ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING SPALLING IN REINFORCED CONCRETE

KHAN GAK NGAW

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ABSTRACT

Corrosion-related spalling is a major durability and engineering problem that reinforced concrete structures have to tackle, and this is very critical in humid tropical areas where moisture and chloride exposure are rampant causing corrosion of steel reinforcement, the rust expands and, in doing so, it puts internal tensile pressure on the concrete cover causing it to crack and eventually detach (Moccia et al., 2021; Liu et al., 2021.)

Accelerated corrosion test was carried following RILEM guidelines to simulate extreme conditions and to observe the development of cracks using the optimum 5% SCBA mix. Concrete cylinders are cast with 12 mm steel bars embedded at the center and cured for 28 days, ensuring a concrete cover of 20–25 mm. After curing, the specimens are partially immersed in a 3.5% NaCl solution so that only part of the concrete and steel is exposed to chloride attack. An external direct current (200–500 μA/cm²) is applied using a potentiostat, with the steel bar acting as the anode and a stainless-steel or graphite electrode as the cathode.

The study conclusively claims that sugarcane bagasse ash is a low-priced, green, and durable material for supplementing the next upgrade of concrete. Using this constituent alongside traditional methods induces advantages like cost-saving, and sustainability as it would not only eliminate expensive corrosion prevention techniques but also support eco-friendly construction practices. To be assured about the performance in actual exposure conditions, more long-term field studies are suggested.

DECLARATION

I, **KHAN GAK,** declare that this research is my own work; everything here is unique and has never been submitted to a publication in any institution for awards

Signature……….............. Date………………..…………..

KHAN GAK NGAW

APPROVAL

This research was done under supervision and is to be submitted to Uganda Christian University Faculty of Engineering, Design and Technology, Department of engineering and environment as one of the requirements for Bachelor degree in civil and environmental engineering

Academic Supervisor (Uganda Christian University):

Name: Mr**. ZZIWA MARVIN**

Signature……………………………… *Date*…………………………………

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LIST OF ACRONYMS AND ABBREVATIONS

SCBA	Sugar Cane Bagasse Ash
ACV	Aggregate Crushing Value
AIV	Aggregate Impact Value
ACT	Accelerated Corrosion test
ASR	Alkali silica reactions
ASTM	American Standard Testing Method
BS EN	European Standards
BS	British Standards
C25	Class 25
CAH	Calcium aluminum hydrate
CSH	Calcium silicate hydrate
FI	Flakiness index
LAAV	Los Angeles Abrasion Value
SSM	supplementary cementitious material

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

Cement originated during ancient civilizations. The Greeks and Romans used volcanic ash, lime, and water to create a binding substance that could solidify underwater a method found in many Roman monuments such as the Pantheon and aqueducts. However, modern cement emerged in 1824, when an English mason named Joseph Aspdin invented Portland cement. He called it after the Portland stone, a construction stone from Dorset, England, due to its resemblance in appearance (Lea, F.M 2004).

In the modern infrastructure concrete has been a key material, but its performance can be compromised by harsh physical and chemical processes, especially in bridges and structures near water. One significant issue is spalling, which occurs when the concrete cover flakes off due to internal stress exceeding the concrete's tensile strength, exposing the reinforcing bars (Moccia et al., 2021; Liu et al., 2021). Water entry can cause grave negative repercussions, particularly for carbonation and steel reinforcement corrosion. With the entry of water into the material, harmful ions such as chlorides and sulfates tend to migrate and can cause chemical reactions leading to the development of fissures and material loss as a result of spalling (Thomas et al., 2020). The material loss and strength reduction can lead to reduced durability and can cause hazards such as concrete material falling off in densely populated zones (Zhang et al., 2017). Additionally, spalling can increase the cost of maintenance (Neville, 2011).

Studies have focused on the concept of the use of agricultural waste material, specifically sugarcane bagasse ash (SCBA), as a concrete additive for enhancing durability (Ahmad J et al., 2021). The amorphous silicon content within SCBA reacts with the hydration products of cement to form a calcium silicate hydrate gel (C-S-H) (Azmatullah et al., 2019). A number of supplementary cementitious materials (SCMs) have been found to be potential candidates for reducing porosity and spalling. For instance, Silica fume provides a 50-60% reduction in porosity due to its ultra-fine particles (Tang et al., 2020); on the other hand, sugarcane bagasse ash (SCBA) provides a reduction of 30-45% when partially replaced (Kabir et al., 2020). In the context of corrosion spalling, various studies have been conducted to investigate a range of methods such as cathodic protection and epoxycoated reinforcement. While such methods can successfully restrict the process of corrosion, they can be expensive and undergo failure after several years due to technical difficulties (Brueckner et al., 2022; NAP, 2022). Epoxy-coated rebar can be more resistant to corrosion compared to uncoated rebar; however, imperfections and reduced bonding strength can impair rebar quality.

1.2 PROBLEM STATEMENT

When reinforced concrete is exposed to water for long periods, the water penetrates the concrete through the micro fractures of the concrete till it gets to the reinforcement (Liu et al., 2021; Zhao et al., 2021). When the water reaches the reinforcement, it reacts with the steel, leading to the formation of corrosion products such as iron (III) oxide. As corrosion continues, the formation of rust (iron (III) oxide) expands several times the original metal volume, generating internal radial pressure within the surrounding concrete cover (Moccia et al., 2021). This expansive force eventually exceeds the tensile strength of the concrete cover, resulting in radial or longitudinal cracking. As the corrosion and cracking continue, the cracks widen and propagate until the concrete cover detaches (Moccia et al., 2021; Ye et al., 2020).

Spalling has been witnessed in various structures in Uganda, such as the Nyamwamba Bridge in Kasese District, Western Uganda, which is a critical transportation connection in Western Uganda. However, flooding and heavy rains along the Nyamwamba River nearly constantly leave the bridge abutments and the deck exposed to water ingress (Bihamba, 2024). Another example is the students' called CNN in Kauga, Mukono University that has experienced spalling due to rainwater that is captured at the top of the butterfly roof that entered the slab.

This research, therefore, aims to investigate how this hybrid natural system can provide a low-cost, sustainable, and performance-based solution to corrosion-related deterioration in reinforced concrete.

Figure 1: *Images showing the start of spalling in a reinforced concrete column(left) and a column with lost concrete cover (right) at CNN hostel.*

1.3 OBJECTIVES OF THE RESEARCH

1.3.1 Main Objective

To assess the suitability of sugar cane bagasse ash and bamboo fibre in preventing corrosion-induced spalling in RC

1.3.2 Specific Objectives

1. To determine the properties of the Sugarcane bagasse ash.
2. To determine the optimum amount of Sugarcane bagasse ash required in the concrete to reduce porosity.
3. To determine the effect of Sugarcane bagasse ash in minimizing corrosion-induced spalling in reinforced concrete

1.4 RESEARCH QUESTIONS

1) What are the properties of the Sugarcane bagasse ash?
2) What is the optimum amount of Sugarcane bagasse ash required in the concrete to reduce porosity?
3) What is the effect of Sugarcane bagasse ash in minimizing corrosion-induced spalling in reinforced concrete

1.5 SCOPE OF THE STUDY

1.5.1 Geographical Scope

The sugarcane bagasse ash (SCBA) used in this study was obtained from Kakira Sugar Limited (KSL) in Jinja District, at coordinates 0°30'36.0"N, 33°17'24.0"E (Latitude: 0.5100; Longitude: 33.2900). Also the cement, fine aggregate, coarse aggregate and water will be acquired from Stirling lab in Mukono, Mbalala.

1.5.2 Content Scope

This stage of the investigation is essentially laboratory analysis and literature review with the aim of ascertaining the basic properties and potential application prospects for Sugarcane Bagasse Ash (SCBA). The criteria for evaluation include chemical properties (specifically the amount of silicon dioxide present), particle size distribution, specific surface area, and loss on ignition. The analysis is carried out through various methods such as XRF analysis and sieving analysis. The aim is to determine whether this material meets the criteria for application as a pozzolanic material and reinforcing material for concrete production.

The effect of incorporating SCBA on the behavior of fresh concrete is also discussed. Some of the important parameters that are assessed include workability (slump), consistency, and setting time. Due to its fine particles and higher surface area, the addition of SCBA is expected to increase the water requirement and thereby affect the workability. A number of standard tests such as the slump test (BS EN 12350-2) and the determination of the initial and final setting time (BS EN 196-3) are used to determine the effect on workability. This is important for assessing its application.

In this section, the implication of adopting SCBA to minimize water entry and corrosion inhibitor for reinforced concrete is assessed. Accelerated corrosion tests (e.g., impressed current technique or salt spray exposure) are used to simulate corrosive environments. The corrosion potential is measured using half-cell potential or linear polarization methods. The tendency of concrete to spall due to reinforcement expansion is observed visually and through mass loss or spalled volume measurements. The aim is to link reductions in porosity (from Objective 2) to lower corrosion rates and assess whether the fibre bridging effect of bamboo delays crack propagation and surface delamination.

1.5.3 Time Scope

The project is to run for eight months from May 2025 to the end of December 2025. The time is inclusive of material collection, preparation of the specimens, laboratory tests, and data analysis.

1.6 JUSTIFICATION

According to multiple studies, it is stated that the corrosion-induced spalling of reinforced concrete surface was mainly triggered by the expansion of the corroded steel reinforcement inside, which causes tensile stresses that exceed the concrete's tensile strength, the latter being the cause of surface cracking and subsequent spalling of the concrete cover (Liu et al., 2021; Cao et al., 2019). To enhance the durability of reinforced concrete, several agricultural waste materials, such as sugarcane bagasse ash (SCBA), have been proposed due to their high silica content and pozzolanic reactivity (Memon et al., 2020; Jagadesh et al., 2023). Sugarcane bagasse ash in concrete produces secondary C-S-H gel, which densifies the cement matrix with reduced porosity so that it can restrain the ingress of water or other aggressive agents that can accelerate corrosion (Srinivasan and Sathiya, 2021).

Equation for the hydration of cement:

$2C_3S + 6H_2O \rightarrow C_3S_2H_3$ (C-S-H gel) $+ 3Ca(OH)_2$

It is for the above reason that the pozzolanic reaction between SCBA and calcium hydroxide reduces the amount of free lime, which, if present, would otherwise be undesirable, as its presence raises the permeability of concrete (Muthusamy et al., 2018).

This refined pore structure acts as a physical barrier, obstructing the flow of moisture and ions and thereby slowing the initiation of corrosion (Kumar et al., 2022). Also, SCBA improves the adhesion at the interface around the reinforcement bars, assisting in bonding, thereby minimising cracking and spalling under expansion pressure (Khalid et al., 2021).

Equation for the reaction of silica from the sugarcane bagasse ash and calcium hydroxide from the cement reaction:

$Ca(OH)_2 + SiO_2 \rightarrow C\text{-}S\text{-}H$

On the other hand, SCBA improves the chemical resistance of concrete, which, on the other hand, suffers from typical early-age cracking phenomena related to shrinkage and low tensile capacity (Srinivasan and Sathiya, 2021).

This study aims to check the efficacy of using sugarcane bagasse ash as a sustainability additive in concrete to prevent spalling due to corrosion. More specifically, this research aims to investigate the effect of partial replacement of cement with SCBA on the mechanical, durability, and corrosion characteristics of reinforced concrete. Through corrosive exposure and testing of different mix proportions, it becomes possible to select the best mix proportions that enhance structural strength and prolong the life span of reinforced concrete in tough environments. The results will offer a backbone for the development of eco-friendly and durable construction materials for infrastructures subjected to corrosion.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

The chapter outlines the theories on which this research is based and presents the knowledge gap. Concrete is a composite material made from cement, water, fine aggregates (sand), and coarse aggregates (gravel and crushed stones); the strength is developed through a chemical process known as hydration. Cement works as a binder and requires hydration reactions to bind aggregates through interaction with water. Admixtures can be used to endow certain properties on either fresh concrete or hardened concrete. Hydration is responsible for producing a strong and durable material with versatile applications within the construction industry owing to the high compressive strength (Neville, A.M., et al., 2020).

2.2 Compositions of concrete

Cement

Cement can be termed as a fine-grained inorganic binder that undergoes chemical reactions with water to form a hardened compound with the ability to bind aggregates, thus playing a vital role in the production of concrete. The combination of cement and water undergoes a series of complex chemical reactions that result in the production of concrete with strength and rigidity due to the formation of stable calcium silicon hydrate gel and calcium hydroxide as the principal products. The binding properties of cement make it possible to form a solid and hard compound with aggregates ranging from fine to coarse aggregates, thus playing a core role in civil engineering works (Neville, A.M., et al., 2020; Mehta, P.K., 2021). Cement plays several roles in concrete production ranging from strength to durability and resistance to attacks from the environment.

Cement production requires two chief raw materials: limestone (a source of calcium carbonate) and clay/shale (a provider for silicon, alumina, and iron oxides). The two ingredients are broken down and mixed and then fired at around 1450°C in a rotary kiln to obtain a mix known as "clinker," which is then ground with a small amount of "gypsum" (calcium sulfate). In other types of cement production, auxiliary raw materials such as "bauxite," "iron ore," and "by-products from industry (such as fly ash and slag aggregate*)" may be added. The raw material formula needs to be precisely calculated for the proper chemical mix for optimal "cement compounds" (Pavithra et al., 2020; Siddique R, et al.,2022).

The choice of the type of cement to be used is project dependent. Some of the types of cement widely used depending on the construction project include:

1. Ordinary Portland Cement (OPC) – The general-purpose cement available for general use for the majority of constructions.

2. Portland Pozzolana Cement (PPC): It contains pozzolanic materials like fly ash and calcined clay. It provides increased durability and resistance to sulfates and lower heat of hydration. It is specifically used for particular purposes.

3. Rapid Hardening Cement (RHC) – achieves high strength at an earlier age and is mostly used for time-dependent constructions and unfavorable work conditions.

4. Sulfate-Resistant Cement (SRC): It is suitable for conditions with high sulfate levels that can impact the concrete (Siddique R et al.,2020; IS 269:2021; ASTM C150/C595

Chemical Composition of Cement

Cement properties depend on its chemical composition and the dominant oxides that produce specific compounds upon the formation of clinker. The typical chemical composition is depicted in the accompanying table blow.

Table 1: showing chemical characteristic of cement

Compound	Chemical Formula	Typical Content (%)
Tricalcium Silicate	$3CaO \cdot SiO_2$ (C_3S)	45–60 ±0.33
Dicalcium Silicate	$2CaO \cdot SiO_2$ (C_2S)	15–30±0.41
Tricalcium Aluminate	$3CaO \cdot Al_2O_3$ (C_3A)	6–12±0.22

Tetracalcium Aluminoferrite	$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ (C_4AF)	6–10±0.21
Calcium Oxide	CaO	60–67±0.51
Silicon Dioxide	SiO_2	17–25±0.40
Aluminum Oxide	Al_2O_3	3-8±0.11
Iron Oxide	Fe_2O_3	0.5-6±0.22
Magnesium Oxide	MgO	0.1–4±0.01
Sulfur Trioxide	SO_3	1–3±0.09

Cement properties depend on its chemical composition and the dominant oxides that produce specific compounds upon the formation of clinker. The typical chemical composition is depicted in the accompanying table. Concrete made from OPC may be highly permeable if proper attention is not given to its design and curing process. Water can pass through this permeable concrete cover and reach the steel reinforcement. Water comes into contact with steel and triggers the passive oxide layer on steel to break down and form rust, leading to steel expansion while producing pressure responsible for concrete spalling (NRMCA, 2021).

The paste is also subjected to shrinkage and micro-cracking as a result of cooling and drying and hydration reactions. The micro-cracking may be invisible on the surface and can act as routes for the entry of water into the concrete system. Water entry can lead to acceleration of steel corrosion and then cracking and spalling of the surface concrete (Liu et al., 2024)

Fine Aggregates (Sand)

Fine aggregates refer to aggregates that pass through a sieve measuring 4.75 mm (natural sand), crushed stone sand, and manufactured sand. It serves to fill the gaps between the coarse aggregates and ensures the cohesiveness and workability of the concrete mixture. The international specs state that fine aggregates must be free from any contaminants that can impair the strength and workability properties and be free from organic and clay content (ASTM C33/C33M-18). Fine aggregates help determine the smoothness and work ability and water demand of the concrete mix – well-graded sand gives a dense mix with reduced bleeding and segregation (Pavithra et al., 2020).

Fine aggregates have a significant effect on the durability and integrity of concrete. Contamination within sand can be caused by the presence of silt, clay particles, and organic materials that can prevent a good bonding interface between the paste and the aggregates. The effect can be the high permeability within the concrete that allows water to seep to the reinforced steel and cause spalling (Ohorongo Cement, 2024).

Further, poorly graded and fine sand raises the hydration needs for the paste, thus allowing for a higher water/cement ratio and consequent porosity after drying. Porosity promotes the entry of aggressive substances such as chlorides and CO_2, leading to steel reinforcement corrosion. As rust forms and expands under the pressure created from within due to the formation and growth of rust, cracking and spalling occurs on the surface cover (Zheng et al., 2023).

Additionally, the shape and texture of sand particles can affect the micro-structure found at the interfacial transition zone (ITZ) between the aggregate and the cement paste. A smooth and rounded particle can lead to a weaker ITZ that can cause micro-cracking resulting in pathways for harmful material entry. Often, thismicro-cracking goes unnoticed till the corrosion and spalling stages reach an advanced stage (Li et al., 2022).

Coarse Aggregates (Gravel/Crushed Stone)

Coarse aggregates refer to particles that are retained on a sieve with a diameter of 4.75 mm and can vary between 10mm and 40mm depending on the desired use. Typically, coarse aggregates can come from crushed granite, limestone, and river gravel.

Coarse aggregates play a dominant role in the strength and durability properties of concrete. Shape and size parameters influence the workability and interlock properties between coarse aggregates and other material constituents with respect to the concrete mix (Siddique R. et al., 2020; Siddique R. et al., 2022). A mix with aggregates measuring no more than 20mm is normally employed for structural works compared to aggregates measuring 10mm for heavily reinforced and precast concrete works for greater compactness. Additionally, well-graded aggregates maximize the reduction of voids within the concrete mix for greater strength.

The coarse aggregates affect the mechanical properties and durability of the concrete; on the other hand, their properties may strongly influence the micro-structure and cracking mechanism, and thus affect the process and rate of initiation and propagation of spalling due to corrosion. The dominant factors for aggregates relate to their size and grading; for instance, ungraded aggregates can lead to segregation and voids within the mix, thus reducing impermeability and allowing water to pass and corrode steel within the concrete (Zhou et al., 2022). Weaker and irregular aggregates with coarse surfaces may be responsible for mechanical bonding between the ITZ and aggregates; on the other hand, they may lead to stresses within the concrete and drying shrinkage and cracking, thus providing a continuous path for water and ions leading to steel expansion and spalling (Liu et al., 2021).

The aggregate porosity and water absorption values play important roles as well; this is due to the fact that highly porous coarse aggregates tend to absorb water and increase the water-cement content. The damaged areas tend to be more vulnerable to attacks from outside forces (Zhou et al., 2022).

In summary, due to the coarse aggregates with improper quality and suitability, there might be occurrences of internal cracking, reduced ITZ strength, increased permeability, and unfavorable chemical reactions.

CONCRETE

The aggregates are batched proportionally depending on the grade and desired properties of concrete. A general mix proportion (such as M25 and C25/30) requires a fine to coarse aggregate proportion of 1:2 to 1:2.5. Optimization of the water-cement ratio and amount of cement and aggregates is required for preventing segregation and providing proper compaction to obtain desired strengths and durability. A combination of aggregates with varying sizes optimizes the packing efficiency of the concrete mix and requires reduced amounts of cement and water as well. Unsound and dirty aggregates may lead to increased shrinkage, strength loss, and reduced performance (Mehta P.K. et al., 2021).

SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMS)

Supplementary Cementitious Materials (SCMs) are the finely distributed materials added to and partially substituting for cement in concrete to increase properties and sustainability. The chemical reactions occur between SCM and the calcium hydroxide produced from the hydration process of cement through pozzolanic and/or hydraulic reactions to produce more C-S-H gel with improved strength and durability (Mehta P.K. et al., 2021). The addition and use of SCM influence the reduction of environmental impact due to reduced cement and, therefore, reduced CO2 emission (Mehta P.K. et al., 2021). In addition to other advantages, SCM reduces workability and affects the alkalisilica reaction and chemical attacks such as sulfates and chlorides.

TYPES OF SCMS

Natural SCMS

Natural SCMs originate from natural mineral sources with pozzolanic properties. Some examples of natural SCMs include calcinated clays, volcanically active ash, and natural pozzolans like diatomaceous earth and metakaolin. Volcanic ash is among the natural pozzolans that can be found mostly in regions close to East Africa and has been found to lower the porosity of concrete (Siddique R. et al., 2020). Another example is natural pozzolans such as diatomaceous earth, which is found to be rich in silicon and aluminas and can produce secondary C-S-H gel upon interaction with calcium hydroxide (Pavithra et al., 2020).

