
COMPARATIVE ANALYSIS OF MATERIAL PROPERTIES AND FRESH CONCRETE CHARACTERISTICS OF SCBA FROM DIFFERENT SOURCES

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Abstract:

This study investigates the chemical and physical properties of sugarcane bagasse ash (SCBA) obtained from Dabai and Samunaka, and their influence on the fresh concrete characteristics and durability-related aspects of concrete. The chemical composition, physical properties of SCBA from both sources were analyzed. Fresh concrete mixes incorporating these SCBAs were evaluated. Furthermore, initial water absorption characteristics were assessed to provide insights into potential durability. The findings reveal differences in the inherent properties of SCBA from the two locations, which subsequently affect the fresh concrete behavior and early-stage water absorption.

Keywords: SCBA, Chemical Properties, Physical Properties, Fresh Concrete, Workability, Water Absorption, Durability

Introduction

Concrete being the most important component of construction sector can be called as the pillar of the infrastructural development of the nation. Hence Ordinary Portland cement, the key ingredient of concrete is recognized as a major construction material throughout the world. Neville, A. M., & Brooks, J. J. (2010). Researchers all over the country today are studying about the use of industrial or agricultural waste in construction sector in one form or another. The increase in cost of cement and scarcity of river sand also need of sustainable material which is also cost effective. Industrial wastes, such as blast furnace slag, rice husk ash, fly ash and silica fume are being used as supplementary cement replacement materials.

Currently, it has been tried to utilize the large amount of bagasse ash, fibrous residue obtained from sugar cane during extraction of sugar juice at sugarcane mills, in concrete when this waste is burned under controlled conditions, it also gives ash containing high amounts of unburned matter, e.g. silicon and aluminum oxides as main components. Therefore, it is expected that it is possible to use sugarcane bagasse ash (SCBA) as a replacement to cement to improve quality and simultaneously also to reduce the cost of construction materials. Also, there is a growing shortage of landfills in most countries. The amount of ashes generated in the process represents 3–5% of the initial residues, which constitutes a considerable volume of ashes. Amongst the total crushed a sugar factory produces nearly 30% of bagasse. When these industrial wastes are further dumped land, they possess a serious threat to the society as they pollute the air and waste bodies,

The thrust area is to find good performance sustainable material at reasonable cost with the least impact on environment. India holds second position in the world cement production with large number of cement manufacturing plants. India also has abundant quantity of bagasse ash process in sugar industries. Bagasse ash has reactive silica and can be used as supplementary cementing material in the manufacturing process of blended cement. In view of the discussion, the use of supplementary cementing materials (SCMs), such as fly ash, slag, silica fume, and rice husk ash and sugar cane bagasse ash as a replacement for Portland cement can be viable solution with multiple benefits for the sustainable development of the concrete industry. Research and development have shown that sugar cane bagasse ash actually represents a highly valuable concrete material. In order to considerably increase the utilization of sugarcane bagasse ash as replacement for cement, such concrete must meet engineering performance requirements comparable to those for conventional Portland cement concrete and be cost effective (Mehta, P. K., & Monteiro, P. J. M., 2006).

Statement of the research problem

With increasing industrial activities around the world, it is imperative to search for materials that can be replace some of the current components in commercial cement, with others that have a similar chemical composition and that can reduce production costs without affecting the quality of the concrete (Chusilp et al., 2009a). An important alternative found in research on this topic, is the use of an agro-industrial byproduct of the sugar industry, sugar cane bagasse ash (SCBA), as a mineral additive for cement. As part of the productive process of the sugar industry, sugar cane stalks are ground to extract the juice, the remaining fibrous residue, called bagasse, is one of the most valuable products in the sugar industry as its net calorific value is about 8000 kJ/kg (Batra et al., 2008). 1.3 Justification: (Emphasize the need to characterize SCBA from different sources to optimize its use, and how the initial properties influence fresh concrete handling and long-term durability).

Aim and Objectives the aim is Comparative study on strength and durability of concretes containing sugarcane bagasse ash obtained from different sources using experimental.

Objectives:

To determine the chemical and physical properties of SCBA from different sources.

To determine fresh concrete properties of SCBA concrete from different sources.

