International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V71I5P205

Volume 71 Issue 5, 40-48, May 2023

Original Article

Effect of Sisal Juice on the Fresh and Hardened Properties of Concrete

Sidibe Gaoussou[1], David Otieno Koteng[2], Isaac Fundi Sanewu[3]

[1]*Department of Civil Engineering, Pan African University Institute for Basic Sciences, Technology and Innovation hosted at Jomo Kenyatta University of Agriculture and Technology, Kenya.*
[2]*Department of Civil & Construction Engineering, School of Civil & Resource Engineering, Technical University of Kenya, Kenya.*
[3]*Construction Management Department, Jomo Kenyatta University of Agriculture and Technology, Kenya.*

[1]*Corresponding Author : gaousousidibe219@gmail.com*

Received: 01 February 2023 Revised: 04 April 2023 Accepted: 29 April 2023 Published: 25 May 2023

Abstract *- This study examines the effect of sisal juice (SJ) on the fresh and hardened properties of concrete. Fresh concrete behavior largely depends on the water-binder ratio (w/b). Low w/b greatly affects the strength, workability, and durability of concrete. In the case of excess water, the paste becomes too weak to hold aggregates, causing segregation and bleeding, which leads to porosity. Chemical admixtures increase workability at the same w/b and improve concrete strength and durability. However, their production includes some inputs, which increases their costs in the market hence the construction cost. On the other hand, experiments with agricultural wastes like SJ have shown their potential for use as workability-enhancing admixtures to concrete. In this study, the properties of concrete incorporating 1.25, 2.5, 3.75, and 5% SJ by weight of cement were compared to a control mix using a 1% industrial superplasticizer. A slump test was carried out for each dosage of SJ and compared to a control mix to determine the optimum SJ dosage for use in concrete. With the optimum SJ dosage, cubes and cylinders were tested and compared to the control at specified ages. The results showed that SJ dosages above 2.5% improved both the workability and workability retention better than the control. However, an SJ dosage of 5%, used to evaluate the strength and water absorption of hardened concrete, showed lower strength and increased water absorption when compared to the control. Thus, SJ can act as a bio-admixture for constructing ecological, sustainable, and cost-effective houses.*

Keywords *- Sisal juice, Strength, Water absorption, Workability, Workability retention.*

1. Introduction

Concrete is one of construction's most widely used substances [1], [2]. Concrete is defined as the addition of cement and water to make a paste that allows the connection between aggregates to harden over time to give a resistant and load-bearing material [3]. The behaviour of fresh and hardened concrete depends on the water-cement ratio [4], [5]. The lack or excess of water in concrete enormously affects workability, strength, and durability. In the case of excess water, the paste becomes weak to hold aggregates, causing segregation and bleeding, which form porosity. The paste's viscosity defines the mix's cohesiveness, affecting workability.

Workability affects the transportation, placement, and compaction of fresh concrete, which should take place without any segregation and bleeding. The use of chemical admixtures in concrete or mortar improves its mechanical performance as well as its rheological properties [6]–[12]. Admixtures have been in use for many centuries, allowing the Roman civilization to strengthen the structures' performance, robustness, and durability. They have allowed engineers to construct in harsh sites while preserving the quality of fresh concrete. The admixtures permit to optimize of concrete properties by inducing an electrostatic repulsion force and/or stress between cement particles, which causes a deflocculation [13]–[16].

For concrete operations, admixtures like water reducers and retarders are useful to increase the workability and extend the cement's initial setting [17]. The absorption of retarder compounds on cement particles slows the rate of hydration by blocking the reaction between particles and water [18]. The role of retardation is useful for concrete transportation, placement, and compaction in a hot climate. However, chemical admixtures are available at a high cost due to the manufacturing processes and affect the cost of construction [19]. In addition, carbon dioxide and CO_2 are released during the chemical process, which accelerates global warming [20], [21].

On the other hand, there are abundant agricultural wastes such as sisal juice (SJ) from the sisal fibers extraction process, sugarcane bagasse from sugarcane manufacturing, palm oil wastes from palm oil production and rice husks from rice processing which fill the land and affect the environment [22], [23]. It will be important and useful to exploit such alternative waste materials in concrete manufacturing [24], [25] to improve durability and mechanical properties and increase concrete workability while maintaining cohesion between particles. Workability is an asset for the fresh and hardened state of concrete, affecting its strength and durability [2]. Many studies have investigated the use of agricultural wastes as bio-admixtures to strengthen the mechanical properties of concrete [26,27,35].