Artificial SCMs

Artificial SCMs: Industrial by-products and residues resulting from various processes with cementitious/ pozzolanic properties. Principal types of artificial SCM:

1. Fly Ash: It is a by-product material produced from the burning of coal. It is designated as Class F (Low Calcium) and Class C (High Calcium). It is used for enhancing workability and strength properties. It also decreases the water demand and heat of hydration (IS:3812:2013).

2. Ground Granulated Blast Furnace Slag (GGBFS): It is a by-product from iron production through blast furnaces. It is a slow-reacting material that provides improved strength and resistance to sulfates and chlorides and is used for producing low-heat concrete for massive structures (ASTM C989/C989M-18).

3. Silica Fume: It is a highly fine product with high pozzolanic activity. It provides superior strength, abrasion resistance, and impermeability to high-performance concrete.

4. Sugarcane Bagasse Ash (SCBA) – a bio-machine waste produced through the incineration of bagasse. When SCBA is produced finely and with reduced carbon content, it becomes a pozzolanic substance owing to its high content of silica (Bisht, K. et al., 2021).

5. Rice Husk Ash (RHA) – highly reactive pozzolana produced by controlled burning of rice husks; rich in amorphous Silicon Dioxide and provides strength and durability to concrete and resilience to alkali-silica reaction and chloride ion penetration.

Synthetic SCMss provide a dual benefit with respect to the improvement of concrete strength and the application of industry waste (Mehta P.K. et al., 2021).

Sugarcane Bagasse: Origin and Characteristics

Sugarcane bagasse (SCB) is the fibrous residue left after extracting the sugarcane juice from sugarcane stalks during sugar production. It consists mainly of cellulose (40-50%), hemicellulose (25-35%), and lignin (15-25%), with small amounts of waxes and ash (Singh et al., 2021). Sugarcane bagasse is produced on a massive scale by top sugarcaneproducing nations (such as Brazil, India, Thailand, and Uganda). It is estimated that for every 10 tonnes of crushed sugarcane processed, approximately 2.5-3 tonnes of sugarcane bagasse is produced. Due to this high production and being an organic material, sugarcane bagasse is a significant agricultural residue with potential industrial use

Applications of Sugarcane Bagasse in Other Fields

Apart from the production of ash, SCB is employed for several other reasons such as:

1. Bioenergy and Power Generation: SCB is utilized as biofuel at cogeneration complexes for energy autonomy at sugar mills (Chandel et al., 2020).

2. Paper and Pulp Industry: With high cellulose content, SCB is used for manufacturing paper products such as cardboard and biodegradable packaging material, providing a good alternative for wood-based pulp (Rabelo et al., 2020).

3. Bioethanol Production: It is possible to enzymatically hydrolyze the bagasse to obtain fermentable sugars that can be utilized as a principal feedstock for second-generation bioethanol with reduced carbon output (Gaurav et al., 2021).

Sugarcane Bagasse Ash (SCBA) as a Supplement Cementitious Material Controlled-burn process for sugarcane bagasse is a method for producing sugarcane bagasse ash (SCBA) under typical conditions at 500°C to 800°C which produce fine powder rich in amorphous silica that has the following advantages: -

i. High content of silicon: The content of silicon is between 60-80% and is mostly amorphous. It combines with the release of Ca(OH)2 to form C-S-H gel (Bisht R. et al., 2021). ii. Lower Carbon Emissions: Reduced emissions of carbon dioxide.

iii. Abundant and Low-Cost: In the form of SCBA, this waste is abundant and available at a very cheap rate at sugar mills.

iv. Comparable/superior performance: The strength gain and durability properties of SCBA can be compared with fly ash and rice husk ash and perform equally well and even better with respect to availability near sugarcane production areas.

CHEMIAL COMPOSITION OF SCBA

Table 2: showing of SCBA

Property	Volcanic Ash	Rice Husk Ash (RHA)	Silica Fume	Sugarcane Bagasse Ash (SCBA)	Fly Ash
Source	Naturally occurring (lava dust)	Agricultural waste (rice husks)	Industrial by-product	Agricultural waste (sugarcane)	Industrial by-product (coal combustion)
Silica content (%)	50–65	85–95	>90	60–80	40–60
Pozzolanic activity	Moderate to high	High	Very high	Moderate to high	Moderate to high
Loss on ignition (LOI) (%)	<6	1–6	<3	2–10	<6
Water demand	Low to moderate	High	Very high	Moderate	Moderate
Effect on workability	Slight decrease or neutral	Decreases	Decreases	Slightly decreases	Often improves (Class F)
Effect on strength (28day)	Improves gradually	Improves significantly	Major early and longterm strength gain	Improves at optimal dosage	Improves (especially Class F)
Effect on porosity to water	Reduces moderately	Significantly reduces	Greatly reduces	Reduces at optimal dosage	Moderately reduces
Environmental impact	Low (natural material)	Very low (agrowaste)	Moderate (industrial processing)	Very low (agrowaste)	Moderate (industrial by-product)

Sugarcane Bagasse Ash (SCBA) is a promising supplementary cementitious material for mitigating corrosion-induced spalling due to its high silica content (60–80%) and moderate-to-high pozzolanic activity, which enhances calcium silicate hydrate (C-S-H) formation and densifies the concrete matrix, reducing water permeability and limiting ingress of corrosive agents (Kabir et al., 2020; Ganesan et al., 2021). Compared to fly ash, which typically has lower silica content (40–60%) and moderate pozzolanic reactivity, SCBA can achieve similar or improved reductions in porosity and improved microstructure when used at optimal replacement levels (Zhao & Zhang, 2022). Its finer particle size and greater surface area contribute to better packing density and crack resistance than many traditional pozzolans. While fly ash also improves workability and long-term durability, SCBA's agro-waste origin offers greater sustainability and local availability in sugarcaneproducing regions, reducing environmental impact (Kabir et al., 2020). Hence due to the properties of SCBA it proves that SCBA can increase concrete durability and it is ecofriendly compared to our SCMs

Introduction to Corrosion-induced Spalling in Concrete

Introduction to Corrosion-induced Spalling in Concrete

The Corrosion-induced spalling: This occurs when reinforcement steel in concrete undergoes corrosion as a result of penetration by chlorides, carbonation, and moisture. The corrosion generates iron rust with a volume six times larger than that of reinforcement steel. This leads to stresses responsible for creation of cracks in the surrounding concrete that ultimately lead to spalling of the concrete cover. This deterioration significantly aects the durability and strength of reinforced concrete structures (Bihamba, 2024; Mehta & Monteiro, 2021).

To overcome this problem, a number of protection and control techniques have already been considered. But most of those techniques had certain limitations regarding expense, sustainability, and viability. This prompted this current study to pursue other methods.

1. Use of Corrosion Inhibit

Corrosion inhibitors, which may be in the form of calcium nitrites or amino alcohols, are admixtures used in concrete to resist corrosion of steel. They work as a passive protecting layer for steel.

Limitations in Corrosion Inhibit

(a) Cost: High performance corrosion inhibitors are costly. This limits their use for largescale and low-cost buildings.

(b) Limited Lifespan: Their effectiveness expires with time, either because of leaching or chemical changes.

(c) Environmental Issues: Certain inhibitors might be harmful or environmentally dangerous; this may lead to sustainability issues (Siddique & Khan, 2022).

(d) Dependency on Uniform Distribution: Lack of sufficient mixing may cause a failure in protection, especially for larger pours.

2. Coatings on the reinforcement/concrete surface

Protection coatings can be applied directly to steel rebar (epoxy coatings and galvanized steel, for example) or directly to the surface of hardened concrete (silane sealers and bituminous coatings, for example) to resist the entrance of corrosive substances.

(a) Poor Bond: Epoxy coating may cause a reduction in bond strength between rebar and surrounding concrete.

(b) Damage Handling: ¡The protected rebar may be scratched while being transported or installed. This may form corrosion sites.

(d) Requirements for Maintenance: As surface coatings need to be replenished for their continued effect.

3. Cathodic Protection

Cathodic protection: This is an electrochemical process where a sacrificial anode protection system or an impressed current system can be used to inhibit corrosion attack on steel.

Limitations of Cathodic Protection

a) High Cost and Complexity: This demands constant power supply, observation systems, and expertise.

b) Limited Applicability: Not economically viable for residential and low-rise buildings.

c. Interference Issues: There might be interference with other structures/equipment when using impressed current.

d) Retrofit Challenges: Installation for existing buildings is a labor-intensive process.

4. Use of Low Permeability Concrete Mixes

High-performance concrete with a low water-to-cement ratio, silica fume concrete, and fly ash concrete are used to limit permeability and chloride diffusion.

Limitations of low-permeability mixes

(a) Workability Problems: Low water-cement ratio mixes may be problematic with regard to workability.

(b) Shrinkage Cracking: Early-age shrinkage-related problems such as shrinkage cracking may occur with high-performance concretes.

(c) Availability of Materials: Certain SCMs such as silica fume or fly ash may be unavailable in some areas and may be out of budget for some countries.

5. **Stainless Steel or Non-Metallic Reinforcement** such as FRP Bars By using stainless steel, fibre reinforced polymer (FRP), and/or basalt bars instead of conventional steel bars, corrosion problems can be completely eliminated. Limitacies de refinerços de aço inoxidável i refer

a) High Starting Cost: Such materials are much more costly compared to conventional steel.

b) Limited Structural Ductility: FRP reinforcement has low ductility and tends to be brittle compared to steel. c. Specialized design: This requires new designs and professionals who may be unaware of such materials.

d) Issues regarding recyclability: Certain FRP forms may be problematic for recyclability.

Despite various developments in methods for corrosion protection, most methods are currently limited either by cost considerations, longevity and complexity of application techniques, and adaptability for use in rural and developing countries. In this regard, the use of locally available low-cost sustainable materials such as sugarcane bagasse ash (SCBA) and bamboo fibers emerges as a viable substitute. The use of SCBA adds to the durability and density of a composite material but reduces its porousness and permeability. Bamboo fibers add toughness and strength to a composite material. They can effectively counteract corrosion induced spalling.

KNOWLEDGE GAP

In tropical environments with high levels of humidity and carbonation/chloride exposure, spalling due to corrosion in reinforced concrete remains a leading durability issue. Despite numerous studies for possible remedial measures such as coating systems, corrosion inhibitors, cathodic protection, and low-permeability mixes being available, such methods are often deemed ineffective because of their high cost, shorter life span requirements for maintenance, and other practical limitations. Although some work has been conducted using supplementary cementitious materials such as fly ash and silica fume for potential use in this regard, a large research gap does exist. Sugarcane bagasse ash (SCBA), a residue material generated in sugar factories, has shown promising pozzolanic properties to reduce permeability and inhibit the entry of corrosive agents. Nevertheless, most of the recent studies based on SCBA would be categorized as either strength enhancement research or shrinkage reduction but without focus on corrosion protection and resistance. The target of this research would be to assess whether SCBA can provide a sustainable and economical means for protecting reinforced concrete structures susceptible to corrosion. This would be extremely beneficial for decreasing future maintenance expenses and increasing the life span of concrete structures, apart from providing economic benefits.

CHAPTER THREE: METHODOLOGY

3.1 INTRODUCTION

This chapter is a comprehensive analysis and description of the materials used in this research and the experimental methods employed to meet the research objectives. This research focuses on the use of Sugarcane Bagasse Ash (SCBA) with the intention of reducing the permeability and strengthening the concrete. This research aims to combat spalling due to corrosion caused by the production of iron oxides that result from water penetrating concrete structures with steel reinforcement.

To properly evaluate the potential available in SCBA, a series of tests will be carried out. These tests include X-Ray Fluorescence (XRF), which provides information on elemental composition, the Chapelle Test for pozzolanic activity, Loss on Ignition (LOI), which tests for organic content among other properties, Sieve analysis for particle size distribution, and specific gravity. Further evaluation is carried out on fresh concrete mixtures with varying ratios of SCBA content for workability and consistency tested with the Slump Test.

Additionally, the mechanical properties and durability aspects of the hardened concrete can be assessed by testing its compressive strength, water absorption capacity, and accelerated corrosion to determine the resistance to spalling. Finally, the optimal mix design ratio can be determined for superior performance and compatibility among materials.

Altogether, these laboratory experiments are carefully planned and intended to contribute towards generating consistent research findings for the potential application of Sugarcane Bagasse Ash (SCBA) for the durability enhancement of reinforced concrete structures under severe climatic conditions.

3.1.1 Research Design

The research employs an experimental study to gather data, since the objective is to evaluate the efficacy of sugar cane bagasse ash in mitigating corrosion-induced spalling in reinforced concrete. The experimental investigation to acquire data goes as follows,

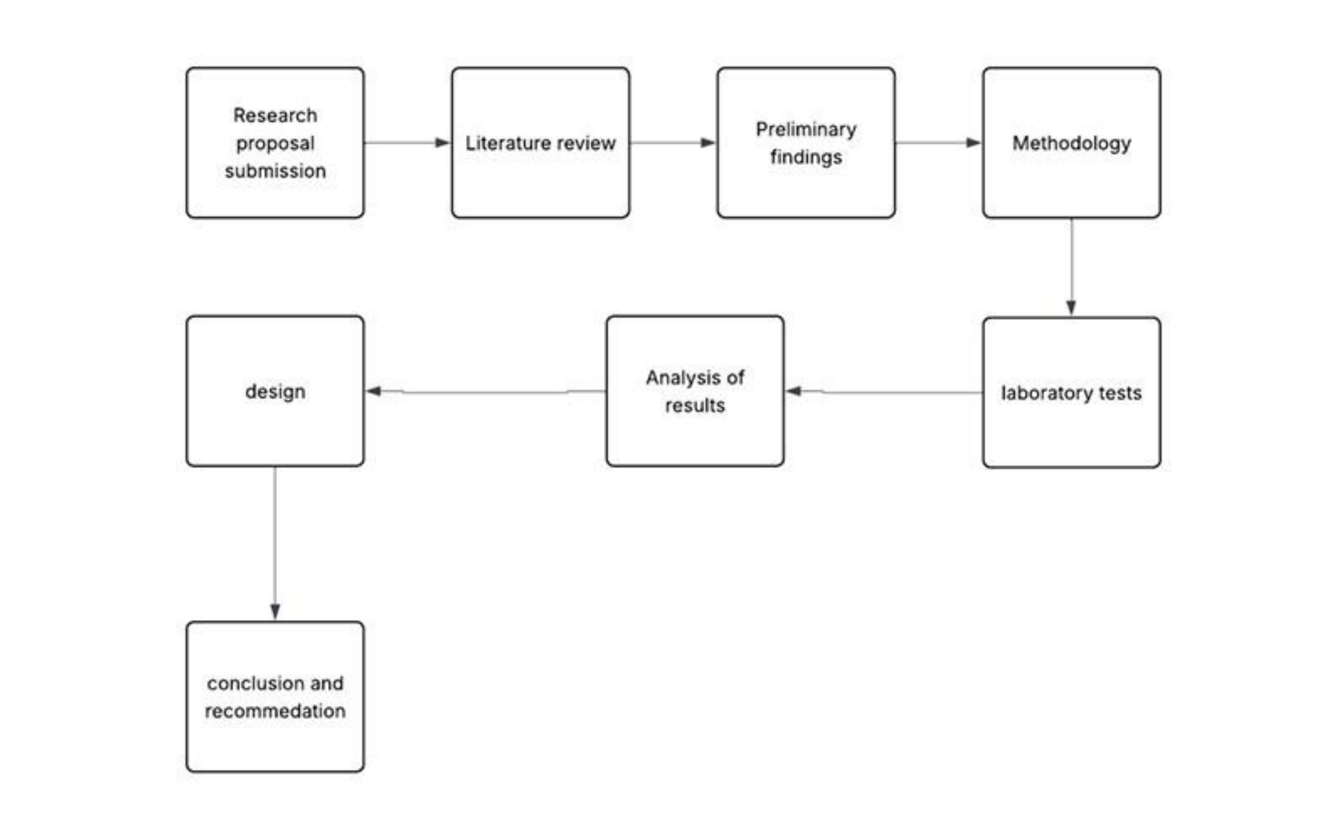


Figure 2: Research design

3.2 MATERIALS AND METHODS

I. Sugarcane Bagasse Ash

Sugarcane bagasse is a fibrous by-product created after sugarcane juice has been extracted in sugar manufacturing. For the research, the bagasse ash is to be acquired from the Kakira Sugar Limited (KSL) located in Jinja district. It primarily consists of cellulose, hemicellulose, and lignin, along with small amounts of ash and residual sugars.

The Raw Bagasse: Unprocessed/raw bagasse is just a light, fibrous material with low density and high organic content. Usually, it is employed as a biofuel or raw material for the paper and board industries, and is seen as a waste product to be removed along with the accompanying dust. However, in its raw state, it possesses low cementitious binding capacity.

Activated sugarcane bagasse is to be used in this study. The material is to be mixed into the cementitious mixtures in blends of 5%, 10%, 15%, and 20% by weight of cement. When sugarcane bagasse is heated at temperatures between 600 °C and 700°C, it is transformed into sugarcane bagasse ash. This ash is pozzolanic since it contains amorphous silica, thus qualifying it as a supplementary cementitious material for partial replacement of cement in concrete.

II. Cement

The binder to be used in this research is pozzolanic Portland cement to be purchased from a local supplier in Mukono town. This type of cement can be used with supplementary cementitious materials to enhance the properties of concrete. In this research, the combination of SCMs and natural fibres in the form of bamboo is aimed at improving the crack resistance, ductility and resistance of reinforced concrete to spalling.

III. Sand

The sand is to be procured from the Stirling labs located along the Kampala-Jinja highway and in Mbalala.

IV. Coarse aggregates

These are larger particles used in concrete, and they are to be acquired from the Stirling Laboratory located in Mbalala.

3.3 LABORATORY TESTS

3.3.1 Tests on the fine aggregates (Sand)

These are the tests that were conducted on the fine aggregates to ensure that they comply with the required standards for concrete

1. Sieve Analysis

Sieve analysis is important because it determines the particle size distribution of fine aggregates, which directly affects the workability, strength, and durability of concrete or mortar. Well-graded aggregates ensure good compaction, reduced voids, and lower cement consumption, while poorly graded aggregates can lead to segregation and weak concrete.

A dried sample of fine aggregates is passed through a set of standard sieves arranged in decreasing mesh size, usually ranging from 4.75 mm down to 150 µm. The weight retained on each sieve is measured, and the cumulative percentage passing is calculated. A grading curve is then plotted to assess whether the aggregate meets standard specifications.

2. Silt Content Test

This test is important because excess silt in fine aggregates coats the sand particles and reduces the bond between cement paste and aggregates, leading to lower strength and higher shrinkage in concrete. Most standards limit silt content to below 6–8% for fine aggregates.

A sample of sand is placed in a measuring cylinder, and water is added up to a certain mark. The mixture is shaken thoroughly and allowed to settle for about 2 hours. The thickness of the silt layer that settles on top of the sand is measured against the total height of the sand sample, and the percentage of silt content is calculated using the formula.

$$silt\ content = \frac{height\ of\ the\ silt\ layer}{height\ of\ the\ sediment} \times 100\%$$

3. Fineness Modulus (FM) Test

The fineness modulus is a single numerical value that indicates the average size of particles in fine aggregates. It is important because it helps in proportioning concrete mixes. Lower FM means finer sand (which increases water demand), while higher FM indicates coarser sand (which improves workability but may reduce cohesiveness). FM values for fine aggregates usually range from 2.3 to 3.1.

The test is conducted using the results of sieve analysis. The cumulative percentage retained on a standard set of sieves (from 150 µm to 4.75 mm) is added together and divided by 100. The resulting number is the fineness modulus, which is then used in concrete mix design calculations.

$$fineness\ modulus = \frac{cumulative\ weight\ retained\ on\ sieves}{total\ weight\ of\ the\ sample} \times 100\%$$

Figure 3: showing fine aggregate sampling

2 Tests on the coarse aggregates

i. Sieve Analysis

Sieve analysis for coarse aggregates is important because it determines the particle size distribution, which affects the strength, void ratio, and workability of concrete. Wellgraded coarse aggregates reduce voids, minimize cement paste requirements, and improve concrete durability, while poorly graded aggregates can cause segregation and honeycombing.

A representative dried sample of coarse aggregate is passed through a stack of standard sieves, usually ranging from 80 mm down to 4.75 mm. The amount retained on each sieve is weighed, and the cumulative percentage passing is calculated. A grading curve is plotted to check compliance with standard specifications for coarse aggregate.

2. Aggregate Strength Tests

Aggregate Impact Value (AIV): This test is important because it measures the aggregate's resistance to sudden shocks or impact loads. Aggregates with low AIV are tougher and better suited for concrete and road construction.

A small sample of aggregates is placed in a mould and subjected to repeated blows from a standard hammer. The percentage of fines (passing 2.36 mm sieve) generated is calculated as the AIV.

$$AIV = \frac{aggregate\ weight\ that\ passing\ through\ a\ 2.36\ mm}{weight\ of\ the\ oven\ dried\ sample\ of\ aggregate} \times 100\%$$

Aggregate Crushing Value (ACV): Important because it assesses the aggregate's ability to resist compressive loads, which is crucial for structural concrete. Low ACV indicates stronger aggregates

$$ACV = \frac{aggregate\ weight\ that\ passing\ through\ a\ 2.36\ mm}{weight\ of\ the\ oven\ dried\ sample\ of\ aggregate} \times 100\%$$

A sample of aggregate is placed in a cylindrical mould and subjected to a gradually applied compressive load. The fines produced (passing 2.36 mm sieve) are weighed and expressed as a percentage of the total sample weight.