To evaluate the durability properties of SCBA concrete from the two sources.

Scope: The SCBA was only sourced from two places- Samunaka, Kaduna state and Danja, Katsina state, burning at 800⁰c

Literature Review

Composition of Concrete:

Concrete is a composite material, engineered to achieve specific performance characteristics through the controlled combination of several key constituents. These are:

Cement: Typically, Ordinary Portland Cement (OPC), acts as the primary binder. When mixed with water, cement undergoes a chemical process called hydration, leading to the formation of calcium silicate hydrate (C-S-H) gel, which binds the other components together (Mehta, P.K., & Monteiro, P.J.M., 2006).

Concrete as a Construction Material

- I. **Aggregates:** These granular materials constitute the bulk of concrete volume (60-75%). They are classified as:
- II. **Fine Aggregates:** Sand or crushed stone with particles passing through a 4.75 mm sieve. They improve workability and fill voids between coarser particles. Citation: IS 383: 2016,

Coarse Aggregates: Gravel or crushed stone with particles retained on a 4.75 mm sieve. They provide strength and dimensional stability to the concrete matrix. IS 383: 2016

Admixtures: These are chemical or mineral substances added to the concrete mix to modify its properties.

Chemical Admixtures: Added in small amounts to alter setting time, workability, air entrainment, etc. Examples include plasticizers, superplasticizers, retarders, and accelerators. Ramachandran, V.S. (Ed.). (1995).

Mineral Admixtures: Pozzolanic or cementitious materials added to replace a portion of cement. They can improve long-term strength and durability. Examples include fly ash, slag, silica fume, and, relevant to your research, sugarcane bagasse ash (SCBA). Siddique, R. (2011).

The careful proportioning and mixing of these components are fundamental to achieving the desired concrete properties.

Properties of Concrete:

Fresh Concrete Properties: These characteristics are critical during the mixing, transporting, placing, and compacting stages.

Workability: The ease with which concrete can be mixed, handled, placed, compacted, and finished. It is influenced by water content, aggregate properties, and admixtures. Workability is often assessed through tests like the slump test. Gambhir, M.L. (2004).

Hardened Concrete Properties: These properties determine the long-term performance of the structure.

Compressive Strength: The ability of concrete to resist crushing loads. It is the most common design parameter. It is typically measured using cylindrical or cubical specimens after 28 days of curing. ACI Committee 318. (2019).

Tensile Strength: The ability of concrete to resist pulling forces. Concrete is significantly weaker in tension than in compression. Tensile strength is important for resisting cracking due to bending and shear. It can be measured through tests like the splitting tensile test. IS 5816: 1999,

Flexural Strength: The ability of concrete to resist bending. It is important for structural elements like beams and slabs. It is measured by loading a concrete beam until it fails. ASTM C78 / C78M - 18 .

Durability: The ability of concrete to withstand environmental conditions and resist deterioration over time.

Water Permeability: The ease with which water can penetrate concrete. High permeability can lead to leaching of harmful substances and increased susceptibility to chemical attack. ACI Committee 222. (2016).

Proportions

Concrete proportion, also known as mix design, is the process of determining the appropriate quantities of each ingredient (cement, aggregates, water, and admixtures if used) to produce concrete with the desired properties in its fresh and hardened states. It's a crucial step in concrete production, as the proportions significantly influence the concrete's workability, strength, durability, and overall performance, (Neville & Brooks, 2010),

The objective in designing concrete mixtures is to determine the most economical and practical combination of readily available materials to produce a concrete that will satisfy the performance requirements under specific conditions of use. To fulfill this objective, a properly proportioned concrete mix will possess these qualities:

- i. Acceptable workability of freshly mixed concrete.
- ii. Durability, strength, and uniform appearance of hardened concrete.
- iii. Economy.

