EVALUATING BAGASSE ASH AS PARTIAL CEMENT REPLACEMENT MATERIAL

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Abstract: The main goal of this study was to evaluate sugarcane bagasse ash as a partial cement replacement material. Sugarcane bagasse ash is a by-product of fuel blending in the sugar industry. Yet all economic sugar is obtained after extraction from the cane. The disposal of the discharged waste in agriculture causes environmental problems in the sugar industry. The cement industry also creates environmental problems due to carbon dioxide emissions during cement manufacturing. Initially, bagasse ash samples were collected from the rubble of the Arjo Didessa sugar factory. The crude bagasse ash was sieved with a sieve size of 250µm. The strength of grade C-25 concrete was designed using five different concrete mixture proportions ranging from 5 to 20% cement by weight, including a water-cement ratio of 0.45. Impact strength tests were conducted at 7, 14, 21, and 28 days of age for each replacement ratio. For the experimental work, a total of 60 cubic concrete specimens were cast for compressive strength tests, and 15 cylindrical concrete specimens were cast for water absorption tests. Working compressive strength results indicated that bagasse ash could replace up to 5% of ordinary Portland cement concrete.

Keyword: building materials; sugar cane bagasse; Portland cement; Concrete; water absorption.

1. Introduction

Concrete is defined as a mixture of cement, sand, gravel, and water that dries hard and strong and is used as a material for building [3, 10, and 13]. A byproduct of sugar factories cogeneration boilers. It is what remains after all the economically viable sugar has been extracted. [5, 4, 7, 9, and 14]. The disposal of this agricultural waste causes environmental problems in the sugar industry. The cement industry also creates an environmental problem through the emission of carbon dioxide during the manufacturing of cement and consumes a lot of raw materials. Therefore, this research deals with sugarcane bagasse ash as a partial replacement for cement in concrete production [2, 4, 11, and 16]. First, the sugarcane bagasse ash samples were collected from the Arjo Didessa sugar factory. Sugarcane bagasse ash was sieved with a 250µm sieve size. The M25 grade strength of concrete was designed with five different proportions of concrete. Sugarcane bagasse ash ranging from 5-20 percent by weight of cement, including the control mix, was prepared with a water cement ratio of 0.45[1, 14]. For each substitution ratio, 3 sets (a total of 12) of concrete specimens were prepared for the compressive strength test conducted at the ages of 7, 14, 21, and 28 days. For this experimental work, a total of 60 cubic concrete specimens for the compressive strength test and 15 cylindrical concrete specimens for the water absorption test were cast [1, 12].

According to studies [1, 14, and 17], sugar cane bagasse ash has a higher surface area and a lower density than cement. The overall value of $SiO2$, $Al2O3$, and $Fe2O3$ in the bagasse ash studied was 87.68 percent, exceeding the standard value of 70 percent and qualifying as a Class N Pozzolan [12, 18]. According to the compressive strength of concrete construction results, bagasse ash can replace ordinary Portland cement up to 5% of the time. Furthermore, increased compressive strength was seen at all test ages—7, 14, 21, and 28 days. Concrete with 5% sugarcane bagasse ash replacement increased its strength by about 8% and 6% over the 21- and 28-day compressive strength values, respectively.

2. Materials and Methods

2.1. Investigation of the physical properties of SBA

The investigation of the physical properties of SBA was to determine the density, fineness, and particle size of SBA [15].

2.1.1. Materials

The sources of the materials used for the study, as well as any pertinent physical and chemical attributes, are given. The Wallaga University Civil Engineering Department's material laboratory conducts all laboratory tests on aggregates, cement, bagasse ash fineness, pastes, mortars, and concrete; in contrast, the Geological Survey Center in Nekemte, Ethiopia, performs tests on the chemical characteristics of bagasse ash. The sources of the materials used for the study, as well as any pertinent physical and chemical attributes, are given. The Wallaga University Civil Engineering Department's material laboratory conducts all laboratory tests on aggregates, the fineness of cement and bagasse ash, pastes, mortars, and concrete; in contrast, the Geological Survey Center of Ethiopia performs tests on the chemical characteristics of bagasse ash.

2.1.1.1. Bagasse ash

The Arjo Didessa Sugar factory in Western Ethiopia's Oromia Regional State provided the bagasse ash used in this study. Every eight hours, the furnace in this factory collects the bagasse ash, which is then deposited all over the place, not far from where the workers live.

Because the measuring device was too short to fit into the furnace, it was not able to measure the furnace's temperature while collecting bagasse ash. Even though the temperature could not be measured, the majority of furnaces have a temperature well over the 800 °C threshold needed for full combustion [11]. However, it has been hypothesized that mineral crystallization takes place at a temperature of about 650 °C [1, 11].

Methods: The Wallaga University received sufficient BA that had been removed from the furnace and was carried there in sacks. The moisture in the BA was eliminated by drying it at room temperature before the examination of its physical properties. Large and lumpy particles, as well as some bagasse ash larger than 250 m, were sieved out of the dry BA using a 250 m sieve. The image below contrasts the results of sieving BA using a 250-m sieve before and after.

Figure 1 BA before and after sieved with 250µm sieve.

Particle Size: The particle size distribution of BA sieved with 250µm and cement was done in the chemical engineering unit operation laboratory. The particle size distribution is as shown in Table 1 below:

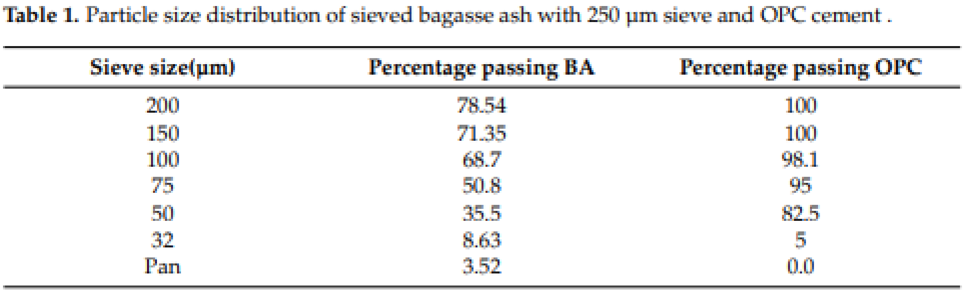


Table 1. Particle size distribution of sieved bagasse ash with 250 µm sieve and OPC cement .

