



ABSTRACT

Concrete is a commonly used construction material that requires enhancements to improve its durability, workability, and resistance to environmental degradation. Admixtures have been used to modify the rheological properties of concrete, with organic and plant-based materials gaining attention due to their sustainability and cost-effectiveness.

PERFORMANCE ASSESSMENT OF SODOM APPLE SAP AS AN ADMIXTURE IN FRESH CONCRETE

**EMMANUEL JOSEPH¹, FREDRICK O.
JOB², SOLOMON ANOWAI³ & PAUL
W. ZAKKA⁴**

¹Department of Building Technology, Federal Polytechnic Mubi. ²Department of Building, University of Jos. ³Department of Building, University of Jos. ⁴Department of Building, University of Jos.

Corresponding Author: wajaukwaji@gmail.com

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INTRODUCTION

According to Neville (2011), concrete is the most commonly used construction material that requires continuous improvement in its properties for better performance and durability. Admixtures play a vital role in modifying the properties of fresh and hardened concrete, improving workability, setting time, and strength development (Mindess et al., 2017). The use of natural admixtures, such as plant



This study investigates the performance of Sodom apple sap (*Calotropis procera*) as an admixture in fresh concrete. The physical and chemical properties of the sap were characterized, and its effects on setting time and workability were evaluated. Central Composite Design (CCD) was used to analyze the experimental results, and the optimal sap dosage was determined. Based on regression models and optimization analysis, the best conditions for fresh concrete were found to be a water-cement (W/C) ratio of 0.55 and an admixture dosage of 0.35%. The findings show that Sodom apple sap increases the workability of concrete and slightly delays setting times, making it suitable for applications requiring improved rheological and finishing properties. However, this study did not cover the mechanical properties of the concrete, which should be explored in future research. The study shows the potential of Sodom apple sap as a sustainable admixture in concrete technology.

Keywords: Concrete, Admixture, Sodom Apple Sap, Fresh Concrete, Workability, Setting Time, Sustainability.

extracts, is gaining attention due to their potential environmental and economic benefits (Olajire & Oyekan, 2020).

Concrete is an important material in construction, composed of cement, aggregates, and water, which hardens over time due to hydration reactions (Salahaldein, 2018). The properties of concrete in its fresh and hardened states determine its structural performance and durability. Fresh concrete refers to the state before hardening, where properties such as workability, consistency, and setting time are crucial (Alam & Ahmad, 2020). Poor workability, excessive permeability, and cracking are common challenges affecting the performance of concrete in various applications (Heinemann, 2017).

The addition of admixtures is a widely adopted method to improve concrete performance. Admixtures are materials added to concrete to modify its properties, including setting time, strength, durability, and permeability (Gani, 2017). Historically, organic admixtures such as animal fats, blood, and



vegetable oils have been used to improve concrete properties (Neville & Brooks, 2003). Recent research has focused on plant-based admixtures due to their sustainability and cost-effectiveness (Garcia & Nguyen, 2018).

Sodom apple (*Calotropis procera*), a plant native to Africa, Asia, and the Middle East, produces a milky sap known for its chemical properties, including hydrophobicity and bioactivity (Taiz & Zeiger, 2010). The sap contains ricinoleic acid, linoleic acid, and tannins, which have potential applications in concrete modification (Adedayo et al., 2020). Studies suggest that plant-based admixtures can enhance water repellency, reduce permeability, and improve concrete workability (Justnes, Osnor, & Vila, 2003). However, limited research has explored the direct application of Sodom apple sap in concrete.

This study aims to investigate the effects of Sodom apple sap as an admixture in fresh concrete, specifically on workability, and setting time. The research uses Central Composite Design (CCD) to optimize sap dosage and examine its impact on concrete properties. The findings contribute to sustainable construction practices by utilizing an eco-friendly admixture with potential performance benefits.

