ISSN (E): 2959-3921
(P): 2959-393X
DOI: *https://doi.org/10.59122/EIJET1015*
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 4, Issue 1, 2026

Performance Evaluation of Solanum Incanum Juice as a Sustainable Bio-Admixture for Concrete

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Abstract

Cement production harms the environment and often relies on chemically produced admixtures imported from developing countries like Ethiopia. This reliance has encouraged efforts to find alternatives to conventional cement and concrete technologies. The use of Solanum incanum (əməbʷay juice (EJ)) is a potential additive to Portland cement. EJ contains compounds that demonstrate similar properties to currently produced water-reducing and retarding chemical admixtures. A C25/30 mix was created according to ACI 211.4R-08 and was treated with EJ at percentages of 0.5%, 1%, 1.5%, 2%, 3%, 4%, and 5% of the weight of the cement. Both the partial water replacement and additive methods were used. The fresh properties of the concretes were tested according to ASTM C143 for slump, ASTM C191 for setting time, and the hardened properties were tested according to BS EN 12390-3 for compressive strength. Samples of 150 mm cubes were cured for 3, 7, 14, and 28 days before testing. The physicochemical analysis of EJ indicated a pH of 4.2. The main components of EJ were found to consist of % of fatty acids, which ranged from 26.64% to 50.41% (on a dry basis). This crude EJ significantly enhanced the workability of concrete, up to 863.6% increase in slump value at 5% dosage by weight of cement. The effect of EJ on the cement showed retarding effect on the setting of cement. The results of this study also indicated that higher dosages (3%–5%) of EJ accelerate the setting time of cement by up to 57.14% than that of control sample. Based on the experimental results, the work identified the optimal percentage of EJ to be used as a bio-admixture for concrete under partial water replacement conditions. The result indicated that 2% of EJ yielded a 28-day compressive strength of 28.6 MPa, which corresponded to an increase of 3.36% over that of the reference specimen (M40 mix) and was almost comparable to that of Sika Plastiment BV40 (commercial admixture). Higher dosages (3%–5%) of EJ caused a decrease in the strength of concrete and even led to the

Received: *April 26, 2026;* ***Revised***: *May 6, 2026;* ***Accepted:*** *June 1, 2026;* ***Published:*** *June 15, 2026*
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disintegration of specimens. In the long-term perspective, the study revealed that the use of EJ is a more economically viable option than the usage of imported admixtures for a period of ten years within the Ethiopian market. The findings revealed that EJ has great potential as a sustainable, cost-effective, and locally available bio-admixture for use in concrete.

Keywords: Bioadmixture, Solanum incanum, ʾəməbʷay juice, Sustainable concrete, Workability, Setting time, Compressive strength

I. INTRODUCTION

Concrete is the backbone of global infrastructure; however, its production, especially that of ordinary Portland cement (OPC), raises significant environmental concerns, contributing approximately 7-8% of global CO_2 emissions. [1][2]. To mitigate this impact, the construction sector is increasingly exploring sustainable materials, such as bio-based admixtures derived from renewable resources. [3][4]. Admixtures, which are substances added to concrete before or during mixing, improve properties such as workability, setting time, and mechanical strength. [5][6][7]. While chemical admixtures, such as retarders and water reducers, dominate the market, their production and use entail environmental and economic costs, especially in developing countries such as Ethiopia, which import most of these products. [8][9].

In contrast, bio-admixtures extracted from plants, agricultural by-products, and organic materials are biodegradable and cost-effective alternatives. Plant-derived polymers like mucilage and saponins can function as natural retarders and water reducers by modifying cement hydration and matrix microstructure[3][4][10]. Notable examples include cassava starch, sugarcane juice, cactus extract, and water hyacinth, all shown to influence setting time and strength profiles of cementitious materials [11][9][11].

Solanum incanum, commonly known in Ethiopia as *ʾəməbʷay (Fig 1)*, is a native plant with a high yield of bioactive juices rich in polysaccharides, glycosides, alkaloids, and saponins.[12] [13]. Although traditionally used in medicine, its application as a concrete admixture has not been explored. Given its organic composition and abundance, ʾəməbʷay juice (EJ) is a promising candidate for enhancing the properties of fresh and hardened concrete while reducing the reliance on synthetic chemicals.

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Fig. 1. ʾəməbʷay berry

This study aimed to evaluate the impact of EJ on the workability, setting time, and compressive strength of concrete. It also compares EJ's effectiveness to that of commercial admixtures and assesses its economic viability. The broader goal is to provide a scientific basis for utilizing indigenous bio-resources in sustainable construction, thereby supporting local economies and environmental stewardship [6][10].