Sieve size(µm)	Percentage passing BA	Percentage passing OPC
200	78.54	100
150	71.35	100
100	68.7	98.1
75	50.8	95
50	35.5	82.5
32	8.63	5
Pan	3.52	0.0

Density: The density of BA is defined as the mass per unit volume. For this study, the density of BA was tested in a geological survey center in Ethiopia.

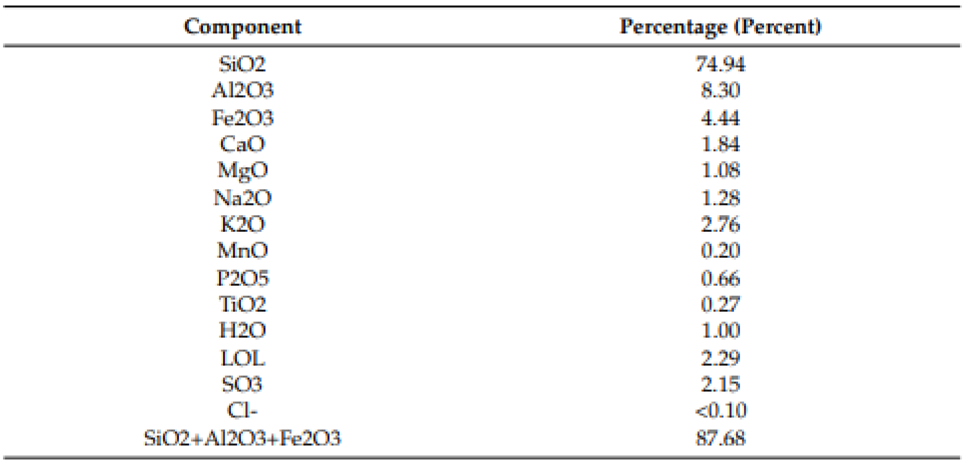
Fineness test: A standard sample of cement with a specific surface (SS) of 2183 cm2/g is utilized to calibrate the research equipment. In calibration with the standard sample (TS), the equivalent measured time interval is 15 seconds. The average amount of time needed to pump air through the three cement samples during the fineness test for the BA used in this study is used as the manometer drop measurement time for the test sample (T). The three samples' three-time intervals were measured as 61, 59, and 60 seconds. The three samples' combined average time interval is therefore 60 seconds.

$$S = (2183\ \text{cm2/g} * \sqrt{60}\ \text{Sec})/\sqrt{15}\ \text{Sec} = 4371.6\ \text{cm2/g}$$

2.2. Investigation of the chemical composition of SBA

The Geological Survey center in Ethiopia analyzed the chemical composition of BA for the full silicate analysis and other associated tests. Its chemical makeup was evaluated using the LIBO2 FUSION, HF attack, gravimeter, colorimetric, and AAS analytical methods. Table 2 below provides the results of the chemical composition of BA.

Table 2. The chemical composition of bagasse ash.



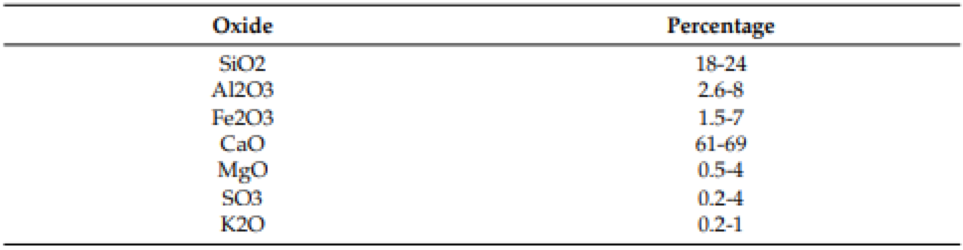
Component	Percentage (Percent)
SiO_2	74.94
Al_2O_3	8.30
Fe_2O_3	4.44
CaO	1.84
MgO	1.08
Na_2O	1.28
K_2O	2.76
MnO	0.20
P_2O_5	0.66
TiO_2	0.27
H_2O	1.00
LOL	2.29
SO_3	2.15
Cl^-	<0.10
$SiO_2+Al_2O_3+Fe_2O_3$	87.68

2.2.1. The compressive strength of concrete

Materials: The main materials used in the preparation of concrete specimens and checking the compressive strength of concrete are listed below.

Cement: In this study, BA served as a partial replacement for cement specimens, and control samples were made with ordinary Portland cement (OPC) of the Dangote brand. The standard set by ES 11766:2005 for OPC cement is the chemical makeup of the cement.

Table 3. Oxide composition of OPC cement as per ES 1176-6:2005.



Oxide	Percentage
SiO_2	18-24
Al_2O_3	2.6-8
Fe_2O_3	1.5-7
CaO	61-69
MgO	0.5-4
SO_3	0.2-4
K_2O	0.2-1

For this study, typical river sand with a specific gravity of 2.6 and a particle size below 4.75 mm was employed. It was free of trash and brought in from the area.

Crushed rock that was accessible in the Wallaga University construction area was used as the coarse aggregate for this study. The aggregate was properly washed and dried outside to rid it of unwanted dust. An aggregate with a maximum size of 20 mm was used.

Water was used for all concrete mixing and curing in the laboratory, which is a part of the Naqamte Water and Sewerage Authority.

Balance: to measure materials such as cement, aggregate, bagasse ash, and water.

Slump cone: to measure the workability of concrete, or slump test.