Flakiness Index (FI): Important because flaky aggregates (thin and elongated particles) negatively affect workability, compaction, and strength of concrete. Standards specify a maximum percentage of flaky particles.

Procedure: Aggregate particles are passed through a set of sieves and then checked using a flakiness gauge. The proportion of flaky particles (with thickness less than 0.6 of mean size) is calculated as the FI.

$$flakiness\ index = \frac{total\ mass\ passing\ through\ the\ gauge}{total\ mass\ retained\ on\ all\ the\ sieves} \times 100$$

3. **Water Absorption Test**

Water absorption is important because it measures the porosity of aggregates, which influences durability and strength. High water absorption means more porous aggregates, which can weaken concrete and increase shrinkage and permeability. Most standards limit water absorption of coarse aggregates to below 2%.

A dried sample of aggregates is weighed (W1) and then immersed in water for 24 hours. After removing surface moisture with a cloth, the sample is weighed again (W2). The percentage increase in weight due to water absorption is calculated as:

3.4 DETERMINING THE CHEMICAL AND PHYSICAL PROPERTIES OF SUGARCANE BAGASSE ASH

The ash will be produced using an electric kiln. The bagasse will be fired using an electric kiln at 600 to 700°C for 2-4 to ensure that all organic matter is removed and to ensure total activation of the amorphous silica in the bagasse. The

TESTS TO BE CONDUCTED ON THE SUGARCANE BAGASSE ASH

3.4.1 CHEMICAL TESTS

1. X-RAY FLUORESCENCE TEST (XRF), BS EN 10315: 2006

This test will be conducted to determine the elemental composition of the SCBA. For this research, the main components being looked at are silica, alumina and iron oxides contained within the ash, which promote pozzolanic activity in the concrete.

In this test, the sample will first be prepared by grinding it into a fine powder and pressing it into a pellet or placing it in a sample holder. Once inside the XRF spectrometer, the sample will then be exposed to a beam of primary X-rays, which causes the atoms in the material to become excited and emit secondary (fluorescent) X-rays. These emitted Xrays have energies that are characteristic of specific elements. A detector measures the energy and intensity of these fluorescent X-rays, and specialised software analyses the data to determine the types and quantities of elements present in the sample.

2. CHAPELLE TEST FOR POZZOLANIC ACTIVITY, BS EN 196 -9

This test will be done to determine the pozzolanic reactivity by measuring the amount of calcium hydroxide consumed by a sample material.

In the test, a known quantity of the pozzolanic material (SCBA) will be mixed with an excess of calcium hydroxide and distilled water in a sealed container. The mixture will then be heated in a water bath at 90 ± 1°C for 16 hours to accelerate the reaction between the pozzolan and calcium hydroxide. After cooling, the solution is filtered, and the remaining calcium hydroxide in the filtrate is determined through chemical titration using hydrochloric acid. By comparing the amount of calcium hydroxide added initially with the amount remaining after the test, the amount that has reacted with the pozzolan is calculated.

3. LOSS OF IGNITION TEST BS EN 15935: 2012

This experiment will be conducted to determine the organic content in the material, and for this research, the raw form was used due to the increased presence of organic matter in its natural state. During this test, a pre-weighed of the ash will be placed in a crucible and heated in a muffle furnace at a specified high temperature, usually around 550°C to 950°C, for a fixed period (commonly 1 to 2 hours). At the same time that the heating process is carried out, there is a combustion or decomposition of organic materials, carbonates, and other volatile substances. The crucible, after cooling, is again weighed in a desiccator. The mass difference before and after burning is known as "loss on ignition" and is calculated as a percentage of the initial sample weight.

The formula for calculating loss on ignition is $loss\ of\ ignition=(W2-W3)W2-W1\times100\%$.

Where: W1 = weight of dry crucible

W2 = weight of crucible + dry SCBA before ignition

W3 = weight of crucible + ash after burning

PHYSICAL CHARACTERISTICS OF THE SCBA 1. PARTICLE SIZE DISTRIBUTION, BS EN 933 - 1:1977

This particle size is determined through sieve analysis, which is an important method for assessing both the fineness and grading of SCBA, these characteristics being of prime importance as they determine the performance of SCBA, the use of which is as a supplementary cementitious material in concrete. The process involves taking a representative sample of SCBA that has been dried in an oven, exactly weighing it, and then putting it in a set of standard test sieves that are placed in order of decreasing size of mesh. The sieves are then stacked on top of each other and put on a mechanical shaker, which shakes the sample for a certain amount of time so that the finer particles are able to pass through the mesh while the coarser ones stay on top. After the sieving, the different fractions collected on each sieve are weighed one by one. The weights are then calculated as proportions of the entire sample weight in order to assess the particle size distribution.

2. SPECIFIC GRAVITY, BS 812: PART 2: 1995

This test is used to determine the density of a material in relation to the density of other materials, usually water. This value is a pointer to the density characteristics of SCBA, which has a direct influence on its behavior in mix design and its effectiveness as a partial cement replacement.

For powdered materials like SCBA, the test involves using a pycnometer. First, the pycnometer is to be weighed empty, then filled with a known mass of the dry SCBA sample and weighed again. After that, water will be added to fill the pycnometer, ensuring no air bubbles remain, and the final mass is recorded. A separate measurement of the pycnometer filled only with water is also taken. Using these recorded weights, the specific gravity is calculated by comparing the volume of the displaced water to the mass of the SCBA sample.

$$specific\ gravity = \frac{weight\ of\ the\ sugarcane\ bagasse}{weight\ of\ an\ equal\ volume\ of\ water}$$

1. WATER ABSORPTION, BS 812: PART 2: 1995

Water absorption entails the determination of the water a material will soak up, and thus the process will indicate its absorption rate that will be expressed as a percentage. Water absorption is done by means of the material being submerged for a set period and the amount of water it absorbs being measured.

As for the test, a dry SCBA sample will first be subjected to oven-drying at a determined temperature (normally 105–110°C) until it attains a constant weight. The dry sample will then be immersed in water for 24 hours so that it can take in moisture. When the soaking time is over, the sample will be surface-dried with a cloth to get rid of any water that is not part of the material and then weighed again. The difference between the weights of the wet sample and dry sample is then determined, and the result is given as a percentage of the weight of the dry sample, which reflects the water absorption capacity of the SCBA.$water\ absorption = \frac{wet\ weight\ of\ substance - dry\ weight\ of\ the\ substance}{dry\ weight\ of\ the\ substance} \times 100\%$

3.5 DETERMINING THE PROPERTIES OF FRESH CONCRETE ON ADDITION OF SUGARCANE BAGASSE ASH (SCBA)

1. SLUMP TEST, BS 1881: PART 102: 1983

This test is to be used to assess the workability and consistency of fresh concrete. This is important for low-grade concrete due to its major problems with workability, and is an important factor for durability.

The slump test is to be conducted following BS 1881: Part 102: 1983 by filling a standard slump cone, placed on a flat non-absorbent surface, with fresh concrete in three equal layers. Each layer is compacted by tamping 25 times with a 16 mm diameter steel rod, evenly distributing the strokes to remove air voids. After the final layer is levelled off with the top of the cone, the cone is carefully lifted vertically to allow the concrete to slump. The slump is measured immediately as the vertical distance between the top of the cone and the highest point of the slumped concrete, indicating the workability of the mix.

Figure 4: showing slam test of 5% SCBA Concrete mix

3.6 DETERMINING THE RESISTANCE OF THE HARDENED CONCRETE TO SPALLING AT VARYING PROPORTIONS OF SUGARCANE BAGASSE ASH (SCBA)

Metallic cube moulds will be cleaned and lubricated for easy placement of the concrete. The dimensions of the cube moulds to be used will be 150 mm x 150 mm x 150 mm, which follows the specifications of BS EN 12390 -2: 2000. The moulds will then be filled with concrete in layers and compacted for uniformity and left for 24 hours before curing.

CURING OF THE CUBES BS EN 12390 – 3: 2002.

The concrete cubes are to be kept in a curing tank to gain strength after being removed from the moulds, and the tests on the cubes are to be done at 7 days, 14 days and 24 days. This process is important to ensure proper development of compressive strength.

1. COMPRESSIVE STRENGTH TEST BS 1881: PART 108:1983

After the curing period, the cubes are to be subjected to a compressive strength test. The cubes are loaded at a constant rate until failure occurs. The maximum load at which failure occurs will then be recorded, and the compressive strength calculated.

Before testing, the specimens were surface-dried and placed centrally in a calibrated compression testing machine. Load was applied continuously and without shock at a constant rate until the specimen failed. The maximum load at failure was recorded, and the compressive strength was calculated by dividing this load by the cross-sectional area of the cube.

$$compressive\ strength = \frac{maximum\ force\ at\ the\ failure\ point}{area\ of\ the\ concrete\ cube}$$

2. WATER ABSORPTION TEST BS 812: PART 2: 1995

After the curing period, the cubes will be weighed to determine the amount of water they have absorbed.

The water absorption test on concrete blocks is to be conducted as per BS 812: Part 2: 1995 by first oven-drying the concrete blocks at 105 ± 5°C until a constant mass is achieved, then cooling them to room temperature and recording the dry mass. The blocks are then fully immersed in clean water at room temperature for 24 hours to ensure complete saturation. After immersion, the blocks are then removed, surface water is wiped off with a damp cloth without extracting moisture from the pores, and the saturated surface-dry mass is recorded. The water absorption percentage is to be calculated by taking the difference between the saturated surface-dry mass and the dry mass, divided by the dry mass, and multiplied by 100.

$$water\ absorption\ = \frac{wet\ weight\ of\ substance - dry\ weight\ of\ the\ substance}{dry\ weight\ of\ the\ substance} \times 100\%0$$

Figure 5: showing curing of cubes and water absorption

3. ACCELERATED CORROSION TEST RILEM TC 154-EMCI

In order to measure the degree of corrosion of reinforced concrete under aggressive conditions the accelerated corrosion test is to be carried out. This particular technique imitates the process of corrosion of the reinforcement by the use of an external electric current that introduces the chloride ions and at the same time oxidizes the steel that is already buried. The making and curing of the concrete cylinders with the 12 mm diameter steel bars embedded in their centers will take 28 days. The thickness of the concrete cover will be between 20 to 25 mm at all times. Once curing is done, the specimens will be submerged in a solution of 3.5% NaCl, in such a way that only part of the concrete surface and the embedded steel is exposed to the chloride environment. Using a potentiostat, a constant direct current of 200-500 μA/cm² will be applied across the steel surface area, with the steel bar being the working electrode (anode) and a stainless-steel plate or graphite rod being the counter electrode (cathode). The test arrangement will also involve the continuous observation of the voltage drop across the system. The test will be for a period that will vary according to the current density and corrosion rate, usually ranging from several days to weeks. The specimens are to be checked every now and then for the development of cracks on the surface and spalling. After the test, the samples will be cut in half, one part for the measurement of the corrosion depth, the other for showing the presence of rust and the extent of cracking along the reinforcement. This rapid method yields important information regarding the corrosion resistance of concrete combined with sugarcane bagasse ash and bamboo fibers, thus mimicking the long-term degradation in marine or chloride-laden environments in a matter of days or weeks.

Figure 6: Showing accelerated corrosion test set up

CHAPTER FOUR: RESULTS AND DISCUSSION

In this section, there is a summary on the results gathered from various laboratory tests conducted to determine the suitability of Sugarcane Bagasse Ash (SCBA) towards preventing the spalling effect that occurs due to corrosion on the concrete. The tests included the identification and analysis of fine and coarse aggregates, chemical and physical analysis of SCBA, and tests on the concrete properties such as slump test, compressive strength, water absorption capacity, and accelerated corrosion.

Fine Aggregates

The specific gravity for the fine aggregates was found to be 2.633 with a water absorption capacity of 0.463% as shown in result ***Table 3.*** The percentage content of silt was found to be 4.3%, which is well within the criteria laid down by BS 882 (Specification for aggregates from natural sources for concrete). This analysis shows that the fine aggregates possess desirable properties with regard to specific gravity and water absorption capacity for reinforced concrete.

Table 3: showing properties of fine aggregate.

FINE AGGREGATE RESULTS		
Property	**Test Result**	**Typical Standard Requirement / Limit**
Water Absorption	0.46%	<1% is considered excellent
Silt Content (Fines)	4.30%	≤10% is common for most applications
Bulk Specific Gravity (OD)	2.633	> 2.00

Coarse Aggregates

The bulk specific gravity and water absorption for the coarse aggregates were found to be 2.622 and 0.3% respectively.

Mechanical properties for the coarse aggregates: Aggregate Crushing Value (ACV), Aggregate Impact Value (AIV), Los-Angeles Abrasion Value and Ten Percent Fines Value were determined to confirm whether the coarse aggregates were suitable for the production of concrete based on BS 882 Specification for aggregates from natural sources for concrete.

Table 4: Showing results for the properties of coarse aggregate

COARSE AGGREGATE RESULTS		
Property	Test Result	Typical Standard Requirement / Limit
Water Absorption	0.30%	<1% is considered excellent
Ten Percent Fines Value (TFV)	209.7 kN	> 110 kN is a common specification threshold
Wet/Dry Strength Variation	98%	> 75% is typically required
Aggregate Crushing Value (ACV)	16%	≤20% for high-strength concrete
Aggregate Impact Value (AIV)	16.40%	≤18% for high-strength concrete
Los Angeles Abrasion (LAA)	17%	≤20% for high-quality concrete
Bulk Specific Gravity (OD)	2.622	> 2.00

Chemical and Physical Characterization of Sugarcane Bagasse Ash

From ***Table 5***. It is observed that the chemical analysis showed a percentage content of total silica and alumina at 92.55% higher than the ASTM C618 criteria for Class F pozzolans with a requirement of at least 70% on total chemical analysis. The Loss on Ignition (LOI) was marginally higher at 9.038% compared with the allowed criteria for ASTM and is thus satisfactory. Additionally, the lime reactivity given at 3.382% $MgCa(OH)_2$ was satisfactory for pozzolanic activity as required by Chapelle tests. With a specific gravity and grading modulus of 2.705 and 0.61 respectively, this is a highly reactive material from a physical point of view. It can thus be inferred that this material would be responsible for contributing to more calcium silicate hydrate (C-S-H) gel with consequent improvements within the permeability and pore structure.

Table 5: Showing results for the properties of coarse aggregate

Parameter	Units	Results Sugarcane bagasse ash DFD 355/2025
Silicon dioxide	% m/m	72.62±0.33
Aluminum Oxide	% m/m	19.93±0.32
Iron (III) Oxide	% m/m	4.71±0.22
Potassium Oxide	% m/m	1.04±0.09
Calcium Oxide	% m/m	1.02±0.32
Chlorine	% m/m	0.31±0.08
Manganese (II) Oxide	% m/m	0.25±0.11
Europium (III) oxide	% m/m	0.006±0.19
Titanium di oxide	% m/m	0.003±0.05
chromium (III) oxide	% m/m	0.0020±0.01
	Test result	Standard
Loss on ignition	9.0% m/m	>10%
Chapelle test	3.38% Mg $Ca(OH)_2$	>0.330%

Concrete Mix Design and Performance

Concrete was made for Class 25/20 with cement content of 375 kg/m^3 and w/c ratio of 0.5. A slump test with a range of 90 ± 30 mm showed a moderate workability suitable for reinforced concrete. The air content with just 2% and fineness and coarse aggregates mix proportion was within the standard design limits. The above-mentioned parameters ensured that there was a proper mix between strength and workability.

Discussion of Findings

The results give a unanimous voice that the local materials used are fit for the manufacture of their structurally sound and durable concrete. The chemical composition and the pozzolanic behavior of SCBA imply that it can be replaced to a partial extent with cement for improving microstructure and decreasing permeability, thus reducing corrosion of the steel embedded. The mechanical test results of the aggregates gave confirmation of the materials' suitability for load-bearing applications, whereas the controlled mix design proved sufficient strength and workability. The results of this study back the assumption that SCBA can increase the corrosion resistance and durability of reinforced concrete, thus participating in the development of eco-friendly and economical construction practices.

Effect of the sugarcane bagasse ash on the workability of the concrete

The observed variation in slump with increasing Sugarcane Bagasse Ash (SCBA) replacement in ***Fig.7*** can be attributed to the physical and chemical characteristics of SCBA, particularly its high specific surface area, porosity, and water absorption capacity. At low replacement levels, the slump initially increases before decreasing at moderate levels and then rising again at 20% replacement.

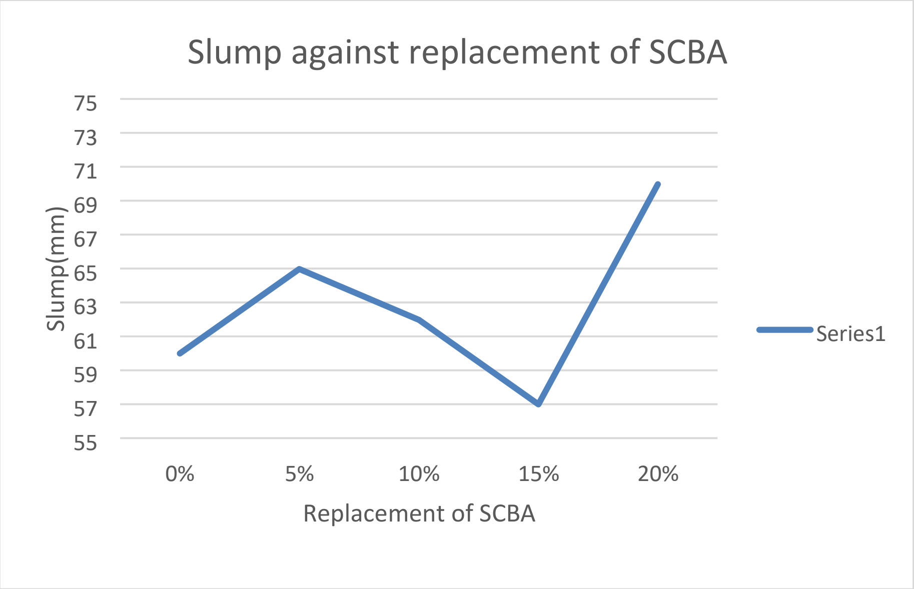


Figure 7: Showing slum test against replacement of SCBA.

However, at 5% mix replacement with SCBA, the slump is higher compared to the mix proportion of the control mix. Such a trend can be associated with the micro-filler effect resulting from the fineness of the particles of SCBA. The effect is known to increase the packing density and thus facilitate the lubricating process within the mixes (Olutoge et al., 2021; Waryoba et al., 2022).

Between 10% and 15% SCBA, the slump gradually drops. The typical surface morphology of SCBA is highly irregular and very porous; this feature gives higher absorbability to water. As the proportion of SCBA increases, more and more mixing water gets sucked into the ash particles. As such, the free water content within the cement paste ends up being reduced; this means less workability and reduced slump (Srinivas et al., 2020; Nguyen et al., 2023). The reduced slump at this point can be attributed to the higher water demand required for mixes containing highly absorbent and lightweight ash particles.

However, at higher dosages of 20% SCBA, the slump considerably increases. Despite violating the general trends for pozzolanic material replacement, such phenomena can be noticed for higher amounts of lightweight particles of SCBA that might influence the paste rheology and lead to the production of a more cohesive and less dense paste. This can lead to lower interparticle friction and easier flow of the mix. Although opposite to normal trends for pozzolanic material replacement, a little deviation in mixing water content and fineness for higher amounts can trigger considerable improvements in mix workability (Kumar and Rai, 2021; Mehta and Siddique, 2022). For similar unexpected trends observed for mixes with higher amounts of SCBA content, relevant literature can be found.

Effect of replacement of cement with Sugarcane bagasse ash on the compressive strength of concrete

There is a marked trend noticed for the compressive strength at 7, 14, and 28-days with the increase in the percentage replacement of cement with Sugarcane Bagasse Ash (SCBA). For the reference mix (0% SCBA), the hydration process for the normal Portland cement follows normally and gives strength values of 30.2±0.34MPa at 7-days, 34.1±0.59MPa at 14-days, and finally at 28-days reaches values of 38.5±0.46MPa. For mixes containing 5% replacement with SCBA, the increase is marked for all periods with the strength at 28-days touching a high of 39.8±0.78MPa.

This is chiefly due to the high amorphous content of silica found within the SCBA that triggers higher pozzolanic reactions and thus additional formations of Calcium Silicate Hydrate (C-S-H). Also, due to its fine particles contributing towards the microfiller effect resulting in higher concrete packing and reduction within the void content resulting thus within the enhancement of strength. For similar findings being noticed, reference may be made to various researches pointing out similar facts and confirming thus that small amounts of SCBA can be highly beneficial for enhancement within the mechanical strength due to improved particle and higher pozzolanic reactivities (Srinivas et al., 2020; Mehta and Siddique, 2022; Nguyen et al., 2023).