II. MATERIALS AND METHODS

This study examined Ordinary Portland cement manufactured by the Messebo Cement Factory. The fineness of the cement was measured at 3442.7 cm^3/g, which meets the factory's established specifications and a normal consistency of 26% by weight of the cement, with initial and final setting times recorded at 115 min and 220 min, respectively. Natural sand was obtained from Werkamba, situated near Abi-Adi and approximately 45 km from Mekelle City, whereas the coarse aggregates were sourced from Aregit Ketema, located approximately 10 km from Mekelle City. All necessary tests on the aggregates were performed at the Construction Materials Laboratory of Mekelle University. A comprehensive summary of the properties of both fine and coarse aggregates is provided in Table I. Throughout the study, potable water was used to wash the fine aggregates as well as for mixing and curing the concrete. The study incorporated Plastiment BV 40, manufactured by Sika Abyssinia Chemical Manufacturing PLC, as a commercial water-reducing and retardant admixture. A detailed summary of these properties is presented in Table II.

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TABLE I

PROPERTIES OF THE FINE AND COARSE AGGREGATES

S. No.	Property	Fine aggregates	Coarse aggregates
1.	Fineness Modulus	2.6	-
2.	Specific gravity	2.56	2.26
3.	Water absorption (%)	0.17	0.45
4.	Moisture content (%)	2.04	0.18
5.	Silt content (%)	3.8	-
6.	Unit weight ($\frac{Kg}{m^3}$)	-	1556

TABLE II

PROPERTIES OF SIKA PLASTIMENT BV40 WATER-REDUCING AND RETARDING ADMIXTURE

S. No.	Parameter	Sika Plastiment BV40
1	Appearance	Liquid
2	Color	Brown
3	Density	$1.9 \pm 0.03 \frac{Kg}{l}$
4	Recommended dosage	0.5-1.2%

A. Plant Material Collection

The plant (*Solanum incanum*) was collected from Mekelle City, Tigray Region, Northern Ethiopia, within the Endayesus Branch area of Mekelle University. The study site is located at geographical coordinates 13°28′50.6″N, 39°29′08.1″E (13.480736°N, 39.485594°E), representing an urban institutional environment within the urban landscape of Mekelle. The area is characterized by a semi-arid highland climate and developed residential and institutional land use. The location was verified using Google Maps for spatial accuracy.

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The ʾəməbʷay used in this study was sourced from the main campus of Mekelle University. The berries were then extensively cleaned and washed to remove contaminants. After drying, the samples were cut, and the juice was prepared using a hand tool squeezer and stored in plastic bottles.

Fig.2. Solanum incanum (Locally Known as ʾəməbʷay) Juice

The physicochemical properties of ʾəməbʷay juice were assessed by analyzing random samples. The pH of the juice was determined using a pH meter. To evaluate the fatty acid content, a 10 ml sample of ʾəməbʷay juice was titrated with 0.5 M NaOH using phenolphthalein as the indicator. The findings regarding the physicochemical and acidic properties of ʾəməbʷay juice are explained in detail in Tables III and IV.

TABLE III

PHYSICOCHEMICAL ANALYSIS OF ʾƏMƏBʷAY JUICE

S. No.	State	Color	pH amount	Specific gravity
	liquid	Dark gray	4.2	1.01

TABLE IV

ACID CONTENT

Acid type	Oleic Acid	Lauric Acid	Ricinoleic acid	Palmitic acid
% mass	16.92	12.0	17.88	15.36

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B. Specimen Preparation

Following the completion of the tests on the concrete ingredients, a concrete mixture was developed with a strength grade of 25/30 MPa. The mix was designed according to the standards outlined in ACI 211.4R-08 [14]. The specific proportions of the mixtures are listed in **Table V**. To investigate the effects on setting time, workability, and compressive strength, ʾəməbʷay juice was incorporated into the mixture by substituting 0.5, 1, 1.5, 2, 3, and 5% of the cement weight, with corresponding adjustments made to the water content.

Studies have indicated that admixtures are typically added to cement mixes at levels below 5% of the cement weight. Nonetheless, most admixtures are used at rates below 2%, with a common range of 0.3%-1.5% [15][16]. After noting the beneficial effect of partial replacement, the influence of ʾəməbʷay juice on compressive strength was evaluated without decreasing the water content. Additionally, concrete samples containing Sika Plastiment BV 40 were produced for comparative analysis with dosages varying from 0.5% to 5%.

TABLE V

CONCRETE MIX-DESIGN RESULT

S. No.	Material	Quantity (Kg/m^3)
1.	Cement	337
2.	Water	181
3.	Fine aggregate	643
4.	Coarse aggregate	990
5.	w/c	0.54

C. Setting Time Test

As seen in **Fig. 2,** Vicat needles were used to assess the initial and final setting times of the cement paste samples. The samples incorporated different proportions of ʾəməbʷay juice and Sika Plastiment BV 40, specifically 0, 0.5, 1, 1.5, 2, 3, and 5%. Testing was performed according to the procedures specified in ASTM C-191.[17]. It is important to note that during the setting time assessments, a portion of the admixture was substituted with water.

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Fig. 2. Setting time test

C. Slump Test

The workability of fresh concrete containing different dosages (0, 0.5, 1, 1.5, 2, 3, and 5% by weight of cement) of ʾəməbʷay juice and Sika Plastiment BV40 was evaluated using a slump cone in accordance with ASTM C143[18]. In all mixtures, a portion of the mixing water was replaced with the respective admixture. To ensure statistical reliability and repeatability, the slump test was conducted in triplicate (n = 3) for each concrete mix. The reported results represent mean values, while standard deviations were calculated using Microsoft Excel to assess experimental variability and consistency of the fresh concrete properties.