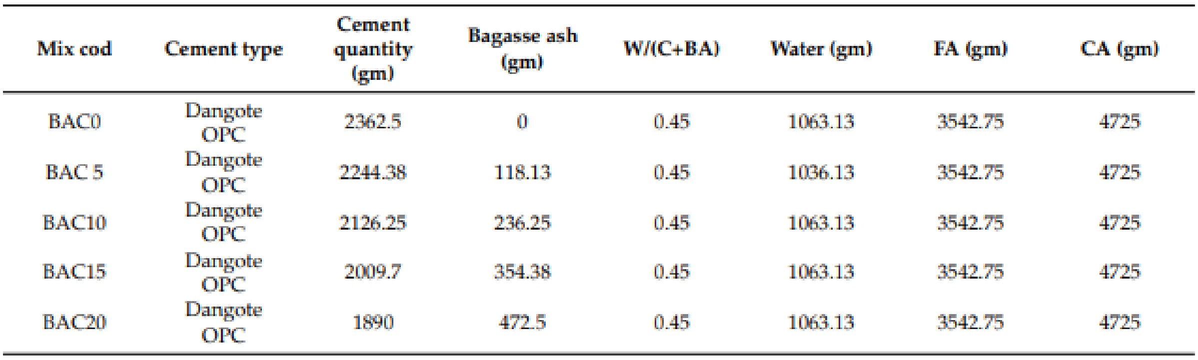
A compressive strength testing machine was used to test the concrete cubes for crushing compressive strength at 7, 14, 21, and 28 days, respectively.

2.2.2. Methodology

Five different proportions of concrete mixes (bagasse ash ranging from 5% to 20% by weight of cement) were prepared for a design cube compressive strength of M25 grade, including the control mix. Three sets of concrete specimens (4 x 3 = 12) were made for each replacement ratio to conduct a compressive strength test at the ages of 7, 14, 21, and 28 days. 60 concrete examples in all were made for this experimental research.

The weighing was done using weight measurement for cement, BA, and aggregate. The aggregates, cement, and BA were dry mixed for one minute at various percentages of BA as replacing cement (0 percent, 5 percent, 10 percent, and 20 percent), then water was added after calculating the relative amounts of materials to use for the specimens. Water was then added, and the mixture was continued for an additional two minutes. For each BA replacement mix and control mix, the workability or slump test was assessed right after mixing using a slump cone. Mineral oil is applied to all sides of the cast molds to remove any remaining dust before concrete is poured into them. Molds were filled with thoroughly mixed concrete, which was then kept on the vibration table. The specimens were then compacted into two layers using a vibrating table and set on a firm, level surface of molds (150 mm x 150 mm x 150 mm). For the two steel molds and one steel mold, the specimens vibrated for 45 and 30 seconds, respectively. After vibration, a trowel is used to polish the top surface. Then the specimens were removed from the molds after 24 hours and allowed to cure in a curing pond in the laboratory for 7, 14, 21, and 28 days at room temperature. Table 4 shows the proportions for mixing one cubic meter of M25 concrete.

Table 4. Mix proportion for the concrete preparation.



Mix cod	Cement type	Cement quantity (gm)	Bagasse ash (gm)	W/(C+BA)	Water (gm)	FA (gm)	CA (gm)
BAC0	Dangote OPC	2362.5	0	0.45	1063.13	3542.75	4725
BAC 5	Dangote OPC	2244.38	118.13	0.45	1036.13	3542.75	4725
BAC10	Dangote OPC	2126.25	236.25	0.45	1063.13	3542.75	4725
BAC15	Dangote OPC	2009.7	354.38	0.45	1063.13	3542.75	4725
BAC20	Dangote OPC	1890	472.5	0.45	1063.13	3542.75	4725

Where:

BAC0 is a concrete mix that contains 100% OPC and 0% BA by mass.

BAC 5 is a concrete mix that contains 95% OPC and 5% BA by mass.

BAC 10 is a concrete mix that contains 90% OPC and 10% BA by mass.

BAC 15 is a concrete mix that contains 85% percent OPC and 15% percent BA by weight.

BAC 20 is a concrete mix that contains 80% OPC and 20% BA by mass.

Fresh concrete's workability: A slump cone was used to gauge the concrete's workability. The type of concrete fall can be used to classify the concrete slump. The three varieties of the slump test are as follows:

In a true slump, the concrete just subsides quickly and largely holds the shape of the mold. The best kind of slump is one like this.

A shear slump occurs when one-half of a cone slips downward on an inclined plane. Shear slump is a sign that the concrete mix is not cohesive.

Fresh concrete entirely crumbles in this instance of a collapse slump. The genuine slump is the only dependable condition for determining whether the concrete is workable. The test should be repeated if other types emerge. This piece's slump test was a real slump test. The concrete slump test is an empirical test that gauges the consistency of new concrete. The slump test was conducted using a cone-shaped frustum with a height of 300 mm, a lower diameter of 200 mm, and an upper diameter of 100 mm. The base plate and mold were moistened before being set on a flat surface. The mold was firmly secured to the base plate while being filled with three layers, each of which was crushed with 25 strokes of the steel tamper. The concrete's surface was struck off by sawing and rolling the tamping rod after the top layer had been compacted. The mold was then lifted by a gradual uplift after the spilled concrete was taken out of the base plate. A straight was used to measure the height difference between the mold and the highest point of the slumping test specimen. To examine the workability of fresh concrete, the slump test was carried out on both the concrete with and without SBA.

Checking the compressive strength of prepared concrete:- Each specimen had its compressive strength measured in the compressive strength machine after the required curing period of 7, 14, 21, and 28 days had passed. Tested samples were left outside the lab after the appropriate examinations.

2.2.3. Evaluating water absorption of developed concrete

Materials: The cylindrical concrete was developed with different mix percent of BA and control mix concrete was used for evaluating water absorption tests and water was also used to immerse the concrete. An oven to dry the cylindrical concrete before being immersed in water and a balance to measure the weight of the concrete before and after absorption was used.

Methodology: Similar to how cylindrical concrete was prepared for the compressive strength test, it was utilized to assess water absorption with various BA as partial replacements for cement (0, 5, 10, 15, and 20 percent) mixes. At the age of 28 curing days, specimens were created for each mix and put to the test. The cylindrical specimens (100 mm x 200 mm) were oven dried for 24 hours at 105 °C before being weighed after the requisite curing period. After 24 hours in the water, it was weighed again. The calculation for water absorption is as follows. Absorption of water: WA percent = ws-wd/wd x100

Where Wd is the weight of the dried specimens before the absorption test and Ws is the weight of the dried specimens immersed in water for 24 h.