Since the majority of concrete used for agricultural applications is supplied by ready-mix producers, an understanding of the basic principles of mixture design is more important than the actual calculations. With this understanding, the customer can communicate better with the ready-mix supplier, and thus obtain concrete that is best suited to the project at hand. Mix design strives to produce concrete with all the desired properties from start to completion of a project. Workability is the property that determines the ease with which freshly mixed concrete can be placed, consolidated, and finished without segregation. Workability is difficult to measure. Thus, proportioning a concrete mixture for acceptable workability is an art as well as a science. For this reason, it is important to accurately describe what the concrete is to be used for, and how it will be placed. (Shelton & Harper, 2000)(Modani & Vyawahare, 2013)

SCBA as a Supplementary Cementitious Material (SCM)

Pozzolan Activity of SCBA:

SCMs are materials that, when finely divided and in the presence of moisture, react with calcium hydroxide (CH) released during the hydration of cement to form additional calcium silicate hydrate (C-S-H) gel. This secondary hydration contributes to the long-term strength and durability of concrete. Mehta, P.K. (1992).

SCBA exhibits pozzolanic activity due to its high silica (SiO₂) content. The degree of pozzolanic activity depends on the fineness of the ash and its chemical composition. Cordeiro et al. (2009).

SCBA can improve the durability of concrete; by Reducing Permeability: The finer SCBA particles fill pores in the concrete matrix, making it less permeable to water and aggressive chemicals. Ganesan et al (2007).

Environmental Benefits:

- I. Using SCBA as a partial replacement for cement reduces the demand for cement production, which is a major source of CO₂ emissions.
- II. It also provides a beneficial use for an agricultural waste material, reducing disposal problems. Mehta, P.K. (2001).

Challenges and Limitations of Using SCBA in Concrete:

- I. Variability in Ash Quality:
- II. The properties of SCBA can vary significantly depending on factors such as:
- III. Sugarcane variety
- IV. Soil conditions
- V. Combustion methods (temperature, duration)
- VI. Ash processing techniques (grinding, sieving). Ribeiro, et al (2008).

This variability makes it essential to characterize SCBA from different sources and control its quality to ensure consistent concrete performance.

Optimum Replacement Levels:

There is an optimum percentage of cement that can be replaced by SCBA to achieve the desired balance of strength, workability, and durability. Massazza, F. (1993).

Excessive replacement can sometimes lead to reduced early strength, increased water demand, or other adverse effects.

Long-Term Performance:

While research has shown promising results for the use of SCBA in concrete, more studies are needed to evaluate its long-term performance under various environmental conditions. Bapat et al (2014).

Effect of SCBA on Concrete Properties

- i. Effect of SCBA on Fresh Concrete Properties:
- ii. Workability:
- iii. Workability is a key factor influencing the ease of placing and compacting concrete. Gambhir, M.L. (2004)

SCBA can affect workability in several ways:

Fine SCBA particles can increase the cohesiveness of the mix, improving its plasticity and reducing segregation. Ferreira, V.M., & Ribeiro, A.B. (2006). The spherical shape of SCBA particles can provide a "ball-bearing" effect, improving flowability.

However, if the SCBA is very fine and used in high proportions, it can increase the water demand of the mix, leading to reduced workability if the water content is not adjusted. Ribeiro et al (2008)

Utilizing bagasse ash in concrete

Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tons. In India only, sugarcane production is over 300 million tons/year that cause about 10 million tons of sugarcane (Modani & Vyawahare, 2013), bagasse ash as an un-utilized and waste material. After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue is obtained, which is reused in the same industry as fuel in boilers for heat generation leaving behind 8 -10 % ash as waste, known as sugarcane bagasse ash (SCBA). The SCBA contains high amounts of un-burnt matter, silicon, aluminum and calcium oxides. But the ashes obtained directly from the mill are not reactive because of these are burnt under uncontrolled conditions and at very high temperatures. The ash, therefore, becomes an industrial waste and poses disposal problems. A few studies have been carried out in the past on the utilization of bagasse ash obtained directly from the industries to study pozzolanic activity and their suitability as binders by partially replacing cement. The present study was carried to study the use of SCBA as a partial Modani & V et al, (2013) replacement of fine aggregate in cement concrete since the availability of natural sand is on the cry off in the last decades as a result of ecological and environmental limitations. The experimental study examines the workability properties of fresh concrete such as slump and compaction factor and also 7- and 28-days compressive strength, 28 days tensile strength and sorptivity coefficients with 10%, 20%, 30% and 40% replacement of fine aggregate with bagasse ash by volume.

