding line in India. It is characterized by high cane yield, good field vigor, and moderate-to-high sucrose levels. The variety matures in mid-to-late season, allowing flexible harvest strategies. Co 945 has shown excellent adaptability to local conditions and offers resistance against major pests and diseases, and thus is a preferred cultivar in industrial sugar estates (Kamusiime *et al.*, 2019).

Co 449, another one from the Coimbatore series, enjoys a sound growth history and sturdy cane yields. It is a widely grown cultivar in most sugar estates and was before planted for its reliability. Its resistance to certain diseases, though, demands careful agronomic management. Nevertheless, Co 449 is still an important contributor in the support of varietal diversity in Kakira Sugar Works' fields.

Co 421 is an older variety of Coimbatore that has seen wide usage in comparative trials across the country. It has medium yield, excellent ratooning, and acceptable sucrose content. Though less productive than more recent introductions, Co 421 is useful as a check variety and continues to be cultivated on estates such as the variety at Kakira Sugar Works for its well-documented agronomic performance (Kamusiime *et al*, 2019).

R83–2089 belongs to the R-series of sugarcane clones. The clones are generally developed for regional disease resistance and tolerance. Though limited information on R83–2089 is published, R-series varieties as a class are said to have good ratooning character and reliable production under local conditions. Its inclusion in Kakira Sugar Works' portfolio brings in the estate's capacity to manage environmental variability and disease pressure.

CB 38–22 is a product of Brazilian/Campos breeding material and known for its vigorous vigor and resistance to smut disease. It can withstand heavy soils and possesses medium fiber with satisfactory sucrose. It has been the preferred one in Uganda due to its hardness and strength, thereby making it a major contributor to estate productivity.

FR 93–761 is among the FR series of hybrid combinations. It was made available for its combined traits of sucrose accumulation, disease resistance, and ability to ratoon well. Although comprehensive agronomic information on the variety has not been widely reported, its adoption at Kakira Sugar Work indicates its compatibility with the agroecological conditions of the estate and its ability to provide a continuous and diversified supply of cane (Kamusiime *et al.*, 2019).

2.1.8 STABILIZATION OF PAVEMENT SUBGRADE WITH SBA AND LIME

Soft to medium clay soils are susceptible to moisture and traffic damage. Stabilization enhances their engineering properties. Sugarcane bagasse ash (SBA) and lime are used herein as stabilizers for Taxila clay soil in Pakistan. The stabilizers were used separately and together. Atterberg limits, compaction tests, and California Bearing Ratio (CBR) tests were conducted on soil samples using 2.5%, 5%, and 7.5% SBA or lime on a dry weight basis. Ratios of lime and SBA were 1:1, 2:1, 3:1, 1:2, and 1:3 with 5%, 7.5%, and 10% total stabilizer content (Teddy *et al.*, 2021). Results indicate that 7.5% SBA increased the liquid limit by 28%, and 2.5% lime and 7.5% SBA increased the plastic limit by 40%. The plasticity index increased by 42% using 7.5% SBA. The most satisfactory reduction of plasticity was using 2.5% lime and 2.5% SBA. Additionally, 2.5% SBA and 5% lime increased CBR by approximately 69% relative to the control soil. Cost analysis determined SBA reduced pavement costs, increased structural life, and saved energy and reduced environmental burdens due to the reuse of agricultural residues (Teddy *et al.*, 2021).

2.1.9 CEMENT KILN DUST ON THE MECHANICAL, THERMAL AND DURABILITY PROPERTIES OF COMPRESSED EARTH BLOCKS

The use of industrial by-products, specifically Cement Kiln Dust (CKD), in the formulation of compressed earth blocks (CEBs) has increasingly attracted the attention of the academic community concerned with sustainable construction practices and the recycling of waste materials. A body of literature explores the impacts of the use of

CKD, whether individually or in combination with other constituents, on the strength, thermal conductivity, and durability of earth bricks. The results are encouraging but vary depending on the dosage. A 2002 study by Udoeyo F. Indicated that when used additively, rather than as a substitute, the use of CKD can bring about improvements of up to 54% compared to control samples. This study also illustrated the effects of the presence of CKD on the density of the material and the water absorption, both of which are indicators of porosity.

Likewise, current studies recognize the reaction of the anhydrous fractions of CKD with soil and clay components of CEBs, contributing to the filling of the voids, hence improving the strength of the matrices. Linked studies on concrete and high-performance composite materials have identified the use of CKD (around 10%–15%) as increasing the long-term strength of the material, along with decreased porosity and absorbability.

However, the benefits provided by the presence of CKD also become dosage-dependent, specifically for HPC, where higher amounts of CKD (above specific limits, e.g., above 10-15% of the total mixture) can contribute to the development of broader microcracks and the depletion of binding phases, specifically calcium-silicate-hydrates (C-S-H) gels, which can degrade the strength and durability. Accordingly, the use of CKD, within the specific context of the CEBs or earth bricks, also finds promise for improving the strength and density, specifically when used as additives and/or partial stabilizers, provided that the dosage is properly optimized. In earth-based masonry materials, durability is often associated with porosity, water absorption, and the resistance of erosion or chemical reactions. Among the cementitious materials, the use of CKD has shown improvements in the long-term density and decreased absorbability when used at controlled proportions.

2.1.10 SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

Sugarcane bagasse ash (SBA) came into prominence as a potential stabiliser for the manufacture of compressed earth bricks (CEBs), mainly because of the need for a lower cement requirement, along with the use of sustainable construction approaches that attempt to add value to agricultural waste. Being a material that has been processed using controlled combustion and fine grinding, it contains a substantial level of amorphous silica, which gives it the ability to react with calcium hydroxide, leading to the formation of calcium silicate hydrate (C–S–H) gel, also known as calcium silicate.

The major mechanisms through which the SBA improves the CEB performance include both chemical and physical processes. On the chemical front, the pozzolanic reaction aids in the enhancement of the soil particle bond, which results in the improvement of the compressive strength of the material (Salim *et al.*, 2014). Additionally, on the physical front, the smaller particles of the SBA work as microfillers. This reduces the pores within the bricks, hence increasing the material density and the water absorption properties of the material.

Experimental studies have attested strength increments with the addition of SBA in CEBs, although the degree of enhancement varies with soil types, ash quality, and the method of stabilisation used. Several studies have also shown that the optimal strength is attainable at rather low proportions of SBA, between 5% and 15%, especially when admixed with small proportions of cement/lime (Ali, 2016). Strength increments are also often greater at mature ages of curing, due to the comparatively lower rate of pozzolanic reactions compared with cement hydration reactions, and hence, SBA admixed mixtures are often found to possess similar or better strength at 28 days compared with conventionally cement-stabilised bricks (James, 2016). Apart from the remarkable enhancement of the compressive strength, it has also been demonstrated that the use of SBA decreased the absorption of water, a parameter of paramount importance for enhancing the durability of earthen construction materials, especially those exposed to wetting and drying cycles (Xu et al., 2018). Despite these benefits, the effectiveness of SBA is highly dependent on the processing of the material. Over-ashed materials will lose their activator properties, while inadequately ashed material will have unburnt carbon, which can inhibit the binding process. This means that the need for quality control, especially when it comes to the burn temperature, fineness, and chemical make-up, cannot be overemphasized, especially for engineering purposes (Aburili, 2020). It can, therefore, be said that the literature suggests that the use of SBA can effectively stabilize CEBs by increasing their strength and durability, among other benefits.

CHAPTER THREE: METHODOLOGY

3.1 MATERIALS AND METHODS

3.1.1 EARTH SOIL

Earth soil was sampled from the brick-making site in Adekokwok sub-county at Latitude: 2.2287° N and Longitude: 32.9246° E at three different points within the brick-making site and put in air-tight containers for lab tests, and then sun-dried to remove moisture to facilitate dry mixing with SBA and CKD. 400 kg of soil were sourced in this manner.

3.1.2 SUGARCANE BAGASSE ASH (SBA)

Sugarcane Bagasse Ash (SBA) used in this study was obtained from Kakira Sugar Works Limited, in Jinja District, Uganda. 400 kg of SBA was sourced directly from the factory.

The material was sun-dried before using to eliminate its naturally occurring water content and achieve a constant dry state, ready for dry mixing with CKD and Earth soil. The dried SBA was then sieved through a 0.075 mm sieve to further enhance its fineness by eliminating coarser particles that would negatively affect the homogeneity and performance of the mix (Saidou *et al.*, 2025). The increased fineness of the SBA enhances its surface area–to–volume ratio, thus enabling more efficient pozzolanic reactions that lead to the precipitation of calcium silicate hydrate (C–S–H) gel, contributing to the improvement in strength of the composite material.

To prevent any health and safety risks, treated SBA was stored in dry, sealed bags and handlers wore face masks, as the material is extremely dispersible and could easily turn into airborne particulate matter.

3.1.3 CEMENT KILN DUST (CKD)

The Cement Kiln Dust (CKD) used in this study was obtained from the Hima Cement Plant, located in the Namanve Industrial Park, Uganda. 200 kg of CKD was obtained from the plant.

The sampled CKD was pre-calciner dust, as recommended by Mr. Julius Simbwa, an Innovations Engineer at Hima Cement Plant, due to its higher free lime content, which enhances its possible reactivity in pozzolanic and stabilization reactions.

During collection, the CKD had developed small clumps, and these were hand crushed. This was done to ensure uniform particle size and consistency. The processed CKD was kept in dry, airtight bags to prevent moisture absorption and loss of reactivity.

All handlers and processors utilize protective masks and gloves to minimize health risks associated with dust inhalation and skin contact.

3.2 METHODS OF STUDY

3.3 DETERMINATION OF THE PHYSICAL, MECHANICAL, AND CHEMICAL PROPERTIES OF THE EARTH SOIL, CKD, AND SBA

3.3.1 DETERMINATION OF THE PHYSICAL, MECHANICAL AND CHEMICAL PROPERTIES OF EARTH SOIL

a) Soil particle size distribution

To determine the particle sizes least and most present in the soil used to make CEBs at the brick laying site in Adekokwok sub-county, sieve analysis was done according to BS 1377: Part 2: 1990. Wet sieve analysis was preferred due to the sticky nature of the soil at the brick-making site in Adekokwok. Below is the procedure to be followed;

Apparatus: Weighing balance, sieve shaker, standard sieve set, pan, oven, brushes, and datasheet.

Sample preparation

i) The oven-dried soil sample was weighed to 0.1% accuracy for its total weight (m_1).

ii) Break up any lumps gently, without damaging the grains.

iii) Wet Sieving to Remove Fines

iv) Position the sample on a 2 mm test sieve stacked on top of a 63 µm sieve.

v) The soil can was washed gently using clean water, a small amount at a time, using a gentle jet or stream, until the water exiting the 63 µm sieve was almost clear, thereby ensuring that the silt and clay-sized particles are fully washed through.

vi) Sieve overload, particularly for a 200mm sieve, was avoided by ensuring that the retained mass remains below 150 grams.

vii) The fine sediment obtained from the washings, finer than the 63 μm sieve, is then reserved for sedimentation or separate fine analysis, if required.

Drying the retained fraction

i) The retained material from both sieves (2 mm and 63 μm) was transferred to a tray.

ii) The sample was oven dried at 105–110°C until a constant weight was obtained.

iii) The sample was cooled to room temperature and weighed (m_2).

iv) Dry sieving of coarse fraction

v) Sieve the dried sample using the corresponding sieves (20 mm, 10 mm, 6.3 mm, 2 mm, and 1 mm).

vi) The retained materials on each sieve were weighed for accuracy to 0.1% of the total weight.

Calculations

Mass retained on each sieve to be recorded, calculation for percentage retained and percentage passed for each sieve size:

Percentage Retained = $\frac{Mass\ Retained}{Total\ Mass} * 100\%$ Eq (3.1)

Cumulative percentage passing = 100−Cumulative percentage retained plot the grain size distribution curve on semi-log graph paper (sieve size logarithmic scale, % passing arithmetic scale).

$$\text{Grading modulus} = \frac{(300 - (\text{Percentage retained at 2mm} + 0.425\text{mm} + 0.075\text{mm}))}{100} \qquad \text{Eq (3.2)}$$

b) Atterberg limit tests

To assess the workability and shrinkage rate, Atterberg tests were done based on BS 1377: Part 2: 1990. This was important in determining the dosage of SBA and CKD as stabilizers and workability when the molding is finally done.

The Liquid Limit (LL) test was determined through the cone penetrometer method based on BS 1377: Part 2: 1990 as follows;

Apparatus: Cone penetrometer, glass mixing plate, spatula, 0.01g balance, evaporating dishes, oven, and wash bottle.

Procedure

i) The soil sample was ground with distilled water into a paste.

ii) The cone penetrometer cup was filled with soil.

iii) The cone dropped and let it go for 5 seconds.

iv) The penetration depth was then measured. Repeat for several different moisture contents.

v) The penetration against moisture content was plotted, and LL was determined at 20 mm penetration.

With the LL determined, the Plastic Limit (PL) and Plastic Index (PI) were determined as shown below;

Apparatus: Glass plate, spatula, 0.01g balance, moisture containers, oven, and wash bottle.

Procedure

i) A section of the LL sample was converted into threads.
ii) The threads were rolled on a glass plate until they disintegrated at a diameter of 3 mm.
iii) The fragmented soil was gathered, and its moisture level was assessed.
iv) The meaning of at least three readings gave the PL.

Plastic Index, PI = LL – PL Eq (3.3)

c) Specific gravity test of the earth soil

To measure the consistency of the CEBs and assess the effectiveness of the stabilizers, the specific gravity of the soil was determined using BS 1377: Part 2: 1990 through the pycnometer method. This allows for quality control to ensure consistency of the bricks.

Apparatus: pycnometer, 0.01g balance, distilled water, oven, thermometer, and spatula

Procedure

i) The weight of the pycnometer (M_1)
ii) The soil sample was dried and weighed (M_2).
iii) The pycnometer was filled with soil, and distilled water was added to half the capacity.
iv) Air bubbles were removed through vacuuming or tapping.

v) The pycnometer was then filled to the mark with water and weight (M_4).

The pycnometer was washed and filled with water only and weighed (M_3).

The specific Gravity was obtained through the formula below;

$$\text{Specific gravity of earth soils} = \frac{(M_2 - M_1)}{((M_4 - M_1) - (M_3 - M_2))} \quad \text{Eq (3.4)}$$

d) X-ray fluorescence test on the earth soil, Adekokwok sub-county, Lira district.

To identify the chemical compounds present in the soil, an XRF test was done according to ASTM D8438 through XRF spectroscopy. This was to identify any minerals that may impact the durability and strength of the brick and may be reactive with the SBA and CKD.

Apparatus: X-ray analyzer and X-ray spectrometer

Procedure

i) The soil sample was subjected to X-ray radiation from the X-ray spectrometer.

ii) The soil sample was then analyzed using the X-ray analyzer, and based on the fluorescent print observed, the chemical composition was determined and tabulated.

3.3.2 DETERMINATION OF THE PHYSICAL AND CHEMICAL PROPERTIES OF SBA

a) Atterberg limit tests on SBA.

To assess the workability and shrinkage rate, Atterberg tests were done based on BS 1377: Part 2: 1990. This was important in determining the dosage of SBA and CKD as stabilizers and workability when the molding was finally done.

The Liquid Limit (LL) test was determined through the cone penetrometer method based on BS 1377: Part 2: 1990 as follows;

Apparatus: Cone penetrometer, glass mixing plate, spatula, 0.01g balance, evaporating dishes, oven, and wash bottle.

Procedure

i) The SBA sample was mixed with distilled water into a paste.
ii) The cone penetrometer cup was filled with soil.
iii) The cone was dropped and allowed to go for 5 seconds.
iv) The penetration depth was measured. This was repeated for several different moisture contents.
v) Penetration against moisture content was plotted, and LL at 20 mm penetration.

With the LL determined, the Plastic Limit (PL) and Plastic Index (PI) were determined as follows;

Apparatus: Glass plate, spatula, 0.01g balance, moisture containers, oven, and wash bottle.

Procedure

i) A section of the LL sample was converted into threads.

ii) The threads were rolled on a glass plate until they disintegrated at a diameter of 3 mm.

iii) The fragmented SBA was assessed for moisture levels.

iv) The average of at least three readings gave the PL.

Plastic Index, PI = LL – PL   Eq (3.5)

b) Specific gravity test on the SBA.

To determine the dry density of the SBA from Kakira Sugar Works, the specific gravity of the SBA was determined according to BS 1377: Part 2: 1990 through the pycnometer method. This allows for quality control to ensure consistency of the bricks.

Apparatus: pycnometer, 0.01g balance, distilled water, oven, thermometer, and spatula

Procedure

i) The pycnometer was weighed and the value recorded (M_1)

ii) The soil sample was dried and weighed 50g (M_2).

iii) The pycnometer with the soil was filled with distilled water to half its capacity.

iv) Air bubbles in the pycnometer were removed through vacuuming or tapping.

v) The pycnometer was filled to the mark with water and weight (M_4).

vi) The pycnometer was washed and filled with water only and weighed (M_3).

The specific Gravity was obtained through the formula below;

Specific gravity of SBA, G_{SBA} = $\frac{(M_2 - M_1)}{((M_4 - M_1) - (M_3 - M_2))}$ Eq (3.6)

c) X-ray fluorescence test on SBA

To identify the chemical compounds present in SBA, an XRF test was done according to ASTM D8438 through XRF spectroscopy. This was done to determine the silica content available in the SBA after adequate synthesis, which is necessary in the formation of calcium silicate hydrates.

Apparatus: X-ray analyzer and X-ray spectrometer

Procedure

i) The SBA was subjected to X-ray radiation from the X-ray spectrometer.

ii) The SBA was then analyzed using the X-ray analyzer, and based on the fluorescent print observed, the chemical composition was determined.

3.3.3 DETERMINATION OF THE PHYSICAL AND CHEMICAL PROPERTIES OF CKD

a) Atterberg limit tests on CKD

To assess the workability and shrinkage rate, Atterberg tests were done based on BS 1377: Part 2: 1990. This was important in determining the dosage of SBA and CKD as stabilizers and workability when the molding is finally done.

The Liquid Limit (LL) test was determined through the cone penetrometer method based on BS 1377: Part 2: 1990 as follows;

Apparatus: Cone penetrometer, glass mixing plate, spatula, 0.01g balance, evaporating dishes, oven, and wash bottle.

Procedure

i) The CKD sample was mixed with distilled water into a paste.

ii) The cone penetrometer cup was filled with soil.

iii) The cone was dropped and allowed it go for 5 seconds.

iv) Penetration depth was measured. This was repeated for several different moisture contents.

v) Penetration against moisture content was plotted, and LL at 20 mm penetration was determined.

With the LL determined, the Plastic Limit (PL) and Plastic Index (PI) were determined;

Apparatus: Glass plate, spatula, 0.01g balance, moisture containers, oven, and wash bottle.

Procedure

i) A section of the LL sample was converted into threads.

ii) Threads on a glass plate were rolled until they disintegrated at a diameter of 3 mm.

iii) The fragmented CKD was collected and its moisture level assessed.

iv) The meaning of at least three readings gave the PL.

Plastic Index, PI = LL – PL Eq (3.7)

b) Specific gravity test on the CKD.

To determine the dry density of the CKD sourced from Hima Cement, Namanve, the specific gravity of the CKD was determined according to BS 1377: Part 2: 1990 through the pycnometer method. This allows for quality control to ensure consistency of the bricks.

Apparatus: pycnometer, 0.01g balance, distilled water, oven, thermometer, and spatula

Procedure

i) The pycnometer was weighed (M_1)

ii) The soil sample was dried and weighed (M_2).

iii) The pycnometer was filled with soil and distilled water added to half the capacity.

iv) Air bubbles were removed through vacuuming or tapping.

v) The pycnometer was filled to the mark with water and weight (M_4).

vi) The pycnometer was washed and filled with water only and weigh (M_3).