3. Result

In this section, laboratory test findings of BA for its acceptability as a cement replacement in the manufacture of concrete and an evaluation of the generated concrete qualities were provided and analyzed. The following are some of the differences between BA and developed concrete:

- comparing BA's fineness to OPC's in terms of specific surface area, particle size distribution, and density;
- The chemical properties of BA in terms of chemical compositions[4, 10];
- Fresh concrete's workability, compressive strength, and water absorption, as well as hardened concrete containing BA—which took the place of regular Portland cement—all underwent testing.

3.1. Physical and chemical properties of SBA

The test results in this part were the physical properties of BA in terms of fineness, particle size distribution, and density, and the chemical properties of bagasse ash in the form of chemical composition.

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Table 5. Physical properties of cement and SBA .

Material + Average size (µm)	Density in cm2/g	Blain air in cm2/gm
OPC74	3.15	2910
BA43	1.92	4371.6

N.B The sieve size through which 50% of the particles pass is determined by linear interpolation of the average particle size.

The graph for the particle size distribution of the BA and cement is shown in Figure 2 below

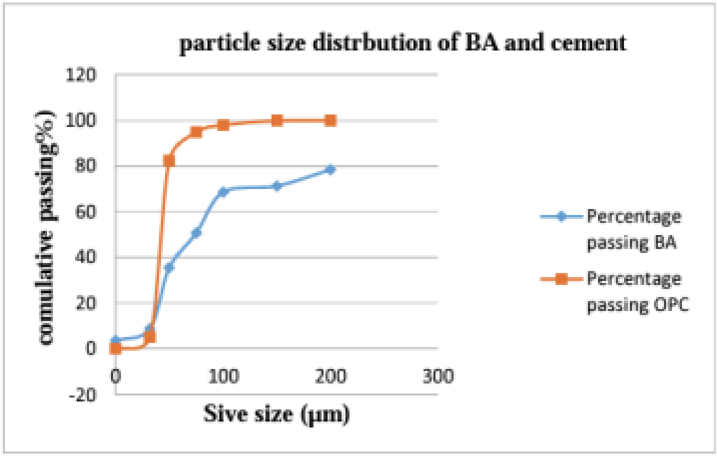

Figure 2. particle size distributions of bagasse ash and cement.

Particle size examination of samples of bagasse ash revealed, as shown in Table 5, that the average size of the BA passed with 250m particles was 74µm. The cement was larger than the ash, with an average size of 43µm. The BA and cement particle size distribution in Figure 2 demonstrates this as well. This graph demonstrates that the cement is finer for sieve sizes greater than 20µm (where the two graphs meet), while the bagasse ash is coarser for sieve sizes greater than 20µm. This figure demonstrates that the BA passed with 250µm contains some finer particles than cement, though it is almost as coarse as cement.

The blain air permeability method determined that BA had a fineness of 4371.6 cm2/g, which is more than cement, which had a surface area of 2910 cm2/g. The benefit of BA's high specific surface area is that it speeds up the reaction of free lime released during cement hydration to create more calcium silicate hydrate, a novel hydration product that enhances the mechanical qualities of hardened concrete.

As compared to OPC, BA has a lower density (1.92g/cm3) and a larger surface area (4371.6cm2/g for the Blaine surface area). The results demonstrate that bagasse ash has a higher fineness than cement due to its lower density, and it also shows that bagasse ash has a higher blain air than cement [24]. Large surface areas have also been observed to favor the pozzolanic reactivity of amorphous silica and other minerals.

3.2. Chemical composition of SBA

The chemical composition tests were carried out for the elements that characterize the nature of SBA, which included silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), sodium oxide (Na_2O), potassium oxide (K_2O), calcium oxide (CaO), magnesium oxide (MgO), sulfur trioxide (SO_3), and loss on ignition [5].

Atomic absorption spectrometry (AAS): AAS is an analytical technique that measures the concentration of elements. The technique makes use of the wavelength of light specifically absorbed by an element. AAS works by atoms of different elements absorbing characteristic wavelengths of light. The greater the number of atoms there are in the vapor, the more radiation is absorbed. The amount of light absorbed is proportional to the number of atoms.

Table 6. Chemical composition of cement and bagasse ash.

Chemical Composition (Percent)	Dangote OPC cement (2005)	Bagasse ash
SiO2	18-24	74.94
Al2O3	2.6-8	8.3
Fe2O3	1.5-7	4.44
CaO	61-69	1.84
MgO	0.5-4	1.08
Na2O	-	1.28
K2O	0.2-1	2.76
MnO	-	0.20
P2O5	-	0.66
TiO2	-	0.27
H2O	-	1.00
LOL	-	2.29
SO3	0.2-4	2.15
Cl-	-	<0.015
SiO2+Al2O3+Fe2O3	30.55	87.68

Results from the analysis of the chemical composition of SCBA are shown in Table 6 It was observed that the biggest component of ash is silicon dioxide. This plays a major role in binding as it forms complexes that include Tricalcium silicate and Dicalcium silicate, which are the major components of cement, hence making it a material with good binding properties.

According to ASTM C-618 specifications, the combined chemical composition of SiO2, Al2O3, and Fe2O3 = 87.68 percent, indicating that bagasse ash is pozzolanic. According to this specification, the bagasse ash qualifies to be a Class N Pozzolan.

Work-ability of fresh concrete: The slump test was carried out to determine the fresh concrete's workability. It should be possible to lay, compact, and finish a concrete mix. The proportions of the elements in concrete should allow for good workability and enough strength to support the necessary load after hardening. These workability values for the control and blended concrete are provided in Table 7 below.

Table 7. Slump test results.