2.1.0 Properties of bagasse ash

Bagasse ash is a pozzolanic material, meaning it contains silica and alumina that can react with calcium hydroxide ($\text{Ca}(\text{OH})_2$) in the presence of water to form additional calcium silicate hydrate (C-S-H) gel, the primary binding agent in concrete. The chemical composition of bagasse ash varies depending on the sugarcane variety, soil conditions, and burning process, but it typically contains high amounts of silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3). The physical properties of bagasse ash, such as particle size distribution and specific surface area, also play a crucial role in its performance as a supplementary cementitious material. Studies have shown that finer bagasse ash particles with a higher specific surface area can improve the packing density of concrete mixes, leading to enhanced strength and durability.

Effect of bagasse ash on compressive strength

Several studies (Chi, 2012), have reported an increase in compressive strength of concrete containing bagasse ash compared to conventional concrete. This is attributed to the pozzolanic reaction between the ash and calcium hydroxide, which produces additional C-S-H gel and dandifies the concrete microstructure.

Effect of bagasse ash on concrete durability

Bagasse ash concrete has shown improved resistance to sulfate attack, chloride penetration, and carbonation compared to conventional concrete. The refined pore structure and reduced permeability of bagasse ash concrete contribute to its enhanced durability.

Effect of bagasse Ash on workability

The incorporation of bagasse ash can improve the workability of concrete mixes due to the spherical shape and smooth surface of the ash particles, which act as a lubricant between the aggregate. Tsinker, G. (2014).

Environmental Benefits of Sugarcane Bagasse Ash

The utilization of bagasse ash in concrete reduces the amount of cement required, thereby lowering the carbon footprint of concrete production. Additionally, the uses of bagasse ash as a waste material divert it from landfills and open burning, mitigating environmental pollution. (Sundaravadivel, 2018)

Composition of sugarcane bagasse ash

Silicon Dioxide (SiO_2): This is the primary component of bagasse ash, making up approximately 54.9% of the as-received ash. The SiO_2 content can increase significantly after acid pre-treatment, reaching levels of up to 5.27%. (Htun et al., 2018)

Iron Oxide (Fe_2O_3): Iron oxide is another significant component, accounting for around 10.0% of the as-received ash.

Aluminum Oxide (Al_2O_3): Aluminum oxide is present in smaller amounts, typically around 7.8% of the as-received ash.

Calcium Oxide (Cao): Calcium oxide is also present, making up approximately 4.9% of the as-received ash. Its content can decrease significantly after acid pre-treatment due to dissolution in the acid solution. **Other Oxides and Impurities:** Bagasse ash may also contain smaller amounts of other oxides such as magnesium oxide (MgO), potassium oxide (K_2O), and sulfur trioxide (SO_3), as well as inorganic impurities like carbon.

Sugar Cane Processing: Bagasse ash is primarily generated during the combustion of bagasse, which is the fibrous residue left over after the extraction of juice from sugarcane.

Local Sugar Factories: Bagasse ash can be collected from local sugar factories, where it is often used as a renewable energy source.

Settling Ponds: In some cases, bagasse ash can be extracted directly from settling ponds of sugar and alcohol plants.

MATERIALS AND METHOD

The sugarcane bagasse was collected from the two sources, Samunaka, Kaduna state and Dabai, Katsina state, then bagasse was properly dried under the sun for more than a week to ensure maximum removal of moisture to enhance adequate combustion, to reduce carbon contained which may affect pozzalanic properties of the bagasse, the bagasse was burnt in an electric furnace with the thermostat control burning at 800°C , then taken to industrial development center (IDC) in Samara, Zaria for burning controlled at 800°C



Figure 3.1 bagasse sourced from Samunaka and Dabai



Figure 3.2 Calcination machined for sugarcane burning at (IDC) center Zaria

3.2 Fine Aggregate

The research utilized natural occurring clean sand sourced from Zaria, which are recognized for the concrete. Fine aggregate refers to solid materials that pass through a 5mm sieve and predominantly consist of particles finer than 5mm. Any material passing through a 75µm sieve is classified as fine aggregate under BS standard, BS 882:1992 progressively smaller mesh sizes to determine its particle size distribution. Kingley et al, 2023.