D. Compressive Strength Test

Concrete specimens were prepared, cast, cured, and tested in accordance with ASTM C192 [19]. Cube specimens measuring 150 mm × 150 mm × 150 mm were cast and demolded after 24 hours before being cured in water until testing [20]. Compressive strength tests were performed at curing ages of 3, 7, 14, and 28 days for mixtures containing additional admixtures, while specimens prepared using partial replacement were tested at 3 and 28 days. To ensure statistical reliability and experimental validity, three specimens (n = 3) were tested for each concrete mix and curing age. The reported compressive strength values represent mean results, and standard deviations were calculated using Microsoft Excel to evaluate experimental variability and data consistency.

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E. Cost Comparison

Following the completion of the technical investigation, the costs of ʾəməbʷay juice and Sika Plastiment BV40 were compared. This involved gathering data on material, labor, and juice-squeezing tool costs from the years 2016-2017 E.C. Subsequently, the costs of ʾəməbʷay juice and Sika Plastiment BV40 were projected for a period of five and ten years, respectively, considering the inflation rate. Consequently, cash flow diagrams were generated. The inflation rate was calculated using the empirical formula below.

$$Inflation\ rate\ (f_n) = \frac{f_n - f_{n-1}}{f_{n-1}} \times 100\%,\ [21]\ldots\ldots\ldots\text{Eq-1}$$

Where, fn = Cost in succeeding year

f_{n-1}= Cost in the base period

The empirical formula provided below was used to calculate the future value of the cost of ʾəməbʷay juice and the chemical admixtures.

$$F_v = P_v(1+i)^n [18]\ldots\ldots\ldots[21].\ \text{Eq-2}$$

where: P_v= Present worth

i=annual interest rate

n=number of years

III. RESULTS AND DISCUSSIONS

The characteristics of both fresh and hardened concrete were evaluated by performing tests on the setting time, slump, and compressive strength.

A. Setting time test results

The setting time results confirmed that ʾəməbʷay and ʾəməbʷay juices acted as retardants. As seen in Fig. 3, the setting time of cement paste prepared with 0.5, 1, 1.5, and 2% ʾəməbʷay juice showed an additional 30, 80, 130, and 40 min delay over the reference concrete, respectively. However, at higher dosages (3 and 5%), the cement pastes set faster than the reference mix.

The reason for the delay in the setting time is the fatty acids found in the juice. Sathya (2014) revealed that palmitic and oleic acids delayed the setting time by hampering the evaporation of water molecules from the mixed paste. (Roar Myrdal (2007) reported that carboxylic acids

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containing greater than two carbon lengths (>C_2) retard the setting time of concrete [23]. As shown in **Table IV**, ʾəməbʷay juice contains 15.36% palmitic acid, 16.92% oleic acid, and other fatty acids with higher carbon lengths. The reason for the shortening of setting times at higher dosages is that when the concentration of fatty acids found in ʾəməbʷay juice increases, the fineness increases, and as the fineness increases, the setting time decreases. [24].