Mix code	W/(C+BA) (Percent	Slump value(mm)
BAC0	0.45	6
BAC5	0.45	50
BAC10	0.45	45
BAC15	0.45	40
BAC20	0.45	20

Table 7 shows that the slumps of the concrete containing BA have slightly decreased as the BA content has increased. This could be a sign that OPC-BA blended concrete requires more water than concrete without BA. The higher specific surface area of the BA and its lower density may be the cause of this, which gives it a higher porosity and higher water demand. As the BA content rises, the water content can be raised to achieve a slump similar to that of the control and OPC-BA concrete.

Unit Weight of fresh concrete: The hardened concretes are evaluated for weight, compressive strength, and water absorption in this research unit, and the results are provided in the sections below. The weights of cylindrical concrete were measured before they were immersed in water in a water absorption test. This was used for evaluating the unit weight of concrete mixed with and without BA as a replacement for cement after 28 days of curing and drying in an oven. The unit weights of the concrete are shown in Table 4.4 given below.

Table 8. Unit weights of concretes.

Mix code	Unite wt.(gm)	Reduction (percent)
BAC0	3514	0.0
BAC5	3509	0.15
BAC10	3500	0.26
BAC15	3490	0.28
BAC20	3475	0.43

According to the data in table 8, the replacement of 20 percent of the cement in sample BAC20 with bagasse ash resulted in a minor loss of unit weight of up to 0.43 percent. While using bagasse ash at replacement rates of 5, 10, and 15%, samples BAC5, BAC10, and BAC15 showed decreases of 0.15 percent, 0.26 percent, and 0.28 percent, respectively. The unit weights of the blended concrete were reduced as a result of the bagasse ash's low density (1.92g/cm3 versus 3.15g/cm3 for OPC).

The compressive strength of concrete: The most common test for hardened concrete is the compressive strength test. There are several reasons for this, including the fact that numerous rules and design guidelines are based on this property; numerous other qualities of concrete depend on compressive strength, and this test is straightforward in comparison to others. The compressive strength of concrete grade M25 (1:1:12:2) was examined for both the control mix and when SBA was used to replace some of the cement.

By testing the cubes in a compression machine, the compressive strength of each concrete is identified. The compressive strength of each mix is determined by averaging three samples. The average compressive strength test results at various curing days (7, 14, 21, and 28) are provided in table 9.

Figure 3. Specimen before (left) and after (right) testing compressive strength.

Table 9. Average compressive strength values of concrete.

Mix code	at 7days	at 14 days	at 21days	at 28 days
BAC0	28.37	32.68	33.38	36.6
BAC5	29.76	33.6	36.08	38.84
BAC10	25.24	28.37	32.54	36.12
BAC15	24.76	28.37	30.91	32.82
BAC20	23.25	27.75	29.98	32.12

According to Figure 4 the compressive strength of the concrete cubes increases with increasing curing time for all mix ratios. On all curing days, the average compressive strength value of concrete containing 5 percent bagasse ash was relatively higher than the control and the BA of 10, 15, and 20 concrete samples (7, 14, 21, and 28). The 21- and 28-day compressive strength values of concrete with 5% bagasse ash replacement showed a strength improvement of around 8% and 6%, respectively. At 14 days, the compressive strength of concrete that had been strengthened by 10% and 15% had slowed to the same strength value of 28.37Mpa. Similar to this, concrete's compressive strength at 28 days with 0 percent BA and 10 percent BA is practically identical, coming in at 36.6 and 36.12 Mpa. Based on these findings, cement could be replaced by BA in high-quality concrete by up to 5% without sacrificing quality. With a modest drop in concrete performance, a larger BA replacement percentage is also possible.

Water Absorption: The water absorption of concrete mixes containing SBA is given in Table 4.6. With an increasing amount of BA, there was a slight increase in water absorption with an increasing amount of BA. Mixes BAC5 have a slightly lower water absorption observed than the control mix (BAC0). However, when compared to the control mix (BAC0), the mixes containing 10% SCBA (BAC10) show a 0.3 percent increase in water absorption. Water absorption increases noticeably when the cement replacement of SCBA is increased to 20%. The high water absorption of the mixes containing BA was due to the porous nature and rough surface of the BA particles. The percentage of water absorption serves as a gauge for the number of hardened concrete's pores, or porosity, which are occupied by water under saturated conditions. As a result, the ideal water absorption limit can be considered a 5% cement replacement of BA.

Table 10. The percentage water absorption of concrete.

Mix code	Average weight of concrete (gm) Before absorption	Average weight of concrete (gm) After absorption	Water absorption /percent
BAC0	3493.3	3641.3	4.3
BAC5	3509	3622.7	3.2
BAC10	3464.2	3624.5	4.6
BAC15	3504	3675.7	4.9
BAC20	3377.5	3547	5

From table 4.6, the percentage of water absorption was calculated as follows. It absorbs water.

WA percent = [ws-wd]/wd x 100 %

Where Ws is the weight of the dried specimens immersed in water for 24 hours, and Wd is the weight of the specimens that were dried before the absorption test.

4. Discussion

First, samples of bagasse ash were taken from the sugar refinery in Arjo Didessa and their chemical characteristics were studied. The bagasse ash was then processed to a consistency that was close to typical Portland cement about 85 percent of the particles passing the 63µm test. Grounded bagasse ash was used in place of regular Portland cement and Portland pozzolana cement. The typical consistency and setting times of pastes containing regular Portland cement and bagasse ash at replacement levels ranging from 5 percent to 30 percent were examined. The compressive strength of mortars containing regular Portland cement and Portland pozzolana cement with bagasse ash replacements ranging from 5% to 30% was also investigated. For 35MPa concrete with a water-to-cement ratio of 0.55 and 350kg/m3 cement content, four different concrete mixes with bagasse ash replacing 0 percent, 5 percent, 15 percent, and 25 percent of the standard Portland cement were created. Then, both the fresh and hardened states of these combinations' characteristics were evaluated.