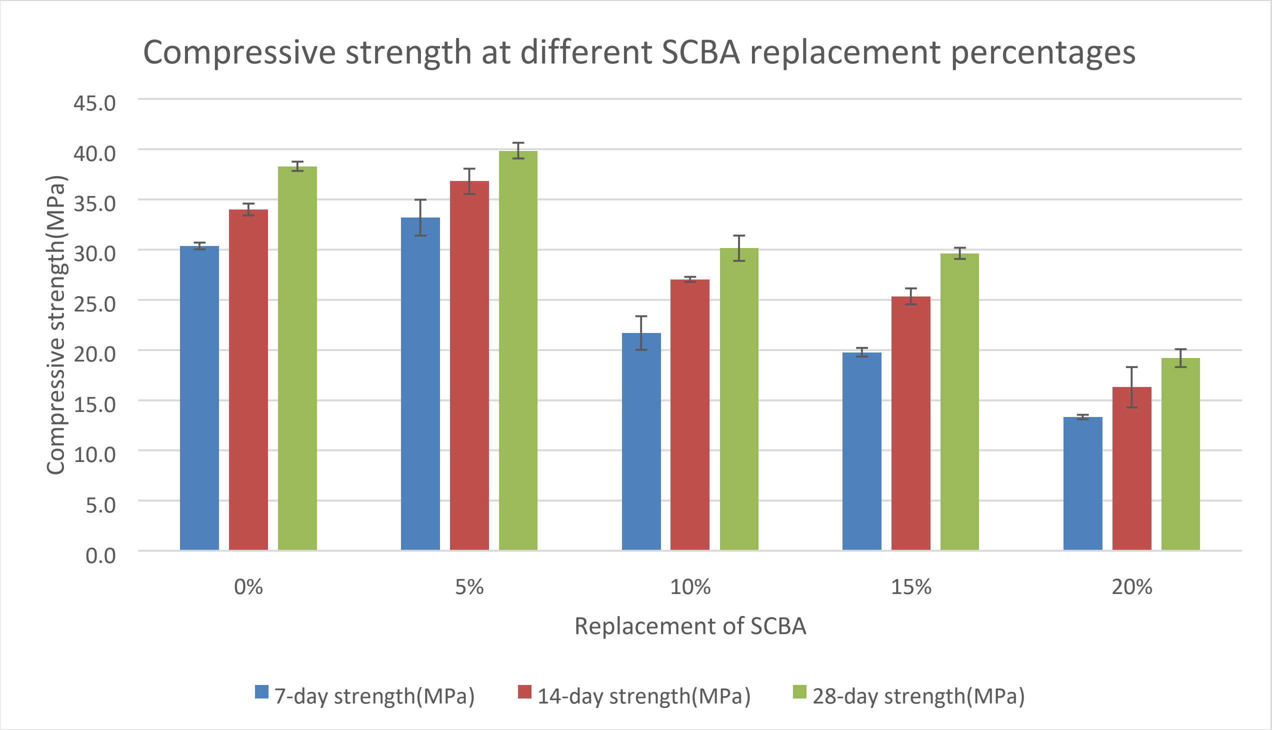


Figure 8: Compressive Strength at different Sugarcane bagasse ash replacement percentages

In Figure.8, as the replacement level is raised to 10%, there is a gradual reduction in the compressive strength from 39.8±0.78 MPa to 30.1±1.26 MPa. However, this is still within tolerable limits. With the increase in replacement levels comes a reduction in the amount of cement paste available for hydration processes and is therefore unable to fully benefit from the pozzolanic reaction exhibited by SCBA at this content percentage. In addition to this effect on strength, the higher water requirement for hydration resulting from the porous and irregular particle shape and size for SCBA works to increase workability and compactness difficulties, thus reducing strength. It can be supported by literature that moderate levels of SCBA can result in reduced compressive strength due to dilution and pozzolanic reaction (Olutoge et al., 2021; Waryoba et al., 2022).

With a replacement level of 15% for SCBA, the compressive strength is reduced further to 29.6±0.56 MPa at 28 days. Although pozzolanic reactions continue to occur to some extent, they cannot compensate for the drastic reduction in the amount of cement paste. Too much sugarcane bagasse ash functions more as the inactive filler material instead of the reactive one material, and the higher internal porosity created by improper particle distribution reduces the strength of the binder material. This is consistent with other research works that found higher levels of SCBA tend to produce inferior mechanical strength owing to cement dilution and variability in fineness and reactivity properties of ash (Kumar & Rai, 2021).

At a replacement rate of 20% for SCBA, the compressive strength is found to be least for all curing periods for concrete, while at the end of 28 days, the compressive strength is reduced to 19.1 ± 0.9 MPa. This is due to the higher replacement rate of cement paste, thereby reducing the C-S-H gel content to a great extent. Unreacted particles of SCBA form voids at the micro-level and bring down the strength. A higher percentage replacement is known to cause inadequate pozzolanic reactions owing to the limited availability of calcium hydroxide for reactions with fly ash. This is reportedly a limiting factor for the use of SCBA at higher percentages (Nguyen et al., 2023; Mehta and Siddique, 2022).

In general, the overall trend shows that the optimal replacement percentage of cement with SCBA is at 5% for optimal compressive strength. For replacement percentage ranging between 10% and 15%, there is a gradual reduction in strength owing to reduced cement content and underactivity of ash, and for a replacement percentage of 20%, there is a sharp fall in strength showing that higher percentage content of SCBA is not suitable for application where higher structural strength is desired.

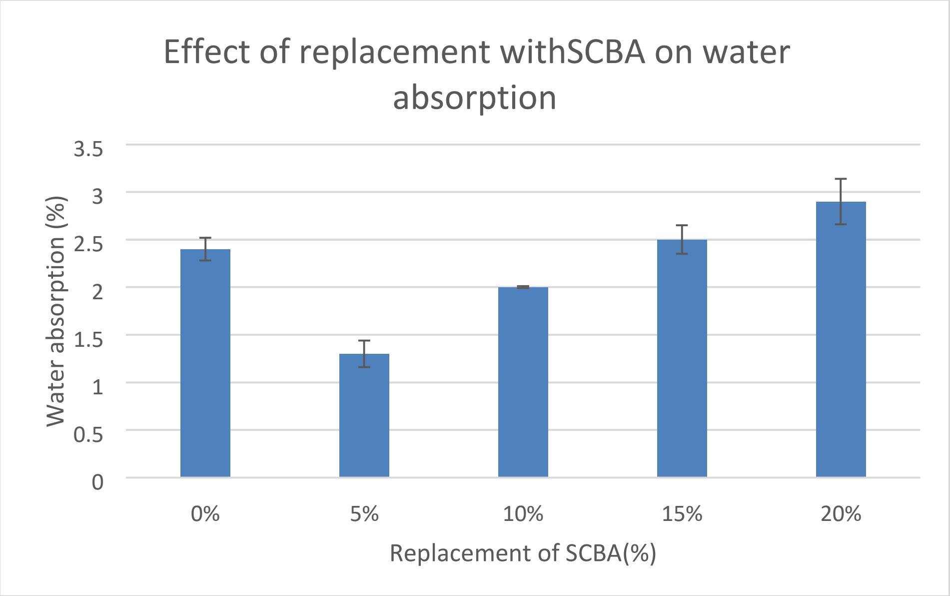


Figure 9: Effect of replacement of cement with Sugarcane bagasse ash on the water absorption of concrete

From ***Figure.9*** it can be observed that initially the percentage of water absorption declines at a rate of 5% SCBA mix replacement from 2.4% ±0.12% at 0% SCBA to 1.3% ±0.14% at 5% and then a gradual increase with every increase in the percentage from 10% to 20% at 2.0% ±0.01% at 10% and then ascending to 2.5% ±0.15% at 15% and finally at 2.9% ±0.24% at 20% respectively. The decline at the 5% mix replacement is mainly manifested by the microfiller properties possessed by the fine particles of the SCBA mix filling the voids and thus hardening with intensified impermeability (Mehta & Siddique, 2022). Thus, fewer passage ways for water movement through the concrete mix would be realized with the optimized percentage mix. However, with the increase above the optimized mix percentage at 5%, the water absorption increases once again. As such, higher mix percentage levels increase the porosity properties and thus reduced reactivity with lower impermeable properties (Nguyen et al., 2023). Additionally, with higher mix levels above the optimized percentage mix at 5%, the overall mix is diluted with reduced levels of hydration products (Nguyen et al., 2023)

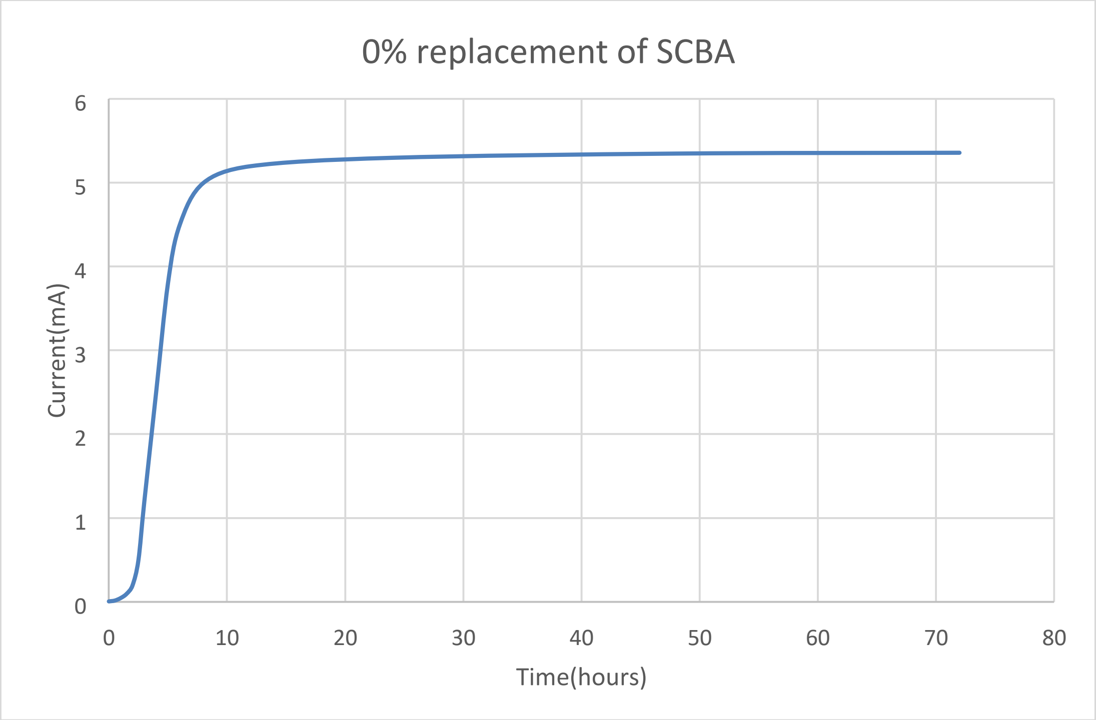


Figure 10: Effect of SCBA on the corrosion resistance of the reinforced concrete

In ***Figure.10*** For the control mix (0% SCM replacement rate), a typical sharp increase in the corrosion current is observed with the first critical time occurring at around 2.3 hours (Lin and Cheng, 2013; NT BUILD 356, 1989). From the experimental details given above, the current was observed to increase from 0.01 mA at time zero to reach a peak of 1.2 mA at the end of the third hour. However, this sharp increase means that the chloride ions from the NaCl solution (3.5%) readily penetrated the concrete cover with minimal resistance to reach the steel surface. As soon as the ion concentration at the steel surface exceeded the threshold necessary for the depassivation threshold of the protective oxide layer on the steel surface, active corrosion began (Lin and Cheng, 2013). However, the continued increase in current to reach a plateau at around 5.3 mA is consistent with sustained corrosive activity. It can be noticed that minimal ion transfer resistance is enabled for mixes with high permeability and without supplementary cementitious materials (SCMs); this resulted in both advanced depassivation and high corrosion rates with higher current at the end (Caré and Raharinaivo, 2007).

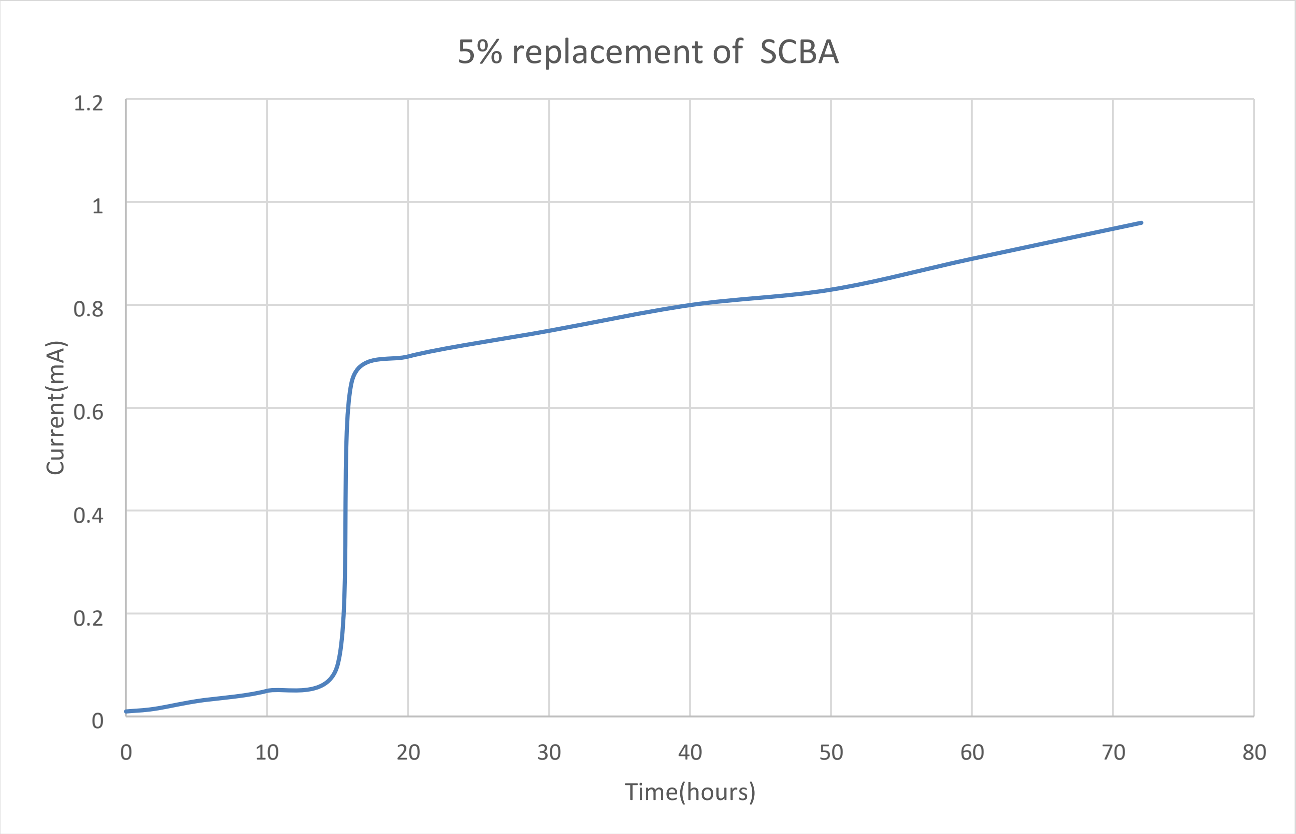


Figure 11:5 Percentage Replacement of Sugarcane bagasse ash

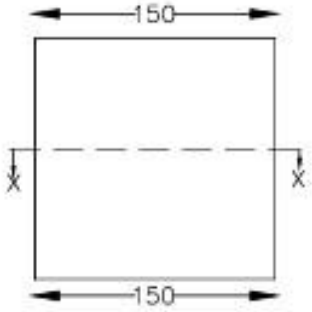
In ***Figure.11*** the result for the composite containing a replacement of 5% Sugarcane Bagasse Ash (SCBA), which shows a remarkable enhancement in the anti-corrosion properties. In this case, the critical time is remarkably postponed and occurs between 15 and 16 hours. The sudden increase in current from 0.1 mA to 0.65 mA affirms this finding. This pronounced delay can be explained scientifically by the ability of the SCBA to block the pores and display pozzolanic reactions. In this regard, fine SCM particles such as SCBA form a chemical reaction with calcium hydroxide ($Ca(OH)_2$), which is produced as a result of the hydration process. As such, additional calcium silicate hydrate gel (C-S-H gel) is produced (Lin and Cheng, 2013). In this process, the secondary reaction leads to a refinement and reduction in the volume and capillary connectivity within the cement paste. In this regard, the transfer rate for chloride ions is remarkably reduced, and this accounts for the time taken for the threshold amount for the initiation of corrosion to be achieved.

Additionally, after the corrosive process has begun, the rate of corrosion for the 5% SCBA mix is still well below that for the control mix. For the 5% mix, the current reaches a plateau at approximately 0.96 mA after the first 72 hours, which is more than five times lower than that for the control mix at plateau current (~5.36 mA). This shows that even after the protective barrier has broken down, the closely packed structure produced by the addition of the SCBA agent works to restrict ion movement to hinder the process of ion transfer for the continuation of the corrosive reaction (Lin and Cheng, 2013). The performances mixes containing SCM is consistent with the finding made by other research carried out by Lin and Cheng (2013); they found that material such as fumed silica and slag can increase compactness and prevent the corrosion of rebar. Thus, replacement with SCBA at a percentage rate of 5% is effective for improving durability by either preventing the start and rate of corrosion.

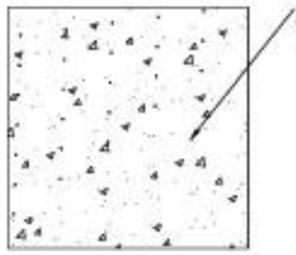
4.1 DESIGN MIX AND ENGINEERING DRAWING

Concrete Mix Design (Class 25/20) for 1m^3 of concrete

- Binder & Water
- Cement (CPC 42.5): 356.25 kg/m^3 Water: 187.5 L
- w/c ratio: 0.5
- Mass of sugarcane bagasse ash 18.75 kg/m^3
- Aggregates Distribution
- 14–20 mm (25%): 421.9 kg
- 10–14 mm (12%): 212.6 kg
- 5–10 mm (20%): 353.6 kg
- Natural sand (43%): 762.6 kg
- Key Parameters
- Slump: 90 ± 30 mm
- Total volume: 1.0 m^3
- Air content: 2%

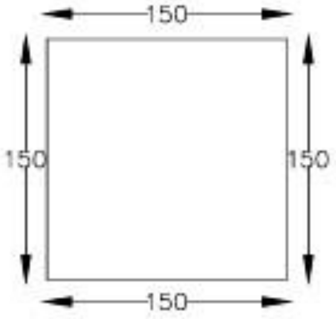


PLAN

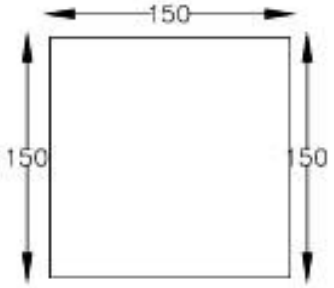


C25 CONCRETE
WITH CEMENT, AGGREGATES
AND 5% SUGARCANE
BAGASSE ASH

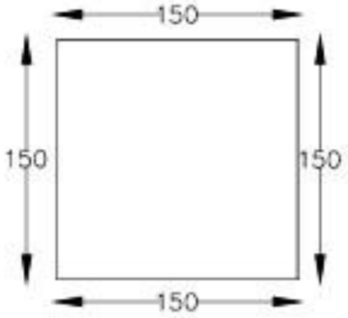
SECTION X-X



EAST END ELEVATION



FRONT ELEVATION
Scale 1:100



WEST END ELEVATION

PROJECT NAME
ASSESSING THE
SUITABILITY OF
SUGAR CANE
BAGASSE ASH IN
PREVENTING SPALLING

DRAWING NAME
TYPICAL CONCRETE
BLOCK

NAME
KHAN GAK NGAW
M22B32/019

SCALE
1:100

A3

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1Conclusions

From the experimental findings, it can be observed that Sugarcane Bagasse Ash (SCBA) has significant influence on concrete at fresh, hardened, and durability stages with high amorphous silica content an eco-friendly supplementary cementitious material able to enhance the density of concrete and reduce corrosion-induced deterioration very effectively (Kabir et al., 2020; Singh et al., 2021).

The result for water absorption showed that the optimal content was at 5% replacement with SCBA. Water absorption was higher for replacement between 10% and 20% with lower cement content. Workability decreased with a gradual increase in the content of the SCBA due to the higher water demand of the material as depicted by the slump values.The replacement percentage of 5% SCBA produced superior results for all tests.

For the accelerated corrosion test, breakthrough time for chloride was observed to be very rapid for the control mix (0% SCBA), and the current due to corrosion started escalating at around 2.5 hours. However, for the mix containing 5% SCBA, the time for chloride breakthrough was higher at approximately 15.7 hours. Also at 72 hours, the current for the 5% mix was observed to be much lower.

5.2 Recommendations

On the basis of overall durability and resistance to corrosion parameters, the use of 5% SCBA in structural concrete under a chloride environment is recommended. This dosage ensures maximum pore refinement without any dilution effect.