The specific Gravity was obtained through the formula below;

$$\textbf{Specific gravity of CKD, } G_{CKD} = \frac{(M_2 - M_1)}{((M_4 - M_1) - (M_3 - M_2))} \qquad \text{Eq (3.8)}$$

c) X-ray fluorescence test of CKD.

To identify the chemical compounds, present in CKD, an XRF test was done according to ASTM D8438 through XRF spectroscopy. This was done to determine the presence of Calcium Oxide that will be hydrated to form Calcium Hydroxide, which was necessary in the formation of Calcium Silicate Hydrates.

Apparatus: X-ray analyzer and X-ray spectrometer

Procedure

i) The CKD was subjected to X-ray radiation from the X-ray spectrometer.
ii) The CKD was then analyzed using the X-ray analyzer, and based on the fluorescent print observed, the chemical composition was determined.

3.3.4 DETERMINATION OF THE MIX RATIO OF SBA AND CKD IN COMPRESSED EARTH BRICKS

The mixing of the different materials was done according to WD-ARS 1333:2018(E) by ARSO. The ratios of soil, CKD, and SBA were based on proportional analysis with the average size of CEBs in the brick laying site in Adekokwok sub-county, Lira district.

a) Production of stabilized compressed earth bricks

i) Soil from beneath the topsoil (subsoil) was excavated, as topsoil contains organic matter which weakens bricks.

ii) After excavation, large clumps of soil (over 200mm) were broken into smaller pieces to ensure even mixing. Hard particles like gravel were left intact.

iii) Using mesh screens oversized particles were removed to get a uniform soil mix.

iv) Proportioning of SBA, CKD, and soil by mass (Measuring Materials) using standardized measuring boxes were used to maintain consistent proportions in each batch.

v) The soil and the stabilizer were dry mixed in the determined percentages, then water was gradually added while mixing.

vi) The SCEBs were then air dried away from direct sunlight for 28 days (Compressed stabilized earth blocks-Requirements, production and construction, 2018).

3.3.5 DETERMINATION OF THE PERFORMANCE OF COMPRESSED EARTH BRICKS WITH SBA AND CKD.

a) Efflorescence test

To determine the presence of soluble salts in the CEBs soil, an efflorescence test was done according to ASTM C67. This was done to assess the possibility of unsightly white patches when the bricks are exposed to water/moisture.

Apparatus: Non-corrodible pan, ruler, distilled water, oven, and white background.

Procedure

i) Distilled water was added to the pan to a depth of 25 millimeters.

ii) The brick samples were placed vertically in the pan with 25 mm immersed.

iii) The setup was left in a well-ventilated area for 7 days.

iv) White salt efflorescence was identified on the brick.

Evaluate as:

Table 1: A table showing the observations and deductions of efflorescence tests in CEBs

Observation	Deduction
Nil	No deposits
Slight	≤10% surface area
Moderate	10–50%
Heavy	>50%

b) Block-drop test

A block drop test was performed to determine the durability of the CEB with SBA and CKD. This is done according to EN 772-1.

Apparatus: Measuring tape, hard impact surface, and observation sheet.

Procedure

i) The CEB was placed at a height of 1.5 meters.
ii) The brick was dropped onto the firm earth in a horizontal position.
iii) This was done using three different samples.
iv) The bricks were inspected for fissures, fractures, or structural irregularities.
v) The durability was assessed both in terms of the number and intensity of visible defects.

c) Water absorption test

To determine the amount of water absorbed by a brick when immersed in water for a specific period. This indicates the brick porosity, durability, and compactness, key factors in assessing the effectiveness of stabilization with Sugarcane Bagasse Ash and Cement Kiln Dust. Bricks with lower water absorption (<20%) are more durable and suitable for construction.

Apparatus: Weighing balance (accurate to 0.01 g), water bath or container, oven (105–110 °C), dry cloth or towel, and timer.

Sample selection and preparation

i) Three representative brick samples from each mix proportion were selected (e.g., control, SBA mix, CKD mix, and SBA–CKD mix).

ii) The bricks were dried in an oven at 105–110 °C until a constant weight was achieved.

iii) The samples were cooled to room temperature in a desiccator.

iv) After cooling, each dry brick was weighed and recorded accurately to 0.01 g.

v) The dry bricks were immersed completely in clean water at room temperature (27 ± 2 °C) for 24 hours.

vi) After 24 hours, remove the bricks from the water.

vii) Surface water gently was wiped off using a damp cloth (avoid water loss from pores).

viii) Each wet brick was weighed and recorded as wet mass (W_2).

Calculation

Compute the percentage of water absorbed by each brick using the formula:

$$\textbf{Water Absorption} \ (\%) = \frac{(W_2 - W_1)}{W_1} * 100\% \qquad \text{Eq (3.9)}$$

d) **Compressive strength test**

To determine the impact of CKD and SBA on the compressive strength of the CEB, a compressive strength test was done according to EN 772-1.

Apparatus: Compression Testing Machine, steel bearing plates, and Sulphur capping.

Procedure

i) Oven-dry bricks and cool to room temperature.
ii) Hold the upper and lower pieces by applying sulfur to ensure even bearing surfaces.
iii) The brick samples were placed in the gap between the apparatus bearing plates.
iv) A load at 0.5 MPa/s was applied until failure.
v) The maximum load was recorded.

Calculate compressive strength:

$$\textbf{Compressive strength} = \frac{\text{Maximum applied load}}{\text{Loaded Area}} \qquad \text{Eq (3.10)}$$

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

The tests done and brick laying were all done according to African Standard: Compressed stabilized earth blocks—Requirements, production and construction. This chapter will report and discuss the results of the experiments conducted in the process of characterizing the lateritic soils in the Adekokwok Sub-county, followed by the production and experimentation of the stabilized compressed earth bricks (SCEBs) made from the combination of the Sugarcane Bagasse Ash (SBA) and the Cement Kiln Dust (CKD) materials based on the results and findings of the characterization process discussed in the next chapter.

The chapter begins with the assessment of the properties of the natural soil in terms of its mechanical and chemical properties and establishes the basis for comparison of its performance in the production of SCEBs. The chapter continues with a thorough assessment of the effect of the variation in the amounts of the two stabilizers, namely SBA and CKD, and their effect on the performance indicators of the SCEBs in terms of their compression strengths, density, porosity, water absorption capacity, and durability.

Ultimately, the chapter will attempt to illustrate how the blends of the selected stabilizers affect the soil matrix, determine the optimal design composition, and discuss the significance of the results to sustainable construction in the region.

4.2 PHYSICAL, MECHANICAL, AND CHEMICAL PROPERTIES OF THE EARTH SOIL, CKD, AND SBA

4.2.1 EARTH SOIL PROPERTIES

a) PARTICLE SIZE DISTRIBUTION OF EARTH SOIL

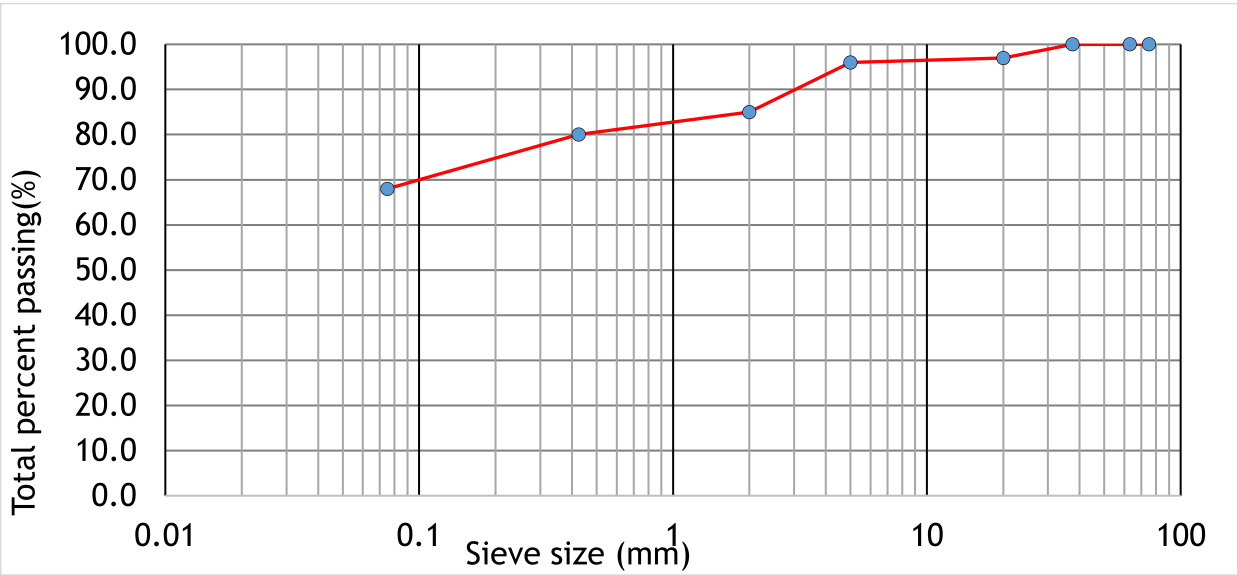


Figure 1: A graph showing the percentage passing of laterite soils from Adekokwok Sub-county, Lira district.

The particle size distribution analysis of the lateritic earth soil from Adekokwok Sub-county, Lira District, conducted via wet sieve analysis (**BS 1377: Part 2: 1990**), revealed that the material is predominantly fine-grained. The average Grading Modulus (GM) of the soil samples was consistently low, measured at **0.40**. This was as shown below Eq (3.2);

$$\textbf{Grading modulus} = \frac{[300-(96+85+80)]}{100}$$

Grading modulus = 0.40

This low GM classifies the soil as very fine (since GM < 1.5) and confirms its silt-clayed nature, as a high percentage of the material, ranging from 79.5% to 80.3%, passed through the 0.075 mm sieve (sieve No. 200). While the Fine Gravel and Sand content (67.4%) falls within the range recommended by the African Standard WD-ARS 1333 for CEB production (50–70% sand), the Silt (9.9%) and Clay (4.2%) fractions are below the ideal minimums (15–30% silt and 5–15% clay). The high proportion of fine particles contributes to the soil's high plasticity (Plasticity Index, PI = 21.6%) and its expansive nature (Free Swell Index = 28.1%), rendering the unstabilized soil prone to cracks and requiring effective stabilization to enhance its structural integrity and compaction characteristics.

Table 2: A table showing the required particle size (%) for soil to make SCEBs against the Sample soil's particle size distribution

Particle size (%)	Required particle size (%) (WD-ARS 1333 first Edition 2018)	Sample soil's particle size (%)
Fine Gravel and Sand	50% - 70%	67.4%
Silt	15% - 30%	9.9%
Clay	5% - 15%	4.2%

b) CLASSIFICATION OF THE EARTH SOIL BY AASHTO

To classify the earth soil, the AASHTO method was used as follows;

79.54% passed through sieve no. 200; the soil is silt-clayed in nature because this is more than 35% of the material passes.

% passing sieve no. 10 (2.00mm) = 96%

% passing sieve no. 40 (0.425mm) = 85%

% passing sieve no. 200 (0.075mm) = 80%

Plasticity Index (PI) = 21.6%

Liquid Limit (LL) = 45.3%

Plasticity Limit (PL) = 23.7%

Since the LL is greater than 41% (45.3% > 41%) and the PI is greater than 11% (21.6% > 11%).

Considering that the PL is less than 30% (23.7% < 30%), the soil is an A-7-6

Computing the Group Index (GI);

$$\mathbf{GI} = (F_{200} - 35)\,[0.2 + 0.005(LL - 40)] + 0.01[F_{200} - 15]\,[PI - 10]$$

$$= (80 - 35)\,[0.2 + 0.005(45.3 - 40)] + 0.01[80 - 15]\,[21.6 - 10]$$

$$= 17.7325 \approx 18$$

$$\mathbf{GI} = 18$$

<u>Hence the soil is clayey, i.e., A-7-6(18)</u>

c) **FREE SWELL INDEX TEST ON THE EARTH SOIL**

The free swell index of the soil was found to be 28.1%. This shows that the soils at Adekokwok Sub-county are expansive because of the fall within the range of 20% - 35% (Singh et al., 2008). This value will be contrasted with the soil after the addition of the SBA and CKD to see if these two have reduced the water layer in the soil and increased the density of the CEBs (Saidou et al., 2025).

d) **ATTERBERG LIMIT TEST OF THE EARTH SOIL**

The soil exhibits high plasticity and high shrink–swell potential, indicating a potential for cracking. Despite these limitations, its measured Liquid Limit (LL) of 45.3% falls within the acceptable range of 25–46% specified by the African Standard WD-ARS 1333, First Edition (2018).

The Plastic Limit (PL) was determined to be 23.7%, from which the Plasticity Index **(PI)** was calculated as 21.6% (PI = LL − PL). This PI value also lies within the standard recommended range of 2–30%. These results indicate that while the soil possesses adequate plasticity for molding, proper stabilization is required to mitigate excessive shrink–swell behavior, which would otherwise compromise the structural integrity of the bricks.

e) **SPECIFIC GRAVITY OF EARTH SOIL**

The specific gravity of the earth soil from Adekokwok Sub-county, Lira District, was measured using the pycnometer method, as specified by the AASHTO T100-95 standard. Determining the specific gravity of soil is a key aspect of determining the compressibility of Compressed Earth Bricks (CEBs) and the ability of stabilizers to improve them, since the calculation of dry density of soil is possible. The soil type that was analyzed was typically classified as being composed of reddish-brown soil, termed to be a type of lateritic soil. The method involved determining the specific gravity using the weight of the oven-dry soil, the weight of the pycnometer filled with water, and finally the weight of the pycnometer when the soil is submerged in water. The mean value for the specific gravity for the soil from Adekokwok Sub-county was obtained to be 2.705.

f) CHEMICAL COMPOSITION OF EARTH SOIL

Based on ASTM C618, natural pozzolans must have a combined content of at least 70% of the total SiO_2, Al_2O_3, and Fe_2O_3. The soil obtained from the Adekokwok Sub-County meets this requirement, as its combined oxide content is 89.324%. This indicates a high capacity to form pozzolanic reactions.

In addition, the soil contains significant amounts of aluminum oxide (12.673%), calcium oxide (6.384%), and silicon dioxide (37.387%). These materials act as key precursors for the gel formation of calcium silicate hydrate, or C–S–H, and calcium aluminate hydrate, or C–A–H. The hydration products derived from these gels improve strength, stability, and adhesion of stabilized soil bricks.

Table 3: A table showing the chemical compositions for the earth soil from Adekokwok, Sub-county, Lira district

PARAMETER	**Results (**%m/m**)**
Iron (III) Oxide	39.264
Silicon dioxide	37.387
Aluminum Oxide	12.673
Calcium Oxide	6.384
Manganese (II) Oxide	1.655
Titanium di oxide	1.5
Chromium (III) Oxide	0.152
Europium (III) Oxide	0.625
Phosphorus pentoxide	0.204
Potassium Oxide	0.076

g) LOSS OF IGNITION TEST

A soil sample extracted from Adekokwok Sub-County was analyzed by Loss on Ignition (LOI) in accordance with the AASHTO T267 test to determine the percentage of organic matter. The LOI test revealed that the soil contains 3.73% organic matter, which is appropriate because, according to the African Standard for Compressed Earth Bricks, the standard is that between 2-4% of the soil's composition is acceptable, standard WD-ARS 1333:2018(E). This is a key factor for the long-term functionality of CEBs. Excess levels of organic matter may lead to a decomposition of the matter as the CEBs undergo the ageing process, thus creating air pockets or voids that may affect the strength of the bricks, making them brittle or liable to crack, hence failing to withstand loads, thus compromising the structure's strength (Ma *et al.*, 2016).

4.2.2 CEMENT KILN DUST PROPERTIES

a) PARTICLE SIZE DISTRIBUTION OF CEMENT KILN DUST

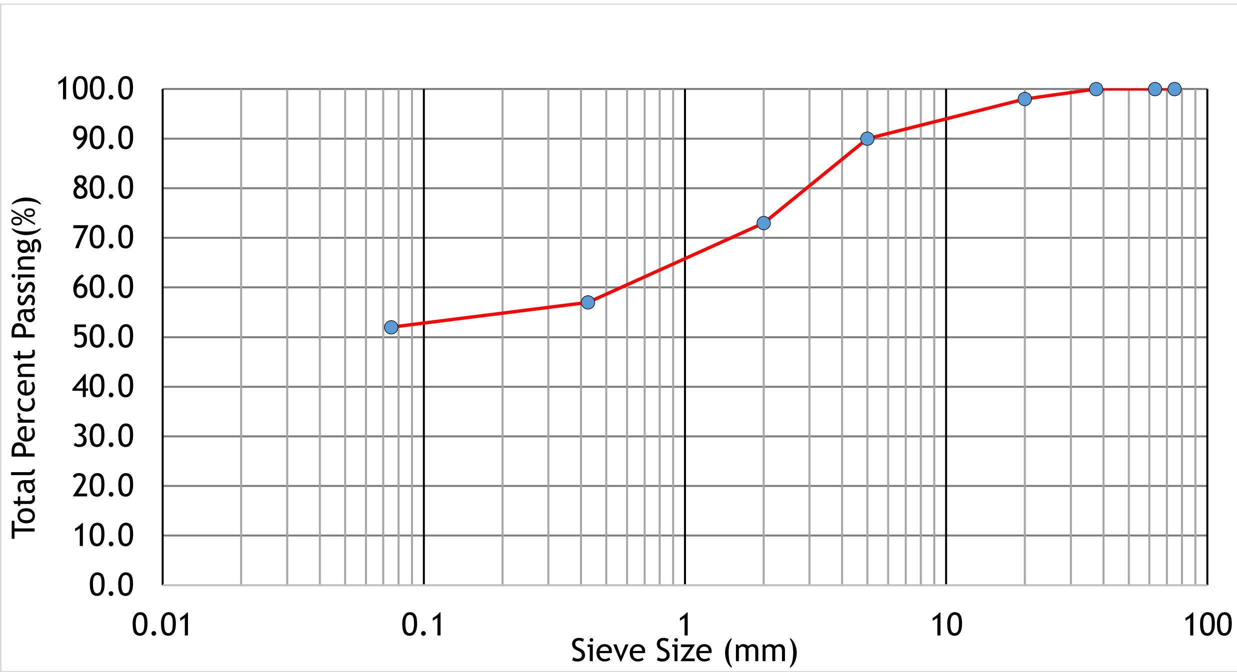


Figure 2: A graph showing the percentage passing against sieve size of a particle size test done in CKD, Hima Cement, Namanve

Cement Kiln Dust (CKD) showed a grading modulus of 0.8. From literature, CKD particles are more than 90% finer than 0.075 mm, and they can be classified as silt-sized particles (Miller et al., 2000). This observation agrees with that of this study, in which CKD consists of mainly very fine particles and very little sand-sized particles. Below is the equation that was used to get it;

$$\text{Grading modulus} = \frac{[300-(90+57+73)]}{100}$$

Grading modulus = 0.8

The fineness of CKD is due to the intensive heating and mechanical action in cement kilns, causing dust generation due to volatilization, breakdown of clinker, and grinding of raw materials. Since CKD is an industrial by-product fine, its particle size distribution curve can be expected to be relatively uniform and steep (Adaska *et al.*, 2008).

b) ATTERBERG LIMIT TEST OF CEMENT KILN DUST

The CKD showed a liquid limit (LL) and plastic limit of 46.3% and 32.6% that gave a plastic index of 13.7%. The CKD demonstrated moderate plasticity and the capability to be molded. Further evidence supporting that CKD causes a substantial decrease in the plasticity of expansive clays, sometimes above 50% at low levels of replacement (even at 5-10%), is given in the work of Zaman and Naji (2013). CKD can be considered an efficient stabilizer due to this property, especially for clay soil types that are beyond the permissible limits of plasticity for brick manufacturing and construction.

c) SPECIFIC GRAVITY OF CEMENT KILN DUST

The specific gravity of the Cement Kiln Dust (CKD) sourced from the Hima Cement Plant, Namanve Industrial Area, was determined using the pycnometer method (AASHTO T100-95), resulting in an average specific gravity of 1.847.