3.3 Coarse aggregate (Stone)

The coarse aggregate used was crushed granite stone obtained from a single quarry along Zaria-Sokoto road. The particle size distribution of coarse aggregate is determined using sieves in compliance with BS410. These sieves must meet precise tolerance to ensure reliable results during testing. The gradation of coarse aggregate must fall within specified limits, which are determined using the sieves of sizes outlined in BS410 and related standards e.g. BS812-103.1, BS882, 1992.

3.4 Cement

In this research, Ordinary Portland Cement (PLC) locally available (Dangote cement) conforming primarily to the British/European Standard (BS EN 197-1) was used.

Water

Clean portable water sourced from the Concrete Laboratory at Department of Building, Ahmadu Bello University Zaria was used for the concrete preparation.

4 Mix Design

A concrete of target strength 30N/mm^2 was designed using the DOE method of mix design and the quantity of material and mix ratio of 1:1.56:2.66 (see appendix for design calculation). This is in accordance with the BS 8110 – 95

Physical Properties

The physical properties of the SCBA are presented in Table 1. The properties include specific gravity and bulk density.

The specific gravity for Samunaka is 2.63, and for Danja, it is 2.24.

Table 1: Physical properties of the materials

Physical properties	samunaka	Danja	Coarse aggregate	Fine aggregate
Spe Specific gravity	2.63	2.88	2.8	2.7
Bulk density	1439	1525	1645	1746
Color	Black ash after burning	Ash after burning	-----	-----

Chemical composition of SCBA

Table 2: Chemical Composition of both Samunaka and Danja Samples

S/N	COMPOUND	DANJA	SAMUNAKA
1	SiO_2	57.261	52.878
2	Al_2O_3	6.067	4.476
3	FeO_3	3.813	4.530
4	M_{go}	0.000	0.000
5	CaO	7.048	7.073
6	K_2O	16.341	19.414
7	P_2O_5	3.899	4.449
8	TiO_2	1.251	1.047

The chemical composition of SCBA from Samunaka and Danja is presented in Table 2 of the document. Here's a summary of the key differences:

- **Silicon Dioxide (SiO_2):** Danja has a slightly higher concentration (57.261%) compared to Samunaka (52.878%).

- **Aluminum Oxide (Al_2O_3):** Danja shows a higher percentage (6.067%) compared to Samunaka (4.476%).
- **Iron (III) Oxide (Fe_2O_3):** Samunaka has a slightly higher concentration (4.530%) compared to Danja (3.813%).
- **Calcium Oxide (CaO):** Samunaka has a slightly higher percentage (7.073%) compared to Danja (7.048%).
- **Potassium Oxide (K_2O):** Samunaka exhibits a higher concentration (4.449%) compared to Danja (1.634%).
- **Phosphorus Pentoxide (P_2O_5):** Danja has a higher amount (3.899%) compared to Samunaka (1.047%).
- **Titanium Dioxide (TiO_2):** Danja shows a slightly higher concentration (1.251%) compared to Samunaka (1.047%).

In summary, Danja SCBA is relatively richer in silicon dioxide, aluminum oxide, phosphorus pentoxide, and titanium dioxide, while Samunaka SCBA has higher concentrations of iron(III) oxide, calcium oxide, and potassium oxide.

The document notes that these differences in chemical composition can indicate variations in the pozzolanic activity of SCBA.

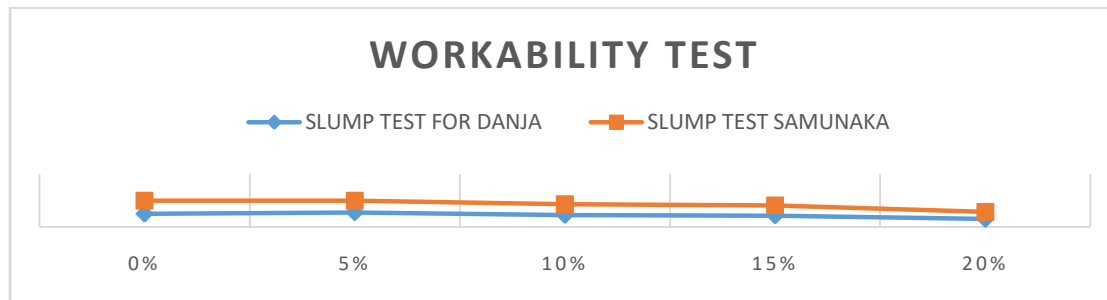
Table 3: Sieve analysis of fine aggregate