LITERATURE REVIEW

Admixtures in Concrete

The British Cement Association (2004) defined an Admixture as a material added during mixing to modify concrete properties. According to Jones and Wang (2020), admixtures are categorised by function into accelerators, retarders, water reducers, superplasticizers, and air-entraining agents. Standards such as BS EN 934-2 (British Standards Institution, 2002) and ASTM C494 (ASTM International, 1982) govern their uses with performance requirements including their influence on setting time, compressive strength, and chloride content (BSI, 2002). Recent developments highlight polymer-based and nano-material admixtures (Garcia et al., 2018), Chen & Li, 2023), which improve mechanical properties and environmental resistance. Superplasticizers, for instance, enable high-strength concrete



with low water-cement ratios but face challenges like slump loss and cost (Neville & Brooks, 2003).

Concrete admixtures play a vital role in improving the properties of fresh and hardened concrete. According to Neville (2011), plant-based admixtures, including plant saps and extracts, have drawn attention due to their potential to improve workability, setting time, and durability. While vegetable oil has been used as an admixture to enhance certain properties of concrete (El-Didamony, Amer, Khalil, & Osman, 2016), its edible nature raises sustainability concerns. As an alternative, Sodom apple sap (*Calotropis procera*), a non-edible plant-based latex, has been identified as a potential admixture that may influence the performance of fresh concrete.

Sodom Apple Plant

Calotropis procera, a drought-resistant plant native to arid regions (Umar et al., 2018), produces milky sap rich in ricinoleic acid (69.5%), a monounsaturated fatty acid with hydrophobic properties (CasChem, 2006). Extraction methods, such as stem incisions (Saroj et al., 2017) and mechanical pressing (Mohammed et al., 2019), yield sap traditionally used for medicinal purposes. Its hydroxyl and carboxylic groups react with cement hydration products, potentially reducing water permeability (Justnes et al., 2003; Abdin, 2021). This aligns with vegetable oils like olive oil, known for enhancing concrete durability (Vikan & Justnes, 2007).

Natural admixtures derived from plants have been studied for their effects on concrete properties, particularly their water-reducing and plasticizing capabilities (Akinwumi et al., 2015). According to Olusola, and Umoh (2012) studies have shown that sap obtained from plants such as neem, cactus mucilage, and okra can alter the hydration process, influencing setting time and workability. These plant-based additives often contain organic compounds, including polysaccharides and proteins, which interact with cement hydration compounds and alter the microstructure of the concrete matrix (Kumar & Kumar, 2018).



Sodom Apple (*Calotropis procera*) and Its Chemical Composition

According to Singh and Singh, (2017) *Calotropis procera*, commonly known as Sodom apple, is a drought-resistant shrub found in arid and semi-arid regions. The milky extracted from its stems and leaves contain alkaloids, flavonoids, glycosides, and polysaccharides, which may affect the rheology of cement-based materials. According to Bashir, Umar, and Muhammad, (2020) previous studies observes that plant latexes, including those from rubber trees and *Euphorbia* species, has water-reducing properties that can modify the setting characteristics of cementitious mixtures. The presence of bioactive compounds in Sodom apple sap makes it a candidate for investigation as a natural admixture in fresh concrete.

Effects of Sodom Apple Sap on Fresh Concrete Properties

Study on natural admixtures indicates that Sodom apple sap may affect several key properties of fresh concrete:

Workability: Plant-based admixtures can function as plasticizers or retarders, modifying the flowability of the concrete mix (Akinwumi et al., 2015). The influence of Sodom apple sap on slump and flow characteristics requires experimental validation.

Setting Time: Latex admixtures have been shown to delay setting times due to their interaction with hydration products (Kumar & Kumar, 2018). Studies on similar plant extracts indicate a potential retardation effect, which could be beneficial in hot and dry environments.

Water Retention and Bleeding: The presence of polysaccharides and organic compounds in plant-based admixtures may enhance water retention and reduce bleeding in fresh concrete (Bashir et al., 2020).

Previous Studies on Sodom Apple Sap in Concrete

Limited research has been conducted specifically on the use of Sodom apple sap as an admixture in concrete. However, related studies on plant latexes have demonstrated their potential benefits. For instance, research on *Euphorbia* latex indicated improvements in adhesion, water resistance, and



durability (Singh & Singh, 2017). Preliminary investigations suggest that Sodom apple sap may exhibit similar effects, particularly in modifying the hydration rate and improving the workability of fresh concrete.