The specific gravity of 1.847 results in a dry density of 1847 kg/m3. This value indicates that the CKD is lighter than conventional cement.

In the context of stabilizing lateritic soil (G_S = 2.705), the introduction of CKD, despite its low specific gravity relative to the soil, is primarily targeted at chemical stabilization through the formation of cementitious gels (Mohamed *et al.*, 2012).

d) CHEMICAL COMPOSITION OF CEMENT KILN DUST

The chemical composition of the Cement Kiln Dust (CKD) obtained from the Hima Cement Plant, Namanve Industrial Park, was analyzed using the X-Ray Fluorescence (XRF) test. The XRF analysis is performed to identify the chemical compounds present in the CKD, specifically focusing on the Calcium Oxide (CaO) content necessary for hydration and the formation of Calcium Silicate Hydrates (C-S-H).

The CKD sample used was specified as pre-calciner dust, chosen for its expected higher free lime content which enhances its reactivity in pozzolanic and stabilization reactions.

Table 4: A table showing the chemical composition of CKD from Hima Cement, Namanve

Parameter	**Results (%m/m)**
Calcium Oxide	64.52
Silicon dioxide	19.73
Aluminum Oxide	11.09
Iron (III) Oxide	2.33
Potassium Oxide	0.96
Titanium dioxide	0.23
Chlorides	0.23
Magnesium (II) Oxide	0.26

The presence of Calcium Oxide (64.52%), Aluminum Oxide (11.09%), Silicon dioxide (19.73%), and Iron (III) Oxide (2.33%) within the CKD are significant as these compounds, together in the right proportions, have the potential to produce cement-like properties. The high CaO content in CKD is crucial because when hydrated, it forms Calcium

Hydroxide **(**$Ca(OH)_2$**)**, which is a reactive alkaline. This reactive lime combines with the silica ions (SiO_2) and aluminum oxide (Al_2O_3) present in the stabilizing agents (CKD and SBA) to form the cementitious Calcium Silicate Hydrate (C-S-H) and Calcium Aluminate Hydrate (C-A-H) gels. The formation of these gels acts as a binder, improving the density, compressive strength, and stability of the soil. The availability of these primary reactive oxides confirms the CKD's suitability to participate in stabilization reactions when combined with SBA, which is rich in silica.

4.2.3 SUGARCANE BAGASSE ASH PROPERTIES

a) PARTICLE SIZE DISTRIBUTION OF SUGARCANE BAGASSE ASH

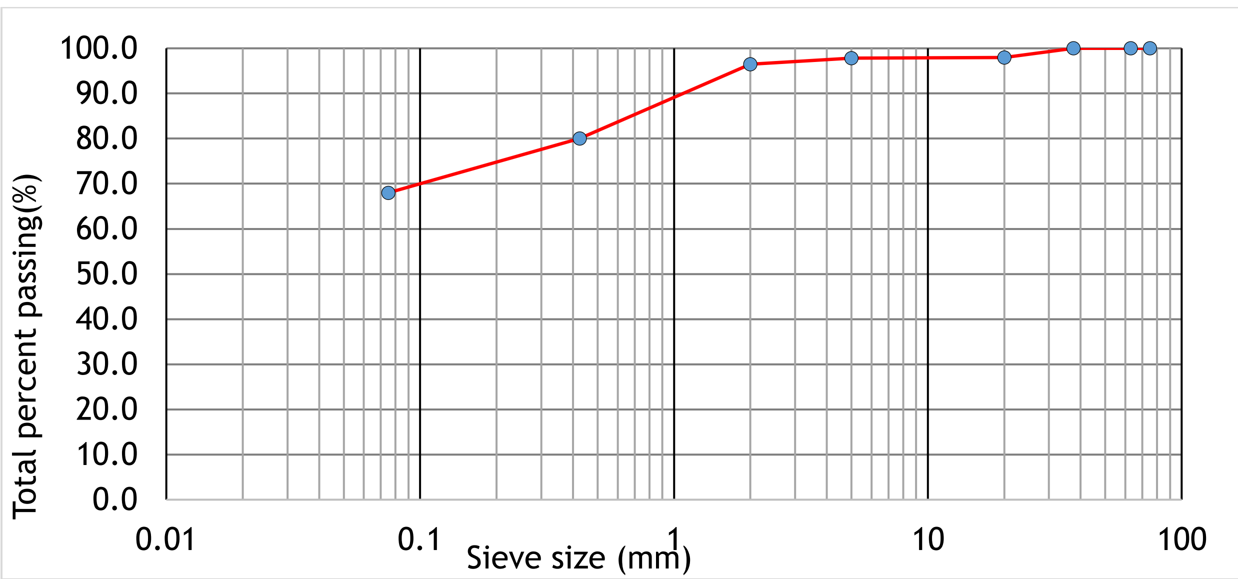


Figure 3: A graph of the percentage passing against the sieve size of SBA from Kakira Sugar Works Limited

The particle size distribution of SBA sample from Kakira Sugar works indicated the dominance of fines, supporting earlier literature observations that SBA contains little or no coarse sand and that it can be classified as a fine-grained pozzolan with a Grading Modulus of 0.69. As shown below (Eqn 3.2);

Grading modulus = 0.69

Fines increase the reactivity and the workability of the mixture when blended with clay or other soil types (Cordeiro *et al.,* 2012). However, the dominance of fines can lead to poor workability or shrinkage in case it is not well mixed with coarser particle admixture such as sand or cement.

The high fineness of SBA indicates its ability to fill the pores in the soil matrix, enhancing particle interlock, and reducing permeability. SBA of fine size can also enhance pozzolanic reaction due to increased surface area, thus contributing to strength gain when used as a partial substituent of cement or as a stabilizer (Frias *et al.*, 2011).

b) ATTERBERG LIMIT OF SUGARCANE BAGASSE ASH

The SBA demonstrated relatively hydrophobic properties, i.e., it is not cohesive on its own. This informed the decision to add CKD before SBA during the mix design. The liquid limit (LL) = 41.7%.

The SBA kept water at the surface and dried quickly, which made it hard to mold on its own. This is due to the highly porous, and rough microstructure that interacts poorly with the water molecules (Janbuala *et al.*, 2019).

4.2.4 SPECIFIC GRAVITY OF SBA

The specific gravity of the Sugarcane Bagasse Ash (SBA) obtained from Kakira Sugar Works was determined using the pycnometer method according to BS 1377: Part 2: 1990. The test involved three sets, yielding individual specific gravity values of 2.12, 2.19, and 2.25. The average specific gravity of the SBA was calculated as 2.19.

This specific gravity value (GSBA =2.19) is relatively low, especially when compared to the specific gravity of the lateritic soil (GS =2.705). This difference aligns with previous observations that SBA typically has a lower specific gravity (e.g., 2.00) compared to soil (e.g., 2.48).

The low specific gravity of SBA has direct implications for the engineering properties of the composite material. As the Sugarcane Bagasse Ash content increases in the soil-Cement Kiln Dust (CKD) mix, the Maximum Dry Density (MDD) of the material tends to decrease, contributing to a lighter material. Furthermore, the addition of SBA generally increases the Optimum Moisture Content (OMC) due to the high specific surface area of its fine particles, demanding more water.

The SBA was also noted to exhibit hydrophobic properties, showing low cohesion and quick drying, which necessitates the introduction of Cement Kiln Dust (CKD) before SBA during the mix design phase. This low specific gravity and high-water demand influence the overall compaction characteristics and density achieved in the final Compressed Earth Bricks (CEBs).

Table 5: A table showing specific gravity results of SBA from Kakira Sugar Works Limited, Jinja

Lab test	SPECIFIC GRAVITY TEST (BS 1377: Part 2: 1990)		
Sample Date	13 Nov 2025		
	Sample 1	Sample 2	Sample 3
Weight of empty pycnometer, W_1 (grams)	435.9	436.5	435.7
Weight of pycnometer and dry sample, W_2 (grams)	486.2	488	487.1
Weight of pycnometer with sample and water, W_3 (grams)	717.5	720.1	719
Weight of pycnometer with water only, W_4 (grams)	676.8	678.3	677.4
Specific gravity of samples	2.12	2.19	2.25
Average specific gravity	2.19		

c) CHEMICAL COMPOSITION OF SUGARCANE BAGASSE ASH

The sugarcane bagasse ash (SBA) was rich in silicon dioxide (SiO_2), measured to be 75.62% by XRF. The high silica content indicates that enough reactive silica can be obtained from the sugarcane bagasse ash to form a C–S–H gel through its hydration, in the presence of cement kiln dust.

Based on ASTM C618, the classification of SBA is a Class N pozzolan. In addition, for materials that belong to this class, a combined percentage of SiO_2, Al_2O_3, and Fe_2O_3 of no less than 70% is required to possess adequate pozzolanic activity. The combined oxide content of the Kakira Sugar Works' SBA was found to be 96.26%, which is well above the required standard.

Table 6: A table showing the chemical suitability of SBA from Kakira Sugar Works Limited, Jinja according to ASTM C618

Parameter	Percentage of parameter	Required standard (ASTM C618)	Closest standard	% deviation	% Suitability
Silica	75.62%	70 - 77	_	0	99.790%
Alumina	14.93%	11 - 13%	13%	14.85%	
Iron Oxide	5.71%	2 - 3%	3%	90.33%	
Lime	1.02%	1 -2%	_	0	
Magnesia	0.25%	> 1%	_	0	

4.2.5 OPTIMAL MIX OF CKD-SOIL COMPOSITE

For three samples chosen at random at the Adekokwok brick laying site, an average weight of the dry mix that enters the brick mold of dimensions 205mm by 150mm by 70mm (these are the dimensions of the brick molds found at the brick laying site). It is 3.12kg.

The three bricks sampled had the following weigh; 2.9847, 3.45, and 2.93kg

Table 7: A table showing the batching portions for a soil-CKD composite with varying percentages of CKD

BATCH NO.	PERCENTAGES	CKD (kg)	SOIL (kg)
C1	0	0.00	3.12
C2	2	0.06	3.06
C3	4	0.12	3.00
C4	6	0.19	2.93
C5	8	0.25	2.87
C6	10	0.31	2.81

a) **COMPRESSIVE STRENGTH OF THE SCEBS WITH VARYING PERCENTAGES OF CKD**

Compressive strength of Stabilized Compressed Earth Bricks (SCEBs) was determined after 7, 14, and 28 days of curing for combinations of different proportions of Cement Kiln Dust (CKD). All materials were batched by weight for uniformity. The proportion of CKD was optimized to provide optimal contents of free lime and reactive silica available in the Sugarcane Bagasse Ash (SBA), since these two components play a vital role in the creation of gels of calcium silicate hydrates (C–S–H) and calcium aluminate hydrates (C–A–H), which are key to strength development (Arif Kamal et al., 2025).

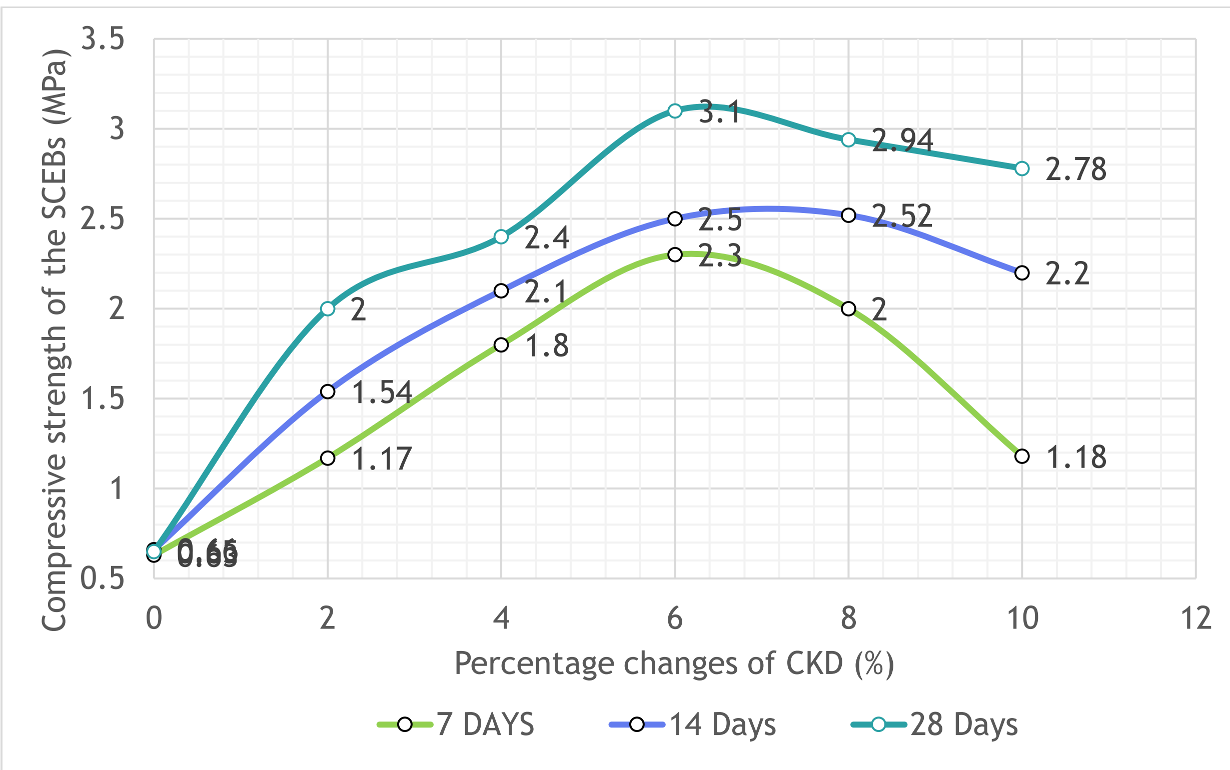


Figure 4: A graph showing the compressive strength of CEBs with varying amounts of CKD

On day 7, there was an increase in compressive strength for every increase in the CKD content from 2% to 6% and then a decrease in compressive strength. The linear regression line that can be obtained from these results is y = 0.082x + 1.1033. Here, there is a constant increase in strength for each unit increase in CKD. Although the value of R^2 is 0.2417, implying that strength at this initial curing stage is explained by only 24.17% of the content of CKD, the initial positive contribution of CKD to hydration or gel formation is recognized.

On day 14, the bricks showed improved compressive strength, where the highest strength was obtained at 6% CKD. The strength increased from 2.3 MPa to 2.5 MPa, a percentage increase of 26.87%, and the regression value increased by 44.4%, hence a greater effect of CKD on the hydration process. These results, therefore, infer that CKD's effect on the formation of binding gels is increasingly evident at this stage of the curing process.

On day 28, the compressive strength showed a relative increase of 24% from the fourteen-day value to 3.1 MPa at 6% CKD. The regression coefficient increased significantly to $R^2 = 0.6993$, indicating that about 70% of the compressive strength variability at this point can be explained by the variation of CKD. This strong correlation is a result of the prolonged curing time, where CKD continues to hydrate and assist in the creation of C–S–H, thus creating a denser and stronger brick matrix (Siddique, 2006). At this point, the linear correlation can be defined by the equation y = 0.2024x + 1.2995, where for every 2% increase in CKD, the compressive strength increases by 0.2024 MPa.

Despite the improvement, the compressive strength of 3.1 MPa at 6% CKD is still short of the desirable strength of 5 MPa for structural compress earth bricks (Sapna et al., 2023). However, this improvement is a step up from the local brick strength of 0.65 MPa, made from unstabilized bricks of Adekokwok, making this result a proof of the efficacy of CKD and SBA additives to improve strength, although probably better proportions can be optimized to cross the threshold. Another thing to note is the correlation between compressive strength and the value of water absorption. It was observed that the brick with a mixture of 6% CKD, which had the highest compressive strength of 28 days, had the lowest value of water absorption.

b) WATER ABSORPTION OF THE SCEBS WITH VARYING PERCENTAGES OF CKD

The brick samples with varying amounts of CKD in 2% increments were subjected to water absorption tests after 28 days of air-drying (Saidou et al., 2025). The water absorption decreased progressively with an increase in CKD and reached its lowest at 5.17% and further increments in CKD lead to an increase in water absorption.

Below is the table showing the % changes in water absorption;

Table 8: A table showing the water absorption and the percentage changes of water absorption of soil-CKD with varying percentages of CKD

BATCH NO.	PERCENTAGE OF CKD (%)	AVERAGE WATER ABSORPTION (%)	% Δ IN WATER ABSORPTION
C1	0	9.550	0.000
C2	2	8.742	-8.456
C3	4	7.957	-16.681
C4	6	5.166	-45.905
C5	8	7.110	-25.546
C6	10	6.830	-28.478

The water absorption test result analysis brings to prominence the influence of CKD on the behavior of stabilized compressed earth bricks concerning humidity. Regression analysis of the result obtains a value of R^2 = 0.5572 for the correlation of the data, meaning that about 55.72% of the result variability can be explained based on the presence of CKD in the mixture. The linear correlation of the result, $y = 0.3324x + 9.111$, shows that for every 2% increase in CKD content, there is a corresponding average decrease of 0.3324% of water absorption. This assumes that the result is due to the ability of CKD to increase the brick's density, from 1382.09 kg/m^3 for the original bricks to 1835.69 kg/m^3 for the CKD-treated bricks. The result shows that the increased density reduces the voids present in the soil, thus decreasing porosity and hence the route for water entry (Mohamed Ali *et al*., 2012).

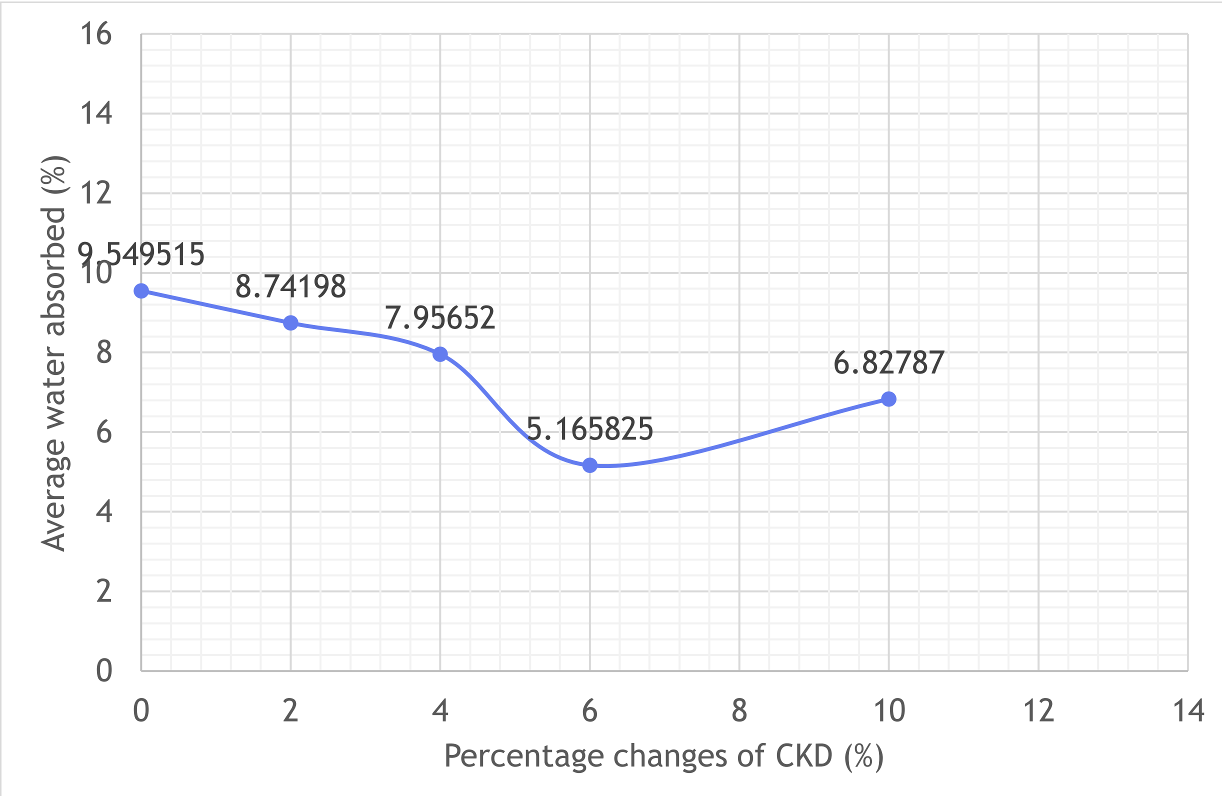


Figure 5: A graph showing the Water absorption of CEBs with varying amounts of CKD after 28 days

However, for CKD above 6%, the trend is inverted, and the presence of 8% and 10% CKD shows higher water absorption. This can be explained by the available reactive silica and alumina, which is less at high percentages of CKD. When these two components become less available, the excess CKD beyond that percentage is less capable of contributing to the formation of C–S–H gels. It is, therefore, postulated that excess CKD can cause porosity to increase rather than decrease, as a percentage of the CKD can be left unreacted and result in microstructural voids.

c) BULK DENSITY OF SCEBS CONTAINING 6% CKD

The bulk density of the SCEB with the optimal mix was measured in three sets after 28 days. The average bulk density of a sample set of three was found to be 1835.6929kgm^{-3} that is 32.82% higher than the average of the CEBs at the Adekokwok brick-laying site (control sample). This demonstrates that CKD produced C-S-H and C-A-H gel that filled up the voids between the earth soil particles, decreasing void ratio and increasing density ((Ghavami et al., 2021).