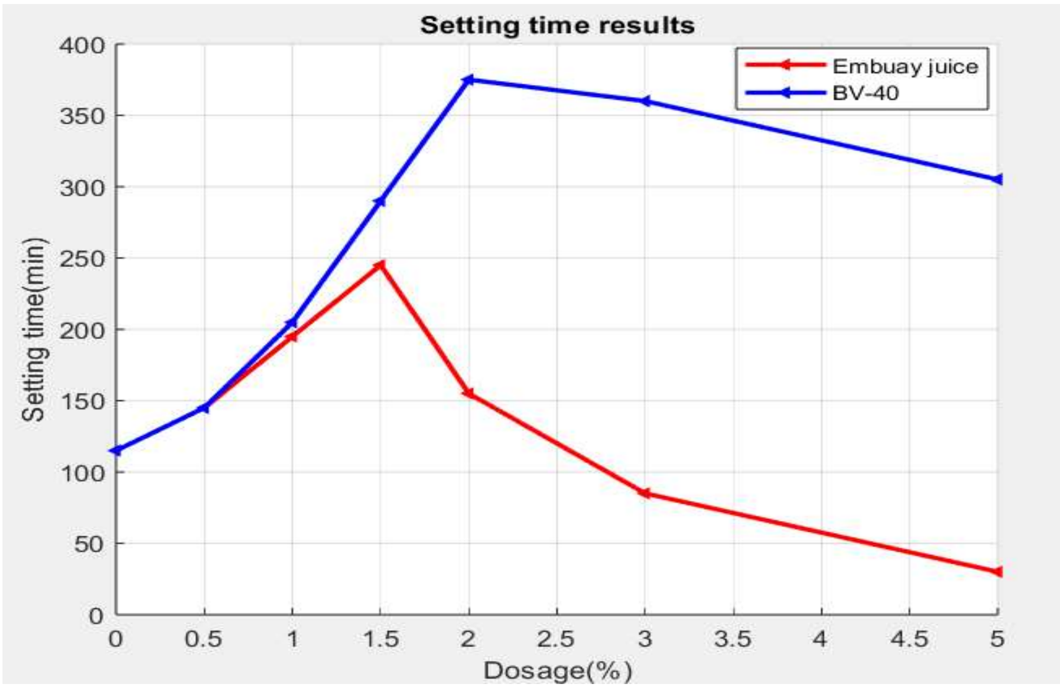

Fig. 3. Effect of ʾəməbʷay juice and Plastiment BV40 on setting time

The data are presented in Fig. 3, which indicates that the initial setting time of the mixture was extended by 30, 90, 175, 260, 245, and 190 min, respectively, when 0.5, 1, 1.5, 2, 3, and 5% of commercial Sika Plastiment BV 40 was substituted with cement pastes. In contrast, the reference concrete showed a 113% increase in setting time with 1.5% ʾəməbʷay juice replacement, while 2% commercial Sika Plastiment BV40 substitution led to a remarkable 326% increase in the initial setting time.

B. Slump Test Results

The workability performance of concrete containing ʾəməbʷay juice was evaluated by progressively increasing the dosage from 0.5% to 5%, and the results were compared with the reference concrete and Sika Plastiment BV40, as illustrated in Fig. 4. The results demonstrated a substantial increase in slump with increasing ʾəməbʷay juice dosage, indicating significant

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improvement in concrete workability. Relative to the control mixture, slump values increased by 87.47%, 231.2%, 516.8%, 632.3%, 724.9%, and 863.6% for concrete mixtures containing 0.5%, 1%, 1.5%, 2%, 3%, and 5% ʾəməbʷay juice, respectively. Values are presented as mean ± standard deviation ($n = 3$). Error bars represent ±1 SD.

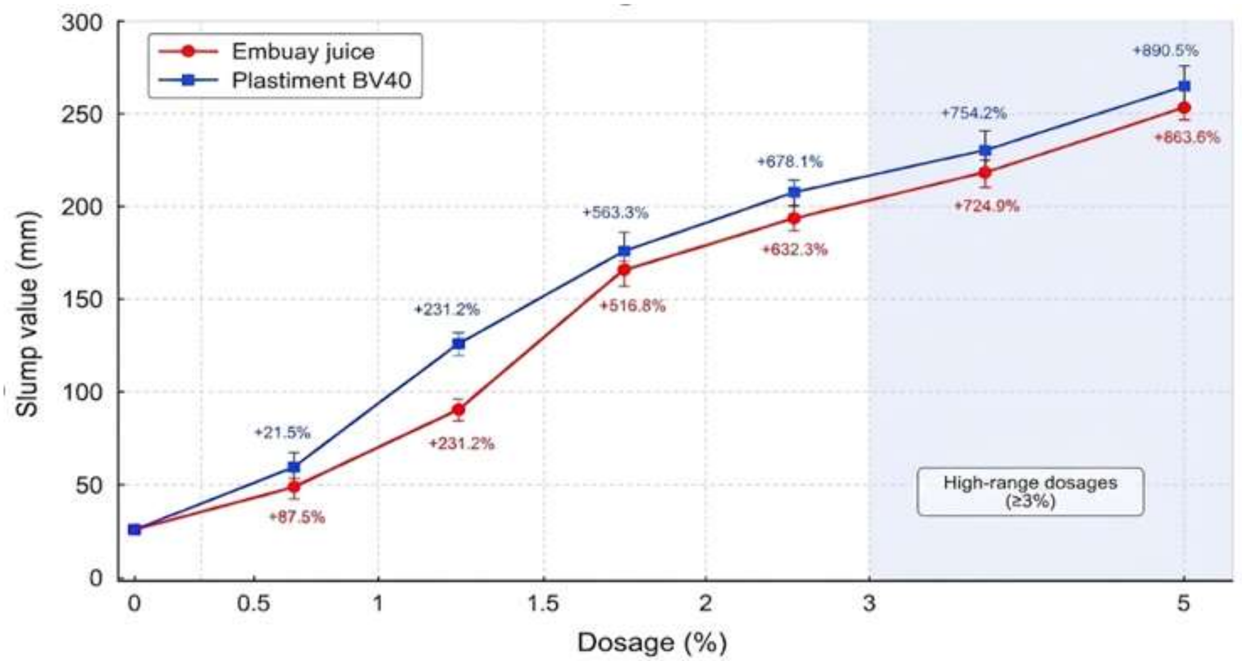

Fig. 4. Effect of Embuay juice and Plastiment BV40 on workability.

The remarkable increase in slump is attributed not only to physical dilution effects but also to chemical interactions within the cementitious matrix. The fatty acids identified in Table IV, particularly ricinoleic acid (17.88%), oleic acid (16.92%), and palmitic acid (15.36%), function as surface-active agents that adsorb onto cement particles and induce electrostatic repulsion between adjacent grains. This mechanism enhances deflocculation and promotes more uniform dispersion of cement particles, thereby reducing internal friction and improving the fluidity of the concrete mixture. In addition, the lubricating characteristics of ʾəməbʷay juice further contributed to the enhancement of workability.