With higher levels of SCBA, workability decreases and water content increases. In case higher amounts of SCBA above 10% should be employed, plasticizes and water-reducing admixtures can be used to mitigate adverse effects. For extra strength and durability, I recommend the use of bamboo fibers as mini reinforcement to prevent formation of micro-cracks in the future

In addition to this, natural exposure tests for a duration ranging from 6-12 months should be carried out to ensure the improved properties found in the accelerated tests persist under natural conditions it can be used for structural works such as beams, slabs, columns, stairs, and foundations for marine structures and other wet and chloride environment conditions.

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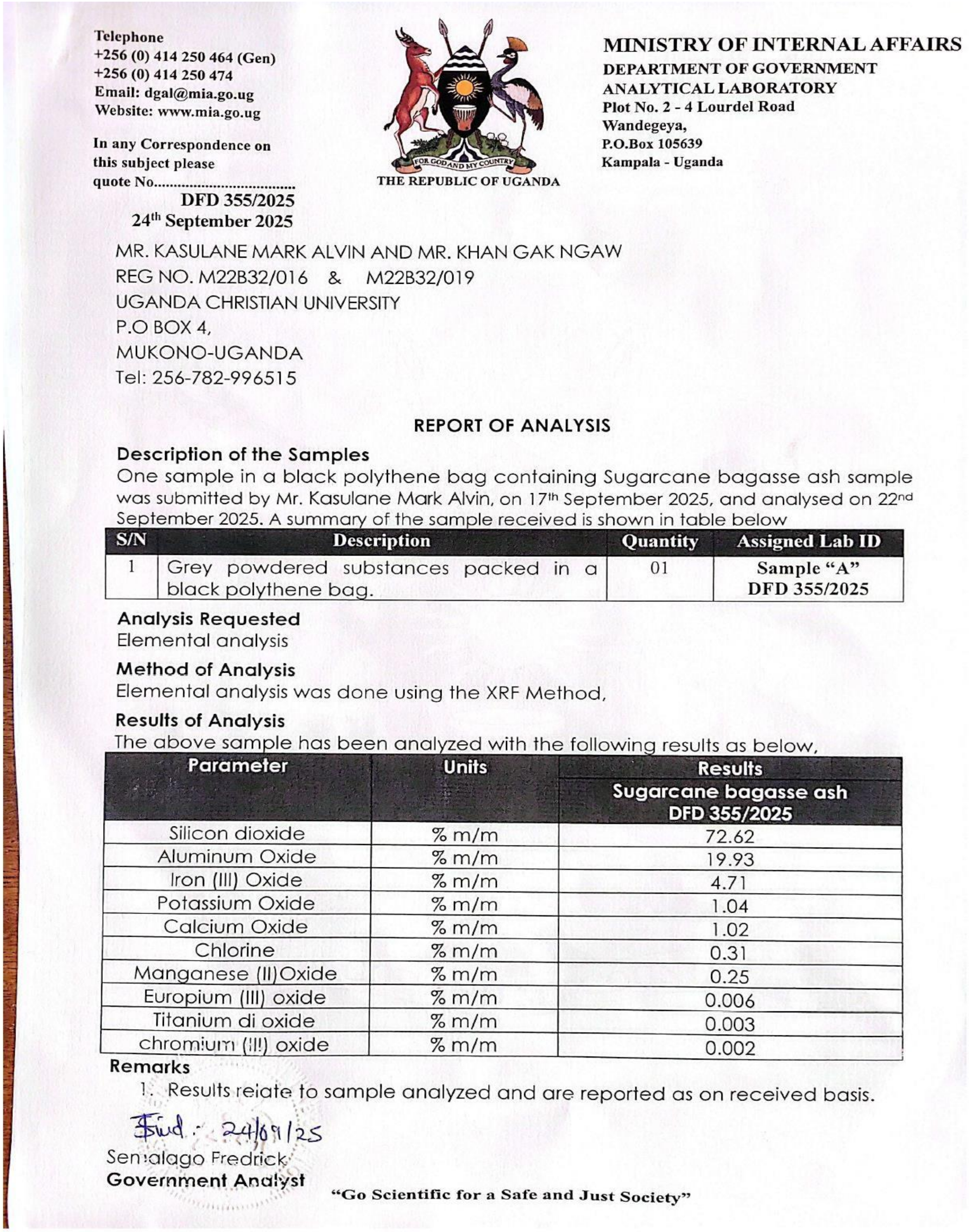
APPENDICES



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

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

In any Correspondence on
this subject please
quote No....................................
DFD 355/2025
24th September 2025

MR. KASULANE MARK ALVIN AND MR. KHAN GAK NGAW
REG NO. M22B32/016 & M22B32/019
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. Kasulane Mark Alvin, 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 355/2025

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,

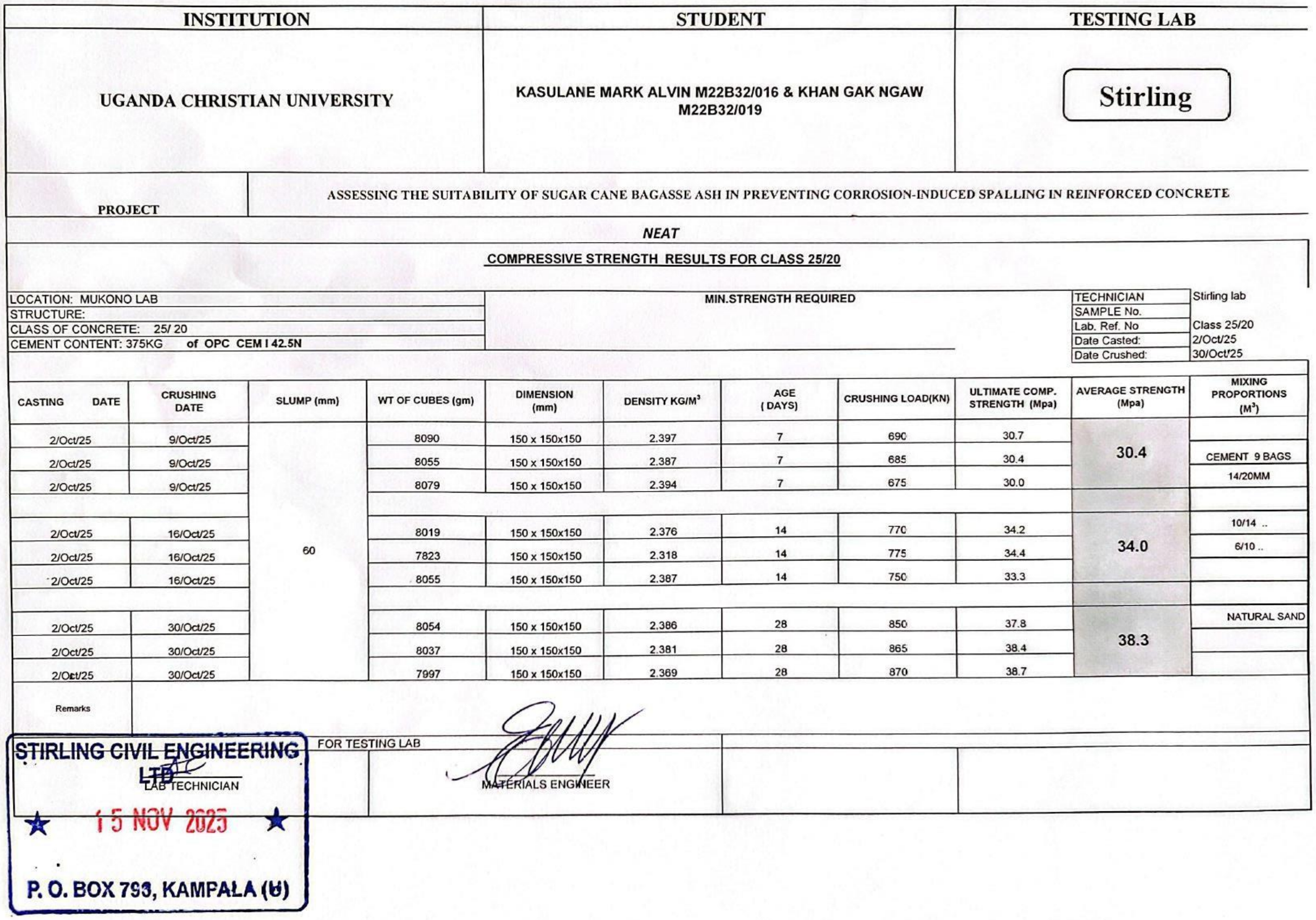
Parameter	Units	Results
		Sugarcane bagasse ash DFD 355/2025
Silicon dioxide	% m/m	72.62
Aluminum Oxide	% m/m	19.93
Iron (III) Oxide	% m/m	4.71
Potassium Oxide	% m/m	1.04
Calcium Oxide	% m/m	1.02
Chlorine	% m/m	0.31
Manganese (II)Oxide	% m/m	0.25
Europium (III) oxide	% m/m	0.006
Titanium di oxide	% m/m	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"



INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	Stirling
PROJECT	ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE	

NEAT

COMPRESSIVE STRENGTH RESULTS FOR CLASS 25/20

LOCATION: MUKONO LAB
STRUCTURE:
CLASS OF CONCRETE: 25/ 20
CEMENT CONTENT: 375KG **of OPC CEM I 42.5N**

MIN.STRENGTH REQUIRED

TECHNICIAN	Stirling lab
SAMPLE No.	
Lab. Ref. No	Class 25/20
Date Casted:	2/Oct/25
Date Crushed:	30/Oct/'25

CASTING DATE	CRUSHING DATE	SLUMP (mm)	WT OF CUBES (gm)	DIMENSION (mm)	DENSITY KG/M³	AGE (DAYS)	CRUSHING LOAD(KN)	ULTIMATE COMP. STRENGTH (Mpa)	AVERAGE STRENGTH (Mpa)	MIXING PROPORTIONS (M³)
2/Oct/25	9/Oct/25	60	8090	150 x 150x150	2.397	7	690	30.7	30.4	
2/Oct/25	9/Oct/25		8055	150 x 150x150	2.387	7	685	30.4		CEMENT 9 BAGS
2/Oct/25	9/Oct/25		8079	150 x 150x150	2.394	7	675	30.0		14/20MM
2/Oct/25	16/Oct/25		8019	150 x 150x150	2.376	14	770	34.2	34.0	10/14 ..
2/Oct/25	16/Oct/25		7823	150 x 150x150	2.318	14	775	34.4		6/10 ..
2/Oct/25	16/Oct/25		8055	150 x 150x150	2.387	14	750	33.3		
2/Oct/25	30/Oct/25		8054	150 x 150x150	2.386	28	850	37.8	38.3	NATURAL SAND
2/Oct/25	30/Oct/25		8037	150 x 150x150	2.381	28	865	38.4		
2/Oct/25	30/Oct/25		7997	150 x 150x150	2.369	28	870	38.7		
Remarks										

FOR TESTING LAB			
LAB TECHNICIAN	MATERIALS ENGINEER		

STIRLING CIVIL ENGINEERING LTD
15 NOV 2025
P. O. BOX 793, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	Stirling

PROJECT ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE

5% SUGARCANE BAGASSE ASH

COMPRESSIVE STRENGTH RESULTS FOR CLASS 25/20

LOCATION: MUKONO LAB
STRUCTURE:
CLASS OF CONCRETE: 25/ 20
CEMENT CONTENT: 375KG of OPC CEM I 42.5N

MIN.STRENGTH REQUIRED

TECHNICIAN	Stirling lab
SAMPLE No.	
Lab. Ref. No	Class 25/20
Date Casted:	2/Oct/25
Date Crushed:	30/Oct/25

CASTING DATE	CRUSHING DATE	SLUMP (mm)	WT OF CUBES (gm)	DIMENSION (mm)	DENSITY KG/M³	AGE (DAYS)	CRUSHING LOAD(KN)	ULTIMATE COMP. STRENGTH (Mpa)	AVERAGE STRENGTH (Mpa)	MIXING PROPORTIONS (M³)
2/Oct/25	9/Oct/25	65	8085	150 x 150x150	2.396	7	705	31.3	33.2	
2/Oct/25	9/Oct/25		8075	150 x 150x150	2.393	7	785	34.9		CEMENT 9 BAGS
2/Oct/25	9/Oct/25		8065	150 x 150x150	2.390	7	750	33.3		14/20MM
2/Oct/25	16/Oct/25		8085	150 x 150x150	2.396	14	860	38.2	36.8	10/14 ..
2/Oct/25	16/Oct/25		8105	150 x 150x150	2.401	14	820	36.4		6/10 ..
2/Oct/25	16/Oct/25		8045	150 x 150x150	2.384	14	805	35.8		
2/Oct/25	30/Oct/25		8222	150 x 150x150	2.436	28	915	40.7	39.9	NATURAL SAND
2/Oct/25	30/Oct/25		8196	150 x 150x150	2.428	28	880	39.1		
2/Oct/25	30/Oct/25		8256	150 x 150x150	2.446	28	895	39.8		

Remarks

FOR TESTING LAB

MATERIALS ENGINEER

STIRLING CIVIL ENGINEERING LTD
LAB TECHNICIAN
15 NOV 2025
P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	Stirling

PROJECT	ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE

10% SUGARCANE BAGASSE ASH

COMPRESSIVE STRENGTH RESULTS FOR CLASS 25/20

LOCATION: MUKONO LAB
STRUCTURE:
CLASS OF CONCRETE: 25/ 20
CEMENT CONTENT: 375KG of OPC CEM I 42.5N

MIN.STRENGTH REQUIRED

TECHNICIAN	Stirling lab
SAMPLE No.	
Lab. Ref. No	Class 25/20
Date Casted:	2/Oct/25
Date Crushed:	30/Oct/25

CASTING DATE	CRUSHING DATE	SLUMP (mm)	WT OF CUBES (gm)	DIMENSION (mm)	DENSITY KG/M^3	AGE (DAYS)	CRUSHING LOAD(KN)	ULTIMATE COMP. STRENGTH (Mpa)	AVERAGE STRENGTH (Mpa)	MIXING PROPORTIONS (M^3)
2/Oct/25	9/Oct/25	62	8000	150 x 150x150	2.370	7	525	23.3	21.7	
2/Oct/25	9/Oct/25		8070	150 x 150x150	2.391	7	450	20.0		CEMENT 9 BAGS
2/Oct/25	9/Oct/25		8045	150 x 150x150	2.384	7	490	21.8		14/20MM
2/Oct/25	16/Oct/25		8030	150 x 150x150	2.379	14	605	26.9	27.0	10/14 ..
2/Oct/25	16/Oct/25		7950	150 x 150x150	2.356	14	605	26.9		6/10 ..
2/Oct/25	16/Oct/25		8014	150 x 150x150	2.375	14	615	27.3		
2/Oct/25	30/Oct/25		8040	150 x 150x150	2.382	28	670	29.8	30.1	NATURAL SAND
2/Oct/25	30/Oct/25		8124	150 x 150x150	2.407	28	710	31.6		
2/Oct/25	30/Oct/25		8032	150 x 150x150	2.380	28	655	29.1		

Remarks

FOR TESTING LAB

LAB TECHNICIAN

MATERIALS ENGINEER

STIRLING CIVIL ENGINEERING
LTD
15 NOV 2025
P. O. BOX 798, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	Stirling

PROJECT	ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE

Test	Water absorption test	Cast date:	10/02/25
Location		Test date:	10/30/25
sample description	C25 CONCRETE	Age (days)	28
		Temperature(°C)	24
		Density of water	1000 Kg/m^3

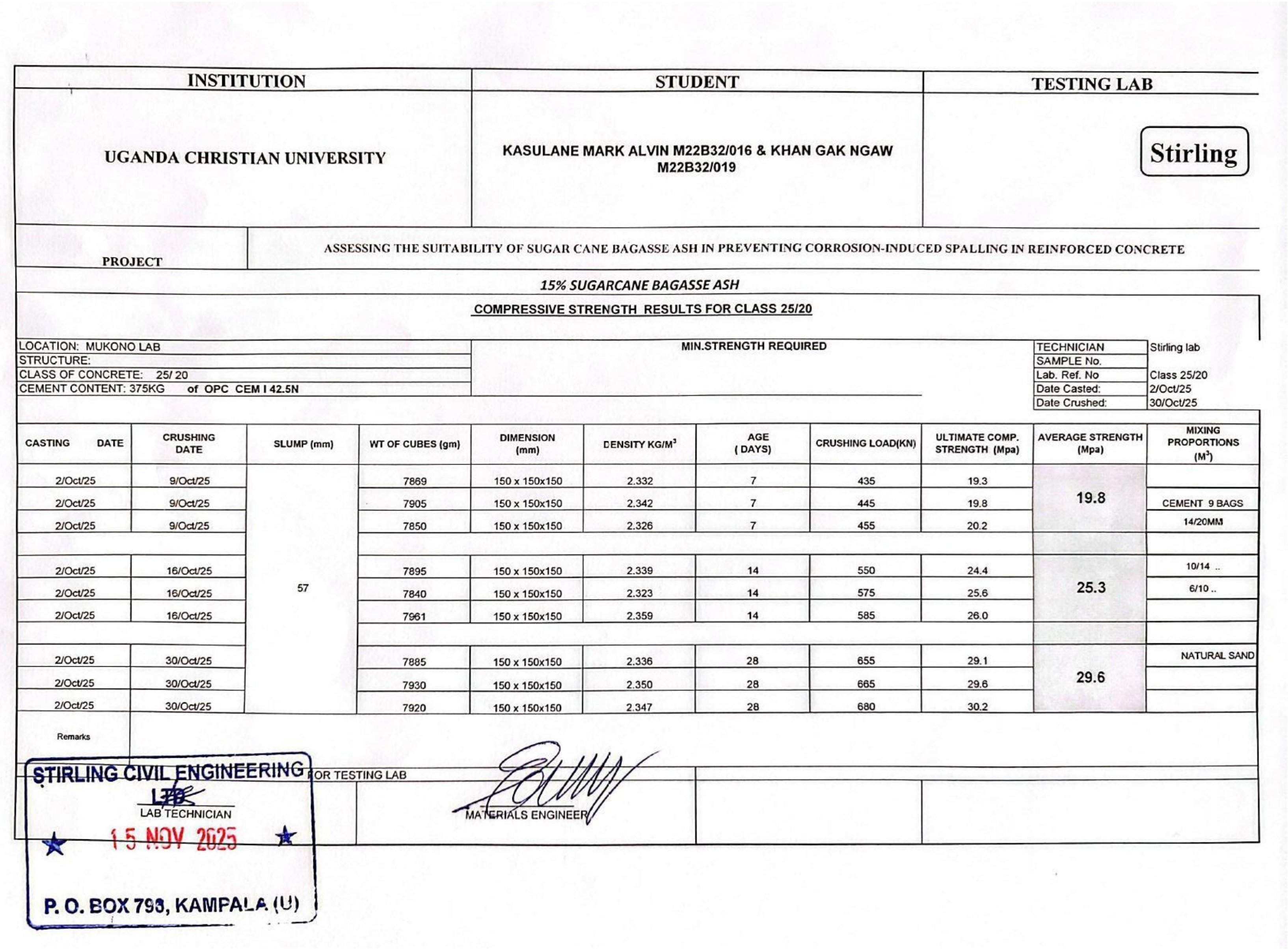
Trial mix	Cube dimension (mm)	Oven dried weight (g)	SSD weight (g)	Water absorption (%)	Average water absorption (%)	
0%	150x150x150	8124	8299	2.2	2.3	
	150x150x150	8116	8307	2.4		
5%	150x150x150	8197	8296	1.2	1.3	
	150x150x150	8193	8308	1.4		
10%	150x150x150	7899	8056	2.0	1.7	
	150x150x150	8025	8186	2.0		
15%	150x150x150	7855	8056	2.6	2.5	
	150x150x150	7890	8075	2.3		
20%	150x150x150	7756	7969	2.7	2.9	
	150x150x150	7880	8123	3.1		

TESTING LAB

LAB Technician

Materials engineer

STIRLING CIVIL ENGINEERING LTD
15 NOV 2025
P. O. BOX 798, KAMPALA (U)



INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	Stirling

PROJECT: ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE

15% SUGARCANE BAGASSE ASH

COMPRESSIVE STRENGTH RESULTS FOR CLASS 25/20

LOCATION: MUKONO LAB
STRUCTURE:
CLASS OF CONCRETE: 25/ 20
CEMENT CONTENT: 375KG of OPC CEM I 42.5N

MIN.STRENGTH REQUIRED

TECHNICIAN	Stirling lab
SAMPLE No.	
Lab. Ref. No	Class 25/20
Date Casted:	2/Oct/25
Date Crushed:	30/Oct/25

