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Enhancing Concrete Properties with Banana Stem Juice Additive: A Study on Workability and Compressive Strength

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***Abstract* - Additives are integral components of modern concrete mixing materials. This study aimed to evaluate the workability and compressive strength of concrete incorporating banana stem juice as a natural additive (BSJA). A laboratory experiment was conducted to assess the impact of BSJA on concrete properties. Concrete mixtures with a ratio of 1:2:4 were prepared both with and without BSJA. A total of 36 cube specimens were created with varying percentages of banana stem juice, and their compressive strengths were measured. The results indicated that the inclusion of banana stem juice affected the concrete properties. On the 21st day, the compressive strength of the concrete without BSJA was 27.67 N/mm², compared to 29.67 N/mm² for 5% BSJA, 16.33 N/mm² for 10% BSJA, and 8.00 N/mm² for 15% BSJA. The slump values recorded were 15 mm for 0% BSJA, 20 mm for 5% BSJA, 45 mm for 10% BSJA, and 65 mm for 15% BSJA. The average compressive strengths of concrete specimens with 5% BSJA at 14 days (23.3 N/mm²) and 21 days (29.2 N/mm²) were higher than those of specimens without BSJA. Over the 14 and 21-day periods, specimens with BSJA consistently showed higher compressive strengths compared to those without. These results suggest that 5% BSJA enhances the compressive strength properties of concrete.**
***Keywords:* Concrete, Banana Stem Juice (BSJA), Compressive Strength, Workability, Additives**

I. INTRODUCTION

Additives are integral components of modern concrete mixing materials [4] used to adjust concrete properties. The final products of these additives are environmentally friendly and contribute to reducing atmospheric carbon emissions [5]. Cadere *et al.,* investigated the engineering properties of concrete with polystyrene and observed improvements in the workability of fresh concrete and decreased density, making polystyrene suitable for producing lightweight concrete. Sarhya *et al.,* [15] extracted water hyacinth and used it as a bio-additive in cement and concrete. Duran *et al.,* [6] also highlighted that additives are crucial in modern concrete mixing materials. Optimization studies have focused on achieving desired workability without compromising mechanical strength [7]. While chemical additives improve concrete properties, banana stem juice additive (BSJA) reduces the need for chemical additives, aiding in economic improvement and reducing environmental pollution. Several researchers [17] have examined banana stem juice or chemical additives to assess their performance in enhancing workability. Ali [4] noted that using banana stem juice as a natural additive in concrete is an emerging research area. BSJA is beneficial for reducing environmental damage and improving concrete durability [19].

Adesanya *et al.,* [2] used banana stem juice in concrete production to mitigate the environmental impact of traditional chemical additives. Compressive strength and slump tests have been conducted to evaluate the additive's influence on durability and performance [14], [16]. Banana stem juice, viscosity, and fiber content enhance the flow and cohesiveness of the mix [13]. This study aimed to determine the workability and compressive strength of concrete incorporating banana stem juice as a natural additive.

II. LITERATURE REVIEW

A. BSJ Composition, Properties, and Environmental Impact

The use of banana stem juice (BSJ) in concrete helps reduce waste generation and lowers the carbon footprint [11], [20]. BSJ has the potential to modify concrete properties, enhance performance, and improve compressive strength [13]. The minimum compressive strength required for concrete used in building foundations is typically 2,500 psi (17.2 MPa), while for high-rise buildings, it can be as high as 8,000 psi (55.2 MPa). The workability of concrete is defined as the property of freshly mixed concrete that determines its ease of mixing, placement, consolidation, and finishing [1]. Several researchers (Ahmed *et al.,* [3]; Kumari and Sandeep [9]) have tested how different levels of banana stem juice affect the compressive strength of concrete. Dosage optimization studies were conducted to achieve the desired compressive strength enhancement without compromising other properties [7]. As an eco-friendly material, BSJ contributes to waste reduction and has the potential to lower the carbon footprint [11], [20].

Singh *et al.,* [17] and Tan *et al.,* [18] compared the effects of BSJ as an additive on compressive strength. BSJ has shown potential in influencing concrete properties [13]. Its pH level and chemical composition can affect compatibility with other materials [12]. BSJ is a promising sustainable additive that contributes to waste reduction and environmental preservation [11] and supports sustainable agricultural practices [7]. The compatibility and dispersion mechanisms of BSJ can significantly impact its performance [20]. Additionally, BSJ has varying and multifaceted properties suitable for innovative and sustainable applications [10], [17].