For instance, research by [29] investigated the effect of sisal leaf extract (SLE) on the mechanical properties of concrete using ordinary Portland cement (OPC 42.5N) for various grades (M20, M25, and M30) of concrete. They observed that as the SLE dosage increased, both compressive strength and split tensile strength yielded more than in control concrete in all three concrete grades. Substances like cellulose, hemicellulose and lignin in SLE improve the binding properties of the paste. In addition, lignin is a water-reducing agent [6].

Similarly, in research by [30], the sisal juice was used at various dosages (5%, 10%, 15%, 20%, 25%, and 30%) by weight of cement on the compressive strength and flexural strength of concrete using OPC 52.5N. It was shown that the optimum crushing and flexural strength was obtained at 5% water replacement by sisal juice, and a decrease occurred for all the higher dosages due to the acidity of sisal juice.

In a different research, the water hyacinth extract (WHE) was investigated in concrete with various concentrations of solution (0.25%, 0.5%, 0.75%, and 1%) [20]. Crushing strength and slump tests were performed on concrete. Gas Chromatography-Mass Spectrometry (GCMS) tests confirmed the presence of lignin, a water-reducing compound. Results showed that WHE in the liquid state increases the workability of concrete with the increase in the concentration of WHE in the solution.

In yet another research, the investigation was done on using mulberry extract on concrete's fresh and hardened behaviour [31]. They observed that the juice yielded more strength and increased workability compared to the control. The addition of materials increasing the setting time is an asset to control the transportation, placement, and compaction of concrete without any segregation and bleeding, particularly in a hot climate where the heat accelerates the reaction between cement and water in the mix, causing premature shrinkage and cracks [32].

However, few researchers have experimented with agricultural wastes acting as water-reducer like SJ on the workability retention and durability of concrete incorporating ordinary Portland cement blended with natural pozzolana. The Portland Pozzolana Cement, through its physical properties and microstructures, absorbs water present in the mix so, affecting the behavior of fresh and hardened concrete [33]. It is unsuitable to use this type of blended cement without a water-reducing agent to preserve concrete's durability and ensure strength development. Durability is an important parameter in concrete to ensure a long service life of the structures. Instead of using industrial chemical admixtures, which increase the construction cost, this study investigated the suitability of SJ as a water-reducing admixture to concrete made with Portland Pozzolana CEMII/B-P 42.5N cement manufactured to European standard EN 197.

With the goal of designing a good concrete mix and constructing sustainable, eco-friendly, and cost-effective structures, this study investigated the effect of SJ on the mechanical behaviour of concrete with Portland pozzolana cement.

2. Materials and Methods

2.1. Materials

Through this study, cement, fine aggregate (FA), coarse aggregate (CA), water, superplasticizer, and sisal juice (SJ) were used as materials. The cement used was Portland pozzolana cement, CEM II/B-P 42.5 N, manufactured in Kenya as per KS-EAS 18-2017, which meets the requirement of European standard EN 197.

The FA was river sand from Meru, Kenya. Aggregates were crushed stones of maximum aggregate size (MAS) of 12.5mm obtained from a quarry in Mlolongo in Machakos County. The sisal plant locally available at Juja Town in Kiambu County was used and crushed to provide the juice. The superplasticizer was carboxylic-based and was bought locally. Potable water from the university mains was used throughout the experiment.

2.2. Materials Preparation

2.2.1. Sisal Juice

The preparation of the sisal juice (SJ) followed the process shown in Figure 1. The leaves were collected from the sisal plant, cleaned in running water and dried in air for 30 minutes. The leaves were then crushed, and the juice was squeezed out with a clean cloth. The juice was stored in a refrigerator to prevent early fermentation as it awaited use.

2.2.2. Fine Aggregate

FA was washed with running water sieve #200 to remove clay and dust particles, followed by oven drying at 105ºC for 24 hours.