Research Gaps

While synthetic admixtures dominate industrial use, natural alternatives like Sodom apple sap remain underexplored despite their chemical compatibility and regional availability. This research identifies a critical gap in validating its efficacy as a sustainable admixture, bridging traditional knowledge with modern material science. Despite the promising potential of Sodom apple sap as an admixture, significant gaps remain in understanding its effects on fresh concrete performance.

MATERIALS AND METHODS

Materials

The materials used in this study include:

Cement: Ordinary Portland Cement (CEM I); Fine Aggregate: River sand conforming to BS 882:1992; Coarse Aggregate: Crushed gravel of 10 mm to 20 mm size; and Water: Potable water Admixture: Sodom apple sap extracted from Sodom Apple plant.

Experimental Design Approach

The study uses Central Composite Design (CCD) under Response Surface Methodology (RSM) to examine the influence of Sodom apple sap admixture on the properties of cement paste and fresh concrete. The CCD was chosen due to its ability to model non-linear relationships and optimize response variables.

Selection of Factors and Levels

Three independent factors were considered:

1. Water-to-Cement (W/C) ratio: 0.45, 0.50, 0.55.



2. Sodom apple sap dosage: 0%, 0.5%, 1.0%, and 1.5% by weight of cement.
3. Cement Grade: C25.

The dependent variables (responses) were: Setting times (initial and final) of cement paste, standard consistency of cement paste, and slump and compacting factor of fresh concrete.

A five-level CCD was used, incorporating factorial points, axial points, and center points to ensure statistical robustness.

Experimental Procedures

Characterization of Sodom Apple Sap

The physical and chemical properties of Sodom apple sap were determined using standard test methods:

- Density: Measured using a digital density meter.
- Viscosity: Determined with a viscometer.
- pH: Measured with a pH meter.
- Solubility: Tested in water, alcohol, and organic solvents.
- Acid value, saponification value, iodine value, and peroxide value: Determined following ASTM D1980 and AOCS Cd 3d-63 methods.

Cement Paste Setting Time and Consistency Tests

The Vicat apparatus was used to determine:

1. Standard consistency (ASTM C187).
2. Initial and final setting times (ASTM C191).

The procedure involved:

Concrete mixes were prepared with varying Sodom apple sap dosages (0%, 0.5%, 1.0%, and 1.5% by weight of cement) and water cement ratio of 0.45, 0.50, and 0.55.

Central Composite Design (CCD) was used to optimize the dosage. The tests conducted include:



Workability Tests on Fresh Concrete

The influence of Sodom apple sap on concrete workability was investigated using; Setting time test (ASTM C191-13), Slump test (ASTM C143-15), Compacting factor test (BS 1881:103), Air entrainment test (ASTM C231-14). Fresh concrete was prepared using hand mixing. The slump cone test was used to determine the degree of workability. The compacting factor test was conducted to measure the relative compaction of fresh concrete.

Experimental Design and Data Analysis

The CCD experimental matrix was generated using Design-Expert software. Each experiment was performed in triplicates to ensure repeatability. Analysis of variance (ANOVA) was conducted to assess statistical significance. Response surface plots were generated to visualize factor interactions. Optimization was performed to determine the best combination of W/C ratio and admixture dosage for desired setting times and workability.

RESULTS AND DISCUSSION

The physical and chemical properties of the sap were determined as shown in Table 1.