4.2.6 OPTIMAL MIX OF SCEBS WITH CKD AND SBA

Using the two parameters i.e. compressive strength and water absorption, the CKD- soil composite is maintained with a 6% CKD because it had the highest compressive strength and lowest water absorption among the changing percentages of CKD; hence, it was taken as the optimum.

SBA was added in 5% increments to the optimal mix of CKD-Soil composite mix and cast in a mold of 205mm by 150mm by 70mm to facilitate the hydration to form C-S-H/ C-A-H gel from the free silica in the SBA and the free lime in the CKD (Saidou et al., 2025).

Below is a table showing the batching portions of the CKD-soil composite having 6% CKD and varying amounts of SBA in 5% increments (Janbuala et al., 2018; Saidou et al., 2025).

Table 9: A table showing the batching portions of brick samples with 6% CKD, soil and varying percentages of SBA

BATCH NO.	PERCENTAGES	SBA (kg)	CKD (kg)	SOIL (kg)
CS7	0	0.00	0.22	3.39
CS8	5	0.18	0.21	3.22
CS9	10	0.36	0.19	3.05
CS10	15	0.54	0.18	2.88
CS11	20	0.72	0.17	2.71
CS12	25	0.90	0.16	2.54

a) COMPRESSIVE STRENGTH OF SCEBS WITH 6% CKD AND VARYING AMOUNTS OF SBA

Maintaining the optimal mix of CKD and soil as determined, SBA is added to the dry mix in increments of 5% of the total dry mix containing 6% CKD and soil that is batched by mass (Teddy *et al.*, 2021). This is forming C-S-H and C-A-H gel.

Below is a table showing the highest compressive strength recorded at the batching portions for soil, CKD, and SBA by mass for CEBs for compressive strength tests;

Table 10: A table showing the average compressive strength and the percent increments with varying amounts of SBA

Batch no.	% of SBA	Average compressive strength (MPa)	% Δ of compressive Strength
CS7	0	3.83	0.00
CS8	5	4.70	22.72
CS9	10	5.10	33.16
CS10	15	4.66	21.67
CS11	20	4.40	14.88
CS12	25	4.10	7.05

The result obtained after a curing period of fourteen days shows that the maximum compressive strength was found in bricks made of 6% CKD and 10% SBA. This shows that there is a positive effect provided by the addition of SBA. The linear regression equation, $y = 0.0066x + 3.3462$, along with the value of R^2, that is, 0.0201, shows that the impact of SBA is merely 2.01%, indicating that to improve strength, a relatively larger quantity of SBA was required compared to the reactive CKD.

Chemically, the evolution of strength for these stabilized earth bricks is a two-step process that is linked to the hydration (followed by pozzolanic reactions) of calcium-containing compounds provided by the CKD additions, and a slower pozzolanic reaction of the produced $Ca(OH)_2$ by the reactive silica provided by the SBA. In fact, CKD, especially pre-calciner dust, usually contains high concentrations of free lime and calcium compounds that quickly react to form Ca $(OH)_2$ after hydration. These provide a short-term availability of calcium and basic compounds, promoting early strength formation through the precipitation of calcium aluminate/silicate hydrates (C-A-H and C-S-H). The main role of the added SBA is to take part in a slower pozzolanic reaction, where its amorphous silica is non-cementitious but consumes Ca $(OH)_2$ to form C-S-H. The pozzolanic reaction is slower, being Ca $(OH)_2$-driven; thus, a small dosage of SBA added during early curing periods up to 14 days is reflected only by a weak, noisy magnitude of compressive strength development, hence a poor value of R^2. When the curing time advances, the available concentration of $Ca(OH)_2$ increases, and so is the available time for a slower pozzolanic reaction of a higher concentration of added SBA.

It was observed that higher proportions of SBA above 10% lead to a silica-rich system, thus effectively diluting the calcium sources. Unreacted portions of the SBA act as inert materials, sometimes forming voids or weak boundaries, if unreacted, thus hindering adequate C-S-H formation. These combined phenomena increase the porosity, water capacity, reduced bulk density, poor mechanical locking, and hence reduced compressive strength.

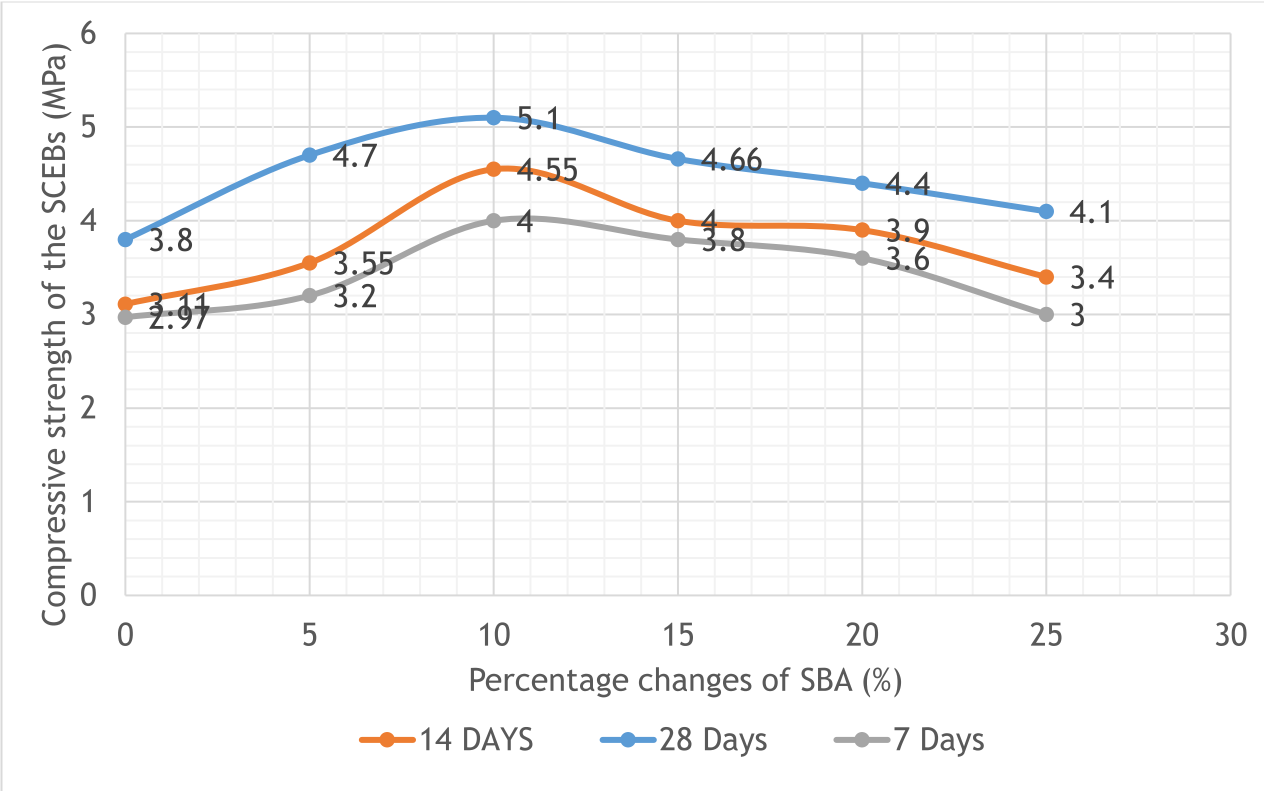


Figure 6: A graph showing the compressive strength of brick samples of 6% CKD with varying amounts of SBA

At 28 days, the bricks had a maximum compressive strength of 5.1 MPa for the same 6% CKD and 10% SBA mixture, representing a 12.08% increase from the previous value at fourteen days. After 10% SBA, there is a reduction in strength due to increased porosity contributed by high percentages of SBA, hence high-water absorption, lower density, and poor mechanical properties (Janbuala *et al.*, 2018). The maximum strength at 6% CKD and 10% SBA corresponded to the lowest value of water absorption, 8.101%, for this blend. The occurrence of maximum compressive strength and concomitant minimum water absorption reveals that the combined percentage of 6% CKD and 10% SBA is the optimal dose of stabilizer for improving strength and durable properties of compressed earth bricks.

b) WATER ABSORPTION OF SCEBS WITH 6% CKD AND VARYING AMOUNTS OF SBA

The addition of sugarcane bagasse ash to the dry mix was found to increase the overall water absorption of the stabilized CEBs. This is because of the natural ability of these materials to increase the porosity of the CEB components. The optimum value of water absorption, taken as the lowest value, increased from 5.17% for CKD-soil to 8.10% for a mixture of 6% CKD and 10% SBA. Despite this increase, the bricks that incorporated both CKD and SBA performed better than the local CEBs produced by the company based at Adekokwok, experiencing a 15.18% decrease in water absorption compared to the non-stabilized CEBs.

This finding coordinates with a 2018 study demonstrating that SBA causes a corresponding increase in porosity, thus enhancing the rate of water absorption. The researchers added that a dosage of SBA above the optimal content may negate its positive impact on compressive strength, as this can generate a high number of pore sites within the brick (Janbuala *et al.,* 2018).

The test for water absorption was carried out on the 28th day to quantify the effect of curing, CKD, and SBA on the durable properties of the stabilized bricks. It is at this point that the hydration compounds, especially C–S–H and C–A–H gels, have developed to a greater extent, to effectively determine the extent to which different proportions of materials affect the reduction of pore spaces. It can thus be inferred that, although SBA increases the pozzolanic properties, its effect on porosity requires optimization to achieve a balance between strength and durability.

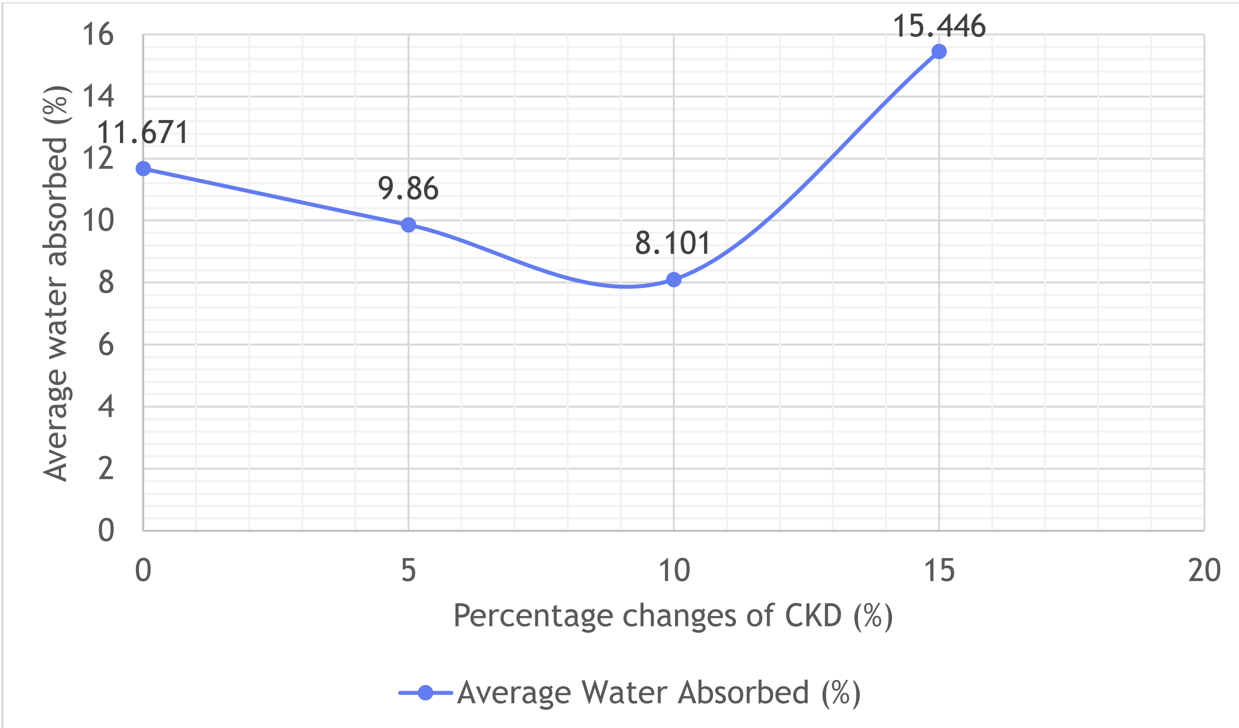


Figure 7: A graph showing the water absorption of CKD-Soil CEBs with varying amounts of SBA.

c) PARTICLE SIZE DISTRIBUTION OF THE OPTIMAL MIX

The combined physical properties of the soil, Cement Kiln Dust (CKD), and Sugarcane Bagasse Ash (SBA) were evaluated through the PSD analysis of the final dry mix, following the BS 1377-2-9 procedure. This combined mix resulted in a grading modulus (GM) of 0.754 and showed that 65.8% of the material passed through the 0.075 mm sieve. Importantly, the resulting GM of 0.754 represents an improvement over the GM of the neat lateritic soil (0.40), indicating enhanced overall grading and better particle packing efficiency due to the incorporation of fine stabilizer materials. The residual fine fraction in the mixture is crucial as the fine particles of CKD and SBA act as fillers, maximizing the interfacial contact points necessary for the hydration and pozzolanic reactions that produce Calcium Silicate Hydrate (C-S-H) and Calcium Aluminate Hydrate (C-A-H) gels. This filler effect and chemical binding mechanism are demonstrated by the increase in the average bulk density of the final CEB product (6% CKD and 10% SBA) to 1690.94 kg/m3, which is a 22.35% increase compared to the control bricks (1382.09 kg/m3). This optimized particle packing and gel formation ultimately result in improved mechanical performance, with the optimal composite achieving a compressive strength of 5.1 MPa, meeting the desired strength standard.

4.2.7 PERFORMANCE OF THE FINAL BRICK PRODUCTS (10% SBA & 6% CKD)

a) BULK DENSITY OF FINAL BRICK PRODUCT

The final bricks were subjected to bulk density to determine the effectiveness of the stabilizers in comparison to the control bricks at Adekokwok brick laying site. The final brick product demonstrated a 22.35% increase in bulk density to 1690.94 kgm^{-3} from 1382.09 kgm^{-3}. This indicates the formation of C-S-H and C-A-H gel that decreases the voids in the earth soil, decreases in air pockets, and facilitates more compaction of the soil (Teddy *et al.,* 2021).

b) BLOCK DROP TEST ON FINAL BRICK PRODUCT

A block drop test carried out on the brick samples with 6% CKD and 10% SBA, was carried out according to BS EN771-1 to determine the robustness and durability of the brick during real life construction. The final brick sample containing the optimal dry mix showed minor edge chipping but remained intact. A few shallow edge hairline cracks formed around the chipped region, with crack thicknesses of approximately 0.3–0.6 mm and depths of 2–4 mm. These cracks followed the natural weak planes in the soil matrix but did not extend across the block.

c) EFFLORESCENCE OF THE FINAL BRICK PRODUCT

The efflorescence increased progressively with an increase in sugarcane bagasse ash. From 5% to 15% addition of SBA, the bricks displayed an average efflorescence of 1.2 to 8.6% that, according to BS EN 771-1, is slight. Further increments in SBA displayed moderate efflorescence. This progressive increase in efflorescence indicates an increase in pathways for moisture containing soluble salts that are naturally occurring in the clay in the earth soil in Adekokwok (A-7-6). This increase in pathways is due to the increase in the porosity brought about by the increase in SBA in the dry mix (Malkapuram *et al.*, 2024).

This test is important because the people in the area are reluctant to plaster their walls. After all, it is considered an unnecessary expense (Nuwagaba, 2020), and considering that efflorescence affects the durability of the brick.

4.3 MIX DESIGN AND DRAWING

4.3.1 MIX DESIGN

The brick dimensions and manufacturing process remained constant (205 × 150 × 70 mm brick size with dry weight of about 3.60 kg), with only the stabilizer proportion being varied while retaining the other parameters (28 days air-drying period) constant.

CKD was added in 2% increments; brick samples were prepared and cured. At each CKD concentration, 7, 14, and 28-day tests were conducted in terms of compressive strength, water absorption, and bulk density, and these parameters used to determine the optimum as 6% CKD.

a) **Illustration of Δ 2% OF CKD in CKD-soil brick samples (Yusef *et al.*, 2023; WD-ARS 1333)**

BATCH NO.	PERCENTAGES	CKD(kg)	SOIL (kg)
C1	0	0	3.60
C2	2	0.07	3.53
C3	4	0.14	3.46
C4	6	0.22	3.38
C5	8	0.29	3.31
C6	10	0.36	3.24

CKD fixed at 6%; SBA in 5% increments from 0-25% - Optimum dosage of both combined: All mixes were analyzed by mass for 28 day compressive strength, water absorption, and density. The compressive strength increased slightly from 3.83 MPa to 5.10 MPa with 10% SBA addition beyond which the strength reduced with further increase in SBA percentage from 15-25%. Water absorption increased beyond CKD alone mix; however, optimized mix with 6% CKD + 10% SBA met the 5 MPa BS strength requirement with higher density and reasonable absorption.

b) **Illustration of Δ 5% of SBA in 6% CKD-soil brick samples (Ndambuki .M *et al*., 2025; WD-ARS 1333)**

BATCH NO.	% OF SBA	SBA (kg)	CKD (kg)	SOIL (kg)
CS7	0	0.00	0.22	3.39
CS8	5	0.18	0.21	3.22
CS9	10	0.36	0.19	3.05
CS10	15	0.54	0.18	2.88
CS11	20	0.72	0.17	2.71
CS12	25	0.90	0.16	2.54

c) **Final dry mix of SCEBs containing CKD & SBA (Ndambuki .M *et al*., 2025; WD-ARS 1333)**

MATERIAL	AMOUNT (kg)	% IN DRY MIX BY MASS
SOIL	3.05	84.67 ≈ 85%
SBA	0.36	9.995 ≈ 10%
CKD	0.19	5.40 ≈ 5%

CKD: SBA: SOIL = 5: 10: 85

Dividing by the lowest common factor of 5;

CKD: SBA: SOIL = $\frac{5}{5} : \frac{10}{5} : \frac{85}{5}$

CKD: SBA: SOIL = 1: 2: 17

4.3.2 FINDINGS

The soil used in this study was classified as A-7-6(18), indicating a clayey material with a fineness modulus of 1.11. Its organic matter content was 3.71%, which falls within the acceptable range specified by the WD ARS–1333 standard for Stabilized Compressed Earth Blocks (SCEBs). Both Sugarcane Bagasse Ash (SBA) and Cement Kiln Dust (CKD) met the requirement of a combined oxide content exceeding 70%, confirming their suitability for pozzolanic reactions.