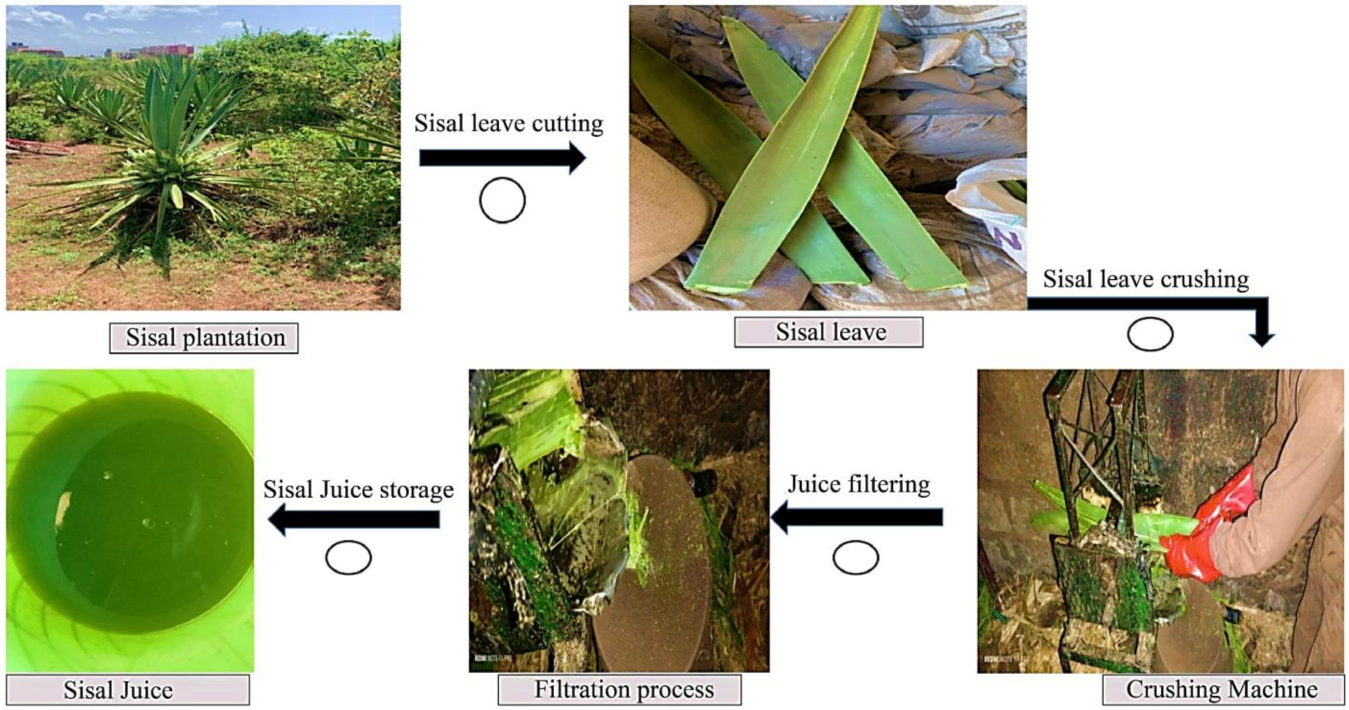

Fig. 1 Sisal juice production

2.2.3. Coarse Aggregate

The coarse aggregate (CA) was washed to remove clay and dust particles and oven dried for 24h at 105°C.

2.3. Material Characterization

2.3.1. Cement

The properties, including physical and chemical properties, were determined according to BS EN 197-1 (2011).

2.3.2. Sisal Juice

XRF was used for the chemical analysis of the juice, and the compounds present in the juice were determined using Gas Mass Spectrometry (GMS).

2.3.3. Fine Aggregate

FA was sieved through a sieve size of 4.75mm to remove any particle bigger than 4.75 mm. The FA was further run through a series of FA sieve sizes 150µm, 300µm, 600µm, 1.25mm, 2.36mm, 4.75mm and 9.5mm to determine the particle size distribution and the fineness modulus of the FA. Other physical characteristics of the FA were also determined.

2.3.4 Coarse Aggregate

The CA was sieved through sieve sizes 2.36mm, 5mm, 10mm and 12.5mm to determine the particle size distribution. Other tests were also carried out.

2.4. Concrete Mix Design

Concrete was designed in accordance with ACI 211-4R at a constant w/b of 0.35.

2.5. Concrete Mixing

A rotating drum mixer was used to mix concrete. The mixer was turned on, and water was poured into the mixer together with half a portion of the plasticising admixture (superplasticizer or SJ). The water and admixture were allowed to mix for 1 minute before cement was added and mixed to make a paste. FA was added and mixed to obtain uniform mortar. Then aggregates were added and mixed to obtain a uniform consistency. The remaining plasticising admixture was added as necessary during mixing.

2.6. Workability and Workability Retention

A standard cone with a top diameter of 100mm, a bottom diameter of 200mm, and a height of 300mm was used for the workability test to BS 1881-102. After the initial slump, the concrete was returned to the mixer and remixed. Slump tests were repeated after 30 minutes and 60 minutes.

2.7. Preparation and Curing of Test Samples

A total of 18 cubes of size 100 mm were cast using the industrial superplasticizer to be tested in compression at the ages of 3, 7, 14, 28, 56, and 90 days to act as the control. A further 18 cubes were made with 5% SJ; in addition, 6 cubes were made for the control mix, and another 6 cubes with 5% SJ dosage to test for water absorption and sorptivity at 28 days. For the split cylinder tensile test, 18 cylinders of 150mm diameter and 300mm length were cast to be tested at 28, 56, and 90 days, with a similar number being cast with 5% SJ. All test samples were demoulded after 24 hours and cured in water at room temperature until the time of the test.