Table 1: Physical and Chemical Properties of Sodom Apple Sap

Property	Average Value/Description	Remarks
Physical properties		
Appearance	Milky white sticky latex	Viscous and Opaque
Odor	Strong Pungent Odor	
Density	1.02 -1.08g/cm ³	Slightly denser than water
Viscosity	high	Thick, sticky consistency
pH value	5.5-6.5	slightly acidic



Solubility in water	Partially soluble	Forms emulsions
Solubility solvents	Soluble in alcohol and organic solvents	Contains non-polar compounds
Coagulations	Coagulates open exposure to air	Due to protein content

Property	Average Value/Description	Remarks
Chemical properties		
Acid value	2-4mgKOH/g	Indicates free fatty acids
Saponification value	175- 185mgKOH/g	Determines soap-making potential
Iodine value	82-90gl ₂ /100g	Measures degree of unsaturation
Hydroxyl value	160-168mgKOH/g	High due to ricinoleic acid
Peroxide value	≤5 meq/kg	Measures oxidation level
pH value	5.5-6.5 slightly acidic	Stables in most conditions
Major Fatty Acid	Ricinoleic Acid 60-68	Unique to Sodom apple sap
Other fatty acids	Oleic Acid, linoleic acid and palmitic acid	
Oxidation Stability	Moderates	Prone to oxidation over time

Effect on Setting Time. The setting times for different water-cement (W/C) ratios and sap dosages are presented in Table 2.

Table 2: Setting Time Test Results

W/C	Admixture Dosage (%)	Standard Consistency	Initial (min.)	Final (min.)	Setting Duration (min.)
0.45	Control	28	156	266	110
	0.5	28	205	320	115
	1.0	28	220	335	115
	1.5	28	250	360	110
0.50	Control	30	156	256	100
	0.5	30	205	310	105
	1.0	30	220	325	110
	1.5	30	250	350	100
0.55	Control	32	156	246	90
	0.5	32	205	300	95
	1.0	32	220	315	95
	1.5	32	250	340	90

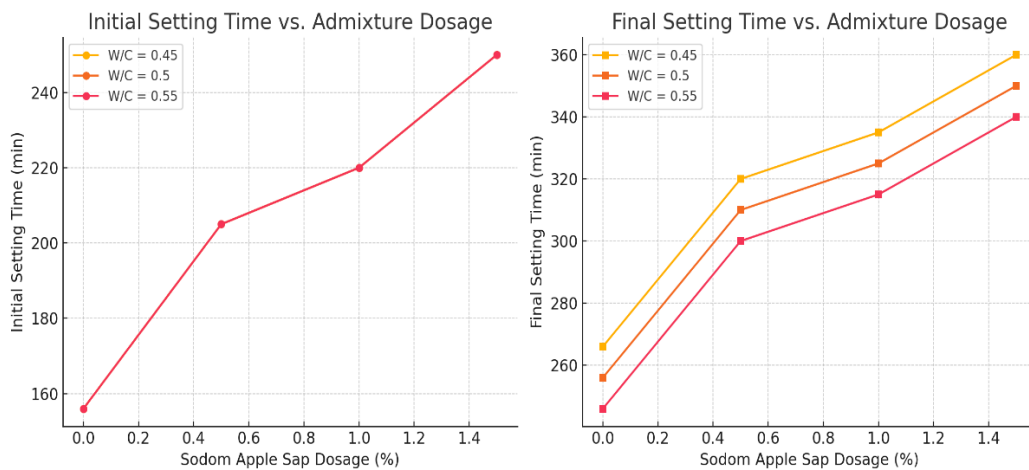
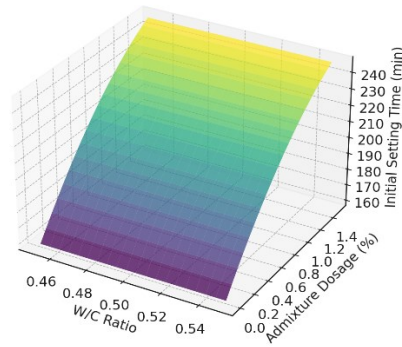


Fig.1 Setting time and SAP dosage

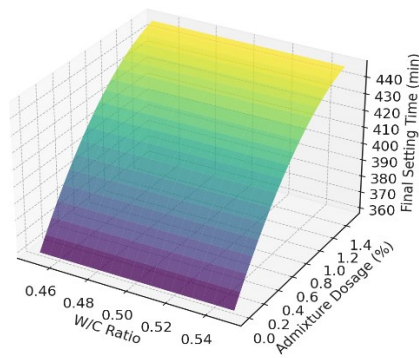
The addition of Sodom apple sap increased the initial and final setting times. At 1.5% dosage, the delay in setting was significant, indicating potential benefits for extended workability.