The results of the mortar work showed that up to 10 percent substitution of bagasse ash for regular Portland cement resulted in higher compressive strengths at all test ages, i.e., 3, 7, and 28 days, whereas 15 percent substitution of bagasse ash for cement in concrete resulted in a slightly lower compressive strength at 56 days. All of the blended concretes demonstrated a greater maximum penetration depth than the control concrete, and it was discovered that the water penetration depth rose as the bagasse ash level increased. As a result, it can be deduced that 10% cement replacement with bagasse ash produces concrete with equivalent properties, and higher replacement levels may be used with only a minor drop in performance.

5. Conclusion

This research was carried out to investigate sugarcane bagasse ash as a partial replacement for cement in concrete production. The following conclusions were derived from the experimental results of bagasse ash properties and concrete with BA.

- Compared to OPC, which has a density of 3.15g/cm2, bagasse ash has a low density (1.92g/cm3) and a greater surface area (Blaine surface area, 4371.6cm2/g);
- According to an investigation of SCBA's chemical makeup, silicon dioxide makes up the majority of bagasse ash (SiO2). This has a significant impact on the binding because it creates complexes with Tricalcium silicate and Dicalcium silicate, the main building blocks of cement, making it a substance with good binding qualities;
- According to ASTM C-618 criteria, the overall chemical composition of the BA under investigation in this study—SiO2, Al2O3, and Fe2O3 = 87.68 > 70 percent—attested to the pozzolanic nature of bagasse ash. The bagasse ash meets the requirements of this specification to be a Class N Pozzolan;
- In comparison to 0, 10, 15, and 20 percent replacement of BA at all curing days, it has been noted that the experimental result for the 5 percent replacement of bagasse ash concrete to OPC has an increase in the compressive strength of the concrete. The 21- and 28-day compressive strength values of concrete with 5% bagasse ash replacement increased in strength by approximately 8% and 6%, respectively. As a result, BA concrete outperformed regular cement concrete by up to 5% when compared to SBA. The compressive strength dropped once bagasse ash supplementation exceeded 5 percent.
- All concrete with bagasse ash has water absorption greater than the control except for the average water absorption for the concrete with 5 percent bagasse ash, which increases as the concrete's bagasse ash level does. Concrete with a 5% BA substitution of OPC is thus the best way to prevent water absorption.
- Finally, the results of this experiment have obscured the fact that up to 5% of cement could be successfully replaced with BA. High concrete characteristics are achieved as compared to the control concrete after this replacement. Higher replacement percentages may be used as well, albeit the concrete's performance may be slightly compromised.

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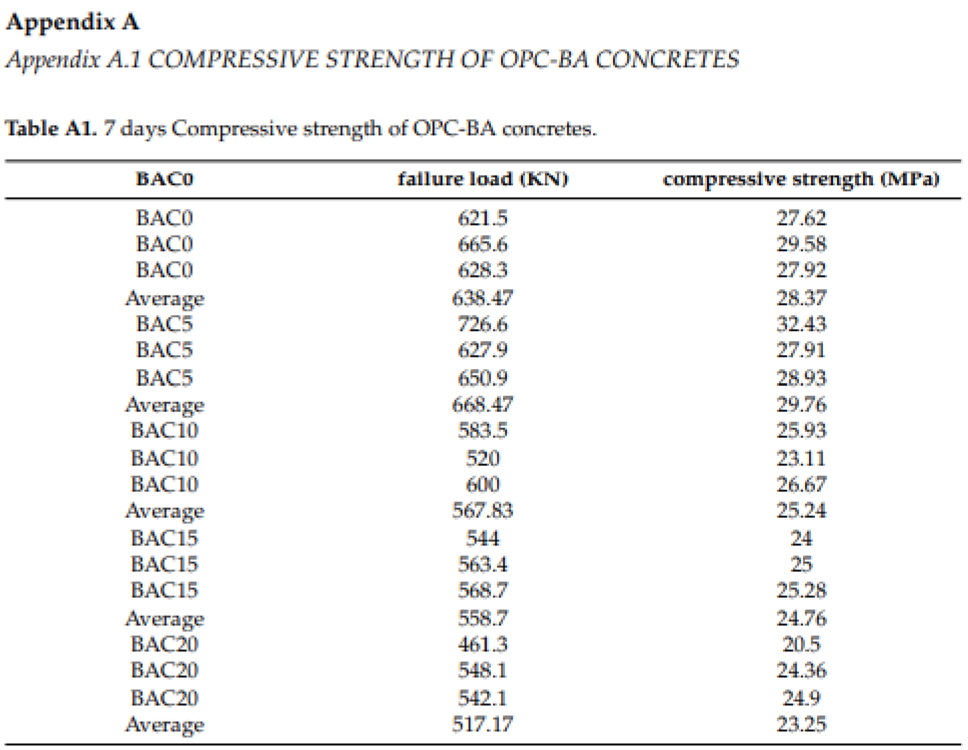
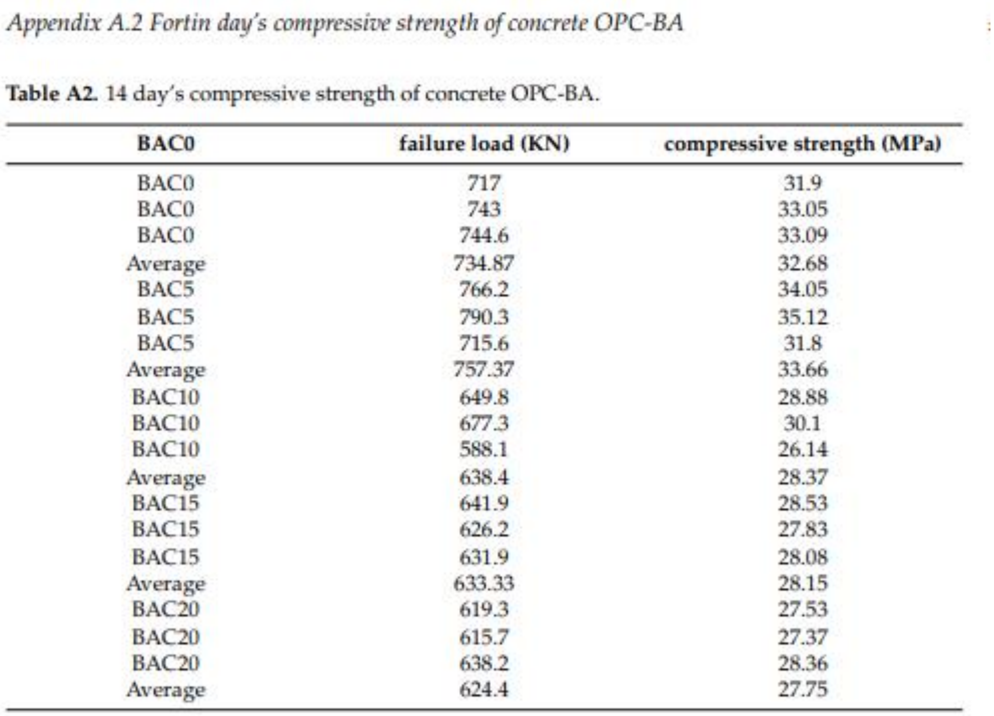