S/N	SIEVE SIZES	Net wet (g)	net pass	Cumulative Weight net	Cumulative WEIGHT NET	% Cumulative
1	20	14	983	98.3	14	2.25
2	10	608	375	37.5	622	64.79
3	5	338	37	37.7	960	96.48
4	PAN	35	0	-----	995	1.64

Table 4: Sieve Analysis of coarse Aggregate

S/N	SIEVE SIZES	Net wet (g)	Net ret(g)	net pass	Cumulative Weight net	% cumulative
1	5	18	482	96.4	18	48.64
2	2..5	19	463	92.6	37	26.24
3	1.25	104	359	71.8	141	42.85
4	0.6	188	171	34.2	329	73.93
5	0.3	116	55	11.0	445	92.32
6	0.15	37	98	3.6	482	96.4
7	PAN	18	-----	-----	500	3.80

SLUMP TEST RESULT



The graph shows how the slump values for both DANJA and Samunaka change as the percentage increases. It appears that for both samples, the slump value generally decreases as the percentage increases. This suggests that increasing the percentage leads to a reduction in the workability or consistency of the material being tested.

Comparison between DANJA and Samunaka:

- I. **Initial Slump (0%):** At 0%, the Samunaka sample exhibits a significantly higher slump value compared to the DANJA sample. This indicates that without any added percentage, Samunaka has a higher initial workability or is more fluid than DANJA.
- II. **Slump Behavior with Increasing Percentage:** As the percentage increases from 0% to 20%, the slump value for both samples decreases. However, the rate of decrease appears to be different:
 - a) **Samunaka:** The slump value for Samunaka starts high and gradually decreases across the tested percentages. It remains consistently higher than the DANJA sample throughout the experiment.
 - b) **DANJA:** The slump value for DANJA starts lower and also decreases as the percentage increases. The decrease appears less pronounced in the initial stages (0% to 5%) but becomes more evident at higher percentages.
- III. **Final Slump (20%):** At 20%, both samples show the lowest slump values, indicating the least workability. However, even at this highest percentage, the slump value for Samunaka is still noticeably higher than that of DANJA.

Interpretation:

Based on this slump test result, we can infer the following about the workability of the DANJA and Samunaka samples as the percentage increases:

- I. **Samunaka generally exhibits higher workability than DANJA across all tested percentages.** This means that the Samunaka material tends to be more fluid or easier to mold and handle.
- II. **Increasing the percentage in both samples leads to a decrease in workability.** This could be due to the addition of a component that stiffens the mixture or reduces its flowability.
- III. **The impact of the increasing percentage on workability seems more significant for Samunaka in terms of the absolute reduction in slump value.** Although both decrease, the initial high slump of Samunaka sees a larger drop.

Further Considerations:

To provide a more in-depth discussion, it would be helpful to know:

- I. **What the "percentage" refers to.** Is it the addition of water, a specific admixture, or another

material? Knowing this would allow for a more specific interpretation of why the workability changes.

- II. **The units of the slump value.** Understanding the scale of the slump (e.g., in millimeters or inches) would provide context to the magnitude of the differences observed.
- III. **The intended application of these samples.** The desired workability of a material often depends on its intended use (e.g., concrete for different types of structures requires varying slump ranges).

In conclusion, this figure clearly demonstrates that the Samunaka sample has higher workability than the DANJA sample across the tested percentages, and increasing the percentage leads to a reduction in workability for both. Understanding what this "percentage" represents is crucial for a more complete interpretation.