III. METHODOLOGY

A. Materials

1. Cement: Different cement brands exhibit varying strength development characteristics and rheological behavior due to differences in compound composition and fineness. Consequently, this study utilized Ordinary Portland Cement (OPC) class 32.5 produced in Ghana for the experiment.

Fig. 1 GHACEM super cool cement

2. Fine Aggregates: The fine aggregate used in the experiment was clean, sharp river sand sourced from the Kakum River in the Central Region. It was free from silt, loam, dirt, and any organic or chemical matter.

3. Coarse Aggregates: The crushed granite stones, with a size of 14 mm, were obtained from a quarry site near Cape Coast.

4. Water: The water used for the entire experiment was fresh, colorless, odorless, and tasteless potable water supplied by the Ghana Water Company Limited (GWCL).

B. Methods

Extraction of Banana Stem Juice Additive (BSJA) - Banana stem juice was obtained from banana stems after the bananas were harvested. The stems were cut into pieces and then pounded in a mortar with a pestle. After pounding, the paste was squeezed to extract the juice (see Figs. 2-4) and filtered for use in the experiment.

Fig. 2 Cutting of banana stem

Fig. 3 Cutting of banana stem into pieces

Fig. 4 Pounding of banana stem

Fig. 5 Squeezing of banana stem

Weight and compressive strength tests were conducted on concrete specimens with different percentages (0, 5, 10, and 15) of banana stem juice additive (BSJA) to determine their strength. A total of 36 cubes, each with dimensions of 100 mm × 100 mm × 100 mm, were used for these tests. Concrete mixtures were cured for 7 days, 14 days, and 21 days at the Construction Technology and Management Laboratory, Cape Coast Technical University.

C. Specimen Preparation

1. Mix Ratio: The mix ratio used for the entire study was 1:2:4 (one-part cement, two parts sand, and four parts stones) with a water-cement ratio of 0.6, and BSJA percentages of 0%, 0.5%, 10%, and 15%, respectively.

2. Specimen Details: A total of 36 cubes, each with dimensions of 100 mm × 100 mm × 100 mm, were produced under laboratory conditions for weight and compressive strength testing. Table I provides details of the materials used and the number of specimens produced.

TABLE I MATERIALS USED FOR THE EXPERIMENT

Type of Specimen	Number of Specimens	Volume of Concrete (M^3)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (L)	BSJA (L)
0%	9	0.036	1.54	3.80	6.16	924	0
5%	9	0.036	1.54	3.80	6.16	878	46
10%	9	0.036	1.54	3.80	6.16	832	92
15%	9	0.036	1.54	3.80	6.16	786	138
Total	36	0.144	6.16	15.2	24.64	3420	276

3. Mixing: Mechanical mixing of concrete was employed. The following procedure was followed.

1. The concrete materials - cement, sand, and coarse aggregate - were batched by weight. The water and BSJA were measured in liters using a cylinder.
2. The coarse aggregates were placed in the mixer first, followed by cement, sand, water, and the specified percentage of banana stem juice.
3. The materials were allowed to mix in the concrete mixing pan for about 3 minutes.
4. After 3 minutes, a uniform mix was obtained.

4. Workability Test (Slump Test): Slump cone tests were conducted to compare the workability of concrete with 0% banana stem juice to concrete with banana stem juice at 5%, 10%, and 15%. The slump test was performed according to BS 1881-102 immediately after the concrete was discharged from the mixer. Fig. 6 illustrates the slump test conducted at the Civil Engineering Materials Laboratory, Cape Coast Technical University.

Fig. 6 Conducting a slump test

5. Casting: For casting, a standard steel mold with dimensions of 100 mm × 100 mm × 100 mm was used for the cubes (specimens). The interior of the mold was first lubricated with mold oil to prevent the cubes from sticking and to provide a smooth surface for easy removal of the mold after casting. Fig. 7 shows the casting of the specimens in the laboratory.

Fig. 7 Casting of specimen

6. Curing: Adequate curing of cubes is essential to ensure sufficient hydration of the cement and to gain strength. The cubes (specimens) were demolded the day after casting and immersed in water using a curing tank for 7 days, 14 days, and 21 days, respectively. Fig. 8 shows the specimens undergoing the curing process.