The optimal dry mix for stabilizing the earth soil with CKD alone was achieved at 6% CKD, resulting in a water absorption of 5.17% and a compressive strength of 3.1 MPa. When SBA was incorporated, the ideal mix consisted of 6% CKD and 10% SBA, which produced a water absorption of 8.10% and a compressive strength of 5.1 MPa.

The final brick products made with the 6% CKD and 10% SBA blend demonstrated moderate efflorescence, along with a 22.35% increase in bulk density, indicating improved compactness and structural integrity.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

In conclusion, the data obtained indicates that the addition of 6% CKD and 10% SBA significantly improves the engineering properties of the CEBs. The mixture resolved a compressive strength of 5.1 MPa compared to the 0.65 MPa exhibited by locally manufactured unstabilized bricks. This not only met but also surpassed the standard compressive strength of 5 MPa outlined in BS 3921:1985.

The improvement in the performance is attributable to the pozzolanic reaction between the silica-rich SBA and the calcium-rich CKD. This reaction promoted the formation of gels of Calcium Silicate Hydrate (C-S-H) and Calcium Aluminate Hydrate (C-A-H), leading to the densification of the soil. Further, there was as been an improvement in the brick's properties in terms of density increase by 22.35% and reduction in water absorption from 9.55% to 8.10%. According to BS 3921:1985, these CEBs are recommended for use in the construction of load-bearing walls as a masonry unit.

5.2 RECOMMENDATION

This research could be expanded on by academicians and students to determining other pozzolanic materials and mechanical methods of stabilizing CEBs in Adekokwok sub-county for suitable brick making.

In addition, further research can be done on optimization to reduce porosity and water absorption in SCEBs. Although the 6% CKD + 10% SBA mix achieved satisfactory compressive strength and met the BS 3921:1985 requirement for load-bearing masonry units, the bricks still exhibited notable residual porosity and moderate water absorption levels. Finally, further research can be done on the long-term durability of these stabilized compressed earth bricks with the optimal 10% SBA + 6% CKD mix.

REFERENCES

i) . N, S., Senthil, T.S., Kumaravel, V., 2019. Fabrication of Hydrophobic Coatings Using Sugarcane Bagasse Waste Ash as Silica Source. Applied Sciences 9, 190. https://doi.org/10.3390/app9010190

ii) Arif Kamal, M., Chinna Saidulu, H., 2025. Exploratory Study of Calcium Silicate Bricks as a Potential Material for Building Construction. American Journal of Civil Engineering and Architecture 13, 13–18. https://doi.org/10.12691/ajcea-13-1-3

iii) Brooks, N., Biswas, D., Maithel, S., Miller, G., Mahajan, A., Uddin, M.R., Ahmed, S., Mahzab, M., Rahman, M., Luby, S.P., 2025. Reducing emissions and air pollution from informal brick kilns: Evidence from Bangladesh. Science (1979) 388. https://doi.org/10.1126/science.adr7394

iv) Compressed stabilized earth blocks-Requirements, production and construction, 2018.

v) Ghavami, S., Naseri, H., Jahanbakhsh, H., Moghadas Nejad, F., 2021. The impacts of nano-SiO2 and silica fume on cement kiln dust-treated soil as a sustainable cement-free stabilizer. Constr Build Mater 285, 122918. https://doi.org/10.1016/J.CONBUILDMAT.2021.122918

vi) Heath, A.C., Pestana, J.M., Harvey, J.T., Bejerano, M.O., 2004. Draft: Normalizing the Behavior of Unsaturated Granular Pavement Materials.

vii) Jackson, P., Hale, A., Bonnett, G., Lakshmanan, P., 2014. Sugarcane, in: Pratap, A., Kumar, J. (Eds.), Alien Gene Transfer in Crop Plants, Volume 2: Achievements and Impacts. Springer New York, New York, NY, pp. 317–345. https://doi.org/10.1007/978-1-4614-9572-7_14

viii) Jahanzaib Khalil, M., Aslam, M., Ahmad, S., 2021. Utilization of sugarcane bagasse ash as cement replacement for the production of sustainable concrete – A review. Constr Build Mater 270, 121371. https://doi.org/10.1016/J.CONBUILDMAT.2020.121371

ix) Janbuala, S., Eambua, M., Satayavibul, A., Nethan, W., 2018. Effect of bagasse and bagasse ash levels on properties of pottery products. Heliyon 4, e00814. https://doi.org/https://doi.org/10.1016/j.heliyon.2018.e00814

x) Kamusiime, S., 2019. Investigation of the effect of bagasse from sugarcane varieties on power production. Makerere University.

xi) Ma, C., Chen, B., Chen, L., 2016. Effect of organic matter on strength development of self-compacting earth-based construction stabilized with cement-based composites. Constr Build Mater 123, 414–423. https://doi.org/10.1016/J.CONBUILDMAT.2016.07.018

xii) Malkapuram, D., Ballari, S.O., Chinta, S., Rajasekaran, P., Venkatesan, B., Vellingiri, S., Paulraj, P., Ramaswamy, A., Ramamurthy, D., Salam, F.A., Varma, U.D.S.P., 2024. Mechanical, water absorption, efflorescence, soundness, and morphological analysis of hybrid brick composites. Matéria (Rio de Janeiro) 29, e20240179. https://doi.org/10.1590/1517-7076-RMAT-2024-0179

xiii) Maslehuddin, M., Al-Amoudi, O.S.B., Shameem, M., Rehman, M.K., Ibrahim, M., 2008. Usage of cement kiln dust in cement products – Research review and preliminary investigations. Constr Build Mater 22, 2369–2375. https://doi.org/10.1016/J.CONBUILDMAT.2007.09.005

xiv) Megawati, Fardhyanti, D.S., Artanti Putri, R.D., Fianti, O., Simalango, A.F., Akhir, A.E., 2018. Synthesis of Silica Powder from Sugar Cane Bagasse Ash and Its Application as Adsorbent in Adsorptive-distillation of Ethanol-water Solution, in: MATEC Web of Conferences. EDP Sciences. https://doi.org/10.1051/matecconf/201823702002

xv) Miller, G.A., Azad, S., 2000. Influence of soil type on stabilization with cement kiln dust. Constr Build Mater 14, 89–97. https://doi.org/10.1016/S0950-0618(00)00007-6

xvi) Mohamed Ali, M., Yang, H.-S., 2012. Utilization of Cement Kiln Dust in Industry Cement Bricks: Geosystem Engineering. https://doi.org/10.1080/12269328.2011.10541327

xvii) Moses Mumpembe, N., Lawrence, M., Michael, K., 2020. Assessment of Artisan Clay Bricks for Structural Strength, Chemical Stability, and Durability. Journal of Civil, Construction and Environmental Engineering 5, 178. https://doi.org/10.11648/j.jccee.20200506.15

xviii) Nnadi, H.C., Ossai, O.G., Nwokocha, V.C., 2024. Urbanization factors and the vagaries of the rural health care industry in Nigeria: an analysis of the accessibility of healthcare services by older adults in the Nsukka Local Government Area. Humanit Soc Sci Commun 11. https://doi.org/10.1057/s41599-024-03799-4

xix) Nuwagaba, H.Mwesigye, 2020. Opportunities for affordable construction in Uganda using locally available materials.

xx) Saidou, A.A., Abongo, K., M'tulatia, M., 2025. Effect of Cement Kiln Dust and Sugarcane Bagasse Ash on Black Cotton Soil to be used as Road Subgrade Material in Flexible Pavement Construction. Engineering, Technology and Applied Science Research 15, 21076–21085. https://doi.org/10.48084/etasr.9902

xxi) Sapna, A., Anbalagan, C., 2023. Sustainable Eco-Friendly Building Material – A Review Towards Compressed Stabilized Earth Blocks and Fire Burnt Clay Bricks. IOP Conf Ser Earth Environ Sci 1210, 12023. https://doi.org/10.1088/1755-1315/1210/1/012023

xxii) Siddique, R., 2006. Utilization of cement kiln dust (CKD) in cement mortar and concrete—an overview. Resour Conserv Recycl 48, 315–338. https://doi.org/10.1016/J.RESCONREC.2006.03.010

xxiii) Singh, S.K., Srivastava, R.K., John, S., 2008. Settlement characteristics of clayey soils contaminated with petroleum hydrocarbons. Soil Sediment Contam 17, 290–300. https://doi.org/10.1080/15320380802007028

xxiv) Teddy, Z., Annette, B., Ainomugisha, S., 2021. Blending lime with sugarcane bagasse ash for stabilizing expansive clay soils in subgrade. Journal of Engineering and Technological Sciences 53. https://doi.org/10.5614/j.eng.technol.sci.2021.53.5.10

xxv) Thomas, B.S., Yang, J., Bahurudeen, A., Abdalla, J.A., Hawileh, R.A., Hamada, H.M., Nazar, S., Jittin, V., Ashish, D.K., 2021. Sugarcane bagasse ash as supplementary cementitious material in concrete – a review. Materials Today Sustainability 15, 100086. https://doi.org/10.1016/J.MTSUST.2021.100086

xxvi) Tjebane, M., Musonda, I., Onososen, A., Ramabodu, M., 2023. Challenges for the Implementation of Sustainable Construction Practices in Developing Countries: A Bibliometric Review. pp. 109–123. https://doi.org/10.1007/978-3-031-32515-1_9

xxvii) Wang, Y.A.-N.H., 2025. Unfired Bricks from Wastes: A Review of Stabiliser Technologies, Performance Metrics, and Circular Economy Pathways. EBSCO Buildings (2075-5309), 2025, Vol 15, Issue 11, p1861 15, 1861.

APPENDIX: A SUMMARY OF LABARATORY TEST RESULTS

7.1 PHYSICAL, MECHANICAL, AND CHEMICAL PROPERTIES OF THE EARTH SOIL, CKD, AND SBA

7.1.1 EARTH SOIL

Table 11: A table showing a summary of the lab results for earth soil, Adekokwok sub-county, Lira district

Material	Characteristic	Parameter	Value obtained
Earth soil	Physical	Grading modulus (BS 1377: Part 2: 1990)	0.40
		Soil Classification (AASHTO method)	A-7-6(18)
		FM	1.11
		Free swell Index	28%
		Plastic Limit	23.7%
		Plastic Index	21.6%
		Liquid Limit	45.3%
		Specific Gravity	2.705
	Chemical	Loss Of Ignition (OM)	3.73%
		Silica	37.39%
		Alumina	12.67%
		Calcium Oxide	6.38%
		Magnesia	1.66%
		Iron Oxide	39.26%

7.1.2 CKD

Table 12: A table showing a summary of the lab results for Cement Kiln Dust, Namanve Industrial Area

Material	Characteristic	Parameter	Value obtained
Cement kiln dust	Physical	Grading modulus	0.8
		Liquid Limit	46.3%
		Plastic Limit	32.6%
		Plastic Index	13.7%
		Specific Gravity	1.847
	Chemical	Silica	19.73%
		Alumina	11.09%
		Calcium Oxide	64.52%
		Magnesia	0.26%
		Iron Oxide	2.33%

7.1.3 SBA

Table 13: A table showing a summary of the lab results for SBA, Kakira Sugar Works

Material	Characteristic	Parameter	Value obtained
Sugarcane bagasse ash	Physical	Grading modulus	0.69%
		Liquid Limit	41.7%
		Plastic Limit	Non plastic
		Plastic Index	
		Specific Gravity	2.19
	Chemical	Silica	75.62%
		Alumina	14.93%
		Calcium Oxide	1.02%
		Magnesia	0.25%
		Iron Oxide	5.71%

7.1.4 PERFORMANCE OF FINAL BRICK PRODUCT

Table 14: A table showing a summary of the lab results for brick products

Material	Characteristic	Parameter	Value obtained
6% CKD + Soil	Physical	Compressive strength	3.1 MPa
		Water absorption	5.17%
		Bulk density	1835.69kgm^{-3}
6% CKD+ 10% SBA + Soil	Physical	Water absorption	8.10%
		Compressive strength	5.1 MPa
		Bulk density	1690.94kgm^{-3}
		Efflorescence	1.2% – 8.6%
		Grading modulus	0.75

APPENDIX B: SAMPLES AND LAB TESTS SCANS

Figure 8: An image of the soil, SBA, and CKD in batching portions.

Figure 9: An image of the compression test on brick samples

Figure 10: An image of the Particle Size Distribution test

Figure 11: An image of a brick sample with 20% SBA & 6% CKD being weighed

.

	
Figure 12: An image of the block drop test in progress	**Figure 13:** An image of the final brick product with 10% SBA & 6% CKD

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

GEO-MATERIALS LABORATORY

TEST REPORT

Certificate Number: Test 046		
Client Name: Ebal Goodluck Jonathan, M22B32/012 Chemtai Emson Kalenjin, M22B32/041	**Sample Receipt Date:** 10/10/2025	**Analysis Start Date:** 13/10/2025 - 21/11/2025
Client Address & Contact Physical Address: Uganda Christian University Client Status: Students Phone No.: N/A Email: N/A	**Date of Analysis Completion:** 21/11/2025	**Date of issue of the Certificate:** 25/11/2025
Client Sample ID	**Tests conducted:**	
N/A	Compressive strength test, Water absorption test, Specific gravity test, Bulk density and Block drop test	
Sample type and location:	Compressed Earth Brick	Adekokwok
	Cement Kiln Dust	Hima Cement Plant, Namanve
	Sugarcane Bagasse Ash	Kakira Sugar Works Limited, Jinja
State of the sample on delivery:	1. Compressed Earth Brick The sample was received as intact solid blocks, uniformly shaped and properly cured. The bricks arrived clean, dry and free from visible cracks, excessive surface defects or contamination. 2. Cement Kiln Dust The sample was delivered as a fine, dry powder, light grey in color stored in a sealed moisture-proof bag. The CKD arrived free-flowing. No foreign materials or impurities were visually detected. 3. Sugarcane Bagasse Ash The sample was received as a finely divided ash material, dark grey to black in color, contained in a clean, airtight container. The ash appeared dry with no clumping. The sample showed no evidence of moisture, odor or contamination.	

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY

A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

TEST RESULTS

1. **BULK DENSITY CONTROL (BS EN771-1)**

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT		
LAB TEST	BULK DENSITY (BS EN771-1)		
SAMPLE TYPE	COMRESSED EARTH BRICKS (6% CKD) WITH VARYING AMOUNTS OF SBA AT 28 DAYS		
SAMPLE DATE	11-Nov-25		
SAMPLE TEST DATE	12-Nov-25		
NO.	Sample 1	Sample 2	Sample 3
DIMENSIONS (mm)	0.200 x 0.148 x 0.070	0.205 x 0.152 x 0.072	0.202 x 0.150 x 0.069
VOLUME (m^3)	0.0021	0.0022	0.0021
DRY MASS (kg)	2.8352	3.1000	2.9190
BULK DENSITY (kg/m^3)	1368.34	1381.76	1396.18
AVERAGE BULK DENSITY (kg/m^3)	1382.09		

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

2. **BULK DENSITY SOIL+CKD (BS EN771-1)**

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT		
LAB TEST	BULK DENSITY (BS EN771-1)		
SAMPLE TYPE	COMRESSED EARTH BRICKS AND CKD		
SAMPLE DATE	11-Nov-25		
SAMPLE TEST DATE	12-Nov-25		
NO.	Sample 1	Sample 2	Sample 3
DIMENSIONS (mm)	0.200 x 0.148 x 0.070	0.205 x 0.152 x 0.072	0.202 x 0.150 x 0.069
VOLUME (m^3)	0.0021	0.0022	0.0021
DRY MASS (kg)	3.892	3.82	3.82
BULK DENSITY (kg/m^3)	1878.38	1704.46	1704.46
AVERAGE BULK DENSITY (kg/m^3)	1835.69		

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

3. BULK DENSITY SOIL+CKD+SBA (BS EN771-1)

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT		
LAB TEST	BULK DENSITY (BS EN771-1)		
SAMPLE TYPE	COMRESSED EARTH BRICKS (6% CKD) WITH VARYING AMOUNTS OF SBA AT 28 DAYS		
SAMPLE DATE	11-Nov-25		
SAMPLE TEST DATE	12-Nov-25		
NO.	Sample 1	Sample 2	Sample 3
DIMENSIONS (mm)	0.200 x 0.148 x 0.070	0.205 x 0.152 x 0.072	0.202 x 0.150 x 0.069
VOLUME (m^3)	0.0021	0.0022	0.0021
DRY MASS (kg)	3.8230	3.4620	3.5230
BULK DENSITY (kg/m^3)	1844.69	1543.11	1685.08
AVERAGE BULK DENSITY (kg/m^3)	1690.94		

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY

A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

4. COMPRESSIVE STRENGTH TEST CKD (BS:3921-1985)

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT						
LAB TEST	COMPRESSIVE STRENGTH TEST (BS:3921-1985)						
SAMPLE TYPE	COMPRESSED EARTH BRICKS WITH VARYING AMOUNTS OF CEMENT KILN DUST						
SAMPLE DATE	7-Oct-25						
SAMPLE TEST DATE							
BATCH NO.	**% OF CKD**	**CASTING DATE**	**TESTING DATE**	**DURATION**	**DIMENSIONS (mm)**	**COMPRESSIVE STRENGTH (MPa)**	**AVERAGE COMPRESSIVE STRENGTH**
C1 (CONTROL)	0	7-Oct-25	14-Oct-25	7 Days	205 x 150 x 70	0.47	0.63
		7-Oct-25	14-Oct-25		205 x 150 x 70	0.79	
		7-Oct-25	21-Oct-25	14 Days	205 x 150 x 70	0.59	0.66
		7-Oct-25	21-Oct-25		205 x 150 x 70	0.73	
		7-Oct-25	4-Nov-25	28 Days	205 x 150 x 70	0.52	0.65
		7-Oct-25	4-Nov-25		205 x 150 x 70	0.78	
C2	2	7-Oct-25	14-Oct-25	7 Days	205 x 150 x 70	1.05	1.17
		7-Oct-25	14-Oct-25		205 x 150 x 70	1.29	
		7-Oct-25	21-Oct-25	14 Days	205 x 150 x 70	1.42	1.54
		7-Oct-25	21-Oct-25		205 x 150 x 70	1.66	
		7-Oct-25	4-Nov-25	28 Days	205 x 150 x 70	1.70	2.00
		7-Oct-25	4-Nov-25		205 x 150 x 70	2.30	

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

C3	4	7-Oct-25	14-Oct-25	7 Days	205 x 150 x 70	1.60	1.80
		7-Oct-25	14-Oct-25		205 x 150 x 70	2.00	
		7-Oct-25	21-Oct-25	14 Days	205 x 150 x 70	1.90	2.10
		7-Oct-25	21-Oct-25		205 x 150 x 70	2.30	
		7-Oct-25	4-Nov-25	28 Days	205 x 150 x 70	2.25	2.40
		7-Oct-25	4-Nov-25		205 x 150 x 70	2.55	
C4	6	7-Oct-25	14-Oct-25	7 Days	205 x 150 x 70	2.10	2.30
		7-Oct-25	14-Oct-25		205 x 150 x 70	2.50	
		7-Oct-25	21-Oct-25	14 Days	205 x 150 x 70	2.35	2.50
		7-Oct-25	21-Oct-25		205 x 150 x 70	2.65	
		7-Oct-25	4-Nov-25	28 Days	205 x 150 x 70	2.95	3.10
		7-Oct-25	4-Nov-25		205 x 150 x 70	3.25	
C5	8	7-Oct-25	14-Oct-25	7 Days	205 x 150 x 70	1.85	2.00
		7-Oct-25	14-Oct-25		205 x 150 x 70	2.15	
		7-Oct-25	21-Oct-25	14 Days	205 x 150 x 70	2.40	2.52
		7-Oct-25	21-Oct-25		205 x 150 x 70	2.64	
		7-Oct-25	4-Nov-25	28 Days	205 x 150 x 70	2.80	2.94
		7-Oct-25	4-Nov-25		205 x 150 x 70	3.08	
C6	10	7-Oct-25	14-Oct-25	7 Days	205 x 150 x 70	1.05	1.18
		7-Oct-25	14-Oct-25		205 x 150 x 70	1.31	
		7-Oct-25	21-Oct-25	14 Days	205 x 150 x 70	2.05	2.20
		7-Oct-25	21-Oct-25		205 x 150 x 70	2.35	
		7-Oct-25	4-Nov-25	28 Days	205 x 150 x 70	2.65	2.78
		7-Oct-25	4-Nov-25		205 x 150 x 70	2.91	