Concrete mixtures containing ʾəməbʷay juice exhibited improved workability compared with the reference concrete; however, mixtures incorporating Sika Plastiment BV40 consistently produced slightly higher slump values at equivalent dosage levels. At a dosage of 1.5%, concrete containing Plastiment BV40 began to exhibit flow characteristics, indicating a stronger plasticizing effect.

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The highest slump values for both admixtures were observed at the 5% dosage level, where the Plastiment BV40 mixture showed approximately 3.10% higher slump than the corresponding ʾəməbʷay juice mixture.

This can be explained by the plasticizing characteristics of fatty acids, which adhere to the surfaces of cement particles and impart a negative charge. Consequently, this leads to particle repulsion, facilitating the deflocculation and dispersion of cement grains. Consequently, the fluidity of the mixture improved, reducing the amount of water required to achieve the desired workability.[11]. Additionally, the lubricating properties of ʾəməbʷay juice further enhanced the workability of the concrete mix.

C. Compressive Strength Test Results

1)Partial Replacement of Water by ʾəməbʷay Juice and Plastiment BV40: The compressive strength results obtained at curing ages of 3 and 28 days for concrete mixtures prepared with partial replacement of mixing water by ʾəməbʷay juice and Sika Plastiment BV40 are presented in Fig. 5 and Fig. 6, respectively. The reported values represent the mean compressive strength obtained from three independent specimens (n = 3), while the error bars indicate the corresponding standard deviation values.

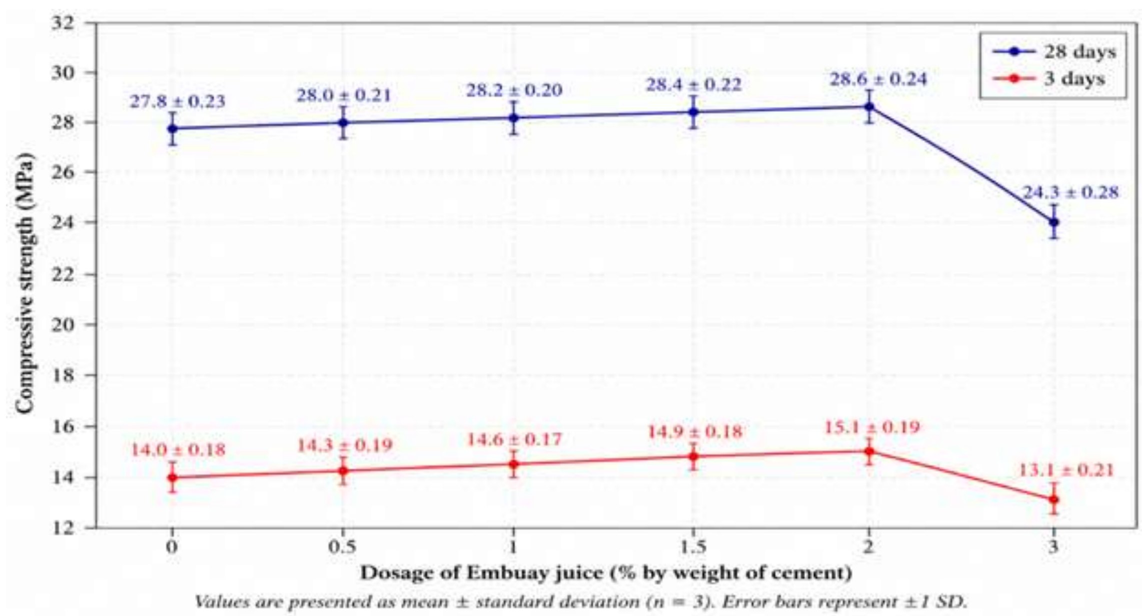

Fig. 5. Effect of partial replacement of ʾəməbʷay juice on compressive strength. Values are presented as mean ± standard deviation (n = 3). Error bars represent ±1 SD.

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Concrete mixtures containing ʾəməbʷay juice exhibited a progressive increase in compressive strength with increasing dosage up to 2% at both 3 and 28 days, as illustrated in Fig. 5. Relative to the control concrete, the compressive strength at 3 days increased by 1.9%, 3.92%, 6.05%, and 7.69% for mixtures containing 0.5%, 1%, 1.5%, and 2% ʾəməbʷay juice, respectively. Similarly, after 28 days of curing, strength enhancements of 0.86%, 1.50%, 2.31%, and 3.36% were recorded for the corresponding dosage levels. The observed improvement in compressive strength may be attributed to the reduction in the effective water–cement ratio and the enhancement of cement particle bonding caused by fatty acid compounds present in ʾəməbʷay juice [22].

However, concrete specimens containing higher dosages (3% and 5%) exhibited noticeable deterioration and cracking during water curing. This behavior is likely associated with excessive fatty acid concentrations, which may contribute to the degradation of cementitious bonding and destabilization of the concrete matrix [18] and [25].