Fig. 2 Concrete slices for testing

2.8. Compressive Strength

Tests were carried out as per BS 1881-116. The average value of samples was used for each record.

2.9. Splitting Tensile Strength

Tests were carried out as per BS 1881-117. The average value of samples was used for each record.

2.10. Water Absorption

Tests were carried out as per BS 1881-122. The average value of samples was used for each record.

2.11. Sorptivity

Tests were carried out as per ASTM C1585. The average value of samples was used. The samples are presented in Figure 2.

3. Results and Discussion

3.1. Cement

The physical and chemical properties, as shown in Table 1 and Table 2, were determined as per BS EN 197-1 (2011). The specific gravity was found to be 2.86 in the range of specific gravity of 2.8-3.1 in accordance with ASTM C188 (2017). The determination of standard consistency gave 31%, within the 25% and 40% range. In addition, the initial and final setting times were 232min and 322min in accordance with BS EN196-3 (2016).

3.2. Coarse and Fine Aggregates

CA and FA were graded according to ASTM C136 (2019). It was observed that for both FA and CA, the curves of percentage passing were within the upper and lower limits, as presented in Figure 3 and Figure 4, respectively. Thus results satisfied the requirements of the standard. The physical properties are shown in Table 3 and Table 4. The fineness modulus of FA was 2.99, classified as coarse sand, ideal for the paste quality.

Table 1. Physical properties of cement

TEST	UNIT	RESULT
Density	g/cm3	2.86
Specific surface	Cm2/g	4016
Standard consistency	%	31
Initial setting	Min	232
Final setting		322
Soundness	mm	0.5

Table 2. Chemical composition of cement

PARAMETER	RESULT (%)
LOI	4.19
SiO_2	24.42
I.R.	12.05
Al_2O_3	6.02
Fe_2O_3	3.75
CaO	57.06
MgO	1.28
SO_3	2.66
Na_2O	0.84
K_2O	8.92
Cl-	<0.01

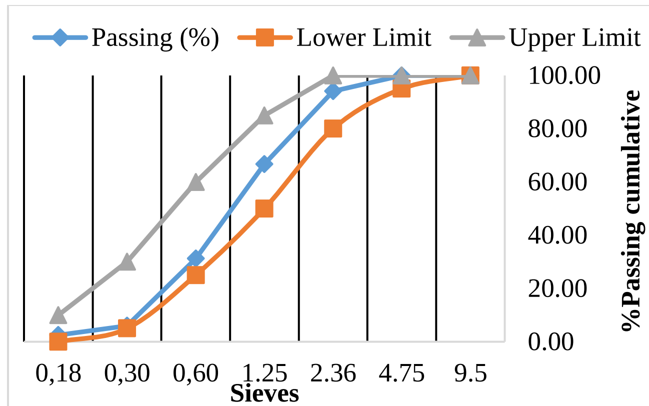

Fig. 3 Sieves analysis of FA

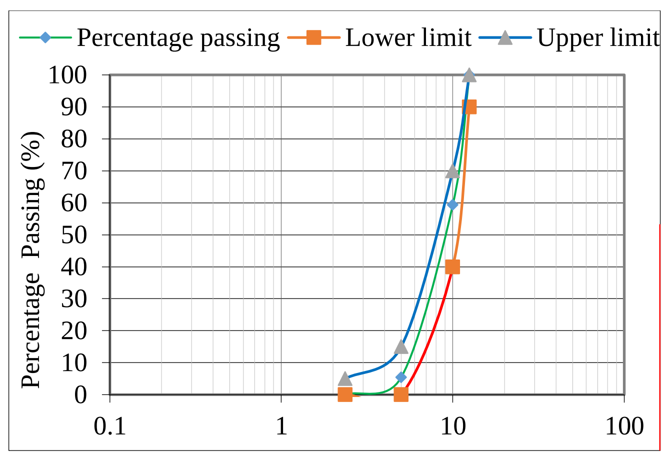

Fig. 4 Sieves analysis of CA

Table 3. Physical properties of FA

TEST	RESULT
Specific Gravity	2.64
Water Absorption	2.39%
Silt Content	1%
Moisture Content	1.3%
Fineness Modulus	2.99
Bulk Density (kg/m^3)	1649
Voids	29%

Table 4. Physical properties of CA

TEST	RESULT
Specific gravity	2.66
Water Absorption	3.5%
Aggregate impact value	6.2%
Aggregate crushing value	17.6%
Bulk Density (kg/m^3)	1468
Voids	41%

3.3. Sisal Juice

The physical and chemical properties of SJ are given in Tables 5 and 6, respectively. The pH was 4.66, and the SJ was, therefore, acidic. On the other hand, the main chemical compounds were calcium oxide and potassium oxide. As shown In Table 7, SJ contains compounds like carboxylic acids and lignin. Lignin is responsible for water reduction in bio-admixtures [6]. In addition, the carboxylic acids chelate the calcium in the cement paste, making protection around the cement particle [34].