Durability test

- Water Absorption

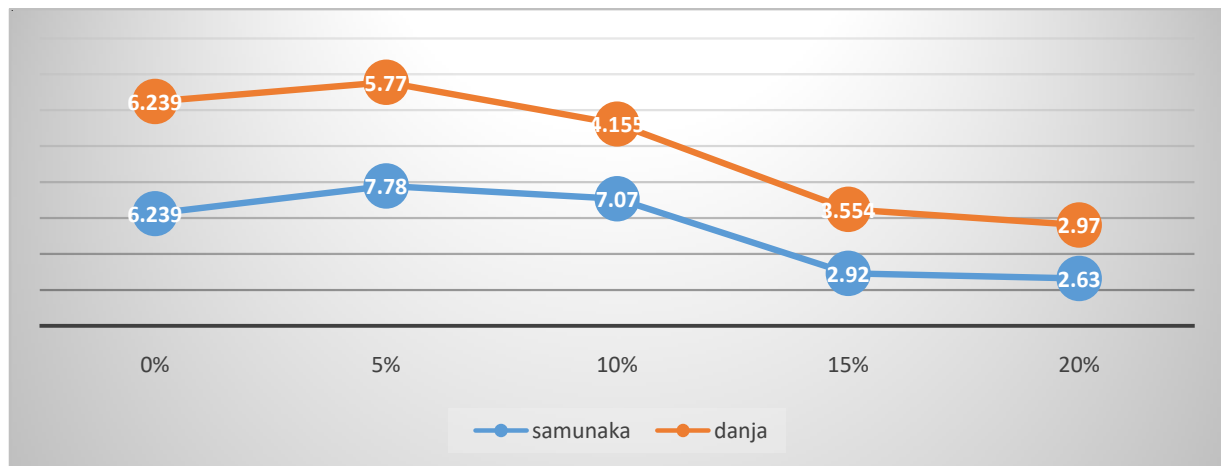


Figure 1, Water Absorption

The graph illustrates how water absorption changes for both Samunaka and Danja as the percentage increases. It's evident that the water absorption behavior differs significantly between the two samples across the tested percentages.

Detailed Analysis by Sample:

- a) **Samunaka** At 0%, Samunaka shows a water absorption of 6.239%.
 - b) As the percentage increases to 5%, the water absorption rises to 7.78%.
 - c) At 10%, the water absorption decreases to 7.07%.
 - d) Further increase to 15% leads to a more substantial drop in water absorption to 2.92%.
 - e) Finally, at 20%, the water absorption slightly increases to 2.63%.
- Overall, Samunaka's water absorption shows an initial increase at 5%, followed by a decrease at 10%, a significant drop at 15%, and a slight plateauing at 20%.
- **Danja**
 - a) At 0%, Danja exhibits a higher water absorption of 12.39%.
 - b) As the percentage increases to 5%, the water absorption slightly increases to 13.77%.
 - c) At 10%, there's a notable decrease in water absorption to 11.55%.
 - d) A further increase to 15% results in a more significant drop to 6.654%.
 - e) At 20%, the water absorption continues to decrease to 2.97%.

Danja's water absorption shows a slight initial increase at 5%, followed by a consistent decrease as the percentage increases further, with the most significant drop occurring between 10% and 20%.

Comparative Discussion:

- I. **Initial Water Absorption (0%):** At 0%, Danja has a considerably higher water absorption (12.39%) compared to Samunaka (6.239%). This suggests that without any added percentage, Danja is more porous or has a greater affinity for water absorption than Samunaka.
- II. **Response to Increasing Percentage:** The two samples react differently to the increasing percentage:
 - Samunaka's water absorption fluctuates, initially increasing and then decreasing significantly at higher percentages.
 - Danja's water absorption, after a slight initial rise, consistently decreases as the percentage increases, showing a more direct negative correlation at higher percentage levels.
- III. **Water Absorption at Higher Percentages (15% and 20%):** At 15% and 20%, both samples exhibit significantly reduced water absorption compared to their initial values. Notably, at 15%, Samunaka shows a lower water absorption (2.92%) than Danja (6.654%). However, at 20%, their water absorption values become quite similar (Samunaka at 2.63% and Danja at 2.97%)