Fig. 8 Curing of specimen

D. Specimen Testing

1. Weight of Specimen: The weight of the specimens was determined using a scale at the Civil Engineering Department, Cape Coast Technical University. The weighing of the cubes is shown in Fig. 9.

Fig. 9 Weighing of specimen

2. Compressive Strength Test of Specimen: The cube specimens were subjected to a compressive strength test at 7, 14, and 21 days of curing using a compressive testing machine at the Civil Engineering Laboratory, Cape Coast Technical University. The crushing was performed in the laboratory. Fig. 10 shows the compressive strength test being conducted. The specimens were loaded until failure occurred. The compressive strength was calculated using the following formula:

Compressive strength = failure load (N) / Load acting area (mm^2) (1)

Fig. 10 Specimen under compressive strength test

IV. FINDINGS AND DISCUSSION

A. Workability Performance of Concrete Incorporated with BSJA

Table II presents the results of the slump test conducted for concrete specimens with 0%, 5%, 10%, and 15% BSJA. The slump values were 15 mm for 0% BSJA, 20 mm for 5% BSJA, 45 mm for 10% BSJA, and 65 mm for 15% BSJA.

TABLE II SLUMP TEST RESULTS

% BSJA Replacement	Slump (mm)		
	Recorded	Diff.	% Diff
0%	15	-	-
5%	20	5	33%
10%	45	30	200%
15%	65	50	333%

B. Weight of Concrete Specimen Incorporated with BSJA

The weights of the concrete specimens were measured on the 7th, 14th, and 21st days to assess the effect of BSJA on the age of the concrete. The corresponding observations are presented in the following sections.

C. Weights of the Specimen on the 7th Day

The observations on the weights of concrete specimens incorporating BSJA at 7 days are shown in Table III. It is observed that the weight of the concrete varied with different percentages of BSJA, with the following measurements recorded at 7 days: 2.43 kg for 0% BSJA, 2.39 kg for 5% BSJA, 2.37 kg for 10% BSJA, and 2.36 kg for 15% BSJA. The table below shows the comparison of the average weight for concrete with 0%, 5%, 10%, and 15% BSJA. It indicates that the average weight of concrete with 0% BSJA is higher than that of concrete with 5% BSJA, and the average weight of concrete with 10% BSJA is higher than that of 15% BSJA.

TABLE III WEIGHTS OF SPECIMEN ON THE 7TH DAY

% BSJA Replacement	Weight (kg)					
	S1	S2	S3	Average	Diff.	% Diff.
0%	2.44	2.45	2.40	2.43	-	-
5%	2.38	2.41	2.39	2.39	-0.04	-2%
10%	2.37	2.40	2.34	2.37	-0.06	-2%
15%	2.36	2.38	2.33	2.36	-0.07	-3%

D. Weights of Specimen at the Age of 14th Day

The observations on the weights of concrete specimens incorporating BSJA at 14 days are shown in Table IV. It was observed that the weight of the concrete varied with different percentages of BSJA, with the following measurements recorded at 14 days: 2.39 kg for 0% BSJA, 2.39 kg for 5% BSJA, 2.37 kg for 10% BSJA, and 2.38 kg for 15% BSJA. Table IV shows the comparison of the average weight for concrete with 0%, 5%, 10%, and 15% BSJA. It indicates that the average weight of concrete with 0% BSJA is higher than that with 5% BSJA, and the average weight of concrete with 10% BSJA is lower than that with 15% BSJA.

TABLE IV WEIGHTS OF SPECIMEN AT 14TH DAY

% BSJA Replacement	Weight (kg)					
	S1	S2	S3	Average	Diff.	% Diff.
0%	2.36	2.44	2.38	2.39	-	-
5%	2.42	2.38	2.38	2.39	0.00	0%
10%	2.34	2.39	2.38	2.37	-0.02	-1%
15%	2.36	2.46	2.32	2.38	-0.01	0%

E. Weights of specimen at age 21st Day

The observations on weights of BSJA incorporated concrete specimen at age (21st day) are shown by Table V. From Table V, it was observed that the weight of concrete from the same mix increased at the various percentages, and the weight was recorded based on the given ages. 2.45kg for 7th day at 0% BSJA, 2.36kg for 7th day at 5% BSJA, 2.29kg for 7th day at 10% BSJA and 2.33kg for 7th day at 15% BSJA. From table 4.4 below, shows the comparison of average weight between 0%, 5%, 10% and 15% BSJA concrete. This shows that the average weight of concrete with 0% BSJA is higher than that of concrete with BSJA of 5%, the average weight of concrete with 10% BSJA is lower than that of 15% BSJA.