Concrete mixtures incorporating Plastiment BV40 also demonstrated strength enhancement at lower dosage levels, as shown in Fig. 6. At 3 days, mixtures containing 0.5% and 1% Plastiment BV40 exhibited compressive strength increases of 0.52 MPa and 0.90 MPa, respectively, relative to the reference concrete. In contrast, strength reductions of 0.22 MPa and 3.86 MPa were observed at dosage levels of 1.5% and 2%, respectively.

After 28 days of curing, concrete mixtures containing 0.5% and 1% Plastiment BV40 showed additional strength gains of 0.94 MPa and 0.54 MPa, respectively, compared with the control mixture. Conversely, higher dosage levels resulted in significant reductions in compressive strength. This reduction may be associated with increased air entrainment within the concrete matrix caused by elevated lignosulfonate content, which can increase internal void formation and consequently reduce the overall mechanical strength of concrete [26].

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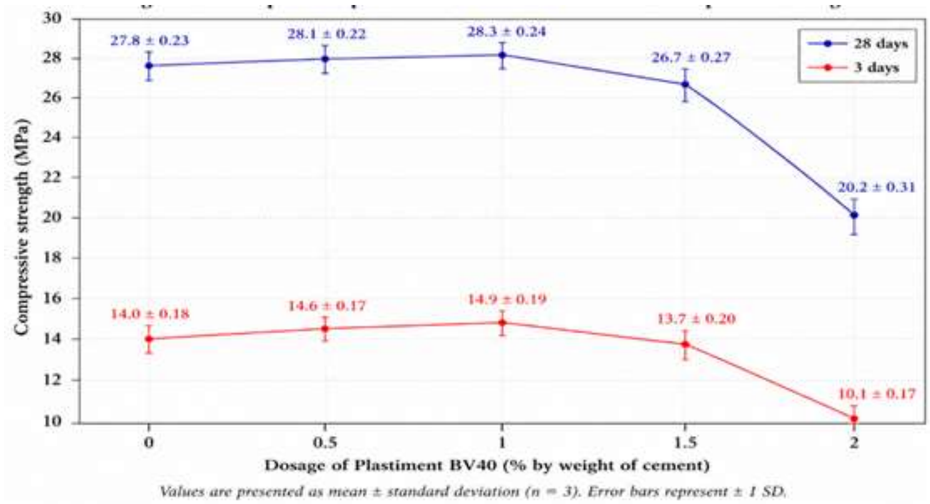

Fig. 6. Effect of partial replacement of Plastiment BV40 on compressive strength. Values are presented as mean ± standard deviation (n = 3). Error bars represent ±1 SD.

The optimum compressive strength at 28 days was achieved at a dosage of 2% for ʾəməbʷay juice and 1% for Plastiment BV40. At their respective optimum dosage levels, concrete containing ʾəməbʷay juice achieved a compressive strength of 28.6 ± X.X MPa, which was approximately 1.4% higher than the corresponding concrete containing Plastiment BV40.

2)Extra Addition of ʾəməbʷay Juice: The effect of additional ʾəməbʷay juice on the compressive strength of concrete at curing ages of 3, 7, 14, and 28 days is presented in Fig. 7. The results indicate that compressive strength increased with curing age for all mixtures, confirming continuous cement hydration and progressive strength development.

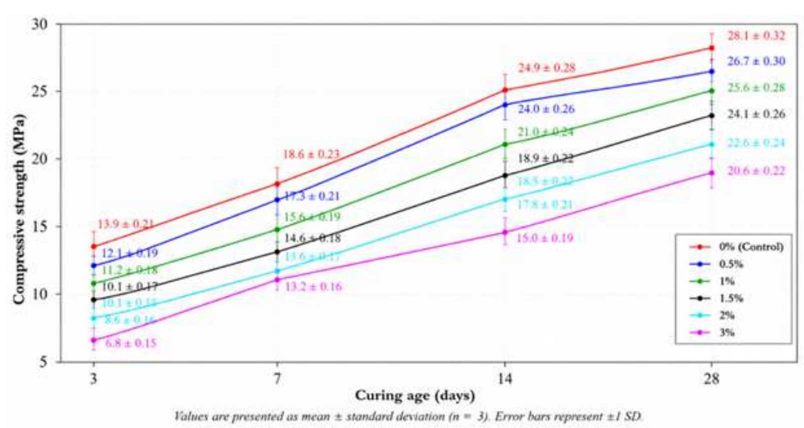

Fig. 7. Effect of extra addition of ʾəməbʷay juice on compressive strength. Values are presented as mean ± standard deviation (n = 3). Error bars represent ±1 SD.

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The control mixture exhibited the highest compressive strength throughout the curing period, reaching approximately 28.1 MPa at 28 days. Concrete mixtures containing 0.5% and 1% ʾəməbʷay juice also demonstrated relatively high compressive strength values, indicating that low dosages did not significantly affect the hydration process or mechanical performance of concrete. However, higher dosages (1.5-3%) resulted in a gradual reduction in compressive strength at all curing ages. This reduction may be attributed to the increased concentration of organic compounds and fatty acids, which can interfere with cement hydration and weaken the interfacial bonding within the concrete matrix.