3.4. Superplasticizer

SP was a high-range water reducer with extended workability properties for concrete. It fills the requirements for set retarding and super-plasticizing admixtures as per EN 934-2: 2001. The results shown in Table 8 are obtained from the product data-sheet.

3.5. Mix design

The results of the mix design to ACI 211-4R are shown in Table 9.

Table 5. Physical properties of sisal juice

Relative Density	971kg/m^3
pH value	4.66
Specific gravity	0.971
Appearance	Green

Table 6. Chemical properties of sisal juice

PARAMETER	% BY WT
CaO	35.80
K_2O	32.35
MgO	13.80
Al_2O_3	4.19
SiO_2	4.10
Fe	3.61
S	2.87
P_2O_5	1.47
Cl	1.15
Zn	0.63
Mn	0.35
Ti	0.21
Sr	0.10

Table 7. Composition of juice using GCMS

No	Elements	Chemical formula	Area (%)
1	1-Dimethyl silyloxypropane	$C_8H_{20}OSi$	11.574
2	n-Decanoic acid	$C_{10}H_{20}O_2$	9.309
3	7-Tridecanol, 7-ethyl	$C_{15}H_{32}O$	0.585
4	Ketone, isopropylidenecyclopropyl methyl	$C_8H_{12}O$	1.387
5	Hexadecanoic acid, methyl ester		21.564
6	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	26.881
7	Dihexyverine	$C_{20}H_{35}NO_2$	2.89
8	Heptanoic acid,3,7-dimethyl-2,6-octadienyl ester, (E)	$C_{17}H_{30}O_2$	1.111
9	4-Nonenoic acid, methyl ester	$C_{10}H_{18}O_2$	5.10
10	9-Octadecenoic acid (Z), methyl ester	$C_{19}H_{36}O_2$	14.18
11	2,7-Octadien-1-ol	$C_8H_{14}O$	2.55

Table 8. Technical data

Density	1.05kg/l
pH-value	4.5+
Dosage	0.2-1.5%
Total chloride ion Content	Free (EN934.01)

Table 9. Mix design quantities (kg/m^3)

Admixture Type	Dosage (%)	W	C	CA	FA	A
SP	1.00	170	500	998	543	5.50
SJ	1.25	169	500	998	543	6.26
SJ	2.50	163	500	998	543	12.50
SJ	3.75	156	500	998	543	18.75
SJ	5.00	150	500	998	543	25.00

Table 10. Slump value (mm)

Admixture	Dosage (%)	Slump (mm)		
		0min	30min	60min
SP	1.00	175	0	0
SJ	1.25	56	0	0
SJ	2.50	157	0	0
SJ	3.75	183	21	0
SJ	5.00	190	117	1

3.6. Workability

The results of the workability test are shown in Table 10. It is observed that the workability of concrete increases with an increase in SJ dosage. This is attributed to the increasing amount of lignin in SJ as dosage increases.

3.7. Compressive Strength

The development of strength with time for the control concrete and concrete with 5% SJ is given in Figure 5. At all ages, the concrete with SJ admixture posts lower strengths in comparison with the control mix. This is attributed to the increasing amount of acid incorporated in concrete with the high dosage of SJ when compared to the lower dosage of SP. The acid, which acts as a retarder, slows down the hydration of cement grains leading to lower strength. However, as observed in Table 11, SJ with %% SJ is still able to produce structural grade concrete >25MPa at 3 days. The setup is presented in Figure 6.

3.8. Splitting Tensile Strength

Results are given in Table 12. As in the case of compressive strength, the mix with 5% SJ posted lower strength at all ages.

3.9. Water Absorption

Table 13 gives the results of the water absorption test at 28 days. The mix with 5% SJ had higher water absorption of 44% when compared to the control mix. As cement hydrates, larger compounds are formed, which fill the concrete pores and reduce its porosity. In the case of the mix with 5% SJ, less hydration had taken place; therefore, the level of pore filling was less.