TABLE V WEIGHTS OF SPECIMEN AT 21ST TH DAY

% BSJA Replacement	Weight (kg)					
	S1	S2	S3	Average	Diff.	% Diff.
0%	2.39	2.42	2.55	2.45	-	-
5%	2.38	2.36	2.35	2.36	-0.09	-4%
10%	2.27	2.31	2.28	2.29	-0.16	-7%
15%	2.33	2.32	2.34	2.33	-0.12	-5%

F. Compressive Strengths of Concrete Specimen Incorporated with BSJA

The compressive strengths of concrete specimens were determined at 7, 14, and 21 days to assess the effect of BSJA on the age of the concrete. The corresponding observations are presented in the following sections.

G. Compressive Strengths of Specimen at Age 7th Day

The observation on the compressive strength of concrete specimens incorporating BSJA at 7 days is presented in Table VI. It was revealed that the average compressive strength of concrete increased with 5% BSJA, from 22.0 N/mm² at 0% BSJA to 21.7 N/mm² at 5% BSJA. Thereafter, it decreased and then increased, from 6.3 N/mm² at 10% BSJA to 6.5 N/mm² at 15% BSJA.

The results show that the average compressive strength of concrete with 0% BSJA is higher than that with 5% BSJA, and the average compressive strength of concrete with 10% BSJA is lower than that with 15% BSJA.

TABLE VI COMPRESSIVE STRENGTH OF SPECIMEN AT 7TH DAY

% BSJA Replacement	Compressive Strength (N/mm2)					
	S1	S2	S3	Average	Diff.	% Diff.
0%	23.0	21.0	22.0	22.0	-	-
5%	23.0	21.0	21.0	21.7	-0.3	-1%
10%	6.5	6.5	6.0	6.3	-15.7	-71%
15%	6.5	7.0	6.0	6.5	-15.5	-70%

H. Compressive Strengths of Specimen at Age Fourteen (14th Day)

Table VII indicates that the compressive strength of concrete with 5% BSJA increased from 20.5 N/mm² at 0% BSJA on the 14th day to 23.3 N/mm² at 5% BSJA on the 14th day. It then decreased to 6.7 N/mm² at 10% BSJA and increased again to 7.3 N/mm² at 15% BSJA on the 14th day.

This shows that the average compressive strength of concrete with 0% BSJA is lower than that with 5% BSJA, and the average compressive strength of concrete with 10% BSJA is lower than that with 15% BSJA.

TABLE VII COMPRESSIVE STRENGTH OF SPECIMEN AT AGE 14TH DAY

% BSJA Replacement	Compressive Strength (N/mm2)					
	S1	S2	S3	Average	Diff.	% Diff.
0%	19.5	22.0	20.0	20.5	-	-
5%	25.0	22.0	23.0	23.3	2.8	14%
10%	7.5	7.5	5.0	6.7	-13.8	-67%
15%	6.5	7.0	8.5	7.3	-13.2	-64%

I. Compressive Strengths of Specimen at Age Twenty-One (21st Day)

From Table VIII, it can be observed that the compressive strength of concrete with 5% BSJA was higher than that with 0% BSJA. The average compressive strength of concrete with 15% BSJA was the lowest.

TABLE VIII COMPRESSIVE STRENGTH OF SPECIMEN AT 21ST DAY

% BSJA Replacement	Compressive Strength (N/mm2)					
	S1	S2	S3	Average	Diff.	% Diff.
0%	27.0	29.5	26.5	27.7	-	-
5%	30.0	28.0	29.5	29.2	1.5	5%
10%	29.0	10.0	10.0	16.3	-11.4	-41%
15%	8.0	9.0	7.0	8.0	-19.7	-71%

IV. CONCLUSION

The study sought to determine the workability and compressive strength of concrete incorporating banana stem juice as a natural additive (BSJA). Based on the results of the various tests performed, the incorporation of BSJA into the concrete increased the slump and reduced the weight at 5% BSJA. The average compressive strength was higher with 5% BSJA compared to 0%. However, the strength decreased significantly with additions beyond 5% BSJA. The results and the low cost of the additive suggest that BSJA is a cost-effective alternative to chemical additives for concrete. Using BSJA can reduce the need for imported chemical additives, which are costly, and it can help boost the national economy by decreasing reliance on foreign currencies for imports.

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