Despite the reduction observed at higher dosages, all mixtures showed continuous strength gain with increasing curing age, suggesting that the addition of ʾəməbʷay juice did not completely inhibit cement hydration. Furthermore, the relatively small standard deviation values and narrow error bars presented in Fig. 7 indicate acceptable consistency and repeatability of the experimental results obtained from the triplicate specimens (n = 3).

Overall, the results suggest that lower dosages of ʾəməbʷay juice, particularly within the range of 0.5–1%, provide comparatively better compressive strength performance, whereas excessive addition negatively affects the mechanical properties of concrete.

However, when 5% ʾəməbʷay juice was added, it led to the fracture of the concrete cubes, as depicted in Fig.9a. This loss of strength can be attributed to the increased workability of concrete with higher dosages, causing the cement pastes to fail in filling the voids of the coarser grains and consequently weakening the overall strength of the concrete. Furthermore, the elevated water content results in a greater separation between aggregates and cement, adversely affecting the compaction process. Consequently, this leads to an increase in moisture content while diminishing compressive strength [27] [28].

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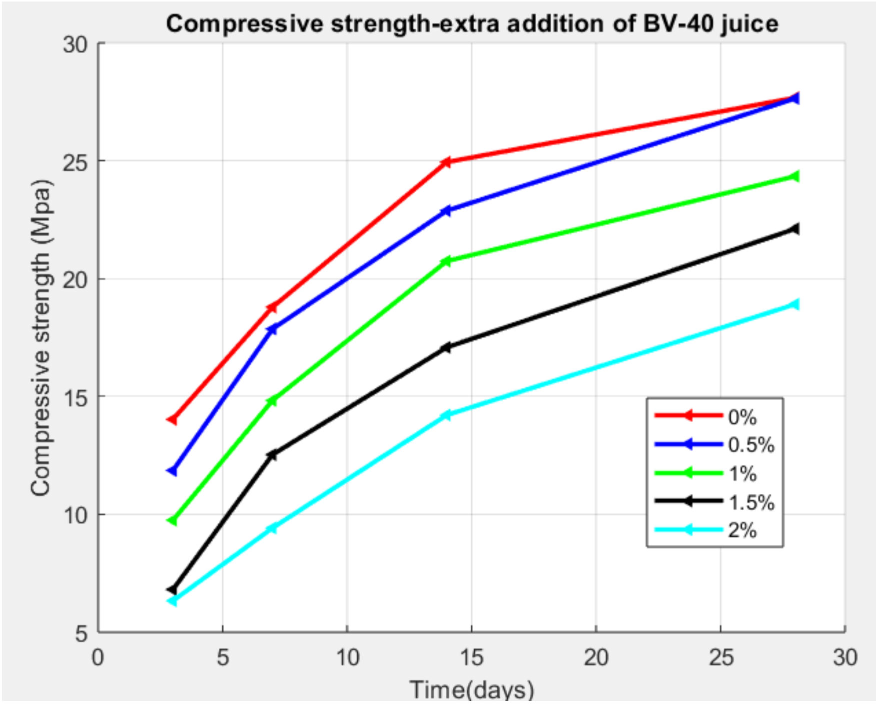

Fig. 8. Effect of extra addition of Plastiment BV40 on compressive strength

For comparison, concrete with 0.5, 1, 1.5% and 2% extra addition of commercial admixture Plastiment BV 40 were casted. The results show in Fig. 8 that the Compressive strength decreases with an increase in dosage up to 2% at all curing ages. As T. R. Alnejaili (2015) reports, the loss of strength was essentially due to the air entraining in the concrete mix; these air voids weaken the strength of concrete. The air entraining increases as the content of lignosulphonate increases [26].

Generally, at all dosages of ʾəməbʷay juice and Plastiment BV 40, the compressive strength decreased compared with the reference mix.

Fig. 9a. Effect of high dosage of ʾəməbʷay juice

Fig. 9b. Effect of high dosage of BV40

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The concrete cubes experienced fracture and disintegration when a significant amount (5% by weight of cement) of ʾəməbʷay and plastiment BV 40 were added, as evident in Fig.9a and Fig.9b. The increase in ʾəməbʷay juice and plastiment BV 40 quantity led to the breakdown of concrete components upon contact with a concentrated acid solution [22].

D. Cost Comparison Results

An analysis was performed to compare the costs associated with ʾəməbʷay juice and Plastiment BV40 by examining the expenses related to juice extraction from the year 2008 onward, as detailed in Table VIa and Table VIb. In 2011, the prices for ʾəməbʷay juice and Plastiment BV40 were recorded at 113.6 and 150 ETB per litre, respectively, in Ethiopia. This indicates that the Sika Plastiment BV40 commercial admixture entails an additional expense of 32.04% when compared to ʾəməbʷay juice. Furthermore, as illustrated in Table VIc, the projected costs for ʾəməbʷay juice and Plastiment BV40 were estimated for 5 and 10 years ahead, using 2008 as the reference year and factoring in the average inflation rate for each admixture. The results indicate that, even after 5 and 10 years, ʾəməbʷay juice continues to be a more economical option than Sika Plastiment BV40 in Ethiopia.