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

5. **COMPRESSIVE STRENGTH TEST CEB+CKD+SBA (BS:3921-1985)**

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT						
LAB TEST	COMPRESSIVE STRENGTH TEST (BS:3921-1985)						
SAMPLE TYPE	COMRESSED EARTH BRICKS (6% CKD) WITH VARYING AMOUNTS OF SBA AT 28 DAYS						
SAMPLE DATE	7-Oct-25						
SAMPLE TEST DATE							
BATCH NO.	**% OF CKD**	**CASTING DATE**	**TESTING DATE**	**DURATION**	**DIMENSIONS (mm)**	**COMPRESSIVE STRENGTH (MPa)**	**AVERAGE COMPRESSIVE STRENGTH**
CS7	0	14-Oct-25	21-Oct-25	7 Days	205 x 150 x 70	2.85	2.97
		14-Oct-25	21-Oct-25		205 x 150 x 70	3.09	
		14-Oct-25	28-Oct-25	14 Days	205 x 150 x 70	2.98	3.11
		14-Oct-25	28-Oct-25		205 x 150 x 70	3.24	
		14-Oct-25	11-Nov-25	28 Days	205 x 150 x 70	3.70	3.83
		14-Oct-25	11-Nov-25		205 x 150 x 70	3.96	
CS8	5	14-Oct-25	21-Oct-25	7 Days	205 x 150 x 70	3.05	3.20
		14-Oct-25	21-Oct-25		205 x 150 x 70	3.35	
		14-Oct-25	28-Oct-25	14 Days	205 x 150 x 70	3.40	3.55
		14-Oct-25	28-Oct-25		205 x 150 x 70	3.70	
		14-Oct-25	11-Nov-25	28 Days	205 x 150 x 70	4.55	4.70
		14-Oct-25	11-Nov-25		205 x 150 x 70	4.85	

UGANDA CHRISTIAN UNIVERSITY
H.O.D.
27 NOV 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

CS9	10	14-Oct-25	21-Oct-25	7 Days	205 x 150 x 70	3.85	4.00
		14-Oct-25	21-Oct-25		205 x 150 x 70	4.15	
		14-Oct-25	28-Oct-25	14 Days	205 x 150 x 70	4.40	4.55
		14-Oct-25	28-Oct-25		205 x 150 x 70	4.70	
		14-Oct-25	11-Nov-25	28 Days	205 x 150 x 70	4.95	5.10
		14-Oct-25	11-Nov-25		205 x 150 x 70	5.25	
CS10	15	14-Oct-25	21-Oct-25	7 Days	205 x 150 x 70	3.65	3.80
		14-Oct-25	21-Oct-25		205 x 150 x 70	3.95	
		14-Oct-25	28-Oct-25	14 Days	205 x 150 x 70	3.80	4.00
		14-Oct-25	28-Oct-25		205 x 150 x 70	4.20	
		14-Oct-25	11-Nov-25	28 Days	205 x 150 x 70	4.50	4.66
		14-Oct-25	11-Nov-25		205 x 150 x 70	4.82	
CS11	20	14-Oct-25	21-Oct-25	7 Days	205 x 150 x 70	3.45	3.60
		14-Oct-25	21-Oct-25		205 x 150 x 70	3.75	
		14-Oct-25	28-Oct-25	14 Days	205 x 150 x 70	3.75	3.90
		14-Oct-25	28-Oct-25		205 x 150 x 70	4.05	
		14-Oct-25	11-Nov-25	28 Days	205 x 150 x 70	4.25	4.40
		14-Oct-25	11-Nov-25		205 x 150 x 70	4.55	
CS12	25	14-Oct-25	21-Oct-25	7 Days	205 x 150 x 70	2.85	3.00
		14-Oct-25	21-Oct-25		205 x 150 x 70	3.15	
		14-Oct-25	28-Oct-25	14 Days	205 x 150 x 70	3.25	3.40
		14-Oct-25	28-Oct-25		205 x 150 x 70	3.55	
		14-Oct-25	11-Nov-25	28 Days	205 x 150 x 70	3.95	4.10
		14-Oct-25	11-Nov-25		205 x 150 x 70	4.25	

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

6. WATER ABSORPTION CEB WITH SOIL & CKD (BS:3921-1985)

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRES[illegible]ICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT				
LAB TEST	WATER ABSORPTION TEST (EN 1996-2:2006)				
SAMPLE TYPE	WATER ABSORPTION OF CKD-SOIL CEBs				
SAMPLE DATE	11-Nov-25				
SAMPLE TEST DATE	12-Nov-25				
VOLUME (m³)		**DIMENSIONS**			**BULK DENSITY (kg/m³)**
0.0021525		205mm x 150mm x 70mm			1690.924
BATCH NO.	**PERCENTAGE OF SBA (%)**	**Dry Mass (kg)**	**Wet Mass After 24hrs (kg)**	**Water Absorbed (%)**	**Average Water Absorbed (%)**
C1	0	3.02	3.39	11.20	9.55
		2.71	3.00	7.89	
C2	2	2.81	3.14	9.14	8.74
		3.07	3.34	8.34	
C3	4	3.15	3.46	9.88	7.96
		2.74	2.96	6.03	
C4	6	2.72	2.93	5.84	5.17
		2.81	2.97	4.49	
C5	8	2.71	3.00	7.89	7.11
		2.80	3.03	6.33	

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY

A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

C6	10	2.97	3.25	8.23	6.83
		2.81	3.00	5.42	

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

7. **WATER ABSORPTION CKD+SBA (BS:3921-1985)**

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT				
LAB TEST	WATER ABSORPTION TEST (EN 1996-2:2006)				
SAMPLE TYPE	WATER ABSORPTION OF CKD-SOIL CEBs WITH VARYING AMOUNTS OF SBA				
SAMPLE DATE	11-Nov-25				
SAMPLE TEST DATE	12-Nov-25				
VOLUME (m^3)		**DIMENSIONS**			**BULK DENSITY (kg/m^3)**
0.0021525		205mm x 150mm x 70mm			1690.924
BATCH NO.	**PERCENTAGE OF SBA (%)**	**Dry Mass (kg)**	**Wet Mass After 24hrs (kg)**	**Water Absorbed (%)**	**Average Water Absorbed (%)**
CS7	0	2.98	3.52	16.09	11.67
		3.09	3.32	7.25	
CS8	5	3.06	3.30	7.34	9.86
		2.75	3.20	12.38	
CS9	10	2.89	3.20	9.09	8.10
		3.04	3.27	7.11	
CS10	15	2.96	3.33	10.98	15.45
		2.72	3.45	19.91	
CS11	20	3.11	Crumbled	Crumbled	N/A
		2.84	Crumbled	Crumbled	

UGANDA CHRISTIAN UNIVERSITY

A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

CS12	25	2.90	Crumbled	Crumbled	N/A
		2.68	Crumbled	Crumbled	

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025 *
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY

A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

8. BLOCK DROP TEST (BS EN771-1.)

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT		
LAB TEST	BLOCK DROP TEST (BS EN771-1.)		
SAMPLE TYPE	COMPRESSED EARTH BRICKS CONTAINING 6% CKD & VARYING AMOUNTS OF SBA		
SAMPLE DATE	–		
SAMPLE TEST DATE	13-Nov		
VOLUME (m^3)		**DIMENSIONS**	**BULK DENSITY (kg/m^3)**
0.0021525		205mm x 150mm x 70mm	1690.924
BATCH NO.	% OF SBA	DESCRIPTION	
CS7	0	The brick maintained its structural integrity with no visible cracking. Only negligible surface bruising was observed, with slight corner abrasion of less than 1 mm depth. There were no measurable cracks, and the block remained fully intact after impact.	
CS8	5	The brick kept its structural integrity with no major cracks; however, very fine surface micro-lines formed on the impacted face. These were extremely small, with crack thicknesses ranging between about 0.1–0.2 mm and shallow depths less than 1 mm. The cracks were non-propagating, indicating minor cosmetic damage only.	
CS9	10	The brick showed minor edge chipping but remained intact. A few shallow edge hairline cracks formed around the chipped region, with crack thicknesses of approximately 0.3–0.6 mm and depths	

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

		of 2–4 mm. These cracks followed the natural weak planes in the soil matrix but did not extend across the block.
CS10	15	Noticeable damage occurred after the drop, though the brick still retained its form without complete failure. The affected surfaces exhibited irregular, non-linear cracks typically found in unfired earth blocks under impact. These cracks had thicknesses of around 0.8–1.2 mm, penetrating to depths of about 4–7 mm. Corner crushing was visible, with approximately 3–5 mm of material lost.
CS11	20	At this level of SBA, the brick showed reduced impact resistance. Opening cracks developed along edges and across the impact face, with measured crack widths between 1.5–2.5 mm and depths of *8–12 mm. Partial disintegration occurred where material loosened and small* chunks, up to 10 mm in size, detached from the corners
CS12	25	The brick displayed poor mechanical stability upon impact. Instead of clean fractures, the block developed wide crumbling fissures characteristic of weak unfired earth material. The fissures had crack thicknesses ranging from 3–4 mm and extended 12–20 mm deep. Major corner failure occurred, with 15–25 mm of material breaking away, and the block partly shattered.

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025 *
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

9. SPECIFIC GRAVITY TEST (BS 1377: Part 2: 1990)

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT		
LAB TEST	SPECIFIC GRAVITY TEST (BS 1377: Part 2: 1990)		
SAMPLE TYPE	SUGARCANE BAGASSE ASH		
LOCATION OF SAMPLE COLLECTION	KAKIRA SUGAR WORKS		
SAMPLE DATE	13-Nov-25		
SAMPLE TEST DATE	14-Nov-25		
PARAMETERS	**SET 1**	**SET 2**	**SET 3**
Weight of empty pycnometer, W1 (grams)	435.9	436.5	435.7
Weight of pycnometer and dry sample, W2 (grams)	486.2	488.0	487.1
Weight of pycnometer containing sample and water, W3 (grams)	717.5	720.1	719.0
Weight of pycnometer containing water only, W4 (grams)	676.8	678.3	677.4
SPECIFIC GRAVITY OF SAMPLES	2.120	2.190	2.250
AVERAGE SPECIFIC GRAVITY		2.187	

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

10. PARTICLE SIZE DISTRIBUTION (BS 1377-2-9)

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT				
LAB TEST	PARTICLE SIZE DISTRIBUTION (BS 1377-2-9)				
SAMPLE TYPE	SAMPLE A_SUGARCANE BAGASSE ASH				
LOCATION OF SAMPLE COLLECTION	KAKIRA SUGAR WORKS				
SAMPLE DATE	12-Nov-25				
SAMPLE TEST DATE	12-Nov-25				
INITIAL SAMPLE MASS, g (A) :	478			Dry mass before washing, g (B) :	
TOTAL DRY MASS					
Sieve size (mm)	**Mass retained (g)**	**Cumulative mass Retained**	**% retained**	**% passing**	
2.000	0.0	0.0	0.0	100.0	
1.180	0.0	0.0	0.0	100.0	
0.600	28.0	28.0	0.2	99.8	
0.425	51.0	79.0	2.7	97.1	
0.300	93.0	172.0	3.2	93.9	
0.212	98.0	270.0	10.7	83.2	
0.150	76.0	346.0	5.5	77.7	
0.075	68.0	414.0	14.2	63.5	
Pan	63.0	477.0	63.5		
GM	0.756				

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY
Department of Engineering and Environment

11. PARTICLE SIZE DISTRIBUTION (BS 1377-2-9)

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT				
LAB TEST	PARTICLE SIZE DISTRIBUTION (BS 1377-2-9)				
SAMPLE TYPE	SAMPLE B_SUGARCANE BAGASSE ASH				
LOCATION OF SAMPLE COLLECTION	KAKIRA SUGAR WORKS				
SAMPLE DATE	12-Nov-25				
SAMPLE TEST DATE	12-Nov-25				
INITIAL SAMPLE MASS, g (A) :	431			Dry mass before washing, g (B) :	
TOTAL DRY MASS					

Sieve size (mm)	Mass retained (g)	Cumulative mass Retained	% retained	% passing
2.000	0.0	0.0	0.0	100.0
1.180	0.0	0.0	0.0	100.0
0.600	0.9	0.9	0.2	99.8
0.425	11.6	12.5	2.7	97.1
0.300	13.8	26.3	3.2	[illegible]
0.212	46.1	72.4	10.7	83.2
0.150	23.7	96.1	5.5	77.7
0.075	75.0	171.1	17.4	[illegible]
Pan	76.0	431.0	60.3	[illegible]
GM	0.788			

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

12. PARTICLE SIZE DISTRIBUTION (BS 1377-2-9) FOR SBA

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT			
LAB TEST	PARTICLE SIZE DISTRIBUTION (BS 1377-2-9)			
SAMPLE TYPE	SAMPLE C_SUGARCANE BAGASSE ASH			
LOCATION OF SAMPLE COLLECTION	KAKIRA SUGAR WORKS			
SAMPLE DATE	12-Nov-25			
SAMPLE TEST DATE	12-Nov-25			
INITIAL SAMPLE MASS, g (A) :	241			Dry mass after washing, g (B) :
TOTAL DRY MASS				
Sieve size (mm)	**Mass retained (g)**	**Cumulative mass Retained**	**% retained**	**% passing**
2.000	0.0	0.0	0.0	100.0
1.180	0.0	0.0	0.0	100.0
0.600	28.0	28.0	0.2	99.8
0.425	24.0	38.4	2.7	97.1
0.300	55.5	40.5	3.2	93.9
0.212	54.0	96.0	10.7	83.2
0.150	34.0	150.0	5.5	77.7
0.075	57.0	184.0	23.7	54.0
Pan	53.0	241.0	54.0	
GM	0.851			

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

13. PARTICLE SIZE DISTRIBUTION (BS 1377-2-9) FOR THE DRY MIX OF CKD, SBA AND SOIL

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT				
LAB TEST	PARTICLE SIZE DISTRIBUTION (BS 1377-2-9)				
SAMPLE TYPE	SAMPLE 1_SUGARCANE BAGASSE ASH				
LOCATION OF SAMPLE COLLECTION	KAKIRA SUGAR WORKS, ADEKOKWOK AND HIMA CEMENT PLANT				
SAMPLE DATE	12-Nov-25				
SAMPLE TEST DATE	12-Nov-25				
INITIAL SAMPLE MASS, g (A) :	500			Dry mass after washing, g (B) :	
TOTAL DRY MASS					
Sieve size (mm)	**Mass retained (g)**	**Cumulative mass Retained**	**% retained**	**% passing**	
2.000	0.0	0.0	0.0	100.0	
1.180	0.0	0.0	0.0	100.0	
0.600	28.0	28.0	1.3	98.7	
0.425	24.0	52.0	3.3	95.4	
0.300	55.5	107.5	2.7	92.7	
0.212	54.0	161.5	11.1	81.6	
0.150	34.0	195.5	4.4	77.2	
0.075	57.0	252.5	11.4	65.8	
Pan	53.0	499.9	65.8		
GM	0.754				

UGANDA CHRISTIAN UNIVERSITY

A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

14. PARTICLE SIZE DISTRIBUTION (BS 1377-2-9) FOR THE DRY MIX OF CKD, SBA AND SOIL

PROJECT	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT				
LAB TEST	PARTICLE SIZE DISTRIBUTION (BS 1377-2-9)				
SAMPLE TYPE	SAMPLE 2_SUGARCANE BAGASSE ASH				
LOCATION OF SAMPLE COLLECTION	KAKIRA SUGAR WORKS, ADEKOKWOK AND HIMA CEMENT PLANT				
SAMPLE DATE	12-Nov-25				
SAMPLE TEST DATE	12-Nov-25				
INITIAL SAMPLE MASS, g (A) :	500			Dry mass after washing, g (B) :	
TOTAL DRY MASS					
Sieve size (mm)	**Mass retained (g)**	**Cumulative mass Retained**	**% retained**	**% passing**	
2.000	0.0	0.0	0.0	100.0	
1.180	0.0	0.0	0.0	100.0	
0.600	28.0	28.0	2.9	97.1	
0.425	33.0	61.0	5.2	91.9	
0.300	55.5	116.5	3.8	88.1	
0.212	54.0	170.5	7.4	80.7	
0.150	44.0	214.5	6.1	74.6	
0.075	57.0	271.5	6.3	68.3	
Pan	35.0	499.9	68.3		
GM	0.764				

UGANDA CHRISTIAN UNIVERSITY
H.O.D
27 NOV 2025
DEPARTMENT OF ENGINEERING AND ENVIRONMENT

UGANDA CHRISTIAN UNIVERSITY

A Centre of Excellence in the Heart of Africa

FACULTY OF ENGINEERING, DESIGN AN TECHNOLOGY

Department of Engineering and Environment

....	....
Econi Kenneth Y,	UGANDA CHRISTIAN UNIVERSITY H.O.D 27 NOV 2025 * DEPARTMENT OF ENGINEERING AND ENVIRONMENT
Laboratory Technician,	**Head of Department,**
Engineering and Environment,	**Engineering and Environment,**
Uganda Christian University	**Uganda Christian University**

Block 109, Plot No. 225, Kireka, Namugongo Road.
P. O. Box 860003, Kireka, Kampala - Uganda
Tel.: +256200900287, +256709013553
Email: info@terzaghislab.com,
Website: www.terzaghislab.com

TERZAGHI'S
Soils & Materials Lab

Document No.: TSML-TEC-F002
Revision No. : 31
Revision Date : June 25
Approved by : MD

Organic content (loss on ignition)

Project:	ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS ADEKOKWOK SUB-COUNTY, LIRA DISTRICT		
Client:	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON	**Sampling date:**	11-11-25
Location:	ADEKOKWOK SUB-COUNTY, LIRA DISTRICT	**Testing date:**	12-11-25
Sample type	soil		

Test method: AASHTO T267

Sample no.	unit	1	2	3
Mass of Initial Sample	g	20	20	20
mass of soil after Ignition	g	19.25	19.27	19.24
Mass lost on ignition	g	0.75	0.73	0.76
Organic matter content	%	3.75	3.65	3.80
Average organic content	%	3.73		

Remarks:

1. These results only apply the sample that were delivered and tested

Checked by

Labaratory Engineer

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

Checked by

Technical manager

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

EFFORESCENCE TEST CERTIFICATE

Project	ASSESSING THE USE OF VARYING AMOUNTS OF SUGERCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS		
Client:	Ebal Goodluck Jonathan & Chemtai Emson	**Casting Date:**	22-10-25
Location/ Chainage:	Adekokwok Sub-county, Lira District	**Date received:**	19-11-25
		Tested Date:	19-11-25
Sample Description:	Bricks cured for 28days	**Technician:**	MF

Reference Method: BS EN771-1

BATCH NO	SUGERCANE BAGASSE (%)	EFFLORESCENCE PERCENTAGE	AVERAGE EFFLORESCENCE (%)	EFFLORESCENCE GRADE
CS7	CONTROL	0.0	0.0	No perceptible deposit
		0.0		
CS8	5.0	1.0	1.2	slight
		1.4		
CS9	10.0	3.5	3.8	slight
		4.1		
CS10	15.0	7.5	8.6	slight
		9.7		

Remarks:

1. These results only apply to the samples that were delivered and tested.

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

Telephone
+256 (0) 414 250 464 (Gen)
+256 (0) 414 250 474
Email: dgal@mia.go.ug
Website: www.mia.go.ug

In any Correspondence on this subject please quote No..................................