Table 11. Compressive strength test (MPa)

Mix	3 days	7 days	14 days	28 days	56 days	90 days
Control	55.4	56.19	59.36	68.07	73.84	74.14
5% SJ	28.71	35.95	45.14	50.28	55.13	55.75

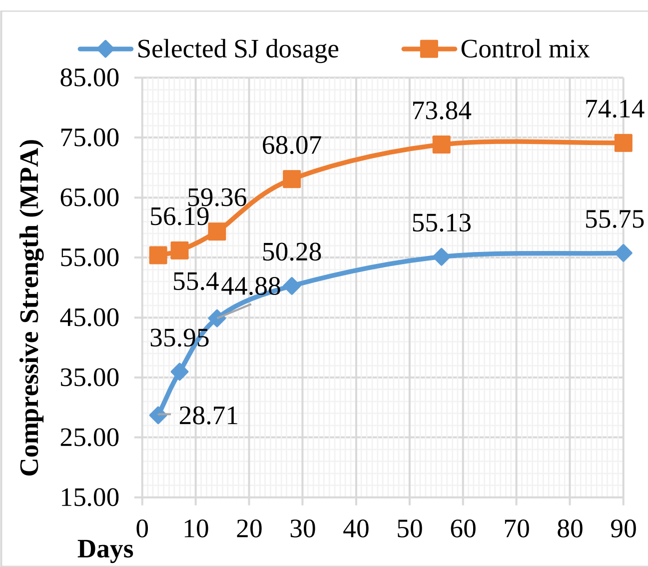

Fig. 5 Compressive strength (MPa)

Fig. 6 Crushing machine setup

Table 12. Split tensile strength (Mpa)

Mix	28 days	56days	90days
Control	3.20	4.12	4.13
5% SJ	2.43	3.05	3.38

Table 13. Water absorption test

Mix	Dry (g)	Wet (g)	WA (g)	WA (%)
Control	3688	3777	89	2.41
5% SJ	3526	3648	122	3.46

3.10. Sorptivity Test

Results are given in Table 14, Table 15. Sorptivity is the ease with which liquid is sucked into concrete pores by capillary action. The results signify greater continuity in the pores of SJ concrete, as shown in Figure 7.

Table 14. Sorptivity test at the control

Test time Second (s)	I (mm)	$S^{1/2}$
0	0.00	0.00
900	0.49	30.00
1800	0.74	42.43
2700	0.99	51.96
3600	1.23	60.00

Table 15. Sorptivity test with 5% SJ

Test time Second (s)	I (mm)	$S^{1/2}$
0	0.00	0.00
900	1.69	30.00
1800	1.98	42.43
2700	2.26	51.96
3600	2.55	60.00

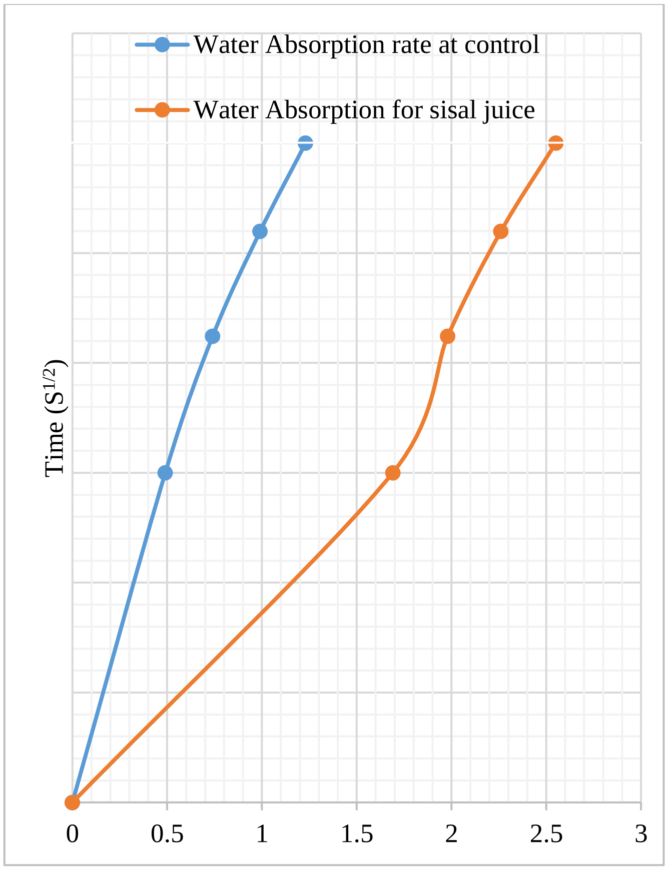

Fig. 7 Water penetration rate (mm)

4. Conclusion

The results of this research have shown that within the range of sisal juice dosage used, concrete workability increases with sisal juice dosage. This is attributed to the presence of lignin in sisal juice which has workability-enhancing properties.

On the other hand, both the compressive and tensile strength reduces when concrete with 5% sisal juice is compared to a control concrete with 1% carboxylic-based industrial superplasticizer. At the high dosage of 5%, the acid in sisal juice inhibits the hydration of cement, leading to lower strength. However, 5% SJ can be used to produce structural grade concrete >25MPa in 3 days.

Further, the concrete with 5% sisal juice had higher water absorption than the control concrete at all ages investigated. As indicated by lower strengths, cement's reduced degree of hydration reduced the pore-filling effect of the larger hydration products.