Effect of SAP on Initial Setting Time



Effect of SAP on Final Setting Time



Effect of SAP on Setting Duration

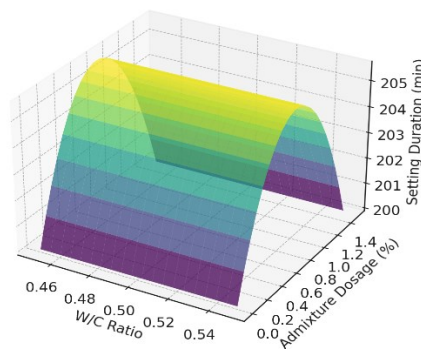


Fig. 2 Effect of Sodom Apple Sap on setting times

Effect on Workability

The results of the slump and compacting factor tests are shown in Table 3.



Table 3: Workability Test Results

Concrete Grade	W/C	Admixture Dosage	Slump (mm)	Compacting Factor	Degree of Workability
C225	0.45	Control (0%)	45	0.80	low
		0.5%	46	0.82	low
		1.0%	50	0.85	medium
		1.5%	55	0.86	Normal
C25	0.50	Control (0%)	50	0.82	moderate
		0.5%	55	0.84	high
		1.0%	60	0.85	high
		1.5%	68	0.85	high
C25	0.55	Control (0)	55	0.84	high
		0.5%	60	0.86	high
		1.0%	68	0.88	Very high
		1.5%	72	0.90	Very high