THE REPUBLIC OF UGANDA

FOR GOD AND MY COUNTRY

MINISTRY OF INTERNAL AFFAIRS
DEPARTMENT OF GOVERNMENT ANALYTICAL LABORATORY
Plot No. 2 - 4 Lourdel Road
Wandegeya,
P.O.Box 105639
Kampala - Uganda

DFD 351/2025
24th September 2025

MR. EBAL GOODLUCK JONATHAN AND MR. CHEMTAI EMSON KALENJIN
REG NO. M22B32/012 & M22B32/041
UGANDA CHRISTIAN UNIVERSITY
P.O BOX 4,
MUKONO-UGANDA
Tel: 256-782-996515

REPORT OF ANALYSIS

Description of the Samples

One sample in a black polythene bag containing Sugarcane bagasse ash sample was submitted by Mr. Ebal Goodluck Jonathan, on 17th September 2025, and analysed on 22nd September 2025. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	Grey powdered substances packed in a black polythene bag.	01	Sample "A" DFD 351/2025

Analysis Requested

Elemental analysis

Method of Analysis

Elemental analysis was done using the XRF Method,

Results of Analysis

The above sample has been analyzed with the following results as below,

Parameter	Units	Results
		Sugarcane bagasse ash DFD 351/2025
Silicon dioxide	% m/m	75.62
Aluminum Oxide	% m/m	14.93
Iron (III) Oxide	% m/m	5.71
Potassium Oxide	% m/m	2.04
Calcium Oxide	% m/m	1.02
Chlorine	% m/m	0.31
Manganese (II)Oxide	% m/m	0.25
Europium (III) oxide	% m/m	0.006
Titanium di oxide	% m/m	0.003
chromium (III) oxide	% m/m	0.002

Remarks

1. Results relate to sample analyzed and are reported as on received basis.

24/09/25

Semalago Fredrick
Government Analyst

"Go Scientific for a Safe and Just Society"

Telephone
+256 (0) 414 250 464 (Gen)
+256 (0) 414 250 474
Email: dgal@mia.go.ug
Website: www.mia.go.ug

In any Correspondence on
this subject please
quote No........DFD 350/2025

THE REPUBLIC OF UGANDA

MINISTRY OF INTERNAL AFFAIRS
DEPARTMENT OF GOVERNMENT ANALYTICAL LABORATORY
Plot No. 2 - 4 Lourdel Road
Wandegeya,
P.O.Box 105639
Kampala - Uganda

24th September 2025

MR. EBAL GOODLUCK JONATHAN AND MR. CHEMTAI EMSON KALENJIN
REG NO. M22B32/012 & M22B32/041
UGANDA CHRISTIAN UNIVERSITY
P.O BOX 4,
MUKONO-UGANDA
Tel: 256-782-996515

REPORT OF ANALYSIS

Description of the Samples

One sample in black polythene bag containing Cement Kiln dust sample was submitted by Mr. Ebal Goodluck Jonathan, on 17th September 2025, and analysed on 22nd September 2025. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	Cement Kiln dust substances packed in a black polyihene bag.	01	Sample "A" DFD 350/2025

Analysis Requested

Elemental analysis

Method of Analysis

Elemental analysis was done using the XRF Method

Results of Analysis

The above sample has been analyzed with the following results as below,

Parameter	Units	Results for DFD 350/2025 Cement Kiln dust sample
Calcium oxide	% m/m	64.52
Silicon dioxide	% m/m	19.73
Aluminum oxide	% m/m	11.09
Iron (III) Oxide	% m/m	2.33
Potassium Oxide	% m/m	0.96
Titanium dioxide	% m/m	0.87
Chlorides	% m/m	0.23
Magnesium (II)Oxide	% m/m	0.26

Remarks

1. Results relate to sample analyzed and are reported as on received basis

24/09/25
Semalago Fredrick
Government Analyst

Telephone
+256 (0) 414 250 464 (Gen)
+256 (0) 414 250 474
Email: dgal@mia.go.ug
Website: www.mia.go.ug

In any Correspondence on
this subject please
quote No.................................

FOR GOD AND MY COUNTRY
THE REPUBLIC OF UGANDA

MINISTRY OF INTERNAL AFFAIRS
DEPARTMENT OF GOVERNMENT
ANALYTICAL LABORATORY
Plot No. 2 - 4 Lourdel Road
Wandegeya,
P.O.Box 105639
Kampala - Uganda

DFD 353/2025
24th September 2025

MR. EBAL GOODLUCK JONATHAN AND MR. CHEMTAI EMSON KALENJIN
REG NO. M22B32/012 & M22B32/041
UGANDA CHRISTIAN UNIVERSITY
P.O BOX 4,
MUKONO-UGANDA
Tel: 256-782-996515

REPORT OF ANALYSIS

Description of the Samples

One sample in black polythene bag containing Red soil sample was submitted by Mr. Ebal Goodluck Jonathan, on 17th September 2025, and analysed on 22nd September 2025. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	Red Soil substances packed in a black polythene bag.	01	Sample "A" DFD 353/2025

Analysis Requested

Elemental analysis

Method of Analysis

Elemental analysis was done using the XRF Method

Results of Analysis

The above sample has been analyzed with the following results as below,

Parameter	Units	Results Red soil sample DFD 353/2025
Iron (III) Oxide	% m/m	39.264
Silicon dioxide	% m/m	37.387
Aluminum Oxide	% m/m	12.673
Calcium Oxide	% m/m	6.384
Manganese (II)Oxide	% m/m	1.655
Titanium di oxide	% m/m	1.500
Chromium (III) oxide	% m/m	0.152
Europium (III) oxide	% m/m	0.625
Phosphorous pent oxide	% m/m	0.204
Potassium Oxide	% m/m	0.076

Remarks

1. Results relate to sample analyzed and are reported as on received basis.

Fred. 24/09/25
Semalago Fredrick
Government Analyst

"Go Scientific for a Safe and Just Society"

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling
PROJECT	ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS	

NATURAL MOISTURE CONTENT

Test sample reference :	Laboratory Reference No.:	Sampling Date :	25/Sep/25
Location:	ADEKOKWOK SUB-COUNTY		
DEPTH	0.3M	Testing Date :	27/Sep/25
Sample Description:	LATERATIC GRAVEL	Technician :	Lab team
		Volume of Mould used (m^3)	2305

MOISTURE CONTENT	
Tin No.	BOR
Tin + air dried soil sample (g)	1704
Tin + oven dry soil sample (g)	1627
Tin (g)	814
Dry soil sample	813
Water (g)	77
N.M.C (%)	9.5
Average (%)	9.5

Observations		
Contractor		ENGINEER
Lab technician Materials Engineer		.... Lab technician .... Materials Engineer

STIRLING CIVIL ENGINEERING
29 SEP 2025
P. O. BOX 756, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT	ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS		
SAMPLE DISCRIPTION	LATERATIC GRAVEL SOIL	Sampling Date	25/09/2025
TEST METHOD	DETERMINATION OF FREE SWELL INDEX		
ASTM D720			

S.no	Description	Sample 1	Sample 2	Sample 3
1	Volume of sample soil + water (V2)	19	20	18
2	Volume of sample soil + kerosen (V1)	15	15.5	14
3	Free swell index % ((V1-v2)/V2)*100	26.7	29.0	28.6
Average Free swell index % ((V1-v2)/V2)*100		28.1		

FOR TESTING LAB

STIRLING CIVIL ENGINEERI[illegible]
LTD
29 SEP 2025
P. O. BOX 796, KAMPA[illegible]

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling
PROJECT:	ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS	

SPECIFIC GRAVITY FOR LATERATIC SOIL (AASHTO T100-95 (1995))

LOCATION:	ADEKOKWOK SUBCOUNTY	OPERATOR:	
SAMPLE No		SAMPLE DATE:	25-Sep-25
TYPE:	REDDISH BROWN LATERATIC SOIL	TESTING DATE:	26-Sep-25

	Beaker K		Beaker 1
[A) Wt. OVEN dry sample (gm)	460.13		425.89
[B) Wt. of Pycnometer containing water alone (gm)	1805.85		1610.32
[C] Wt of Pyconometer containing Sample and water (gm)	2094.97		1879.62
SPECIFIC GRAVITY OF FILLER $\frac{A}{A+(B-C)}$	2.691		2.720
AVERAGE	2.705		

FOR TESTING LAB

STIRLING CIVIL ENGINEERING LTD
29 SEP 2025
P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling
PROJECT:	ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS	

SPECIFIC GRAVITY CEMENT KILN (AASHTO T100-95 (1995))

LOCATION: HIMA CEMENT NAMANVE	OPERATOR:
SAMPLE No	SAMPLE DATE: 25-Sep-25
TYPE: CEMENT KILN	TESTING DATE: 26-Sep-25

	Beaker K		Beaker 1
[A) Wt. OVEN dry sample (gm)	625.6		595.7
[B) Wt. of Pycnometer containing water alone (gm)	1805.85		1610.32
[C] Wt of Pyconometer containing Sample and water (gm)	2092.9		1883.5
SPECIFIC GRAVITY OF FILLER $\frac{A}{A + (B - C)}$	1.848		1.847
AVERAGE	1.847		

FOR TESTING LAB

STIRLING CIVIL ENGINE... LTD
29 SEP 2025
P. O. BOX 798, KAMPA...

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling
PROJECT:	ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS	

SPECIFIC GRAVITY CEMENT KILN (AASHTO T100-95 (1995))

LOCATION: HIMA CEMENT NAMANVE	OPERATOR:		
SAMPLE No	SAMPLE DATE:	25-Sep-25	
TYPE: CEMENT KILN	TESTING DATE:	26-Sep-25	

		Beaker K		Beaker 1
[A) Wt. OVEN dry sample	(gm)	625.6		595.7
[B) Wt. of Pycnometer containing water alone	(gm)	1805.85		1610.32
[C] Wt of Pyconometer containing Sample and water (gm)		2092.9		1883.5
SPECIFIC GRAVITY OF FILLER	$\frac{A}{A+(B-C)}$	1.848		1.847
AVERAGE		1.847		

FOR TESTING LAB

STIRLING CIVIL ENGINE... LTD
29 SEP 2025
P. O. BOX 798, KAMPA...

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT: ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

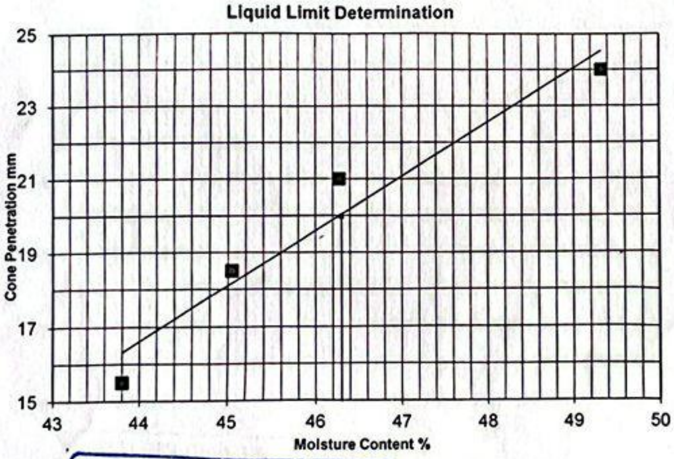
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	HIMA CEMENT NAMANVE		Technician:	Lab Team
mix			Sample Date	24/Sep/2025
Test method	BS 1377: Part 2, 1990:4.3/4.4		Test Date	26/Sep/2025
LAYER	CEMENT KILN DUST			
Depth:	0.5m			

PLASTIC LIMIT	Test No.	LL	DT		Average
Mass of wet soil + container (g)		27.48	27.81		27.645
Mass of dry soil + container (g)		26.21	26.58		26.395
Mass of container (g)		22.35	22.76		22.555
Mass of moisture (g)		1.27	1.2		1.25
Mass of dry soil (g)		3.86	3.82		3.84
Moisture content %		32.9	32.2		32.6
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.5	18.5	21	24.0
penetration (mm)		15.5	18.5	21.0	24.0
AVERAGE		15.5	18.5	21.0	24.0
Container No.		PI82	PI66	PI52	A15
Mass of wet soil + container (g)		48.79	52.16	53.06	52.48
Mass of dry soil + container (g)		36.11	38.16	39.05	37.48
Mass of container (g)		7.16	7.08	8.77	7.07
Mass of moisture (g)		12.68	14	14.01	15
Mass of dry soil (g)		28.95	31.08	30.28	30.41
Moisture content (%)		43.8	45.0	46.3	49.3
AVERAGE		43.8	45.0	46.3	49.3



Liquid limit (%)	46.3
Plastic limit (%)	32.6
Plasticity Index (%)	13.7
Linear shrinkage	
Trough No.	J
Trough length (cm)	14.0
Specimen length (cm)	13.3
L.shringage =	0.7
% L.shrinkage =	5.0

Remarks:

TESTING LAB

STIRLING CIVIL ENGINEERING LTD
29 SEP 2025
P. O. BOX 738, KAMPALA (U)

Materials Engineer.

Lab Technician

STUDENTS

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT:	ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

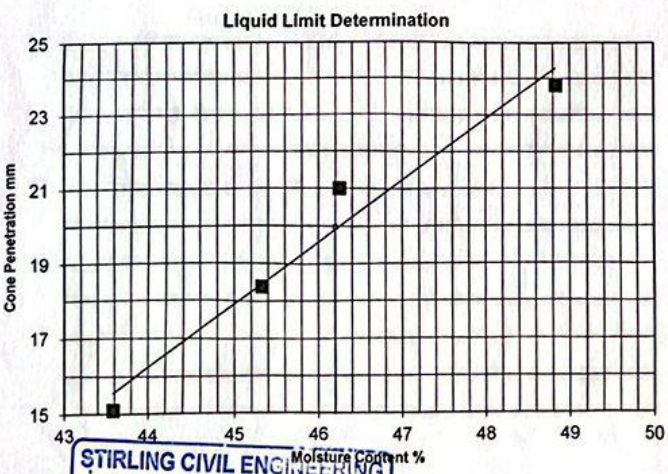
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	HIMA CEMENT NAMANVE			Technician:	Lab Team
mix	0			Sample Date	24/Sep/2025
Test method	BS 1377: Part 2, 1990:4.3/4.4			Test Date	26/Sep/2025
LAYER	CEMENT KILN DUST				
Depth:	0.5m				

PLASTIC LIMIT	Test No.	4P	13		Average
Mass of wet soil + container (g)		45.63	41.72		43.675
Mass of dry soil + container (g)		39.92	36.95		38.435
Mass of container (g)		22.28	22.46		22.37
Mass of moisture (g)		5.71	4.8		5.24
Mass of dry soil (g)		17.64	14.49		16.065
Moisture content %		32.4	32.9		32.6
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.1	18.4	21	23.8
penetration (mm)		15.1	18.4	21.0	23.8
AVERAGE		15.1	18.4	21.0	23.8
Container No.		PI8	FORD	4B	PIBB
Mass of wet soil + container (g)		45.32	55.35	53.09	61.66
Mass of dry soil + container (g)		33.57	40.30	38.41	43.68
Mass of container (g)		6.61	7.10	6.67	6.86
Mass of moisture (g)		11.75	15.05	14.68	17.98
Mass of dry soil (g)		26.96	33.2	31.74	36.82
Moisture content (%)		43.6	45.3	46.3	48.8
AVERAGE		43.6	45.3	46.3	48.8



Liquid limit (%)	46.2
Plastic limit (%)	32.6
Plasticity Index (%)	13.6
Linear shrinkage	
Trough No.	J
Trough length (cm)	14.0
Specimen length (cm)	13.3
L.shringage =	0.7
% L.shrinkage =	5.0

Remarks:

TESTING LAB	STUDENTS
Materials Engineer	
Lab Technician	

STIRLING CIVIL ENGINEERING LTD
26 SEP 2025
P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT:	**ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS**

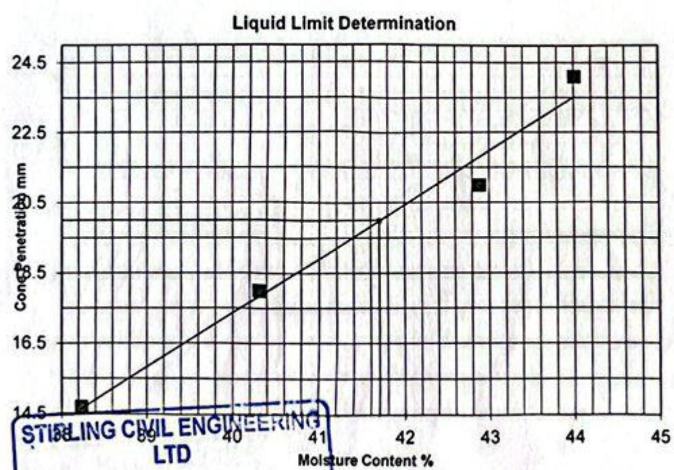
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	KAKIRA SUGAR WORKS	Technician:	Lab Team
mix	NEAT SAMPLE	Sample Date	24/Sep/2025
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	26/Sep/2025
LAYER	SUGARCANE BARGASH		
Depth:			

PLASTIC LIMIT	Test No.	
Mass of wet soil + container (g)		NON PLASTIC
Mass of dry soil + container (g)		
Mass of container (g)		
Mass of moisture (g)		
Mass of dry soil (g)		
Moisture content %		
AVERAGE		

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		14.7	18	21	24.1
penetration (mm)		14.7	18.0	21.0	24.1
AVERAGE		14.7	18.0	21.0	24.1
Container No.		A	PA	28PI	A7
Mass of wet soil + container (g)		36.62	39.54	40.38	51.09
Mass of dry soil + container (g)		28.45	30.22	30.37	38.34
Mass of container (g)		7.08	7.10	7.03	9.37
Mass of moisture (g)		8.17	9.32	10.01	12.75
Mass of dry soil (g)		21.37	23.12	23.34	28.97
Moisture content (%)		38.2	40.3	42.9	44.0
AVERAGE		38.2	40.3	42.9	44.0



Liquid limit (%)	41.7
Plastic limit (%)	NON PLASTIC
Plasticity Index (%)	
Linear shrinkage	
Trough No.	1
Trough length (cm)	14.0
Specimen length (cm)	13.9
L.shringage =	0.1
% L.shrinkage =	0.9

Remarks:

STIRLING CIVIL ENGINEERING LTD
29 SEP 2025
P.O. BOX ... KAMPALA (U)

TESTING LAB		STUDENTS
Materials Engineer:		
Lab Technician		

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT: ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

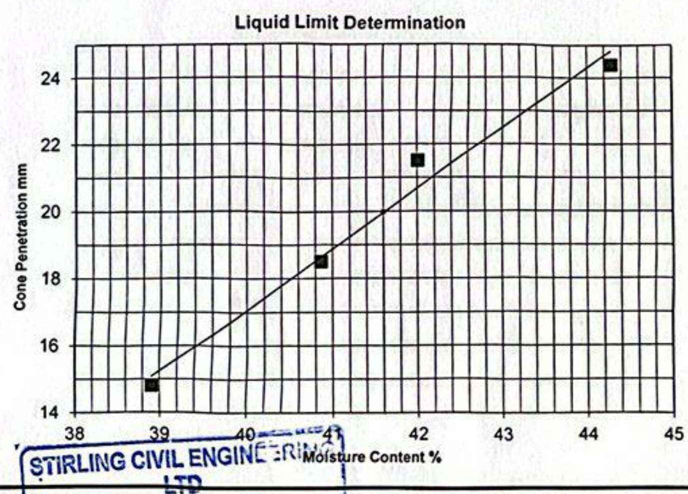
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

SOURCE :	KAKIRA SUGAR WORKS	Technician:	Lab Team
mix	NEAT SAMPLE	Sample Date	24/Sep/2025
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	26/Sep/2025
LAYER	SUGARCANE BARGASH		
Depth:	0		

PLASTIC LIMIT	Test No.	
Mass of wet soil + container (g)		NON PLASTIC
Mass of dry soil + container (g)		
Mass of container (g)		
Mass of moisture (g)		
Mass of dry soil (g)		
Moisture content %		
AVERAGE		