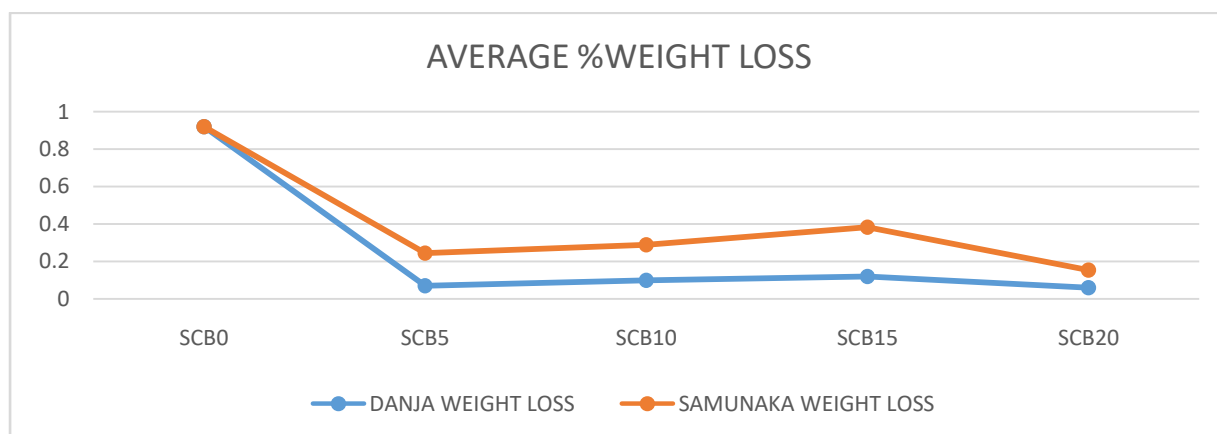


Figure 2, Durability test AVERAGE WIGHT LOSS

Table 5: Danja Sorptivity

X ($\sqrt{\text{Time}}$)	Y (ΔV)	Average absorption(mm)
3.16	0	1049.78
4.47	2.72	1052.50
5.48	4.11	1053.89
6.32	5.11	1054.89
7.75	7.66	1057.44
10.95	11.11	1060.89
13.42	12.22	1062.00
15.49	13.83	1063.61

Table 6: **Samunaka Sorptivity**

X ($\sqrt{\text{Time}}$)	Y (ΔV)	Average absorption(mm)
3.16	0	1049.79
4.47	1.55	1052.50
5.48	2.55	1053.89
6.32	3.55	1054.89
7.75	4.55	1057.44
10.95	6.00	1060.89
13.42	7.11	1062.00
15.49	8.72	1063.61

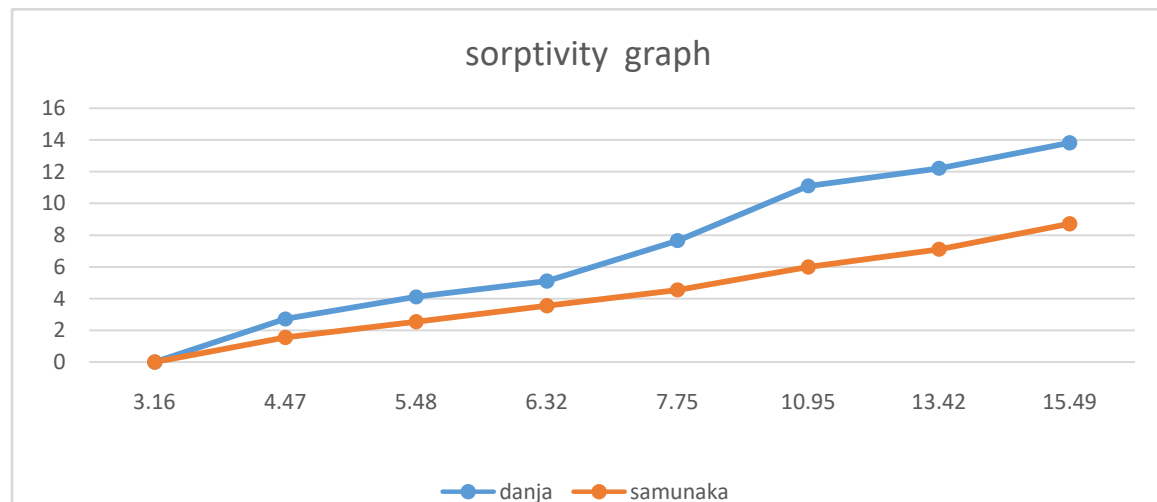


Figure 3, Slump Test

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