CASTING DATE	CRUSHING DATE	SLUMP (mm)	WT OF CUBES (gm)	DIMENSION (mm)	DENSITY KG/M³	AGE (DAYS)	CRUSHING LOAD(KN)	ULTIMATE COMP. STRENGTH (Mpa)	AVERAGE STRENGTH (Mpa)	MIXING PROPORTIONS (M³)
2/Oct/25	9/Oct/25	57	7869	150 x 150x150	2.332	7	435	19.3	19.8	
2/Oct/25	9/Oct/25		7905	150 x 150x150	2.342	7	445	19.8		CEMENT 9 BAGS
2/Oct/25	9/Oct/25		7850	150 x 150x150	2.326	7	455	20.2		14/20MM
2/Oct/25	16/Oct/25		7895	150 x 150x150	2.339	14	550	24.4	25.3	10/14 ..
2/Oct/25	16/Oct/25		7840	150 x 150x150	2.323	14	575	25.6		6/10 ..
2/Oct/25	16/Oct/25		7961	150 x 150x150	2.359	14	585	26.0		
2/Oct/25	30/Oct/25		7885	150 x 150x150	2.336	28	655	29.1	29.6	NATURAL SAND
2/Oct/25	30/Oct/25		7930	150 x 150x150	2.350	28	665	29.6		
2/Oct/25	30/Oct/25		7920	150 x 150x150	2.347	28	680	30.2		

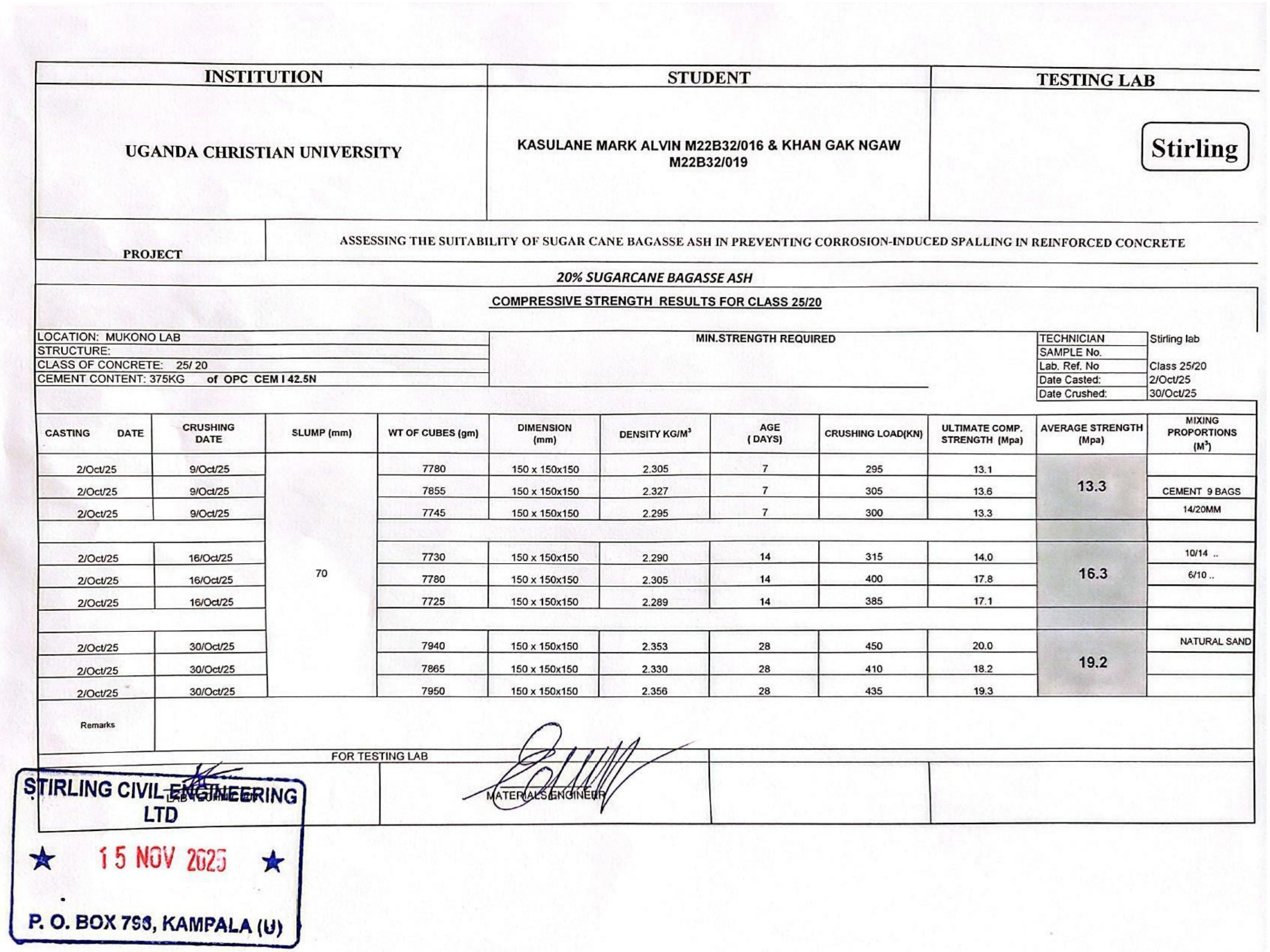
Remarks

FOR TESTING LAB

LAB TECHNICIAN

MATERIALS ENGINEER

STIRLING CIVIL ENGINEERING LTD
15 NOV 2025
P. O. BOX 793, KAMPALA (U)



INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	Stirling

PROJECT ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE

20% SUGARCANE BAGASSE ASH

COMPRESSIVE STRENGTH RESULTS FOR CLASS 25/20

LOCATION: MUKONO LAB
STRUCTURE:
CLASS OF CONCRETE: 25/ 20
CEMENT CONTENT: 375KG **of OPC CEM I 42.5N**

MIN.STRENGTH REQUIRED

TECHNICIAN	Stirling lab
SAMPLE No.	
Lab. Ref. No	Class 25/20
Date Casted:	2/Oct/25
Date Crushed:	30/Oct/25

CASTING DATE	CRUSHING DATE	SLUMP (mm)	WT OF CUBES (gm)	DIMENSION (mm)	DENSITY KG/M^3	AGE (DAYS)	CRUSHING LOAD(KN)	ULTIMATE COMP. STRENGTH (Mpa)	AVERAGE STRENGTH (Mpa)	MIXING PROPORTIONS (M^3)
2/Oct/25	9/Oct/25	70	7780	150 x 150x150	2.305	7	295	13.1	13.3	
2/Oct/25	9/Oct/25		7855	150 x 150x150	2.327	7	305	13.6		CEMENT 9 BAGS
2/Oct/25	9/Oct/25		7745	150 x 150x150	2.295	7	300	13.3		14/20MM
2/Oct/25	16/Oct/25		7730	150 x 150x150	2.290	14	315	14.0	16.3	10/14 ..
2/Oct/25	16/Oct/25		7780	150 x 150x150	2.305	14	400	17.8		6/10 ..
2/Oct/25	16/Oct/25		7725	150 x 150x150	2.289	14	385	17.1		
2/Oct/25	30/Oct/25		7940	150 x 150x150	2.353	28	450	20.0	19.2	NATURAL SAND
2/Oct/25	30/Oct/25		7865	150 x 150x150	2.330	28	410	18.2		
2/Oct/25	30/Oct/25		7950	150 x 150x150	2.356	28	435	19.3		

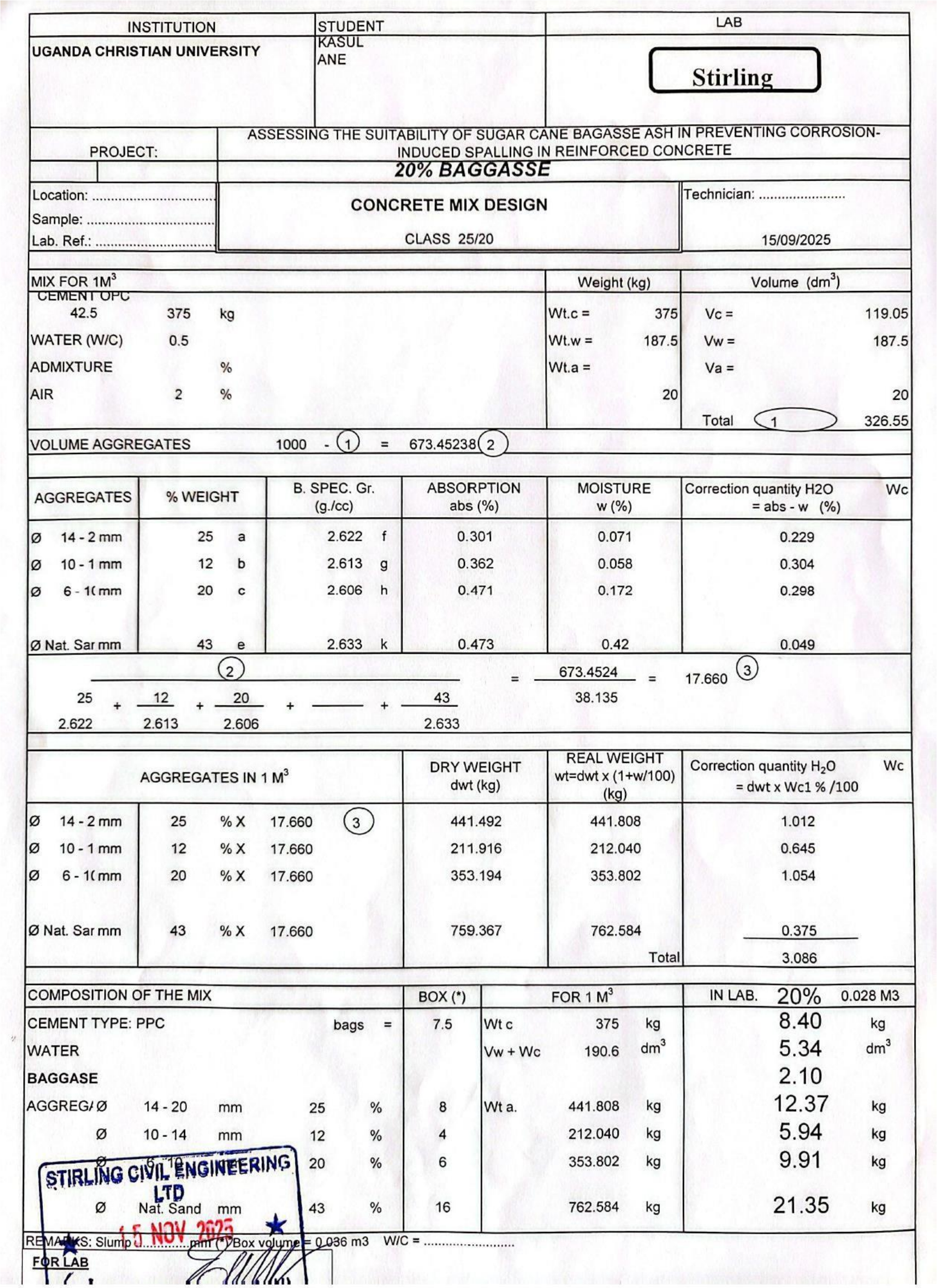
Remarks

FOR TESTING LAB

LAB TECHNICIAN

MATERIALS ENGINEER

STIRLING CIVIL ENGINEERING LTD
15 NOV 2025
P. O. BOX 798, KAMPALA (U)



INSTITUTION	STUDENT	LAB
UGANDA CHRISTIAN UNIVERSITY	KASUL ANE	**Stirling**

PROJECT:	ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE
	20% BAGGASSE

Location: .... Sample: .... Lab. Ref.:	**CONCRETE MIX DESIGN** CLASS 25/20	Technician: 15/09/2025

MIX FOR 1M^3			Weight (kg)		Volume (dm^3)	
CEMENT OPC 42.5	375	kg	Wt.c =	375	Vc =	119.05
WATER (W/C)	0.5		Wt.w =	187.5	Vw =	187.5
ADMIXTURE		%	Wt.a =		Va =	
AIR	2	%		20		20
					Total ①	326.55

VOLUME AGGREGATES 1000 - ① = 673.45238 ②

AGGREGATES	% WEIGHT		B. SPEC. Gr. (g./cc)		ABSORPTION abs (%)	MOISTURE w (%)	Correction quantity H2O Wc = abs - w (%)
Ø 14 - 2 mm	25	a	2.622	f	0.301	0.071	0.229
Ø 10 - 1 mm	12	b	2.613	g	0.362	0.058	0.304
Ø 6 - 1(mm	20	c	2.606	h	0.471	0.172	0.298
Ø Nat. Sar mm	43	e	2.633	k	0.473	0.42	0.049

$$\frac{②}{\frac{25}{2.622}+\frac{12}{2.613}+\frac{20}{2.606}+\frac{\quad}{\quad}+\frac{43}{2.633}}=\frac{673.4524}{38.135}=17.660 \; ③$$

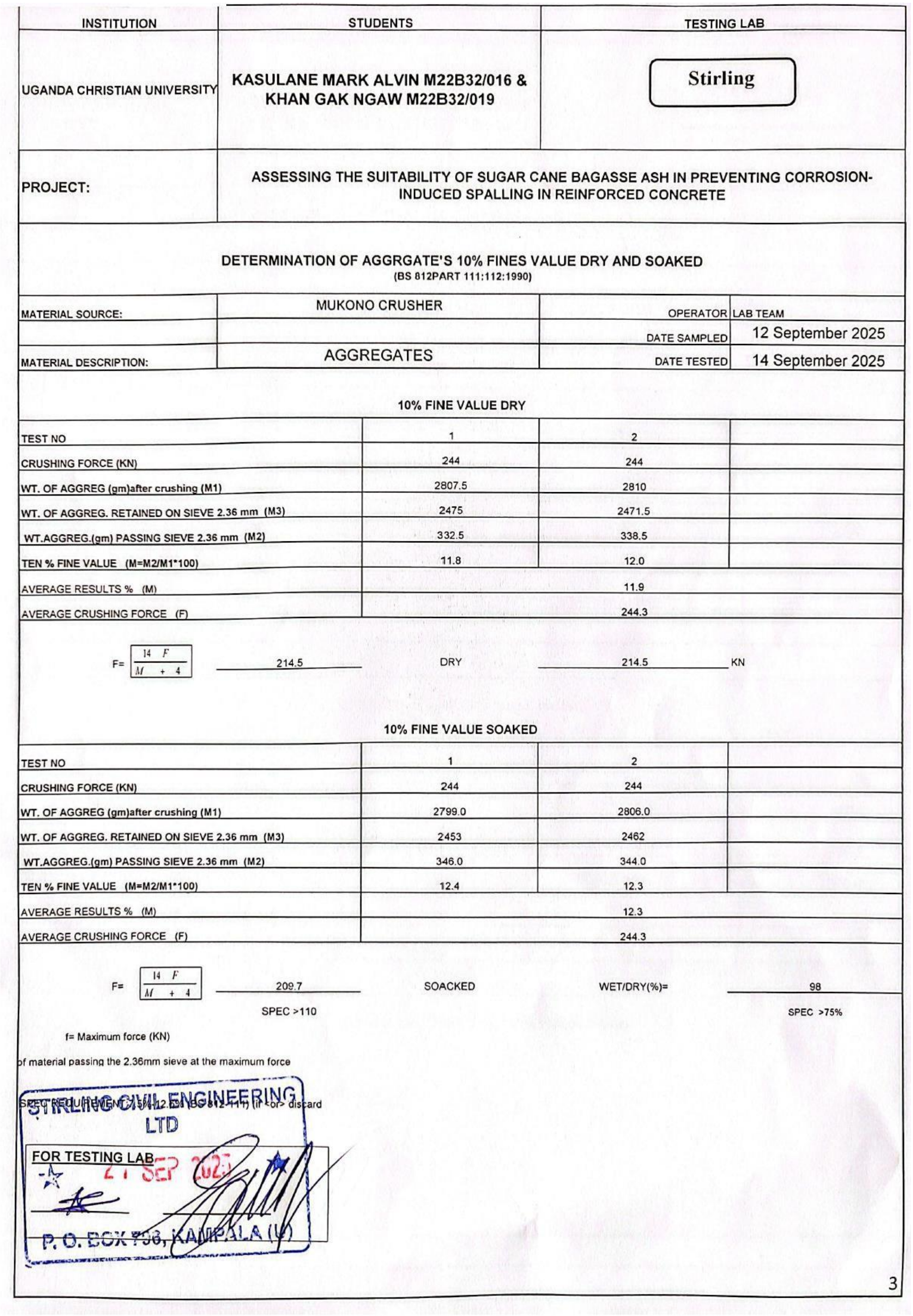
AGGREGATES IN 1 M^3				DRY WEIGHT dwt (kg)	REAL WEIGHT wt=dwt x (1+w/100) (kg)	Correction quantity H$_2$O Wc = dwt x Wc1 % /100
Ø 14 - 2 mm	25	% X	17.660 ③	441.492	441.808	1.012
Ø 10 - 1 mm	12	% X	17.660	211.916	212.040	0.645
Ø 6 - 1(mm	20	% X	17.660	353.194	353.802	1.054
Ø Nat. Sar mm	43	% X	17.660	759.367	762.584	0.375
					Total	3.086

COMPOSITION OF THE MIX					BOX (*)	FOR 1 M^3			IN LAB. 20%	0.028 M3
CEMENT TYPE: PPC			bags	=	7.5	Wt c	375	kg	8.40	kg
WATER						Vw + Wc	190.6	dm^3	5.34	dm^3
BAGGASE									2.10	
AGGREG/ Ø	14 - 20	mm	25	%	8	Wt a.	441.808	kg	12.37	kg
Ø	10 - 14	mm	12	%	4		212.040	kg	5.94	kg
Ø	6 - 10	mm	20	%	6		353.802	kg	9.91	kg
Ø	Nat. Sand	mm	43	%	16		762.584	kg	21.35	kg

REMARKS: Slump ....mm (*) Box volume = 0.036 m3 W/C = ...

FOR LAB

STIRLING CIVIL ENGINEERING LTD
15 NOV 2025



INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	Stirling
PROJECT:	ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE	

DETERMINATION OF AGGRGATE'S 10% FINES VALUE DRY AND SOAKED

(BS 812PART 111:112:1990)

MATERIAL SOURCE:	MUKONO CRUSHER	OPERATOR	LAB TEAM
		DATE SAMPLED	12 September 2025
MATERIAL DESCRIPTION:	AGGREGATES	DATE TESTED	14 September 2025

10% FINE VALUE DRY

TEST NO	1	2	
CRUSHING FORCE (KN)	244	244	
WT. OF AGGREG (gm)after crushing (M1)	2807.5	2810	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2475	2471.5	
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	332.5	338.5	
TEN % FINE VALUE (M=M2/M1*100)	11.8	12.0	
AVERAGE RESULTS % (M)		11.9	
AVERAGE CRUSHING FORCE (F)		244.3	

$F = \boxed{\frac{14\ F}{M\ +\ 4}}$ 214.5 DRY 214.5 KN

10% FINE VALUE SOAKED

TEST NO	1	2	
CRUSHING FORCE (KN)	244	244	
WT. OF AGGREG (gm)after crushing (M1)	2799.0	2806.0	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2453	2462	
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	346.0	344.0	
TEN % FINE VALUE (M=M2/M1*100)	12.4	12.3	
AVERAGE RESULTS % (M)		12.3	
AVERAGE CRUSHING FORCE (F)		244.3	

$F = \boxed{\frac{14\ F}{M\ +\ 4}}$ 209.7 SOACKED WET/DRY(%)= 98

SPEC >110 SPEC >75%

f= Maximum force (KN)

of material passing the 2.36mm sieve at the maximum force

SPEC REQUIREMENT 7.5%-12.5% (BS 812-111) (if <or> discard

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LTD
FOR TESTING LAB
21 SEP 2025
P. O. BOX 796, KAMPALA (U)