TABLE VI A

ESTIMATED COST OF ʾƏMƏBʷAY JUICE PER ONE LITTER FROM 2008-2011 EC

Year (EC)	*2008*	*2009*	*2010*	*2011*
ʾəməbʷay juice cost $\left(\frac{ETB}{lit}\right)$	59.25	78.94	99.5	113.6
Inflation rate (%)	-	33.23	26.04	14.07
Average inflation (%)	24.4			

TABLE VI B

COST OF SIKA PLASTIMENT BV 40 PER ONE LITTER FROM 2008-2011 EC

Year (EC)	*2008*	*2009*	*2010*	*2011*
Plastiment BV 40 cost $\left(\frac{ETB}{lit}\right)$	50-70	90-100	120-130	140-160
Average cost $\left(\frac{ETB}{lit}\right)$	60	95	125	150

***Received**: April 26, 2026;* ***Revised**: May 6, 2026;* ***Accepted:** June 1, 2026;* ***Published:** June 15, 2026*
Corresponding author- ***Besrat Berhanu***

ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/EIJET1015
Ethiopian International Journal of Engineering and Technology (EIJET)
Volume 4, Issue 1, 2026

Inflation rate (%)	-	58.33	31.58	20
Average inflation (%)	36.5			

TABLE VI C

COST OF SIKA PLASTIMENT BV40 PER ONE LITTER IN 2016 AND 2021 EC

Year	*2016*	*2021*
Estimated cost of Plastiment BV40 $\left(\frac{ETB}{lit}\right)$	995.07	6601.15
Estimated cost of ʾəməbʷay juice cost$\left(\frac{ETB}{lit}\right)$	472.76	1967.40

E. Limitations of The Study

Despite the promising findings, several limitations should be acknowledged:

- The study was conducted under controlled laboratory conditions using a single mix design (C25/30), which may limit the generalizability of the results to other concrete grades and field conditions.
- The chemical composition of ʾəməbʷay juice was only partially characterized; therefore, the specific mechanisms governing its interaction with cement hydration remain insufficiently understood.
- Variability in the natural composition of plant-based materials may lead to inconsistent performance, depending on factors such as source, season, and extraction method.
- Due to current laboratory constraints, long-term durability properties such as sulfate resistance, chloride penetration, drying shrinkage, and permeability were not evaluated in this study. These parameters are critical for assessing the long-term field performance and durability of concrete containing ʾəməbʷay juice and are therefore recommended for future research investigations.
- The study did not assess large-scale or field applications, which are necessary to evaluate practical feasibility and performance under real construction conditions.

Future research should address these limitations to better establish the reliability and applicability of ʾəməbʷay juice as a sustainable concrete admixture.

Received: April 26, 2026; **Revised**: May 6, 2026; **Accepted:** June 1, 2026; **Published:** June 15, 2026
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IV. CONCLUSION

This study evaluated the potential use of ʾəməbʷay juice (*Solanum incanum*) as a bio-admixture in concrete and compared its performance with a commercial admixture (Sika Plastiment BV40). Based on the experimental findings, the following conclusions can be drawn:

- The incorporation of ʾəməbʷay juice increased workability, with slump values increasing as dosage increased. However, the performance remained slightly lower than that of the commercial admixture.
- ʾəməbʷay juice exhibited retarding effects at lower dosages, increasing the setting time of cement paste, which may be attributed to the presence of fatty acids.
- An improvement in compressive strength was observed at lower dosages (up to 2% replacement), although higher dosages (≥3%) resulted in strength reduction and, in some cases, specimen deterioration.
- The results suggest that the performance of ʾəməbʷay juice is highly dependent on dosage and method of incorporation.
- Although the cost analysis indicates potential economic advantages, the variability in mechanical performance suggests that further validation is required before practical application.

Overall, ʾəməbʷay juice shows potential as a locally available bio-admixture; however, its application should be approached with caution due to performance limitations at higher dosages.

Availability of Data The datasets generated and analyzed during the study are available from the corresponding author upon reasonable request. Additional details regarding the nature and origin of the data have also been provided to improve transparency.

Acknowledgement

The authors would like to acknowledge the financial support provided by the Ministry of Education, Ethiopia, for this research. The study was conducted at the Ethiopian Institute of Technology, Mekelle University, and the authors are grateful for the laboratory facilities and

Received: *April 26, 2026;* ***Revised***: *May 6, 2026;* ***Accepted:*** *June 1, 2026;* ***Published:*** *June 15, 2026*
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technical support provided. The authors also acknowledge the staff of the Construction Materials Laboratory at Mekelle University for their assistance during the experimental work.

Funding

This research was supported by the Ministry of Education, Ethiopia, as part of a postgraduate (Master's) research program conducted at Mekelle University.

Declaration of Conflict of Interest

The authors declare that they have no known competing or conflict of financial interests or personal relationships that could have appeared to influence the work reported in this paper

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ISSN (E): 2959-3921
(P): 2959-393X
DOI: https://doi.org/10.59122/EIJET1015
Ethiopian International Journal of Engineering and Technology (EIJET)
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