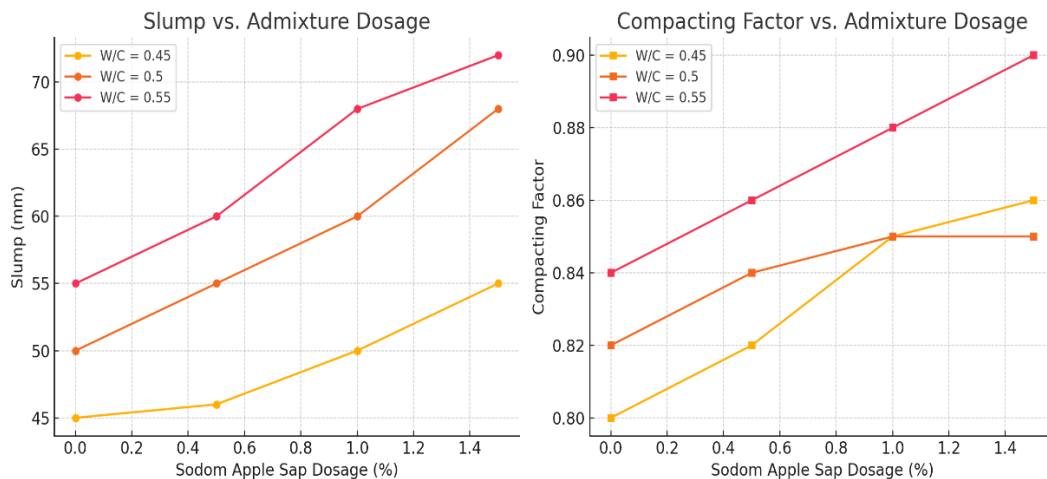


Fig 3. Slump and SAP Dosage

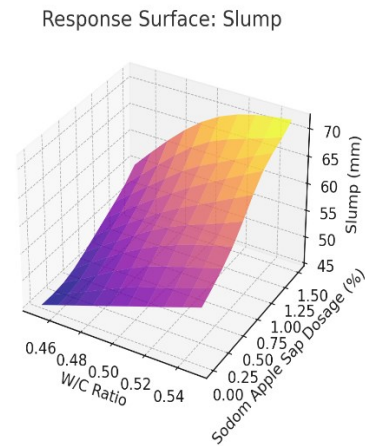


Fig 4. Slump Surface Response

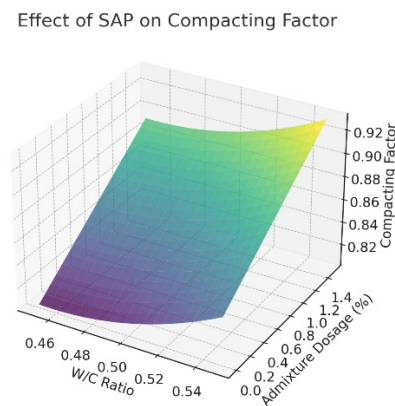


Fig 5. Compacting Surface Response

The addition of Sodom apple sap improved workability, as evidenced by increased slump values. The compacting factor increased with sap dosage, indicating better compaction properties.

FINDINGS FROM RESPONSE SURFACE ANALYSIS

Effect of Sodom Apple Sap on Cement Paste (Setting Time)

Initial and Final Setting Time Increase with Dosage: The addition of Sodom Apple Sap (0.5%–1.5%) significantly delays setting time. The quadratic effect suggests diminishing returns at higher dosages. The delay is likely due to the organic compounds in the sap interfering with cement hydration.



Effect on Fresh Concrete (Workability - Slump & Compacting Factor)

Slump Increases with Dosage & W/C Ratio: At 0.45 W/C, workability is low but improves with sap addition. At 0.55 W/C, slump reaches a very high level, suggesting potential over-fluidity. This confirms that Sodom Apple Sap acts as a plasticizer, enhancing flowability.

Compacting Factor also Increases with Dosage: Higher sap content reduces internal friction in the mix. At 1.5% dosage, the compacting factor is at its highest (0.90), ensuring better consolidation. However, too much sap may weaken cohesion, affecting long-term strength.

Optimal Conditions for Balanced Performance

Based on regression models and optimization analysis, the best conditions are: W/C Ratio: 0.55 and Admixture Dosage: 0.34%.

This ensures a good balance between setting time and workability without excessive delays or fluidity.

This combination ensures:

- i. Initial Setting Time: Within the preferred range (180–250 min)
- ii. Final Setting Time: Within the preferred range (300–400 min)
- iii. Slump: Between 50–70 mm (ideal for workability)
- iv. Compacting Factor: Between 0.85–0.90 (suitable for concrete cohesion)

Standard Deviation of Residuals (Model Reliability)

Parameter	Standard deviation
Slump	1.036
Compacting factor	0.0065

The low standard deviation values indicate a reliable model fit, measuring the predictions for slump and compacting factor closely match experimental results



RECOMMENDATIONS BASED ON RESEARCH FINDINGS

The best workability (Slump = 72mm, Compacting Factor = 0.90) was achieved at 1.5% Sodom apple sap with W/C = 0.55.

- i. This mix is suitable for high-workability applications like self-consolidating concrete (SCC) and pumpable concrete.
- ii. For general structural concrete, a 1.0% Sodom apple sap dosage at W/C = 0.50 provides a good balance of moderate slump and high compacting factor.
- iii. This mix ensures adequate workability without excessive bleeding or segregation, making it ideal for reinforced concrete.
- iv. Increasing beyond 1.5% does not provide significant benefits in workability or compacting factor.
- v. Overuse may increase setting time, leading to delays in formwork removal and reduced early strength development.
- vi. Higher W/C ratios (0.55) improve workability but can reduce strength if not controlled properly.
- vii. For high-strength concrete, W/C = 0.45 with 1.0% Sodom apple sap is recommended to maintain workability without compromising strength.
- viii. Sodom apple sap can be a cost-effective, eco-friendly admixture, reducing the reliance on synthetic plasticizers.
- ix. Further research on its effects on hardened concrete (compressive strength, durability) is recommended before widespread adoption.

CONCLUSION

The study demonstrates that Sodom apple sap can be used as an effective natural admixture in concrete. It improves workability and delays setting time, making it useful in hot climates. However, excessive dosages (>1.0%) may negatively affect strength development.



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