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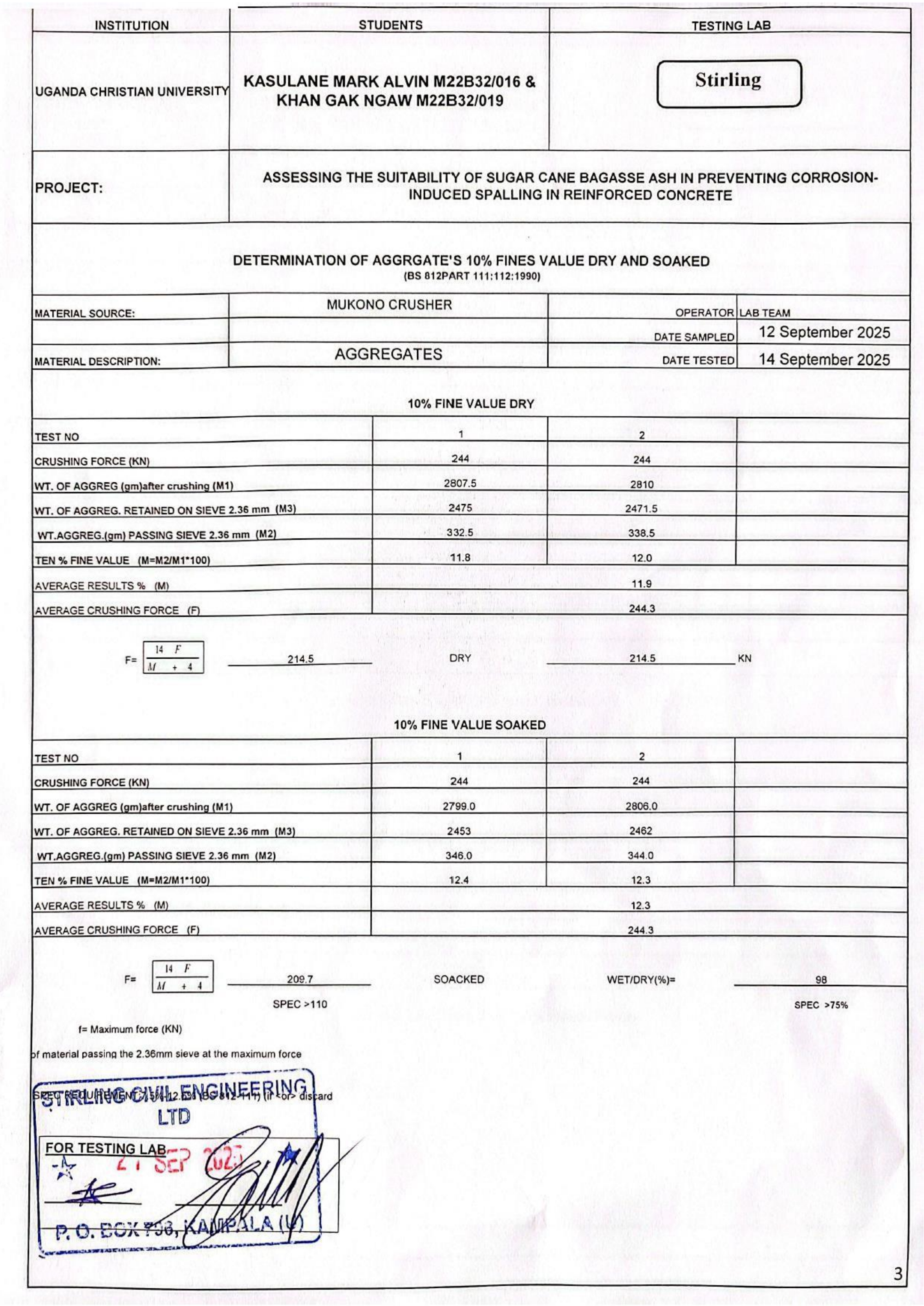

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	Stirling
PROJECT:	ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE	

DETERMINATION OF AGGRGATE'S 10% FINES VALUE DRY AND SOAKED

(BS 812PART 111:112:1990)

MATERIAL SOURCE:	MUKONO CRUSHER	OPERATOR	LAB TEAM
		DATE SAMPLED	12 September 2025
MATERIAL DESCRIPTION:	AGGREGATES	DATE TESTED	14 September 2025

10% FINE VALUE DRY

TEST NO	1	2	
CRUSHING FORCE (KN)	244	244	
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TEN % FINE VALUE (M=M2/M1*100)	11.8	12.0	
AVERAGE RESULTS % (M)		11.9	
AVERAGE CRUSHING FORCE (F)		244.3	

F= $\boxed{\frac{14\ F}{M\ +\ 4}}$ 214.5 DRY 214.5 KN

10% FINE VALUE SOAKED

TEST NO	1	2	
CRUSHING FORCE (KN)	244	244	
WT. OF AGGREG (gm)after crushing (M1)	2799.0	2806.0	
WT. OF AGGREG. RETAINED ON SIEVE 2.36 mm (M3)	2453	2462	
WT.AGGREG.(gm) PASSING SIEVE 2.36 mm (M2)	346.0	344.0	
TEN % FINE VALUE (M=M2/M1*100)	12.4	12.3	
AVERAGE RESULTS % (M)		12.3	
AVERAGE CRUSHING FORCE (F)		244.3	

F= $\boxed{\frac{14\ F}{M\ +\ 4}}$ 209.7 SOACKED WET/DRY(%)= 98

SPEC >110 SPEC >75%

f= Maximum force (KN)

of material passing the 2.36mm sieve at the maximum force

SPEC REQUIREMENT 7.5%-12.5% (BS 812-111) (if <or> discard

STIRLING CIVIL ENGINEERING LTD

FOR TESTING LAB

27 SEP 2025

P. O. BOX 796, KAMPALA (U)

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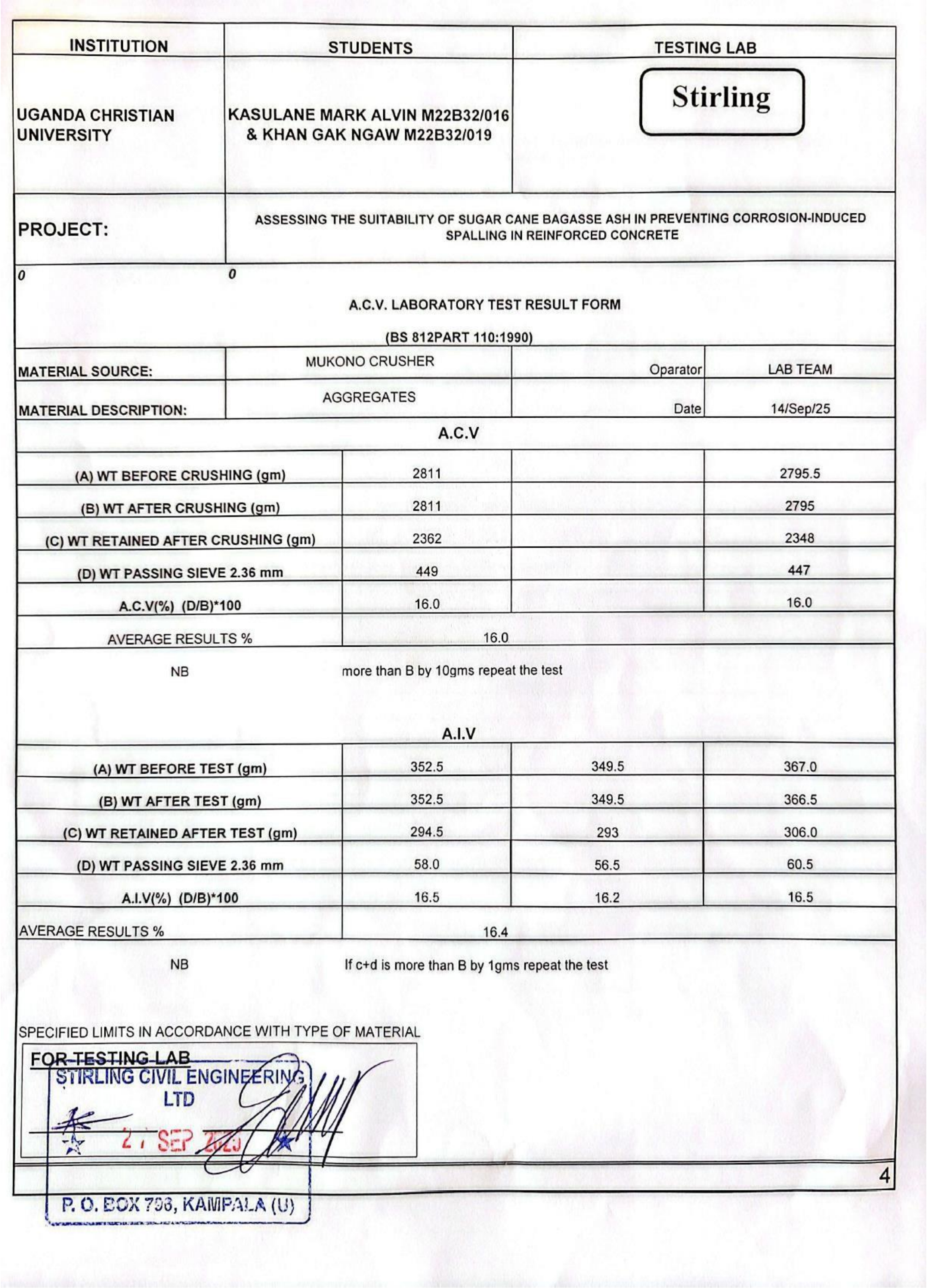

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	**Stirling**
PROJECT:	ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE	
0	*0*	

A.C.V. LABORATORY TEST RESULT FORM

(BS 812PART 110:1990)

MATERIAL SOURCE:	MUKONO CRUSHER	Oparator	LAB TEAM
MATERIAL DESCRIPTION:	AGGREGATES	Date	14/Sep/25

A.C.V

(A) WT BEFORE CRUSHING (gm)	2811		2795.5
(B) WT AFTER CRUSHING (gm)	2811		2795
(C) WT RETAINED AFTER CRUSHING (gm)	2362		2348
(D) WT PASSING SIEVE 2.36 mm	449		447
A.C.V(%) (D/B)*100	16.0		16.0
AVERAGE RESULTS %	16.0		

NB more than B by 10gms repeat the test

A.I.V

(A) WT BEFORE TEST (gm)	352.5	349.5	367.0
(B) WT AFTER TEST (gm)	352.5	349.5	366.5
(C) WT RETAINED AFTER TEST (gm)	294.5	293	306.0
(D) WT PASSING SIEVE 2.36 mm	58.0	56.5	60.5
A.I.V(%) (D/B)*100	16.5	16.2	16.5
AVERAGE RESULTS %	16.4		

NB If c+d is more than B by 1gms repeat the test

SPECIFIED LIMITS IN ACCORDANCE WITH TYPE OF MATERIAL

FOR TESTING LAB

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

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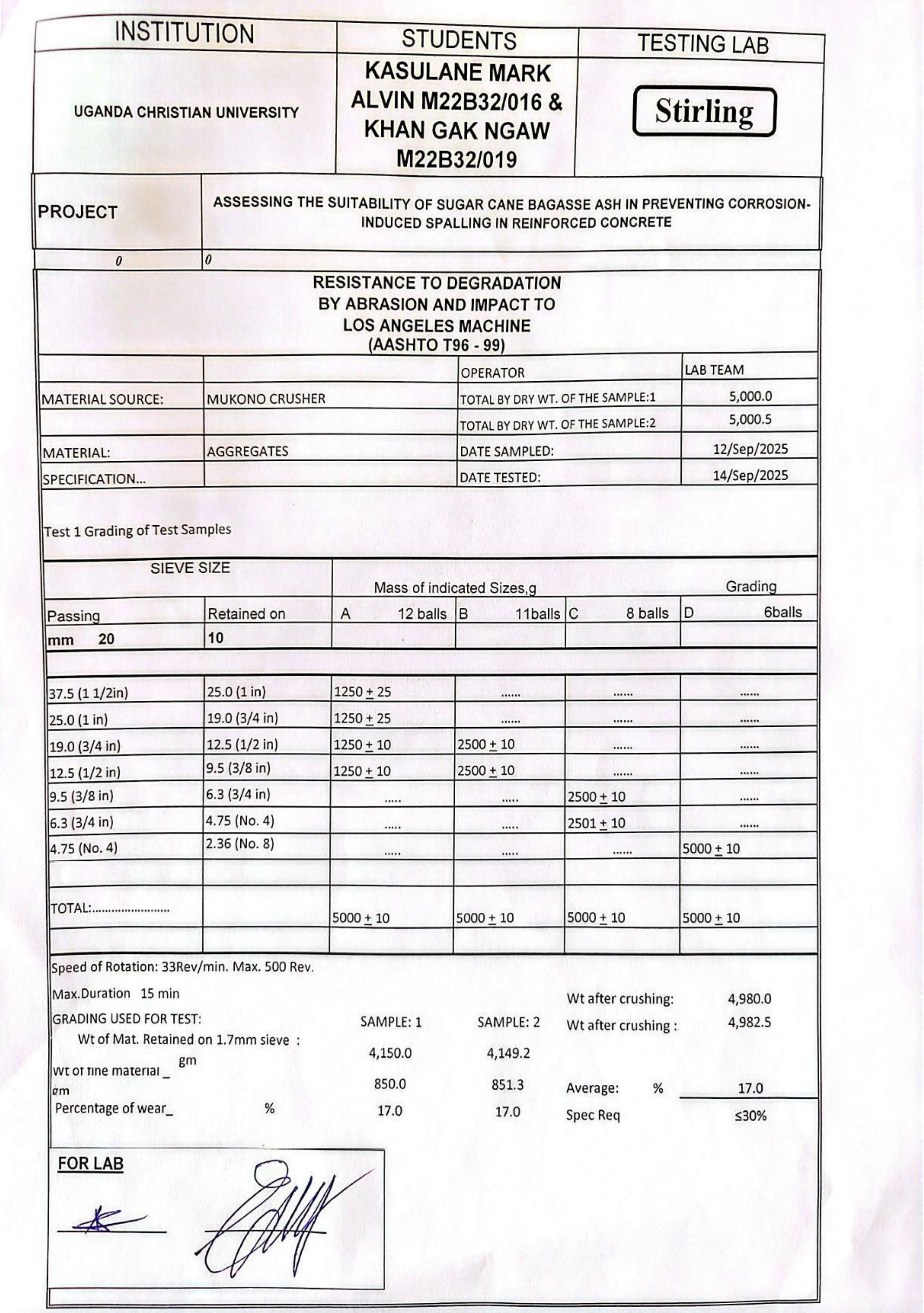


INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	**KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019**	**Stirling**

PROJECT	**ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE**
0	*0*

RESISTANCE TO DEGRADATION BY ABRASION AND IMPACT TO LOS ANGELES MACHINE (AASHTO T96 - 99)

		OPERATOR	LAB TEAM
MATERIAL SOURCE:	MUKONO CRUSHER	TOTAL BY DRY WT. OF THE SAMPLE:1	5,000.0
		TOTAL BY DRY WT. OF THE SAMPLE:2	5,000.5
MATERIAL:	AGGREGATES	DATE SAMPLED:	12/Sep/2025
SPECIFICATION...		DATE TESTED:	14/Sep/2025

Test 1 Grading of Test Samples

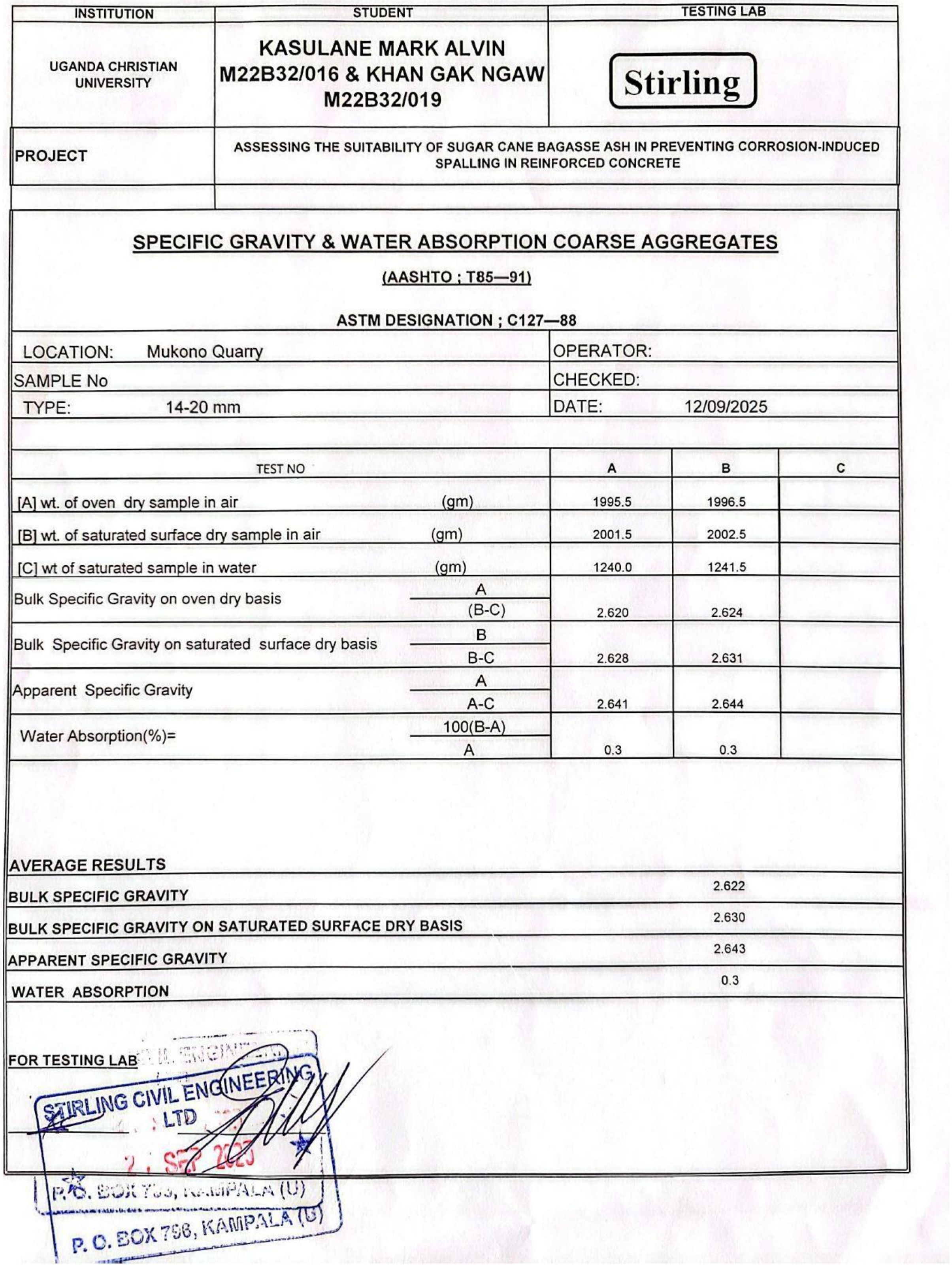
SIEVE SIZE		Mass of indicated Sizes,g			Grading
Passing	Retained on	A 12 balls	B 11balls	C 8 balls	D 6balls
mm 20	10				
37.5 (1 1/2in)	25.0 (1 in)	1250 ± 25	......	......	......
25.0 (1 in)	19.0 (3/4 in)	1250 ± 25	......	......	......
19.0 (3/4 in)	12.5 (1/2 in)	1250 ± 10	2500 ± 10	......	......
12.5 (1/2 in)	9.5 (3/8 in)	1250 ± 10	2500 ± 10	......	......
9.5 (3/8 in)	6.3 (3/4 in)	.....	.....	2500 ± 10	......
6.3 (3/4 in)	4.75 (No. 4)	.....	.....	2501 ± 10	......
4.75 (No. 4)	2.36 (No. 8)	.....	.....	......	5000 ± 10
TOTAL:........................		5000 ± 10	5000 ± 10	5000 ± 10	5000 ± 10

Speed of Rotation: 33Rev/min. Max. 500 Rev.