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		14.8	18.5	21.5	24.4
penetration (mm)		14.8	18.5	21.5	24.4
AVERAGE		14.8	18.5	21.5	24.4
Container No.		PIBO	FORD	4B	FOO
Mass of wet soil + container (g)		38.37	39.46	45.85	45.96
Mass of dry soil + container (g)		29.64	30.11	34.34	33.95
Mass of container (g)		7.20	7.23	6.94	6.83
Mass of moisture (g)		8.73	9.35	11.51	12.01
Mass of dry soil (g)		22.44	22.88	27.4	27.12
Moisture content (%)		38.9	40.9	42.0	44.3
AVERAGE		38.9	40.9	42.0	44.3



Liquid limit (%)	41.6
Plastic limit (%)	NON PLASTIC
Plasticity Index (%)	
Linear shrinkage	
Trough No.	1
Trough length (cm)	14.0
Specimen length (cm)	13.9
L.shringage =	0.1
% L.shrinkage =	0.9

STIRLING CIVIL ENGINEERING LTD
29 SEP 2025
P. O. BOX 798, KAMPALA (U)

Remarks:

TESTING LAB

Materials Engineer

Lab Technician

STUDENTS

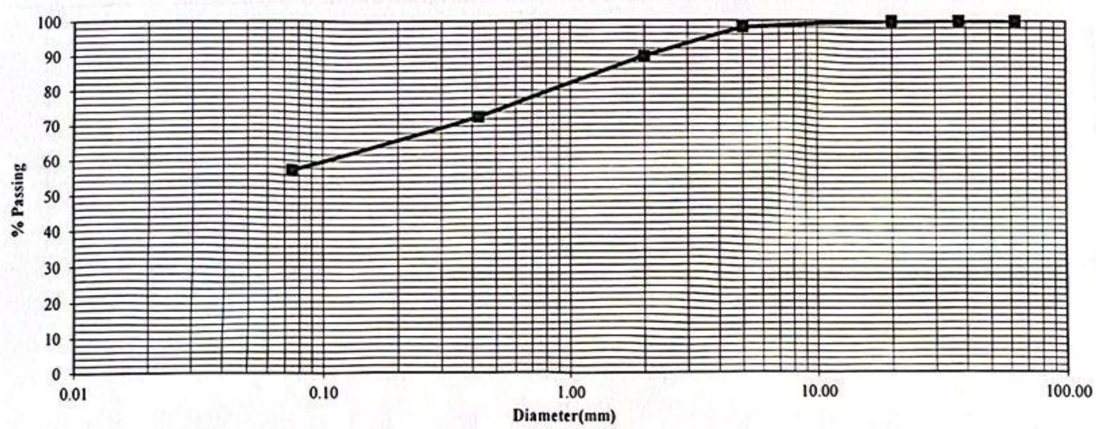
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT : ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	HIMA CEMENT NAMANVE	Dry wt. of sample before washing: (g)		3025.09
Depth: (m)		Dry wt. of sample after washing: (g)		1301.4
Material description:	CEMENT KILN DUST	Date Sampled:	Date Tested:	Technician
		23/Sep/2025	27/Sep/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	56.3	1.9	98
2.00	250.7	8.3	90
0.425	524.2	17.3	73
0.075	457.1	15.1	57
Total fines	1736.8	57.4	
Bottom Pan	13.1		
Extracted fines	1723.7		
Total sample	3025.1		
Grading Modulus		0.80	



FOR TESTING LAB

STIRLING CIVIL ENGINEERING LTD

Lab Technician — Materials Engineer

29 SEP 2025

P. O. BOX 798, KAMPALA (U)

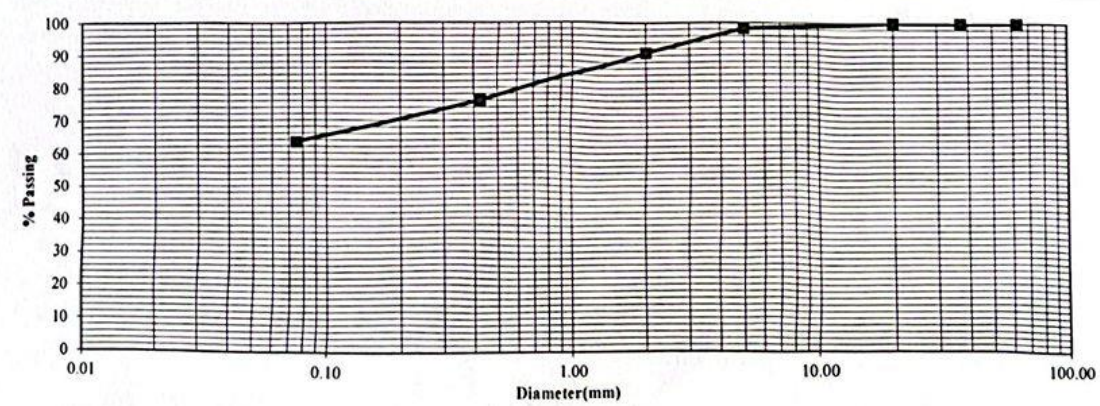
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT : ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	HIMA CEMENT NAMANVE	Dry wt. of sample before washing: (g)		3227.4
Depth: (m)		Dry wt. of sample after washing: (g)		1196.6
Material description:	CEMENT KILN DUST	Date Sampled:	Date Tested:	Technician
		23/Sep/2025	27/Sep/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	56.1	1.7	98
2.00	242.6	7.5	91
0.425	474.8	14.7	76
0.075	411.5	12.8	63
Total fines	2042.4	63.3	
Bottom Pan	11.6		
Extracted fines	2030.8		
Total sample	3227.4		
Grading Modulus		0.70	



FOR TESTING LAB

STIRLING CIVIL ENGINEERING LTD

Lab Technician

Materials Engineer

P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT:	ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

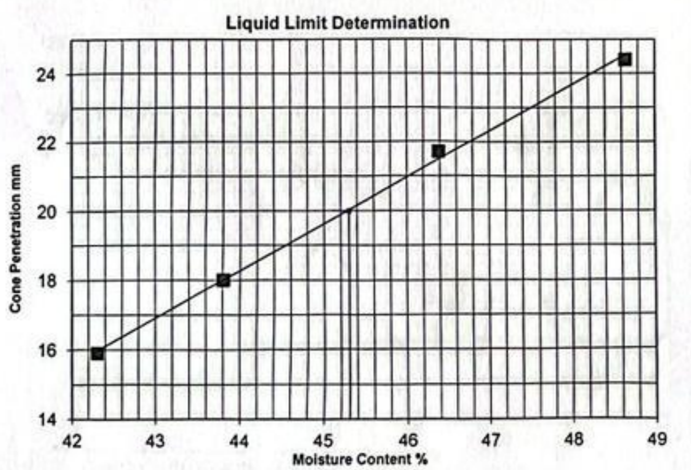
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	ADEKOKWOK SUB COUNTY	Sample Date	22/Sep/2025
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	26/Sep/2025
LAYER	LATERATIC GRAVEL		

PLASTIC LIMIT	Test No.	Q	13		Average
Mass of wet soil + container (g)		30.2	32.45		31.325
Mass of dry soil + container (g)		28.56	30.55		29.555
Mass of container (g)		21.68	22.46		22.07
Mass of moisture (g)		1.64	1.9		1.77
Mass of dry soil (g)		6.88	8.09		7.485
Moisture content %		23.8	23.5		23.7
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.9	18	21.7	24.4
penetration (mm)		15.9	18.0	21.7	24.4
AVERAGE		15.9	18.0	21.7	24.4
Container No.		A6	PIB6	28PI	PP
Mass of wet soil + container (g)		50.40	46.51	46.82	54.44
Mass of dry soil + container (g)		37.43	34.48	34.18	38.94
Mass of container (g)		6.77	7.02	6.93	7.08
Mass of moisture (g)		12.97	12.03	12.64	15.5
Mass of dry soil (g)		30.66	27.46	27.25	31.86
Moisture content (%)		42.3	43.8	46.4	48.7
AVERAGE		42.3	43.8	46.4	48.7



Liquid limit (%)	45.3
Plastic limit (%)	23.7
Plasticity Index (%)	21.6
Linear shrinkage	
Trough No.	2
Trough length (cm)	14.0
Specimen length (cm)	12.4
L.shringage =	1.7
% L.shrinkage =	11.8

Remarks:

TESTING LAB

STIRLING CIVIL ENGIN... LTD
29 SEP 202...
P.O. BOX ...36, KAMP...

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT: ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

ATTERBERG LIMITS

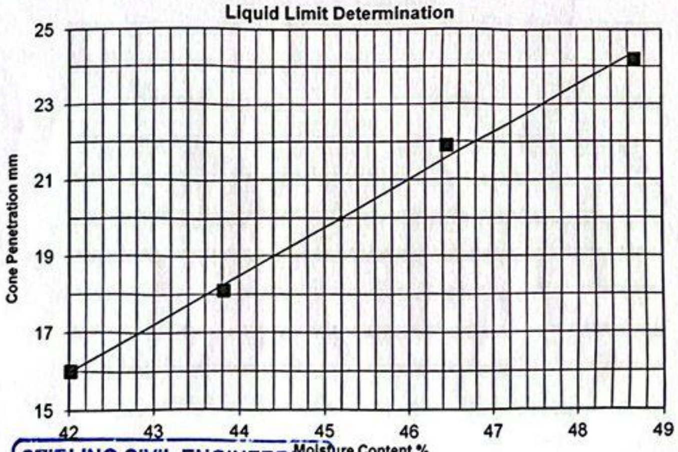
Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	ADEKOKWOK SUB COUNTY	Sample Date	22/Sep/2025
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	26/Sep/2025
LAYER	LATERATIC GRAVEL		

PLASTIC LIMIT	Test No.	OG	LL		Average
Mass of wet soil + container (g)		28.86	31.11		29.985
Mass of dry soil + container (g)		27.43	29.4		28.415
Mass of container (g)		21.41	22.35		21.88
Mass of moisture (g)		1.43	1.7		1.57
Mass of dry soil (g)		6.02	7.05		6.535
Moisture content %		23.8	24.3		24.0
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		16.0	18.1	21.9	24.2
penetration (mm)		16.0	18.1	21.9	24.2
AVERAGE		16.0	18.1	21.9	24.2
Container No.		PI600	PI26	KO	PI38
Mass of wet soil + container (g)		55.21	43.13	50.71	53.14
Mass of dry soil + container (g)		40.94	32.11	36.81	38.07
Mass of container (g)		6.98	6.96	6.89	7.11
Mass of moisture (g)		14.27	11.02	13.9	15.07
Mass of dry soil (g)		33.96	25.15	29.92	30.96
Moisture content (%)		42.0	43.8	46.5	48.7
AVERAGE		42.0	43.8	46.5	48.7

Liquid Limit Determination



Liquid limit (%)	45.2
Plastic limit (%)	24.0
Plasticity Index (%)	21.2
Linear shrinkage	
Trough No.	2
Trough length (cm)	14.0
Specimen length (cm)	12.4
L.shringage =	1.7
% L.shrinkage =	11.8

Remarks:

TESTING LAB

STIRLING CIVIL ENGINEERING LTD
29 SEP 2025
P.O. BOX 738, KAMPALA (U)

Materials Engineer.

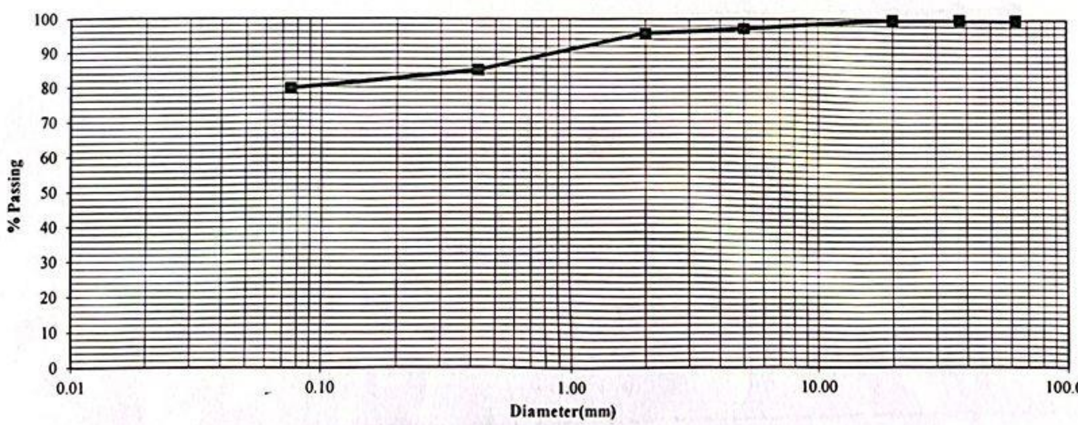
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT : ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:			
Location :(km)	ADEKOKWOK SUBCOUNTY	Dry wt. of sample before washing: (g)			5011
Depth: (m)		Dry wt. of sample after washing: (g)			1028.2
Material description:	LATERATIC SOIL	Date Sampled:	Date Tested:		Technician
		23/Sep/2025	27/Sep/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	10.6	0.2	100
5.0	137.0	2.7	97
2.00	63.0	1.3	96
0.425	538.6	10.7	85
0.075	277.5	5.5	80
Total fines	3984.3	79.5	
Bottom Pan	1.5		
Extracted fines	3982.8		
Total sample	5011.0		
Grading Modulus		0.40	



FOR TESTING LAB

STIRLING CIVIL ENGINEERING LTD
29 SEP 2025
P. O. BOX 798, KAMPALA (U)

Lab Technician | Materials Engineer

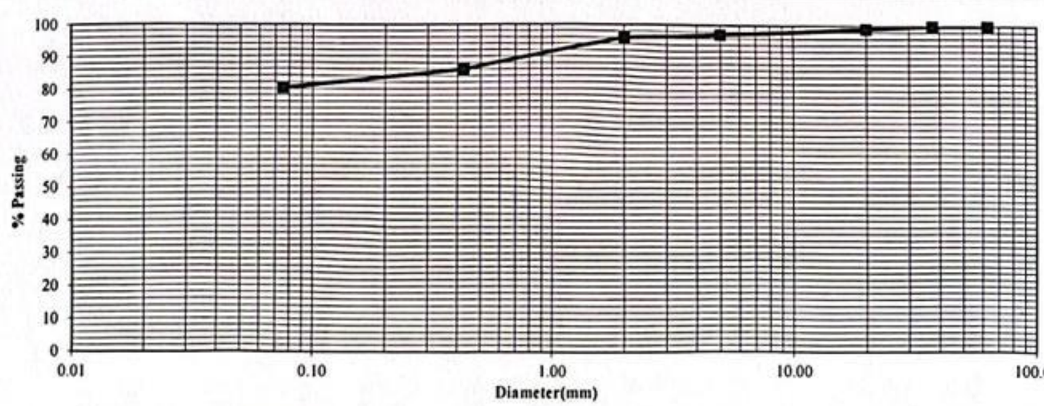
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN	Stirling

PROJECT : ASSESING THE USE OF CEMENT KILN DUST AND SUGARCANE BAGASSE ASH IN COMPRESSED EARTH BRICKS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	ADEKOKWOK SUBCOUNTY	Dry wt. of sample before washing: (g)		4209.7
Depth: (m)		Dry wt. of sample after washing: (g)		831.8
Material description:	LATERATIC SOIL	Date Sampled:	Date Tested:	Technician
		23/Sep/2025	27/Sep/2025	Lab team

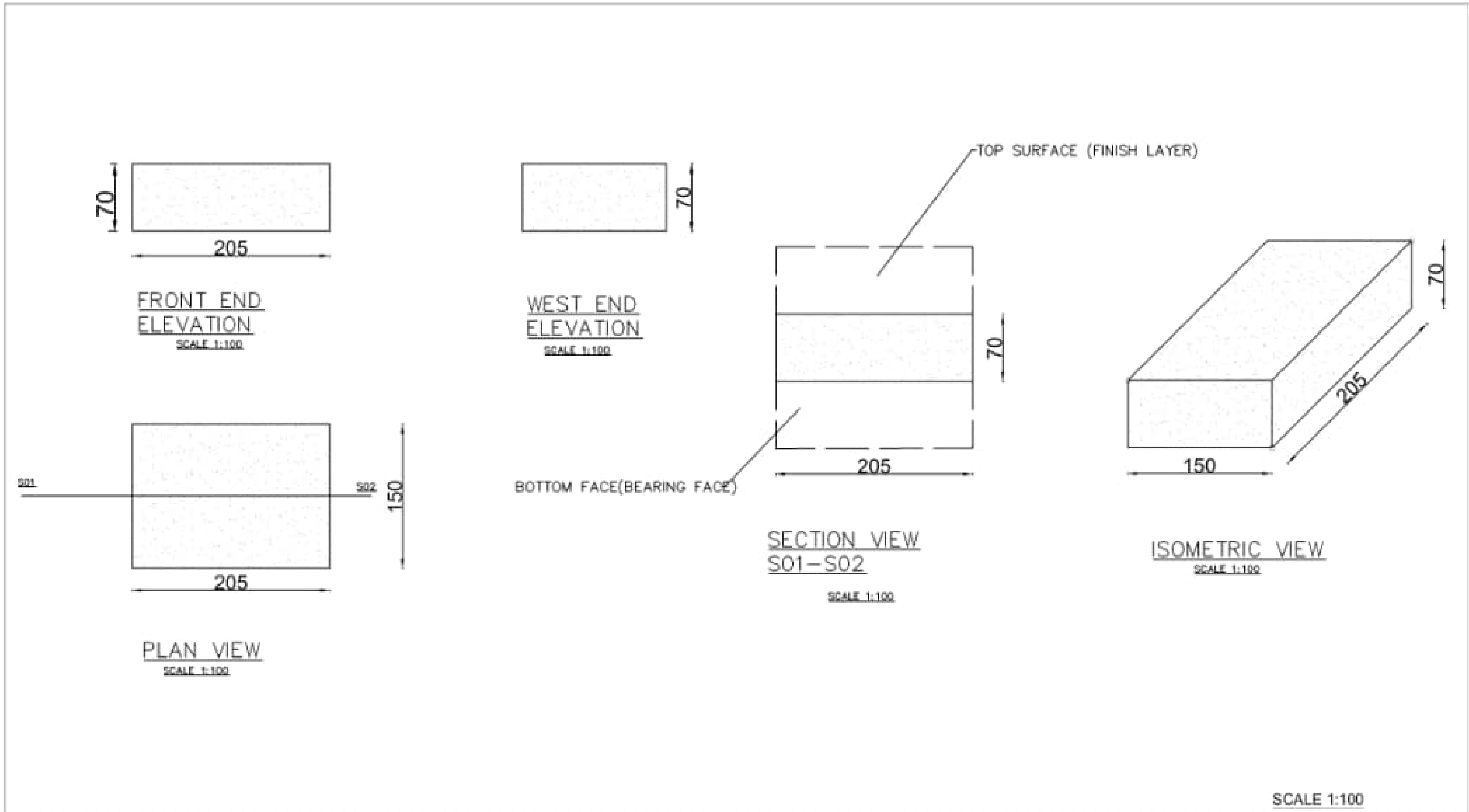
Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)
63.0	0.0	0	100
37.5	0.0	0.0	100
20.0	42.0	1.0	99
5.0	80.1	1.9	97
2.00	48.4	1.1	96
0.425	416.9	9.9	86
0.075	243.4	5.8	80
Total fines	3378.9	80.3	
Bottom Pan	1.0		
Extracted fines	3377.9		
Total sample	4209.7		
Grading Modulus		0.38	



FOR TESTING LAB

Lab Technician *Materials Engineer*

APPENDIX C: DESIGN DRAWING OF THE FINAL BRICK PRODUCT



PROJECT: ASSESSING THE USE OF SUGARCANE BAGASSE ASH AND CEMENT KILN DUST IN COMPRESSED EARTH BRICKS IN ADEKOKWOK SUB-COUNTY, LIRA DISTRICT.
DRAWING TITLE: COMPRESSED EARTH BRICK MASONRY UNIT
AUTHOR: EBAL GOODLUCK JONATHAN & CHEMTAI EMSON KALENJIN
REG. NUMBERS: M22B32/012 M22B32/041