It is, therefore, reasonable to conclude that sisal juice can act as an admixture to strengthen concrete and increase its workability. It is cheap and eco-friendly, making the construction cost-effective. In addition, if the sisal juice is to be used effectively as an admixture to concrete, the juice must be concentrated to allow lower dosages to be used, or a means of controlling acidity must be found.

References

[1] Colin R. Gagg, “Cement and Concrete as an Engineering Material: An Historic Appraisal and Case Study Analysis,” *Engineering Failure Analysis*, vol. 40, pp. 114–140, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[2] Zongjin Li, Advanced concrete technology, 2011. [Online]. Available: https://books.google.com/books/about/Advanced_Concrete_Technology.html?hl=fr&id=usz3I9Q5QK0C

[3] Zongin Li, Advanced concrete technology, 2011. [Online]. Available: https://books.google.com/books/about/Advanced_Concrete_Technology.html?hl=fr&id=1lthdPkTS9wC

[4] S.B. Singh, Pankaj Munjal, and Nikesh Thammishetti, “Role of Water/Cement Ratio on Strength Development of Cement Mortar,” *Journal of Building Engineering*, vol. 4, pp. 94–100, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[5] Sandor Popovics, and Janos Ujhelyi, “Contribution to the Concrete Strength versus Water-Cement Ratio Relationship,” *Journal of Materials in Civil Engineering*, vol. 20, no. 7, pp. 459–463, 2008. [CrossRef] [Google Scholar] [Publisher Link]

[6] Peter Hewlet, Lea’s Chemistry of Cement and Concrete, 2001. [Online]. Available: https://books.google.com/books/about/Lea_s_Chemistry_of_Cement_and_Concrete.html?hl=fr&id=v1JVu4iifnMC

[7] A. Mardani-Aghabaglou et al., “Effect of Different Types of Superplasticizer on Fresh, Rheological and Strength Properties of Self-Consolidating Concrete,” *Construction and Building Materials*, vol. 47, pp. 1020–1025, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[8] Luigi Coppola et al., “Performance and Compatibility of Phosphonate-Based Superplasticizers for Concrete,” *Buildings*, vol. 7, no. 3, 2017, [CrossRef] [Google Scholar] [Publisher Link]

[9] S. Alsadey, and A. Omran, “Effect of Superplasticizers to Enhance the Properties of Concrete,” *Design, Construction, Maintenance*, vol. 2, pp. 84–91, 2022, [CrossRef] [Google Scholar] [Publisher Link]

[10] Yazan Alrefaei et al., “Effect of Superplasticizers on Properties of One-Part Ca(OH)2/Na2SO4 activated Geopolymer Pastes,” *Construction and Building Materials*, vol. 241, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[11] Elsa Paul, “Influence of Superplasticizer on Workability and Strength of Ambient Cured Alkali Activated Mortar,” *Cleaner Materials*, vol. 6, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[12] Guiyan Xiong, and Xiaolu Guo "Effects and Mechanism of Superplasticizers and Precursor Proportions on the Fresh Properties of Fly Ash – Slag Powder Based Geopolymers," *Construction and Building Materials*, vol. 350, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] Thomas Omollo Ofwa, David Otieno Koteng, and John Nyiro Mwero, "Evaluating Superplasticizer Compatibility in the Production of High Performance Concrete using Portland Pozzolana Cement CEM II/B-P," *SSRG International Journal of Civil Engineering*, vol. 7, no. 6, pp. 92–100, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[14] Chen Zhi Yuan, and Wang Jian Guo, "Effect of Bond Strength Between Aggregate and Cement Paste on the Mechanical Behaviour of Concrete," *MRS Online Proceedings Library*, vol. 114, no. 1, pp. 41–47, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[15] Olga Burgos-Montes et al., "Compatibility between Superplasticizer Admixtures and Cements with Mineral Additions," *Construction and Building Materials*, vol. 31, pp. 300–309, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[16] Caroline Autier et al., "Mesostructure Evolution of Cement Pastes with Addition of Superplasticizers Highlighted by Dispersion Indices," *Powder Technology*, vol. 249, pp. 282–289, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[17] M. H. R. Khudhair, M. S. Elyoubi, and A. Elharfi, "Study of the Influence of Water Reducing and Setting Retarder Admixtures of Polycarboxylate 'Superplasticizers' on Physical and Mechanical Properties of Mortar and Concrete," *Journal of Materials and Environmental Sciences*, vol. 9, no. 1, 2018. [Google Scholar] [Publisher Link]