Max.Duration 15 min

GRADING USED FOR TEST:	SAMPLE: 1	SAMPLE: 2	Wt after crushing:	4,980.0
			Wt after crushing :	4,982.5
Wt of Mat. Retained on 1.7mm sieve : gm	4,150.0	4,149.2		
Wt of fine material _ gm	850.0	851.3	Average: %	17.0
Percentage of wear_ %	17.0	17.0	Spec Req	≤30%

FOR LAB



INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	**KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019**	**Stirling**
PROJECT	ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE	

SPECIFIC GRAVITY & WATER ABSORPTION COARSE AGGREGATES

(AASHTO ; T85—91)

ASTM DESIGNATION ; C127—88

LOCATION: Mukono Quarry	OPERATOR:
SAMPLE No	CHECKED:
TYPE: 14-20 mm	DATE: 12/09/2025

TEST NO		A	B	C
[A] wt. of oven dry sample in air	(gm)	1995.5	1996.5	
[B] wt. of saturated surface dry sample in air	(gm)	2001.5	2002.5	
[C] wt of saturated sample in water	(gm)	1240.0	1241.5	
Bulk Specific Gravity on oven dry basis	$\frac{A}{(B-C)}$	2.620	2.624	
Bulk Specific Gravity on saturated surface dry basis	$\frac{B}{B-C}$	2.628	2.631	
Apparent Specific Gravity	$\frac{A}{A-C}$	2.641	2.644	
Water Absorption(%)=	$\frac{100(B-A)}{A}$	0.3	0.3	

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.622
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.630
APPARENT SPECIFIC GRAVITY	2.643
WATER ABSORPTION	0.3

FOR TESTING LAB

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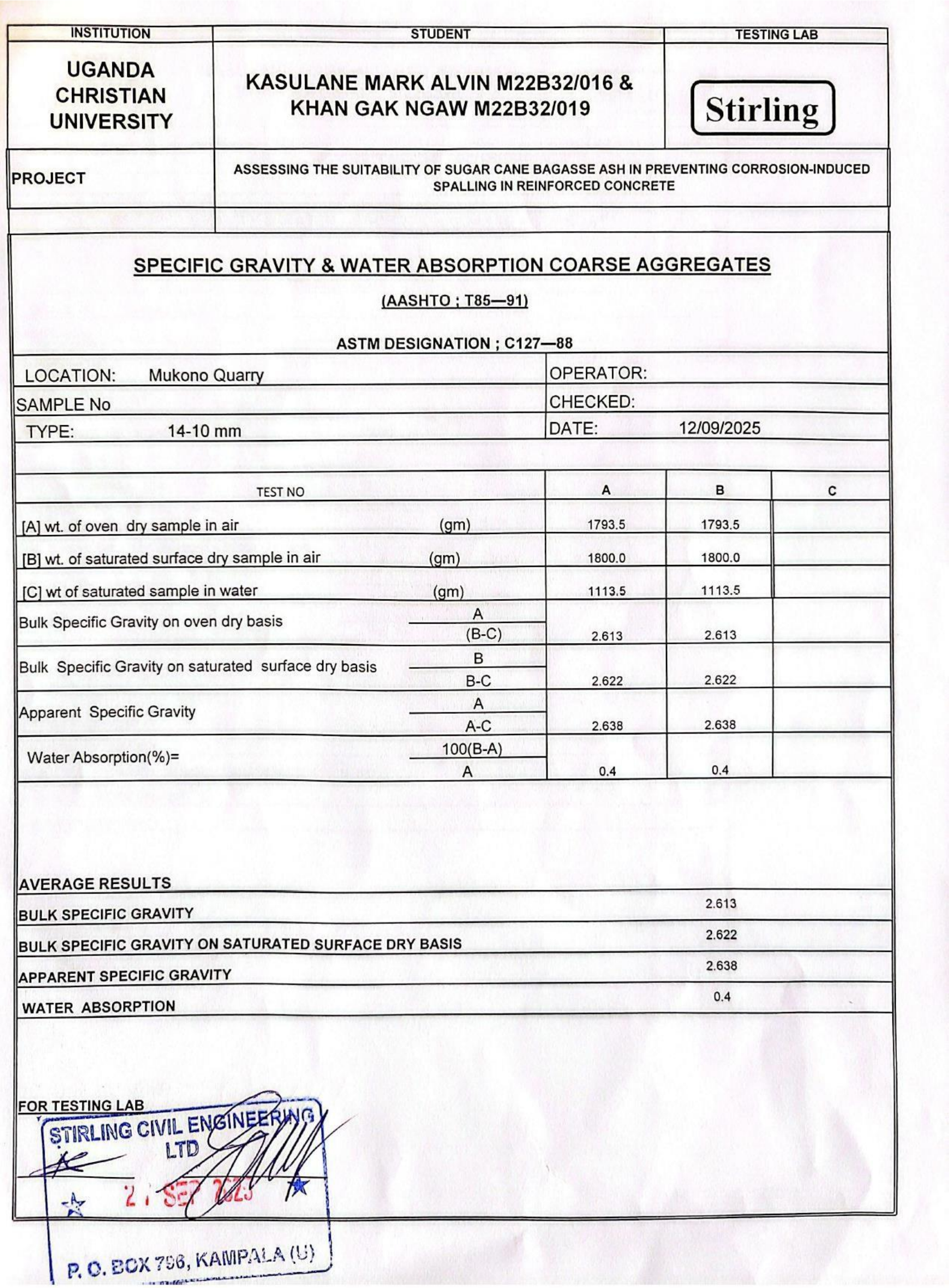

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	**KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019**	**Stirling**
PROJECT	**ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE**	

SPECIFIC GRAVITY & WATER ABSORPTION COARSE AGGREGATES

(AASHTO ; T85—91)

ASTM DESIGNATION ; C127—88

LOCATION: Mukono Quarry	OPERATOR:
SAMPLE No	CHECKED:
TYPE: 14-10 mm	DATE: 12/09/2025

TEST NO		A	B	C
[A] wt. of oven dry sample in air	(gm)	1793.5	1793.5	
[B] wt. of saturated surface dry sample in air	(gm)	1800.0	1800.0	
[C] wt of saturated sample in water	(gm)	1113.5	1113.5	
Bulk Specific Gravity on oven dry basis	$\frac{A}{(B-C)}$	2.613	2.613	
Bulk Specific Gravity on saturated surface dry basis	$\frac{B}{B-C}$	2.622	2.622	
Apparent Specific Gravity	$\frac{A}{A-C}$	2.638	2.638	
Water Absorption(%)=	$\frac{100(B-A)}{A}$	0.4	0.4	

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.613
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.622
APPARENT SPECIFIC GRAVITY	2.638
WATER ABSORPTION	0.4

FOR TESTING LAB

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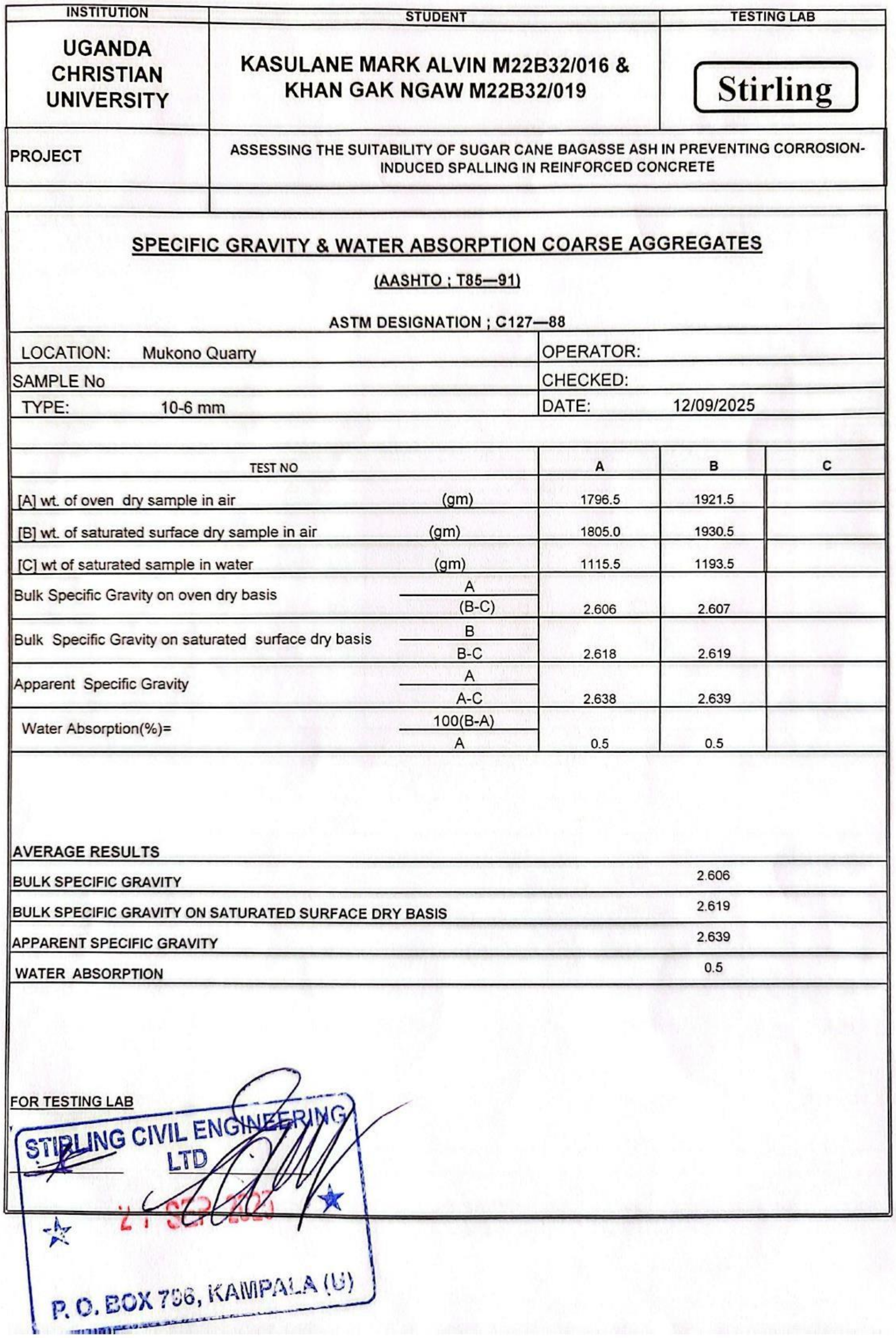
P. O. BOX 796, KAMPALA (U)



INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	**KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019**	**Stirling**
PROJECT	**ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE**	

SPECIFIC GRAVITY & WATER ABSORPTION COARSE AGGREGATES

(AASHTO ; T85—91)

ASTM DESIGNATION ; C127—88

LOCATION: Mukono Quarry	OPERATOR:
SAMPLE No	CHECKED:
TYPE: 10-6 mm	DATE: 12/09/2025

TEST NO		A	B	C
[A] wt. of oven dry sample in air	(gm)	1796.5	1921.5	
[B] wt. of saturated surface dry sample in air	(gm)	1805.0	1930.5	
[C] wt of saturated sample in water	(gm)	1115.5	1193.5	
Bulk Specific Gravity on oven dry basis	$\frac{A}{(B-C)}$	2.606	2.607	
Bulk Specific Gravity on saturated surface dry basis	$\frac{B}{B-C}$	2.618	2.619	
Apparent Specific Gravity	$\frac{A}{A-C}$	2.638	2.639	
Water Absorption(%)=	$\frac{100(B-A)}{A}$	0.5	0.5	

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.606
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.619
APPARENT SPECIFIC GRAVITY	2.639
WATER ABSORPTION	0.5

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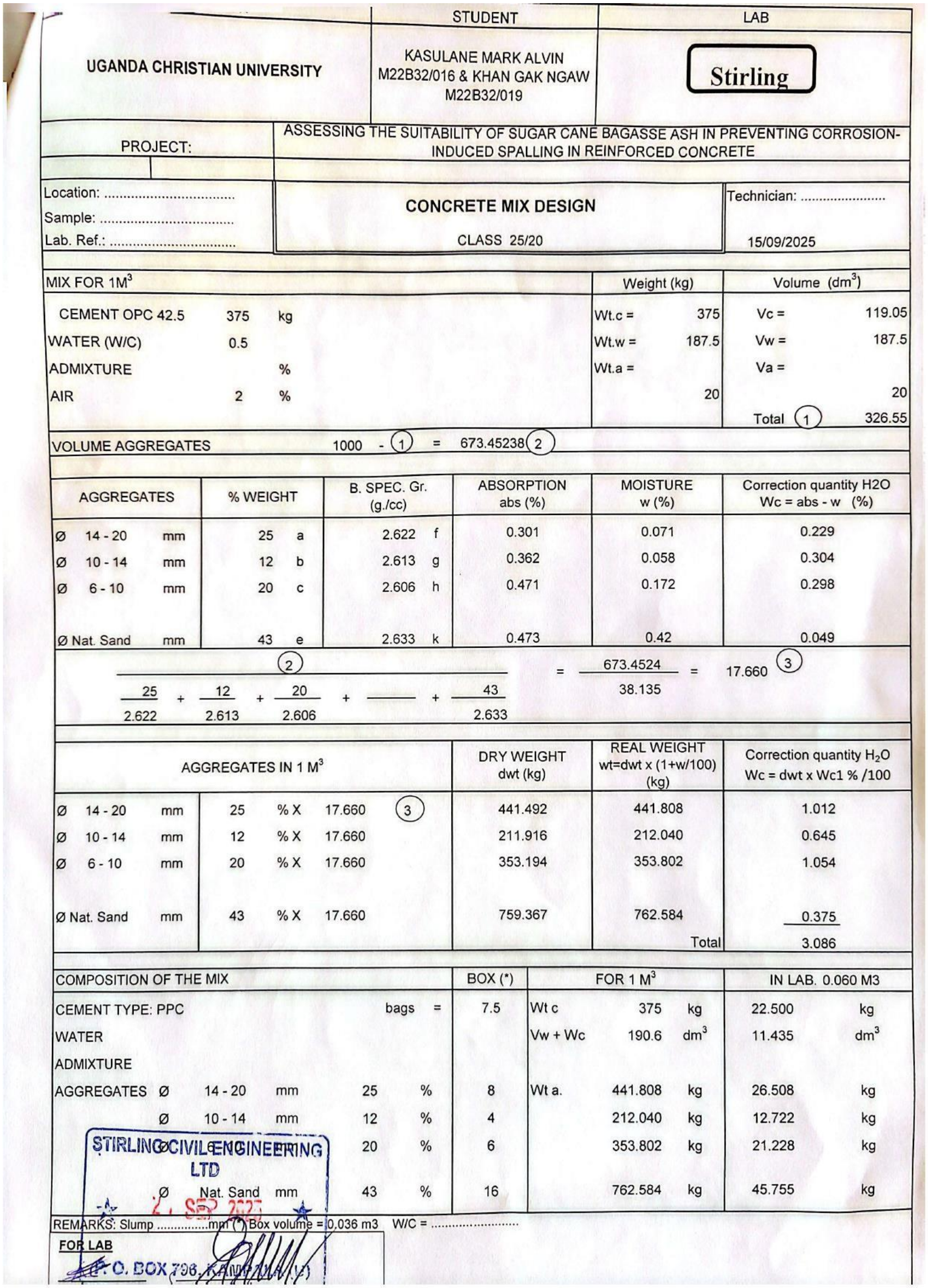

	STUDENT	LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	Stirling

PROJECT: ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE

Location: ....

Sample: ....

Lab. Ref.: ....

CONCRETE MIX DESIGN

CLASS 25/20

Technician: ....

15/09/2025

MIX FOR 1M³			Weight (kg)		Volume (dm³)	
CEMENT OPC 42.5	375	kg	Wt.c =	375	Vc =	119.05
WATER (W/C)	0.5		Wt.w =	187.5	Vw =	187.5
ADMIXTURE		%	Wt.a =		Va =	
AIR	2	%		20		20
					Total ①	326.55

VOLUME AGGREGATES 1000 - ① = 673.45238 ②

AGGREGATES			% WEIGHT		B. SPEC. Gr. (g./cc)		ABSORPTION abs (%)	MOISTURE w (%)	Correction quantity H2O Wc = abs - w (%)
Ø	14 - 20	mm	25	a	2.622	f	0.301	0.071	0.229
Ø	10 - 14	mm	12	b	2.613	g	0.362	0.058	0.304
Ø	6 - 10	mm	20	c	2.606	h	0.471	0.172	0.298
Ø Nat. Sand		mm	43	e	2.633	k	0.473	0.42	0.049

$$\frac{②}{\frac{25}{2.622}+\frac{12}{2.613}+\frac{20}{2.606}+\frac{\quad}{\quad}+\frac{43}{2.633}} = \frac{673.4524}{38.135} = 17.660 \text{ ③}$$

AGGREGATES IN 1 M³							DRY WEIGHT dwt (kg)	REAL WEIGHT wt=dwt x (1+w/100) (kg)	Correction quantity H_2O Wc = dwt x Wc1 % /100
Ø	14 - 20	mm	25	% X	17.660	③	441.492	441.808	1.012
Ø	10 - 14	mm	12	% X	17.660		211.916	212.040	0.645
Ø	6 - 10	mm	20	% X	17.660		353.194	353.802	1.054
Ø Nat. Sand		mm	43	% X	17.660		759.367	762.584	0.375
								Total	3.086

COMPOSITION OF THE MIX							BOX (*)	FOR 1 M³			IN LAB. 0.060 M3	
CEMENT TYPE: PPC				bags	=		7.5	Wt c	375	kg	22.500	kg
WATER								Vw + Wc	190.6	dm³	11.435	dm³
ADMIXTURE												
AGGREGATES	Ø	14 - 20	mm	25	%		8	Wt a.	441.808	kg	26.508	kg
	Ø	10 - 14	mm	12	%		4		212.040	kg	12.722	kg
	Ø	6 - 10	mm	20	%		6		353.802	kg	21.228	kg
	Ø	Nat. Sand	mm	43	%		16		762.584	kg	45.755	kg

REMARKS: Slump ....mm (*) Box volume = 0,036 m3 W/C = ...

FOR LAB

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P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENT	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	**KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019**	Stirling
PROJECT	ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE	

SPECIFIC GRAVITY & WATER ABSORPTION FINE AGGREGATES

(AASHTO ; T84—00)
ASTM DESIGNATION ; C128—97

LOCATION:	OPERATOR:
SAMPLE No	CHECKED:
TYPE: Natural sand	DATE: 12/09/2025

TEST NO		A	B	C
[A] wt. of oven dry sample in air	(gm)	513.99		504.43
[B] wt. of pycnometer filled with water	(gm)	1770.3		1770.82
[C] wt. of pycnometer with specimen and water	(gm)	2091.19		2086.32
[S] wt of saturated surface dry sample	(gm)	516.02		507.21
Bulk Specific Gravity on oven dry basis	$\frac{A}{(B+S-C)}$	2.634		2.631
Bulk Specific Gravity on saturated surface dry basis	$\frac{S}{(B+S-C)}$	2.644		2.646
Apparent Specific Gravity	$\frac{A}{(B+A-C)}$	2.662		2.670
Water Absorption(%)=	$\frac{100(S-A)}{A}$	0.4		0.6

AVERAGE RESULTS	
BULK SPECIFIC GRAVITY	2.633
BULK SPECIFIC GRAVITY ON SATURATED SURFACE DRY BASIS	2.645
APPARENT SPECIFIC GRAVITY	2.666
WATER ABSORPTION	0.5

FOR TESTING LAB

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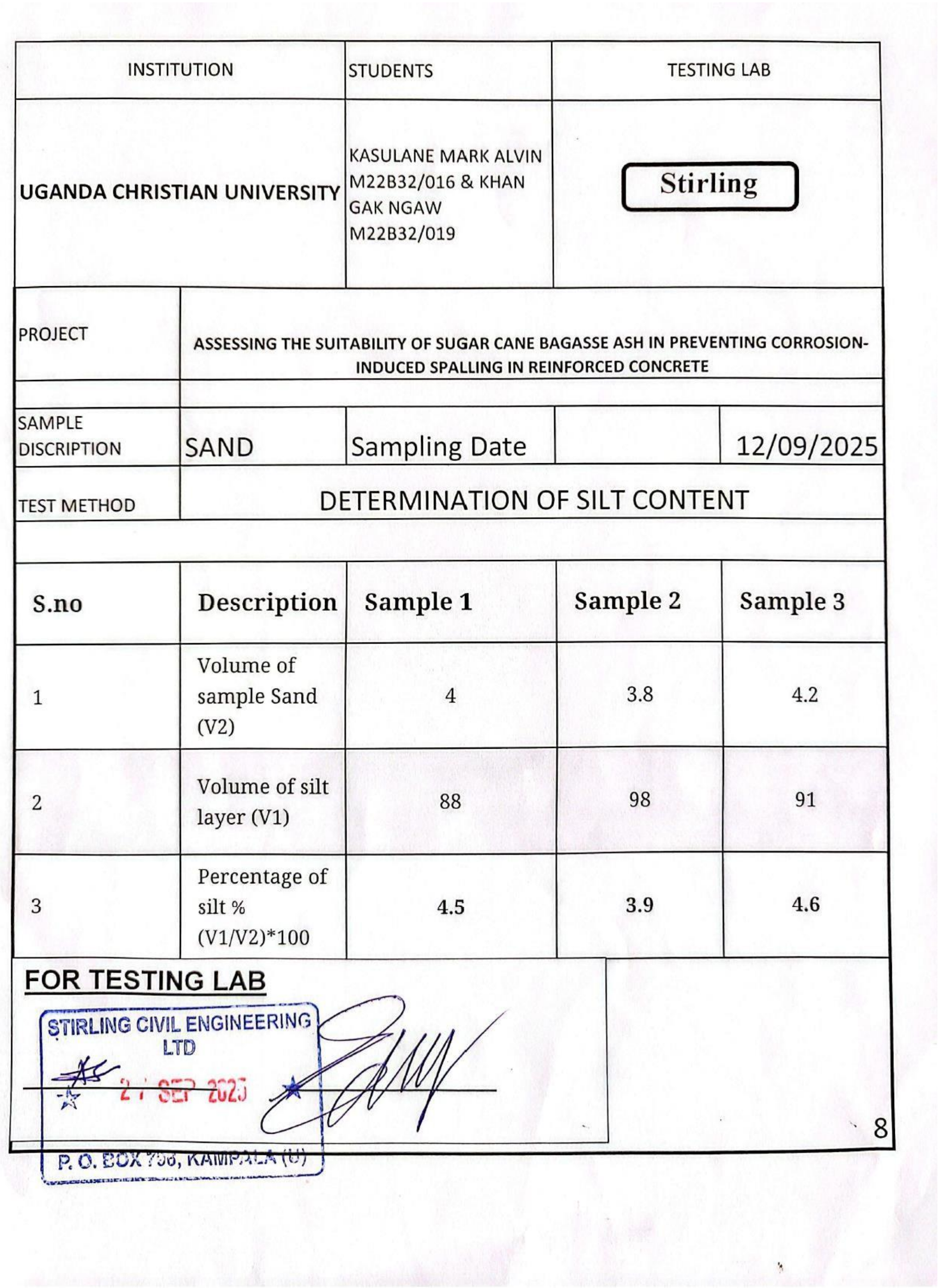

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	KASULANE MARK ALVIN M22B32/016 & KHAN GAK NGAW M22B32/019	**Stirling**

PROJECT	**ASSESSING THE SUITABILITY OF SUGAR CANE BAGASSE ASH IN PREVENTING CORROSION-INDUCED SPALLING IN REINFORCED CONCRETE**			
SAMPLE DISCRIPTION	SAND	Sampling Date		12/09/2025
TEST METHOD	DETERMINATION OF SILT CONTENT			

S.no	**Description**	**Sample 1**	**Sample 2**	**Sample 3**
1	Volume of sample Sand (V2)	4	3.8	4.2
2	Volume of silt layer (V1)	88	98	91
3	Percentage of silt % (V1/V2)*100	**4.5**	**3.9**	**4.6**

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