Appendix A

Appendix A.1 COMPRESSIVE STRENGTH OF OPC-BA CONCRETES

Table A1. 7 days Compressive strength of OPC-BA concretes.

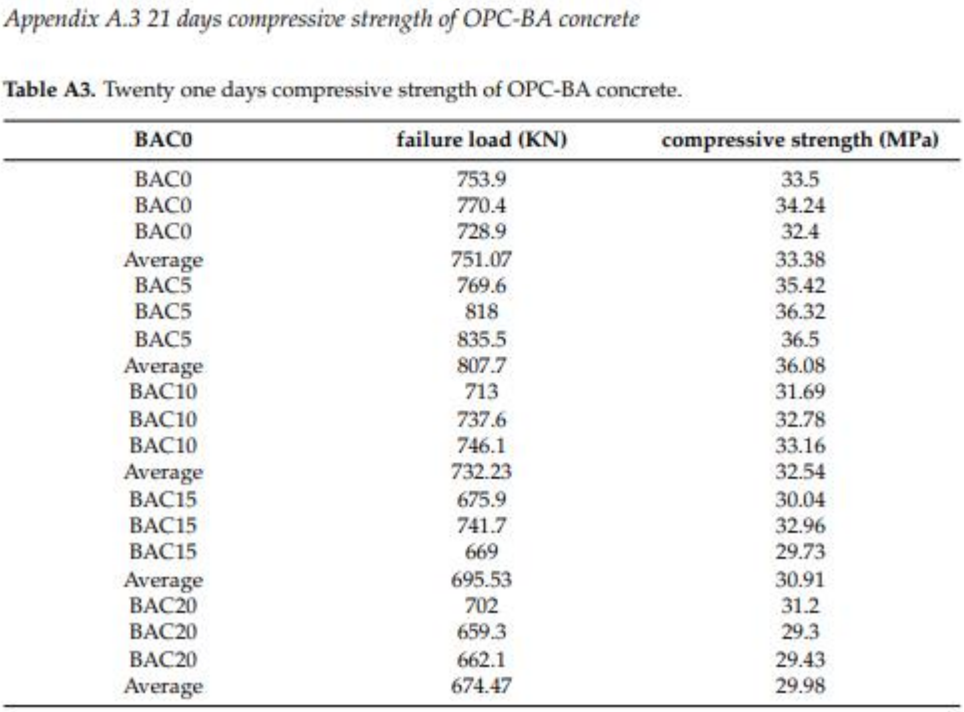
BAC0	failure load (KN)	compressive strength (MPa)
BAC0	621.5	27.62
BAC0	665.6	29.58
BAC0	628.3	27.92
Average	638.47	28.37
BAC5	726.6	32.43
BAC5	627.9	27.91
BAC5	650.9	28.93
Average	668.47	29.76
BAC10	583.5	25.93
BAC10	520	23.11
BAC10	600	26.67
Average	567.83	25.24
BAC15	544	24
BAC15	563.4	25
BAC15	568.7	25.28
Average	558.7	24.76
BAC20	461.3	20.5
BAC20	548.1	24.36
BAC20	542.1	24.9
Average	517.17	23.25



Appendix A.2 Fortin day's compressive strength of concrete OPC-BA

Table A2. 14 day's compressive strength of concrete OPC-BA.

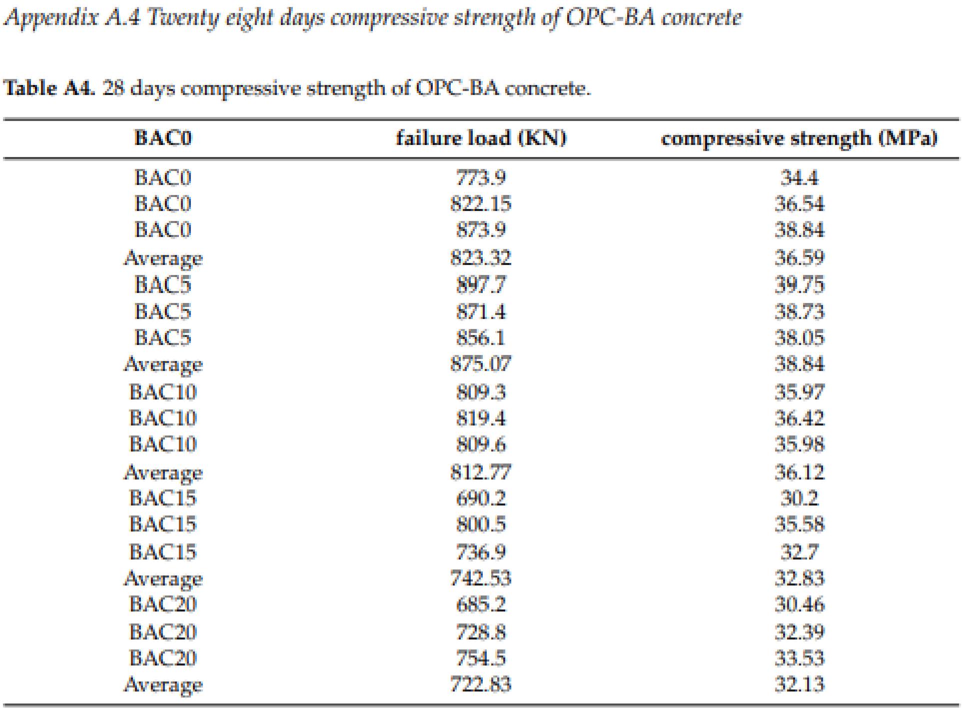
BAC0	failure load (KN)	compressive strength (MPa)
BAC0	717	31.9
BAC0	743	33.05
BAC0	744.6	33.09
Average	734.87	32.68
BAC5	766.2	34.05
BAC5	790.3	35.12
BAC5	715.6	31.8
Average	757.37	33.66
BAC10	649.8	28.88
BAC10	677.3	30.1
BAC10	588.1	26.14
Average	638.4	28.37
BAC15	641.9	28.53
BAC15	626.2	27.83
BAC15	631.9	28.08
Average	633.33	28.15
BAC20	619.3	27.53
BAC20	615.7	27.37
BAC20	638.2	28.36
Average	624.4	27.75