[18] Shahidkha B. Pathan, and V.V.Singh, "Using Molasses in Concrete as a Time Retarding Admixture," *International Journal of Engineering Research & Technology*, vol. 6, no. 11, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[19] Ilham Aguida Bella et al., "Contribution on the Use of Household Waste as Bio-Admixture," *Construction Technologies and Architecture*, vol. 1, pp. 569–574, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[20] Aadarsha Lamichhane, Gokarna Bahadur Motra, and Thaman Bahadur Khadka, "Evaluation of Water Hyacinth Extract of Nepalese Lakes as an Admixture in Concrete Production," *8th IOE Graduate Conference*, vol. 8914, pp. 983–988, 2020. [Google Scholar] [Publisher Link]

[21] G. K. Patel and S. V. Deo, "Effect of Natural Organic Materials as Admixture on Properties of Concrete," *Indian Journal of Science and Technology*, vol. 9, no. 37, 2016.[CrossRef] [Google Scholar] [Publisher Link]

[22] Tareg Abdalla Abdalla et al., "Mechanical Properties of Eco-friendly Concrete Made with Sugarcane Bagasse Ash," *Civil Engineering Journal*, vol. 8, no. 6, pp. 1227–1239, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[23] Bassirou Kone, John N. Mwero, and Erick K. Ronoh, "Experimental Effect of Cassava Starch and Rice Husk Ash on Physical and Mechanical Properties of Concrete," *International Journal of Engineering Trends and Technology*, vol. 70, pp. 343–350, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[24] Nimisha Tripathi et al., "Biomass Waste Utilisation in Low-Carbon Products: Harnessing a Major Potential Resource," *NPJ Climate and Atmospheric Science*, vol. 2, no. 35, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[25] Nancy T. Hussien, and Ahmed F. Oan, "The Use of Sugarcane Wastes in Concrete," *Journal of Engineering and Applied Science*, vol. 69, no. 1, pp. 1–9, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[26] Samwel Daud Lupyana et al., "Use of Phyto-Based Polymeric Material as Chemical Admixture in Well Cement Slurry Formulation," *Upstream Oil Gas Technology*, vol. 7, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[27] A. Thankaswamy, and C. S. Belarmin Xavier, "Investigation on the Effect of Colocasia Esculenta Extract on the Fresh Properties of Cement Paste," *Materials Today Procceedings*, vol. 45, pp. 4712–4718, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[28] Isaiah Kiburi Achini, David Otieno Koteng, and John Nyiro Mwero, "Effect of Mixing Method on the Rheology and Hardened Properties of Concrete with Low Water/Binder Ratio," *SSRG International Journal of Civil Engineering*, vol. 8, no. 10, pp. 1-8, 2021. [CrossRef] [Publisher Link]

[29] S. Thirougnaname, and G. Ramakrishna, "Issue 6 www.jetir.org (ISSN-2349-5162),", *Journal of Emerging Technologies and Innovative Research*, vol. 6, 2019, Accessed: May 09, 2022. [Online]. Available: www.jetir.org

[30] M. O. Eloget, S. O. Abuodha, and M. M. O. Winja, "The Effect of Sisal Juice Extract Admixture on Compressive and Flexural Strength of Cement Concrete," *Engineering, Technology & Applied Science Research (ETASR)*, vol. 11, no. 2, pp. 7041–7046, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[31] Hersh F. Mahmood, Hooshang Dabbagh, and Azad A. Mohammed, "Improvement of Mechanical and Physical Properties of Normal Concrete Using Mulberry Extract as an Admixture," *Asian Journal of Civil Engineering*, vol. 24, pp. 1309–1321, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[32] M. Jammal, J. Nurdiana, and A. Mirza Ghulam, "The Effect of the Combination Additive Admixtures to Increase Setting Time and Compressive Strength at the Concrete Casting in Warm Tropical Temperature," *International Journal of Civil Engineering and Technology (IJCIET)*, vol. 11, no. 4, pp. 61–72, 2020. [Google Scholar] [Publisher Link]

[33] Rika Deni Susanti et al., "Studies on Concrete by Partial Replacement of Cement with Volcanic Ash," *Journal of Applied Engineering Science*, vol. 16, no. 2, pp. 161–165, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[34] Ojas Chaudhari, Joseph J. Biernacki, and Scott Northrup, "Effect of Carboxylic and Hydroxycarboxylic Acids on Cement Hydration: Experimental and Molecular Modeling Study," *Journal of Materials Science*, vol. 52, no. 24, pp. 13719–13735, 2017. [CrossRef] [Google Scholar] [Publisher Link]
[35] G. D. O. Okwadha, and D. M. Makomele, "Evaluation of Water Hyacinth Extract as an Admixture in Concrete Production," *Journal of Building Engineering*, vol. 16, pp. 129–133, 2018. [CrossRef] [Google Scholar] [Publisher Link]