Appendix A.3 21 days compressive strength of OPC-BA concrete

Table A3. Twenty one days compressive strength of OPC-BA concrete.

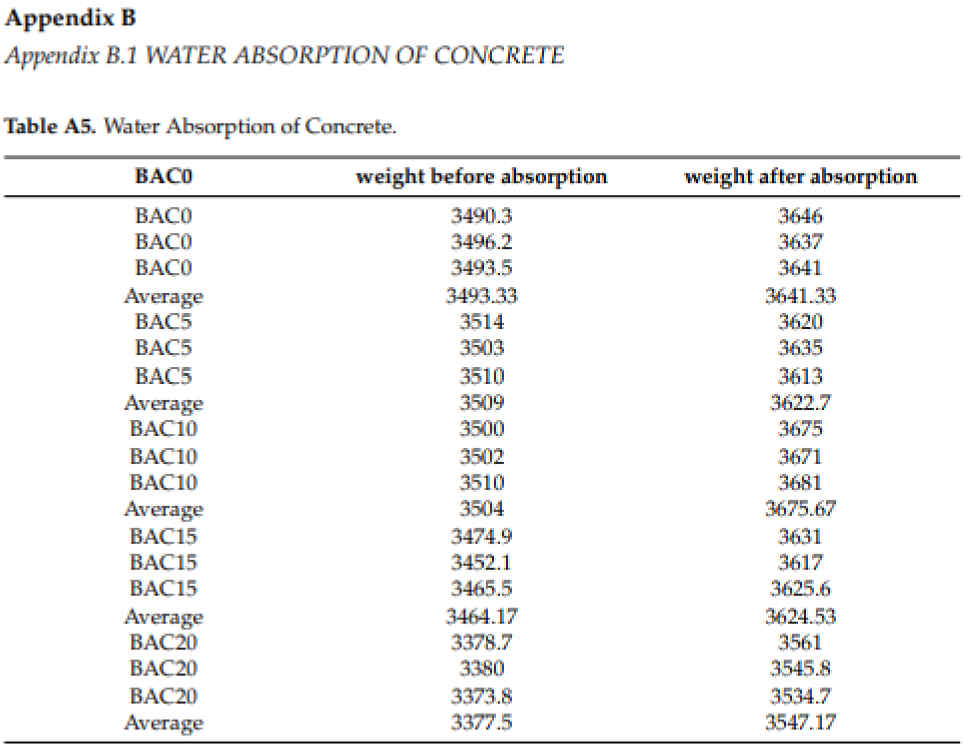
BAC0	failure load (KN)	compressive strength (MPa)
BAC0	753.9	33.5
BAC0	770.4	34.24
BAC0	728.9	32.4
Average	751.07	33.38
BAC5	769.6	35.42
BAC5	818	36.32
BAC5	835.5	36.5
Average	807.7	36.08
BAC10	713	31.69
BAC10	737.6	32.78
BAC10	746.1	33.16
Average	732.23	32.54
BAC15	675.9	30.04
BAC15	741.7	32.96
BAC15	669	29.73
Average	695.53	30.91
BAC20	702	31.2
BAC20	659.3	29.3
BAC20	662.1	29.43
Average	674.47	29.98



Appendix A.4 Twenty eight days compressive strength of OPC-BA concrete

Table A4. 28 days compressive strength of OPC-BA concrete.

BAC0	failure load (KN)	compressive strength (MPa)
BAC0	773.9	34.4
BAC0	822.15	36.54
BAC0	873.9	38.84
Average	823.32	36.59
BAC5	897.7	39.75
BAC5	871.4	38.73
BAC5	856.1	38.05
Average	875.07	38.84
BAC10	809.3	35.97
BAC10	819.4	36.42
BAC10	809.6	35.98
Average	812.77	36.12
BAC15	690.2	30.2
BAC15	800.5	35.58
BAC15	736.9	32.7
Average	742.53	32.83
BAC20	685.2	30.46
BAC20	728.8	32.39
BAC20	754.5	33.53
Average	722.83	32.13



Appendix B

Appendix B.1 WATER ABSORPTION OF CONCRETE

Table A5. Water Absorption of Concrete.

BAC0	weight before absorption	weight after absorption
BAC0	3490.3	3646
BAC0	3496.2	3637
BAC0	3493.5	3641
Average	3493.33	3641.33
BAC5	3514	3620
BAC5	3503	3635
BAC5	3510	3613
Average	3509	3622.7
BAC10	3500	3675
BAC10	3502	3671
BAC10	3510	3681
Average	3504	3675.67
BAC15	3474.9	3631
BAC15	3452.1	3617
BAC15	3465.5	3625.6
Average	3464.17	3624.53
BAC20	3378.7	3561
BAC20	3380	3545.8
BAC20	3373.8	3534.7
Average	3377.5	3547.17

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